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Bureau of Mines
Special Publication

**LIST OF BUREAU OF MINES
PUBLICATIONS AND ARTICLES**

January 1, 1970, to December 31, 1974

With Subject and Author Index



UNITED STATES DEPARTMENT OF THE INTERIOR

1975

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Special Publication

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With Subject and Author Index

Compiled by Rita D. Sylvester
Division of Technical Reports, Washington, D.C.



UNITED STATES DEPARTMENT OF THE INTERIOR

Stanley K. Hathaway, Secretary

Jack W. Carlson, Assistant Secretary—Energy and Minerals

BUREAU OF MINES

Thomas V. Falkie, Director

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

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LIST OF BUREAU OF MINES PUBLICATIONS AND ARTICLES

January 1, 1970, to December 31, 1974

With Subject and Author Index

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Rita D. Sylvester

Introduction

The Bureau of Mines was established in the public interest to conduct inquiries and scientific and technologic investigations concerning mining and the preparation, treatment and utilization of mineral substances; to promote health and safety in the mineral industries; to conserve material resources and prevent their waste; to further economic development; to increase efficiency in the mining, metallurgical, quarrying, and other mineral industries; and to inquire into the economic conditions affecting those industries. The organic act of the Bureau, as amended by Congress and approved February 25, 1913, made it the province and duty of the Bureau to "disseminate information concerning these subjects in such manner as will best carry out the purposes of this Act."

In accordance with this directive, the Bureau reports the findings of its research and investigations in its own series of publications and also in articles that appear in scientific, technical, and trade journals; in proceedings of conventions and seminars; in reference books; and in other

non-Bureau publications. The number of these reports, the wide range of subjects they cover, and the variety of mediums in which they appear make the kind of list and index presented in this special publication both necessary and valuable. This issue describes reports and articles published during the period January 1, 1970, to December 31, 1974. It supplements the 50-year list of Bureau publications issued from July 1, 1910, to January 1, 1960;² the 50-year list of articles by Bureau authors published outside the Bureau from July 1, 1910, to January 1, 1960;³ and the 5-year lists of Bureau publications and articles from January 1, 1960, to December 31, 1964,⁴ and from January 1, 1965, to December 31, 1969.⁵ It includes all the material in the four annual lists of Bureau publications and articles from January 1, 1970, to December 31, 1973.

¹ Editor.
² Out of print.
³ Out of print.
⁴ Out of print.
⁵ Out of print.

BUREAU PUBLICATIONS

Some Bureau of Mines publications, including Bulletins and the Minerals Yearbook, are sales publications; other series contain both free and sales publications. Because the price of sales publications varies, the price is indicated in the individual listing of any publication for which a charge is made.

Sales publications of the Bureau of Mines must be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, to whom orders should be sent directly. Remittances for such publications may be made by money order or check or by coupons, sold in sets of 20 for \$1 and good until used. Do not send postage stamps. Remittances from foreign countries should be made by international money order or a draft on a U.S. bank payable to the Superintendent of Documents.

Free publications of the Bureau of Mines may be obtained from the Publications Distribution Branch, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213. Because of the limited editions, only one copy of any free publication can be sent to the person applying and only a few different publications to any one applicant.

The following types or series of publications are issued by the Bureau of Mines:

Bulletins report the results of broad and significant projects or programs of scientific, historical, or economic research, or other investigations, including comprehensive and important mineral resource studies and compilations. Bulletins are usually prepared after all laboratory and field work has been completed, but they sometimes report a major phase of a larger or continuing investigation or research study. They rarely represent the first public report on the subject. As a rule, they encompass published work together with essential unpublished data and details.

Minerals Yearbook—annual statistical publication of the Bureau—summarizes the significant economic and technologic developments in the mineral industries. It presents, by mineral commodity, the salient statistics on production, trade, consumption, and other pertinent data. The U.S. mineral industry is reviewed by States, island possessions, and the Canal Zone. The latest available mineral statistics for more than 150 countries and areas are presented, together with a review of the role of minerals in the economies of these nations. Three separate vol-

umes are issued each year, as follows: Volume I, Metals, Minerals, and Fuels; Volume II, Area Reports: Domestic; and Volume III, Area Reports: International. Chapters in these volumes are issued separately as preprints before the bound volumes are available.

Reports of Investigations present the results of research and investigations conducted by the Bureau at its research centers or laboratories, or in mines, quarries, smelters, refineries, oilfields, plants, and other non-Bureau properties. They differ from Bulletins in that they describe the principal features and results of individual experiments (single or multiple); minor research projects; or a significant coordinated phase of a major project or program. Reports of investigations may include a summary of several projects or activities in a given subject area that are not necessarily related directly to each other, new technical or economic theory, mineral resource studies that emphasize original evaluation of deposits, results of laboratory analyses of an unusual nature, and comparative and nonroutine testing of cores, explosives, and other commodities.

Information Circulars differ from Reports of Investigations in that they are not concerned primarily with original Bureau research or investigative work. They cover surveys of mineral resources and related mining and operating activities; guides to marketing of mineral commodities; compilations of historical or statistical and economic data on minerals; summaries of scientific and technical meetings and symposiums; bibliographies; descriptions of new instrumentation and techniques; and descriptions of new industrial mining methods and metallurgical processes (as distinguished from those developed by the Bureau).

Technical Progress Reports present highly significant and newsworthy developments in Bureau of Mines programs and are intended for use in conveying information that, to be of maximum value, must be published in a matter of days. They are expanded fact sheets giving the technical background and details necessary to supplement a press release that reports important progress in an area of Bureau activity meriting widespread public interest. A more comprehensive treatment of the subject may be published later as a Report of Investigations.

Handbooks are instruction or information manuals designed to improve efficiency in the mineral industries or to promote the wise use

of mineral resources. Based on research and the practical experience of Bureau personnel, they cover a wide range of subjects, such as questions and answers on boiler-feedwater conditioning.

Mineral Industry Surveys contain timely statistical and economic data on minerals and fuels. The surveys are designed to keep Government agencies and the public, particularly the minerals industry and business community, regularly informed of trends in the production, distribution, inventories, and consumption of minerals and fuels. Frequency of issue depends on the need for current data. For example, the bituminous coal report is issued weekly; other reports are issued monthly, quarterly, and annually. Preliminary annual data on commodities are published as soon as possible after the close of each calendar year and comprise statistics that are later finalized in the Minerals Yearbook. Preliminary annual area reports also contain data on mineral production by States, and final figures are published in Volume II of the Yearbook.

Foreign Mineral Reports are issued to help domestic producers and consumers of mineral commodities keep abreast of developments in the mineral industries and markets abroad, and provide a brief summary of significant information from U.S. Foreign Service offices and other sources, which may otherwise not be made available to the general public.

Special Publications include the annual list of Bureau of Mines Publications and Articles and popular-type pamphlets prepared for the general public and distributed in response to requests for information on specific subjects, such as air pollution and mineral waste reclamation. Special publications also include certain long and detailed publications that do not belong in any of the other series.

ASSOCIATED DOCUMENTS

Although the material in the categories that follow is not published by the Bureau of Mines, it is listed and indexed in this publication as a service to those who may be interested.

Cooperative Publications result from investigations conducted cooperatively by the Bureau of Mines and another Government or outside organization. Although usually written either wholly or in part by Bureau personnel, they are published by the other organization. Cooperative publications include monographs and joint reports.

Open File Reports are unpublished Bureau of Mines manuscripts, reports prepared for the Bureau under contract, or material not in manuscript form, such as diamond drill logs or a collection of crude or raw data from an experiment, which the Bureau makes available for consultation in a library or Bureau facility. See the list of open file reports for information as to where they are available for examination.

Outside Publications (OP's) are journal articles, papers in proceedings and transactions of symposia and society meetings, and other non-Bureau publications published by technical and trade journals, scientific organizations, and publishing houses.

Patents issued to Bureau personnel from January 1, 1970, to December 31, 1974, are listed, with instructions on how to apply for permission to use such patents.

Reprints of Bureau of Mines publications that have been made available by the National Technical Information Service, U.S. Department of Commerce, are listed in the section "Reports Available from the National Technical Information Service."

LIBRARIES

Under the provisions of the law, certain libraries are designated by Congress as depositories for printed publications issued by the Government agencies. Through these libraries, various documents printed by the Government Printing Office are made available to residents of every State. Distribution of these printed publications is made by the Superintendent of Documents.

Many of these depository libraries also receive multilith publications of the Bureau of Mines, particularly the Reports of Investigations and the Information Circulars, which are distributed mainly by the Bureau. Libraries maintaining a file of Bureau of Mines publications are the best sources for reports published by the

Bureau when the publications are out of print or copies no longer are available from the Superintendent of Documents or the Bureau.

In the United States some libraries maintain complete files of Bureau reports; others carry only selected series. The following list contains the names and locations of depository libraries receiving various series of reports and documents issued by the Bureau of Mines. The figures in parentheses, following the names of the libraries, indicate the type of Bureau publications generally received on a regular basis by each library.

- (1) Reports of Investigations and Information Circulars.
- (2) Bulletins.
- (3) Minerals Yearbooks.

State	City	Library and Type of Publication Received
Alabama	Alexander City	Alexander City State Junior College, Thomas D. Russell Library (3).
	Auburn	Auburn University, Ralph Brown Draughon Library (1, 2, 3).
	Birmingham	Birmingham Public Library (1, 2, 3).
		Birmingham-Southern College, M. Paul Phillips Library (2, 3).
		Samford University, Harwell G. Davis Library (3).
	Florence	Florence State University, Collier Library (3).
	Gadsden	Gadsden Public Library (2, 3).
	Huntsville	University of Alabama, Huntsville Campus Library (2, 3).
	Jacksonville	Jacksonville State University, Ramona Wood Library (3).
	Maxwell A. F. Base	Air University Library (3).
	Mobile	Mobile Public Library (1, 2, 3).
		Spring Hill College, Thomas Byrne Memorial Library (3).
		University of South Alabama Library (1, 2, 3).
	Montgomery	Auburn University at Montgomery Library (1, 3).
	Normal	Alabama Agricultural and Mechanical College, Drake Memorial Library (3).
	St. Bernard	St. Bernard College Library (3).
	Troy	Troy State University, Lurleen B. Wallace Educational Resources Center (3).
	Tuskegee Institute	Tuskegee Institute, Hollis Burke Frissell Library (2, 3).
	University	University of Alabama Library (1, 2, 3).
		University of Alabama School of Law Library (3).
Alaska	Anchorage	Alaska Methodist University Library (1, 3).
		Anchorage Higher Consortium Library (1, 2, 3).
	Fairbanks	University of Alaska, Elmer E. Rasmuson Library (1, 2, 3).
	Juneau	Alaska State Library (3).
Arizona	Coolidge	Central Arizona College, Instructional Materials Center (3).
	Flagstaff	Northern Arizona University Library (2, 3).
	Phoenix	Department of Library and Archives (1, 2, 3).
		Phoenix Public Library (1, 2, 3).
	Prescott	Prescott College Library (3).
	Tempe	Arizona State University, Matthews Library (1, 2, 3).
	Tucson	Tucson Public Library (3).
		University of Arizona Library (1, 2, 3).
	Yuma	Yuma City-County Library (2, 3).

State	City	Library and Type of Publication Received
Arkansas	Arkadelphia	Ouachita Baptist University, Riley Library (2, 3).
	Conway	Hendrix College, O. C. Bailey Library (3).
	Fayetteville	University of Arkansas Library (1, 2, 3).
	Little Rock	Little Rock Public Library (1, 3).
	Magnolia	Southern State College, J. M. Peace Library (2, 3).
	Monticello	University of Arkansas at Monticello Library (3).
	Russellville	Arkansas Polytechnic College, Tomlinson Library (3).
	Searcy	Harding College, Beaumont Memorial Library (3).
	State University	Arkansas State University, Dean B. Ellis Library (2, 3).
	Walnut Ridge	Southern Baptist College, Felix Goodson Library (3).
California	Anaheim	Anaheim Public Library (3).
	Arcata	Humboldt State College Library (1, 2, 3).
	Bakersfield	California State College Library (3).
	Berkeley	Kern County Library System (1, 2, 3).
		University of California, General Library (1, 2, 3).
	Berkeley	University of California, Law Library, Earl Warren Legal Center (2).
		Carson Regional Library (3).
	Carson	California State University, Chico Library (3).
	Chico	Pomona College, Honnold Library (1, 2, 3).
	Claremont	Compton Library (1, 2, 3).
	Compton	Contra Costa County Library (3).
	Concord	Culver City Library (3).
	Culver City	University of California at Davis, School of Law Library (1, 2, 3).
	Davis	Downey City Library (3).
	Downey	California State University at Fresno Library (1, 2, 3).
	Fresno	Fresno County Free Library (1, 2, 3).
	Fullerton	California State College at Fullerton Library (2, 3).
	Garden Grove	Garden Grove Regional Library (3).
	Gardena	Gardena Public Library (3).
	Hayward	California State College at Hayward Library (2, 3).
	Huntington Park	Huntington Park Library, San Antonio Region (3).
	Inglewood	Inglewood Public Library (2, 3).
	Irvine	University of California at Irvine Library (1, 2, 3).
	La Jolla	University of California at San Diego Library (1, 2, 3).
	Lakewood	Angelo Jacoboni Public Library (1, 3).
	Lancaster	Lancaster Regional Library (3).
	Long Beach	California State College at Long Beach Library (1, 2, 3).
	Los Angeles	Long Beach Public Library (1, 2, 3).
		California State College at Los Angeles, John F. Kennedy Memorial Library (1, 2, 3).
		Los Angeles Public Library (1, 2, 3).
		Loyola University of Los Angeles Library (3).
		Occidental College, Mary Norton Clapp Library (3).
	Menlo Park	University of California at Los Angeles Library (1, 2, 3).
		University of Southern California Library (1, 2, 3).
		Geological Survey Library, U.S. Department of the Interior (2, 3).
	Montebello	Montebello Library (3).
	Monterey	Naval Postgraduate School Library (3).
	Monterey Park	Bruggemeyer Memorial Library (3).
	Northridge	California State University at Northridge (1, 2, 3).
	Norwalk	Norwalk Library (3).
	Oakland	Oakland Public Library (1, 2, 3).
	Palo Alto	Stanford University Library (1, 2, 3).
	Pasadena	California Institute of Technology, Millikan Memorial Library (1, 2, 3).
	Pasadena	Pasadena Public Library (1, 2, 3).
		Shasta County Library (2, 3).
	Redding	University of Redlands, Armacost Library (2, 3).
	Redlands	Redwood City Public Library (3).
	Redwood City	West Valley Regional Branch Library (3).
	Reseda	Richmond Public Library (3).
	Richmond	Riverside Public Library (1, 2, 3).
	Riverside	University of California at Riverside Library (1, 2, 3).
	Sacramento	California State Library (1, 2, 3).
		Sacramento City-County Library (2, 3).
		Sacramento State College Library (1, 2, 3).
	San Bernardino	San Bernardino County Free Library (2, 3).
	San Diego	California State University at San Diego, Love Library (1, 2, 3).
		San Diego County Library (3).
		San Diego Public Library (1, 2, 3).

State	City	Library and Type of Publication Received
California	San Francisco	Mechanics Institute Library (2, 3) . San Francisco Public Library (1, 2, 3) . San Francisco State College Library (1, 2, 3) . Supreme Court of California Library (1, 2, 3) . U.S. Court of Appeals for Ninth Circuit Library (3) . University of San Francisco, Gleeson Library (2, 3) .
	San Jose	San Jose State College Library (1, 2, 3) .
	San Leandro	San Leandro Community Library Center (3) .
	San Luis Obispo	California State Polytechnic University Library (1, 2, 3) .
	Santa Ana	Santa Ana Public Library (3) .
	Santa Barbara	University of California at Santa Barbara Library (1, 3) .
	Santa Clara	University of Santa Clara, Michel Orradre Library (3) .
	Santa Cruz	University of California at Santa Cruz Library (1, 2, 3) .
	Santa Rosa	Santa Rosa-Sonoma County Free Public Library (3) .
	Stockton	Public Library of Stockton and San Joaquin County (2, 3) .
	Thousand Oaks	California Lutheran College Library (2, 3) .
	Torrance	Torrance Civic Center Library (3) .
	Turlock	Stanislaus State College Library (3) .
	Valencia	Valencia Regional Library (3) .
	Van Nuys	Los Angeles Valley College Library (3) .
	Walnut	Mount San Antonio College Library (3) .
	West Covina	West Covina Library (3) .
Colorado	Alamosa	Adams State College Learning Resources Center (1, 2, 3) .
	Boulder	University of Colorado Libraries (1, 2, 3) .
	Colorado Springs	Colorado College, Charles Leaming Tutt Library (1, 2, 3) .
	Denver	Bureau of Mines, U.S. Department of the Interior (1, 2, 3) .*
		Bureau of Reclamation, U.S. Department of the Interior (2, 3) .
		Colorado State Library (1, 2, 3) .
		Denver Public Library (1, 2, 3) .
		Regis College, Dayton Memorial Library (1, 2, 3) .
		University of Denver, Mary Reed Library (1, 2, 3) .
	Fort Collins	Colorado State University, W. E. Morgan Library (1, 2, 3) .
	Golden	Colorado School of Mines, Arthur Lakes Library (1, 2, 3) .
		Jefferson County Public Library (3) .
	Greeley	University of Northern Colorado Library (1, 3) .
	Gunnison	Western State College, Leslie J. Savage Library (1, 2, 3) .
	La Junta	Otero Junior College, Wheeler Library (3) .
	Pueblo	Pueblo Regional Library (1, 2, 3) .
Connecticut	U. S. Air Force Academy	Southern Colorado State College Library (1, 2, 3) . U.S. Air Force Academy Library (1, 3) .
	Bridgeport	Bridgeport Public Library (1, 2, 3) .
	Danbury	Western Connecticut State College, Ruth A. Haas Library (1, 2, 3) .
	Hartford	Connecticut State Library (1, 2, 3) . Hartford Public Library (1, 2, 3) . Trinity College Library (2, 3) .
	Middletown	Wesleyan University, Olin Library (1, 2, 3) .
	New Britain	Central Connecticut State College, Elihu Burritt Library (1, 2, 3) .
	New Haven	Southern Connecticut State College, Hilton C. Buley Library (1, 2, 3) . Yale University Library (2, 3) .
	New London	Connecticut College, Palmer Library (3) .
	Stamford	Stamford Public Library (3) .
	Storrs	University of Connecticut, Wilbur Cross Library (1, 2, 3) .
	Waterbury	Silas Bronson Library (3) .
Delaware	Dover	Delaware State College, William C. Jason Library (3) .
	Georgetown	Delaware Technical and Community College Library (2, 3) .
	Newark	University of Delaware, Hugh M. Morris Library (1, 2, 3) .
	Wilmington	Wilmington Institute and New Castle County Free Library (1, 2, 3) .
District of Columbia	Washington	Advisory Commission on Intergovernmental Relations Library (1, 2, 3) . District of Columbia Public Library (3) . Federal Deposit Insurance Corporation Library (3) . Georgetown University Library (2, 3) . National War College Library (3) . Office of Management and Budget Library (3) . Pentagon, Army Library (3) . U.S. Atomic Energy Commission Library (1, 3) .

* Not a depository library.

State	City	Library and Type of Publication Received
District of Columbia	Washington	U.S. Department of Agriculture, National Agricultural Library (2, 3). U.S. Department of Commerce Library (1, 3). U.S. Department of Housing and Urban Development, Library and Information Division (3). U.S. Department of the Interior, Central Library (1, 2, 3). U.S. Department of Justice, Main Library (3). U.S. Department of the Navy Library (3). U.S. Department of State Library (3). U.S. Department of the Treasury Library (3).
Florida	Boca Raton	Florida Atlantic University Library (1, 2, 3).
	Daytona Beach	Volusia County Public Libraries (3).
	De Land	Stetson University, DuPont-Ball Library (2, 3).
	Fort Lauderdale	Fort Lauderdale Public Library (2, 3). Nova University Libraries (3).
	Gainesville	University of Florida Libraries (1, 2, 3).
	Jacksonville	Haydon Burns Library (1, 2, 3). Jacksonville University, Swisher Library (3).
	Lakeland	Lakeland Public Library (3).
	Leesburg	Lake-Sumter Community College Library (3).
	Miami	Florida International University Library (2, 3). Miami Public Library (1, 2, 3). University of Miami Library (1, 2).
	Orlando	Florida Technological University Library (1, 2, 3).
	Palatka	St. Johns River Junior College Library (3).
	Pensacola	University of West Florida, John C. Pace Library (3).
	Punta Gorda	Charlotte County Library (3).
	St. Petersburg	St. Petersburg Public Library (3).
	Sarasota	Sarasota Public Library (3).
	Tallahassee	Florida Agricultural and Mechanical University, Coleman Memorial Library (2, 3). Florida State Library (3). Florida State University, R. M. Strozier Library (1, 2, 3).
	Tampa	Tampa Public Library (1, 2, 3). University of South Florida Library (1, 2, 3). University of Tampa, Merl Kelce Library (3).
	Winter Park	Rollins College, Mills Memorial Library (3).
Georgia	Albany	Albany Public Library (2, 3).
	Americus	Georgia Southwestern College, James Earl Carter Library (2, 3).
	Athens	University of Georgia Libraries (1, 2, 3).
	Atlanta	Atlanta Public Library (1, 2, 3). Atlanta University, Trevor Arnett Library (3). Emory University, Robert W. Woodruff Library (2, 3). Georgia Institute of Technology, Price Gilbert Memorial Library (1, 2, 3). Georgia State Library (3). Georgia State University Library (1, 2, 3).
	Augusta	Augusta College Library (1, 2, 3).
	Brunswick	Brunswick Public Library (3).
	Carrollton	West Georgia College Library (1, 2, 3).
	Dahlonega	North Georgia College, Stewart Library (3).
	Decatur	DeKalb Community College, South Campus Learning Resources Center (3).
	Gainesville	Chestatee Regional Library (3).
	Macon	Mercer University, Stetson Memorial Library (3).
	Marietta	Kennesaw Junior College Library (3).
	Milledgeville	Georgia College at Milledgeville, Ina Dillard Russell Library (3).
	Savannah	Savannah Public and Chatham-Effingham-Liberty Regional Library (3).
	Statesboro	Georgia Southern College, Rosenwald Library (1, 2, 3).
	Valdosta	Valdosta State College, Richard Holmes Powell Library (3).
Hawaii	Hilo	University of Hawaii Library (2, 3).
	Honolulu	Chaminade College of Honolulu Library (3). Hawaii State Library (3). University of Hawaii Library (1, 2, 3).
	Pearl City	Leeward Community College Library (3).
Idaho	Boise	Boise Public Library (1, 2, 3). Boise State College Library (1, 3). Idaho State Law Library (3). Idaho State Library (1, 2, 3).

State	City	Library and Type of Publication Received
Idaho -----	Caldwell -----	College of Idaho, Terteling Library (2, 3) .
	Moscow -----	University of Idaho Library (1, 2, 3) .
	Pocatello -----	Idaho State University Library (1, 2, 3) .
	Rexburg -----	Ricks College, David O. McKay Library (1, 2, 3) .
	Twin Falls -----	College of Southern Idaho (3) .
Illinois -----	Bloomington -----	Illinois Wesleyan University Libraries (2) .
	Carbondale -----	Southern Illinois University, Morris Library (1, 2, 3) .
	Carlinville -----	Blackburn College, Lumpkin Library (3) .
	Carterville -----	Shawnee Library (2, 3) .
	Champaign -----	University of Illinois, College of Law Library (2, 3) .
	Charleston -----	Eastern Illinois University, Booth Library (1, 2, 3) .
	Chicago -----	Chicago Public Library (1, 2, 3) .
		Chicago State University Library (3) .
		Field Museum of Natural History Library (1, 2, 3) .
		John Crerar Library (1, 2, 3) .
		Loyola University of Chicago, E. M. Cudahy Memorial Library (2, 3) .
		Northeastern Illinois State University Library (3) .
		University of Chicago Library (1, 2, 3) .
		University of Chicago, Law Library (3) .
		University of Illinois Library (1, 2, 3) .
	De Kalb -----	Northern Illinois University, Swen Franklin Parson Library (1, 2, 3) .
	Decatur -----	Decatur Public Library (3) .
	Edwardsville -----	Southern Illinois University, Lovejoy Memorial Library (1, 2, 3) .
	Elsah -----	Principia College, Marshall Brooks Library (3) .
	Evanston -----	Northwestern University Library (1, 2, 3) .
	Freeport -----	Freeport Public Library (3) .
	Galesburg -----	Galesburg Public Library (3) .
	Jacksonville -----	MacMurray College, Henry Pfeiffer Library (3) .
	Lake Forest -----	Lake Forest College, Donnelley Library (1, 2, 3) .
	Lebanon -----	McKendree College, Holman Library (3) .
	Lisle -----	Illinois Benedictine College, Theodore Lownik Library (3) .
	Macomb -----	Western Illinois University Library (1, 2, 3) .
	Moline -----	Black Hawk College, Learning Resources Center (3) .
	Monmouth -----	Monmouth College Library (2, 3) .
	Normal -----	Illinois State University at Normal, Milner Library (1, 2, 3) .
	Palos Hills -----	Moraine Valley Community College Library (3) .
	Peoria -----	Bradley University Library (3) .
		Peoria Public Library (1, 2, 3) .
	River Forest -----	Rosary College Library (3) .
	Rockford -----	Rockford Public Library (3) .
	Springfield -----	Illinois State Library (1, 2, 3) .
	Urbana -----	University of Illinois at Urbana Library (1, 2, 3) .
	Wheaton -----	Wheaton College Library (3) .
Indiana -----	Anderson -----	Anderson College, Charles E. Wilson Library (3) .
	Bloomington -----	Indiana University Library (1, 2, 3) .
	Crawfordsville -----	Wabash College, Lilly Library (3) .
	Evansville -----	Evansville and Vanderburgh County Public Library (1, 2, 3) .
		Indiana State University Library (1, 3) .
	Fort Wayne -----	Public Library of Fort Wayne and Allen County (1, 2, 3) .
		Indiana-Purdue Universities, Regional Campus Library (3) .
	Gary -----	Gary Public Library (3) .
		Indiana University, Northwest Campus Library (2, 3) .
	Greencastle -----	De Pauw University, Roy O. West Library (1, 2, 3) .
	Hammond -----	Hammond Public Library (2, 3) .
	Hanover -----	Hanover College Library (3) .
	Huntington -----	Huntington College Library (3) .
	Indianapolis -----	Butler University, Irwin Library (3) .
		Indiana State Library (1, 2, 3) .
		Indianapolis Public Library (1, 3) .
	Kokomo -----	Indiana University, Kokomo Campus Library (3) .
	Lafayette -----	Purdue University Library (1, 2, 3) .
	Muncie -----	Ball State University Library (1, 2, 3) .
		Muncie Public Library (3) .
	Notre Dame -----	University of Notre Dame, Memorial Library (1, 2, 3) .
	Rensselaer -----	St. Joseph's College Library (2, 3) .
	Richmond -----	Earlham College, Lilly Library (2, 3) .
		Morrison Reeves Library (3) .
	South Bend -----	Indiana University at South Bend Library (3) .
	Terre Haute -----	Indiana State University, Cunningham Memorial Library (2, 3) .
	Valparaiso -----	Valparaiso University, Moellering Memorial Library (2, 3) .

State	City	Library and Type of Publication Received
Iowa	Ames	Iowa State University of Science and Technology Library (1, 2, 3).
	Cedar Falls	University of Northern Iowa Library (1, 3).
	Council Bluffs	Free Public Library (2, 3).
	Davenport	Iowa Western Community College, Hoover Media Library (3).
	Des Moines	Davenport Public Library (1, 2).
		Drake University, Cowles Library (1, 2, 3).
		Iowa State Traveling Library (2, 3).
		Public Library of Des Moines (2, 3).
	Dubuque	Carnegie-Stout Public Library (3).
		Loras College, Wahlert Memorial Library (3).
	Grinnell	Grinnell College, Burling Library (3).
	Iowa City	University of Iowa Library (1, 2, 3).
	Lamoni	Graceland College, Frederick Madison Smith Library (3).
	Mount Vernon	Cornell College, Russell D. Cole Library (1, 2, 3).
Kansas	Orange City	Northwestern College, Ramaker Library (3).
	Sioux City	Sioux City Public Library (3).
	Baldwin City	Baker University Library (3).
	Colby	Colby Community Junior College Library (3).
	Emporia	Kansas State Teachers College, William Allen White Library (2, 3).
	Hays	Fort Hays Kansas State College, Forsyth Library (1, 2, 3).
	Hutchinson	Hutchinson Public Library (2, 3).
	Lawrence	University of Kansas, Watson Library (1, 2, 3).
		University of Kansas Law Library (3).
	Manhattan	Kansas State University, Farrell Library (1, 2, 3).
	Pittsburg	Kansas State College of Pittsburg, Porter Library (2, 3).
	Salina	Kansas Wesleyan University, Memorial Library (1, 2, 3).
	Topeka	Kansas State Historical Society Library (3).
		Kansas State Library (2, 3).
Kentucky	Wichita	Wichita State University Library (1, 2, 3).
	Ashland	Ashland Public Library (3).
	Barbourville	Union College, Abigail E. Weeks Memorial Library (3).
	Bowling Green	Western Kentucky University, Margie Helm Library (1, 2, 3).
	Covington	Thomas More College Library (3).
	Danville	Centre College, Grace Doherty Library (3).
	Frankfort	Kentucky Department of Libraries (3).
		Kentucky State College, Blazer Library (2).
		State Law Library (3).
	Lexington	University of Kentucky, M. I. King Library (1, 2, 3).
	Louisville	Louisville Free Public Library (1, 2, 3).
		University of Louisville, Belknap Campus Library (2, 3).
	Morehead	Morehead State University, Johnson Camden Library (3).
	Murray	Murray State University Library (1, 2, 3).
Louisiana	Newport	Northern Kentucky State College Library (3).
	Owensboro	Kentucky Wesleyan College Library (3).
	Pikeville	Pikeville College, O'Rear-Robinson Library (3).
	Richmond	Eastern Kentucky University, John Grant Crabbe Library (1, 3).
	Baton Rouge	Louisiana State University Library (1, 2, 3).
	Eunice	Louisiana State University at Eunice, LeDoux Library (1, 2, 3).
	Hammond	Southeastern Louisiana University, Sims Memorial Library (2, 3).
	Lafayette	University of Southwestern Louisiana Library (1, 2, 3).
	Lake Charles	McNeese State University, Frazar Memorial Library (1, 2, 3).
	Monroe	Northeast Louisiana University, Sandel Library (3).
	Natchitoches	Northwestern State University, Watson Memorial Library (2, 3).
	New Orleans	Isaac Delgado College, Moss Technical Library (1, 2, 3).
		Loyola University Library (3).
		New Orleans Public Library (1, 2, 3).
Maine		Tulane University, Howard-Tilton Memorial Library (1, 2, 3).
		Southern University of New Orleans Library (1, 2, 3).
	Pineville	Louisiana College, Richard W. Norton Memorial Library (3).
	Ruston	Louisiana Polytechnic University, Prescott Memorial Library (1, 2, 3).
	Shreveport	Louisiana State University in Shreveport Library (1, 3).
		Shreve Memorial Library (1, 2, 3).
	Thibodaux	Francis T. Nicholls State University (2, 3).
	Augusta	Maine State Library (2, 3).
	Brunswick	Bowdoin College, Hawthorne-Longfellow Library (2, 3).
	Castine	Maine Maritime Academy, Nutting Memorial Library (1, 2, 3).
	Lewiston	Bates College Library (2, 3).

State	City	Library and Type of Publication Received
Maine -----	Orono -----	University of Maine, Raymond H. Fogler Library (1, 2, 3).
	Portland -----	Portland Public Library (2, 3).
	Springvale -----	University of Maine Law Library (3).
	Waterville -----	Nasson College Library (3).
	Waterville -----	Colby College Library (3).
Maryland -----	Annapolis -----	Maryland State Library (3).
	Baltimore -----	U.S. Naval Academy Library (2, 3).
	Baltimore -----	Enoch Pratt Free Library (1, 2, 3).
	Baltimore -----	Johns Hopkins University, Milton S. Eisenhower Library (1, 2, 3).
	Baltimore -----	Morgan State College, Soper Library (3).
	Baltimore -----	University of Baltimore, Langsdale Library (1, 3).
	Baltimore -----	University of Maryland, School of Law Library (3).
	Bel Air -----	Hartford Community College Library (3).
	College Park -----	University of Maryland, McKeldin Library (1, 2, 3).
	Frostburg -----	Frostburg State College Library (1, 3).
	Rockville -----	Montgomery County Department of Public Libraries (3).
	Salisbury -----	Salisbury State College, Blackwell Library (2, 3).
	Towson -----	Goucher College, Julia Rogers Library (3).
Massachusetts -----	Westminster -----	Western Maryland College Library (3).
	Amherst -----	Amherst College Library (2, 3).
	Boston -----	University of Massachusetts, Goodell Library (1, 2, 3).
	Boston -----	Belmont Memorial Library (3).
	Boston -----	Boston College, Bapst Library (3).
	Boston -----	Boston Public Library (1, 2, 3).
	Boston -----	Northeastern University, Dodge Library (1, 2, 3).
	Boston -----	State Library of Massachusetts (2, 3).
	Brookline -----	Public Library of Brookline (3).
	Cambridge -----	Harvard University Library (2, 3).
	Cambridge -----	Massachusetts Institute of Technology Libraries (1, 2, 3).
	Chicopee -----	Our Lady of the Elms College (3).
	Lowell -----	Lowell Technological Institute, Alumni Memorial Library (3).
	Lynn -----	Lynn Public Library (3).
	Marlborough -----	Marlborough Public Library (3).
	Medford -----	Tufts University Library (2, 3).
	Milton -----	Curry College Library (3).
	New Bedford -----	New Bedford Free Public Library (3).
	North Dartmouth -----	Southeastern Massachusetts University Library (1, 2, 3).
	North Easton -----	Stonehill College, Cushing-Martin Library (3).
	Springfield -----	Springfield City Library (3).
	Waltham -----	Brandeis University Library (3).
	Wellesley -----	Wellesley College Library (3).
	Williamstown -----	Williams College Library (3).
	Wilmington -----	Wilmington Memorial Library (3).
	Worcester -----	Worcester Public Library (1, 2, 3).
Michigan -----	Albion -----	Albion College, Stockwell Memorial Library (1, 2, 3).
	Allendale -----	Grand Valley State College Library (1, 2, 3).
	Ann Arbor -----	Great Lakes Basin Library (3).
	Ann Arbor -----	University of Michigan, Harlan Hatcher Library (1, 2, 3).
	Bloomfield Hills -----	Cranbrook Institute of Science Library (3).
	Dearborn -----	Henry Ford Centennial Library (2, 3).
	Dearborn -----	Henry Ford Community College Library (3).
	Detroit -----	Detroit Public Library (1, 2, 3).
	Detroit -----	Mercy College of Detroit Library (3).
	Detroit -----	University of Detroit Library (3).
	Detroit -----	Wayne State University, G. Flint Purdy Library (1, 2, 3).
	East Lansing -----	Michigan State University Library, Upper Peninsula Branch (1, 2, 3).
	Escanaba -----	Michigan State Library (3).
	Farmington -----	Oakland Community College, Martin L. King Learning Resources Center (1, 3).
	Flint -----	Charles Stewart Mott Library (3).
	Flint -----	Flint Public Library (3).
	Grand Rapids -----	Calvin College Library (3).
	Grand Rapids -----	Grand Rapids Public Library (1, 2, 3).
	Houghton -----	Michigan Technological University Library (1, 2, 3).
	Jackson -----	Jackson Public Library (3).
Kalamazoo -----	Kalamazoo -----	Kalamazoo Library System (3).
	Kalamazoo -----	Western Michigan University, Dwight B. Waldo Library (1, 2, 3).
	Lansing -----	Michigan State Library (1, 2, 3).

State	City	Library and Type of Publication Received
Michigan	Livonia	Schoolcraft College Library (1, 3).
	Marquette	Northern Michigan University, Olsen Library (1, 2, 3).
	Mt. Clemens	Macomb County Library (3).
	Mt. Pleasant	Central Michigan University Library (1, 2, 3).
	Muskegon	Hackley Public Library (3).
	Rochester	Oakland University, Kresge Library (1, 3).
	Saginaw	Hoyt Public Library (1, 2, 3).
	Traverse City	Northwestern Michigan College, Mark Osterlin Library (3).
	University Center	Delta College Library (3).
	Warren	Warren Public Library, Arthur J. Miller Branch (3).
	Wayne	Wayne County Public Library (3).
	Ypsilanti	Eastern Michigan University (1, 2, 3).
Minnesota	Bemidji	Bemidji State College, A. C. Clark Library (1, 2, 3).
	Collegeville	St. Johns University, Alcuin Library (3).
	Duluth	Duluth Public Library (1, 2, 3).
	Mankato	Mankato State College, Memorial Library (1, 2, 3).
	Minneapolis	Anoka County Library (3).
		Minneapolis Public Library (1, 2, 3).
		Southdale-Hennepin Area Library (2, 3).
		University of Minnesota, Wilson Library (1, 2, 3).
	Moorhead	Moorehead State College Library (3).
	Morris	University of Minnesota at Morris Library (3).
	Northfield	Carleton College Library (3).
		St. Olaf College, Rolvaag Memorial Library (2, 3).
	St. Cloud	St. Cloud State College Library (3).
	St. Paul	Minnesota Historical Society Library (2, 3).
		St. Paul Public Library (2, 3).
	St. Peter	Gustavus Adolphus College Library (1, 3).
	Willmar	Crow River Regional Library (3).
	Winona	Winona State College, Maxwell Library (3).
Mississippi	Columbus	Mississippi State College for Women, J. C. Fant Memorial Library (3).
	Hattiesburg	University of Southern Mississippi Library (1, 2, 3).
	Jackson	Mississippi Library Commission (3).
		Mississippi State Law Library (3).
	Lorman	Alcorn Agricultural and Mechanical College Library (1, 2, 3).
	State College	Mississippi State University, Mitchell Memorial Library (1, 2, 3).
	University	University of Mississippi Library (1, 2, 3).
		University of Mississippi School of Law Library (1, 2, 3).
Missouri	Cape Girardeau	Southeast Missouri State College, Kent Library (3).
	Columbia	University of Missouri Library (1, 2, 3).
	Fayette	Central Methodist College Library (3).
	Jefferson City	Lincoln University, Inman E. Page Library (3).
		Missouri State Library (3).
	Joplin	Missouri Southern State College Library (3).
	Kansas City	Kansas City Public Library (1, 2, 3).
		Rockhurst College Library (3).
		University of Missouri at Kansas City Library (1, 2, 3).
	Kirkville	Northeast Missouri State College, Pickler Memorial Library (3).
	Liberty	William Jewell College Library (3).
	Rolla	University of Missouri at Rolla Library (1, 2, 3).
	St. Joseph	St. Joseph Public Library (2, 3).
	St. Louis	St. Louis County Library (3).
		St. Louis Public Library (1, 2, 3).
		St. Louis University, Pius XII Memorial Library (1, 2, 3).
		St. Louis University Law Library (3).
		University of Missouri at St. Louis, Thomas Jefferson Library (1, 2, 3).
		Washington University, John M. Olin Library (1, 2, 3).
	Springfield	Drury College, Walker Library (2, 3).
		Southwest Missouri State College Library (1, 2, 3).
	Warrensburg	Central Missouri State College, Ward Edwards Library (1, 2, 3).
Montana	Billings	Eastern Montana College Library (1, 3).
	Bozeman	Montana State University Library (1, 2, 3).
	Butte	Montana State College of Mineral Science and Technology Library (1, 2, 3).
	Helena	Montana Historical Society Library (1, 2, 3).
	Missoula	Montana State Library (1, 2, 3).
		University of Montana Library (1, 2, 3).
Nebraska	Blair	Dana College, C. A. Dana-Life Library (3).
	Crete	Doane College, Whitin Library (3).

State	City	Library and Type of Publication Received
Nebraska	Fremont	Midland Lutheran College Library (1, 2, 3).
	Kearney	Kearney State College, Calvin T. Ryan Library (2, 3).
	Lincoln	Nebraska Library Commission (1, 2, 3).
		University of Nebraska, D. L. Love Memorial Library (1, 2, 3).
	Omaha	Creighton University, Alumni Memorial Library (3).
		Omaha Public Library (1, 2, 3).
		University of Omaha, Gene Eppley Library (1, 3).
	Scottsbluff	Scottsbluff Public Library (3).
	Wayne	Wayne State College, U.S. Conn Library (3).
Nevada	Carson City	Nevada State Library (1, 2, 3).
	Las Vegas	University of Nevada at Las Vegas Library (1, 2, 3).
	Reno	University of Nevada Library (1, 2, 3).
New Hampshire	Concord	Franklin Pierce Law Center Library (2, 3).
		New Hampshire State Library (1, 2, 3).
	Durham	University of New Hampshire Library (1, 2, 3).
	Hanover	Dartmouth College, Baker Library (1, 2, 3).
	Henniker	New England College Library (3).
	Manchester	Manchester City Library (3).
New Jersey	Bayonne	Bayonne Free Public Library (2, 3).
	Bloomfield	Free Public Library of Bloomfield (2, 3).
	Bridgeton	Cumberland County Library (3).
	Camden	Rutgers University at Camden Library (3).
	Convent Station	College of Saint Elizabeth, Mahoney Library (3).
	East Orange	East Orange Public Library (3).
	Elizabeth	Free Public Library of Elizabeth (2, 3).
	Glassboro	Glassboro State College Library (1, 2, 3).
	Hackensack	Johnson Free Public Library (3).
	Irvington	Free Public Library of Irvington (3).
	Jersey City	Jersey City Public Library (2, 3).
		Jersey City State College, F. A. Irwin Library (3).
	Madison	Drew University, Rose Memorial Library (3).
	Mount Holly	Burlington County Library (3).
	New Brunswick	Free Public Library (3).
		Rutgers University Library (1, 2, 3).
	Newark	Newark Public Library (1, 2, 3).
		Rutgers-State University, John Cotton Dana Library (1, 2, 3).
	Passaic	Passaic Public Library (3).
	Plainfield	Plainfield Public Library (3).
	Pomona	Stockton State College Library (1, 2, 3).
	Princeton	Princeton University Library (1, 2, 3).
	Rutherford	Fairleigh Dickinson University, Messler Library (3).
	Shrewsbury	Monmouth County Library (1, 2, 3).
	South Orange	Seton Hall University, McLaughlin Library (3).
	Teaneck	Fairleigh Dickinson University, Teaneck Campus Library (3).
	Toms River	Ocean County College Library (2, 3).
	Trenton	New Jersey State Library, Law and Reference Bureau, Department of Education (3).
		Trenton Free Public Library (1, 2, 3).
	Upper Montclair	Montclair State College, Harry S. Sprague Library (3).
	Wayne	Wayne Public Library (2, 3).
	West Long Branch	Monmouth College, Guggenheim Memorial Library (3).
	Woodbridge	Free Public Library of Woodbridge (3).
New Mexico	Albuquerque	University of New Mexico, Zimmerman Library (1, 2, 3).
	Hobbs	New Mexico Junior College, Pannell Library (2, 3).
	Las Cruces	New Mexico State University Library (1, 2, 3).
	Las Vegas	New Mexico Highlands University, Donnelly Library (1, 2, 3).
	Portales	Eastern New Mexico University Library (1, 2, 3).
	Santa Fe	New Mexico State Library (1, 2, 3).
	Silver City	Supreme Court Law Library (3).
		Western New Mexico University, Miller Library (1, 2).
New York	Albany	New York State Library (1, 2, 3).
		State University of New York at Albany Library (1, 2, 3).
	Auburn	Seymour Library (3).
	Binghamton	State University of New York at Binghamton Library (2, 3).
	Brockport	State University of New York, Drake Memorial Library (1, 2, 3).
	Bronx	Fordham University Library (3).
		Herbert H. Lehman College Library (3).
		New York Public Library, Mott Haven Branch (3).
		State University of New York, Maritime College Library (3).

State	City	Library and Type of Publication Received
New York	Brooklyn	Brooklyn College Library (3). Brooklyn Public Library (1, 2, 3). Polytechnic Institute of Brooklyn, Spicer Library (2, 3). Pratt Institute Library (3).
	Buffalo	Buffalo and Erie County Public Library (1, 2, 3). State University of New York at Buffalo, Lockwood Memorial Library (1, 2, 3).
	Canton	St. Lawrence University, Owen D. Young Library (1, 2, 3).
	Corning	Corning Community College, Arthur A. Houghton, Jr., Library (3).
	Cortland	State University of New York College at Cortland, Memorial Library (3).
	Delhi	State University Agricultural and Technical College Library (3).
	East Islip	East Islip Public Library (3).
	Elmira	Elmira College Library (3).
	Farmingdale	State University Agricultural and Technical Institute at Farmingdale Library (2, 3).
	Flushing	Cathedral College Library (3).
	Garden City	Queens College, Paul Klapper Library (3). Adelphi University Library (2, 3).
	Geneseo	Nassau Library System (2, 3).
	Great Neck	State University College, Milne Library (1, 2, 3).
	Greenvale	U.S. Merchant Marine Academy Library (3).
	Hamilton	Long Island University, B. Davis Schwartz Memorial Library (2, 3).
	Hempstead	Colgate University Library (1, 2, 3).
	Huntington	Hofstra University Library (1, 2, 3).
	Ithaca	Huntington Public Library (1, 2, 3).
	Jamaica	Albert R. Mann Library (3). Cornell University Library (1, 2, 3).
	Mount Vernon	Queens Borough Public Library (1, 3). St. Johns University (3).
	New Paltz	Mount Vernon Public Library (3).
	New York	State University College (1, 2, 3). City University of New York, City College Library (1, 2, 3). Columbia University Library (1, 2, 3). New York Law Institute Library (3). New York Public Library, Astor Branch (2, 3). New York Public Library, Lenox Branch (1, 2, 3). New York University Law Library (3). New York University Library (1, 2).
	Newburgh	Newburgh Free Library (3).
	Oakdale	Dowling College Library (3).
	Oneonta	State University College, James M. Milne Library (1, 2, 3).
	Oswego	State University of New York, Penfield Library (1, 2, 3).
	Plattsburgh	State University College, Benjamin F. Feinberg Library (1, 2, 3).
	Potsdam	Clarkson College of Technology, Burnap Memorial Library (1, 2, 3).
	Poughkeepsie	State University College, Crumb Memorial Library (1, 2, 3).
	Purchase	Vassar College Library (3).
	Rochester	State University of New York College at Purchase Library (3). Rochester Public Library (1, 2, 3). University of Rochester Library (1, 2, 3).
	St. Bonaventure	St. Bonaventure University, Freidsam Memorial Library (3).
	Saratoga Springs	Skidmore College Library (3).
	Schenectady	Union College, Schaffer Library (2, 3).
	Southampton	Southampton College Library (2).
	Staten Island	Wagner College, Horrmann Library (2, 3).
	Stony Brook	State University of New York at Stonybrook Library (1, 2, 3).
	Syracuse	Syracuse University Library (2, 3).
	Troy	Troy Public Library (3).
	Utica	Utica Public Library (3).
	West Point	U.S. Military Academy Library (3).
	Yonkers	Sarah Lawrence College Library (3). Yonkers Public Library (3).
North Carolina	Asheville	University of North Carolina, D. Hiden Ramsey Library (3).
	Boone	Appalachian State University Library (1, 3).
	Buies Creek	Campbell College, Carrie Rich Memorial Library (3).
	Chapel Hills	University of North Carolina Library (1, 2, 3).
	Charlotte	Public Library of Charlotte and Mecklenburg County (3). University of North Carolina at Charlotte, Atkins Library (1, 2, 3).
	Cullowhee	Western Carolina University, Hunter Library (2, 3).

State	City	Library and Type of Publication Received
North Carolina	Davidson	Davidson College, Hugh A. and Jane Grey Memorial Library (3).
	Durham	Duke University, William R. Perkins Library (1, 2, 3). North Carolina Central University, James E. Shepard Memorial Library (3).
	Greensboro	North Carolina Agricultural and Technical State University, F. D. Bluford Library (2, 3). University of North Carolina at Greensboro, Walter Clinton Jackson Library (1, 2, 3).
	Greenville	East Carolina University, Joyner Library (1, 2, 3).
	Laurinburg	St. Andrews Presbyterian College, DeTamble Library (3).
	Murfreesboro	Chowan College, Whitaker Library (3).
	Pembroke	Pembroke State University, Mary H. Livermore Library (3).
	Raleigh	Department of Cultural Resources State Library (3). North Carolina State University, D. H. Hill Library (1, 2, 3). Wake County Public Library (3).
	Rocky Mount	North Carolina Wesleyan College Library (3).
	Salisbury	Catawba College Library (2, 3).
	Wilmington	University of North Carolina at Wilmington, William M. Randall Library (1, 2, 3).
	Wilson	Atlantic Christian College, Clarence L. Hardy Library (3).
	Winston-Salem	Forsyth County Public Library (3). Wake Forest University, Z. Smith Reynolds Library (3).
North Dakota	Bismarck	Veterans Memorial Public Library (3).
	Dickinson	Dickinson State College Library (1, 3).
	Fargo	Fargo Public Library (3). North Dakota State University Library (1, 2, 3).
	Grand Forks	University of North Dakota, Chester Fritz Library (3).
	Minot	Minot State College, Memorial Library (1, 2, 3).
	Valley City	State College Library (3).
Ohio	Ada	Ohio Northern University, J. P. Taggart Law Library (1, 3).
	Akron	Akron Public Library (1, 2, 3). University of Akron Library (1, 3).
	Alliance	Mt. Union College Library (1, 2, 3).
	Ashland	Ashland College Library (3).
	Athens	Ohio University Library (1, 2, 3).
	Batavia	University of Cincinnati, Clermont General and Technical Library (3).
	Bluffton	Bluffton College, Musselman Library (3).
	Bowling Green	Bowling Green State University Library (1, 2, 3).
	Canton	Malone College, Everett L. Cattell Library (3).
	Cincinnati	Public Library of Cincinnati and Hamilton County (1, 2, 3). University of Cincinnati Library (1, 2, 3).
	Cleveland	Case Western Reserve University, Freiburger Library (1, 2, 3). Cleveland Heights-University Heights Public Library (3). Cleveland Public Library (1, 2, 3). Cleveland State University Library (1, 2, 3).
	Columbus	John Carroll University, Grasselli Library (3). Capital University Library (2, 3). Columbus Public Library (3). Ohio State Library (1, 2, 3). Ohio State University Library (1, 2, 3).
	Dayton	Dayton and Montgomery County Public Library (1, 2, 3). University of Dayton, Albert Emanuel Library (2, 3). Wright State University Library (2, 3).
	Delaware	Ohio Wesleyan University, L. A. Beeghly Library (3).
	Elyria	Elyria Public Library (1, 2, 3).
	Findlay	Findlay College, Shafer Library (3).
	Gambier	Kenyon College Library (3).
	Granville	Denison University Library (3).
	Hiram	Hiram College, Teachout-Price Memorial Library (3).
	Kent	Kent State University Library (1, 2, 3).
	Marietta	Marietta College, Dawes Memorial Library (1, 2, 3).
	Middletown	Miami University at Middletown, Gardner-Harvey Library (2, 3).
	New Concord	Muskingum College Library (3).
	Oberlin	Oberlin College Library (3).
	Oxford	Miami University Library (1, 2, 3).
	Rio Grande	Rio Grande College, Jeanette Albiez Davis Library (2, 3).
	Springfield	Warder Public Library (3).
	Steubenville	Public Library of Steubenville and Jefferson County (3).
	Tiffin	Heidelberg College, Beeghly Library (3).
	Toledo	Toledo Public Library (1, 2, 3).

State	City	Library and Type of Publication Received
Ohio	Toledo	University of Toledo Library (1, 2, 3).
	Westerville	Otterbein College Library (3).
	Wooster	College of Wooster, Andrews Library (1, 2, 3).
	Youngstown	Public Library of Youngstown and Mahoning County (1, 2, 3). Youngstown State University Library (3).
Oklahoma	Ada	East Central State College, Linscheid Library (2, 3).
	Alva	Northwestern State College Library (3).
	Bethany	Bethany Nazarene College, R. T. Williams Library (3).
	Durant	Southeastern State College Library (3).
	Edmond	Central State University Library (3).
	Langston	Langston University, G. Lamar Harrison Library (3).
	Muskogee	Muskogee Public Library (3).
	Norman	University of Oklahoma Library (1, 2, 3).
	Oklahoma City	Oklahoma City University, Gold Star Memorial Library (3). Oklahoma Department of Libraries (1, 2, 3).
	Stillwater	Oklahoma State University Library (1, 2, 3).
	Tahlequah	Northeastern State College, John Vaughan Library (1, 3).
	Tulsa	Tulsa City-County Library (1, 2, 3). University of Tulsa, McFarlin Library (1, 2, 3).
	Weatherford	Southwestern State College Library (3).
Oregon	Ashland	Southern Oregon College Library (1, 2, 3).
	Eugene	University of Oregon Library (1, 2, 3).
	Forest Grove	Pacific University Library (3).
	La Grande	Eastern Oregon College Library (2, 3).
	McMinnville	Linfield College, Northup Library (3).
	Monmouth	Oregon College of Education Library (3).
	Portland	Bonneville Power Administration Library, U.S. Department of the Interior (3). Lewis and Clark College Library (2, 3). Library Association of Portland (1, 2, 3). Portland State University Library (1, 2, 3).
	Salem	Oregon State Library (1, 2, 3). Willamette University Library (3).
	State University	Oregon State University Library (1, 2, 3).
Pennsylvania	Allentown	Muhlenberg College Library (3).
	Altoona	Altoona Public Library (3).
	Bethlehem	Lehigh University Library (1, 2, 3).
	Carlisle	Dickinson College Library (2, 3).
	Cheyney	Cheyney State College, Leslie Pinckney Hill Library (3).
	Collegeville	Ursinus College, Myrin Library (3).
	Doylestown	Bucks County Free Library (3).
	East Stroudsburg	East Stroudsburg State College, Kemp Library (3).
	Greenville	Thiel College, Langenheim Memorial Library (1, 2, 3).
	Harrisburg	State Library of Pennsylvania (1, 2, 3).
	Haverford	Haverford College Library (3).
	Hazleton	Hazleton Area Public Library (1, 2, 3).
	Indiana	Indiana University of Pennsylvania, Rhodes R. Stabley Library (3).
	Johnstown	Cambria County Library System (2, 3).
	Lancaster	Franklin and Marshall College, Fackenthal Library (1, 2, 3).
	Lewisburg	Bucknell University, Ellen Clarke Bertrand Library (1, 2, 3).
	Mansfield	Mansfield State College Library (1, 2, 3).
	Meadville	Allegheny College, Reis Library (1, 2, 3).
	Millersville	Millersville State College, Ganser Library (3).
	Monessen	Monessen Public Library (3).
	New Castle	New Castle Free Public Library (3).
	Newtown	Bucks County Community College Library (3).
	Norristown	Montgomery County-Norristown Public Library (3).
	Philadelphia	Drexel University Library (1, 2, 3). Free Library of Philadelphia (1, 2, 3). Temple University, Paley Library (1, 2, 3). University of Pennsylvania Library (1, 2, 3).
	Pittsburgh	Bureau of Mines Library, U.S. Department of the Interior (2, 3). Carnegie Library of Pittsburgh (1, 2, 3). University of Pittsburgh, Hillman Library (1, 2, 3).
	Pottsville	Pottsville Free Public Library (2, 3).
	Reading	Reading Public Library (2, 3).
	Scranton	Scranton Public Library (1, 2, 3).
	Shippensburg	Shippensburg State College, Ezra Lehman Memorial Library (3).
	Slippery Rock	Slippery Rock State College, Maltby Library (1, 2, 3).
	Swarthmore	Swarthmore College Library (3).
	University Park	Pennsylvania State University Library (1, 2, 3).

State	City	Library and Type of Publication Received
Pennsylvania	Warren	Warren Public Library (3).
	Waynesburg	Waynesburg College Library (3).
	West Chester	West Chester State College, Francis Harvey Green Library (1, 2, 3).
	Wilkes-Barre	Kings College Library (2, 3).
	Williamsport	Lycoming College Library (3).
	York	York Junior College Library (3).
	Youngwood	Westmoreland County Community College Library (3).
Rhode Island	Newport	Naval War College Library (3).
	Providence	Brown University, John D. Rockefeller, Jr., Library (1, 2, 3).
		Providence College, Phillips Memorial Library (3).
		Providence Public Library (3).
		Rhode Island College, James P. Adams Library (3).
	Wakefield	University of Rhode Island Library (1, 2, 3).
	Warwick	Warwick Public Library (3).
South Carolina	Westerly	Westerly Public Library (3).
	Charleston	Baptist College Library (2, 3).
		Charleston College Library (3).
		The Citadel, The Citadel Memorial Library (1, 3).
	Clemson	Clemson University Library (1, 2, 3).
	Columbia	Benedict College, Starks Library (3).
		Columbia College Library (3).
		South Carolina State Library (3).
		University of South Carolina, Undergraduate Library (1, 2, 3).
	Due West	Erskine College, McCain Library (3).
	Florence	Florence County Library (3).
	Greenville	Furman University Library (1, 2, 3).
		Greenville County Library (3).
South Dakota	Rock Hill	Winthrop College, Dacus Library (1, 3).
	Spartanburg	Spartanburg County Public Library (3).
	Aberdeen	Northern State College Library (3).
	Brookings	South Dakota State University, Lincoln Memorial Library (1, 2, 3).
	Pierre	South Dakota State Library (3).
	Rapid City	South Dakota School of Mines and Technology Library (1, 2, 3).
	Sioux Falls	Augustana College, Mikkelsen Library (3).
		Sioux Falls Public Library (3).
	Spearfish	Black Hills State College Library (3).
	Vermillion	University of South Dakota, I. D. Weeks Library (3).
Tennessee	Bristol	Kings College Library (1, 2, 3).
	Chattanooga	Chattanooga Public Library (1, 2, 3).
	Clarksville	Austin Peay State University, Woodward Library (1, 2, 3).
	Cleveland	Cleveland State Community College Library (3).
	Cookeville	Tennessee Technological University, Jere Whitson Memorial Library (1, 2, 3).
	Jackson	Lambuth College, Luther L. Gobbel Library (3).
	Jefferson City	Carson-Newman College Library (3).
	Johnson City	East Tennessee State University, Sherrod Library (1, 2, 3).
	Knoxville	Lawson McGhee Library (2).
		University of Tennessee Library (1, 2, 3).
	Martin	University of Tennessee at Martin Library (3).
	Memphis	Memphis Public Library and Information Center (1, 2, 3).
		Memphis State University, John W. Brister Library (1, 2, 3).
	Murfreesboro	Middle Tennessee State University Library (3).
	Nashville	Fisk University Library (2).
		Joint University Libraries (1, 2, 3).
		Public Library of Nashville (3).
		Tennessee State Library and Archives (1, 2, 3).
	Sewanee	University of the South, Jesse Ball DuPont Library (2, 3).
Texas	Abilene	Hardin-Simmons University Library (3).
	Arlington	Arlington Public Library (3).
		University of Texas at Arlington Library (1, 2, 3).
	Austin	Texas State Library (1, 2, 3).
		University of Texas, Law Library (1, 2, 3).
		University of Texas, Lyndon B. Johnson School of Public Affairs (3).
		University of Texas, Main Library (1, 2, 3).
	Baytown	Lee College Library (1, 2, 3).
	Beaumont	Lamar University Library (1, 2, 3).
	Brownwood	Howard Payne College, Walker Memorial Library (3).

State	City	Library and Type of Publication Received
Texas	Canyon	West Texas State University Library (1, 2, 3).
	College Station	Texas Agricultural and Mechanical University Library (1, 2, 3).
	Commerce	East Texas State University Library (2, 3).
	Dallas	Bishop College, Zale Library (3).
		Dallas Public Library (1, 2, 3).
		Southern Methodist University, Fondren Library (1, 2, 3).
		University of Texas Library (1, 2, 3).
	Denton	North Texas State University Library (1, 2, 3).
	Edinburg	Pan American University Library (3).
	El Paso	El Paso Public Library (1, 2, 3).
		University of Texas at El Paso Library (1, 2, 3).
	Fort Worth	Fort Worth Public Library (1, 2, 3).
		Texas Christian University, Mary Couts Burnett Library (1, 2, 3).
	Galveston	Rosenberg Library (3).
	Houston	Houston Public Library (1, 2, 3).
		Rice University, Fondren Library (3).
		University of Houston Library (1, 2, 3).
	Huntsville	Sam Houston State University Library (2, 3).
	Kingsville	Texas Arts and Industries University Library (1, 2, 3).
	Lake Jackson	Brazosport College Library (3).
	Laredo	Laredo Junior College, Harold R. Yearly Library (2, 3).
	Longview	Nicholson Memorial Public Library (2, 3).
	Lubbock	Texas Technological University Library (1, 2, 3).
	Marshall	Wiley College, Cole Library (3).
	Nacogdoches	Stephen F. Austin State University Library (1, 2, 3).
	Plainview	Wayland Baptist College, Van Howeling Memorial Library (3).
	San Angelo	Angelo State University Library (3).
	San Antonio	St. Mary's University, Academic Library (1, 2, 3).
		San Antonio College Library (3).
		San Antonio Public Library (1, 2, 3).
		Trinity University Library (1, 2, 3).
	San Marcos	Southwest Texas State College Library (1, 3).
	Texarkana	Texarkana Community College, Palmer Memorial Library (3).
	Victoria	University of Houston Library (3).
	Waco	Baylor University Library (2, 3).
	Wichita Falls	Midwestern University, Moffett Library (3).
Utah	Ephraim	Snow College, Lucy A. Phillips Library (2).
	Logan	Utah State University, Merrill Library (1, 2, 3).
	Ogden	Weber State College Library (1, 2, 3).
	Provo	Brigham Young University, Lee Library (1, 2, 3).
	Salt Lake City	University of Utah, Law Library (1, 2, 3).
		University of Utah, Marriott Library (1, 2, 3).
Vermont	Burlington	University of Vermont, Bailey Library (1, 2, 3).
	Castleton	Castleton State College, Calvin Coolidge Library (3).
	Lyndonville	Lyndon State College, Samuel Reed Hall Library (3).
	Middlebury	Middlebury College, Egbert Starr Library (2, 3).
	Montpelier	Vermont Department of Libraries (3).
	Northfield	Norwich University Library (3).
	Putney	Windham College, Dorothy Marvin Memorial Library (3).
Virginia	Blacksburg	Virginia Polytechnic Institute Library (1, 2, 3).
	Bridgewater	Bridgewater College, Alexander Mack Memorial Library (1).
	Charlottesville	University of Virginia, Alderman Library (1, 2, 3).
		University of Virginia, Law Library (1, 3).
	Chesapeake	Chesapeake Public Library System (3).
	Danville	Danville Community College Library (3).
	Emory	Emory and Henry College Library (1, 2, 3).
	Fairfax	George Mason College of the University of Virginia, Fenwick Library (3).
	Fredericksburg	Mary Washington College, E. Lee Trinkle Library (3).
	Hampden-Sydney	Hampden-Sydney College, Eggleston Library (3).
	Harrisonburg	Madison College, Madison Memorial Library (3).
	Lexington	Virginia Military Institute, Preston Library (2, 3).
		Washington and Lee University, Cyrus Hall McCormick Library (2, 3).
	Norfolk	Armed Forces Staff College Library (3).
		Norfolk Public Library (3).
		Old Dominion University, Hughes Memorial Library (1, 2, 3).
	Petersburg	Virginia State College, Johnston Memorial Library (3).
	Quantico	Federal Bureau of Investigation Academy Library (1).
	Richmond	U.S. Court of Appeals, Fourth Circuit, Library (2).
		University of Richmond, Boatwright Memorial Library (2, 3).

Virginia	Richmond	Virginia Commonwealth University, James Branch Cabell Library (3).
	Roanoke	Virginia State Library (1, 2, 3).
	Salem	Hollins College, Fishburn Library (3).
	Williamsburg	Roanoke Public Library (3).
	Wise	Roanoke College Library (3).
		College of William and Mary, Swen Library (1, 2, 3).
		Clinch Valley College, John Cook Wyllie Library (1, 2, 3).
Washington	Bellingham	Western Washington State College, Wilson Library (1, 2, 3).
	Cheney	Eastern Washington State College Library (1, 2, 3).
	Ellensburg	Central Washington State College Library (1, 2, 3).
	Everett	Everett Public Library (3).
	Olympia	Evergreen State College Library (1, 2, 3).
	Port Angeles	Washington State Library (1, 2, 3).
	Pullman	North Olympic Library System (3).
	Seattle	Washington State University Library (1, 2, 3).
		Seattle Public Library (1, 2, 3).
		University of Washington Library (1, 2, 3).
	Spokane	Spokane Public Library (1, 2, 3).
	Tacoma	Tacoma Public Library (1, 2, 3).
		University of Puget Sound, Collins Memorial Library (2, 3).
	Vancouver	Fort Vancouver Regional Library (1, 2, 3).
	Walla Walla	Whitman College, Penrose Memorial Library (1, 2, 3).
West Virginia	Athens	Concord College Library (3).
	Bluefield	Bluefield State College Library (1, 2, 3).
	Charleston	Kanawha County Public Library (3).
		West Virginia Department of Archives and History (3).
	Elkins	Davis and Elkins College Library (3).
	Fairmont	Fairmont State College Library (3).
	Glenville	Glenville State College, Robert F. Kidd Library (3).
	Huntington	Marshall University Library (1, 2, 3).
	Institute	West Virginia State College Library (3).
	Morgantown	West Virginia University Library (1, 2, 3).
	Salem	Salem College Library (3).
Wisconsin	Appleton	Lawrence University, Samuel Appleton Library (2, 3).
	Beloit	Beloit College Library (3).
	Eau Claire	University of Wisconsin, William D. McIntyre Library (2, 3).
	Fond du Lac	Fond du Lac Public Library (1, 2, 3).
	Green Bay	University of Wisconsin at Green Bay Library (2, 3).
	La Crosse	La Crosse Public Library (3).
		University of La Crosse, Murphy Library (3).
	Madison	Department of Public Instruction, Reference and Loan Library (3).
		Madison Public Library (2, 3).
		State Historical Society Library (2, 3).
		University of Wisconsin, Memorial Library (1, 2, 3).
	Milwaukee	Milwaukee Public Library (1, 2, 3).
		Mount Mary College Library (3).
		Oklahoma Neighborhood Library (3).
		University of Wisconsin Library (1, 2, 3).
	Oshkosh	Wisconsin State University, Forrest R. Polk Library (1, 2, 3).
	Platteville	University of Wisconsin Library (1, 2, 3).
	Racine	Racine Public Library (1, 2, 3).
	River Falls	University of Wisconsin, Chalmer Davee Library (3).
	Stevens Point	University of Wisconsin Library (1, 2, 3).
	Superior	Superior Public Library (3).
		Wisconsin State University, Jim Dan Hill Library (2, 3).
	Waukesha	Waukesha Public Library (3).
	Wausau	Wausau Public Library (3).
	Whitewater	Wisconsin State University, Harold Andersen Library (1, 2, 3).
Wyoming	Casper	Natrona County Public Library (1, 2, 3).
	Cheyenne	Wyoming State Library (1, 2, 3).
	Laramie	University of Wyoming, Coe Library (1, 2, 3).
	Riverton	Central Wyoming College Library (3).
	Rock Springs	Western Wyoming College (3).
	Sheridan	Sheridan College, Kooi Library (2, 3).
Guam	Agana	Nieves M. Flores Memorial Library (3).
Panama Canal Zone	Balboa Heights	Canal Zone Library Museum (2, 3).

Puerto Rico	Mayaguez	University of Puerto Rico Library (1, 2, 3).
	Ponce	Catholic University of Puerto Rico Library (3).
	San Juan	University of Puerto Rico Library (1, 2, 3).
Virgin Islands	Charlotte Amalie	College of the Virgin Islands, Ralph M. Paiewonsky Library (3).
		St. Thomas Public Library (1).

BULLETINS

B 650. Mineral Facts and Problems, 1970 Edition, by Staff, Bureau of Mines. 1291 pp. Gives up-to-date comprehensive information on all important minerals—metals, nonmetals, and fuels. This one-volume encyclopedia discusses individual mineral commodities separately in 93 chapters under such topics as industry patterns; technology, present and future; reserves; supply-demand relationships; byproduct-coproduct relationships; consumption patterns; economic factors; and environmental considerations. In addition the outlook for each mineral is projected to the year 2000. \$13.60.

B 651. Prereduced Iron Ore Pellets: Preparation, Properties, and Utilization, by M. M. Fine, N. B. Melcher, and others. 1970. 63 pp. 30 figs. A process for simultaneously reducing and indurating iron ore pellets was developed by Bureau of Mines laboratory research and confirmed on a continuous pilot plant basis. Moist iron ore concentrate was balled, mixed with solid reductant, and heated at about 1,100° to 1,150° C. On a small scale, a variety of concentrates and fuels were utilized successfully. The pilot rotary kiln tests were limited to natural magnetite, synthetic magnetite, lignite, and anthracite. In both laboratory and pilot plant, partially reduced pellets with excellent physical properties were regularly produced with average analyses of at least 80 percent total iron and 60 percent or more metallic iron. These and other prereduced pellets were smelted in the Bureau's experimental blast furnace facility, Bruceton, Pa. With prereduced spheres comprising 85 percent of the burden, the coke rate was approximately half that with standard oxide pellets and production of hot metal was increased by 75 percent. Economic appraisal of the cost of making hot metal indicates that reduced pellets could be more profitable than any other iron raw material in both investment capital and daily cost of operation. (*Out of print.*)

B 652. Interstitial Compounds As Fuel Cell Catalysts: Their Preparative Techniques and Electrochemical Testing, by S. Akhtar, C. T. Grein, and D. Bienstock. 1970. 60 pp. 32 figs. Interstitial compounds of iron, cobalt, and nickel, and their binary and ternary mixtures with silver, gold, palladium, and platinum were prepared and tested as fuel cell catalysts. The first step in the preparation of the interstitial compounds consisted of preparing finely divided metals. This was done either by the Raney method or by reduction of precipitated hydroxides of the metals. The finely divided reduced metals were then treated with carbon- and/or nitrogen-containing gases to prepare their carbides, nitrides, and nitrocarbides. The materials were tested for cathodic activity towards O_2 and for anodic activity towards H_2 , C_3H_8 , NH_3 , CO , and N_2H_4 in acid and alkaline electrolytes at 25° to 90° C in half-cell assemblies. Samples of carbided and nitrocarbided 1Ni-1Ag-1Au were about one-fifth as active as Pt-black in the reduction of O_2 in 35-percent-KOH solution whereas the activities of several interstitial preparations exceeded the activity of Pt-black in the reduction

of O_2 in 12M KOH containing N_2H_4 . Nitrocarbides of x-Fe₂C, 3Ni-1Au, and 1Ni-3Au were effective catalysts for oxidizing N_2H_4 in liquid NH_3 containing NH_4SCN . Corrosion of the catalysts by electrolytes was severe in many cases. (*Out of print.*)

B 653. Reduction of Air Pollutants From Gas Burner Flames, Including Related Reaction Kinetics, by Margaret E. Harris, Valeria R. Rowe, E. B. Cook, and J. Grumer. 1970. 67 pp. 21 figs. The formation of nitrogen oxides, the decay of carbon monoxide, and the concentrations of residual hydrocarbons in the secondary combustion zones of propane-air and methane-air flames were studied in three enclosed burners designed to simulate gas appliances such as space and water heaters. The effect of thermally or chemically perturbing the combustion gases above these flames was determined theoretically and by means of factorial experiments. The concentrations of air pollutants and the flame temperatures were measured, and the effects of ingress of secondary air into the primary and secondary combustion zones, flame stability, burner port surface, and simulated recycling of combustion gases were noted.

Based on this study, four principles were derived that, applied to gas appliance design, will insure minimal emissions of these air pollutants:

1. Oxides of nitrogen can best be kept low by depressing peak temperatures to about 3,050° F.

2. If this is not possible, then the secondary combustion zone should be cooled rapidly to this temperature.

3. Carbon monoxide concentrations can be limited by rapid induction of secondary air.

4. Hydrocarbon concentrations can be controlled by designing for well-seated, stable flames.

In addition, empirical reaction rates were derived that predict the concentrations of nitrogen oxides and carbon monoxide in the primary and secondary combustion zones. Work done under an agreement with the National Air Pollution Control Administration, U.S. Department of Health, Education, and Welfare. (*Out of print.*)

B 654. The Chemical Thermodynamic Properties of Hydrocarbons and Related Substances. II. Properties of 25 Organic Sulfur Compounds in the Ideal Gas State From 0° to 1,000° K, by M. Zaki El-Sabban and Donald W. Scott. 1970. 26 pp. Tables of chemical thermodynamic properties for the ideal gas state from 0° to 1,000° K are reported for eight alkanethiols, three cycloalkanethiols and arylthiols, six thiaalkanes, two dithiaalkanes, three thiacycloalkanes, and three thiophenes. They are based on current physical and thermochemical constants and definitions, reliable vibrational assignments, and the latest insights into molecular structure and energetics. (*Out of print.*)

B 655. Thermodynamic, Electrical, Physical, and Compositional Properties of Seeded Coal Combustion Products, by H. F. Feldmann, M. A. Leonardo, W. H. Simons, and D. Bienstock. 1970. 281 pp. 7 figs. This work was done to provide thermodynamic, electrical, physical,

and compositional data on the seeded combustion plasmas of seven coals for the design of MHD generators. The systems were assumed to be at equilibrium, and the design data were generated by solving for the composition of both gas and liquid phases with a digital computer. The coals reported in this study include a western sub-bituminous, a Pennsylvania anthracite, and five representative bituminous coals. The data include dewpoint temperatures of both slag and seed. A Mollier diagram for each coal is given to allow graphical generator calculations. (*Out of print.*)

Bulletin 656. Blasting Vibrations and Their Effects on Structures, by Harry R. Nicholls, Charles F. Johnson, and Wilbur I. Duvall. 1971. 105 pp. 73 figs. This report presents the results of the Bureau of Mines 10-year program to study the problem of air blast and ground vibrations generated by blasting. The program included an extensive field study of ground vibrations; a consideration of air blast effects; an evaluation of instrumentation to measure vibrations; establishment of damage criteria for residential structures; determination of blasting parameters which grossly affected vibrations; empirical safe blasting limits; and the problem of human response. While values of 2.0 in/sec particle velocity and 0.5 psi air blast overpressure are recommended as safe blasting limits not to be exceeded to preclude damage to residential structures, lower limits are suggested to minimize complaints. Millisecond-delay blasting is shown to reduce vibration levels as compared to instantaneous blasting, and electric cap delay blasts offer a slight reduction in vibration levels as compared to Primacord delay blasts. Vibration levels of different blasts may be compared at common scaled distances, where scaled distance is the distance divided by the square root of the maximum charge weight per delay. Geology, rock type, and direction affect vibration level within limits. Empirically, a safe blasting limit based on a scaled distance of 50 ft/lb^{1/2} may be used without instrumentation. However, a knowledge of the particle velocity propagation characteristics of a blasting site determined from instrumented blasts at that site are recommended to insure that the safe blasting limit of 2.0 in/sec is not exceeded. (*Out of print.*)

B 657. The Proton Nuclear Magnetic Resonance Spectra of Pyridines, by F. R. McDonald, A. W. Decora, and G. L. Cook. 1971. 62 pp. 4 figs. The proton nuclear magnetic resonance spectra of 32 pyridines in two solvents, carbon tetrachloride and benzene-d₆, are presented. The chemical-shift and differential-shift values are correlated with the substituent position and with the solvent media. The ring protons and the protons on alkyl substituents are tabulated. The paramagnetic shift of the protons adjacent to the nitrogen is discussed, and a proposed structure for the pyridine-benzene complex that is consistent with the observed anomalous paramagnetic shift is presented. The utility of the data in the identification of pyridine compounds found in shale-oil naphtha is demonstrated. 65 cents.

B 658. Computer Simulation of Particulate Systems, by Lindsay D. Norman and others. 1971. 55 pp. 40 figs. Computer models for simulating the construction and for calculating the properties of particulate solids in random two- and three-dimensional systems (coverings and packings, respectively) were developed

for many different distributions of sizes. The statistical geometry of loose random coverings and packings was studied and several new interpretations of the area-coverings or space-filling requirements in these systems were made. A unique method for predicting the geometrical properties of loose random packings was developed that did not require the simulation of the assembled packing. Instead, the simplicial tetrahedra in any packing were predictable and were used to predict most of the properties of that packing. A review of the packing literature is included. (*Out of print.*)

B 659. Sulfur Compounds in Crude Oil, by H. T. Rall, C. J. Thompson, H. J. Coleman, and R. L. Hopkins. 1972. 187 pp. 99 figs. This report summarizes a systematic 20-year study of the organic sulfur compounds in Wesson, Texas, crude oil and, to a lesser extent, of three other crude oils, that has culminated in some 200 individual sulfur-compound identifications. The development and application of special separation and identification techniques generally suitable for the characterization of sulfur compounds in any crude oil are discussed. This report reviews early sulfur literature covering petroleum sulfur compound identifications completed before this study was begun, and cites 58 papers resulting from this work. The sulfur compounds in petroleum, both as to type and quantity, have long been a concern to the petroleum industry, and such compositional data are not only of theoretical interest, but also of practical value. GPO Stock No. 2401-2081. \$2.45.

B 660. Storage Stability of Gasoline. Development of a Stability Prediction Method and Studies of Gasoline Composition and Component Reactivity, by F. G. Schwartz, M. L. Whisman, C. S. Allbright, and C. C. Ward. 1972. 58 pp. 27 figs. The Bureau of Mines developed a rapid and precise method for predicting the storage stability of motor gasolines. This method resulted from the investigation of many analytical techniques as well as a study of fuel composition and fuel component gum-forming mechanisms. The first section of this bulletin discusses the development of the prediction test through its several phases, including revision of the standard 110° F storage test; attempts to develop a modification of the ASTM D525 induction bomb test; and the ultimate abandonment of this procedure with the adoption of the 16-hour oven test that was both precise and rapid. The second section comprises a discussion of further studies of fuel composition, including the reactivity of certain sulfur compounds and hydrocarbons to form gum. The compositions of various gums and inorganic deposits are reported in terms of elemental analysis and spectroscopic examinations. The reactions of tetraethyllead with selected hydrocarbons are also reported. GPO Stock No. 2404-1030. 60 cents.

B 661. Coal Composition, Coal Plasticity, and Coke Strength, by W. R. K. Wu and W. H. Frederic. 1973. 88 pp. 16 figs. Results of linear correlations of two to four variables by the least-squares method are presented. The variables include 63 parameters representing coal composition, coal plasticity, and coke strength. The composition parameters are based on chemical analyses; the plasticity parameters, on three plastometer and dilatometer tests and four miscellaneous tests; and the coke-strength parameters, on ASTM indices. Seventy-two to 84 plastic coals were used in the plasticity and carbonization tests; 43 nonplastic or weakly plastic coals

were used in the coal-band studies. Plots of relations between volatile matter, carbon, and oxygen contents of 1,860 coals and the 84 coals used are shown. Similar plots between volatile matter and hydrogen or atomic H/C of the 84 coals are also included. Significance of regression coefficient signs for coal composition parameters in the significant correlations found are discussed. Based on these significances, the following relations are shown: (1) Coke strength versus average aromaticity, or mineral matter content, of the parent coal; (2) characteristic temperatures of the plastometer and dilatometers, the free-swelling index, or the Gray-King type versus average hydroaromaticity of the coal; and (3) nontemperature parameters of the plastometer and dilatometers versus the physical properties of a certain group of compounds from thermal decomposition of coal. Significances between the positions of coals in the coal band and the aforementioned relations are also discussed. A structural theory of coal plasticity is proposed. Applications of the correlation results are discussed. Composition parameters may be used as a basis for selecting coking coals for stronger coke. Plasticity parameters may be used for the same purpose. Coke-strength indices may be estimated to within 4 to 8 units of the observed values; the end temperatures of the plastometer and dilatometer tests, within 5° to 10° C; and the free-swelling index, within 1 unit. GPO Catalog No. I28.3:661. Stock No. 2404-01247. \$1.25.

B 662. Mica Beneficiation, by James Browning. 1973. 21 pp. 12 figs. The Bureau of Mines conducted laboratory and continuous process development work on weathered mica pegmatites and micaceous schist ores to determine the feasibility of recovering commercial-grade mica concentrates by flotation. The research resulted in the development of two processes for flotation of mica: an acid cationic method for recovery of coarse mica, and an alkaline anionic-cationic method for recovery of fine mica. The research indicated that the two processes may be effectively utilized separately or in combination for flotation of mica from weathered pegmatites and micaceous schists. Concentrates containing over 98 percent mica, with recoveries ranging from 77 to 92 percent, were obtained from the pegmatite ores. The micaceous schist ores yielded concentrates containing 95 to 98 percent mica, with recoveries ranging from 70 to 83 percent. This report summarizes the process development work and demonstrates the feasibility of producing commercial-grade mica concentrates. It also includes details of commercial beneficiation and grinding of mica. GPO Catalog No. I28.3:662. GPO Stock No. 2404-01144. 50 cents.

B 663. Low-Temperature Lignite Tar: Processing and Utilization, by John S. Berber, Richard L. Rice, and John D. Spencer. 1973. 63 pp. 78 figs. Acids, neutral oils, and pitch were produced by distillation of low-temperature lignite tar and processed to upgrade them into more valuable products. The acids were separated from the distillate and catalytically dealkylated to produce phenol, cresol, and xylene. Aromatic and naphthene fractions of the neutral oil were converted into phthalic and maleic anhydrides by catalytic hydrodealkylation and vapor-phase oxidation. Paraffins and *n*-olefins from the neutral oil were processed into alkylbenzene sulfonate, a biodegradable substance. Aromatic materials from the neutral oil were also extracted with organic compounds and the extract hydrogenated under pressure to produce jet fuel. The pitch was processed by various means to change

its characteristics and make it suitable for similar applications as high-temperature tar pitch, including preparation of carbon black and metallurgical electrodes. In most cases, products obtained from the low-temperature tar were examined for physical and chemical characteristics and for potential commercial utility. Information obtained from this research would be helpful if a new coal-chemical industry based on tar utilization were established. GPO Catalog No. I28.3:663. Stock No. 2404-01220. \$1.25.

B 664. A Study of the Carbon Dioxide-Carbon Reaction by Oxygen Exchange, by M. Mentser and S. Ergun. 1973. 42 pp. 11 figs. The exchange of oxygen between carbon dioxide and carbon monoxide that occurs reversibly on carbon surfaces was studied at temperatures of 750° to 850° C and a pressure of 1 atmosphere. Carbon-14 was used to detect and measure the exchange reaction. The extent of oxygen exchange was a linear function of composition of the gas mixture, and this relationship was used to evaluate the forward and backward rate constants of the reaction. Equilibrium constants, directly determined for oxygen exchange in this study, agreed well with values in the literature that were derived only by indirect procedures. This result establishes the validity of oxygen exchange in the mechanism of carbon gasification by CO₂. Rates of carbon gasification were less than an order of magnitude slower than rates of oxygen exchange. Activation energies for these two processes were 58 and 53 kcal/mole, respectively. The closeness in the activation energies argues against any change in the rate-controlling step over a wide temperature span at atmospheric pressure. The role of CO as a retardant on the CO₂-C reaction and the nature of the carbon-oxygen complex are also discussed. GPO Catalog No. I28.3:664. Stock No. 2404-01227. 75 cents.

B 665. Microseismic Techniques for Monitoring the Behavior of Rock Structures, by Wilson Blake, Fred Leighton, and Wilbur I. Duvall. 1974. 65 pp. 27 figs. This report presents the results of a 7-year Bureau of Mines program to review, revise, and make an effective engineering tool of the microseismic method of determining the stability of rock structures. The program consisted of developing new microseismic equipment and data analysis techniques and extensive field investigations to demonstrate the effectiveness and potential of the broad-band microseismic method. The guidelines for choosing the components of a microseismic system are presented along with approximate cost figures. Different microseismic systems are discussed, including completely automated systems. Procedures for conducting microseismic investigations and analyzing microseismic data are discussed in detail. GPO Catalog No. I28.3:665. Stock No. 2404-01554. \$1.10.

B 666. Chemical Thermodynamic Properties of Hydrocarbons and Related Substances. Properties of the Alkane Hydrocarbons, C₁ Through C₁₀, in the Ideal Gas State From 0 to 1500 K, by D. W. Scott. 1974. 187 pp. Chemical thermodynamic properties for the ideal gas state from 0 to 1500 K are tabulated for all of the alkane hydrocarbons through C₁₀. These properties are based on correlations of the extant data for the entropy, vapor heat capacity, and enthalpy of formation of individual alkanes and the equilibrium constants of alkane isomerization reactions. GPO Catalog No. I28.3:666. Stock No. 2404-01547. \$2.55.

SPECIAL PUBLICATIONS

SP 1-70. List of Bureau of Mines Publications and Articles.

January 1, 1965, To December 31, 1969, With Subject and Author Index, compiled by Rita D. Sylvester. 437 pp. 1970. This compilation supplements the 50-year list of Bureau publications issued from July 1, 1910, to January 1, 1960; the 50-year list of articles by Bureau authors published outside the Bureau from July 1, 1910, to January 1, 1960; and the 5-year list of Bureau publications and articles published from January 1, 1960, to December 31, 1964. It includes all the material in the four annual lists of Bureau publications and articles for January 1, 1965, to December 31, 1968, as well as the Bureau publications and articles for 1969. More than 2,500 publications by Bureau authors published in the regular Bureau of Mines series, in scientific, technical, or trade journals, or in other media are listed and summarized; those available from the Bureau of Mines are indicated. Libraries which maintain files of Bureau publications are listed. Cooperative publications issued by organizations with which the Bureau conducted joint research are described. Patents issued to Bureau personnel are also listed, and instructions are given on how to apply for permission to use them. One of the outstanding features of this Special Publication is an exhaustive subject and author index. (*Out of print.*)

SP 1-71. List of Bureau of Mines Publications and Articles.

January 1 to December 31, 1970, With Subject and Author Index, compiled by Rita D. Sylvester. 130 pp. 1971. This compilation lists and summarizes publications by Bureau authors published in the regular Bureau of Mines series, in scientific, technical, or trade journals, or in other media; those available from the Bureau of Mines are indicated. Patents issued to Bureau personnel are also listed, and instructions are given on how to apply for permission to use them. One of the outstanding features of this Special Publication is an exhaustive subject and author index. (*Out of print.*)

SP 1-72. Towards Improved Health and Safety for America's Coal Miners, by Staff, Bureau of Mines.

January 1972. 79 pp. 5 figs. This publication is the official account of the first year's administration of the Federal Coal Mine Health and Safety Act of 1969. Most provisions of the law took effect during 1970. This new annual report summarizes the law itself and gives an account of all major developments that occurred in connection with it last year. A chronological summary of the year's developments is followed by an introduction that explains the unique features of the new law. A timetable for actions required to be taken by the Secretary of the Interior is included. (*Out of print.*)

SP 2-72. Administration of the Federal Metal and Non-metallic Mine Safety Act. 1970 Annual Report, by Staff, Bureau of Mines. February 1972. 60 pp. 4 figs.

This publication is an official account of the administration of the Federal Metal and Nonmetallic Mine Safety Act in 1970. Health and safety standards, both mandatory and advisory, became effective on July 31, 1970, and refer to underground mines, surface (open pit) mines, and sand and gravel and crushed stone operations. During the period of July 31 to December 31, 1970, a total of almost 16,000 violations of mandatory standards and nearly 5,500 failures to comply with advisory standards were observed by Bureau of Mines inspectors. Before

the inspections were completed, nearly 7,000 corrections of mandatory standards and violations and 1,100 corrections of advisory standards were completed. The report covers development of standards, application, education and training, research and technical support, and plans for developing and enforcing health and safety standards. (*Out of print.*)

SP 3-72. Bureau of Mines Research in 1971. A Summary of Significant Results in Mining, Metallurgy, and Energy, by Staff, Bureau of Mines. 1972. 61 pp. 7 figs.

The Bureau of Mines research and development program comprises essentially projects on the extraction, processing, use, reuse, and disposal of minerals and mineral fuels. Scientific and engineering efforts are directed to developing processes that will provide essential minerals without destruction or impairment of the environment and at minimal hazard to the health and safety of workers in the metal, nonmetal, and coal-producing industries. The research is carried out in the Bureau's 19 research centers and laboratories located throughout the United States and through contracts with industry, universities, and State agencies. This document reports only on in-house research, which accounted for about 68 percent of the Bureau's obligations for research in fiscal year 1971. (*Out of print.*)

SP 4-72. List of Bureau of Mines Publications and Articles, January 1 to December 31, 1971, With Subject and Author Index, by Rita D. Sylvester. 116 pp.

This compilation lists and summarizes publications by Bureau authors published in the regular Bureau of Mines series, in scientific, technical, or trade journals, or in other media; those available from the Bureau of Mines are indicated. Patents issued to Bureau personnel are also listed, and instructions are given on how to apply for permission to use them. One of the outstanding features of this Special Publication is an exhaustive subject and author index. (*Out of print.*)

SP 1-73. Bureau of Mines Research 1972. A Summary of Significant Results in Mining, Metallurgy, and Energy, by Staff, Bureau of Mines. 1973. 82 pp.

The Bureau of Mines research and development program is comprised essentially of projects on the mining, extraction, processing, use, reuse, and disposal of minerals and mineral fuels, including the environmental effects of these operations. The research is carried out in the Bureau's 19 research centers and laboratories located throughout the United States and through contracts with industry, universities, and State agencies. GPO Catalog No. 128.115: 972. Stock No. 2404-01335. \$1.00.

SP 2-73. List of Bureau of Mines Publications and Articles, January 1 to December 31, 1972, With Subject and Author Index, compiled by Rita D. Sylvester. 118 pp.

This compilation lists and summarizes publications by Bureau authors published in the regular Bureau of Mines series; in scientific, technical, or trade journals; or in other media. Those available from the Bureau of Mines are indicated. Patents issued to Bureau Personnel are also listed, and instructions are given on how to apply for permission to use them. An outstanding feature of this Special Publication is an exhaustive subject and author index. GPO Catalog No. 128.5:973. Stock No. 2404-01404. \$1.50.

SPECIAL PUBLICATIONS

SP 1-74. Bureau of Mines Research 1973. A Summary of Significant Results in Mining, Metallurgy, and Energy, by Staff, Bureau of Mines. 1974. 107 pp. Created by the Organic Act of 1910, the Bureau of Mines is the Federal Government's primary research arm in the mineral and fossil fuel fields. Through it, the Nation has 19 research centers and laboratories, located throughout the country, as essential startoff points to answer such challenges as the energy crisis of late 1973 with which we are faced. The research and development being performed by coal, natural gas, and oil specialists at the Bureau's six Energy Research Centers and Laboratories across the Nation have taken on added emphasis with the realization that our once vast quantities of clean energy fuels are being depleted rapidly. For the last 2 years annual reports have been published on significant research projects and mineral intelligence studies conducted by the Bureau of Mines. This, the third report, summarizes the results of scientific and engineer-

ing investigations in developing technology for extracting, processing, and recycling minerals, metals, and fossil fuels. GPO Catalog No. I28.115:973. Stock No. 2404-01577. \$1.25.

SP 2-74. List of Bureau of Mines Publications and Articles, January 1 to December 31, 1973, With Subject and Author Index, compiled by Rita D. Sylvester. 1974. 148 pp. This compilation lists and summarizes publications by Bureau authors published in the regular Bureau of Mines series, in scientific, technical, or trade journals, or in other media; those available from the Bureau of Mines are indicated. Patents issued to Bureau personnel are also listed, and instructions are given on how to apply for permission to use them. One of the outstanding features of this Special Publication is an exhaustive subject and author index. GPO Catalog No. I28.5:973. Stock No. 2404-01643. \$2.60.

HANDBOOKS

HB 1-70. Controlling Employee Exposure to Alpha Radiation in Underground Uranium Mines. Volume 1 of Two Volumes, by R. L. Rock and D. K. Walker. 1970. 72 pp. 5 figs. The Bureau of Mines presents a general discussion of the radon-daughter hazard associated with underground uranium mining and the control measures which are effective in eliminating this danger. The problem of employee exposure to radiation in underground uranium mines is reviewed, methods of determining atmospheric alpha radiation levels are discussed, and practical methods of reducing radon and radon-daughter influx into active mine openings are presented. Other pertinent subjects in radiation control are discussed, such as mine ventilation, mine planning, miner education, and individual exposure protection. 90 cents.

HB 1-71. First Aid for the Mineral and Allied Industries. A Bureau of Mines Instruction Manual, by John S. Kelly. 1971. 191 pp. 74 figs. This handbook is designed for use in first aid training for employees in the mineral and allied industries. It is intended to equip the student with the ability to render prompt, correct emergency care to the injured, especially in mines, as near as

possible to the place where the accident occurred. It is written in simple, straightforward language, is fully illustrated, and is thoroughly indexed. An instructor's outline for a standard 10-hour first aid course is presented in an appendix. \$2.10.

HB 2-71. Controlling Employee Exposure to Alpha Radiation in Underground Uranium Mines. Volume 2 of Two Volumes. (Appendixes for the Use of Radon-Daughter Control Specialists), by R. L. Rock, R. W. Dalzell, and E. J. Harris. 1971. 180 pp. 55 figs. The Bureau of Mines' concern over radiation health hazards in uranium mines is inherent in its responsibility to promote safe health environments in the mining industry. The two volumes of this publication were prepared to make available information that could aid in minimizing radiation exposure of underground uranium miners. This second volume discusses in detail specialized features of the radon-daughter control problem such as mine ventilation, instrumentation and calibration, sampling patterns, and record keeping. Volume 2 will be of interest as a reference guide for ventilation engineers and radon-daughter control specialists. \$2.00.

MINERALS YEARBOOKS

The Minerals Yearbook, 1968, published in three volumes, provides a record of performance of the Nation's minerals industries during the year and a review of world mineral production, consumption, and trade on a country-by-country basis. Volume I-II, Metals, Minerals, and Fuels, was published in 1969.

Volume III, Area Reports: Domestic, prepared by the staff of the Bureau of Mines. 1970. 53 ch. 838 pp. 55 figs. Contains chapters on mineral industries by States, the island possessions, and the Canal Zone. This volume has a statistical summary identical with that in volume I-II, and a chapter on employment and injuries. (*Out of print.*)

Volume IV, Area Reports: International, prepared by the staff of the Division of International Activities. 1970. 85 ch. 979 pp. This volume presents the latest available mineral statistics for more than 130 countries and areas and discusses the importance of minerals to the economies of these nations. A separate chapter reviews minerals in the world economy. (*Out of print.*)

The Minerals Yearbook, 1969, published in three volumes, provides a record of performance of the Nation's mineral industries during the year and a review of world mineral production, consumption, and trade on a country-by-country basis.

Volume I-II, Metals, Minerals, and Fuels, prepared by the staff of the Bureau of Mines. 1970. 80 ch. 1194 pp. 44 figs. Contains chapters on metal and nonmetal mineral commodities, including mineral fuels. It includes a chapter reviewing the mineral industries, a statistical summary, and chapters on employment and injuries and technologic trends. (*Out of print.*)

Volume III, Area Reports: Domestic, prepared by the staff of the Bureau of Mines. 1971. 53 ch. 848 pp. 55 figs. Contains chapters on each of the 50 States, the U.S. possessions in the Pacific Ocean and the Caribbean Sea, the Canal Zone, and the Commonwealth of Puerto Rico. This volume has a statistical summary, identical with that in volume I-II, and a chapter on employment and injuries. (*Out of print.*)

Volume IV, Area Reports: International, prepared by the staff of the Bureau of Mines. 1971. 77 ch. 942 pp. Contains the latest available mineral statistics for more than 130 foreign countries and areas and discusses the importance of minerals to the economies of these nations. A separate chapter reviews minerals in the world economy. (*Out of print.*)

The Minerals Yearbook, 1970, published in three volumes, provides a record of performance of the Nation's mineral industries during the year and a review of world mineral production, consumption, and trade on a country-by-country basis.

Volume I, Metals, Minerals, and Fuels, prepared by the staff of the Bureau of Mines. 1972. 80 ch. 1235 pp. 42

figs. This publication contains chapters on metal and nonmetal commodities including mineral fuels. It includes a chapter reviewing the mineral industries, a statistical summary, and chapters on employment and injuries and technologic trends. GPO Stock No. 2404-1126. \$10.75.

Volume II, Area Reports: Domestic, prepared by the staff of the Bureau of Mines. 1972. 53 ch. 807 pp. 52 figs. Contains chapters on each of the 50 States, the U.S. possessions in the Pacific Ocean and the Caribbean Sea, the Canal Zone, and the Commonwealth of Puerto Rico. This volume has a statistical summary, identical with that in volume I, and a chapter on employment and injuries in the mineral industries. GPO Stock No. 2404-01233. \$8.65.

Volume III, Area Reports: International, prepared by the staff of the Bureau of Mines. 1973. 76 ch. 1052 pp. This volume of the Minerals Yearbook presents the latest available statistics for more than 150 countries and areas and discusses the importance of minerals to the economies of these nations. A separate chapter reviews minerals in the world economy. GPO Catalog No. I28.37:970/v.3. Stock No. 2404-01351. \$9.70.

The Minerals Yearbook, 1971, published in three volumes, provides a record of the performance of the Nation's mineral industries during the year and a review of world mineral production, consumption, and trade on a country-by-country basis.

Volume I, Minerals, Metals, and Fuels, prepared by the staff of the Bureau of Mines. 1973. 81 ch. 1303 pp. This volume of the Minerals Yearbook contains chapters on metal and nonmetal commodities including mineral fuels. It includes a chapter reviewing each of the mineral industries, a statistical summary, and chapters on employment and injuries and technologic trends. GPO Catalog No. I28.37:971/v. 1. Stock No. 2404-01365. \$11.75.

Volume II, Area Reports: Domestic, prepared by the staff of the Bureau of Mines. 1973. 53 ch. 811 pp. 53 figs. Contains chapters on each of the 50 States, the U.S. possessions in the Pacific Ocean and the Caribbean Sea, the Canal Zone, and the Commonwealth of Puerto Rico. This volume has a statistical summary, identical with that in volume I, and a chapter on employment and injuries in the mineral industries. GPO Catalog No. I28.37:971/v. 2. Stock No. 2404-01488. \$8.65.

Volume III, Area Reports: International, prepared by the staff of the Bureau of Mines. 1973. 76 ch. 1111 pp. This volume presents the latest available statistics for more than 150 countries and areas and discusses the importance of minerals to the economies of these nations. A separate chapter reviews minerals in the world economy. GPO Catalog No. I28.37:971/v. 3. Stock No. 2404-01499. \$10.00.

MINERALS YEARBOOK

The Minerals Yearbook, 1972, published in three volumes, provides a record of the performance of the Nation's mineral industries during the year and a review of world mineral production, consumption, and trade on a country-by-country basis.

Volume I, Minerals, Metals, and Fuels, prepared by the staff of the Bureau of Mines. 1974. 81 ch. 1370 pp. 59 figs. Contains chapters on metal and nonmetal commodities including mineral fuels. It includes a chapter reviewing the mineral industries, a statistical summary, and a chapter on technologic trends. GPO Stock No. 2404-01610. \$12.15.

Volume II, Area Reports: Domestic, prepared by the staff of the Bureau of Mines. 1974. 52 ch. 805 pp. Contains chapters on each of the 50 States, the U.S. possessions in the Pacific Ocean and the Caribbean Sea, the Canal Zone, and the Commonwealth of Puerto Rico. It includes a statistical summary, identical with that in Volume I. GPO Stock No. 002-004-01745-7. \$10.20.

Volume III, Area Reports: International, prepared by the staff of the Bureau of Mines. 1974. 76 ch. 1103 pp. Presents the latest available statistics for more than 150 countries and areas and discusses the importance of minerals to the economies of these nations. A separate chapter reviews minerals in the world economy. GPO Stock No. 024-004-01755-4. \$12.40.

The Minerals Yearbook, 1973, published in three volumes, provides a record of the performance of the Nation's mineral industries during the year and a review of world mineral production, consumption, and trade on a country-by-country basis.

Volume I, Metals, Minerals, and Fuels, prepared by the staff of the Bureau of Mines. 82 ch. Contains chapters on metal and nonmetal mineral commodities, including mineral fuels. It includes a chapter reviewing the mineral industries, a statistical summary, and a chapter on technologic trends. The complete volume will be published in 1975. However, to provide the latest available statistical and economic data on minerals and fuels, preprints of individual chapters may be obtained from the Publications Distribution Branch, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, 15213.

Foreword, by Thomas V. Falkie, Director.

Acknowledgments, by Albert E. Schreck.

General reviews:

Review of the mineral industries, by Daniel E. Sullivan and Nicholas G. Theofilos.

Mining and quarrying trends in the metal and non-metal industries, by John L. Morning.

Statistical summary, by Staff, Office of Technical Data Services.

Commodity Reviews:

Abrasive materials, by Robert G. Clarke.

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Sodium and sodium compounds, by Charles L. Klingman.

Stone, by Harold J. Drake.

Sulfur and pyrites, by Roland W. Merwin and William F. Keyes.

Talc, soapstone, and pyrophyllite, by J. Robert Wells.

Thorium, by Roman V. Sondermayer.

Tin, by Keith L. Harris.

Titanium, by F. W. Wessel.

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Commodity reviews:

- Tungsten, by Richard F. Stevens, Jr.
- Uranium, by Walter C. Woodmansee.
- Vanadium, by Harold A. Taylor, Jr.
- Vermiculite, by Frank B. Fulkerson.
- Zinc, by Albert D. McMahon, John M. Hague, and Herbert R. Babitzke.
- Zirconium and hafnium, by Sarkis G. Ampian.
- Minor metals (arsenic, cesium and rubidium, germanium, indium, radium, scandium, selenium, tellurium, thallium), by Staff, Division of Nonferrous Metals—Mineral Supply.
- Minor nonmetals (greensand, iodine, lithium, meerschau, quartz crystal, staurolite, strontium, wollastonite), by Staff, Division of Nonmetallic Minerals—Mineral Supply.

Volume II, Area Reports: Domestic, prepared by the staff of the Bureau of Mines. 52 ch. Contains chapters on each of the 50 States, the U.S. possessions in the Pacific Ocean and the Caribbean Sea, the Canal Zone, and the Commonwealth of Puerto Rico. This volume has a statistical summary, identical with that in volume I. The complete volume will be published in 1975. However, to provide the latest available statistical and economic data on the domestic mineral industry, preprints of individual chapters may be obtained from the Publications Distribution Branch, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213.

Foreword, by Thomas V. Falkie, Director.

Acknowledgments, by Albert E. Schreck.

Statistical summary, by Staff, Office of Technical Data Services.

The mineral industry of—

- Alabama, by Joseph F. Corey.
- Alaska, by Robert J. Jaske.
- Arizona, by Gertrude N. Greenspoon and H. J. Schroeder.
- Arkansas, by Grace N. Broderick.
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- Idaho, by William C. Buttermann.
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- Indiana, by Robert A. Clifton.
- Iowa, by Brinton C. Brown.
- Kansas, by William G. Carrico and David A. Grisafe.
- Kentucky, by L. H. Frey.
- Louisiana, by William B. Harper, Eugene A. Anderson, and Leo W. Hough.
- Maine, by Frank B. Fulkerson.
- Maryland, by Charles L. Klingman.
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- Minnesota, by Cynthia T. Collins.
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- Nebraska, by William F. Keyes.
- Nevada, by V. Anthony Cammarota, Jr.
- New Hampshire, by Avery H. Reed.
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The mineral industry of—

- New York, by E. Chin.
- North Carolina, by Roland W. Merwin and Stephen G. Conrad.
- North Dakota, by Joseph B. Huvo.
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- Oregon, by John D. Corrick.
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- Puerto Rico, Panama Canal Zone, Virgin Islands, Pacific Island Possessions, and Trust Territory of the Pacific Islands, by J. M. West and Sarkis G. Ampian.
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Volume III, Area Reports: International, prepared by the staff of the Bureau of Mines. 76 ch. Presents the latest available statistics for more than 150 countries and areas and discusses the importance of minerals to the economies of these nations. A separate chapter reviews minerals in the world economy. The complete volume will be published in 1975. However, to provide the latest available statistical and economic data on the mineral industries of foreign nations, preprints of individual chapters may be obtained from the Publications Distribution Branch, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213.

Foreword, by Thomas V. Falkie, Director.

Acknowledgments, by Albert E. Schreck.

Minerals in the world economy, by Charles L. Kimbell and George A. Morgan.

The mineral industry of—

- Algeria, by John L. Albright.
- Angola, Mozambique, and Portuguese Guinea, by
Janice L. W. Jolly.
- Argentina, by Ronald F. Balazik.
- Australia, by Charles Wyche.
- Austria, by Grace N. Broderick.
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- RI 7291. Influence of Volatile Fuel Components on Vehicle Emissions**, by B. H. Eccleston, B. F. Noble, and R. W. Hurn. February 1970. 80 pp. 23 figs. The Bureau of Mines, in cooperation with the American Petroleum Institute, studied the effect of fuel volatility and front-end fuel composition on the amount and photochemical reactivity of automobile exhaust and fuel-system evaporative emissions. The study involved six gasolines—the base fuel, three fuels of varied volatility, and two fuels differing from the base and from each other in front-end olefin content. Data were obtained from 16 vehicles operated on a chassis dynamometer using a speed-loadtime cycle that approximated a typical urban trip. Tests were made at ambient temperatures of 20°, 45°, 70°, and 95° F, using a climate-controlled dynamometer room. The amount of hydrocarbon emission and its probable photochemical effect, a potential contribution to pollution, is expressed as weight (reactivity equivalent) of a moderately reactive material, ethylene. Emission of oxides of nitrogen, carbon monoxide, and aldehydes were also observed. Results showed that reduction of volatility from currently typical levels serves to reduce both the amount and the reactivity equivalent of evaporative losses with a slight penalty by way of higher exhaust emissions. Alternatively, reducing the amount of light (low boiling) olefin in the fuel had no effect on the amount of hydrocarbon pollutant but did significantly reduce the reactivity equivalent of the emissions. Neither volatility change nor chemical changes to the fuel significantly affected the non-hydrocarbon emissions. Work done in cooperation with the American Petroleum Institute.
- RI 7326. Geochemistry of Some Petroleum-Associated Waters From Louisiana**, by A. Gene Collins. January 1970. 31 pp. 9 figs. Some of the geochemical relationships that exist between subsurface fluids and the associated geologic strata in petroleum-producing areas of Louisiana have been determined. Samples of petroleum-associated water were obtained from 126 wells in Louisiana that produced from sediments of three geologic ages: Tertiary, Cretaceous, and Jurassic. The samples were transported to a central laboratory for analysis of chemical composition, using standard methods, to determine if the compositions varied with the geologic strata of their source and, if so, why. The dissolved constituents were compared with those of a brine that was concentrated by evaporation. The concentrations of bromide, calcium, and strontium were useful in distinguishing the brines produced from sediments of a late age from those of an earlier age. The concentration ratios of total equivalent magnesium and bromide indicated that dolomitization probably had occurred and altered the composition of the brines. A principal-components analysis of the data indicated an inverse relationship between depth and concentrations of bromide, strontium, calcium, and lithium.
- RI 7327. Stabilization of Hydraulic Backfill With Portland Cement, Including Results With Other Additives**, by Donald R. Corson. January 1970. 33 pp. 20 figs. The effects of adding varying amounts of type I portland cement to hydraulic backfill are described. Six different fill materials, each with three cement contents, were tested to determine which fill properties have the most significant effect on cemented strength. Two strength prediction equations, based on the physical and mineralogical properties of the fills, were formulated, and these accounted for 96 and 99 percent of the variability of the data. Results of both unconfined compression and triaxial tests of cemented fills are given, and the effects of moist curing and fill densification on the 7-day strength are discussed. Permeability test data are given, and the decreased permeability due to cement content and curing time is shown graphically. A discussion of the limited evaluation of other potential stabilization additives (expansive cement, fly ash, sodium silicate, gypsum, and asphalt) is included in an appendix.
- RI 7328. Coal Investigations Using Laser Irradiation**, by F. S. Karn, A. G. Sharkey, Jr., A. F. Logar, and R. A. Friedel. January 1970. 32 pp. 18 figs. Conditions necessary to obtain optimum yield of useful products when coal is rapidly heated to extreme temperatures by laser irradiation were determined by the Bureau of Mines. Product distribution and yield were investigated as functions of several variables. Low-rank coals with high-volatile matter gave highest total gas yields. Medium-rank coals gave the highest yields of H₂ and C₂H₂, and low-rank coals gave highest yields of CO and CO₂. Macerals gave gases of approximately the same composition, but the total gas yield increased in the order fusinite, micrinite, vitrinite, and exinite. Total gas and C₂H₂ yields varied inversely with particle size. The addition of nominally inert gases such as Ar, He, N₂ increased yields of H₂, C₂H₂, and total gas. Metals such as nickel and platinum had little influence on the rate of coal decomposition. Total gas yield increased with total energy of irradiation, and the ratio of C₂H₂-CH₄ increased with concentration of energy. A study was also made of the irradiation temperature, and a material balance was calculated.
- RI 7330. Mine Roof Vibrations From Underground Blasts**, by James J. Olson, Richard A. Dick, Joseph L. Condon, Arlo D. Hendrickson, and David E. Fogelson. January 1970. 55 pp. 19 figs. Previous Bureau of Mines studies of vibrations from quarry blasts have shown that the square root of the charge weight may be used to group particle velocity data from various charge sizes, and that empirical propagation equations may be used to estimate vibration amplitudes. Particle accelerations of the sandstone roof of the White Pine Copper mine, Michigan, were measured to determine whether similar propagation equations may be developed for underground mine blasts.
- Vibration data from White Pine blasts were best grouped by scaling with the square root of the charge

weight. Cube root scaling did not effectively group the data. The empirical propagation equation $AW^{1/2} = 50,000 (R/W^{1/2})^{-2.21}$, where A is peak-to-peak acceleration in g's, W is the zero-delay charge weight in pounds, and R is the distance from the blast in feet, may be used to estimate maximum vibration amplitudes from production sized blasts. Vibration differences among headings and types of explosive charge (AN-FO and dynamite), while statistically significant, were not a major factor in the estimation of maximum vibration amplitudes with an empirical propagation equation. Vibration differences between types of explosive charge were larger than the differences among headings, indicating that some reduction of vibration amplitude might be gained by using AN-FO rather than dynamite. Acceleration records from both White Pine's AN-FO and dynamite production blasts show that high intensity vibrations from the delayed portions of the blast (each delay interval = 25 milliseconds) were separate events, and that the zero-delay portion of the blast produced the maximum vibration amplitudes. If the pull of the underground blast round can be maintained, a reduction of the zero-delay charge weight may effectively reduce the maximum vibration amplitude of the blast.

RI 7331. Comparison of the Triangular, Polygonal, and a Statistical Method of Computing Grade and Tonnage of Ore for the Silver Bell Oxide Porphyry Copper Deposit, by Richard F. Hewlett. January 1970. 33 pp. 27 figs. This report describes a comparison of methods for computing grade and tonnage of ore, leach, and waste material for a mined-out portion of the Silver Bell Oxide porphyry copper deposit; computed values are compared with the actual tonnage of these classes of material produced during mining operations. Comparisons with production records have been made by using both exploration drill-hole assays and development blast-hole assays. The polygonal method is the most accurate for this deposit because it more closely represents the lateral mineral distribution in the deposit. This is demonstrated by plots of the total-copper assay distributions of the development blast-hole assays for a specific bench. The investigation also shows that the smaller vertical assay interval (based on a 5-foot vertical churn-drill-hole sample) yields a more accurate estimate of both grade and tonnage than the 40-foot composite assay interval (based on the average of eight 5-foot assay values). This can be attributed to the fact that selective mining within a bench can separate out much of the waste and leach material that is included as ore in the 40-foot composite assay computations. Work done in cooperation with the Bear Creek Mining Company and under a fellowship agreement with the University of Arizona.

RI 7332. Pretreating Steel Scrap To Speed Oxidation, by S. E. Khalafalla, S. L. Payne, and G. W. Reimers. January 1970. 20 pp. 7 figs. The extremely sluggish oxidation of steel scrap was appreciably accelerated when the charge was pretreated in aqueous solutions of sodium metavanadate or sodium molybdate. The degree of oxidation acceleration was inversely correlated with the melting point of the promoter oxide possessing the highest valency. The magnitude of oxidation enhancement exhibited a systematic inverse dependence on the duration of pickling processes; mere

dipping of the oxidizable charge in the vanadate bath was most effective. In general, the rate of steel scrap oxidation increased with increasing concentration of the pickling reagent.

The results are explained on the basis of the hydrolytic decomposition of the pickling agent with subsequent slow interaction with the metal surface, coupled with the tendency of vanadium to form polyanions in alkaline media. The data not only served to elucidate the mechanism by which catastrophic oxidation takes place but also showed that the accelerating species need not be alloyed with oxidizable metal; surface impregnation by minute amounts of the accelerating species can still produce catastrophic effects.

RI 7336. Solvent Extraction of Nickel and Zinc From a Waste Phosphate Solution, by H. E. Powell, L. L. Smith, and A. A. Cochran. January 1970. 14 pp. 9 figs. The selective recovery of nickel and zinc from a waste phosphate solution by solvent extraction was investigated by the Bureau of Mines as part of a broad program to recover valuable metals and compounds from industrial wastes and to reduce the associated land and water pollution caused by dumping these wastes. The waste, which resulted from the phosphation of automobile bodies, yielded 99 percent of both the nickel and the zinc extraction with dinonyl naphthalene sulfonic acid (DNSA) and di-2-ethylhexyl phosphoric acid (EHPA), respectively. Dilute sulfuric acid was used to recover the metals and regenerate the solvents.

RI 7338. Factors Affecting the Production of Phosgene Using Gamma Radiation, by Arne Landsberg and F. E. Block. January 1970. 15 pp. 9 figs. Experiments were made with a batch reactor to determine the effect of gas pressures, temperature, and gamma radiation intensity on the reaction of $\text{CO} + \text{Cl}_2 \rightarrow \text{COCl}_2$. The equation,

$$\frac{dP}{d\theta} = 0.0110 (1 - 0.01t) (P_{\text{CO}}I)^{1/2} P_{\text{Cl}_2}$$

where $\frac{dP}{d\theta}$ is the change of pressure of phosgene with time (atm/hr), t is the temperature ($^{\circ}\text{C}$), P_{CO} and P_{Cl_2} are the reactant pressures (atm), and I is the radiation intensity (r/hr), was found to best fit the data. Oxygen and a large ratio of reactor surface to volume retarded the reaction, but inert gases had no effect. A low-temperature reactor system is proposed to take advantage of the conditions which give a high reaction rate with gamma radiation and a simple scheme of product purification.

RI 7339. Oxidation Roasting of Chalcocite Concentrate, by M. M. Fine, A. B. Landstrom, and R. B. Schluter. January 1970. 19 pp. 8 figs. Chalcocite flotation concentrates (26 to 34 percent Cu and 6 to 7 percent S) were roasted in air to determine sulfur elimination as a function of temperature, airflow rate, and residence time. Fluosolids roasting was evaluated batchwise and continuously in a 4-inch fluid-bed reactor. Kiln roasting tests were carried out in a 4-inch-ID by 6-inch-long rotary drum. Pelletizing the very fine concentrates prior to roasting was essential to minimize dust losses and accretions. Concentrate pellets, sized minus 10 plus 20 mesh and bonded with 2 percent bentonite, were excellent feed for fluosolids roasting and limited dust losses

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to 10 percent or less. One-fourth-inch pellets were best suited to kiln roasting. Both techniques were capable of producing copper calcines analyzing well under 1 percent residual sulfur when operated at 900° C with average retention times of 3 to 4 hours. Calcined pellets were strong, porous, and readily reducible.

RI 7340. An Improved Maximum-Bubble-Pressure System for Measuring Surface Tension of Molten Metals, by Alfred E. Schwaneke, Wilbert L. Falke, and Vernon R. Miller. January 1970. 10 pp. 4 figs. An improved maximum-bubble-pressure system using the Sugden twin-capillary method for measuring the surface tension and density of molten metals is described. Improvements include (1) internally ground capillary tips, (2) electronic pressure transducers, (3) micrometer adjustment of immersion depth for density measurements, (4) valving arrangements to allow operation at other than atmospheric pressure, (5) temperature range to 1,100°C, and (6) recorder readout of pressures. Data for surface tension of mercury from 20° to 300° C are given.

RI 7341. Slope Stability Analysis by the Finite Element Stress Analysis and Limiting Equilibrium Method, by Fun-Den Wang and Meng-Cherng Sun. January 1970. 16 pp. 6 figs. A new approach for evaluating pit slope stability by the limiting equilibrium method has been developed by the Bureau of Mines. The finite element method of plane strain analysis is used to find the stress field of the pit slope structure. This stress field is then used to find the normal and shear stresses along a potential failure surface. The normal stresses are used with the Coulomb equation to calculate the shear resistance. The shear stresses are integrated to determine the total driving force. The factor of safety is evaluated from the ratio of the resisting force to the driving force along a failure surface and is found to be affected by the elastic material properties, modulus of elasticity, and Poisson's ratio.

RI 7342. Fluid Flow in Channels, Capillaries, and Porous Media Under the Influence of an Electric Field, by L. C. Headley, C. I. Pierce, and W. K. Sawyer. January 1970. 33 pp. 15 figs. A series of exploratory tests was conducted to determine the effects of steady electric fields on fluid flow and streaming potential in narrow passages and porous media, the effects of steady electric fields on fluid interfaces, and the influence of internal voltages on fluid flow in a porous porcelain sample. Voltages greater than about 5 kilovolts were found to influence liquid droplets emanating from a capillary tube. Solutions of polyethylene oxide and polyacrylamide in water exhibited widely different behavior than that of other liquids tested. Liquid-liquid displacement tests in porous samples to determine the influence of high voltage applied to the displacing liquid on flow rates and recovery gave no significant differences. No consistently measurable effects were noted, either on flow rate or streaming potential, when an electric field was applied transverse to the direction of flow in porous media and in narrow rectangular or cylindrical channels. Experimental values of formation factor and streaming potential for a porous porcelain sample agreed qualitatively with those calculated from electrokinetic theory for ultrafine capillaries. However, the agreement for the electroviscous effect was not good.

RI 7343. A Systematic Analysis of Pit Slope Structures by the Stiffness Matrix Method, by Fun-Den Wang and Meng-Cherng Sun. February 1970. 37 pp. 4 figs. A two-dimensional plane strain analysis by the stiffness matrix method was used to analyze two basic pit slope configurations. The magnitudes and the directions of stresses are given for a V-shape and for a flat-bottom pit with the slope angle varying from 30° to 90° at 10° intervals. Stress effects due to irregular pit configuration or to in situ forces are discussed. Equations of similitude for gravity loading are given. Expressions are also given for the stresses at the toe as a function of slope angle. Procedures are given for finding the stresses in any geometrically similar pit slope of different dimensions and material properties from the stresses and equations presented in this report. Numerical results show that the V-shape pit slopes have lower stresses than the flat-bottom pit slopes; hence, they are inferred to be more stable.

RI 7344. Electrolytic Preparation of Tungsten Metal and Tungsten Carbide From Wolframite, by John M. Gomes, Jenji Uchida, and M. M. Wong. February 1970. 8 pp. Two methods for electrowinning tungsten from wolframite [(Fe,Mn) WO₄] were investigated. The first method, direct electrowinning from wolframite concentrate dissolved in molten salt mixtures composed essentially of various combinations of sodium phosphates, sodium borates, and sodium halides, yielded impure products. The second method was electrowinning from a halide-tungstate melt that was obtained from a high-temperature, two-phase extraction of tungstic oxide (WO₃) from wolframite. Electrolysis in electrolytes prepared from addition of sodium metaphosphate (NaPO₃) and boric oxide (B₂O₃) to the halide-tungstate melt produced tungsten metal of 99.9 percent purity. Tungsten carbide (WC) was electrodeposited from the halide-tungstate melt when the melt was adjusted to contain 82 mole-percent NaCl and 6.0 mole-percent each of WO₃, sodium metaborate (Na₂B₂O₄), and caustic soda (NaOH).

RI 7345. An Evaluation of Variables in Basic Oxygen Steel-making, by V. R. Spironello, H. A. Tucker, and W. C. Hill. February 1970. 35 pp. 33 figs. Operating variables affecting the efficiency of the basic oxygen furnace (BOF) and the level of contaminating elements in the steel product were investigated by the Bureau of Mines. Steel was made in a 400-pound-capacity BOF designed to rotate on its vertical axis to increase the area of hot metal surface subject to oxygen attack. Hot metal for the BOF was made by melting pig iron and scrap in an 18-inch-ID cupola. The variables were BOF speed of rotation, rate of oxygen flow, number of jets and angle at which they were machined into the oxygen-lance tip, temperature of hot metal, reactivity of lime, and temperature of scrap for the BOF charge. Experiments were arranged according to a two-level fractional-factorial design. The effects of the seven variables were evaluated for 13 responses. The greatest ingot yield occurred while using the larger angle lance tip and jets. The most carbon burned per unit volume of oxygen resulted from rotating the BOF and using the smaller angle lance tip. The largest sulfur transfer to the slag occurred at the higher hot metal temperature levels and higher rate of oxygen flow.

RI 7346. Analysis of Tipple and Delivered Samples of Coal. Collected During Fiscal Year 1969, by Staff, Coal Sampling and Inspections. 1970. 29 pp. Bureau of Mines analyses, including heating value, ash-softening temperature, free-swelling index, and Hardgrove grindability index, are given in this report for 6,325 samples of coal purchased by the Government in fiscal 1969. The analyses are used to determine whether coal delivered to the Government is of the quality guaranteed by the contractor and to provide data for evaluating future contract bids. (*Out of print.*)

RI 7347. Selection of Anode Materials and Operating Conditions for Electrowinning Beryllium, by D. A. O'Keefe and D. E. Couch. February 1970. 11 pp. 6 figs. The electrowinning of beryllium from beryllium oxide (BeO) using a molten-salt electrolyte composed of 56 LiF -37 BeF_2 -7 BeO (mole-percent) was investigated. Anodes made of porous carbon were found to be superior in current-carrying capacity and gave a lower cell voltage than other types of anode material tested. When porous carbon anodes were used, the resultant increase in anode area prevented anode passivation. The cell voltage was 3.3 volts, and electrode current efficiencies of 50 to 70 percent were obtained. The electrodeposited beryllium was recovered as beryllium powder or was coalesced to metal beads by heating to $1,300^\circ\text{C}$.

RI 7348. Use of Cement Copper in an Iron-Copper-Carbon Powder Metallurgy Alloy, by Robert L. Crosby, D. H. Desy, and Robert M. Doerr. February 1970. 14 pp. The Bureau of Mines investigated the substitution of cement copper powder for commercial copper powder in an Fe-7 percent Cu-1 percent C powder metallurgy alloy. Copper powders from six different commercial cementation operations were separately upgraded by screening and hydrogen reduction. They were then mixed with commercial iron and graphite powders to form the Fe-7 percent Cu-1 percent C alloy. Various chemical and physical properties were determined on the upgraded cement copper and the alloy powders. Mechanical, physical, and chemical properties were determined on green and sintered specimens made from the alloy powders. Mean tensile and bending strength of sintered specimens were significantly lower than the means from specimens made from commercial metal powders. The lower strengths are apparently related to poor sinterability.

RI 7349. Strengths of Sulfur-Basalt Concretes, by Lester J. Crow and Robert C. Bates. March 1970. 21 pp. 11 figs. This study advances the use of elemental sulfur in structural materials by demonstrating its value in bonding high-strength, well-graded basalt aggregates to form sulfur-basalt concretes. Sulfur is an excellent bonding agent, and the strength of a thermoplastic sulfur-aggregate mixture depends, to a large degree, on the strength and grain-size distribution of the aggregate used. A 3-cubic-foot, electrically powered mixer with heat applied to the barrel was used to mix the sulfur and aggregate. Sulfur content of several mixtures was varied to obtain the best workability with a minimum of sulfur in excess of that necessary to fill the voids. The average grain sizes and grain-size distributions were also varied to determine their effects on strength. Unconfined compression tests of forty-five 6- by 12-inch cylinders yielded average strengths of 3,348 psi to 10,398 psi. The highest strength single cylinder was 10,717 psi. The cylinders were

tested from 24 hours to 6 days after pouring; after 24 hours the rise in strength was very slight. The results obtained suggest that sulfur can be a useful construction material.

An evaluation was also made of a high-vacuum application for sulfur concrete. Sulfur has a high vapor pressure at elevated temperatures, 50° to 100°C ; consequently, significant losses by sublimation can be expected. At lower temperatures the losses are not significant; however, this factor will limit its use at a higher temperature.

RI 7351. Mass Spectre and Analytical Correlations of Some Alkylcycloalkyl Sulfides, by J. E. Dooley, R. F. Kendall, and D. E. Hirsch. February 1970. 19 pp. Reference mass spectra and analytical correlations for 20 alkylcycloalkyl sulfides and two dicycloalkyl sulfides are presented to provide information that will facilitate the identification of sulfur compounds occurring in natural or synthetic mixtures. Reference spectra indicate relative intensities in addition to parent and base peak sensitivities. Analytical correlations establish the ionic species that reflect major fragmentation paths for the compounds studied. Specifically, the correlations show that these base peaks are formed by several different processes: (1) Cleavage of the bond α to the ring, (2) fragmentation of the alkyl chain, and (3) fragmentation of the ring plus fragmentation contribution from the alkyl chain. Useful correlations for determining alkyl chain length involve the $\text{C}_n\text{H}_{2n+3}\text{S}^+$ and $\text{C}_n\text{H}_{2n+1}^+$ ions. $\text{C}_n\text{H}_{2n-2}^+$ and $\text{C}_n\text{H}_{2n-1}\text{S}^+$ ions reveal the number of carbon atoms in the cyclic ring. Other important ionic species are also discussed. Work done in cooperation with the American Petroleum Institute.

RI 7352. Compressibility Data For Helium Over the Temperature Range -5° to 80°C and at Pressures to 800 Atmospheres, by Ted C. Briggs. March 1970. 39 pp. Twenty-two compressibility runs were made with helium over the temperature range -5° to 80°C and at pressures to 800 atmospheres. A Burnett apparatus was used. Data from the runs were fitted to a fourth degree polynomial equation of state in the pressure and a weighting factor of $P_r^{-3/4}$ was used. All data for a particular isotherm were treated simultaneously. A temperature function was found to represent the parameters B and C. Compressibility factors determined by this investigation are believed to be accurate to better than 0.05 percent.

RI 7353. Electrowinning Aluminum From Aluminum Chloride: Operation of a Single-Compartment Cell, by D. E. Kirby, E. L. Singleton, and T. A. Sullivan. March 1970. 24 pp. 13 figs. The electrochemical reduction of AlCl_3 was investigated as a process for the production of aluminum. An externally heated, single-compartment cell with a rammed refractory lining was used with molten KCl-NaCl-AlCl_3 electrolyte. Aluminum was deposited at 700° to 760°C with a current of 100 to 200 amperes on a molten aluminum cathode. Chloride was evolved at a graphite anode and collected and measured to provide a quantitative evaluation of the AlCl_3 reduction. Aluminum was removed from the cell by siphoning or ladling. Granular AlCl_3 was added periodically to replenish that depleted from the electrolyte. Concentrations of 7.5 to 17.5 percent AlCl_3 in the electrolyte were optimum for operation. Anode current efficiencies of 83 to 85 percent were attained, using anode current densities of 5.9 amperes per square inch and an anode-cathode distance of

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4 inches. The chemically bonded, alumina liner was resistant to attack by aluminum and chlorine but susceptible to erosion at the surface of the electrolyte. Titanium diboride proved suitable for the electrical connection to the molten aluminum cathode. Aluminum of a purity equal to or better than 1100 series metal was electrowon continuously from commercial $AlCl_3$ for a period of $4\frac{1}{2}$ months.

RI 7354. Air-Sealing Coal Mines To Reduce Water Pollution, by N. N. Moebis and Stephen Krickovic. March 1970. 33 pp. 21 figs. The Bureau of Mines air-sealed a 77-acre, above-drainage coal mine to evaluate sealing as a means of reducing the acid and metallic salt contents in drainage from abandoned mines. An approximate reduction in acidity of 150 ppm (equivalent to 193 pounds per day) and in iron of 98 ppm were directly attributed to sealing. The topographical, hydrological, and other factors involved in air-sealing are discussed, and the construction used to seal the mine is described.

RI 7355. Microbial Conversion of Hydrous Calcium Sulfate to Hydrogen Sulfide, by J. D. Corrick, M. J. Rose, J. A. Sutton, and J. M. Carosella. March 1970. 15 pp. 4 figs. Research was conducted to develop operating techniques and define some of the limiting parameters for microbially converting hydrous calcium sulfate to hydrogen sulfide. The work was carried out in either glass stoppered flasks or anaerobic fermentors. Using the criteria of pH, temperature, number of bacteria per milliliter of test solution, and hydrogen sulfide produced, it was shown that hydrous calcium sulfate could be microbially converted to hydrogen sulfide at a rate of 7.3 g H_2S/l of fermentor volume per 24 hours. The various parameters defined were pH, temperature, and medium exchange rate. These were shown to be a pH range of 7.2 to 8.8, a temperature range of 30° to 35° C, and a medium exchange rate of 70 percent of the fermentor volume per 24 hours. It was also shown that a daily waste was between 50 and 77 percent as effective as sodium lactate in supporting the production of hydrogen sulfide and that by utilizing a gas to purge the fermentation system, a 1.7-fold increase in hydrogen sulfide was obtained.

RI 7356. Effects of Type of Cut, Delay, and Explosives on Underground Blasting in Frozen Gravel, by Richard A. Dick. March 1970. 17 pp. 5 figs. Underground blasting in permanently frozen gravel was studied in a 7-by 12-foot drift by running a nonreplicated $2 \times 2 \times 2$ factorial experiment on the effects of type of cut, delay, and explosive on the fragmentation subsystem. Comparisons were made between a V-cut round and a burn-cut round, millisecond delays and half-second delays, and 40 percent special gelatin and 60 percent high-density ammonia dynamite. The number of large blocks in the muck pile, loading time, shuttle car operating time lost because of cleanup needs, length of advance per round, and length of muck pile were recorded and statistically analyzed. None of the blast parameters had a significant effect on the length of advance or length of muck pile, although the half-second delays tended to give a shorter muck pile than millisecond delays. The burn cut required less secondary breakage, less loading and cleanup time, and gave better overall fragmentation than the V-cut. The ammonia dynamite shots required less secondary breakage and less loading time than those using special gelatin. The half-second delays gave better overall fragmentation and required less cleanup time, but, the millisecond de-

lays gave a better loading rate. None of the differences between delays and explosives were notably significant.

RI 7357. Green River Formation Lithology and Oil Shale Correlations in the Piceance Creek Basin, Colorado, by Laurence G. Trudell, Thomas N. Beard, and John Ward Smith. 1970. 212 pp. 15 figs. A geologic framework for interpreting stratigraphic and geographic variations of the Green River Formation in the Piceance Creek basin is developed from lithologic data accumulated by the Bureau of Mines from oil-shale coreholes. From detailed Bureau of Mines descriptions of samples from nine coreholes and supplementary lithologic data from seven additional sampled sections, three cross sections were constructed along lines transecting the basin. Plotted as lithologic columns with corresponding oil yields and resistivity logs, the sampled sections are correlated on a time-stratigraphic basis. Distribution and correlation of nahcolite and halite zones are shown, and the approximate base of leaching of these saline minerals is indicated. General lithologic characteristics of members and zones are discussed and interpreted. Large-scale lithologic logs illustrate the nine Bureau of Mines core descriptions, and the complete description of Bureau of Mines-Atomic Energy Commission Colorado Corehole No. 1 is included in an appendix. The time-correlated cross sections provide a necessary framework for understanding the depositional history of the Green River Formation and will facilitate evaluation of oil shale and other mineral resources in the Piceance Creek basin. (*Out of print.*)

RI 7358. Properties of an Ion Exchange Resin With High Selectivity for Gold, by T. E. Green and S. L. Law. March 1970. 9 pp. 3 figs. The Bureau of Mines Heavy Metals Program emphasizes the need for improved analytical methods for gold determination. A commercially available ion exchange resin with high selectivity for gold was investigated as a potential method to collect gold from solution. The resin was found to quantitatively collect gold from acid solutions over a wide range of acid concentrations. Common metals were not collected by the resin nor did they seriously interfere with the collection of gold. X-ray spectrographic and neutron activation methods based on the use of papers containing this resin are proposed.

RI 7359. Method for Testing Rate of Gas Diffusion in Crude Oil by Periodic Measurement of Concentration Profiles, by G. T. Brow, C. Q. Cupps, and J. Fry. March 1970. 22 pp. 7 figs. An experimental method is described for testing diffusion of gases in crude oils at pressures and temperatures up to 3,000 psia and 200° F. A sampling technique was developed to withdraw by constant-pressure mercury displacement about 60 μl of oil from the diffusion cell through any of several $\frac{1}{2}$ -inch vertically spaced capillary tubes and to trap about 4 μl of the oil in a specially designed micro-sampler. Oil trapped in the micro-sampler can be completely inserted in the sample inlet of a chromatograph. From analysis in a three-stage chromatograph (GLC), gas concentration in a sample is determined from the ratio of gas peak heights to area of peaks of reference components (hexanes or heptanes) in the oil. A diffusion coefficient is calculated from measured concentration profiles with known equations for diffusion in finite or semi-infinite systems, depending on whether the gas has or has not reached the end of the oil column.

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Results are given for a test of methane diffusing at 2,560 psia and 160° F in crude oil from the Weber Sandstone reservoir in the Rangely field, Colorado. A constant diffusion coefficient of 3.34×10^{-5} cm² per second was obtained which gives a good fit between calculated and experimental profiles determined at six times after start of diffusion. The maximum standard error of gas concentration determinations experienced with this method was ± 0.88 ml per ml of gas-free oil. Work done in cooperation with the University of Wyoming.

RI 7360. Recovery of Lead and Sulfur From Galena Concentrate Using a Ferric Sulfate Leach, by F. P. Haver, K. Uchida, and M. M. Wong. March 1970. 13 pp. 4 figs. A procedure is described for recovering both lead and sulfur from galena flotation concentrate, comprising the following steps: (1) Aqueous oxidation of the concentrate, using ferric sulfate to convert lead sulfide to sulfate and to give elemental sulfur; (2) regeneration of the ferric sulfate by electrolysis in a diaphragm cell; (3) treatment of the leach residue with ammonium carbonate solution to change the lead to an acid-soluble form and to produce ammonium sulfate as a byproduct; (4) solution of the lead carbonate in hydrofluosilicic acid followed by electrolysis to recover the lead as metal and regenerate the acid; and (5) extraction of the elemental sulfur from the final residue with an organic solvent. About 90 percent of the lead can be recovered by the above method as 99.9-percent-pure metal, together with two-thirds of the sulfur—half in the elemental form and half as ammonium sulfate.

RI 7361. High-Temperature Combustion of Coal Seeded With Potassium Carbonate in the MHD Generation of Electric Power, by D. Beinstock, R. J. Demski, and R. C. Kurtzrock. March 1970. 33 pp. 15 figs. A rig was constructed to burn 100 to 125 lb of coal per hour at 4,000° F in a cyclone burner with oxygen-enriched air preheated to 1,500° F to ascertain the problems in the coal-fired MHD generation of power. Potassium carbonate was added to the coal at several concentrations up to 1.23 g-moles/kg of coal (17 lb K₂CO₃/100 lb coal). Boiler-tube materials maintained at wall temperatures of 800° to 1,500° F were exposed to the combustion effluent of 1,800° to 2,500° F. Practically complete removal of sulfur dioxide from the stack gas was achieved with the seed addition. Nitric oxide formation followed theoretical expectations at combustion temperatures with some decomposition of the NO occurring as the gas cooled flowing through the system. Nitrates in the fly ash were less than 1.7 percent of the total fixed nitrogen. With aqueous extraction of the fly ash a maximum recovery of 75 percent of the potassium was obtained. Haynes 25 was unattacked at a wall temperature of 1,500° F in combustion gas at 2,500° F; the stainless steels 310, 316, and 446 were resistant at a metal temperature of 1,100° F in gas at 2,100° F.

RI 7362. Removal of Magnesium Impurities From Phosphate Rock Concentrates, by A. R. Rule, W. G. Gruzensky and W. A. Stickney. March 1970. 12 pp. 7 figs. Laboratory tests were conducted to study removal of magnesium impurities from western phosphate rock concentrates by selective leaching. The systems evaluated included leaching with dilute sulfuric acid, leaching with ammonium sulfate, and leaching in an aqueous medium with sulfur dioxide gas. Set standards for the magnesium impurity level of phosphate rock concentrates are not available, but industrial practice has indicated that

magnesium in excess of 0.3 percent MgO causes problems in phosphoric acid manufacture. Removal of magnesium was accomplished with all three systems. With dilute H₂SO₄, the magnesium level was reduced to less than 0.1 percent MgO with an accompanying P₂O₅ loss of 6 percent. Magnesium oxide levels from 0.3 to 0.2 percent were obtainable with ammonium sulfate. However, the system requires concentrate roasting at temperatures of 900° C or higher, heated pulps (100° C), and large quantities of ammonium sulfate. Selective leaching was obtained using SO₂ gas in an aqueous concentrate slurry. Magnesium oxide content was reduced to less than 0.1 percent without loss of phosphate.

RI 7363. Influence of Rolling Temperature and Copper Content on Creep and Other Properties of Zinc-Copper and Zinc-Titanium-Copper Alloys, by L. A. Neumeier and J. S. Risbeck. April 1970. 45 pp. 31 figs. The Bureau of Mines evaluated the properties and anisotropy in properties of rolled Zn-Cu and Zn-0.12 pct Ti-Cu alloys with various copper additions to 1.25 pct. The alloys were rolled cold and at various hot-rolling temperatures to reductions as high as 92 pct after breakdown rolling. The properties are extremely sensitive to various combinations of composition, rolling temperature, and rolling reduction. Zn-Cu alloys can develop good creep resistance, but they are inferior in that respect to Zn-Ti-Cu alloys. For alloys either with or without the titanium addition, cold-rolling results in recrystallization of the matrix and rejection of copper from solution, causing poor hardness, tensile, and creep properties, but high ductility. Peak tensile strengths develop when the alloys are rolled in the range 320° to 400° F. Best creep resistance for Zn-Cu alloys requires higher rolling temperatures when copper content is increased. Creep resistance is best for Zn-Ti-Cu alloys with about 0.75 to 1.0 pct Cu rolled near 480° F. Some copper is soluble in the TiZn₁₅ phase, which forms into "stringers" during rolling. The possible contributions to creep behavior of factors such as distribution of second-phase particles, grain size, and preferred orientation are discussed.

RI 7364. Preparation Characteristics of Pennsylvania Anthracite From the Kidney Seam, Northern Field, by J. E. Zeilinger and A. W. Deurbroek. March 1970. 19 pp. 3 figs. This Bureau of Mines report describes the preparation characteristics of three samples collected from the Kidney seam, in the Northern field of the anthracite region. Removal of the sink 1.70 specific gravity material from the samples collected would result in greatly reduced ash contents at yields in excess of 90 percent. The Kidney seam, in the locations sampled, proved to be a low-ash anthracite containing an unusually high percentage of float 1.45 specific gravity material.

RI 7365. Geometric Relationship Between Geologic Structure and Ground Stresses Near Atlanta, Ga., by Carl E. Norman. April 1970. 24 pp. 14 figs. An investigation of geologic structure on macroscopic, mesoscopic, and microscopic scales was conducted on near-surface igneous and metamorphic rocks in which the existing stress field was determined by in situ methods. A consistent NE-SW orientation of the maximum compressive stress in the horizontal plane at four of five test localities appears due to the intrusion of NW-trending diabase dikes. Structural features at the mesoscopic scale show no consistent directional relationship to determined stress directions. Petrofabric diagrams of open microfractures show preferred orientations, but these are not consistently related to the orientations of larger

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structural features, such as joints, foliation, or mineralized shear zones. However, at five of six test sites the preferred direction of microfractures occurs nearly perpendicular to the maximum principal stress directions; an anomalous parallel relationship exists at a test site in an intrusive rock body. The results suggest that the open microfracture sub-fabric may provide a means for gaining information on the directional properties of stress fields. Such information can be obtained from oriented cores taken from holes which exceed the approximate 100-foot depth to which other in situ methods are presently limited.

RI 7366. Elastic Pressure Distortion of the Volumes of a 1,000-Atmosphere Burnett Compressibility Apparatus Over the Temperature Range 0° to 75° C, by Ted C. Briggs and Alvin R. Howard. April 1970. 22 pp. 5 figs. A removable-jacket distortion apparatus was constructed and used to measure distortion coefficients for two high-pressure vessels. The measured distortion coefficients were used to compute distortion coefficients for volumes V_1 and $(V_1 + V_2)$ of a 1,000-atmosphere Burnett compressibility apparatus for the temperature range 0° to 75° C. Young's modulus for Armco 17-4 PH stainless steel, heat treated to condition H1150-M, was computed from experimentally determined distortion coefficients. A 10- to 14-percent correction to the values obtained for Young's modulus may be required because pressure vessel end effects were neglected. The distortion coefficients of the compressibility apparatus are believed to be accurate to about 1 percent.

RI 7367. Evaluation of the Penetration Characteristics of a Horizontal Plate Elutriator and of a 10-mm Nylon Cyclone Elutriator, by Thomas F. Tomb and Lewis D. Raymond. March 1970. 9 pp. 5 figs. The penetration characteristics of a horizontal plate elutriator and of a 10-mm nylon cyclone were evaluated. The test aerosols were polydisperse coal dust particles ranging from less than 0.3 to 15 micrometers in diameter. Particle densities ranged from 1.3 to 1.4 grams per cubic centimeter. Equivalent Stokes diameters were measured using Coulter counter analytical techniques.

Experimental results indicate that the penetration characteristics of the horizontal plate elutriator closely approximate the sampling efficiency curve defining the respirable fraction of the dust cloud recommended and adopted by the Johannesburg Pneumoconiosis Conference in 1959. Penetration characteristics of the 10-mm cyclone were evaluated at flow rates of 1.4, 1.5, 2.0, 2.5, and 2.8 liters of air per minute. The data indicate that the penetration curve obtained at 2.0 liters per minute most closely approximates the sampling efficiency curve for respirable dust recommended at a meeting sponsored by the U.S. Atomic Energy Commission in 1961.

RI 7368. Mine Water Research: Plant Design and Cost Estimates for Limestone Treatment, by Edward A. Mihok. April 1970. 13 pp. 1 fig. This paper presents plant design and cost estimates for limestone treatment of acid mine water covering a wide range of quality and quantity conditions. The treatment process consists of limestone neutralization, aeration, solids settling, and concentration. The design criteria for the various operation functions are based on pilot plant performance, laboratory data, and established mine water treatment standards. Unit costs have been assumed and are related to general market prices and conditions. These esti-

mates serve as preliminary indicators of what it would cost to construct and operate a mine water treatment plant.

RI 7369. Low-Temperature Heat Capacities and Entropies at 298.15° K of Goethite and Pyrophyllite, by E. G. King and W. W. Weller. April 1970. 6 pp. 2 figs. Low-temperature heat capacity determinations of the minerals goethite and pyrophyllite were made in the temperature range from 51° to 298° K. The entropies at 298.15° K were evaluated as 14.43 ± 0.15 cal/deg mole for goethite and 56.6 ± 0.5 cal/deg mole for pyrophyllite. The entropies of formation from the constituent oxides are -4.4 ± 0.2 cal/deg mole for goethite and -12.3 ± 0.6 cal/deg mole for pyrophyllite. The standard free energy of formation of goethite from its oxides is $\Delta C^\circ_{298.15} = 0.16 \pm 0.20$ kcal/mole.

RI 7370. Anode Materials for Alumina Reduction: Evaluation of Lignite as a Carbon Source, by V. A. Cammarota, Jr., and David Schlain. April 1970. 45 pp. 16 figs. In this report, the effects of anode-production variables, such as aggregate coke sizes, pitch binder content, and baking cycle, were investigated. A small alumina reduction cell proved effective in evaluating anodes prepared from commercial materials and from lignite coke and pitch. Compressive strength was found to be the physical property most significantly influenced, but it did not appear to affect anode consumption. Specific carbon consumption, that is, the ratio of carbon in the anodic gas to carbon theoretically oxidized at the anode, was used as an index of anode consumption. It was found that an anode made with lignite coke and commercial pitch was very low in consumption; however, anodes made completely from lignite but by a different fabrication method showed high consumption and anode deterioration. Microscopic examination of anodes after electrolysis showed evidence of higher consumption at low current densities and was useful in judging overall anode quality. Based on the physical properties of the anodes and their consumption during electrolysis, lignite can be a suitable material for anodes, provided the proper fabrication conditions are used.

RI 7371. Reaction of Co-Ni-V Alloys With O₂ at 1,351° to 1,429° K, by Robert M. Doerr and J. W. Jensen. April 1970. 20 pp. 8 figs. The objective of this research was to determine the effect of vanadium alloy additions on the oxidation behavior of cobalt-nickel alloys. Eighteen alloys were reacted with O₂ at 0.5 atmosphere and 1,351°, 1,389°, and 1,429° K. The alloy compositions consisted of Co-Ni master alloys (0, 22, 50, 70, 91, and 100 weight percent Ni) with V additions of 0, 0.9, and 2.7 weight percent. Large early deviations from, or changes in, the parabolic rate constant were encountered, but the reaction rate in most cases declined approximately in accordance with the parabolic rate law. Relatively, the vanadium degraded the oxidation resistance most at the highest nickel contents. In some cases, melting of the oxide was inferred from microscopic evidence and X-ray diffraction measurements disclosed the presence of low-melting vanadates.

RI 7372. Surface Tension and Density of Liquid Tin, by Alfred E. Schwaneke and Wilbert L. Falke. April 1970. 9 pp. 2 figs. The surface tension from 240° to 844° C and the density from 236° to 583° C of 99.999 percent purity liquid tin has been measured using the maximum-bubble-pressure method. Results for surface tension (γ) show γ (dynes/cm) = $566.84 - 4.76 \times 10^{-2} T$ (° C) with a

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standard error of ± 1.9 dynes/cm. Results for density (ρ) show ρ (g/cm^3) = $7.16 - 6.3 \times 10^{-4} T$ ($^{\circ}\text{C}$) with a standard error of 0.012 g/cm^3 . Comparisons with other data found in the literature are discussed. The experimental results are considered to be as good as any data presently available.

RI 7373. Preliminary Engineering Studies to Characterize the Marine Mining Environment, by Ernest L. Corp. May 1970. 32 pp. 8 figs. The natural marine environment can be divided into four basic categories: the air-sea interface, the water zone, the seafloor, and the subbottom. Efforts are being made to accumulate data to delineate the conditions in each of these areas and to conduct engineering studies which will determine how these environmental parameters affect the mining process. Laboratory facilities have been constructed and equipment and techniques for scientific data collection and laboratory research have been developed. Major emphasis is being placed on studying the subbottom material. The objective of this emphasis is to study the engineering properties of marine placer deposits in order to assess their influence on the design and performance of the various mining subsystems involving penetration, excavation, transportation, and disposal. Presented are the results of engineering properties tests on a placer simulant which is currently being used for model and prototype testing of coring tools. The effect of these engineering properties on penetrability, core recovery, and sample recovery is discussed.

RI 7374. Adaptation of a Slow-Speed Data Acquisition System to Record Multiple Time-Related Signals, by R. Newman and E. L. Corp. April 1970. 9 pp. 5 figs. An inexpensive slow-speed data acquisition system has been adapted to digitally record multiple parameters simultaneously at intervals of 15 seconds. The system was built for use with standard soils testing equipment to automatically record load and displacement parameters at predetermined instants in time. Simultaneous readout is achieved by the use of special signal conditioner and sample-and-hold circuits which read the multiple signals simultaneously and hold them until the slow acting system can print out. Three channels of a 10-channel system have been converted and found to operate successfully during a series of direct shear tests. A unique feature of the system, which significantly reduced its cost, is the power supply units. Dummy circuits are used to maintain a constant power demand during sampling, thus eliminating the need for a costly power supply with rapid response characteristics. The entire system, having an overall accuracy of 0.25 percent, was put in operation for a cost under \$2,500.

RI 7375. Leach-Precipitation-Flotation Studies on Red Bed Copper Ore Using Controlled Atmosphere, by J. Vanve Batty and B. F. Andrew. April 1970. 9 pp. 1 fig. The Permian red bed copper deposits of the South Central States are a potentially important resource. Only the higher grade, near-surface ores are now exploited, because conventional froth flotation does not recover oxidized copper minerals which comprise 10 to 15 percent or more of the copper content of typical ore.

Laboratory-scale beneficiation studies were initiated to devise a method capable of recovering both sulfide and oxidized copper mineral. Testing established that the high clay and gypsum content of typical ore prevented effective flotation of the oxide mineral using sulfidizing, fatty-acid, or oil emulsion

techniques. A modified leach-precipitation-flotation (L-P-F) procedure recovered over 90 percent of the copper, compared to a recovery of 77 percent obtained by conventional sulfide flotation. The higher costs of the L-P-F method would reduce the increased revenue from higher copper recovery. An increase in copper price and/or an increase in oxide copper content of the ore would make the L-P-F process comparatively more attractive.

RI 7376. Beneficiation of Georgia Kyanite Ore, by James S. Browning and Paul E. Bennett. April 1970. 8 pp. 1 fig. The Bureau of Mines conducted laboratory and small-scale continuous tests of kyanite ore from Georgia to determine the technical feasibility of recovering commercial-grade kyanite concentrates by flotation. The research indicated that combinations of sulfuric acid and petroleum sulfonate may be used effectively for flotation of kyanite from quartzite-kyanite ore. Over 87 percent of the kyanite was recovered in a concentrate analyzing 55.8 percent Al_2O_3 and 5.3 percent acid-soluble Fe_2O_3 . Subsequent treatment of the flotation concentrate by high-intensity wet magnetic separation reduced the acid-soluble Fe_2O_3 to 0.8 percent and increased the alumina content to 57.6 percent, with a recovery of 82.7 percent of the total alumina in the ore.

RI 7377. Evaluating Sulfur and Ash Distribution in Coal Seams by Statistical Response Surface Regression Analysis, by Manuel Gomez and Kathleen Hazen. 120 pp. 24 figs. The purpose of this study was to evaluate the feasibility of using statistical response surface regression analysis to predict sulfur and ash distributions and the washability characteristics of coal along a seam in advance of mining. Prediction equations were developed with experimental data from channel, bench, and core samples from the Pittsburgh coal seam in Greene County, Pa. It was not possible, with the available experimental data, to construct mathematical models to predict ash and sulfur concentrations between sample points. In the authors' opinion, however, the good agreement between experimentally determined and predicted values at given sample points demonstrates the usefulness of the method. More input data, such as geologic information, seam characteristics (rock-to-coal ratio), petrographic analysis, and chemical data, would perhaps make it possible to predict sulfur and ash concentrations and washability characteristics between sample points.

RI 7378. Use of Centrifugal Separation to Investigate How Kerogen Is Bound to the Minerals in Oil Shale, by Rex D. Thomas and Philip B. Lorenz. April 1970. 12 pp. 2 figs. Concentration of the kerogen (organic material) in oil shale was accomplished by centrifuging after pretreating the oil shale with carbonic acid to remove the carbonates and pretreating with sodium hydroxide (pH 11.5) to remove the claylike minerals. Analysis of the materials obtained showed that the concentrations of organic sulfur and organic nitrogen compounds were not affected by centrifuging. These compounds are evenly distributed in the kerogen and are not strongly bound to the mineral constituents. Organic oxygen compounds, however, were concentrated in the light fraction. These compounds are more closely associated with the kerogen and are not bound to the mineral constituents. Iron compounds other than pyrite apparently are closely associated with the organic material.

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RI 7379. Continuous Heavy Liquid Concentration of Spodumene, by R. B. Tippin, James S. Browning, and Thomas O. Llewellyn. May 1970. 24 pp. 5 figs. To study continuous operation of the heavy liquid separation of minerals, the Bureau of Mines concentrated spodumene from a typical ore. The studies included heavy liquid concentration, removal of the heavy liquid from the mineral products, and recovery of the heavy liquid for reuse. The research program examined the influence of feed moisture, steam consumption, stripping time, and condition of steam. Operation of multiple cyclones in series resulted in spodumene concentrates assaying 92 to 95 percent spodumene and indicated mineral recoveries of 86 to 89 percent. Continuous filtration and steam stripping produced mineral products containing less than 1 pound of heavy liquid tetrabromoethane (TBE) per ton of material. Problems unique to this process are discussed, including heavy liquid properties and viscosity, toxicity, material handling hazards, and safety precautions.

RI 7380. Freon 113 as a Test Material for Chemical Cartridge Respirators, by C. F. Swab, Jr., and B. I. Ferber. May 1970. 5 pp. 1 fig. A relatively innocuous halocarbon was investigated as a substitute for the highly toxic carbon tetrachloride in the approval testing of chemical cartridges. The vapor effluent of 1,1,2-trichloro-1,2,2-trifluoroethane from chemical cartridges is continuously monitored by a nondispersive infrared analyzer. Breakthrough times for the cartridges, using the halocarbon, can be equated to those of carbon tetrachloride, if multiplied by the factor, 1.49.

RI 7381. Turf Soil Modification With Sintered Fly Ash, by James C. Patterson and John P. Capp. May 1970. 12 pp. 10 figs. Sintered fly ash was shown to have promise as a modifier for poorly drained soils. Turf grown in mixtures of sintered fly ash and soil benefited from increased water-infiltration rates, greater total pore space, and higher moisture availability. The result was an improved turf stand with increased grass yield and root density.

RI 7382. Wellbore Enlargement Test in a Gas-Storage Well, by Larman J. Heath, Ray V. Huff, and Ray A. Jones. May 1970. 17 pp. 5 figs. Wellbore enlargement was tested using hydrazine hydrate in a gas-storage well in Ohio to increase the well productivity. The wellbore was to be enlarged by chemical disaggregation of the sandstone adjacent to the wellbore. Productivity immediately declined 49.1 percent and gradually declined to zero in 7 months. A down-hole camera survey showed a white-to-gray precipitate covering the entire wellbore surface. The precipitate was chemically analyzed and identified as mostly carbazic acid, a hydrazine derivative of carbonic acid. Formation of this precipitate was not anticipated; this viscous substance caused the gradual loss in productivity of the well. The wellbore was not enlarged.

Laboratory tests were run to determine what clay stabilization measures could be taken in sandstone cores to prevent clay swelling and particle migration caused by hydrazine hydrate. Normal clay stabilization methods did not prevent the virtually complete loss in permeability to hydrazine hydrate. Other laboratory tests using natural gas diluted with small amounts of carbon dioxide confirmed the ease with which carbazic acid could be formed in a hydrazine hydrate-saturated environment within and adjacent to the wellbore.

RI 7383. A Statistical Interpretation of Sample Assay Data

From the Getchell Mine, Humboldt County, Nev., by George S. Koch, Jr. and Richard F. Link. May 1970. 23 pp. 12 figs. The distribution of gold in part of the Getchell mine, Humboldt County, Nev., is presented through the statistical analysis of 956 assays of rock cuttings from wagon-drill holes. Two methods to predict grade in undeveloped parts of the ore body are evaluated, and the possibility of sampling bias is tested. The distribution of gold is compared with that in three other Nevada gold deposits of the same type characterized by gold particles mostly of submicron size associated with carbonaceous rocks, and also with that in deposits with coarse-grained gold. Usually, fewer samples of a given type are required to make a satisfactory grade estimate for submicron deposits than for coarse-grained deposits. The economic consequence is that submicron gold deposits are likely to be less expensive to sample and evaluate than coarse-grained deposits.

RI 7384. Refinement of Hematite Crystal Structure, by R. L. Blake, Tibor Zoltai, R. E. Hessevick, and Larry W. Finger. May 1970. 20 pp. 7 figs. The crystal structure of hematite, $\alpha\text{-Fe}_2\text{O}_3$, has been refined as part of a continuing study of the behavior of phases in the Fe-O system during reduction and oxidation. Three-dimensional diffraction intensities were collected on two spherical single crystals of hematite with a semiautomated Buerger single-crystal diffractometer. The first crystal refined was a natural Elba hematite with minor impurities. The other, a synthetic crystal, was refined at the request of Mössbauer spectroscopy investigators concerned with impurities in the natural crystal. The structure has been refined with a least-squares program, and the final structure for the natural crystal irradiated with $\text{CuK}\alpha$ -radiation gave a discrepancy factor (R) of 3.65 percent using 49 unrejected reflections of the 51 measured. For the synthetic crystal, using $\text{MoK}\alpha$ -radiation, the discrepancy factor converged to 2.8 percent using 95 unrejected reflections and was 3.3 percent for all 109 reflections.

The structure model of Pauling and Hendricks has been confirmed with essentially no change in the iron coordinates and approximately a 5-percent change in the oxygen coordinates. Selected interatomic distances and angles were calculated, as were anisotropic temperature factors.

RI 7385. Evaluation of Electrowon Tungsten Sheet, by G. H. Keith, J. S. Winston, and H. G. Iverson. May 1970. 14 pp. 8 figs. Electrowon tungsten powders were investigated with respect to consolidation, fabrication, and mechanical properties. Sheet, 0.03-inch thick, was produced and its tensile strength measured between 250° and 1,935° C. The large particle size of electrowon tungsten effectively precluded sintering to a density sufficient to allow hot working to sheet or bar. The powders were consolidated by die pressing to 70-percent density, sheathing in molybdenum, and high-energy-rate extruding to either round or sheet bar of 100-percent density. The material was then rolled conventionally to sheet. The mechanical properties of the sheet prepared from the electrowon powders compared favorably with those reported in the literature for sheet prepared from commercially produced hydrogen-reduced powder.

RI 7386. Bench-Scale Carbonization of Lignite From the Northern Great Plains Province: A Statistical Approach, by Daniel C. Boteler, Wayne R. Kube, and Charles C. Boley. June 1970. 32 pp. 6 figs. Five lignites from the northern Great Plains province were carbonized at temperatures from 500° to 1,000°

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C in a bench-scale unit. A replicated Greco-Latin square experimental design was employed to allow testing of four independent variables at five levels. Independent variables investigated were temperature, source of lignite (mine), weight of charge, and moisture content of charge. Dependent variables were char yield, tar yield, light-oil yield, tar plus light-oil yield, carbonization gas yield, and carbonization gas heat yield. An analysis of variance indicated that, at the 99-percent confidence level, the independent variables of carbonization temperature, source of lignite, and weight of charge were significant for yields of char, tar plus light oil, and carbonization gas, whereas moisture content was only significant for carbonization gas yields. At the 95-percent confidence level, moisture content significantly influenced the carbonization gas heat yield per pound of lignite charge and the yields of dry tar plus light oil. All dependent variables were determined on a moisture- and ash-free basis. Multiple regression equations for predicting seven different factors of carbonization yields as functions of carbonization temperature and initial composition were developed using computer techniques. Equations for yields of char, tar plus light oil, and carbonization gas were compared with equations previously developed by others at the 500° C level.

RI 7387. Seismic Effects Associated With an Underwater Explosive Research Facility, by Joseph L. Condon, John N. Murphy, and David E. Fongelson. June 1970. 20 pp. 11 figs. Fifteen shots of three explosives with charge weights of 0.52, 1.1, 3.1, and 5.1 kilograms were fired in a pond to study the seismic effects of detonating explosives in water. Shock pressures and bubble periods were measured with pressure transducers in the water. Vibrations were measured on land in three orthogonal directions with particle velocity gages. Statistical tests indicated that a charge weight exponent of 0.43 best scaled the data. While shock pressures and bubble periods showed considerable differences in explosive performances, the amplitudes of ground vibrations showed less difference, and one prediction equation was therefore derived to estimate vibration amplitudes from all the explosives.

RI 7333. Columbium Alloy Development With Boron, Hafnium, and Tungsten, by H. R. Babitzke, L. L. Oden, and H. J. Kelly. June 1970. 30 pp. 16 figs. As part of a continuing project to develop refractory metal alloys for high-temperature structural applications, the Bureau of Mines applied solid solution and precipitation strengthening techniques to improve the properties of columbium alloys. The purpose was to investigate the effects of hafnium, tungsten, and boron on the formability, strength, and oxidation resistance of columbium. The experiment was of factorial design with two replications which called for 72 ingots of 36 basic compositions, weighing 150 grams each. Hafnium, tungsten, and boron were evaluated at 3, 3, and 4 levels, respectively. Values of alloy content are all in atomic percent.

The highest strength observed was 29,000 psi at 1,200° C for alloys Cb-15Hf, Cb-7.5Hf-5W-2B, and Cb-15Hf-5W-2B. At 1,200° C, the ternary alloy Cb-15Hf-5W which has shown good properties in previous Bureau of Mines investigations was the most resistant to oxidation. For boron additions, the alloys oxidized more readily with increasing amounts of this element. The fabricability of the alloys high in boron became increasingly difficult, resulting in an inadequate number of alloys required for a complete statistical analysis for all the tests.

As a result of the decrease in ductility, an insufficient quantity of tensile samples was available for a proper analysis for the high-temperature strength data.

RI 7389. Reduction Roasting of Nonmagnetic Taconites With Automobile Scrap, by Charles Prasky, R. E. Peterson and D. L. Siebert. May 1970. 19 pp. 6 figs. This report describes bench-scale studies and pilot-plant development of the Bureau of Mines process for roasting iron ores with a ferrous scrap reductant, such as discarded automobile hulks, to yield artificial magnetite. Quality magnetic concentrates containing about 66 percent iron and 6 percent silica with iron recoveries of over 90 percent were obtained after roasting fine-grained oxidized or non-magnetic taconite with unburned, sheared automobile hulks in a rotary kiln. The relatively complete oxidation of the lighter gage metal in the automobile during roasting resulted in a metallic byproduct consisting of the unconsumed heavier gage metal scrap. This residual or tailored scrap is potentially useful as heavy melting stock and has more value than the original automobile hulk.

RI 7390. Comparative Emissions From Some Leaded and Prototype Lead-Free Automobile Fuels, by B. H. Eccleston and R. W. Hurn. May 1970. 24 pp. 6 figs. The effect upon automobile emissions in changing from leaded to lead-free gasolines was studied in experiments by the Bureau of Mines in cooperation with the American Petroleum Institute. Typical U.S. leaded gasolines and prototype lead-free gasolines of comparable octane quality were used in eight vehicles operated to simulate city driving. The experiments were run at 70° and 95° F. Exhaust and evaporative emissions were measured and the photochemical effect of the emissions was experimentally observed in an artificial smog chamber. Results of the study reveal the manner and degree in which the changes in fuel composition alter the amount and characteristics of both exhaust and evaporative emissions. Briefly, it is shown that the compositional differences between leaded and prototype lead-free fuels resulted in higher photochemical pollution potential of the emissions from the lead-free fuels. The effect is attributed to the photochemical characteristics of high-octane fuel components that are used in greater quantity in the lead-free fuels.

RI 7391. Fracturing Hard Rock With Nuclear Explosives and Extraction of Ore by a Modified Block-Caving Method, by W. R. Hardwick. June 1970. 18 pp. 8 figs. Nuclear explosive fracturing has been suggested as a method to make hard rock amenable to extraction by a modified block-caving method. To evaluate this possibility, conventional and nuclear blasting practices are discussed; underground mining methods for large deposits and their costs are described, and the cost of fracturing ore with a nuclear explosive and subsequent mining by a modified caving system is estimated and compared with both open-stope and block-caving mining costs. While the direct cost of fracturing the ore in hard rock with a nuclear explosive is less than with conventional explosives, additional costs imposed by the use of nuclear explosives may make their use unattractive for deep mining.

RI 7392. Spray-Applied Polyurethane Foam To Insulate Heated Rooms Excavated in Permafrost, by K. Robert Dorman and Aldon E. Gooch. June 1970. 43 pp. 30 figs. Spray-applied polyurethane foam was used to insulate the walls of heated rooms excavated in

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permafrost. The experiment was designed to determine whether polyurethane foam can be sprayed successfully on frozen ground under freezing conditions and to measure the effectiveness of the insulation in maintaining—at elevated temperatures for an extended period—a room excavated in frozen ground. Two manufacturers' foams were investigated in the laboratory. Subsequently, one of the foams was employed to insulate two small rooms, one in frozen gravel and one in frozen silt, in an experimental tunnel belonging to the U.S. Army Cold Regions Research and Engineering Laboratory (USACRREL) near Fairbanks, Alaska. Following insulation, heat was introduced into the two rooms. Heat migration across the insulating barrier into the walls, in addition to wall closures, was monitored over an 8-month period. The results show that polyurethane foam can be successfully sprayed on frozen ground in below-freezing temperatures. Given this type of insulation, together with winter cold to supercool the surrounding ground, it should be possible to maintain a shaft or heated room in permafrost for several years.

RI 7393. Development of High-Temperature Vanadium-Base Alloy, by G. H. Keith and J. S. Winston. June 1970. 13 pp. 7 figs. A vanadium-base alloy consisting of the following elements in weight-percent—molybdenum, 20; titanium, 10; carbon, 0.1; silicon, 0.5; and yttrium, 0.5—had exceptionally high strength at temperatures up to 1,200° C. This alloy was capable of fabrication to sheet of ~ 1 mm thickness by a combination of hot swaging and hot and warm rolling. In the warm-rolled condition at ambient temperature, its ultimate tensile strength was 1,205 meganewtons per square meter (MN/m²). The strength at 1,200° C was 150 MN/m². Within the temperature range of 25° to 1,200° C, the ductility of the alloy as measured by elongation increased from 4 to >90 percent. Strengthening was achieved by both solid-solution and dispersed-phase mechanisms. Alloys of 20 percent molybdenum and 10 percent titanium were stronger than the other molybdenum-titanium alloy compositions tested. Strength was increased 15 percent in the temperature range of 25° to 800° C, with no accompanying loss in ductility, by the addition of 0.5 percent silicon. Workability was improved by additions of 0.25 and 0.5 percent yttrium.

RI 7394. Repeatability of Plastometer and Dilatometer Tests of Coal, by W. R. K. Wu. June 1970. 27 pp. 4 figs. This Bureau of Mines report presents a statistical study of the repeatabilities of coal-plasticity parameters obtained in the tests with the Gieseler plastometer and the Audibert-Arnu and Hoffman dilatometers. Repeatability is expressed in terms of one or two standard deviations for the differences between duplicates. The statistical method employed here is summarized. Results are tabulated for the temperature and nontemperature parameters of the three tests.

RI 7395. Leaching Gold-Bearing Mill Tailings From Mercur, Utah, by Ivan L. Nichols and LeRoy Peterson. June 1970. 10 pp. 2 figs. Tailings dumps at Mercur, Utah, contain about \$7 million worth of gold in 3.5 million tons of mill tailings assaying about 0.07 ounce of gold per ton. Commercial mining and milling at Mercur ceased in 1942. To determine whether improved technology was now available that might permit economic reprocessing of the Mercur dumps, the Bureau of Mines probed for a low-cost method that would be applicable to these tailings. A composite prepared for laboratory studies assayed 0.062 ounce gold per ton. About

10 percent of the gold occurred as a water-soluble cyanide. Conventional cyanide leaching dissolved 32 percent of the gold, and hot, strong cyanide solution dissolved 42 percent. Results were not improved by pretreatment with acids, bases, or oxidants. After expensive preroasting, gold recovery by cyanidation was increased to 65 percent. The simple procedures were ineffective, and more effective procedures were too costly for economical processing of Mercur tailings.

RI 7396. Prediction of Penetration Rate for Percussive Drilling, by A. Aly Selim and William E. Bruce. June 1970. 21 pp. This report describes the feasibility of predicting percussive drilling rates by equations derived from statistical regression analysis. The least squares statistical method was used and the analysis was performed both by direct and by stepwise linear regression analysis. The predicted penetration rate is a function of the drill power and the physical properties of the rocks penetrated. The results show promise that the technique may be of value in providing a mathematical model by which percussive drill manufacturers and users can predict the performance of a given drill. Experimental work involved two mining-type percussive drills. Penetration data for these drills were determined from nine rocks drilled in the laboratory. Drill work rates (power) were determined in a separate series of experiments. Rock physical properties were measured from diamond-drill core samples taken from the same blocks used for percussive drilling.

RI 7397. Evaluation of Oil-Shale Fracturing Tests Near Rock Springs, Wyo., by G. G. Campbell, W. G. Scott, and J. S. Miller. June 1970. 21 pp. 9 figs. Bureau of Mines research to develop an in situ retorting recovery method for oil shale has involved field testing of fracturing techniques for creating fluid-flow paths in impermeable oil shale. Electrolinking, hydraulic fracturing without and with sand propping, and explosive fracturing with a liquid explosive were tested in a 25-foot-square, five-spot pattern. These wells were drilled into oil shale at 50- to 88-foot depths near Rock Springs, Wyo. Results of the fracturing tests were evaluated by injecting air into a test well and measuring flow rates and flow profiles in adjacent test wells before and after each test. To identify points of air entry (location of fractures) in wells, flow profiles were determined by use of inflatable packers and by continuous logging with an airflow probe developed during the fracturing program. Electrolinking and hydraulic fracturing without sand propping were relatively ineffective; hydraulic fracturing with sand propping created horizontal fractures with desirable flow capacity; and fracture flow capacity was significantly increased by detonation of nitroglycerin displaced in the natural and hydraulically induced fracture systems.

RI 7398. Electrowinning Misch Metal From a Treated Bastnasite Concentrate, by E. S. Shedd, J. D. Marchant, and M. M. Wong. June 1970. 11 pp. 2 figs. Misch metal was electrowon from a treated bastnasite concentrate in a REE₂-LiF-BaF₂ electrolyte at 950° C. The metal was prepared and tapped from a 1,000-ampere cell, and nearly 100-percent utilization of the rare-earth oxide was achieved. Prolonged operation in a smaller cell (40 amperes) indicated that the composition of the misch metal product was reasonably constant, and no significant increase of impurities, with the exception of carbon, was noted.

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RI 7399. Prediction of Coke Strength and Carbonization Product Yields From Exploration Data, by Manuel Gomez and Kathleen Hazen. July 1970. 37 pp. 6 figs. This report presents prediction equations for 12 variables that are indicative of metallurgical coal quality. The variables include six for coke strength and six for carbonization product yields. All variables were predicted for coking coals having volatile matter contents from 16.3 to 42.1 percent, dry basis. The prediction equations, developed by mathematical-statistical techniques, were based on information from the proximate and ultimate analyses, the size consist, and the petrographic composition of bituminous coals carbonized in BM-AGA retorts at 800°, 900°, and 1,000° C. The equations were evaluated for validity with independent data derived from the 900° C carbonization of 33 binary blends of various coals and 22 binary blends of Pocahontas No. 3 low-volatile bituminous coal with 11 high-volatile bituminous coals. Results show that metallurgical coal quality can be predicted ahead of mining because data used to derive the prediction equations can be obtained at the time of exploration. Capability to forecast coal quality is useful in mine planning and should provide basic information for optimization of blending and crushing techniques and thus lead to the production of uniform coke.

RI 7400. Coal Carbonization Studies. Altering Composition and Yield of Volatile Products by Increasing the Free Space Above the Charge, by C. Ortuglio, J. G. Walters, and D.E. Wolfson. June 1970. 11 pp. The effect of cracking by increasing the free space above the charge on the composition and yields of the volatile products from carbonization of Pittsburgh-bed coal and one industrially used blend from Eastern United States and one from Western United States was investigated with the BM-AGA carbonization apparatus. Increasing the free space above the charge from 1 inch to 3 inches, to 6 inches, and to 9 inches resulted in lower tar yields and increased gas and oil yields. Anthracene and naphthalene yields were increased; quinoline and benzene insoluble fractions of both the tar and pitch increased considerably with increased free space, although the carbon content of the tars and pitches increased only slightly. Increased cracking, occasioned by the increase in free space, resulted in a decrease in the yields of tar acids, tar bases, neutral oils, olefins, aromatics, and paraffins and naphthenes. Gas composition was relatively constant; hydrogen and methane tended to increase and ethane to decrease. Results of the investigation are being used to design a unit to upgrade the volatile products of carbonization by cracking the hot products as they leave the carbonization chamber.

RI 7401. Waters for Waterflooding San Joaquin Valley, Calif., Petroleum Reservoirs, by G. L. Gates and W. H. Caraway. June 1970. 18 pp. 4 figs. Five possible sources of water for waterflooding of petroleum reservoirs in the arid San Joaquin Valley of California were considered. Three of them (water produced with petroleum, water from a shallow saline aquifer, and waste irrigation water) were analyzed chemically; laboratory information for one (sea water) had been developed during a previous study. A series of laboratory tests made on the fifth source (fresh water) determined the solubility of calcium sulfate dihydrate in water. Laboratory analyses included the following: Chemical analyses of water produced with petroleum and waste irrigation water; solubility of calcium sulfate dihydrate in water and brines; the effect of excess sulfate on the solubility of calcium sulfate in brines; the

presence of sulfate-reducing bacteria; and the permeability of cores from a petroleum reservoir to air, to water from other petroleum reservoirs, and to waste irrigation water. The results showed that most of the waters and mixtures of waters are compatible with petroleum reservoir waters and are generally suitable for injection. The calcium content of some of the formation waters is quite high, and care must be taken to prevent precipitation of calcium sulfate dihydrate. The permeability of the few cores tested was about the same to water and brines as to air, indicating that formation damage due to clay swelling will not be serious. The waters most likely to be available for injection are water produced with petroleum, water from shallow saline aquifers, and waste irrigation water.

RI 7402. Electrochemical Recovery of High-Purity Nickel and Cobalt From Crude Nickel and Ferronickel, by P. T. Brooks and G. M. Potter. June 1970. 25 pp. 12 figs. Semipilot scale tests were made to demonstrate a newly developed electrorefining process which could be extrapolated to commercial scale in producing high-purity nickel and cobalt from crude nickel metal and high-grade ferronickel. The new process comprises application of solvent extraction techniques to remove and separate cobalt and iron from nickel and the electrodeposition in diaphragm cells of pure nickel and cobalt from chloride-based purified electrolyte.

Using water insoluble organic amines, the solvent extraction operations enabled production of commercial-sized nickel and cobalt cathodes of higher purity than that of commercial electrolytic metals. The solvent extraction operation for separation of cobalt from nickel was made simpler than the conventional method. Furthermore, the solvent extraction operation for iron removal made possible the electrorefining of ferronickel without the prohibitive loss of nickel resulting from the method ordinarily used for iron removal.

RI 7403. Respirator Filter Penetration Using Sodium Chloride Aerosol, by B. I. Ferber, F. J. Brenenborg, and A. Rhode. June 1970. 10 pp. 3 figs. Sodium chloride aerosol was employed to determine respirator filter penetration in a manner suitable for use in Bureau of Mines approval and certification procedures. The aerosol was produced by an ultrasonic generator and treated to yield the proper conditions of relative humidity, particle size, and concentration. Respirator filters were exposed to the aerosol; filter penetration (down to 0.02 percent) was determined with a flame photometer. Results are comparable with those obtained in another laboratory using different equipment.

RI 7404. Factors Related to Mineral Separation in a Vacuum, by Foster Fraas. June 1970. 13 pp. 4 figs. Under a very high vacuum of 10^{-8} torr the transfer of terrestrial mineral beneficiation methods to the vacuum ambience of extraterrestrial locations such as the lunar surface was investigated. In the size range for the electrostatic and magnetic separation of ores (minus 35 plus 150 mesh) there is no adhesion of particles produced by crushing and grinding due to the limited contact area, and for repeated contacts area size has a frequency of occurrence according to the normal law. The photoelectric effect which is successful in separating a few minerals in an air ambience has a wider application in a vacuum, while the lack of air viscosity and sound transmission provides for high feed velocities and the adaptation of particle vibration to dispersion and grinding. Contact electrification is reversible upon return to atmosphere.

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RI 7405. Viscosity of the Helium-Nitrogen System From 133° to 740° K for Pressures Between 1 and 240 Atmospheres, by Robert E. Wood and W. J. Boone, Jr. July 1970. 130 pp. 13 figs. The temperature dependency of the low-density viscosity coefficients, η_r , of helium and of nitrogen, 100° to 1,000° K, is correlated with empirical equations, and the temperature and composition dependencies of the low-density viscosity coefficients, η_r , of helium-nitrogen mixtures are correlated with the Chapman-Enskog expressions by using the Lennard-Jones (6:12) potential function. The residual viscosity, $\eta_{r,p} - \eta_r$ (the difference between the viscosity of a compressed gas and the dilute gas at a given temperature), was found to be a function of the thermal pressure coefficient, $(\partial P/\partial T)_r$, and two parameters, α and β , which are characteristic of gas composition. The equation $\eta_{r,p} = \eta_r + \alpha [(\partial P/\partial T)_r]^\beta$ represented 1,340 higher pressure experimental viscosity values with a mean absolute deviation of 0.86 percent, and this equation was used to compute viscosities of the gaseous helium-nitrogen for a range of temperatures and pressures including those encountered in Bureau of Mines helium purification processes and in a crude-helium conservation gas reservoir. Tabular viscosities for helium, nitrogen, and 13 helium-nitrogen mixtures are presented for 110 temperatures, 133° to 740° K, and 49 pressures in the range 1 to 240 atmospheres. The accuracy of the tabulated viscosities varies because correlation parameters were obtained from experimental data of unequal reliability. It is estimated that uncertainties in the computed viscosity values are ± 5 percent for the region 325° to 740° K, ± 2 percent for the region 183° to 325° K, and ± 5 percent for temperatures below 183° K. The latter uncertainty may rise to ± 10 percent as critical conditions are approached.

RI 7406. In Situ Tests of Bearing Capacity of Roof and Floor in Selected Coal Mines. A Progress Report—Longwall Mining, by A. J. Barry and Oscar B. Nair. June 1970. 20 pp. 7 figs. A practical method has been developed and field tested which provides an estimate of the bearing capacity of mine roof and floor. The relationship between penetration of the strata and imposed loads is determined by in situ tests. Information of this type is needed to determine the maximum allowable pressure that may be applied by self-advancing support on roof and floor of a longwall face without causing a punching type of failure.

RI 7407. Effects of Explosive Properties on Free-Surface Displacement Pulses and Crater Dimensions, by Richard L. Fischer, Dennis V. D'Andrea, and David E. Fogelson. July 1970. 32 pp. 16 figs. Constant-volume charges of precipitated PETN (pentaerythrit tetranitrate) at three specific gravities (0.50, 1.00, and 1.50) were used in laboratory tests to examine the effects of changes in explosive properties on free-surface displacement pulses and on crater dimensions. The tests were performed in large blocks of cement-mortar. The values for the detonation velocity, detonation pressure, specific energy, energy density, and energy release rate were calculated from the explosive loading density. Calculated explosive properties were correlated with free-surface displacement pulse measurements, strain energy, and measured crater dimensions. Increases in explosive properties resulted in increased free-surface displacement pulse parameters and crater dimensions. The loading density, detonation velocity, energy density, detonation pressure, and energy release rate were found to be best indicators of explosive performance. Simple acoustic relationships involving

impedance ratios were examined and could not be used to predict peak displacement amplitude or strain energy.

RI 7408. Slagging Fixed-Bed Gasification of North Dakota Lignite at Pressures to 400 PSIG, by G. H. Gronhøvd, A. E. Harak, M. M. Fegley, and D. E. Severson. July 1970. 40 pp. 20 figs. This is the final report on a research program to develop a pilot plant gasifier for slagging gasification of lignite at high pressures and to obtain process data under various operating conditions. An operable pilot plant was developed, and the test results show that lignite is well suited for the process. Tests were run at pressures from 80 to 400 psig, and the results indicated that pressure had little effect on gas composition or the material requirements per unit of gas produced. Gas production rates as high as 26,000 scfh/sq ft of reactor area were obtained at 300 psig, but limitations on auxiliary equipment prevented full-capacity operation at 400 psig. In several tests lignite having a 37-percent moisture content and 2,500° F ash-fusion temperature was successfully gasified. Refractory materials were found to have a short life in contact with high-temperature slag, and a water-cooled taphole was developed. Exploratory tests with coking coal were unsuccessful.

RI 7409. Crater Scaling in Granite for Small Charges, by Dennis V. D'Andrea, Richard L. Fischer, and Arlo D. Hendrickson. July 1970. 28 pp. 10 figs. The Bureau of Mines performed cratering experiments in a homogeneous granite to test scaling laws for charge weights of 0.00476, 0.0220, 0.0900, 0.304, and 1.03 lb. Agreement among the data was best when empirical scaling exponents greater than one-third were assumed. Although the analysis showed that the best empirical scaling exponents were 0.37 for crater volume, 0.38 for crater radius, and 0.39 scaling for crater depth, all three crater dimensions could be scaled with a 0.38 scaling exponent.

RI 7410. Tunnel Boring Technology. Disk Cutter Experiments in Sedimentary and Metamorphic Rocks, by Roger J. Morrell, William E. Bruce, and David A. Larson. July 1970. 32 pp. 12 figs. Disk-cutter experiments were performed on five rock types ranging in compressive strength from 9,000 psi to 27,000 psi. A specially constructed testing machine called a linear-cutter apparatus (LCA) was designed to load and traverse a free-rolling disk cutter across a sawed rock surface. The LCA was instrumented to measure the vertical and horizontal forces acting on the cutter during the run. The ability of disk cutters to fragment rock was determined for both 60-degree and 90-degree cutting-edge angles, and relationships and regression equations were developed to predict cutter performance based on rock physical properties and applied forces.

RI 7411. Magnetic Roasting and Leaching for Upgrading Minnesota Manganiferous Iron Ores, by H. D. Jacobs. July 1970. 13 pp. 3 figs. A process for recovering both iron and manganese from four manganiferous ores of the Cuyuna range was evaluated. It comprised (1) low-temperature gaseous reduction to convert non-magnetic iron minerals to magnetite and manganic minerals to manganese oxide, (2) acid leaching to extract manganese, and (3) magnetic separation to reclaim iron from the leach residue. Iron recoveries from the magnetic products ranged from 70 percent up to 90 percent; manganese recoveries from leach filtrates ranged from 75 percent to 95 percent. Two ores, from the Hillcrest and

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South Alstead properties, yielded magnetic products considered adequate for use as blast furnace feed. Although good yields of manganese were attained on all ores, appreciable iron accompanied the manganese into solution. Previous work, however, has shown that this iron can be precipitated almost quantitatively under autoclave oxygen pressure with very little loss of manganese.

RI 7412. Compressibility Factors for Helium and Carbon Dioxide Mixtures at -10° and -20° C and Pressures to 1,000 PSIA, by G. W. Weems and A. R. Howard. July 1970. 44 pp. 2 figs. The specific objective of this investigation was to determine the compressibility factors for helium and carbon dioxide mixtures at -10° and -20° C and pressures to 1,000 psia. A Burnett apparatus was used. Data from the experiments were treated by the method of Barieau and Dalton. Tables of compressibility factors and approximations of the virial coefficients are presented for 10 binary mixtures as well as for helium and carbon dioxide. The results follow the same trend as data previously reported.

RI 7413. Method of Weighing an Object in Gaseous Atmospheres To Obtain Its True Mass and Volume, by Alexander May and Robert E. Barieau. July 1970. 32 pp. 2 figs. This report describes a new method of weighing based upon observing the apparent weight of an object in two separate pure gases. The method is presented in terms of experimental data which prove its soundness, but does not attempt to show the maximum accuracy possible with this technique. The new method incorporates the underlying principle that the apparent weight of an object is a linear function of the density of the atmosphere in which the object is weighed. The coefficients of this linear function are the true mass and volume of the object. From this functional relationship the true mass and volume of the object may be determined.

RI 7414. Sorption of SO_2 and Regeneration of Alkalized Alumina in Fluidized-Bed Reactors, by Jack I. Paige, Joseph W. Town, James H. Russell, and Hal J. Kelly. August 1970. 32 pp. 11 figs. In this Bureau of Mines study, two fluidized-bed reactors were designed, built, and operated, one as a sorber for SO_2 and the other as a contactor for the regeneration of the sulfur-laden alkalized alumina. The target of 90-percent removal of SO_2 from a flue gas stream containing 0.3 percent SO_2 was attained by using a sorbent feed of 10 to 15 grams per minute into a 5-inch bed depth of alkalized alumina. The sorption unit was operated at about 330° C. Complete regeneration of the laden alkalized alumina containing 5 to 10 percent sulfur was accomplished in approximately $\frac{1}{2}$ hour. An excess of reformed propane at about 730° C was the regenerating gas. Attrition losses, a major problem with this sorbent, ranged from 0.9 to 7.9 percent of the inventory. Data from these tests demonstrate, within experimental error, the validity of equations developed from short-term, thin-bed tests related to sorption and regeneration rates.

RI 7415. Mathematical Evaluation of SO_2 Sorption-Regeneration Reactions With Alkalized Alumina (A Supplement to RI 7275 and RI 7414), by James H. Russell, Joseph W. Town, and Hal J. Kelly. August 1970. 29 pp. 18 figs. Alkalized alumina (an active form of sodium

aluminate) has been considered as a sorbent for the removal of sulfur dioxide from industrial flue gases. Four rate equations, each based on a different mechanism, were compared with the results of thin-bed sorption tests. It was found that each equation agreed with the experimental results, within experimental variance, over most of the range of sorption studied. First-order rate equations were generally satisfactory in explaining both sorption and regeneration. It is concluded that the equations developed are adequate for the design of commercial fluidized beds for the sorption of SO_2 from industrial flue gases and regeneration of the alkalized alumina.

RI 7416. The Range in Metals and Metal Oxide Systems of Heavy Ions in the Energy Range 60 to 400 KEV, by B. D. Sartwell, P. B. Needham, Jr., and D. Danforth. July 1970. 19 pp. 11 figs. Multiple-charged beams originating from a 300-kv ion accelerator are important tools in the study of metal surfaces and thin films. A knowledge of the particle range is necessary for an understanding of the interaction processes of the ions with the targets. Utilizing a theory developed by Lindhard for determining the range of low-energy ions in solids, the ranges of H, He, C, N, O, and Ar ions in Al_2O_3 , Al, Fe_2O_3 , Fe_3O_4 , CuO, Cu_2O , Fe, Cu, Sn, and W were calculated for the energy range 60 to 400 kev using a computer program written in BASIC. The range, presented in graphical form, is given in both $\mu\text{g}/\text{cm}^2$ and angstroms. In addition, heavy ion ranges were calculated for comparison with published experimental values. For ions with $Z > 5$, the discrepancy between the calculated values and published experimental values generally ranged from 2 to 40 percent; the largest deviations were probably due to experimental error.

RI 7417. Geochemical Investigations for Gold, Antimony, and Silver at Stibnite, Idaho, by D'Arcy P. Banister. July 1970. 7 pp. 2 figs. Several gold-antimony anomalies were outlined near Stibnite, Idaho, using the humus sampling technique. Several hundred reconnaissance humus samples were collected and analyzed by a combination fire-assay atomic absorption method. The results partially outlined several gold-antimony anomalies and are very encouraging for further work in this part of Idaho.

RI 7418. Hydrodesulfurization of a Residual Fuel From Wilmington, Calif., Crude Oil, by C. M. Frost and P. L. Cottingham. August 1970. 16 pp. 4 figs. The hydrodesulfurization characteristics of a residual fuel prepared from Wilmington, Calif., crude oil were determined at a temperatures from 600° to 900° F, pressures of 200 to 800 psig, and space velocities from 0.2 to $2.0V_0/V_c/\text{hr}$, using cobalt molybdate type catalysts. A prediction equation, developed from the experimental data, satisfactorily predicts the fraction of total sulfur that can be removed under any combination of operating conditions within the ranges investigated. Yields and properties of the low-sulfur product are correlated with the fraction of total sulfur removed. Kinetic calculations show that the apparent reaction order and activation energy change with space velocity and temperature.

RI 7419. Radiographic Test for Electrodeposit Porosity, by Stephen D. Cramer, V. A. Cammarota, Jr., and David Schlain. August 1970. 17 pp. 5 figs. A nondestructive procedure for measuring electrodeposit

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porosity has been developed which records the location and number of deposit defects including pores, pits, and voids. The procedure involves the passage of an X-ray beam through the deposit-substrate system onto suitable film. The defects are recorded as images on the film. Variables studied included intensity and spectra of the X-ray beam, composition and thickness of deposit and substrate, film type and developing procedure, and limits for detecting defects. At an X-ray tube voltage of 40-kv, pores several mils thick were easily detected in copper-nickel specimens more than 20 mils thick. To illustrate the utility of the procedure, the effect of substrate oxidation and of current density on electrodeposit porosity was briefly studied.

RI 7420. Prediction of Sodium Concentration in Lignite, by Manuel Gomez, Kathleen Hazen, and Everett A. Sondreal. August 1970. 17 pp. 5 figs. Prediction models were constructed for seam elevation, overburden, and sodium concentration for a lignite deposit in Ward County, N. Dak. These models were developed by mathematical-statistical techniques using surface coordinates as independent variables to permit interpolation between drill holes. The results suggest that sodium concentration in lignite may be predicted in advance of mining. This information is helpful to mine planning, specifically, in scheduling production to deliver a uniform product to existing powerplants.

RI 7421. Prediction of Coal Grindability From Exploration Data, by Manuel Gomez and Kathleen Hazen. August 1970. 34 pp. 7 figs. A general prediction model for the Hardgrove grindability index was constructed from 735 coal samples using the proximate analysis, heating value, and sulfur content. The coals used to develop the general model ranged in volatile matter from 12.8 to 49.2 percent, dry basis, and had grindability indexes ranging from 35 to 121. A restricted model applicable to bituminous coals having grindabilities in the 40 to 110 range was developed from the proximate analysis and the petrographic composition of the coal. The prediction of coal grindability within a single seam was also investigated.

The results reported support the belief that mechanical properties of the coal are related to both chemical and petrographic factors of the coal. The mechanical properties of coal may be forecast in advance of mining, because the variables used as input to the prediction models can be measured from drill core samples collected during exploration.

RI 7422. Production Potential of Copper Deposits Associated With Permian Red Bed Formations in Texas, Oklahoma, and Kansas, by R. B. Stroud, A. B. McMahan, R. K. Stroup, and M. H. Hibpsman. August 1970. 103 pp. 13 figs. Bureau of Mines studies of copper-bearing Permian red beds, which extend from north-central Texas through western Oklahoma to southwestern Kansas, indicate heretofore undefined commercial possibilities for low-grade, medium-volume, strip-mining operations. Potential ore bodies are indicated containing 0.5 to 1.5 percent copper in zones 6 to 12 inches thick. Cost analysis studies indicate a commercial operation is feasible for a hypothesized 1,000-ton-per-day ore mining and milling complex where a maximum of 60 feet of overburden can be stripped in mining a seam of shale 12 inches thick containing 1.2 percent copper. (*Out of print.*)

RI 7423. Effect of Fuel Composition on Exhaust Emissions From a Spark-Ignition Engine, by R. D. Fleming. September 1970. 68 pp. 16 figs. A single-cylinder research engine was operated on pure hydrocarbons and simple (two-component) mixtures of pure hydrocarbons to study the effect of fuel composition on exhaust emissions from a spark-ignition engine. Used as fuels were three pure hydrocarbons that represented the primary hydrocarbon types present in commercial motor fuels: A paraffin (2,2,4-trimethylpentane), an olefin (2,4,4-trimethylpentene-2), and an aromatic (meta-xylene). The engine was operated at the same equivalence ratio for all of the fuels used in the experiment. Exhaust gas samples were collected and quantitatively analyzed for carbon monoxide, carbon dioxide, hydrogen, nitrogen oxides, aldehydes, and hydrocarbons. Exhaust hydrocarbons were separated and quantitatively measured with a chromatographic system employing a flame-ionization detector. Unknown hydrocarbons and oxygenated materials in the exhaust were identified with a Time-of-Flight mass spectrometer coupled to a chromatographic system.

The results of the exhaust gas analyses showed that ethylbenzene, 1-methyl-3-ethylbenzene, and 1-methyl-3-vinylbenzene were more abundant in the exhausts from either 2,2,4-trimethylpentane-*m*-xylene or 2,4,4-trimethylpentene-2-*m*-xylene fuel mixtures than in exhaust produced from *m*-xylene. Also, the pure 2,4,4-trimethylpentene-2 fuel produced smaller amounts of C₂ to C₇ olefins in the exhaust than that produced by the pure 2,2,4-trimethylpentane fuel. The exhaust from pure *m*-xylene fuel contained aromatic hydrocarbons of higher molecular weight than the parent fuel. The amount of total hydrocarbon (moles of exhaust hydrocarbon per mole of fuel used) in the exhaust from the three pure fuels decreased in the following order: 2,2,4-trimethylpentane > 2,4,4-trimethylpentene-2 > *m*-xylene. The hydrocarbon mole-fractions of unreacted fuel in the exhausts produced from each of the pure fuels were 0.20 for 2,2,4-trimethylpentane, 0.13 for 2,4,4-trimethylpentene-2, and 0.66 for *m*-xylene.

RI 7424. Rock Fragmentation by Creating a Thermal Inclusion With Dielectric Heating, by K. Thirumalai. September 1970. 33 pp. 14 figs. This study forms a part of Bureau of Mines continuing research on thermal fragmentation of rocks. The potential of internal heating techniques for rock fragmentation is discussed. A concept of rock fragmentation with rapid internal heating of a localized inner volume of rock is advanced. The energy required for rock fragmentation is made available by creating a required volume of localized heating. The fragmentation of rock using the proposed method is analyzed and qualitatively compared with the results of experiments with Charcoal granite, Dresser basalt, and Sioux Quartzite. High frequency dielectric heating below 100 MHz is used in the study as an example to examine the working of the concept. The selection of operating conditions for the experimental heating is explained. Fragmentation of Charcoal granite and Dresser basalt test rock blocks is achieved for localized heating below 550° C. The heated volume required for fragmentation is observed to be less than 2 percent of the test block volume and the electrical energy consumption is in the order of 3.5 to 6.5 kwhr/m³. The method offers a possibility for in situ fragmentation of

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rocks favorable for internal heating. The method is highly dependent on rock properties governing internal heat generation. The efficiency of dielectric heating in the experimental study is observed to increase with increasing dielectric loss of the rock material, ranging from about 10 percent in Sioux Quartzite to about 50 percent in Dresser basalt.

RI 7425. Investigation of a Low-Grade Gold Deposit in the Orogande District, Idaho, by William L. Rice. September 1970. 14 pp. 5 figs. Geochemical humus sampling techniques were used by the Bureau of Mines in investigating a potential large, low-grade gold deposit in the Orogande district, Idaho. Conifer needle humus samples were processed by ashing and fire assay-atomic absorption analysis. An area bearing anomalous concentrations of gold and silver was outlined by the geochemical method.

RI 7426. Kyanite Resources in the Northwestern United States (In Two Sections). 1. An Investigation of Selected Kyanite-Group Mineral Deposits. 2. A Market Study for Western Kyanite Ores, by Ronald M. Van Noy, Norman S. Petersen, and Jerry J. Gray. 1970. 81 pp. 37 figs. A reconnaissance study of kyanite-group mineral deposits in the Northwest has revealed large exploitable reserves of the mullite-forming raw materials in the Woodrat Mountain and Goat Mountain districts of north-central Idaho. Potential coproducts or byproducts are garnet and muscovite mica.

The Woodrat Mountain district contains garnet-kyanite-mica schist, which has been traced for 6 miles and may extend farther. Surface samples average 29 percent kyanite and contain up to 15 percent garnet. Inferred reserves of strippable ore with a low waste-to-ore ratio, and containing more than 15 percent kyanite, are more than 3 billion short tons. The Goat Mountain district contains several kyanite-mineral zones. Samples of the richest zones average from 10 to 20 percent kyanite minerals and represent about 200 million short tons of strippable rock. Beneficiation tests indicate that the kyanite minerals and garnet can be concentrated by a combination of gravity, flotation, and electromagnetic methods.

Reserves in these deposits are sufficient to satisfy any foreseeable domestic and export demand. However, the freight tariff to reach the nearest major user of kyanite (located in the Midwest) has discouraged development of western kyanite resources. Western demand of a magnitude to support a moderate to large milling operation has not yet been developed. However, there is some foreign market potential. If a garnet byproduct could be prepared and sold for coated abrasive products or as grinding grains, an offset possibly could be gained to a portion of the mining and milling costs for the Pacific Northwest producer. Such byproduct values would offer a means of expanding the geographical market areas as well as the market potential.

RI 7427. Design and Construction of a Radiation Probe, by C. H. Schwartz and A. A. Orning. September 1970. 20 pp. 15 figs. A thermal radiation probe was constructed and tested in pulverized-coal-fired furnaces. A rotatable sensing head on the side of a water-cooled probe permitted measurement of radiant flux within a 7.2° cone from any desired direction to a point within a furnace. A responsive curve for a corner-fired

furnace showed radiant flux of 130,000 Btu per square foot per hour, when sensing wall reflection. Detailed drawings and fabrication procedures are given.

RI 7428. Conversion of Municipal and Industrial Refuse Into Useful Materials by Pyrolysis, by W. S. Sanner, C. Ortuglio, J. G. Walters, and D. E. Wolfson. August 1970. 14 pp. 3 figs. Pyrolysis (destructive distillation) techniques developed at the Bureau of Mines to determine the yield and quality of the products from coal were used to convert municipal (household) and industrial refuse into potentially useful solids, liquids, and gases without adding to environmental pollution. The tests demonstrated that a ton of municipal refuse can be converted into 154 to 424 pounds of solid residue, 0.5 to 6 gallons of tar, 1 to 4 gallons of light oil, 97 to 133 gallons of liquor, 16 to 32 pounds of ammonium sulfate, and 7,380 to 18,058 cubic feet of gas. A ton of industrial refuse, consisting of paper, rags, and cardboard, can be converted to 618 to 838 pounds of residue, 1.5 to 3 gallons of light oil, 68 to 75 gallons of liquor, 12 to 23 pounds of ammonium sulfate, and 9,270 to 14,065 cubic feet of gas. The energy from the gas is more than sufficient to provide the heat for the pyrolysis.

RI 7429. Bureau of Mines Apparatus for Thermal Analysis: Simultaneous DAT-TG-EGA for Oil Shale and Solid Fuels, by Donald R. Johnson and John Ward Smith. September 1970. 17 pp. 7 figs. Apparatus providing simultaneous differential thermal analysis, thermogravimetry, and evolved gas analysis, has been developed by the Bureau of Mines specifically for thermal study of oil shale and other solid, natural fuels. The apparatus is described in detail, and simultaneous analyses on a single sample of an oil shale mineral, nahcolite, and a thermal analysis demonstration compound, calcium oxalate monohydrate, are presented to demonstrate the instrument's capabilities. Work done in cooperation with the University of Wyoming.

RI 7430. Thermodynamic Data for Silver Chloride and Silver Bromide, by L. B. Pankratz. September 1970. 12 pp. 3 figs. Enthalpies above 298° K were determined for AgCl to 1,400° K and for AgBr to 1,200° K by copper-block calorimetry. Before melting, both compounds showed an anomalous increase in enthalpy, an effect associated with lattice defect formation. Melting points and heats of fusion were determined to be AgCl, 730° K and 2,945 cal/mole; AgBr, 700° K and 2,030 cal/mole. The heat capacity of both melted substances decreased with increasing temperature over the entire liquid ranges investigated. Enthalpies above 298° K were tabulated at even temperatures along with derived entropy increments and heat capacity values. The results were combined with the known heats of formation and entropies at 298.15° K to obtain values of the heats and free energies of formation over the range 298.15° to 1,400° K for AgCl and 298.15° to 1,200° K for AgBr.

RI 7431. Evaluation of Chemical-Cartridge Respirator Face Fit, by Harold A. Watson, Patricia M. Gussey, and Albert J. Beckert. September 1970. 9 pp. 4 figs. A method for measuring leakage of vapors into a chemical-cartridge half-mask facepiece during simulated use is described. The respirator, fitted with high-efficiency cartridges, is worn in a dichlorodifluoromethane (CCl₂F₂)-air test mixture while a series of timed activities (facial movements, varied breathing, exercise, etc.) is performed. Complementing other tightness tests, this method is useful par-

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ticularly for studying face fit and the effect of facial movements on leakage. The concentration of CCl_2F_2 within the facepiece is monitored continuously to observe the immediate effect of physical activity on leakage. A composite sample is collected simultaneously in a plastic bag as a measure of average leakage during the 18-minute test period. Leakage, reported as percent, is calculated from the concentrations of CCl_2F_2 within the facepiece and in the test atmosphere.

RI 7432. Rock Noise Source Location Techniques, by Fred Leighton and Wilson Blake. September 1970. 18 pp. 3 figs. The Bureau of Mines has developed rock noise source location techniques that may be used to obtain precise and practical source locations from microseismic field data. These techniques enable one to monitor all or any part of a rock structure and map progressive stress buildup or rock movement. Thus, the microseismic method of determining instability in rock structures is becoming an invaluable engineering tool for the mining or civil engineer engaged in rock excavation and construction.

RI 7433. On the Function of Hydrocarbon and Nitrogen Oxides in Photochemical-Smog Formation, by Basil Dimitriadis. September 1970. 37 pp. 21 figs. The roles of hydrocarbons and nitrogen oxides in smog formation were investigated by the Bureau of Mines. Samples of automobile exhaust with varying HC and NO_x levels were irradiated in a smog chamber under conditions that resulted in smog levels similar to those observed in the atmosphere. Results were used to define the patterns that describe the dependence of a number of smog manifestations on HC and on NO_x . Using these dependence data and some simplifying assumptions, estimates were made of the ranges within which HC and NO_x must lie in order to obtain specified levels of air quality. Work done under an agreement with the National Air Pollution Control Administration, U.S. Department of Health, Education, and Welfare.

RI 7434. Role of Alumina-to-Silica Mole Ratio in the Lime-Soda Sinter Process, by R. V. Lindquist and D. D. Blue. September 1970. 11 pp. 4 figs. Past reports by the Bureau of Mines have described the extraction of alumina from numerous aluminum silicate materials by the lime-soda sinter process. The results from pilot-plant investigations of six materials, with alumina-to-silica mole ratios from 0.3 to 8.7, indicated a relationship between the alumina-silica ratios and the processing characteristics of the sinter. A series of laboratory tests was conducted to define this relationship. Sinter and leach tests determined that an alumina-to-silica mole ratio of 0.90 or greater resulted in the best alumina and soda recoveries while leaving the leach slurries practically free from any tendency toward gelation. The widely different chemical and mineralogic properties of the various aluminous materials used in compounding the mixes had no perceptible effect on the leaching characteristics of the sinter. The blending of low-cost, high-alumina materials with aluminum silicate materials to give an alumina-to-silica mole ratio of 0.90 or greater would improve alumina and soda extraction and minimize operating problems in the lime-soda sinter process.

RI 7435. High-Temperature Enthalpies and Entropies of Chalcopyrite and Bornite, by L. B. Pankratz and E. G. King. September 1970. 10 pp. 2 figs. Enthalpies were determined for synthetic chalcopyrite (CuFeS_2) between 298° and 1,050° K and for syn-

thetic bornite (Cu_5FeS_4) between 298° and 1,100° K by copper-block drop calorimetry. Two transitions were found for each compound. The lower transitions were both crystal transformations from tetragonal (low-temperature form) to cubic (high-temperature form). The chalcopyrite transformation occurred at 830° K with a heat of transformation of 2,405 cal/mole; the bornite transformation was at 485° K with a heat of 1,430 cal/mole. The other transitions were of the second order and were presumed to be magnetic in character. The second-order transitions for chalcopyrite occurred at 930° K, and the one for bornite at 540° K.

RI 7436. Plates With Rows of Holes Considered as Anisotropic Soft-Inclusion Models of Three-Dimensional Room-and-Pillar Mining Systems, by Clarence O. Babcock. October 1970. 28 pp. 15 figs. In this report, the Bureau of Mines presents a method for reducing the complexity of designing room-and-pillar mining systems by treating them as anisotropic soft inclusions in the surrounding ore or host rock. Theoretical models were derived for the calculation of the effective Young's moduli for these systems. The predicted behavior of the plate-type elements used in these models agreed well with test results from 21 plates each with 49 holes spaced on a 7×7 Cartesian grid. The plates behaved as anisotropic solids, the effective Young's moduli of which could be predicted from the scaled hole size and spacing. Actual hole shape was insignificant. The effective Young's moduli for simple mining systems are calculated in sample problems.

This approach should provide information about field stress in the mining region and the stress distribution in the surrounding ore or host rock when the actual mining configuration is replaced by an anisotropic inclusion in a finite element analysis. The field stress within the inclusion can then be applied to the actual opening shape to determine the stress distribution within the mining region.

RI 7437. Phase Relations in the Alkaline Earth Fluoride-Yttria Systems. (In Three Parts) 1. The $\text{CaF}_2\text{-Y}_2\text{O}_3$ Phase Diagram, by Laurance L. Oden, Philip E. Sanker, Herbert R. Babitzke, and Donald H. Sumner. October 1970. 10 pp. 5 figs. The Bureau of Mines is developing melting data for binary combinations of the alkaline earth fluorides and yttria to facilitate the formulation of slag compositions. The present report deals with the $\text{CaF}_2\text{-Y}_2\text{O}_3$ system for which solidus and liquidus temperatures and solid solubilities were determined. The information is presented as the phase diagram.

All specimen compositions were blended from high-purity materials and encapsulated in Mo or Pt20Rh prior to heat treatment. Liquidus temperatures were determined by ceramographic examination of heat-treated and quenched specimens. Solidus temperatures were determined by differential thermal analysis and by electron microprobe analysis of quenched specimens. Terminal solid solubilities were derived by parametric methods.

The peritectic system was found to be pseudo-binary due to the formation of yttrium oxyfluoride at temperatures near the liquidus. The peritectic point occurs at 7 mole percent Y_2O_3 and $1,438^\circ \pm 5^\circ \text{C}$. The terminal solid solubility of Y_2O_3 in CaF_2 decreases from 7 mole percent at $1,438^\circ \text{C}$ to 1 mole percent at $1,100^\circ \text{C}$, and the solubility of CaF_2 in Y_2O_3 decreases from 9.5 to 7 mole percent over the same temperature interval.

RI 7438. Phase Relations in the Alkaline Earth Fluoride-Yttria

Systems. (In Three Parts) 2. The $\text{BaF}_2\text{-Y}_2\text{O}_3$ Phase Diagram, by Laurance L. Oden, Philip E. Sanker, Herbert R. Babitzke, and Donald H. Sumner. October 1970. 7 pp. 4 figs. The Bureau of Mines is developing melting data for binary combinations of the alkaline earth fluorides and yttria to facilitate the formulation of slag composition. Liquidus and solidus temperatures and solid solubilities were determined for the $\text{BaF}_2\text{-Y}_2\text{O}_3$ system, and the information is presented as the phase diagram.

The phase diagram was constructed from data obtained by ceramography, X-ray diffraction, and thermal analysis of specimens encapsulated in small molybdenum ampoules. The data indicate a simple eutectic system with maximum terminal solid solubilities of less than 1 mole percent. The eutectic temperature is $1,343^\circ\text{C}$, and the composition of the eutectic is less than 1 mole percent Y_2O_3 .

RI 7439. Radiant Heating of Coal Dust Clouds by Flames in Coal Mine Galleries, by J. M. Singer, and E. B. Cook. October 1970. 15 pp. 8 figs. Approximate equations were used to compute the radiant heating of float coal dust by approaching flames for various combinations of particle size, dust path length (flame travel distance), flame temperature, dust concentration, flame speed, and flame length. The computed values of degree of radiant heating and flame travel distance for preheating the coal dust should be useful for estimating the increased fire hazard of different coal dust-flame parameters. Some findings relating to coal mine disaster control are—(1) Coal dust clouds cannot be preheated to ignition temperatures by flame radiation alone when deflagration speeds are greater than about 10 m/sec. Thus it appears unlikely that radiation alone will cause flames propagating in dust clouds to accelerate to detonation velocities. (2) Small particles in the radiation flame zone caused by burnout and soot formation increase the degree of preheat significantly. (3) The concentration of float coal dust (radii = 3 to 40 microns) for maximum radiant heating usually peaks in the range 50 to 200 mg/liter of air.

RI 7440. Electrophoretic-Specific Gravity Separation of Pyrite From Coal, Laboratory Studies, by K. J. Miller and A. F. Baker. October 1970. 12 pp. 6 figs. A laboratory electrophoresis column was designed to separate pyrite from fine coal by utilizing an observed difference in the electrophoretic mobilities of the two materials in water. The apparatus worked well when tested with synthetic mixtures of coal and pyrite, but some modifications in design and procedures were necessary to provide a sharper separation. After these changes were made, the column was tested with a high-pyritic-sulfur raw coal sample. The column successfully fractionated the sample, removing not only the pyritic refuse, but a siliceous refuse as well.

RI 7441. Diffusion Studies of Light Hydrocarbon Gases Through Coal, by F. S. Karn, R. A. Friedel, and A. G. Sharkey, Jr. October 1970. 11 pp. 7 figs. Measurements were made of the flow of helium, methane, ethane, butane, and toluene through thin disks of coal. All measurements were made on a dense layer in the Pittsburgh seam identified as attritus. Flow increased with pressure differential and temperature. At room temperature and a pressure differential of 1 atmosphere flow rates along the bedding plane of Pittsburgh seam coal were helium $881 \times 10^{-10} \text{ cm}^2 \text{ sec}^{-1}$, methane $1.2 \times 10^{-10} \text{ cm}^2 \text{ sec}^{-1}$, ethane $0.54 \times 10^{-10} \text{ cm}^2 \text{ sec}^{-1}$, n-butane $0.35 \times 10^{-10} \text{ cm}^2 \text{ sec}^{-1}$, and toluene $3.8 \times 10^{-10} \text{ cm}^2 \text{ sec}^{-1}$. Flow rates were 50 percent lower across the bedding

plane of the coal than along the bedding plane. Activation energies were $3.9 \text{ kcal mole}^{-1}$ for helium and $13.6 \text{ kcal mole}^{-1}$ for methane, with diffusion measured either along or across the bedding plane.

RI 7442. Structural Models for the Design of Mining Systems. Encasement of Strain Gage Networks in Epoxy, by John R. Zelonka, R. J. Kline, and D. W. Mitchell. October 1970. 31 pp. 21 figs. Models made by encasing strain-gage networks in epoxy are described and evaluated. With this technique relatively complex models can be constructed in which any number of gages can be located aligned precisely. Although the gages are an integral part of the model matrix, they create no important mechanical or thermal stresses.

Model construction techniques and experimental data proved reproducible and reliable. In addition, the solution obtained with these models to the problem of the state of stress around a circular hole in a plate subject to a plane stress condition was in agreement with theoretical, photoelastic, and finite-element solutions.

RI 7443. Optimization of Carbon Deposition Experiments in Thermal Oil Recovery by Statistical Analysis, by A. W. Effinger and L. A. Schrider. November 1970. 17 pp. 2 figs. The Bureau of Mines used regression analysis and applied statistical methods in an effort to rationalize the results of an experiment examining the effects of certain variables on carbon deposition in a reservoir for thermal recovery of petroleum. Although none of the 15 trials of the original experiment resulted in the response of weight-percent of carbon regarded by the experimenter as adequate, values calculated using canonical analysis in two trials yielded responses 33 and 54 percent higher than the minimum acceptable figure. The actual responses differed by less than 3 and 6 percent, respectively, from the predicted responses.

Methods are described for defining a path of increasing response based on the minimum point and the response surfaces and for defining a set of values for the parameters in question, which result in increased response. A detailed explanation of the mathematical process used in this analysis is presented in the appendix for ease in computer programming the technique.

RI 7444. An Improved Method and Apparatus for Analysis of Impurities in Helium, by David E. Emerson, C. A. Hoffman, and G. W. Weems. November 1970. 10 pp. 5 figs. An improved method and apparatus for determining the impurities in helium by preconcentration and subsequent analysis by mass spectrometry are described. Proconcentration of the impurities is accomplished by passing a known volume of helium, at slightly above atmospheric pressure, through a metal coil and trap assembly immersed in liquid helium. The concentrated impurities are then analyzed by mass spectrometry. This method can detect impurities in the range of 0.01 to 600 ppm with an accuracy of better than $\pm 0.05 \text{ ppm}$ at the 1-ppm level. One operator can analyze 15 samples in an 8-hour day.

RI 7445. Dawsonite and Nahcolite Analyses of Green River Formation Oil-Shale Sections, Piceance Creek Basin, Colorado, by Neil B. Young and John Ward Smith. November 1970. 22 pp. 8 figs. Analytical results for nahcolite, dawsonite, total extractable alumina, and oil yield are presented for samples representing Green River Formation oil shales in the saline section of two cores from Colorado's Piceance Creek basin. Analyses are also reported for samples ex-

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tending the analyzed section of Colorado corehole No. 3 beyond that reported previously. These data permit evaluation of the deposit for possible production of three coproducts—shale oil, alumina, and sodium carbonates—from the saline section of the formation at these sampled points.

RI 7446. Control of the Dust Explosion Hazard on Coal Mine Shuttle-Car Runways, by John Nagy, Edward M. Kawenski, and Edward A. Barrett. November 1970. 16 pp. 7 figs. Large-scale tests in the Bureau of Mines Experimental Coal Mine show that the explosion hazard of coal dust on shuttle-car roadways can be controlled by proper application of water, dry rock dust, a saturated solution of ammonium phosphate, or mixtures of water or the water-phosphate solution with rock dust.

The experiments were made with loadings of 1.0 and 5.0 pounds of mine-size coal dust per linear foot of entry, and with a 3- or 4-inch-thick layer of coal rubble on the floor. The data from the tests with mine-size coal and rubble are comparable. The water contents of the dust loading were determined from samples collected just prior to initiation of a gas-air mixture in an ignition zone at the face. Dust samples were collected 1 inch deep from the coal-rubble deposit.

One experiment was made with the dust in the coal rubble bound with latex applied as a water solution by spray. The binding action was inadequate and explosion propagation was obtained.

RI 7447. Photographic Calibrations for Emission Spectrography Using a Small Computer, by R. J. Heemstra. November 1970. 12 pp. 2 figs. A method was developed for calibrating photographic emulsions and retrieving working curves for emission spectrography. The values obtained from a digital readout or a recorder chart of a comparator-microphotometer are converted to light intensity values using an emulsion characteristic curve derived from a quartic polynomial preliminary curve. The characteristic curve, consisting of Seidel transform versus the logarithm of intensity, is split into two cubic polynomials at the zero value of the transform, resulting in eight emulsion calibration coefficients. These methods allow use of the calibration curves even at very small and very high intensities, thus extending the range of analysis. Use of a small computer allows rapid calculations. A computer program was written to formulate, code, and file each working curve along with its statistical error. Proper coding of the input data permits the direct printout of the concentration of the elements under investigation.

RI 7448. Hazards Associated With the Spillage of Liquefied Natural Gas on Water, by D. S. Burgess, J. N. Murphy, and M. G. Zabetakis. November 1970. 22 pp. 17 figs. An investigation of the hazard of spillage of liquefied natural gas (LNG) onto water is described. About 2,000 gallons of LNG were consumed in various tests. The initial vaporization rate of LNG following spillage was found to be 0.037 lb/ft² sec; when the spill was confined, this vaporization rate was moderated after about 20 seconds by the growth of an ice layer on the water surface; when the spill was unconfined, a coherent ice floe was not observed and the vaporization rate was essentially time independent. The maximum diameter (in feet) of the spreading LNG pool was found to be given by $6.25 W_0^{1/3}$, where W_0 is the weight of LNG in pounds. Downwind of a natural gas source, time-averaged methane concentrations were given in good approximation by standard air pollution equa-

tions. However, peak concentrations were as much as twentyfold higher than average, adding an additional factor to the assessment of hazard. The effect of layering by the cold vaporized natural gas was similar to the effect of a temperature inversion on normal gases in the atmosphere. Small-scale explosions were observed on pouring LNG onto a water surface; no single explanation seems pertinent to all of the incidents observed.

RI 7449. A Method for Estimating Strength of Rock Containing Planes of Weakness, by Frank G. Horino and Merlyn L. Ellickson. November 1970. 29 pp. 22 figs. This report presents a method of utilizing the Coulomb strength criteria for estimating the strength and stability of pillars and pit slopes containing planes of weakness. It is assumed that the Coulomb theory, as a special case of the Mohr envelope, is a satisfactory first approximation of failure in uniaxial compression or triaxial loading with low lateral loads. Accepting this assumption for brittle materials, an expression for the strength decrease of rock pillars containing a plane of weakness or fracture at any angle of orientation is derived.

As few as six samples (three solid cores and three fractured cores at a failure-oriented angle) are required for testing uniaxially and triaxially to statistically determine the coefficients of friction and the shear strengths of both the solid rock and the fracture plane and the range of failure angles of the fracture plane. Interpretation of the data shows that the mean normal stress and maximum shear stress technique of analyzing the data is superior for solid core and that shear and normal stress values using angles of failure should be used for fractured specimens with failure-oriented angles. Plots of either the strength or strength ratios against fracture angles obtained from oriented drill core samples give a useful first approximation of strength decrease due to fracture. Using the same test conditions for both fractured and unfractured material increases the validity of the tests.

RI 7450. Heats of Solution and Formation of Oxalic Acid and Some Alkali Metal Oxalates, by Mary H. Brown and Arthur R. Taylor, Jr. November 1970. 13 pp. The heats of formation of oxalic acid and sodium, potassium oxalates, and lithium oxalates were related by solution calorimetry to the heat of formation of $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}$, a value believed to be reliable as reported in the literature. The following heats of formation were determined: $(\text{COOH})_2(\alpha)$, -198.1 ± 0.1 ; $(\text{COOH})_2(\beta)$, -197.8 ± 0.1 ; $\text{Li}_2\text{C}_2\text{O}_4$, -328.7 ± 0.4 ; $\text{Na}_2\text{C}_2\text{O}_4$, -316.2 ± 0.1 ; $\text{K}_2\text{C}_2\text{O}_4$, -321.9 ± 0.2 ; and $\text{K}_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$, -393.5 ± 0.2 kcal/mole. The heat of the crystalline transformation $(\text{COOH})_2(\alpha) \rightarrow (\text{COOH})_2(\beta)$ was determined to be 0.30 ± 0.02 kcal/mole at 298.15°K .

RI 7451. Mechanics of Seafloor Penetration by an Axisymmetric Tube: Static Penetration Studies, by Oleg Terichow. November 1970. 15 pp. 8 figs. The Bureau of Mines studied the penetration of a slender cylindrical tube into a sand bed, simulating seafloor material under the application of a static load. The factorial experimental design was based on three factors: tube diameter, geometry of penetrating bit, and seawater saturation of sand, all of which were found to be significant in influencing the depth of penetration. The geometry of the penetrating bit, or shoe, is of major significance in the mechanics of penetration and should be considered the most important factor for additional study. Linear regression analyses of the load-penetration data show that the relationship is linear.

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RI 7452. Colorimetric Determination of Beryllium in Coal, by Roy F. Abernethy and Elizabeth A. Hattman. November 1970. 8 pp. This report describes a method developed by the Bureau of Mines for the determination of beryllium in coal ash. Samples are put into solution by standard wet chemical procedures. Interfering elements are complexed with Na_2EDTA , and the beryllium is separated by extraction of its acetyl acetone complex with chloroform or carbon tetrachloride. Final determination is made with Beryllon II.

RI 7453. Precipitation Strengthening of Pb-Cd-Sb Alloys, by M. M. Tilman. November 1970. 10 pp. 7 figs. The Bureau of Mines investigated the precipitation strengthening of lead-base alloys containing 0.5 through 4 weight-percent combined Cd plus Sb. The Cd and Sb were alloyed in a 1-to-1 atomic ratio which maintained compositions along the quasi-binary section Pb-CdSb. Tensile properties, creep rates, and stress-rupture values were obtained on alloys in the aged condition. The highest tensile strength was observed in an alloy of Pb-3 CdSb. After aging for 6 months at $90^\circ \pm 3^\circ \text{ F}$, this alloy had a mean tensile strength of 8,950 psi with 15-percent elongation. An aged alloy of Pb-1 CdSb exhibited a steady state creep rate of 1.2×10^{-3} percent per day at a stress of 500 psi and a temperature of $90^\circ \pm 3^\circ \text{ F}$. Times to rupture at stresses up to 4,000 psi and at a temperature of $90^\circ \pm 3^\circ \text{ F}$ were obtained for some compositions.

RI 7454. Utilization of Red Mud Residues From Alumina Production, by Oliver C. Fursman, James E. Mauser, M. O. Butler, and W. A. Stickney. November 1970. 32 pp. 13 figs. The Bureau of Mines undertook this investigation to study methods of utilizing red mud residues from production of alumina from bauxite. Pilot-plant tests were conducted using Jamaican and Surinam red muds. Both the carbon-lime-soda sinter process and electric-arc smelting with coke and limestone were employed to recover iron and alumina. Alumina recoveries of 85 to 90 percent were obtained by the sinter process; although iron recovery was about 80 percent, the magnetic product was finely divided and difficult to separate from the gangue. Smelting red muds in the electric-arc furnace produced a pig iron with 98-percent recovery of iron; up to 84 percent of the Al_2O_3 was recovered by leaching the calcium aluminate slag with Na_2CO_3 solution. A titania product assaying 96 percent TiO_2 was recovered from the nonmagnetic portion of Surinam red mud sinter by extraction with H_2SO_4 . Leached calcium aluminate slags and brown mud (from the combination Bayer process) are possible raw materials in the manufacture of portland cement.

RI 7455. Characteristics of Electrowon and of Hydrogen-Reduced Molybdenum Powder and Sheet, by E. F. Ferrell and H. G. Iverson. December 1970. 28 pp. 9 figs. Electrowon molybdenum powders and a commercial hydrogen-reduced powder, all with different minor impurities, were investigated by the Bureau of Mines with respect to inherent properties, to fabrication techniques, and to properties of the fabricated sheet. Compared with the commercial hydrogen-reduced powder, the electrowon powders had a larger particle size, a greater flow rate, a higher apparent density, and a lower oxygen content. Sheet materials prepared from the two types of powders showed similar mechanical properties, under the same conditions of heat treatments, except for low-temperature ductility. Yield strengths varied with carbon content, heat treatment, and test temperature.

RI 7456. A Torsion Creep Tester for Metals and Alloys Using Electromechanical and Servomechanical Instrumentation, by Alfred E. Schwaneke, Vernon R. Miller, and Robert W. Nash. December 1970. 13 pp. 5 figs. A versatile torsion creep tester was instrumented with electromechanical and servomechanical components to operate automatically and unattended, producing digital printed outputs. The apparatus uses an electrical system for applying torsional stresses, and a unique angular transducer as a null detector operating a servocontrolled strain measuring system with the digital readout. The tester is designed to measure the creep in single-crystal or polycrystalline zinc, zinc alloys, magnesium, magnesium alloys, or other metals and alloys. Applied stresses may be varied from zero up to 2,000 psi in the outermost fibers of a $\frac{1}{8}$ -inch-diameter, 4-inch-long specimen. Strain readings to 0.001 degree, equivalent to a strain of 2.73×10^{-7} , may be made automatically from one every 5 seconds to one per month. The apparatus has provisions for programmed temperature control and special atmospheres or vacuum operation. A discussion of applications of the system to other mechanical testing apparatus is included.

RI 7457. Hydrogen Flare Stack Diffusion Flames: Low and High Flow Stabilities, Burning Rates, Dilution Limits, Temperatures, and Wind Effects, by J. Grumer, A. Strasser, J. M. Singer, Patricia M. Gussey, and Valeria R. Rowe. December 1970. 34 pp. 12 figs. The Bureau of Mines, under the sponsorship of the Space Nuclear Propulsion Office, conducted a laboratory-scale hydrogen safety study which determined several combustion characteristics of hydrogen diffusion flames. Experiments show that ambient air may enter the top of a hydrogen flare stack when the hydrogen flow is low. A new concept, supported by photographic evidence, predicts that diffusion flames burning in air on a wide, upright pipe (stack) and fed with slow, upward flows of buoyant gas will induce a downward flow of air along the walls of the pipe that can support combustion within the pipe. Predicted flamedip limits agree roughly with experimental values determined on 6-, 12-, and 18-inch-diameter stacks and increase with increasing stack diameter.

Measurements were made of the limiting flow at which a hydrogen diffusion flame blows out in still air. By means of an empirical application of the critical boundary velocity gradient concept, these data lead to a blowout limit of about 10^5 reciprocal seconds for a hydrogen diffusion flame. Burning rates of large hydrogen diffusion flames ranging from about 0.03 to 1 ft/sec were used to predict approximate flame heights on flare stacks. Temperatures of larger hydrogen diffusion flames up to about 3,600° F were observed, but the most representative values appears to be about 2,600° F. It was found that crosswinds do not strip significant amounts of unburned hydrogen from its diffusion flame and that water-cooled flare stacks are not likely to be damaged when flame is blown back into them by opposing winds.

RI 7458. Yttria and Dysprosia as High-Temperature Thermistor Materials, by Garrett R. Hyde, Edwin E. Maust, Jr., and LeRoy R. Furlong. December 1970. 8 pp. 2 figs. Sintered yttria and sintered dysprosia can be used to make single-component thermistors having typical thermistor geometries and operable in the temperature range 500° to 1,200° C. However, at these temperatures, instability of platinum electrodes can contribute a slight aging effect if the thermistor is kept near 1,200° C for long pe-

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riods. Typical characteristics at 500° C for an yttria disk thermistor 12 mm in diameter and 2 mm thick are a resistance of 12.4 megohms and a temperature coefficient of resistance of -3.8 percent per degree C. Typical characteristics at 500° C for a dysprosia thermistor of the same dimensions are a resistance of 1.84 kohms and a temperature coefficient of resistance of -1.6 percent per degree C.

RI 7459. Chemical Reactions in the Roasting of Copper Sulfides, by I. D. Shah and S. E. Khalafalla. December 1970. 21 pp. 13 figs. The Bureau of Mines investigated the sequence of principal chemical reactions taking place during the roasting of covellite (CuS). Practically all covellite is converted to digenite (Cu₁₁S₈) before oxidation to Cu₂O begins. Part of the Cu₂O is then converted to CuO, which in turn forms CuSO₄ through CuO • CuSO₄ as an intermediary. CuSO₄ and CuO • CuSO₄ decompose at 600° to 700° C to yield CuO and SO₂ (g) as final products. An overall mechanism is proposed for chemical reactions occurring at different interfaces of partially oxidized CuS pellets.

RI 7460. Surface Areas of Thermally Treated Cadmium Sulfide Powders, by Roy L. Wilfong and Garrett R. Hyde. December 1970. 15 pp. 2 figs. Surface area measurements were conducted on cadmium sulfide powders following thermal treatments at temperatures up to 500° C and treatment times up to 1 week. Thermal treatments at temperatures up to 300° C produced no significant changes in the surface area of the powders even after 1 week of exposure. At 500° C some decomposition of the cadmium sulfide occurred.

RI 7461. Batch Reduction of Iron Ore in Fluidized Bed, by John P. Hansen, J. E. Berryhill, and J. A. Aufman. December 1970. 25 pp. 19 figs. Batches of red or brown iron ore concentrates, weighing 100 or 200 grams, were reduced with gaseous reductants in a laboratory-sized fluidized-bed reactor. Using a loss of weight technique, the rates of reduction were measured and the effects of temperature, gas consumption, and gas flow rates were determined. Below about 725° C the rate of reduction was controlled by the chemical reaction at the reduction interface having an activation energy of about 10 kcal/g mole. Above about 725° C the rate of reduction appeared to be controlled by the flow of the gaseous reductant and therefore to be directly proportional to the flow rate. Above 725° C, hydrogen reduced the iron ore much faster than carbon monoxide. In gas mixtures, carbon monoxide or nitrogen reduced the hydrogen partial pressure and lowered the reaction rate proportionally. When present in large concentrations, carbon monoxide had a serious inhibiting effect on the reduction rate, probably owing to carburization and sintering of the reduced iron.

RI 7462. Mine Roof Vibrations From Production Blasts, Shullsburg Mine, Shullsburg, Wis., by James J. Olson, Richard A. Dick, David E. Fogelson, and Larry R. Fletcher. December 1970. 35 pp. 18 figs. The Bureau of Mines recorded both particle accelerations and velocities from one-stick and production blasts at Eagle-Picher Industries' Shullsburg mine, Shullsburg, Wis., to test the effectiveness of square root scaling in grouping underground blast vibrations and to determine the effects of rock type and mine geometry on blast vibrations. Although the charge weights of subsequent delay periods sometimes exceeded the charge weight of the zero-delay period, both acceleration and velocity records showed that the zero-delay portion of the Shullsburg production blasts produced the highest vibration amplitudes.

Because of the restricted range of charge weights in the Shullsburg experiments, no statistical determination of an appropriate scaling factor could be made. However, the square root scaled peak particle velocity data from the Shullsburg production blasts grouped well within the approximate band width of vibration data obtained by the Bureau from quarry blasts in many different rock types. This indicates that scaling by some factor, perhaps the square root or cube root of the charge weight, may be an effective way to group and study vibration data from underground blasts. Further research is needed to determine which scaling factor is best for underground blasting.

RI 7463. Roll Forming Strip From Oxide Powders, by Henry M. Harris, Bob L. Forkner, and Hal J. Kelly. December 1970. 24 pp. 5 figs. The roll forming of oxide powders was studied in a Bureau of Mines investigation to find the conditions and parameters required to make satisfactory ceramic strip. High-quality porous or dense alumina, zirconia, and porcelain shapes were made by sintering strip roll-formed at room temperature from powders containing minor amounts of binder and water. Strips with thicknesses of 0.04 to 0.08 inch and bulk densities from 40 to 90 percent of theoretical densities were made. The parameters most important to formability were particle size, condition of the powders, and roll gap. Other factors affecting quality were speed and surface condition of the rolls, amount and type of binder, water content, and sintering conditions. Ceramic strip was formed at rates up to 78 feet/minute, which is 13 to 23 times faster than reported by previous investigators, and forming was done in a simple and inexpensive roll unit. Reshaping the strip was possible by cutting, grinding, shearing, and stamping.

The following innovations were developed that allow roll processing not normally possible with ceramic powders: (1) Fine-sized powders were made into strip by preparing these as partially sintered granules; (2) thick strip was formed by pressure feeding powders into the rolls; (3) flexible strip was made using a rubber-base bonding agent; (4) corrugated strip was formed on shaped rolls; and (5) porcelain strip was densified and reduced in thickness by rerolling while hot.

RI 7464. Malononitrile Extraction of Gold From Ores, by H. J. Heinen, J. A. Eisele, and B. J. Scheiner. December 1970. 11 pp. 3 figs. Malononitrile [CH₂(CN)₂], which forms a carbanion in basic solutions, was investigated as a potential leachant for gold and was shown to be an effective extractant in alkaline pulps. Malononitrile was comparable to equal molar quantities of sodium cyanide (NaCN) in leaching gold from an oxide ore and yielded 10 to 20 percent higher recovery in leaching a refractory carbonaceous ore, although dissolution was slower with malononitrile than with cyanide. Complete recovery of the gold from the pregnant solutions was achieved by coprecipitation with a lead salt on zinc dust; the leachant was shown to be capable of regeneration and recycling a limited number of times. Addition of an anion-exchange resin to the carbonaceous pulp containing malononitrile increased gold recovery from 67 to 95 percent. Some malononitrile derivatives were also shown to be gold solvents.

RI 7465. Evaluation and Comparison of Red Fork Sand Water Flood Projects in Oklahoma, by Kenneth H. Johnson. December 1970. 45 pp. 2 figs. Information on oil and water production, volume of water

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injected, core analyses, and well completion data was collected on 28 Red Fork sand water-flood projects for comparison and evaluation of results. An average water injection efficiency of 35 percent, an average water-injected to oil-produced ratio of 16.8:1, and an average loss outside the flood pattern of approximately 45 percent of the injected fluid resulted in an oil recovery to January 1, 1969, of only 5.6 percent of the pore volume, or 9.1 percent of the initial stock-tank oil in place. The principal causes of poor oil recovery from these projects are the losses of large quantities of injection water from the flood patterns through oriented, natural fracture systems or zones of high permeability and excessive channeling of injection fluids from input wells to oil wells. For more efficient operation and a higher percentage of oil recovery from the Red Fork sand and other low-permeability-sand waterflood projects, directional orientation of both induced- and natural-fracture systems should be determined during early development. The success of a low-permeability-sand waterflood project depends to a large extent upon the orientation of the injection wells with the fracture system. Work done in cooperation with the State of Oklahoma.

RI 7466. A Comparison of Sublimation and Vaporization for Purification of Samarium Metal, by J. E. Murphy, E. Morrice, and M. M. Wong. December 1970. 12 pp. 3 figs. Purification of samarium metal by sublimation and by vaporization from a low-melting metal flux, at the same temperature, were compared. Vaporization proved more effective for removing impurities such as magnesium, calcium, and manganese. Recovery of samarium, however, is more rapid by sublimation because of its constant rate of distillation.

RI 7467. Washability Examinations of Colorado Coals, by Albert W. Deurbrouck. December 1970. 44 pp. 1 fig. This Bureau of Mines report describes the washability characteristics of 13 coalbed samples collected in Colorado. Such data are needed to evaluate the quality of the coals of the West, where most of our low-sulfur-content coal reserves are found. Of the 13 samples included in this report, 11 had a total sulfur content of 1 percent or less. All of the samples contained low percentages of ash or could be readily washed to a desirable ash level with minimal loss of yield. The coals ranged in rank from high-volatile A bituminous to subbituminous B; nine of the samples were high-volatile C bituminous. The coalbeds ranged in thickness from 6 to 26 feet; the average was about 8 feet.

RI 7468. Vapor-Liquid Equilibria Data for the Helium-Nitrogen System as Predicted by the Van Der Waals Equation of State, by B. J. Dalton and Robert E. Barieau. 1971. 184 pp. 9 figs. The Bureau of Mines Helium Research Center has developed a computer program for solving two-phase equilibria data for binary mixtures and for evaluating thermodynamic functions of interest, including all critical points. This computer program was used to calculate equilibrium points on the PVTu surface for the helium-nitrogen system as predicted by the Van der Waals equation of state. Numerical values are tabulated and illustrations are presented for 1,279 equilibrium points and for quantities needed to construct Ponchon diagrams. Equilibrium ratios as a function of pressure at constant temperature and of temperature at constant pressure are also shown graphically. In addition, saturated partial molal volume and

partial molal enthalpy data are given. It is shown that the Van der Waals helium-nitrogen system exhibits retrograde condensation of the second type for liquid helium concentrations of about 0.07 mole fraction or less and pressures below about 45 atm. It is also shown that the critical point is at a maximum value of pressure (at constant temperature) and of temperature (at constant pressure). (*Out of print.*)

RI 7469. Waterflooding of Oilfields in Wyoming to 1968, by Paul Biggs and Charles A. Koch. December 1970. 147 pp. 32 figs. This Bureau of Mines report provides information on 138 waterflood projects in Wyoming. Injection was in 25 producing zones and 65 fields. Specific data presented include field location, discovery and development, water supply and injection, oil and water production, estimates of oil in place, and oil recoveries by primary and secondary methods.

RI 7470. Microseismic and Displacement Investigations in an Unstable Slope, by Raymond M. Stateham and John S. Vanderpool. January 1971. 22 pp. 20 figs. Microseismic noise rates and slope movements were measured in an unstable area along the north wall of the Tripp-Veteran pit, Kennecott Copper Corp., Ruth, Nev. Low-noise, wide-band microseismic geophones were located at various points in the wall, and the change in distance across open fractures, resulting from instability, was determined by repeated measurements between fixed points set on each side of the fractures. The microseismic noise rate increased and decreased with corresponding increases and decreases in the rate at which the fractures opened. The microseismic noise rates and changes in width of the fractures show excellent agreement, and the two types of measurements complement each other in monitoring the progress of pit wall failure.

RI 7471. Recovery of Uranium From Natural Mine Waters by Countercurrent Ion Exchange, by J. R. Ross and D. R. George. January 1971. 17 pp. 11 figs. Recovery of uranium from slightly alkaline mine water, available in the Ambrosia Lake district of New Mexico, was studied using countercurrent ion exchange columns developed by the Bureau of Mines. Approximately 5 million gallons of mine water containing 9 to 12 ppm U_3O_8 was treated by ion exchange using a 14-inch-diameter absorption column composed of five or six compartments each 4 feet deep. Uranium recoveries averaged in excess of 98 percent at solution flows ranging from 15 to 25 gallons per square foot per minute and resin loadings up to 3.6 pounds of U_3O_8 per cubic foot.

In subsequent tests, loaded resin was continuously eluted in a countercurrent elution column with a diameter of 4 inches and containing a bed of resin 9 feet deep. The resin was eluted to a residual loading of less than 0.06 pound of U_3O_8 per cubic foot, at a resin-retention time of 224 minutes, using only 1.9 volumes of 1.1 M NaCl-0.05 M $NaHCO_3$ solution per volume of resin.

Compared with existing ion exchange practices for recovering uranium from mine waters in the Ambrosia Lake district of New Mexico, use of these improved ion exchange contactors would reduce ion exchange resin requirements at least 70 percent and allow further substantial reductions in capital and operating costs.

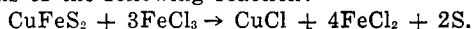
RI 7472. A Graphical Method of Removing Outlier Values

From *Analytical Data*, by E. E. Remmenga and R. G. Burdick. January 1971. 10 pp. 5 figs. Often a collection of analytical data, which should reasonably be expected to follow the normal distribution, contains too many extreme values, which the experimenter is inclined to eliminate according to some arbitrary procedure. The stepwise computer procedure described for this purpose is similar to many other truncation procedures; however, because truncation of a basically normal distribution causes a downward bias in the estimated variance, this procedure provides a graphical method to compensate for the bias.

RI 7473. Processing Manganiferous Sea Nodules, by P. T. Brooks and D. A. Martin. January 1971. 19 pp. 5 figs. Mineral nodules from the ocean floor represent a vast potential source of manganese, nickel, cobalt, and copper. Process development studies to devise methods for recovering these metals were conducted by the Bureau of Mines using two types of nodules—relatively low-grade calcareous nodules from the Atlantic Ocean and higher grade siliceous nodules from the Pacific Ocean. Ammoniacal carbonate leaching of reduced nodules appeared to have the best potential for processing the calcareous nodules, but the method proved to be impractical for recovering manganese. Extraction of 90 percent or better of the nickel, cobalt, and copper showed the technique to be attractive for recovery of these metals.

The siliceous nodules appeared amenable to a process that starts with either a sulfur dioxide leach or a sulfation roast followed by a water leach to dissolve the soluble sulfates.

RI 7474. Recovering Elemental Sulfur From Nonferrous Minerals: Ferric Chloride Leaching of Chalcopyrite Concentrate, by F. P. Haver and M. M. Wong. January 1971. 20 pp. 6 figs. Because of increasing concern with air pollution, the Bureau of Mines has developed a hydrometallurgical procedure to obtain elemental sulfur from chalcopyrite (CuFeS_2) by means of the following reaction:



Under optimum conditions, 99.6 percent of the copper and 71.6 percent of the iron were extracted in 2 hours from a typical mill concentrate containing 75 percent CuFeS_2 and 15 percent pyrite (FeS_2). At the same time, 68.2 percent of the sulfur in the concentrate was oxidized to the elemental form. The leach was highly selective; gangue minerals, including pyrite, were not attacked, thus accounting for the relatively low recoveries of iron and sulfur.

RI 7475. Extraction of Copper and Nickel From the Duluth Gabbro Complex by Selective High-Temperature Sulfatization, by F. E. Joyce, Jr. January 1971. 15 pp. 5 figs. The Bureau of Mines studied copper-nickel minerals (mainly sulfides) of the Duluth Gabbro Complex in north-eastern Minnesota to determine their response to selective high-temperature sulfatization techniques. The gabbro, containing 0.44 percent copper and 0.13 percent nickel, was ground to minus 325 mesh and sulfatized in a heated, rotating, stainless steel bench-scale retort. Tests demonstrated that over 95 percent of the copper and 80 percent of the nickel can be converted to water-soluble sulfates, depending upon the roasting conditions employed. Yield equations were developed using regression analysis for predicting the extraction of copper and nickel between the temperature limits of 520° to 670° C, the roasting time limits of 3 to 7 hours, and SO_2 limits of 10 to 40 percent in SO_2 -air mixtures.

RI 7476. Mathematical Simulation of a Gas-Solid Reaction in a Packed Bed: Reaction of CO_2 With Coke, by Hillary W. St. Clair. February 1971. 29 pp. 6 figs. This report describes an experimental method for determining parameters for the rate of reaction of CO_2 with solid carbon. The method involves the simulation of a flow reactor by a mathematical model based on a hypothetical multistage reactor which permits calculation of the analyses of effluent gas and carbon consumed as functions of the flow rate and duration of the reaction. The method is applied to experimental data on the reaction of coke with CO_2 in fluidized-bed and fixed-bed flow reactors. A method is described whereby two parameters may be determined simultaneously. The method involves a reiterative procedure that finds the values of the parameters that minimize the sum of squares of deviation between calculated and observed analyses of the effluent gas.

RI 7477. Determining Seepage Characteristics of Mill-Tailings Dams by the Finite-Element Method, by C. Daniel Kealy and Richard A. Busch. January 1971. 113 pp. 34 figs. Finite-element, mathematical models that solve Laplace's and Richard's equations numerically were used to locate the phreatic surface within tailings pond embankments and to define the subsurface flow of water from the pond. Both must be known to design structurally and environmentally safe tailings dams. The permeability distribution within and beneath the embankment, the fluid potential values upgradient and downgradient from the embankment, and the geometry and elevation of an approximately impermeable layer at some depth beneath the embankment were used as computer inputs in analyzing over a dozen finite-element models of tailings dams varying structurally from simple to complex. Results predicted with the finite-element model were confirmed with measurements in a laboratory model of a tailings pond and in the field. Of particular importance to the design of safe slopes, all data indicated that the phreatic surface within a tailings dam is concave upward, a configuration opposite that in most earth dams. The close correlation between predicted and experimental values confirmed the practicability of using the finite-element technique to design safe tailings dams.

RI 7478. Removing Sulfur Dioxide From Flue Gases. Regeneration Rates for Alkalized Alumina, by J. W. Town, J. H. Russell, and H. J. Kelly. February 1971. 24 pp. 12 figs. The Bureau of Mines studied the effects of reducing gas composition, temperature, and superficial gas velocity on the regeneration rate of alkalized alumina. Regeneration was assumed to follow the simple first order reaction for removal of sorbed SO_2 : $d\mu/dt = -K\mu$. An Arrhenius relationship can be plotted, which shows an activation energy of about 75 kcal/mole for simulated reformed propane. The general effects of the individual gases can be described as follows: (1) CO and H_2 produced rates proportional to their concentrations, up to about 5 percent for each; (2) addition of CO_2 had no effects on the regeneration rate by CO ; (3) the regeneration rate by H_2 was lowered by the addition of H_2O while the regeneration rate by CO was increased by H_2O addition; (4) H_2S showed a positive effect up to concentration levels of about 2 percent and then produced a rapid negative effect; (5) carbonyl sulfide (COS) increased the sulfur content; and (6) propane was as effective in regenerating the loaded pellets as was simulated reformed propane.

RI 7479. Properties of Cast Columbia Carbide-Carbon Alloys, by Gene Asai, D. L. Paulson, and Hal J. Kelly. February 1971. 68 pp. 51 figs. Properties obtained for columbium carbide-carbon castings ranging in carbon content from 12 to 17 weight-percent were compared with those of hot-pressed composites of similar composition. The properties were oxidation resistance in static air between 500° and 700° C, linear thermal expansion between 20° and 2,400° C, electrical resistivity between 20° and 1,500° C, microhardness between 20° and 1,500° C, and modulus of rupture between 1,300° and 1,800° C. CbC-C castings differed markedly from hot-pressed material with respect to microstructure, electrical resistivity, and modulus of rupture, but behaved quite similarly with respect to oxidation resistance, thermal expansion, and hot hardness.

In oxidation resistance, thermal expansion, and hot hardness both materials were independent of carbon content. Both castings and hot-pressed composites oxidize rapidly in air above 600° C, have thermal expansion coefficients very similar to columbium metal, and the logarithm of the hardness decreases linearly with increasing temperature.

The microstructures of hot-pressed composites contained varying amounts of graphite in a CbC matrix but did not contain significant amounts of a eutectic structure present in all castings, nor did they contain graphite needles which were present in the hypereutectic castings. The higher electrical resistivity of hypereutectic castings over hypereutectic hot pressings was attributed to the presence of highly oriented graphite needles in the castings. The modulus of rupture of castings was 1½ to 2 times that of hot-pressed composites. Both materials displayed bend ductility above 1,800° C.

RI 7480. Electrotransport of Impurities in Rare-Earth Metals, Using a Pulsed Current, by J. D. Marchant, E. S. Shedd, T. A. Henrie, and M. M. Wong. February 1971. 13 pp. 8 figs. Solid-state electrotransport of impurities in cerium, lanthanum, and praseodymium, using a pulsed current, was investigated. The results were compared with those of using a steady current. Impurities that showed appreciable movement with the pulsed current, but not with the steady current, were as follows: Molybdenum and oxygen in cerium, aluminum, iron, and molybdenum in lanthanum. The use of a pulsed current enhances the practical application of solid-state electrotransport to remove a wider variety of impurities from the host metals.

RI 7481. Continuous Heavy Liquid Concentration of Kyanite, by Thomas O. Llewellyn and James S. Browning. March 1971. 11 pp. 5 figs. Laboratory semicontinuous and continuous heavy liquid cyclone separation pilot plant tests were made to determine the feasibility of producing a high-grade kyanite concentrate from a kyanite-quartz rock sample from Graves Mountain, Ga. Use of a three-stage heavy liquid cyclone demonstrated that a 96.4- to 99.0-percent kyanite concentrate could be obtained with recoveries of 95.5 to 96.7 percent. The test work showed that by steam stripping with 6.9 tons of steam per ton of ore and two stages of detergent scrubbing the residual TBE content of kyanite cyclone products was 0.22 pound per ton of ore. Work done in cooperation with University of Alabama.

RI 7482. Heat Contents of Some Green River Oil Shales, by R. L. Wise, R. C. Miller, and H. W. Sohns. March 1971. 16 pp. 4 figs. Heat content studies

were conducted on burned shale, spent shale, and three grades of raw oil shale from the Green River Formation. Corrections were made for product enthalpies. The results were compared with previous work, indicating good agreement below retorting temperatures, but some differences at retorting temperatures. A general equation was developed relating heat content to oil-shale grade and temperature. Work done in cooperation with the University of Wyoming.

RI 7483. Removing Sulfur Dioxide by Carbon Monoxide Reduction, by L. A. Haas, T. H. McCormick, and S. E. Khalafalla. March 1971. 18 pp. 11 figs. The feasibility of removing sulfur dioxide by carbon monoxide reduction in a fixed-bed catalytic reactor was investigated by the Bureau of Mines. The reduction rate of sulfur dioxide with carbon monoxide was significantly dependent upon the iron and alumina content of the mixed catalyst. Maximum catalytic activity was obtained with about 40 percent iron-alumina mixture with a nominal gas mixture of 10 percent carbon monoxide, 5 percent sulfur dioxide, and the balance nitrogen. The synergistic effect of this catalyst mixture was explained by a dual reaction site mechanism, with both iron and alumina augmenting their specific sites at their interparticle contacts. The catalytic activity also increased with decreasing catalyst pellet size. With 0.7-mm pellets, the entire pellet appeared to be catalytically active in a 2-gram catalyst bed. The apparent activation energy of the reaction was 18.3 kcal per mole in the temperature range of 350° to 600° C. Carbonyl sulfide (COS) was produced by the interaction of carbon monoxide and sulfur. The amount decreased with decreasing CO concentration. The ratio of COS formed per SO₂ removed reached a maximum at about 400° C. The reaction rate appeared to be independent of SO₂ concentration in the range of 0.2 to 16 percent. The rate, however, increased directly with the CO concentration in the range of 5 to 20 percent. The presence of CO₂ (<15 percent) had no appreciable effect on the rate. However, not over 0.5 percent oxygen could be tolerated. This method appears feasible for removing SO₂ from waste gas if the oxygen is removed prior to the catalytic SO₂ reduction process.

RI 7434. Electrolytic Preparation of Vanadium From V₂C-Type Carbide, by K. P. V. Lei, and T. A. Sullivan. March 1971. 17 pp. 8 figs. An electrochemical process was developed for the preparation of vanadium from vanadium carbide. Commercially available vanadium carbide (V₂C) was used as the starting material. Vanadium was obtained by electrolysis of the V₂C in a BaCl₂-KCl-NaCl-VCl₂ electrolyte at 670° C using a helium-atmosphere, molten-salt electrolytic cell. Vanadium products were recovered with purities as high as 99.6 percent. Current efficiencies of 87 percent and vanadium recoveries of 84 percent were attained. The cathode products were amenable to electrorefining to high-purity vanadium of 99.96-percent purity.

RI 7485. Tungsten and Dispersion-Strengthened Tungsten Made by Freeze Drying, by M. J. Ferrante, R. R. Lowery, and G. B. Robidart. March 1971. 32 pp. 17 figs. The Bureau of Mines investigated the applicability of the freeze-drying technique for preparing dispersion-strengthened tungsten powders suitable for conversion by powder metallurgy into materials which might have improved high-temperature strength. Extruded rods from compacts of tungsten-5 volume percent thoria had at 1,650° C a tensile strength of 30,300 psi and a 10-hour stress-

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rupture strength of 12,700 psi. These are slightly below those measured for swaged rods of commercial tungsten-3.7 volume percent thoria. Only those tungsten-thoria dispersions containing a stoichiometric deficiency of oxygen yielded a significant strengthening effect. A low-melting eutectic formed in extruded tungsten dispersions containing either zirconia or yttria, which caused a lowering of the tensile strengths. These tensile strengths were only slightly higher than strengths of elemental tungsten made from commercial powder having a particle size of 2.4 microns (Fisher subsieve). Sheet made from this commercial tungsten had a slightly higher tensile strength than tungsten made by freeze drying, but the freeze-dried tungsten sheet had a lower recrystallization temperature, a lower ductile-to-brittle transition temperature, and a higher purity.

RI 7486. Statistical Analysis of Assay Data From the Round Mountain Silver Prospect, Custer County, Colo., by George S. Koch, Jr. March 1971. 32 pp. 11 figs. A statistical analysis of silver assay data from rotary-drill-hole cuttings and diamond-drill-hole cores from the Round Mountain prospect, Custer County, Colo., demonstrates several useful methods for estimating grades and tonnages of ore from the drilling of wide-spaced holes in disseminated deposits of precious metals. A new method of ore appraisal is introduced which estimates grade and tonnage of ore by calculating convex hulls (smallest convex polygons) for sample points with assay values above specified cutoff grades.

Analyses of variance compare the consistency of data from rotary- and diamond-drill holes, from rotary-drill holes sampled at 2- and 4-foot intervals, from two methods of sample preparation, and from atomic-absorption and fire assaying. Evidently, data from the two types of drill holes, from holes sampled at the two intervals, and from different methods of preparation are in agreement. Atomic-absorption silver values are consistently lower than fire-assay silver values. Work done in cooperation with Round Mountain Associates.

RI 7487. Method for Controlling Instability of Liquid-Saturation Computations, by C. Kenneth Eilerts and Eudora F. Sumner. March 1971. 15 pp. 2 figs. A method is described for controlling instability in finite-difference computations of liquid saturation near the borehole of a recovery well. Differences of pressure- and saturation-dependent variables are indexed offcenter, upstream and downstream alternately, to provide a stabilizing average. It was found that size of the time step could be increased by a factor of 4 without loss of numerical stability. Finite differences of the variables occur in a variety of relative numerical sizes and combinations. Those relationships of the differences that contribute to instability may be identified by the computing program in which they occur and modified to assist convergence of the computations and execution of the partial differential equations of liquid and gas flow.

RI 7488. Recovery of Mica From Silt Deposits in the Nolichucky Reservoir, Tennessee, by Ralph B. Adair and Jerome O. Crabtree. March 1971. 9 pp. 2 figs. The Bureau of Mines conducted laboratory batch and small-scale continuous tests on samples of silt from the Nolichucky Reservoir near Greeneville, Tenn., to develop a process for the recovery of commercial-grade muscovite concentrates. Using a combination of Humphreys spirals for preconcentration followed by cationic flotation, 94.5 percent of the muscovite

was recovered in a product containing 96.5 percent muscovite. Work done in cooperation with the University of Alabama.

RI 7489. Gold Transport by Complex Metal Chloride Vapors, by Judith A. Eisele, D. D. Fischer, H. J. Heinen, and D. G. Kesterke. March 1971. 12 pp. 5 figs. The possibility of improving the volatilization of gold through the formation of a metal-gold chloride vapor complex was investigated. Gold-silica mixtures, containing ferrous and nonferrous minerals and salts as additives, were treated in a laboratory tube furnace with a flow of chlorine gas at various temperatures. The addition of pyrite (FeS_2) to a charge of gold-silica increased the volatility of the gold from 3, 20, and 62 percent of the total gold to 62, 93, and 100 percent at 200°, 300°, and 400° C, respectively. Chemical analyses of the condensate indicated the volatile species to be FeAuCl_4 .

RI 7490. Analyses of Tipple and Delivered Samples of Coal Collected During Fiscal Year 1970, by Staff, Coal Sampling and Inspection. 1971. 20 pp. The Bureau of Mines has been active in promoting the purchase of coal for Government use under specifications that define the requirements in terms of heating value of the coal, expressed in British thermal units, and the composition as shown by proximate analyses. To these, when required, are added the ash-softening temperature, the free-swelling index, and the Hardgrove grindability index. Under most of these specification contracts the bidders guarantee the quality of the coal, and that guaranteed by the successful bidder becomes the standard of his contract. The deliveries are sampled in accordance with instructions issued by the Bureau of Mines; the samples are analyzed in the Bureau laboratory to determine whether the coal is of the quality guaranteed by the contractor; if it is not, a price adjustment is made. Analyses of the delivered coal and tipple samples (samples collected at mine tipples as coal is being loaded into railroad cars or trucks) provide valuable data for use in evaluating future bids. In addition, the continuous sampling of coal as delivered is a check on the practical results obtained in burning the coal. The Government, with the exception of the Tennessee Valley Authority, purchased approximately 6.0 million tons of coal in fiscal year 1970. In connection with these purchases, the Bureau analyzed 4,978 samples. These are published for the use of Government officials and the public. (Out of print.)

RI 7491. Effects of Magnesium on the Microstructure, Hardness, and Tensile Properties of Zinc Alloys Containing 25 to 40 Percent Aluminum, by L. A. Neumeier and J. S. Risbeck. March 1971. 34 pp. 23 figs. The Bureau of Mines evaluated the properties of zinc alloys containing 25 to 40 weight-percent Al and 0 to 0.7 percent Mg. Microstructures, hardness, and tensile properties were evaluated for material as extruded at 285° C, solution treated at 300° to 400° C, and subsequently aged at 100° to 200° C. The alloys without magnesium are characterized by low hardness and strength with high tensile elongation and reduction in area. It was verified that magnesium effectively retards the Zn-Al eutectoid transformation below 275° C and markedly increases hardness and strength with decreases in ductility. Solution treating at 350° C results in large grain sizes and gross embrittlement. Subsequent aging of the Zn-Al-Mg alloys at 200° C restores ductility substantially and stabilizes the structures, but strengths are considerably reduced. Combined strength and

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ductility properties are better for the as-extruded condition than for any heat-treated condition. There is usually little advantage in overall tensile properties from increasing magnesium above 0.1 percent.

RI 7492. Compositional Variations of the Organic Material of Green River Oil Shale—Colorado No. 1 Core, by W. E. Robinson and G. L. Cook. March 1971. 32 pp. 14 figs. Sixty samples, selected from a 2,300-foot core of the Green River Formation in Colorado, were studied to ascertain differences in the structure of the organic material present in the oil shale samples. Emphasis was placed upon relating differences in the aromatic content of the insoluble kerogen and the alkane content of the extractable material obtained from the selected samples. The methods used in determining these differences consisted of fractionation of the soluble material, carbon and hydrogen analysis, volatile material determination, carbon residue determination, oxidation rate determination, and infrared analysis. In general it was concluded that the organic material in this core does vary in chemical structure and that some of these variations resulted from factors related to depth of burial. Other observed changes in structure of the organic material were not depth dependent and resulted from other factors such as source material variations, biological alterations, or ecological differences. Work done in cooperation with the University of Wyoming.

RI 7493. Radiotracer Study of Turbine Aircraft Fuel Stability, by M. L. Whisman, F. O. Cotton, J. W. Goetzing, and C. C. Ward. March 1971. 30 pp. 15 figs. The Bureau of Mines developed a radiotracer method for detecting the contribution of selected components and additives to thermally induced deposits of turbine aircraft fuels. Fuels were examined before and after 52 weeks of storage at 130° F. Of particular concern was the influence of aromatic hydrocarbon fuel constituents on thermal-stability quality of jet fuels during storage. A microfuel coker test apparatus was used to thermally stress the test fuels and blends, and the resultant contribution to deposits of selected fuel components, labeled with carbon-14, was determined by radioactive-counting techniques.

Ninety-one blends of five test fuels with carbon-14-labeled fuel additives or components were prepared, tested, stored for 52 weeks at 130° F, and reanalyzed for deposit-forming tendency. These additives included two antioxidants, a metal deactivator, and a corrosion inhibitor. Of the labeled hydrocarbon fuel systems studied, the greatest reaction was observed in blends containing methyl- and ethyl-substituted indenenes. Other aromatic types also showed some contribution to the deposits. Three of the additives showed a marked tendency to degrade and react during storage and thermal stress. A cresol antioxidant, however, barely contributed to deposit formation. Oleic acid interacted with cadmium present in aircraft fuel systems and produced deleterious effects upon the thermal-stability quality of the fuel. Work done under an agreement with the Aero Propulsion Laboratory, Research and Technology Division of the Air Force, Wright-Patterson Air Force Base, Ohio.

RI 7494. Effect of Organic Additives on Impregnated Diamond Drilling, by K. C. Strebig, A. Aly Selim, and C. W. Schultz. March 1971. 31 pp. 27 figs. The effect of some organic additives in diamond drilling of quartzite was investigated in the laboratory with a drill instrumented to measure the rate of penetration, the thrust, and the torque and to

record each as a function of the distance drilled. A statistical plan was followed throughout the investigation, and an equation representing the bit performance was derived from the mathematical theory of reliability. The coefficient of friction in drilling increased with the use of additives, although the wear coefficient decreased. The decrease in wear associated with an increase in energy per unit volume consumed and the increase in penetration rate resulted in a net decrease in the cost per foot of drilling. A hypothesis explaining the effects achieved with the additives is given.

RI 7495. Statistical Analysis of Gold Assay and Other Trace-Element Data, by Richard F. Link, George S. Koch, Jr., and John H. Schuenemeyer. April 1971. 127 pp. 22 figs. The principal procedures for the statistical analysis of gold assay and other trace-element data depend on applying either the normal frequency distribution or the lognormal frequency distribution. The consequences of applying both methods are examined through reference to example data from United States and South African gold mines. It is concluded that for estimation of average grades, except for certain data with a very high coefficient of variation (ratio of standard deviation to mean), use of the lognormal distribution is ordinarily undesirable because bias may be introduced and little efficiency can be gained. However, if biased average grades can be tolerated, as in the examination of data from surveys in exploration geochemistry, use of the lognormal distribution may be desirable. Various statistical analyses are detailed, and the tables presented to implement the analyses are more complete than those previously published.

RI 7496. Oxidation of Cobalt-Nickel-Aluminum Alloys at 1,351° to 1,429° K, by Robert M. Doerr and James W. Jensen. March 1971. 27 pp. 10 figs. The research objective was to determine the effect of aluminum alloy additions on the oxidation behavior of cobalt-nickel alloys. Thirty high-purity alloys were reacted with O₂ at 0.5 atm at 1,351°, 1,389°, and 1,429° K in a volumetric apparatus for about 300 min. The alloy compositions consisted of Co-Ni master alloys (0, 22, 50, 70, 91, and 100 wt pct Ni) with aluminum additions of about 0, 1, 2, 4, and 8 wt pct. Large early deviations from, or changes in, the parabolic rate constant were encountered, but in most cases, the reaction rate declined approximately in accordance with the parabolic rate law. A sharp peak in the parabolic oxidation rate constant was observed for specimens containing 0 to 22 percent nickel and 1 to 2 percent aluminum at 1,351° K, and the rate constants for these compositions were lower at the higher temperatures. Specimens containing 8 percent aluminum reacted far more slowly than did any of the others.

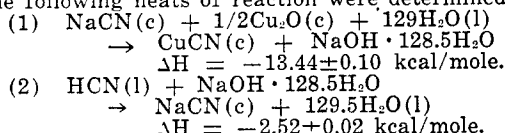
RI 7497. Evaluation of the Madison Limestone in the Williston Basin From Well Logs and Cores, by E. J. White and L. C. Marchant. March 1971. 27 pp. 14 figs. Data from oil well logs and core analyses were used to quantitatively evaluate formation porosity and water saturation of heterogeneous carbonates and to study the pore geometry and performance characteristics of cores from these formations. Logs and cores from the Madison Limestone from 233 wells in three fields in the Williston basin were used in the investigation.

A comparison of log and core analyses shows that log porosities are consistently larger than core porosities, and the differences are correlatable with core porosity ranges. Water saturations from logs are usually smaller than the corresponding core

saturations by summation of fluids, but the difference is attributable to mud filtrate invasion into the cores during drilling. Petrophysical studies show that the low permeabilities and high residual water saturations in these reservoir rocks are due to their fine crystalline texture and complex pore geometry (heterogeneity). It is concluded that both log and core analyses must be used for reliable evaluation of these carbonate formations. Work done in cooperation with the University of Wyoming.

RI 7498. Distribution of Sulfide and Oxide Copper in Copper Mill Tailings, by Jack C. White and Albert R. Rule. April 1971. 19 pp. 12 figs. Studies were made to determine the character and distribution of the copper lost in copper mill tailings. Acid soluble (oxide) and acid insoluble (sulfide) copper were determined for heavy-liquid sink and float products of screen-sized fractions from 12 copper mill tailings. In most of the tailings studied, the coarse-size fractions are higher in copper grade than the respective bulk tailings, high in sulfide copper, and low in oxide copper. Oxide copper occurs predominantly in the minus 325-mesh "slimes." Microscopic examination of heavy-liquid sink products indicated that recovery of liberated copper sulfide minerals is complete in most mills, and that copper minerals not being recovered are locked with gangue particles. Additional copper could probably be recovered from most tailings by size classification, scavenger froth flotation of the coarse fraction, and regrinding of the concentrate to achieve liberation of the locked sulfides.

RI 7499. Heat of Formation of Cuprous Cyanide and Its Heat Capacity From 10° to 400° K, by A. R. Taylor, Jr., Mary H. Brown, and Estelle G. Taylor. April 1971. 12 pp. 1 fig. Using solution calorimetry, the following heats of reaction were determined:



From these reactions, the heats of formation for $\text{CuCN}(c)$ and $\text{HCN}(l)$ were calculated to be 22.7 ± 0.4 kcal/mole and 24.9 ± 0.4 kcal/mole, respectively. Reaction 2 was made to check the consistency of literature values for heats of formation of HCN and NaCN .

Adiabatic calorimetric measurements between 10° and 400° K showed the entropy and heat capacity of $\text{CuCN}(c)$ to be 21.51 ± 0.06 eu and 14.58 ± 0.04 cal/mole deg, respectively, at 298° K. A broad anomaly in the heat capacity was found in the temperature range 285° to 320° K. The heat of transition associated with this anomaly was less than 1 cal/mole, the sensitivity of the measurements. Work done in cooperation with the University of Alabama.

RI 7500. Prediction of Oil- and Gas-Bearing Rock Fractures From Surface Structural Features, by W. K. Overbey, Jr., and R. L. Rough. April 1971. 14 pp. 6 figs. Knowledge of fracture systems in oil or gas reservoirs is essential to the efficiency of both primary and secondary production operations. A relationship was established between structural features of the surface and both natural and induced fractures in oil and gas reservoirs, thus providing a method of predicting the direction of rock fracture prior to field development and well completion. Correlations between the surface features and underground features resulted from analysis of joint

strike measurements, bottom-hole impression packer surveys, photographs of hydraulically fractured wells, fracture data from oriented cores, in situ strain measurements from formation outcrops, and lineament analyses from aerial photographs. The mean orientation of surface fractures, lineaments, and stress field directions ranged from N 53° E to N 73° E, compared with an average orientation of N 63° E for the hydraulically induced fractures. Tectonic stress field was shown to influence the direction of hydraulically induced fractures. This report presents the details and application of techniques to obtain the orientation of the principal horizontal compressive stress field component and thus the direction of induced fractures.

RI 7501. Autoclave and Ambient Pressure Leaching of Lake Superior Manganiferous Ores, by Vance G. Leak. April 1971. 18 pp. 6 figs. Leaching of manganese from low-grade Minnesota ores was studied over the temperature range 25° to 225° C at atmospheric and elevated pressures to demonstrate that good recoveries of manganese could be achieved from unroasted ores using reagents available nearby. Various combinations of ore, pyrite, lignite derivatives, and sulfuric acid were tested on a small scale. Pyrite alone required the highest temperature to effect a good extraction, but the combination of pyrite, lignite char, and sulfuric acid solubilized 99 percent of the manganese after 30 minutes of reaction at 75° C.

RI 7502. Utilization of Waste Fluosilicic Acid (in Two Sections). 1. Laboratory Investigations. 2. Cost Evaluation, by H. E. Blake, Jr., W. S. Thomas, K. W. Moser, J. L. Reuss, and H. Dolezal. April 1971. 60 pp. 16 figs. Section 1 of this report describes two processes for utilizing the waste fluosilicic acid (H_2SiF_6) generated by the manufacture of phosphatic fertilizers. The first process involves conversion of fluosilicic acid to an acid-grade fluorspar (CaF_2) by first precipitating the silica with ammonia and filtering, and then reacting the ammonium fluoride (NH_4F) filtrate with $\text{Ca}(\text{OH})_2$. Over 95 percent of the fluoride is converted to CaF_2 . The second process involves neutralizing the H_2SiF_6 with $\text{Ca}(\text{OH})_2$ and silica and filtering and then, volatilizing HF from the dry precipitate by pyrohydrolytic action at 1,050° C. The $\text{HF-H}_2\text{O}$ vapors are condensed and the fluoride precipitated as $\text{NaF} \cdot \text{HF}$ by addition of NaF to saturation. Anhydrous HF is recovered from $\text{NaF} \cdot \text{HF}$ by pyrolysis at 400° C. By this method, over 80 percent of the fluoride in H_2SiF_6 is recovered as anhydrous HF. Preliminary tests on the synthesis of cell-grade aluminum fluoride (AlF_3) from the rotary reactor offgases and activated alumina showed that an 82-percent AlF_3 product could be produced.

Section 2 is an evaluation made to determine the economics of utilizing waste fluosilicic acid for production of (1) calcium fluoride or (2) anhydrous hydrogen fluoride. On the basis of data obtained from the research described in section 1, two versions of each process were considered and compared. The evaluation showed that both products could be produced and marketed competitively. Lowest estimated product sales prices required to yield a 25-percent return on investment before taxes (discounted cash flow basis) was \$339.34 per ton of hydrogen fluoride and \$48.64 per ton of calcium fluoride. (*Out of print.*)

RI 7503. Heat Content and Specific Heat of Six Rock Types at Temperatures to 1,000° C, by David P. Lindroth and Walter G. Krawza. April 1971. 24 pp.

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7 figs. The heat content above 25.0° C up to 1,000° C was measured for six rock types: St. Cloud Gray Granodiorite, Holston Limestone, Sioux Quartzite, Rockville Quartz Monzonite, Salem Limestone, and the basalt at Dresser, Wis. The calorimetric data were obtained with an isothermal jacket-copper block calorimeter. The experimental heat content data for each rock type are presented, along with specific heat data obtained from the temperature derivative of the heat content. For the six rock types the maximum deviations of the specific heats at a given temperature were within 10 percent below 575° C and within 34 percent above 575° C. The increase in the values of specific heat range from a minimum of 13 percent for the basalt at Dresser, Wis. (temperature range, 100° to 1,000° C) to a maximum of 46 percent for Holston Limestone (temperature range, 100° to 870° C).

RI 7504. Reclamation of Acidic Coal-Mine Spoil With Fly Ash, by L. M. Adams, J. P. Capp, and E. Eisen-trout. April 1971. 29 pp. 15 figs. Experiments in reclaiming acidic surface-mined coal lands with raw fly ash from bituminous-coal-fired powerplants were conducted by the Bureau of Mines at two sites in northern West Virginia. Plots at both sites were treated with varying tonnages of fly ash from three area powerplants and were planted with a variety of grasses, legumes, trees, and shrubs. Eight grasses and seven legumes were investigated. Greatest promise for growth under harsh soil conditions was shown by Kentucky 31 fescue, rye and red top grasses, and birdsfoot trefoil, a legume. Survival of trees and shrubs was negligible. Addition of fly ash to the spoil increased the pH to a range tolerable to some types of plant growth, improved the texture of the soil, and increased the available water of the resulting mixture.

RI 7505. Technique of Measuring Initial Deformation Around an Opening. Analysis of Two Raise-Bore Tests, by Galen G. Waddell, Thomas J. Crocker, and Eugene H. Skinner. April 1971. 60 pp. 34 figs. This report describes a method of measuring and analyzing the initial deformation which occurs in the medium surrounding a mine accessway as the opening is created. Discussed are (1) the hypothesis upon which the research is based; (2) the in situ rock-deformation measuring equipment developed; (3) the field tests, consisting of measuring the deformation of the medium around two 4-foot-diameter raise bores as the boring progressed; and (4) a finite-element technique to correlate theoretical with experimental results, using elastic theory. Described also are the raise-bore operation and performance. The instrumentation developed proved to have the sensitivity and resolution necessary to measure rock deformation around a full-scale raise bore during excavation. Tests show the relationships of rock deformation to progress of the raise boring and to time. The initial deformation of the opening appeared to be elastic. Using the deformation records and an estimated field stress, the modulus of elasticity was determined for the rock mass.

RI 7506. A Method for Sampling and Analyzing Trona Dust, by Murray Jacobson and Samuel L. Terry. April 1971. 4 pp. 1 fig. A method for determining airborne trona dust concentrations using a midjet impinger was developed. During sampling, the trona dust, composed of sodium carbonate and bicarbonate, dissolves in the collecting medium (water). Resulting solutions are then titrated using 0.1 N hydrochloric acid solution. The mass concentration of the trona sample is determined from a calibration curve

relating the volume of acid required for neutralizing a collected sample to the mass of the dust. Test results obtained using this method are equivalent to those obtained using a gravimetric sampling method.

RI 7507. Explosion Development in Closed Vessels, by John Nagy, Earl C. Seiler, John W. Conn, and Harry C. Verakis. April 1971. 50 pp. 32 figs. Data from experiments and literature on gas and dust explosions in closed vessels are presented to show the effects of the vessel size and shape; the initial pressure, temperature, and turbulence; and the fuel-air ratio and the strength of ignition source on pressure and rate of pressure rise. An attempt is made to correlate some of these parameters with an elementary mathematical model. Analyses of data on 17 vessels—spherical, cubical, cylindrical, and rectilinear in shape—ranging from 0.018 to 905 cubic feet in volume were made. Although the study was initiated to provide information primarily on dust-explosion phenomena, some data were obtained for gas explosions so that the factor of initial turbulence caused by the pneumatic blast used to disperse dust could be evaluated.

The mathematical interpretation of the explosion phenomena was in general accord with the experimental data, and correlation was obtained for several factors affecting explosion development. Neither vessel size nor shape affected maximum pressure (when heat loss was neglected). The rate of pressure rise decreased as vessel size increased, and the rate was proportional to the ratio of the surface area of the vessel to its volume. Induced initial turbulence markedly increased the rate of pressure rise and slightly increased the maximum pressure. Changes in initial pressure produced proportional changes in maximum pressure and rate of pressure rise. Initial temperature and maximum pressure were inversely related, but initial temperature had little effect on the maximum rate of pressure rise. Comparative experiments showed no appreciable difference in explosion development of gas and dust fuels. The vessels and experimental work are described, and all data are given in tables. The mathematical model will facilitate extrapolation from laboratory to industrial conditions and will allow comparison of results obtained in different laboratories.

RI 7508. Sampling Gold Ore by Diamond-Drilling in the Homestake Mine, Lead, S. Dak., by George S. Koch, Jr., and Richard F. Link. April 1971. 35 pp. 3 figs. Several methods of calculating ore grades by diamond-drill sampling in the Homestake mine, Lead, S. Dak., have been evaluated by statistical analyses of assay data. The natural distribution of gold particles, partly masked through sampling and assaying procedures, is probably lognormal. As a consequence of the gold particles being clustered rather than randomly distributed within the ore bodies, (1) more mine samples are needed to obtain a specified precision of mean grade than the number predicted by the standard-error-of-the-mean law; (2) the variance of gold values is not inversely proportional to sample volume, and, therefore, small-diameter drill core yields samples nearly as good as larger diameter core; and (3) sampling at 5-foot intervals provides nearly as good results as sampling at shorter intervals.

IC 7509. Ionized Fields in Electrostatic Separation. Applications to Secondary Materials, by Foster Fraas. May 1971. 12 pp. 8 figs. Calculations based on data related to the electrostatic precipitator illustrate the variation in the electric forces on a par-

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ticle with change in position in the ionized field. The feeble forces in some separators are explained by the low field intensity at midpoint locations between the electrodes. When the particles are in contact with the exterior surface of a rotating cylindrical electrode, a high field intensity at the electrode surface combined with the image charge results in large electric forces. The permissible feed velocity increases as the square root of the electrode diameter, providing high values in efficiency and feed rate capacity, particularly in surface-to-mass ratio separations such as are encountered in secondary materials recycling operations.

RI 7510. Tritiated Water as a Tracer in the Dump Leaching of Copper, by F. E. Armstrong, G. C. Evans, and G. E. Fletcher. May 1971. 39 pp. 12 figs. Tritiated water has been used as a tracer to follow the path of leach liquids as they flow through a coppermine dump. Semipermeable layers, produced within the dump by compaction and "stratification" of deposited dump material, restrict the vertical movement of water. Knowledge of this restriction would aid in the optimization of the leaching process. The portion of the dump of particular interest was approximately 2,000 feet long, 800 feet wide, and 200 feet high. A total of 94 curies of tritiated water was injected into the dump at the rate of 650 gpm over a period of 39 hours. The leach liquid was sampled at natural surface outflows and through a series of wells, some drilled to the bottom of the dump and others to intermediate levels. More than 3,300 samples were analyzed, most by liquid scintillation counting, but a few hundred by gas counting. Data obtained permitted calculation of flow paths, recycle times, total fluid volume, and estimates of retention times in various portions of the dump.

RI 7511. Mathematical Simulation of Historic Gas Distribution by Diffusion in an Oil Reservoir, by C. Q. Cupps, G. T. Brow, and J. Fry. May 1971. 26 pp. 6 figs. Rate of gas diffusion in reservoir oil has been investigated in an effort to explain the variation in oil characteristics observed in the Weber Sandstone reservoir, Rangely field, Colorado. Coefficients of gas diffusion were determined experimentally for the Rangely oil system and used in a mathematical simulation of gas diffusion during the probable life of the Rangely reservoir, estimated at 65 million years. The simulator involved solution of Fick's law for diffusion in two dimensions by the method of finite difference and successive over-relaxation. The results show that continuing gas diffusion is a logical explanation for the variation in oil characteristics at Rangely and that the pattern of gas distribution by diffusion in an asymmetrical reservoir will not conform to structural contours as originally proposed. Work done in cooperation with the University of Wyoming.

RI 7512. Multiple Zone Mining Beneficiation of Western Phosphate Rock. A Cost Estimate and Comparison With Selective Mining, by Richard N. Spencer. May 1971. 18 pp. 3 figs. This report describes investigations of the economic merits of multiple zone mining and beneficiation versus selective mining of altered Western phosphate rock. The same deposit was considered in both instances and it was assumed that the grade of selectively mined ore was comparable to the grade of the concentrate from beneficiation. The beneficiating scheme used for the investigation was one proved by small continuous circuit operation. All economic factors were found to favor multiple zone mining plus beneficiation. Capital requirements and

production costs were lower, and production life of the deposit was extended 4.5 times. The concentrate from beneficiation would be a uniform high-quality feed for acidulation and would be low in stable metallic oxide (R_2O_3) content. Such a feed would permit improved plant operating control, and the low R_2O_3 would promote more rapid filtration and minimize sludge formation in the phosphoric acid. With the proposed treatment, the concentrate produced by flotation from this deposit would cost about 1.5 times as much per ton as the concentrate produced by classification sizing. Therefore, inclusion of a flotation step in treatment schemes requires an economic analysis for each ore deposit.

RI 7513. Dissociation and Vaporization of Gold Chlorides and Gold Bromides, by Aarne Visnapuu, Barbara C. Marek, and James W. Jensen. May 1971. 22 pp. 7 figs. Dissociation and vaporization of gold chlorides and bromides were investigated by a static pressure method and by Knudsen cell mass spectrometer. Two distinct chlorine and three distinct bromine pressure-temperature relationships were observed for the respective salts. The chlorine pressures are attributed to the dissociation of Au_2Cl_6 and Au_2Cl_4 and the bromine pressures to the dissociation of Au_2Br_6 , Au_2Br_4 , and Au_2Br_3 . These pressure-temperature relationships were used to calculate dissociation pressure equations, enthalpies, and entropies of dissociation for each salt.

Mass analysis of the vapors over Au_2Cl_6 between 83° and 152° C confirmed the existence of gaseous Au_2Cl_6 . Ionization potential of this molecule is 11.0 ± 0.1 eV and enthalpy of vaporization is 28.1 ± 2.0 kcal/mole. Mass analysis of the vapors over the gold bromides detected only Br_2 in the temperature range 15° to 150° C.

RI 7514. Photochemical Reactivity of Diesel Exhaust. Some Preliminary Tests, by B. Dimitriadis and H. B. Carroll, Jr. April 1971. 6 pp. 1 fig. Exploration of the photochemical reactivity of diesel-exhaust hydrocarbons is described. A smog chamber was built, and reactivities of diesel exhaust, gasoline exhaust, and propylene were measured at two chamber temperatures. Experimental data indicated the problems caused by instability of diesel-exhaust hydrocarbons. With reservations due to these problems, the results are interpreted to reflect comparable reactivities for diesel and gasoline exhaust. Work done under an agreement with the Air Pollution Control Office of the Environmental Protection Agency (formerly National Air Pollution Control Administration, U.S. Department of Health, Education, and Welfare).

RI 7515. Spatial and Temporal Distributions of Halon 1301 From a Commercial Extinguisher, by D. S. Burgess, W. F. Donaldson, A. L. Furno, J. M. Kuchta, and C. R. Summers. April 1971. 17 pp. 9 figs. A commercially available Halon 1301 extinguisher has been evaluated as part of an explosion-suppression system for use in coal mines. Studies were made both of the dispersion pattern of the Halon 1301 at an initial pressure of 280 psig, and of the efficacy of this suppressant against 9.5 percent methane-air flames. These flames were quenched successfully only when the suppressant was applied before the fireball diameter exceeded 18 inches.

RI 7516. Heavy Liquid Concentration of Brucite, by T. O. Llewellyn and James S. Browning. May 1971. 12 pp. 5 figs. Laboratory batch and semi-continuous studies showed the feasibility of using

methylene bromide and trichloroethylene in heavy liquid cyclone concentration of a Nevada brucite ore. Cyclone tests of minus 20- plus 200-mesh material at specific gravities of 2.42 and 2.44 recovered 71.6 to 74.9 percent of the MgO at grades of 95.5 and 95.4, respectively. Neither increasing the feed pulp density from 5 to 25 percent solids, nor varying feed pressures from 25 to 60 psig had any apparent effect on the heavy liquid separation. Work done in cooperation with the University of Alabama.

RI 7517. Recovery of Heavy Minerals From Sand and Gravel Operations in the Southeastern United States, by E. G. Davis and G. V. Sullivan. May 1971. 25 pp. 4 figs. This report summarizes an investigation to determine the occurrence and recoverability of heavy minerals in sand and gravel operations in the Southeastern United States. A total of 61 samples from 34 sand and gravel operations in Alabama, Georgia, South Carolina, and North Carolina were studied. Heavy minerals, in amounts ranging from 3 to 400 pounds per ton, were found in all of the samples. Eighty percent of the samples contained 20 to 40 pounds per ton of heavy mineral. Valuable heavy minerals, in order of decreasing amounts, were ilmenite, kyanite, zircon, rutile, and monazite.

Large-scale concentration tests were made on five samples from four major producers. Gravity concentration by Humphreys spirals and tables resulted in bulk heavy mineral concentrates that graded from 82 to 98 percent total heavy minerals. Mineral recoveries ranged, in percent, as follows: ilmenite 60 to 95; zircon 96 to 100; kyanite 37 to 77; rutile 89 to 100; and monazite 96 to 100. Separation studies on the gravity concentrates showed they would respond to high-tension and high-intensity magnetic separation techniques to produce individual mineral concentrates. Work done in cooperation with the University of Alabama.

RI 7518. Hydrolyzed Metal Ions as Pyrite Depressants in Coal Flotation: A Laboratory Study, by A. F. Baker and K. J. Miller. May 1971. 21 pp. 8 figs. Laboratory flotation of synthetic coal-pyrite mixtures and high-pyritic-sulfur coal indicated that ferric chloride (FeCl_3), aluminum chloride (AlCl_3), chromium chloride (CrCl_3), and cupric sulfate (CuSO_4) are potential pyrite depressants. For each metal salt there appeared to be a range of pH values and optimum concentration for selectively depressing pyrite in coal flotation. Pyrite was depressed in the pH range from 4.5 to 7.0 with ferric chloride, from 5.8 to 7.0 with aluminum chloride, from 6.4 to 7.1 with chromium chloride, and from 6.4 to 7.4 with cupric sulfate. Best separation of pyrite from coal was achieved in flotation solutions containing from 2×10^{-5} to 5×10^{-5} mole/liter of each salt. In solutions containing excess salt concentrations, coal was also depressed.

These Bureau of Mines tests demonstrated on a laboratory scale that, in solutions containing 4×10^{-5} mole/liter ferric chloride and from 1×10^{-4} to 2×10^{-4} mole/liter sodium hydroxide, the pyritic sulfur content of a Lower Freeport bed coal sample could be reduced from about 2.51 percent to less than 0.60 percent with recoveries of over 83 percent.

The depression of pyrite appears to be due to the adsorption of positively charged colloidal metal hydroxide at the pyrite-solution interface. This hypothesis is supported by zeta potential determinations which showed that suspended coal and pyrite particles in solutions containing metal salts are positively charged in the pH range where depression occurs.

RI 7519. Electrical and Hydraulic Flow Properties of Appalachian Petroleum Reservoir Rocks, by W. K. Sawyer, C. I. Pierce, and R. B. Lowe. June 1971. 22 pp. 9 figs. Resistivity, porosity, permeability, and saturation data were obtained on core samples from the Big Injun, Clinton, Gordon, Bradford Second and Third, and Venango Second oil sands and formation factor-porosity relationships were derived using the general form of Archie's equation $F = a\phi^{-m}$, where F is the formation factor, ϕ is the porosity, and a and m are constants that depend on characteristics of the rock. It was found that a and m varied significantly between sands, as did the exponent in the Archie relation $I = S_w^{-n}$, where I is the resistivity index and S_w is the water saturation. The average exponent, n , determined from all data was 50 percent greater at residual oil saturation than at residual water saturation. Samples from each sand exhibited differences in directional resistivity and/or permeability. The Bradford Third sand data showed correlation between resistivity and permeability anisotropy.

RI 7520. Dewatering Florida Phosphate Pebble Rock Slime by Freezing Techniques, by Martin H. Stanczyk, I. L. Feld, and E. W. Collins. June 1971. 20 pp. 4 figs. Freezing to dewater typical Florida phosphate rock slime as demonstrated in laboratory tests appeared to have potential commercial use because of indicated moderate energy requirements, good compaction of dewatered solids, and effective recovery of usable water. After freezing, thawing, decanting, and filtering, batch freezing of gallon-size 13.7 percent solids slime samples yielded 42 percent solids products. Cationic amine, used as a process additive, yielded 46.8 percent solids product with significant filter area reduction. Semicontinuous 8-stage freezing tests also produced thickened slimes. Cooling and freezing 13.7 percent solids slime from 30° to minus 10° C required removal of 183 Btu per pound of slime; Carnot cycle calculation indicated that the theoretical minimum energy to transfer this heat was 27.8 Btu per pound. To produce 1 ton of 44 percent solids slime from 13.7 percent solids slime, the calculated theoretical energy required for cooling and freezing was 52.3 kilowatt-hours. During the research, heat capacity and heat of fusion data were determined for the slime at various percent solids. Work done in cooperation with the University of Alabama.

RI 7521. A New Internal Oxidation Process for Strengthening Tungsten, by Robert Blickensderfer, Mark I. Copeland, and William L. O'Brien. June 1971. 40 pp. 19 figs. Tungsten alloys with high-temperature strength profiles, comparable to the best of alloys recently developed by others, were produced by a new process called here the oxyreaction process. The process involved additions of a powder of a reactive metal compounds, ZrN , ZrW_2 , or HfW_2 , to a base metal powder, tungsten, which contained some oxygen. The powders were blended, compacted, sintered, and extruded. During sintering, diffusion and internal oxidation occurred to produce reactive-metal oxide particles and solid solutions. A dispersion of oxide particles could be precipitated by heat treating. The oxyreaction process circumvents many of the agglomerating and coarsening problems encountered in the current methods for dispersing a stable oxide in a metal.

Oxyreaction strengthening results from solid-solution strengthening and from dispersion strengthening produced by the reactive metal and its oxides. At a test temperature of 1,650° C, the alloys prepared from ZrW_2 had tensile strengths up to 70,000

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psi and stress-rupture lives up to 142 hours at 10,000 psi stress; the alloys prepared from ZrN powders had tensile strengths up to 80,000 psi and stress-rupture lives up to 27 hours at 10,000 psi stress. Tensile strengthening in the alloys was attributed to Zr in solid solution or to Zr-O-W structures too small to be observed in an electron microscope replica. Stress-rupture life was attributed to a dispersion of submicron ZrO_2 particles which precipitated and grew to 0.05- to 0.2-micron size during the test. Tensile strengthening and stress-rupture life were dependent upon both the zirconium and oxygen contents with the maximum occurring at roughly 0.9 atomic percent Zr and 0.9 atomic percent O.

Studies of the details of the oxyreaction process were made on the W-ZrW₂ alloys and three general steps were determined: (1) the reaction of O in tungsten powder with ZrW₂ to form relatively large ZrO_2 particles; (2) the dissolution of remaining ZrW₂ into the W matrix and partial internal oxidation to form ultrafine but sparse zirconium oxide particles and possibly to establish Zr-O-W structures; (3) the development of ultrafine ZrO_2 particles during high-temperature aging.

RI 7522. Effects of Rolling Temperature and Titanium Content on Creep and Other Properties of Zinc-Titanium and Zinc-Copper-Titanium Alloys, by L. A. Neumeier and J. S. Risbeck. June 1971. 31 pp. 27 figs. The Bureau of Mines evaluated the properties and anisotropy in properties of rolled Zn-Ti and Zn-1.0 wt pct Cu-Ti alloys containing up to 0.36 wt pct Ti. Finish rolling was at varied temperatures to total reductions as high as 92 pct. Alloy properties are very sensitive to various combinations of composition, rolling temperature, and reduction. Properly rolled Zn-1.0 Cu-Ti alloys are superior in strength to Zn-Ti alloys. Conditions are described that lead to best tensile properties. Creep resistance for Zn-Ti alloys decreases with increased rolling temperature when finish rolled to 92-pct total reduction, but not when finish rolled to 33- or 67-pct reduction. Creep resistance for Zn-1.0 Cu-Ti alloys improves with increased rolling temperature to about 480° F. Heavily cold-rolled Zn-1.0 Cu-Ti alloys have fine grain sizes and poor hardness, tensile, and creep properties, but high ductility. Thermal expansivity is markedly affected by the copper addition. Data show the anisotropy of tensile, creep, and thermal expansivity properties. Large idiomorphic crystallites of $TiZn_{10}$ appear in both Zn-Ti and Zn-Cu-Ti alloys when more than about 0.2 pct Ti is present. A new Zn-Cu-Ti intermediate phase was also identified. Empirical equations are presented relating creep rates with major process variables.

RI 7523. Using Broad-Line Nuclear Resonance Spectrometry To Estimate Potential Oil Yields of Oil Shales, by A. W. Decora, F. R. McDonald, and G. L. Cook. June 1971. 30 pp. 11 figs. A technique has been developed utilizing proton, broad-line nuclear magnetic resonance spectrometry to estimate the organic carbon contents and the potential oil yields of five domestic oil shales. The quantity of organic hydrogen in the oil shales is mathematically related to the organic carbon contents and to the potential oil yields so that the proton, broad-line nuclear magnetic resonance signal strength can be correlated with both the Fischer assay oil yield and the organic carbon contents of oil shales from Colorado, Utah, Wyoming, and Kentucky. The experimental data indicate that calibration curves need be determined but once for a limited oil shale area under development. The method is rapid, can be applied without

extensive calibration, and gives good estimates of oil yields and organic carbon contents on as many as 30 samples per hour. Work done in cooperation with the University of Wyoming.

RI 7524. Differential Extraction of Rare-Earth Elements in Quaternary Ammonium Compound-Chelating Agent Systems, by D. J. Bauer and R. E. Lindstrom. June 1971. 16 pp. 15 figs. Solvent extraction separation of light group rare-earth elements in a quaternary ammonium compound-chelating agent system was demonstrated in single-stage studies. Typical separation factor values obtained were 93 for lanthanum-praseodymium, 5.4 for praseodymium-neodymium, and 11.6 for neodymium-samarium. These values are significantly higher than those obtained using organophosphate extractants. Further studies in a 20-stage countercurrent mixer-settler resulted in the production of 99 percent lanthanum (oxide basis) at 96-percent recovery. Subsequently, 88 percent of the neodymium with a purity of 92 percent was recovered in the raffinate.

RI 7525. Washability Examinations of Wyoming Coals, by A. W. Deurbrouck. June 1971. 47 pp. 1 fig. This Bureau of Mines report describes the washability characteristics of 14 coalbed samples collected in Wyoming. Such data is needed to evaluate the quality of the coals of the West where most of our low-sulfur-content coal reserves are found. Of the 14 samples included in this report 13 had a total sulfur content of 1.1 percent or less. All of the samples contained low percentages of ash or could be readily washed to a desirable ash level with minimal loss of yield. The coals ranged in rank from high-volatile B bituminous to subbituminous C, although 10 of the samples were high-volatile C bituminous. The coalbeds varied in thickness from 4.5 to an unknown thickness greater than 67.5 feet.

RI 7526. Analysis of Tunnel Support Structure With Consideration of Support-Rock Interaction, by J. D. Dixon. June 1971. 45 pp. 21 figs. The Bureau of Mines investigated the principles of support-rock interaction, based on structural matrix methods which permit mathematical formulation of the problem and computer solution. The principles are given under two main sections: the first discusses the idealization of the tunnel support structural system for matrix analysis; the latter discusses the analysis procedures necessary for carrying out the solution. A general frame matrix computer program and a medium-size computer should be sufficient for carrying out the procedures involved. The example problem consists of a circular tunnel support which is subjected to a uniformly distributed vertical load. Three wall thickness-radius ratios are studied in combination with four support-rock modulus ratios. This problem illustrates the main procedures of the support-rock interaction analysis involved, and examination of the results reveals the influence of the relative rigidities of the support and the rock.

RI 7527. Reactivities of Exhaust Aldehydes, by B. Dimitriades and T. C. Wesson. May 1971. 18 pp. 2 figs. Data on smog-forming reactivities of exhaust aldehydes are scarce. Such data were obtained by irradiating in a smog chamber typical exhaust aldehydes, individually and in exhaustlike mixtures. Observed reactivity manifestations were

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rate of nitrogen dioxide formation ($^{\circ}\text{NO}_2$) and yields of oxidant, peroxyacetyl nitrate, and formaldehyde. Results showed that exhaust aldehydes vary widely in reactivity. Formaldehyde showed high $^{\circ}\text{NO}_2$ reactivity but low oxidant yield; benzaldehyde, *m*-, and *p*-tolualdehyde were totally unreactive when irradiated individually; *o*-tolualdehyde was reactive. In mixtures, benzaldehyde manifested reactivity in terms of peroxybenzoyl nitrate yield. Exhaust aldehydes as a group are judged to be as reactive as the exhaust olefin group. The importance of the aldehyde contribution to exhaust reactivity and methods for assessing such contribution are discussed. Work done under an agreement with the Air Pollution Control Office of the Environmental Protection Agency (formerly National Air Pollution Control Administration, U.S. Department of Health, Education, and Welfare).

RI 7528. Electrical Conductivity and Density of Fluoride Systems, by R. E. Meaker, Bernard Porter, and D. G. Kesterke. June 1971. 20 pp. 11 figs. Electrical conductivities and densities of molten fluoride systems were measured as functions of the melt temperature and composition. For any given mixture, the two properties change linearly with temperature. Three alkali metal fluorides were selected as solvents for melts of the type LiF-M , NaF-M , and KF-MF_2 , where M is a metal selected from the alkali metal or alkaline earth groups, or from the lanthanide or actinide series of elements, and $x = 1-4$. Heats of activation for conductance were calculated from the experimental data and varied from 2.3 to 9.2 kcal/mole at $1,000^{\circ}\text{C}$. Some relation between position in the phase diagram and the conductivity changes was suggested.

RI 7529. Thermal Reactions of 1-Methylindole, by Irven A. Jacobson, Jr. June 1971. 8 pp. The thermal reactions of 1-methylindole were studied in the temperature range of 525° to 627°C in a flow reactor. The major products consisted of 2-methylindole, 3-methylindole, indole, quinoline, hydrogen, and methane. 2-Methylindole is formed from 1-methylindole by an irreversible isomerization reaction. The 2-methylindole isomerizes in a reversible manner to 3-methylindole, the equilibrium favoring the 3-methyl isomer. Indole is formed directly from 1-methylindole. Quinoline is formed from 1-methylindole, 2-methylindole, and 3-methylindole. Work done in cooperation with the University of Wyoming.

RI 7530. Diesel Emissions Reinventoried, by W. F. Marshall and R. D. Fleming. July 1971. 24 pp. 8 figs. This report describes exhaust-emission data from 10 diesel engines: six 4-cycle, direct-injection, naturally aspirated engines; two 4-cycle, direct-injection, turbocharged engines; one 4-cycle, precombustion-chamber, turbocharged engine; and one 2-cycle, direct-injection engine. These engines were tested over a 3-year period (1968-70). Lowest emissions were obtained with a precombustion-chamber engine. Emissions from the 2-cycle, direct-injection engine fell within the range of emission rates for the 4-cycle, naturally aspirated, direct-injection engines. Excluding the precombustion-chamber engine and excepting one of the 4-cycle, naturally aspirated engines, carbon monoxide emission rates were about the same for all engines tested. Test data on smoke, odor, and emissions of hydrocarbons, oxides of nitrogen, carbon monoxide, and aldehydes are given. Work done under an agreement with the Environmental Protection Agency.

RI 7531. Flexible, Spiral-Reinforced Circular Ventilation Tubing. System Pressure Loss Tables for Selection of a Fan. A Supplement to Report of Investigations 7085, by Richard J. Kline and Alfred Reisz. July 1971. 61 pp. This publication comprises tables listing friction loss for a flexible, spiral-reinforced circular ventilation tubing system. The tables were constructed with the following parameters: a friction factor of 62×10^{-10} , 10-foot sections of tubing ranging in total length from 100 to 550 feet, air quantities ranging from 1,000 to 15,000 cfm, and one to four 90° bends in the tubing. The aim of this publication is to improve ventilation tubing analysis and to provide a method of proper fan selection.

RI 7532. Utah Crude Oils: Characteristics of 67 Samples, by W. J. Wenger and J. C. Morris. July 1971. 51 pp. 7 figs. Analytical, geographical, and geological data on 67 samples of crude oils from Utah are presented, along with some correlations and interpretations. Most of the geologic formations that produce oil in other areas are also productive in Utah; and, as in many other locations, the Permian, Pennsylvanian, and Mississippian formations account for the major amount of the total oil produced in the State. Some anomalies and unusual phenomena are noted. Although most Utah oils are low in sulfur, a sample containing the highest percentage of sulfur ever recorded by the Bureau of Mines is among the oils discussed in this paper. Most of the oil from the major producing formations in Utah is low in sulfur; the same formations produce high-sulfur oils in adjoining Rocky Mountain States. Some Utah oils are both waxy and asphaltic, an unusual combination of characteristics. Correlation index curves for some oils are shown suggesting compositional differences in oils from different producing formations. Production statistics trace the rapid rise of oil production in the State after the first commercial discovery in 1947 and indicate a decline in amounts produced since 1959, the year of peak production in Utah. Work done in cooperation with the University of Wyoming.

RI 7533. Recovery of Phosphates and Metals From Waste Phosphate Sludge by Reduction-Sinter Processes, by R. F. Waters, H. E. Powell, and A. A. Cochran. July 1971. 10 pp. 3 figs. The Bureau of Mines developed laboratory-scale processes to recover sodium phosphates and metal values from waste sludges generated by the phosphate treatment of automobile and appliance components. After treatment of the sludge with NaOH , followed by coke or hydrogen reduction and sintering, zinc and lead were recovered as fume; the sinter was separated by leaching into a metallic product, chiefly iron and nickel, and high-purity disodium or trisodium phosphate.

RI 7534. A Small-Scale Test for Free-Swelling Index of Coal, by R. F. Abernethy and J. P. Snyder. July 1971. 17 pp. 8 figs. A small-scale method was developed for determining the free-swelling index of coal samples of limited quantity, especially the macerals. Results of a series of tests using a 0.3-gram sample correlated well with those by the standard method using a 1-gram sample. The standard and small-scale methods are modified to give unrestricted swelling for those coals having swelling index numbers above 7.

RI 7535. **Thermodynamic Properties of $(\text{Na}_2\text{O})_4 \cdot \text{Fe}_2\text{O}_3$, 6° to 1,200° K**, by J. M. Stuve, L. B. Pankratz, and D. W. Richardson. July 1971. 12 pp. 2 figs. Calorimetric determinations of the low-temperature heat capacities, standard enthalpy of formation, and high-temperature enthalpies were made of $(\text{Na}_2\text{O})_4 \cdot \text{Fe}_2\text{O}_3(\text{c})$. The resulting values of entropy (S°), enthalpy of formation (ΔH_f°), and free energy of formation (ΔG_f°) at 298.15° K are 104.676 cal/deg mole, -656.2 ± 1 kcal/mole, and -603.4 ± 1 kcal/mole, respectively. Tabulations of C_p° , S° , $-(G^\circ - H^\circ_{298})/T$, $H^\circ - H^\circ_{298}$, ΔH_f° , ΔG_f° , and $\log K_f$ are given to 1,200° K. Work done under an agreement with the U.S. Atomic Energy Commission.

RI 7536. **Increasing Oil Production From the Venango Second Sand. A Reappraisal of Two In Situ Combustion Tests**, by K. H. Frohne. July 1971. 15 pp. 8 figs. In 1962 and 1963, two in situ combustion pilot tests were conducted in the shallow Second Venango sand near Reno, Pa. Because of poor oxygen utilization and lack of production response, both tests were considered failures and were terminated. The area was then relatively inactive until late 1966, when a development well drilled near the 1963 test site had surprisingly good production in what was considered to be a pressure-depleted reservoir. Other wells drilled in and around the old thermal pilot areas also came in as good oil producers. This report presents a study of the increased oil production from the Second Venango sand in the Reno area, and the apparent connection of the present production response and the old thermal pilot tests. Apparently combustion occurred in the Second Venango sand after the 1962 and 1963 experiments were terminated and, supported by large volumes of air left in the reservoir after the 1963 test, generated carbon dioxide which helped repressure the formation. This field evidence of combustion warrants another pilot experiment to further explore the use of properly designed in situ combustion techniques in increasing production from the Second Venango sand.

RI 7537. **Dry-Pressed Building Bricks From Copper Mill Tailings**, by P. G. Pigott, E. G. Valdez, and K. C. Dean. July 1971. 13 pp. 1 fig. This Bureau of Mines laboratory research demonstrated that building bricks meeting ASTM specification C62-66 for grades SW and MW of FBS-type bricks can be produced from waste copper mill tailings. Waste tailings from accumulations at Magna, Utah, Anaconda, Mont., Hayden, Miami, and San Manuel, Ariz., were dry pressed into bricks, and the products were tested in accordance with ASTM Designation C67-66 on sampling and testing of brick. An evaluation derived from pilot-plant production of similar brick at the Coal Research Bureau of West Virginia University indicated the production cost to be about \$34 per 1,000 bricks. Utilization of such mill tailings on a commercial scale would eliminate the need for digging new pits for brick raw material production, conserve natural resources, and simultaneously remove potential sources of air pollution.

RI 7538. **Creep and Other Properties of Extruded Zinc-30 Percent Aluminum Alloys Containing Magnesium**, by L. A. Neumeier and J. S. Risbeck. July 1971. 27 pp. 17 figs. The Bureau of Mines evaluated creep and other properties of extruded Zn-30 percent Al alloys containing 0 to 0.7 percent Mg. The alloys were extruded both above and below the Zn-Al eutectoid temperature of 275° C. Creep behavior is de-

fined for the alloys as extruded and after various heat treatments. Tensile properties, hardness, thermal expansivity, impact resistance, and microstructures are given. The alloys, either with or without magnesium, required substantially less pressure for extrusion near 275° C than at higher or lower temperatures. The alloys containing magnesium exhibited significantly greater hardness than the Zn-30 percent Al alloy. The properties were very sensitive to the processing conditions.

RI 7539. **Reactivities of Automotive Emissions From Fuels of Varied Front-End Composition**, by F. D. Sutterfield, G. P. Sturm, Jr., and B. Dimitriadis. July 1971. 13 pp. 1 fig. This study was conducted to provide experimental evidence on the effect of modifications of gasoline front-end composition on the photochemical specific reactivities of automotive emissions. Evaporative and evaporative-plus-exhaust emissions from an automobile operated with four fuels of different volatility and varying levels of $\text{C}_4\text{-C}_5$ olefins were irradiated in a 100-ft³ environmental chamber at three sets of initial hydrocarbon-nitrogen oxides concentrations. Reactivity was measured and expressed in terms of rate-of- NO_2 formation and dosages of oxidant, peroxyacetyl nitrate, and formaldehyde. The compositional changes that were necessary in reducing fuel volatility were found to have no significant effect on the reactivity of the emissions. However, replacing $\text{C}_4\text{-C}_5$ olefins with saturated components resulted in sharp decreases in all reactivity manifestations observed for the evaporative emission samples. A lesser influence (of $\text{C}_4\text{-C}_5$ olefin replacement) was found with the composite exhaust-plus-evaporative samples; the effect that was observed could be attributed to the evaporative emission portion of the sample. The data therefore suggest that saturation of front-end fuel olefins had no large effect on exhaust emission reactivity. Work done under an agreement with the Environmental Protection Agency.

RI 7540. **Gas Combustion Retorting of Oil Shale Under Anvil Points Lease Agreement: Stage II**, by J. R. Ruark, H. W. Sohns, and H. C. Carpenter. July 1971. 74 pp. 3 figs. This report presents results of the research and development work and operations performed during stage II of the gas combustion retorting research program conducted by the Colorado School of Mines Research Foundation and six major oil companies at the Bureau of Mines Anvil Points Research Facilities. The experimental program, including retort modification and air-gas distributor development, effects of shale quality and particle-size distribution, and other variables on the process, is discussed. Although operating problems are not fully resolved, it appears that the gas combustion retorting process can be successfully applied to achieve oil yields in excess of 85 percent of Fischer assay at mass shale feed rates of 500 pounds per hour per square foot of cross-sectional bed area, approximately twice the rate previously demonstrated to be reasonably practicable.

RI 7541. **Thermal Conductivities and Prandtl Numbers of Nitrogen From 133° to 740° K Between 1 and 240 Atmospheres**, by Robert E. Wood, F. W. Baer, and W. J. Boone, Jr. July 1971. 34 pp. 4 figs. The temperature dependency of the low-density thermal conductivity coefficients, λ_T , of nitrogen, 100° to 1,200° K, is correlated with the Keyes' equation, $\lambda_T = aT^{1/2} / (1 + bT^{-1} 10^{-1/2})$.

The equation $\lambda_{T,P} = \lambda_T + \alpha \left[\left(\frac{\partial P}{\partial T} \right)_v \right]^\beta$ repre-

sented 509 experimental higher pressure thermal conductivities in the temperature range 131.2° to 973.15° K for pressures to 500 atmospheres, with a mean absolute deviation of 2.35 percent. This equation was used to compute thermal conductivities of gaseous nitrogen for 47 pressures, 1 to 240 atmospheres, and 110 temperatures, 133° to 740° K, which are common to conditions encountered in the Bureau of Mines helium purification process.

Isobaric heat capacities, C_p , and viscosities, $\eta_{T,P}$, from previous work were combined with thermal conductivities, $\lambda_{T,P}$, to compute Prandtl numbers, $C_p \eta_{T,P} / \lambda_{T,P}$, of nitrogen. Tabular values of Prandtl numbers are presented for 49 pressures, 1 to 240 atmospheres, and 75 temperatures, 133° to 740° K.

Estimated uncertainties are ± 5 percent in the tabulated thermal conductivities and ± 15 percent for the computed Prandtl numbers. However, the uncertainty may rise to ± 10 percent for thermal conductivities and to ± 30 percent for Prandtl numbers as the critical conditions of nitrogen are approached.

RI 7542. Preliminary Survey of Polymer-Impregnated Rock, by Lester J. Crow, Dennis J. Kelsh, Meyer Steinberg, and Peter Colombo. July 1971. 35 pp. 11 figs. A preliminary survey was performed to investigate the impregnation of relatively weak, porous volcanic tuff and a relatively strong, dense sandstone with five different monomers. Increases in compressive strengths by factors of 2 to 5, and elastic moduli by factors of 2 to 3.5, are reported for natural rocks (tuff, sandstone, dacite), which were impregnated with five monomers (methyl methacrylate; chlorostyrene; 40 percent TMPTMA-60 percent styrene; 40 percent TMPTMA-60 percent chlorostyrene; 60 percent polyester-40 percent styrene); polymerization took place after monomers were forced into the rock. Impregnation was performed (1) by pressurizing rock specimens from one end, or (2) by a vacuum-soak operation. Polymerization was accompanied by either radiation or chemical initiation techniques.

Strength improvement is dependent on (1) the type of monomer used, (2) the amount of polymer incorporated into the rock, and (3) the degree of water saturation of the rock. Water saturation strongly reduced the effectiveness of the method for the polymer systems tested. The more viscous monomers (for example, 60 percent polyester-40 percent styrene) were more effective in displacing the water from the rock, and compressive strengths of wet rock were doubled with these systems. Water saturations ranging from 25 to 100 percent of maximum saturation gave essentially identical results.

Further tests on other types of mine rock, including shale and coal, are planned. Water-compatible polymer systems should be developed, or present systems should be suitably modified. For application to tunnel stabilization, design studies evaluating the improvement in rock strength and its influence on the support system are also recommended.

RI 7543. Gravity Flow of Powder in a Lunar Environment (in Two Parts). 1. Property Determination of Simulated Lunar Soil, by David E. Nicholson. July 1971. 34 pp. 21 figs. This report investigates the mechanical behavior of fine soils in a lunar environment in engineering gravity-flow bins. The ultra-high vacuum, absence of moisture, and a lunar gravity one-sixth that of earth gravity represents

a unique environment, both advantageous and detrimental to these systems. On earth, moisture and gases contained in powder masses can be responsible for complex descriptions of gravity flow. Their absence appear to simplify the lunar soil behavior. However, simulation of the lunar gravity and vacuum complicates the development of experimental data for designing bins.

The properties of a dry soil powder, its behavior under one-dimensional compression, and its torsional and direct shearing strength under earth atmosphere are described in part 1 of this paper. These properties provide the parameters for a finite-element analysis to optimize the design of bins, to be described by Dr. William Pariseau in part 2.

Shear tests assess the failure criteria for the material. Compression tests provide modules and (K_o) stress-ratio values from the loading portion of the compression cycle, duplicating the condition of a bin at rest with the discharge closed. During the unloading portion of the compression cycle (soil overconsolidated), the residual K_o values rise. It is postulated that this phenomenon creates a high-lateral stress in bins when they approach incipient flow. Assessment of the K_o value, overconsolidation ratio, and the void ratio state is proposed as a criterion to determine the flowability of powder.

RI 7544. Chemical Spot Tests for Aluminum Alloys, by A. W. Maynard and D. A. Wilson. August 1971. 15 pp. 5 figs. Simple chemical spot tests for the identification of major alloying elements in aluminum-base alloys are described. The tests are suitable for use by nontechnical personnel working outside a laboratory. Tests for zinc, copper, manganese, and magnesium employ electrographic sampling methods and sample papers. Use of electrographic sampling in a test for magnesium in aluminum is made possible by using glass fiber filter paper. Differentiations between magnesium and magnesium-silicon alloys of aluminum and between aluminum-base and magnesium-base alloys are made by direct chemical solution tests. Description of a device for obtaining reliable electrographic samples is included. A sequence of testing for identification by alloy groups is given.

RI 7545. Investigation of Pulsation Dampers for Personal Respirable Dust Samplers, by J. A. Lamonica and H. N. Treaffis. August 1971. 13 pp. 10 figs. The Bureau of Mines studied a pulsation damping device designed to smooth pulsating flow in personal respirable dust samplers. The effect on the pulsation dampener efficiency of six parameters was investigated, as follows: Volume, diaphragm elasticity, diaphragm area, center orifice area, inlet-outlet-orifice area, and geometry (L/D ratio). The results indicate that volume predominates in determining snubber efficiency, while the other parameters become important at small volumes. Geometry has no effect on snubber efficiency. Criteria for an efficient pulsation dampener construction were obtained.

RI 7546. Field Evaluation of Hydraulic Backfill Compaction at the Lucky Friday Mine, Mullan, Idaho, by D. R. Corson. August 1971. 24 pp. 20 figs. The Bureau of Mines instrumented two similarly back-filled stopes—one filled in the normal manner and the other with the fill densified using vibratory compactors—to evaluate the effect of fill compaction on subsequent vein-wall closure, proposed as an adjunct process for strengthening cemented fill. Hydraulic pressure cells to monitor pressures within the fill and mechanical closure devices to measure vein-wall

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movement and the procedure for their installation are described. The field compaction work was generally performed manually by utilizing small commercial concrete vibrators. A prototype immersible vibrator using slusher cables to propel the vibrator in the stope was used on several lifts of fill.

Although compaction efforts were less effective than anticipated in increasing the final density of the fill, analysis of the field data does indicate somewhat improved strain characteristics and an increased pressure buildup for the densified fill. The effects of a prolonged period of inactivity and of rock burst occurrences in the immediate area also reflected in plots of strain and pressure within the two instrumented stopes.

RI 7547. Production Decline Curves Using Data From California Oilfields, by R. V. Higgins and H. J. Lechtenberg. 1971. 28 pp. 1 fig. The results of two separate but related studies are given. In the first study, four equations were tested; the object was to determine which would produce a curve that would best fit data points that represent a trend of declining oil production in 90 California fields. Two conventional equations (the Arps and semilog) and two novel equations (extreme-c and double semilog) were tested. The curves were first fitted to the initial 9 years of the 15-year production data and then extrapolated for 6 years to determine how well the extrapolated curve would fit the data points. The generated curves were also extrapolated beyond the last data point to predict rates of future production.

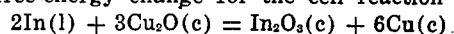
The results of the first study showed that no equation was clearly superior to the others in all respects. The semilog equation resulted in the best fit to production data for the first 9 years, but Arps and extreme-c equations produced a better fit for the extrapolated data for the period of 9 to 15 years. The Arps and extreme-c also gave more realistic production rates when extended to the point where cumulative production equaled reserves.

A second study was made to determine whether the least-squares technique applied to the Arps equation would result in more accurate extrapolations. The merits of the logarithmic and the nonlogarithmic forms of the Arps hyperbolic equation were also tested. For the logarithmic expression, it was found that one of the constants of the Arps equation reached a value so small or so large that the equation was not applicable to the data of 40 of the 90 California fields. The nonlogarithmic form of the Arps equation was applicable to neither the same 40 fields nor to a few additional ones. When the data and the Arps equation were compatible, the use of the least-squares technique as compared with other methods improved the extrapolation accuracy somewhat.

RI 7548. Preparing Copper Powder From Cemented Copper, by R. D. Groves, J. K. Winter, and L. G. Evans. 1971. 20 pp. 1 fig. Techniques were developed for preparing metallurgical-grade copper powder from industrially produced cement copper. Flotation was used for rejecting discrete gangue particles, acid leaching to remove residual iron and aluminum hydrogen reduction to eliminate oxygen, sintering to consolidate the fine-sized copper, and grinding to obtain copper powder. Powders prepared from six different cement copper samples contained, in percent, 98.5 to 99.0 Cu, 0.10 to 0.05 Fe, 0.10 to 0.08 insoluble material, and the remaining individual impurities less than 0.15 percent. The apparent density, flow characteristics, and other physical prop-

erties were suitable for powder metallurgy applications. An economic evaluation showed that this process was economically feasible. Processing costs appeared modest when considering that copper powder commands a price normally about 17.5 cents per pound over that of electrolytic copper.

RI 7549. The Free Energy of Formation of Indium Oxide by EMF Measurements, by S. C. Schaefer. 1971. 10 pp. 4 figs. Thermodynamic properties of indium oxide (In_2O_3) have been studied with a high-temperature galvanic cell employing stabilized zirconia electrolytes. In the temperature range 790° to 1,230° K the free-energy change for the cell reaction



together with the standard free energy of formation of cuprous oxide gives the standard free energy of formation of indium oxide from the elements as $\Delta G_f^\circ = -218.78 + 75.34 \times 10^{-3}T \pm 0.7$ kcal/mole. A third-law analysis yields the standard enthalpy of formation:

$$\Delta H_f^\circ_{298.15} = -221.5 \text{ kcal/mole.}$$

RI 7550. Noise in Underground Coal Mines, by J. A. Lamonica, R. L. Mundell, and T. L. Muldoon. 1971. 11 pp. 3 figs. The Bureau of Mines conducted an environmental noise survey to determine the noise levels to which underground coal mine employees are exposed, to evaluate noise survey techniques and equipment, and to compare noise exposures using two criteria, Walsh-Healey and CHABA, for determining allowable exposures that were not under consideration for the Federal Coal Mine Health and Safety Act of 1969. Time study techniques and Bureau-approved standard sound level meters were employed. The shift exposures of 20 percent of the miners studied were in excess of the safe standards established by both criteria. The shift exposures calculated using the Walsh-Healey criteria were greater than those calculated using the CHABA criteria owing to the intermittent nature of the exposure. Ultimately the CHABA criteria were rejected, and the Walsh-Healey criteria were adopted.

RI 7551. Thermodynamic Properties of Four Crystalline Sodium Borates, by L. B. Pankratz and M. J. Ferrante. 1971. 8 pp. 1 fig. Enthalpies above 298° K were investigated for four crystalline sodium borates by copper-block drop calorimetry. Determinations were made to 1,200° K for NaBO_2 , 1,003° K for $\text{Na}_2\text{B}_2\text{O}_7$, 1,005° K for NaB_3O_6 , and 1,046° K for $\text{Na}_2\text{B}_4\text{O}_{10}$. No phase transitions or other thermal anomalies were found.

The enthalpy determinations, when combined with known heats of formation at 298° K and other supplementary data, enabled the calculation of the heats and free energies of formation of the compounds to their melting points.

Values of relative enthalpies, entropies, heat capacities, free energy functions, enthalpies of formation, free energies of formation, and equilibrium constants of formation were tabulated at even temperatures.

RI 7552. Inhibition of Coal Dust-Air Flames, by J. Grumer and A. E. Bruszak. August 1971. 14 pp. 4 figs. Nine dust and gaseous inhibitors of propagating coal dust-air flames (lean, stoichiometric, and rich) were evaluated in a newly developed 15-cm-id, 3.6-meter-long instrumented flame duct, under conditions such that wall quenching was virtually absent and the dust concentration was temporally and spatially uniform to within about ± 5 percent. Listed roughly in order of increasing efficiency, the inhibi-

tors evaluated were rock dust (calcium carbonate), powdered oyster shells (calcium carbonate), Halon 1301 (trifluorobromomethane), Halon 1211 (difluorochlorobromomethane), sodium chloride, Super-K (potassium chloride), regular-grade fire extinguishant powder (sodium bicarbonate), Purple-K (potassium bicarbonate), and Monnex (potassium bicarbonate combined with urea). Experiments were extended to clouds containing 1 and 2 volume-percent of methane. The inhibition of lean, stoichiometric, and rich methane-air flames without coal dust was also examined in a few instances; results agreed with those obtained for coal dust-air flames.

RI 7553. A Three-Dimensional Dynamic Programming Method for Optimal Ultimate Open Pit Design, by Thys B. Johnson and William R. Sharp. 1971. 25 pp. 15 figs. A three-dimensional dynamic programming method is presented for determining the optimal open pit limit. The method given is based on the block concept and is an extension of the two-dimensional Lerchs-Grossman approach. The three-dimensional technique presented herein is fast and simple and may be used for an initial open pit evaluation when only limited data are available or as a more refined model when the entire deposit is well delineated.

The method is illustrated by simple numerical examples and is also presented in algorithmic form. A computer program was written in Fortran IV which implements the three-dimensional algorithm and some computational aspects are discussed.

RI 7554. Improved Cupric Ammonium Carbonate Leaching of Copper Scrap, by W. L. Staker, C. J. Chindgren, and K. C. Dean. 1971. 9 pp. 2 figs. Alternatives were developed to the conventional ammoniacal carbonate leaching-steam stripping procedure for recovering copper as an oxide from contaminated scrap metal. By entraining air bubbles in the leach solution, the copper dissolution rate was increased to 1.5 g/in² of copper surface per hour, compared to 0.5 g/in²/hr produced by conventional agitation in stirred tanks. Using entrained nitrogen gas bubbles for agitation in conjunction with powdered sulfur not only resulted in rapid dissolution but also simultaneous precipitation of the copper from solution as a high-grade cuprous sulfide.

RI 7555. Sampling Gold Lode Deposits, Bluff, Seward Peninsula, Alaska, by John J. Mulligan. 1971. 40 pp. 7 figs. The Bureau of Mines sampled a gold-bearing schist series 50 miles east of Nome near Bluff, a dormant mining camp on the southern shore of the Seward Peninsula, Alaska. Gold is unevenly distributed through a section of a schist series that extends from the coast northward 4,500 feet. In this section the schists dip westward 20 to 38 degrees and have an outcrop width of about 1,000 feet and a normal width of about 500 feet. An intensely fractured zone within the schists averages 0.015 to 0.017 ounce of gold and 0.03 to 0.05 ounce of silver per ton for outcrop widths of 200 to almost 500 feet. The grade of the remainder of the schist series ranges downward to scant traces. Gold eroded from these schists collected in solution channels in meta-limestones to form the Daniels Creek placers, which also extend from the beach southward under the sea for an unknown distance. The lode sources of the gold placers elsewhere in the southern Seward Peninsula may be similar schists that occupy a similar position in the metasedimentary series.

RI 7556. Effect of Temperature on the Electrolytic Preparation and Recovery of Samarium-Cobalt Alloy, by E. Morrice and M. M. Wong. 1971. 11 pp. 3 figs.

The effect of the temperature of SmF₃-LiF electrolyte on the electrolytic preparation of samarium-cobalt alloy by the consumable cathode technique was investigated. The temperatures of the cathode zone, alloy collection zone, and samarium oxide (Sm₂O₃) feed zone had to be controlled carefully to obtain a satisfactory samarium-cobalt alloy product. Any appreciable deviation from certain temperature values adversely affected yield and product quality.

RI 7557. Hydrosulfurization of Venezuelan Residual Fuel Oils, by C. M. Frost and P. L. Cottingham. 1971. 18 pp. 8 figs. The hydrosulfurization characteristics of a Venezuelan topped crude oil and a Venezuelan crude oil were determined at temperatures from 740° to 850° F, pressures from 800 to 1,600 psig, and space velocities from 1.0 to 2.0 V₀/V_c/hr. Kinetic calculations showed that under these conditions the desulfurization reaction was first order with respect to sulfur and had an average activation energy of 32.5 kcal/mol. Catalyst life tests made at 750° F, with pressures of 800, 1,200, and 1,600 psig and space velocities of 1.0 and 1.25 V₀/V_c/hr, showed that the decrease in the relative activity of the catalyst was a logarithmic function of time or volume of oil processed and the amount of vanadium deposited on the catalyst. Comparative tests made with residual fuels prepared from a Wilmington, California, crude oil and a Wyoming asphaltic crude oil showed that catalyst life may be extended by processing fuel oil with a low metal content, but it may be shortened by the presence of large amounts of asphalt in the feed.

RI 7558. Analysis of Uranium Distribution in Diamond-Drill Cores. Section 23 Mine, Ambrosia Lake Area, Grants District, New Mexico, by George R. Schlottler. 1971. 29 pp. 16 figs. The Bureau of Mines investigated the distribution of uranium and various methods of ore sampling in a uranium deposit typical of those in the Morrison Formation sandstone of the Ambrosia Lake area, Grants mining district, northwestern New Mexico. Chemical and radiometric assays of diamond-drill core samples are compared in detail by statistical techniques, and the assay data are correlated with the stratigraphy of the deposit. Conclusions applicable to ore-reserve estimation in geologically similar uranium deposits are drawn.

RI 7559. Laboratory Evaluation of Some Factors in Cyaniding Gold Placers, by I. L. Nichols, H. B. Salisbury, and B. K. Shabler. 1971. 12 pp. 4 figs. The in-place cyanidation leaching of gold from placer deposits is a potential method for treating gravels too deeply buried and too low in gold content to be processed economically by conventional dredging methods. Laboratory experiments were made to evaluate those placer cyanidation factors adaptable to small-scale studies. The variables investigated included gold particle size and location in sand beds, cyanide solution flow rate, and cyanide solution strength as factors affecting gold solubility rates. The solution flow rate, in turn, was influenced by variables such as bed slope, solution head pressure, and sand size, and the effects of these factors were studied.

Free gold, minus 150-mesh and finer in size, is rapidly dissolved by dilute cyanide solutions from mixtures of gold and silica and prepared to simulate placer deposits. About 94 percent of minus 325-mesh free gold was extracted in 5 hours from silica sand mixtures, and 94 percent extraction of minus 150-mesh gold was obtained in 21 hours with 0.1 percent NaCN solutions. Moving solutions were almost twice as effective in leaching free gold from silica sand mixtures than stagnant solutions.

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RI 7560. Converting Organic Wastes to Oil. A Replenishable Energy Source, by H. R. Appell, Y. C. Fu, Sam Friedman, P. M. Yavorsky, and Irving Wender. 1971. 20 pp. 3 figs. The Bureau of Mines is experimentally converting cellulose, the chief constituent of organic solid waste, to a low-sulfur oil. All types of cellulosic wastes, including urban refuse, agricultural wastes, sewage sludge, wood, lignin, and bovine manure, have been converted to oil by reaction with carbon monoxide and water at temperatures of 350° to 400° C and pressures near 4,000 psig, and in the presence of various catalysts and solvents. Cellulose conversions of 90 percent and better (corresponding to oil yields of 40 to 50 percent) have been obtained.

A continuous reactor for use at maximum conditions up to 500° C and 5,000 psig has been operated successfully. Using sucrose as a feedstock, operation in this system has permitted a simplified and preliminary chemical study of the conversion process. Oil yields of over 30 percent have been obtained with this unit.

RI 7561. Prediction of Low-Temperature Carbonization Properties of Coal in Advance of Mining, by Manuel Gomez and Donald J. Donaven. 1971. 88 pp. 14 figs. Dehydrogenation factors, proximate analysis, and ultimate analysis were examined as predictors of the low-temperature carbonization properties of coals varying in rank from lignite through anthracite. All factors studied contributed to reduction in variance of the sample populations investigated.

Response surface regression models based on variables from proximate and ultimate analyses of coal were constructed for eight low-temperature carbonization assay product and gas component yields. These models were tested with independent samples that included drill cores, sized fractions, petrographic fractions, and run-of-mine coal. The models developed were used to predict low-temperature carbonization yields for coals from major fields of Wyoming. This information was cast in the form of contour plots describing the potential low-temperature carbonization product yields of Wyoming coals and the properties of the resultant char or coke.

The variables used as input to the models may be measured and collected during exploration; thus, the carbonization properties of a seam can be determined in advance of mining. The information presented in this report is useful in that it broadens the decisionmaking base for management when either mine locations or coal conversion plant sites, or both, are being considered.

RI 7562. Recovery of Copper From Converter Slags by Flotation, by V. E. Edlund and S. J. Hussey. 1972. 13 pp. 4 figs. Laboratory batch flotation tests were conducted on copper converter slags to evaluate the relative merits of recovering copper from slow-cooled versus water-quenched slags. Three slags containing 1.6, 5.0, and 6.6 percent copper were used. More than 90 percent of the copper was recovered in a rougher concentrate leaving a 0.2- to 0.3-percent copper tailings when treating slow-cooled slag. Lower recoveries and higher copper tailings ranging from 0.5 to 0.6 percent copper were obtained from quenched slag. Grindability studies were made on the respective heat-treated slags. Quenched slags proved more difficult to grind than slow-cooled slags. Cost studies showed that quenched slags can be treated at slightly lower cost than slow-cooled slags. However, the cost advantage of processing quenched

slags is more than offset by the higher copper recoveries obtained from slow-cooled slags. This 1972 report is a revision of the original RI 7562, published in 1971.

RI 7563. Computer Calculation of Binary Organic Liquid Recovery by Condensation From Mixtures of Binary Organic Vapor and Air, by John P. Gooch and James S. Browning. 1971. 81 pp. 12 figs. The Bureau of Mines wrote a computer program which calculates the saturation curves and condensation characteristics of gaseous mixtures consisting of binary organic vapor and air. The program employs an algorithm which assumes an equilibrium mechanism for condensation, and the degree of fractionation obtained is predicted on the basis of relative volatility. The program incorporates a feature which allows the user to examine the fractionation resulting from condensation as a function of the size of the temperature increments over which condensation is assumed to occur. If a single temperature interval between the dewpoint of the mixture and the outlet temperature of the condenser is assumed for the calculation, the results obtained will be those resulting from a single equilibrium condensation. If the condensation is assumed to occur over a number of temperature increments, the results obtained will approach those predicted by the Rayleigh equation as the magnitude of the temperature increments approaches zero. The results from calculations performed on vapor mixtures from organic heavy liquid solutions used in beneficiating potash and brucite ores are presented. The liquids are solutions of dibromomethane in trichloroethylene or perchloroethylene. The results show the degree of liquid recovery which is possible by cooling mixtures of organic vapor in air. Compositions of the vapor range from 10 to 95 percent air, and assumed condenser exit temperatures range from 110° to 50° F.

RI 7564. Prediction of Coke Strength of American Coals by the Ruhr Dilatometer Method, by J. G. Walters, C. Ortuglio, and D. E. Wolfson. 1971. 18 pp. 1 fig. The method for predicting coke strength developed at Steinkohlenbergbauverein, Germany, in which experimental parameters are readily determined by small-scale laboratory tests, was found to be applicable to cokes produced from industrially used blends of American coals. Predicted 1-inch ASTM tumbler indices for four industrial blends were found to be in excellent agreement with the experimentally determined values. The laboratory determined prediction parameters include the proximate analysis of the coal, the size consist of the coal, and Ruhr dilatometer test data.

RI 7565. Delineation of Clustered Points in Two Dimensions by Measuring Perimeters of Convex Hulls, by John H. Schuenemeyer, Charles E. Lienert, and George S. Koch, Jr. 1972. 69 pp. 32 figs. Consider a set of points, some of which are anomalous (larger than a specified cutoff value), located on a plane. Whether some or all of these points are clustered to form one anomaly or more or, alternatively whether these points are scattered at random, may be investigated by measuring perimeters of convex hulls. A convex hull is the smallest convex polygon that will encompass a group of points. Examples of convex polygons are triangles, rectangles, and all other regular polygons. A set of anomalous points is selected and the perimeters of the convex hulls of this set and all its subsets are measured and compared with tabulated values of perimeters for each subset size. For a given subset

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size consider those perimeters which are less than the tabulated perimeter. If the number of convex hulls is greater than the maximum number expected by chance, then the chance that any one of the observed hulls is a nonrandom cluster is the ratio of the observed number to the sum of the observed and the maximum number expected by chance. Otherwise, the points are evidently not clustered. If many sample points are anomalous, an alternate model defines various configurations of contiguous points and compares the observed number of configurations per unit area with the expected number. Applications are discussed in several fields of geology and geochemistry—including geochemical exploration surveys and heavy mineral spatial distributions—as well as in mining (dust control) and medical geography.

RI 7566. Recovery of Cadmium and Nickel From Scrap Batteries, by D. A. Wilson and B. J. Wiegard, Jr. 1971. 15 pp. 4 figs. A cyclic leaching process was developed for selectively leaching and recovering cadmium from nickel-cadmium scrap battery waste. The six major steps in the process are the following: (1) washing the plates to remove KOH electrolyte, (2) roasting at 550° to 600° C to oxidize metallic cadmium and decompose cadmium and nickel salts, (3) leaching with an ammonium nitrate solution, (4) precipitation of the leached cadmium from solution as cadmium carbonate using CO₂ gas, (5) removal of CO₂ from the lixiviator by adjusting to pH 4.5, heating, and evacuating the system, and (6) removal of small amounts of leached nickel from the lixiviator using a solvent extraction technique. The regenerated lixiviator is then recycled to leach additional plates. Cadmium extraction was 94 percent and the cadmium carbonate product contained 0.14 percent nickel and 0.12 percent cobalt impurity. The leached plates were smelted to a high nickel-low iron alloy with no detectable amounts of cadmium.

RI 7567. Influence of Thermal Treatments Upon Grindability of Low-Grade Nonmagnetic Iron Ores, by R. A. Vik, C. B. Daellenbach, and W. M. Mahan. 1971. 30 pp. 13 figs. The influence of thermal treatments on the grindability of low-grade hematitic iron ores from Michigan and Minnesota was examined in bench-scale tests. Treatment factors were roasting temperature, roasting atmosphere, and ore cooling conditions. Bond ball mill grindability and work indices were used as response indicators in evaluating the condition of the ore. Of the three treatment factors evaluated, roasting atmosphere, which brought about the conversion of iron oxides to magnetite, had the most significant effect; roasting temperature had the next most important effect; and cooling condition had the least effect. Optimum grindability was obtained with reduced-quenched products of both ores at 650° C, near the alpha-beta phase transformation of quartz.

RI 7568. The Use of Rock Bolts or Wire Rope To Increase the Strength of Fractured Model Pillars, by F. G. Horino, W. I. Duvall, and B. T. Brady. 1971. 24 pp. 12 figs. The Bureau of Mines conducted compressive strength tests on model pillars of selected rock types with each pillar containing a critically oriented plane of weakness. The objective of these tests was to determine if a significant increase in the strength of the model pillar could be obtained by either (1) installing tensioned rock bolts through the pillar and normal to the plane of weakness, or (2) wrapping tensioned steel wire ropes around the pillar at uniformly spaced intervals along the pillar.

Equations based on Coulomb's failure criterion are developed to predict uniaxial compressive strength of model pillars that are either rock-bolted or wire-rope.

Laboratory compressive strength tests on unbolted and bolted model pillars of sandstone, marble, Indiana limestone, and oil shale containing a plane of weakness oriented at 45° showed that the bolted pillars are stronger than the unbolted pillars by 84, 31, 52, and 28 percent, respectively. Laboratory compressive strength tests on nonroped and roped model pillars of Texas limestone, sandstone, and granite containing planes of weakness showed that the roped pillars were stronger than the nonroped pillars by factors ranging from 1.01 to 2.41, depending upon the angle of the plane of weakness and the rock type. Rocks with a low Young's modulus benefited most by the wire-rope technique.

RI 7569. Preparation of Thorium-Magnesium Alloys and Pure Thorium by Magnesium Reduction of Thorium Tetrachloride, by T. T. Campbell, G. B. Robidart, and F. E. Block. 1971. 17 pp. 4 figs. Studies were conducted by the Bureau of Mines to develop a process for preparing thorium-magnesium master alloys or pure thorium metal by magnesium reduction of thorium tetrachloride in a semicontinuous reactor. Thorium tetrachloride was prepared in a fluidized-bed reactor by chlorination of thorium oxide or thorium oxalate. Conditions were established for producing a suitable thorium oxide feed for a fluidized-bed reactor. Thorium tetrachloride was purified by vacuum sublimation and subsequently reduced by magnesium in a semicontinuous reactor to form thorium-magnesium alloys. Relatively pure thorium was produced by removing magnesium from the alloys by vacuum sublimation. Close to 100 percent of the thorium fed into the reactor was recovered either as metal (~93 percent) or as thorium oxide (~7 percent). The oxide can be recycled directly into the process.

RI 7570. Dispersion Strengthening of Lead by Coprecipitation, by M. M. Tilman, R. L. Crosby, and D. H. Desy. 1971. 9 pp. 3 figs. The Bureau of Mines conducted research into the dispersion strengthening of lead by the coprecipitation method. Commercially available reagents in water solutions were reacted to form homogeneous precipitates of lead and aluminum compounds. The resulting precipitates were roasted to oxides and reduced in hydrogen to form mixtures of lead powder and alumina. The powders were isostatically pressed into billets which were extruded into rods. The rods were rolled into strip to provide material for testing. Alloys containing 0.5, 1, 2, and 3 nominal volume-percent Al₂O₃ were tested in short-time tensile tests and in tensile creep tests. An alloy of Po-3 volume-percent Al₂O₃ exhibited an average tensile strength of 8,570 psi after rolling to 75-percent reduction at 125° C but had no measurable elongation. Alloys of lower Al₂O₃ content provided a better compromise between tensile strength and ductility. For example, an alloy of Po-0.5 volume-percent Al₂O₃ content had an average tensile strength of 6,590 psi with 9-percent elongation after rolling to 75-percent reduction at 125° C. Creep rates of dispersion-strengthened Pb-Al₂O₃ alloys were below 1 percent in 10,000 hours at stresses of 2,000 to 4,000 psi.

RI 7571. Hardness, Tensile Strength, and Impact Toughness of Reservoir Sandstone at Extreme Temperatures, by C. A. Komar. 1971. 8 pp. Hardness, tensile strength, and impact toughness of dry and brine-

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saturated sandstone specimens were measured at ambient, cryogenic, and elevated temperatures as a measure of the relative stability of reservoir rocks for subsurface disposal of liquid wastes. Hardness measurements were inconclusive. Tensile strength and impact toughness were significantly higher at -320°F than at ambient temperature, but were relatively unaffected at 700°F . Impact toughness was reduced by subjecting the specimens to three cycles of rapid temperature changes (thermal shock) over a $1,000^{\circ}\text{F}$ range. Tensile strength of brine-saturated sandstone was less than that of dry sandstone. Based on results of the tests, reservoir sandstone likely would be stable if exposed to extreme temperatures of liquid wastes, although rapid changes in waste temperatures should be avoided.

RI 7572. Fragmentation of Concrete With Hydraulic Jets, by Jacob N. Frank and John W. Chester. 1971. 32 pp. 13 figs. A factorially designed, hydraulic fragmentation experiment using a high-pressure water jet was conducted on concrete blocks. Three levels of pressure, standoff distance, and impact angle and two levels of traverse time and surface condition were used. Three variables were measured: depth of penetration, volume of material removed, and width of slot. Three stepwise linear regression equations were developed from the jet parameters and the physical properties of the concrete. The three basic equations, describing the significant jet parameters and physical properties, were developed into 15 predictor equations, five for each variable investigated. Direct regression equations were also developed for each variable investigated to show the result of increasing or decreasing each significant variable. Energy efficiencies were developed for the experiment and for each significant factorial variable.

RI 7573. Oxidation Process for Improving Gold Recovery From Carbon-Bearing Gold Ores, by B. J. Scheiner, R. E. Lindstrom, and T. A. Henrie. 1971. 14 pp. 12 figs. Carbonaceous gold-bearing ores of the type that occur in north-central and northeastern Nevada were investigated by the Bureau of Mines as part of its Heavy Metals Program. Specific objectives were to identify the carbon and organic compounds that prevent adequate gold recovery from the ore by cyanidation and to develop an economical process that would overcome the detrimental effect of the carbonaceous constituents. Activated carbon and long-chain organic compounds containing sulfur and nitrogen were found in the ore. Part of the material consisted of stable gold organic complexes. A mild oxidation technique that allowed gold extraction as high as 96 percent by subsequent cyanidation was developed. A variety of oxidants was shown to be effective in improving gold recovery, including chlorine and sodium hypochlorite (NaOCl). An electrolytic oxidation process was developed that was particularly advantageous from an economic and effectiveness standpoint.

RI 7574. Airblast-Overpressure Levels From Confined Underground Production Blasts, by James J. Olson and Larry R. Fletcher. 1971. 24 pp. 10 figs. The Bureau of Mines recorded and analyzed overpressure levels for three production blasts at the White Pine copper mine, Upper Michigan, to obtain representative data from single-heading blasts in a long, straight haulageway and to estimate the damage potential inherent in production blasts fired in close proximity to underground structures. Commercial pressure gages with a flat response to 1 kHz were

used with an FM tape recorder to record the overpressures from one dynamite and two ammonium nitrate-fuel oil, 500-msec production blasts having zero-delay charge weights of about 75 lb (34 kg).

The recorded waveforms from the underground blasts (1) were more complex than the typical free-air wave, (2) were of larger duration, and (3) had numerous secondary arrivals owing to reflections from the ribs and roof. The waveforms showed that the zero-delay charges produced the only high overpressures.

RI 7575. In Situ Strain Orientations: A Comparison of Three Measuring Techniques, by R. L. Rough and W. G. Lambert. 1971. 17 pp. 9 figs. Photoelastic, wire resistance, and borehole-deformation gages were used to measure the in situ strains when an outcropping Black Hand Sandstone Formation in Hocking State Forest, Hocking County, Ohio, was overcored to stress-relieve the surrounding sandstone. Strains transmitted to the photoelastic gage did not produce isochromatic patterns suitable for quantitative analysis. Strain readings from the wire resistance gage indicated tensile-strain loading during overcoring; readings from the strain-gage bridges in the borehole-deformation gage indicated compressive-strain relaxation during overcoring. The magnitude and orientation of the computed stress fields obtained from both gages were comparable when the corresponding tensile and compressive elastic moduli were applied. Measurements of in situ strain in sandstone were shown to have promise but to require further development in field technique that could likely be achieved through experience.

RI 7576. Structural Deformation of Green River Oil Shale as It Relates to In Situ Retorting, by P. R. Tisot and H. W. Sohns. 1971. 27 pp. 9 figs. Structural response and/or deformation was determined for each of four different grade Green River oil shales (27.0-, 34.5-, 45.5-, and 63.5-gal/ton) as they were heated in an inert atmosphere, under constant compressive stress, from ambient to subretorting temperatures; that is, below those required for rapid pyrolysis of the organic matter. Small cores and small columns of confined fragments comprised the test specimens, which were heated in a specially designed microunit at a uniform rate either to 725°F or to 825°F under three different stress levels, 80, 200, and 325 psi. Structural response of some cores was observed as they were heated in a stress-free environment. The obtained stress-strain-time-temperature relationships provide information regarding the oil shale's yield temperature, yield stress, rate of compressive strain, loss of mechanical strength, and nature of structural deformation. Effects of structural deformation on induced permeability in small columns of fragments are presented. Results indicate that underground retorting of Green River oil shale may be seriously impaired through loss of induced permeability brought about by structural deformation of rich oil shale under the influence of heat and compressive stress.

RI 7577. Gravity Flow of Powder in a Lunar Environment (In Two Parts). 2. Analysis of Flow Initiation, by William G. Pariseau. 1971. 20 pp. 11 figs. A small displacement-small strain finite element technique utilizing the constant strain triangle and incremental constitutive equations for elastic-plastic media, which are nonhardening and obey a Coulomb yield condition, has been applied to the analysis of gravity flow initiation in a V-shaped hopper containing a powder under lunar environmental conditions.

tions. Three methods of loading were examined. Of the three, the method of computing the initial state of stress in a filled hopper prior to drawdown by adding material to the hopper layer-by-layer is superior. Results of the analysis of a typical hopper problem show that the initial state of stress, the elastic moduli, and the strength parameters have an important influence on material response subsequent to the opening of the hopper outlet.

RI 7578. Rock-Bolt Anchorage in Tertiary-Gravel Material: Badger Hill, California, by John P. Conway. 1971. 14 pp. 5 figs. This investigation was undertaken to determine the feasibility of rock-bolt support in Tertiary-gravel material. Pull tests were performed on five types of rock-bolt anchors to determine their optimum anchorage capacity. Four of these anchors are commercially available; the fifth, an explosive-anchor bolt, was developed by the Bureau of Mines. To increase anchorage capacity, epoxy grout was used with several of the commercial types of bolt. Tests showed that sufficient anchorage could be obtained by employing epoxy-resin grout with the commercially available wedge bolt, or by using the explosive-anchor bolt.

RI 7579. Modifying Diesel Engine Operating Parameters To Reduce Emissions, by W. F. Marshall and R. W. Hurn. 1971. 14 pp. 9 figs. The effect of engine parameters on exhaust emissions from two diesel engines was studied experimentally. Fuel-injection characteristics and intake air conditions were considered as parameters influencing the emissions. Emphasis was placed on the effect of parameter variations on nitrogen oxide (NO_x) emissions, because diesels generally emit very low levels of carbon monoxide (CO) and unburned hydrocarbons.

Emissions other than NO_x were at lowest levels when the engines were adjusted for best performance. NO_x emissions can be diminished somewhat through variation in fuel-injection characteristics, but there generally are penalties in emissions of CO, smoke, and unburned hydrocarbons or in engine performance.

Temperature and composition of intake air have a significant effect on NO_x emissions. Levels of NO_x are reduced by recirculating the exhaust gas or by adding water to the intake air stream. However, the rate of water added or exhaust gas recirculated must be limited to prevent the degradation of engine performance and increased emissions of CO and smoke. At high exhaust recirculation rates, levels of CO and smoke were increased such that it was necessary to derate the engine and also to use a catalytic system for oxidation of CO.

RI 7580. Comparison of Techniques for Electrowinning Tungsten From Scheelite, by John M. Gomes, Kenji Uchida, and M. M. Wong. 1971. 10 pp. 1 fig. Two techniques were investigated for removing CaO from scheelite (CaWO_4) prior to electrolysis. In the first technique, a crude tungstic oxide (WO_3) containing 0.15 percent lime (CaO) was prepared by digesting scheelite concentrates in hot hydrochloric acid. This oxide was used as cell feed to produce tungsten of 99.9-percent purity. The second technique used a high-temperature, two-phase separation, resulting in the extraction of 99 percent of the WO_3 in the halide-tungstate phase, while 90 percent of the CaO was retained in the silicate phase. Tungsten of 99.9-percent purity was deposited from the halide-tungsten melt after B_2O_3 and NaPO_3 were added to form an electrolyte. The two methods were compared with a previously developed technique of depositing tungsten from scheelite concentrate fed directly to the electrolytic cell.

RI 7581. Explosion-Proof Bulkheads. Present Practices, by D. W. Mitchell. 1971. 16 pp. This report summarizes experience and past research on methods for sealing abandoned areas of a coal mine and areas from which the pillars have been wholly or partially extracted. The Federal Coal Mine Health and Safety Act of 1969 requires that such areas be ventilated or sealed with explosion-proof bulkheads, but the present study indicates that bulkheads alone cannot isolate areas in a coal mine in which methane and other dangerous gases have accumulated. Gas-air exchanges between sealed and open areas must be controlled.

RI 7582. Evaluation of Some Solid Oxides as Sorbents of Sulfur Dioxide, by James H. Russell, Jack I. Paige, and Danton L. Paulson. 1971. 27 pp. 13 figs. Several solid sorbents were compared for their effectiveness in removing sulfur dioxide from flue gases. The materials were tested for the rate of sorption and capacity at about 300°C , and rate of regeneration around 700°C in thin beds and in 4-inch-diameter fluidized beds. Rates of material loss were also estimated. The sorbents tested included three samples of alkalized alumina, two samples of sodium carbonate-impregnated alumina, and one proprietary sample of porous silica impregnated with copper and iron compounds.

RI 7583. Experiments on Gas Flow in Porous Media at Low Pressures, by L. C. Headley, C. I. Pierce, and W. E. Wallace, Jr. 1971. 9 pp. 4 figs. Surface areas of two synthetic and three natural consolidated porous samples were obtained by the Orr low-pressure permeametry technique. The results suggest that the Orr technique is a useful substitute for the low-temperature gas adsorption (BET) method for determining the surface area of rock samples. It was more rapid than the BET method, and the surface-area values obtained were larger but agreed better with BET values than values calculated from the Kozeny-Carman equation. Efforts were unsuccessful to demonstrate the influence of channel-size distribution on pressure-flow rate curves by means of experimental data and a parallel channel model.

RI 7584. Geophysical Measurements of Gold-Bearing Gravels, Nevada County, Calif., by Benton L. Tibbetts and James H. Scott. 1972. 32 pp. 34 figs. Comprehensive geophysical measurements were made in the Tertiary Channel gravel deposits of Badger Hill, Calif., with the refraction seismograph, gravimeter, and well logging equipment, to develop a three-dimensional physical model of the gold-bearing gravels. Tests were also made of the applicability of magnetometer and electrical resistivity techniques. Results of 14 seismic profiles revealed four distinct layers with velocities of 1,600 ft/sec for loose gravel, 5,900 ft/sec for compact gravel, 8,600 ft/sec for cemented, blue gravel, and 15,500 ft/sec for bedrock. The depth to bedrock along the middle of the channel varied from a minimum of 100 feet in the hydraulically mined pit area to a maximum of about 300 feet in the upper bench area immediately south of the pit. These geophysical methods revealed that 40 percent of the drill holes necessary to delineate the deposit could be eliminated, at a cost saving of at least 30 percent. GPO Stock No. 2404-1033. \$1.25.

RI 7585. Enthalpy and Free Energy of Formation of Vanadium Subnitride ($\text{VN}_{0.465}$), 298° to $1,800^\circ\text{K}$, by L. B. Pankratz, J. M. Stuve, H. O. Poppleton, L. L. Oden, and Alla D. Mah. 1971. 13 pp. 2 figs.

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Low-temperature heat capacities, high-temperature enthalpy increments, and the enthalpy of formation at 298° K were determined calorimetrically for vanadium subnitride ($\text{VN}_{0.465}$). The low-temperature investigation gave $S_{298.15}^\circ = 6,379 \pm 0.005$ cal/deg mole, and a combustion calorimeter investigation provided $\Delta H_f^\circ_{298.15} = -31.80 \pm 0.60$ kcal/mole. The two quantities were combined with the high-temperature data to give standard values of enthalpies of formation and free energies of formation above 298° K. These and related thermodynamic functions were tabulated to 1,800° K. Similar data are included in the range of 298° to 1,600° K for the mononitride, VN.

RI 7586. Thermal-Chemical Alteration of Sandstone To Increase Permeability, by Larman J. Heath and Ray A. Jones. 1971. 22 pp. 6 figs. Liquid incendiaries were burned within the interstices of several different types of sandstone cores to determine the technical feasibility of increasing sandstone permeability by this method. Fuel-oxidant mixtures were tested in 186 cores; six cores exploded when ignited. In virtually all instances, the explosion completely pulverized the sandstone cores. In addition to those cores damaged by explosions, 24 cores were fractured so severely that permeability tests were impossible. Although combustion generally increased the permeability, specific mixtures at given pressures were inconsistent in their ignition and burning behavior. Tests indicated that the heat of burning incendiaries significantly increased sandstone permeability. The improved permeability ratios were usually less than 2, but one was 10.3. Permeability alteration by other *in situ* methods was not as effective as that by flame propagation.

RI 7587. Electrowinning of Oxygen From Silicate Rocks, by D. G. Kesterke. 1971. 12 pp. 3 figs. Research was conducted to determine the feasibility of extracting elemental oxygen from silicate-bearing melts by high-temperature electrolysis. The method was based on a modification of existing processes for electrowinning metals from their oxides dissolved in molten halide systems. Electrolyses were performed at temperatures ranging from 1,050° to 1,250° C in boron nitride cells that incorporated a silicon carbide cathode and an iridium anode. The electrolytes contained volcanic scoria as the oxygen source, plus mixtures of BaF_2 and LiF as fluxing agents. Cell gases containing almost 14 volume-percent oxygen were obtained. The average anode current efficiency for several experiments of extended duration was calculated to be 55 percent. Cell design and operating conditions are described, and some of the problems associated with the process are discussed.

RI 7588. Analyses of Tipple and Delivered Samples of Coal (Collected During Fiscal Year 1971), by Staff, Coal Sampling and Inspection. 1972. 20 pp. The Bureau of Mines has long been active in promoting the purchase of coal for Government use under specifications that define the requirements in terms of heating value of the coal, expressed in British thermal units, and the composition as shown by proximate analyses. To these, when required, are added the ash-softening temperature, the free-swelling index, and the Hardgrove grindability index. Under most of these specification contracts, the bidders guarantee the quality of the coal, and that guaranteed by the successful bidder becomes the standard of his contract. The deliveries are sampled in accordance with instructions issued by the Bureau of Mines, and the samples are analyzed in the Bureau laboratory

to determine whether the coal is of the quality guaranteed by the contractor; if it is not, a price adjustment is made. The Government, with the exception of the Tennessee Valley Authority, purchased approximately 5.5 million tons of coal in fiscal year 1971. In connection with these purchases, the Bureau analyzed 4,366 samples. These are published (table 1) for the use of Government officials and the public. Such analyses of delivered coal and tipple samples (samples collected at mine tipples as coal is being loaded into railroad cars or trucks) provide valuable data for use in evaluating future bids. In addition, the continuous sampling of coal as delivered is a check on the practical results obtained in burning the coal. GPO Stock No. 2404-1034. 30 cents.

RI 7589. In Situ Rock Temperature. Stress Investigations in Rock Quarries, by Verne E. Hooker and Wilbur I. Duvall. 1971. 12 pp. 8 figs. Near-surface temperature measurements in two granite quarries show that diurnal temperature variations are significant to a depth of 1 or 2 feet, and annual temperature variations are significant to a depth of at least 25 feet. As a result, ground stress anomalies due to temperature exist near the surface, and their magnitude depends upon the time of day and the time of year. Rock stress and corresponding temperature measurements were made in one granite quarry over a rock temperature range of 33° to 81° F. Measured rock temperatures show good agreement with values predicted from one-dimensional heat flow theory. Calculated and measured stress-temperature coefficients for the two granites in this study are given.

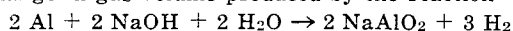
RI 7590. Ionic Constituents of DC Discharges in a He-SO₂ Mixture, by D. G. Kuehn and L. M. Chanin. 1971. 17 pp. 7 figs. Positive ion sampling studies have been conducted on dc discharges containing 0.33 percent sulfur dioxide in helium. Measurements were made for normalized gas pressures from 0.45 to 6.8 torr and discharge currents from 5 to 40 ma. Ion species observed included SO^+ , S^+ , SO_2^+ , SO_3^+ , O^+ , and O_2^+ . Studies were conducted on the functional dependence of the various ion species with respect to axial distance, pressure, current, and gas flow rate. Interpretation of these results is consistent with the assumption of SO_2 dissociation. Deposition of sulfur compounds was observed in the plasma container during these studies.

RI 7591. Methane Emission Rate Studies in a Central Pennsylvania Mine, by Stephen Krickovic and Charles Findlay. 1971. 9 pp. 4 figs. A methane emission rate study was conducted in 1969 on a longwall section of a Lower Kittanning coalbed mine in central Pennsylvania. The longwall face was mined with a drum shearer between developed headings on the head end and headings on the tail end that were driven with a ripper-type continuous miner as needed. The study was conducted over 22 consecutive shifts (7-1/3 days). The average methane emission rate from the Lower Kittanning coalbed during mining at the face and developing the headings at the tail end of the face was 34 cfm. Caving of the gassy overlying strata as the result of mining at the face increased the methane emission to rates ranging from 702 to 1,049 cfm.

RI 7592. Determination of Metallic Aluminum in Recycled Glass, by Thomas E. Green. 1971. 7 pp. 2 figs. A gas volumetric method was developed for determining metallic aluminum at the 0.01- to 0.3-percent level in 100-gram samples of recycled glass. The method is based on the measurement of the

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change in gas volume produced by the reaction



using a simple apparatus assembled from readily available glassware. Apart from sampling errors, the precision of the method is within ± 5 percent. A minor modification of the apparatus would extend the method to larger samples or samples of higher metallic aluminum content.

RI 7593. Classification Test Methods for Flammable Solids, by J. M. Kuchta and A. F. Smith. 1972. 13 pp. 1 fig. Ignition and flammability test methods were developed by the Bureau of Mines for use in the classification of flammable solids by the Department of Transportation. A rotating disk ignition apparatus and a flame-spread-rate apparatus are proposed for determining the ignitability and flammability, respectively, of most flammable solids. Extremely flammable solids, such as pyrophoric materials, are evaluated by determining their ease of spontaneous ignition in an environmental chamber at high-humidity conditions. Data are presented for various representative solids to show the reliability of the test methods for classifying the materials. A classification system is also proposed for use in government transportation regulations.

RI 7594. Classification Test Methods for Oxidizing Materials, by J. M. Kuchta, A. L. Furno, and A. C. Imhof. 1972. 13 pp. 2 figs. Bench-scale test methods were developed by the Bureau of Mines for use by the Department of Transportation in the classification of solid and liquid oxidizers. A burning-rate test is recommended for evaluating the fire hazard of solid inorganic oxidizers when mixed with a red oak sawdust as the reference combustible. A spontaneous ignition test is proposed for evaluating liquid and solid inorganic oxidizers which may decompose violently or ignite spontaneously when unmixed or mixed with the wood sawdust under unconfined conditions. Test results are compared with various representative oxidizers and a classification system is proposed for use in the Government transportation regulations.

RI 7595. Computer Analysis of Seismic Refraction Data, by James H. Scott, Richard G. Burdick, and Benton L. Tibbetts. 1972. 95 pp. 11 figs. A technique of seismic refraction data analysis has been developed in which a digital computer is used to generate a two-dimensional model representing a layered-earth depth interpretation. Travel times are picked on seismic records by the human interpreter. These times, together with shot point and geophone locations and refraction-layer control information, are submitted to the computer on punched cards. A first approximation delineation of each refraction horizon is obtained by a computer adaptation of the delay-time method. The approximation is then tested and improved by the computer through the use of a ray-tracing procedure in which ray travel times computed for the model are compared against field-measured travel times. The model is subsequently adjusted in an iterative manner so as to minimize the discrepancy between computed and measured travel times. The Fortran program is listed in the appendix of the report together with instructions for preparing data cards and examples of results. GPO Stock No. 2404-1049. 30 cents.

RI 7596. Hydraulic Fracturing of Wyoming Green River Oil Shale: Field Experiments, Phase I, by H. E. Thomas, H. C. Carpenter, and T. E. Sterner. 1972. 18 pp. 7 figs. The Bureau of Mines has conducted a field hydraulic fracturing experiment to determine

the preferential orientation of induced fractures in oil shale at a depth of about 400 feet in the Green River Basin of Wyoming. The hydraulic fracturing treatment was performed by injecting extremely viscous water-base gel and 8- to 12-mesh sand into the oil shale through straddle packers set in an impermeable section of smooth-walled, 6¼-inch-diameter open hole. An impression packer proved that a horizontal fracture, which has an average width of about one-half inch at the borehole, was induced. A corehole drilled 100 feet from the fractured well intersected the fracture and confirmed its horizontal orientation. Because a horizontal fracture was successfully initiated, it is inferred that the creation of multiple, closely spaced horizontal fractures may be feasible in Green River Basin oil shale.

RI 7597. Extraction of Gold From Carbonaceous Ores: Pilot Plant Studies, by B. J. Scheiner, R. E. Lindstrom, W. J. Guay, and D. G. Peterson. 1972. 20 pp. 16 figs. Oxidation procedures based on the chlorine-hypochlorite system were investigated for improving gold recovery from carbonaceous gold ores. The oxidation pretreatment prior to cyanidation was accomplished by (1) addition of sodium hypochlorite to ore pulp, (2) by addition of chlorine to ore pulp, and (3) by generation of hypochlorite in situ by electrolysis of a brine solution used to pulp the ore. Gold extraction of 90 pct was achieved by cyanidation of carbonaceous ore that had been pretreated with 20 lb per ton sodium hypochlorite at 50° C for 4 hours. Similarly, pretreatment of the ore pulp with 35 lb chlorine per ton at 24° to 30° C for 15 hours reaction time resulted in 89-pct gold extraction by subsequent cyanidation. Concomitant studies showed that electrolyzing the pulp prepared with a brine solution was equally as effective as electrolyzing hypochlorite and chlorine for oxidizing carbonaceous ore constituents that are deleterious to cyanidation. Gold extraction of 90 pct was obtained by electrolysis when 275 lb of ore was treated at 200 amp for 7 hours in an 8- to 10-pct salt solution. Power consumption was in the range of 60 kw hr per ton.

RI 7598. Vapor-Liquid Equilibria Data for Two Helium-Nitrogen-Methane Mixtures From 76.5° to 164° K and Pressures to 1,200 PSIA, by Harold L. Rhodes, Lowell Stroud, and Philip C. Tully. 1972. 29 pp. 22 figs. Vapor-liquid equilibria data for 65-34-1 and 25-27-48 mole-percent helium-nitrogen-methane mixtures are presented for 12 temperatures from 76.5° to 164° K and pressures from 100 to 1,200 psia. These data were obtained in a windowed phase-equilibria cell equipped with a vapor recirculating pump. Isobaric and isothermal *K*-values are plotted for both mixtures. Two isometric plots are included.

RI 7599. Use of Char To Improve Physical Quality of Coke From Allen (Colorado) Coal, by Charles C. Boley, M. M. Fegley, R. B. Porter, and D. C. Boteler. 1972. 21 pp. 4 figs. High-volatile A bituminous coal from the Allen mine, Las Animas County, Colo., blended with char produced from the same coal, yielded acceptable metallurgical coke in a 500-lb movable-wall test oven. Nineteen experimental runs were carried out using several concentration levels of two different chars, 5.6 and 19.6 percent volatile matter, produced by entrainment carbonization of the base coal. With the higher-volatile char, an acceptable coke was produced at a 22.5-percent concentration; the lower volatile char did not produce an acceptable coke at the concentrations investigated.

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RI 7600. Enthalpies and Entropies above 298.15° K for Copper Sulfate and Copper Oxysulfate, by M. J. Ferrante. 1972. 8 pp. 2 figs. Enthalpy and entropy increments above 298.15° K were determined for copper sulfate between 298° and 1,000° K and for copper oxysulfate between 298° and 1,146° K by the method of copper-block drop calorimetry. Enthalpies, entropies, and heat capacities are tabulated for both compounds. In addition, free-energy functions are tabulated for the sulfate.

RI 7601. Laboratory Flotation Studies of Tennessee Phosphates in the Presence of Slimes, by W. E. Lamont, C. E. Spruiell, Jr., D. R. Brooks, and I. L. Feld. 1972. 17 pp. Flotation studies of phosphate-bearing waste pond materials, low-grade washer products, and raw ores, all from the Tennessee brown phosphate district, showed that these types of materials could be treated without desliming to recover high-grade phosphate concentrates. The investigation showed that fine grinding before flotation was a requisite for increased recovery of the phosphate values, and that the optimum pH conditions were in the range of 10.0 to 10.5 when using anionic collectors. Multiple-cleaning of the rougher phosphate concentrate was required to produce high-grade concentrates. Phosphate recoveries ranged from 60 to 82 percent and were inversely related to the grade of concentrate produced.

RI 7602. Removing Bismuth From Lead With a Submersible Centrifuge, by Dominic Montagna and John A. Ruppert. 1972. 10 pp. 4 figs. The Kroll-Betterton process for debismuthizing lead is based on adding calcium and magnesium to impure molten bullion to form solid Ca-Mg-Bi intermetallic compounds that float on the surface as drosses. Present practice in industry is to hand-skim off these drosses, often followed by hydraulic pressing to squeeze out some of the entrapped liquid lead. In an effort to develop an improved technique, the use of an argon-shrouded dipping centrifuge to perform the required phase separation was investigated. Centrifugation experiments demonstrated that the bismuth content of an impure bullion could be lowered from an initial 0.5 percent down to 0.03 percent with a lead recovery of 90 percent, which is comparable to lead recovery after hand skimming of drosses in commercial lead-debismuthizing operations. Centrifugation provides better control in removing drosses, faster operation with less oxidation and relatively little fuming, and recovery of a lead bullion that approaches commercial specifications.

RI 7603. Recovery of Aluminum From Aluminum-Silicon Alloys, by E. L. Singleton, R. L. de Beauchamp, and T. A. Sullivan. 1972. 12 pp. 6 figs. The extraction of aluminum from aluminum-silicon alloys was investigated as a means of utilizing domestic aluminum silicate ores for aluminum production. Aluminum was extracted from aluminum-silicon alloys by electrolysis in molten electrolytes of NaCl-KCl-AlCl₃ and NaCl-KCl-AlF₃ in a laboratory-scale cell. Six alloys with aluminum contents ranging from 20 to 87 percent aluminum were tested, and aluminum products of primary grade or better were obtained. More than 80 percent of the aluminum was recovered with current efficiencies as high as 91 percent. Recovery of a metallurgical-grade silicon product from the anode residue by an acid leaching procedure was possible with the 50-50 and 65-35 Al-Si alloys.

RI 7604. Mass Spectra and Analytical Correlations for a Series of Alkyl Aryl Sulfides, by J. E. Dooley and R. F. Kendall. 1972. 18 pp. 1 fig. A mass

spectral scheme of analysis, which can be used to identify individually a single compound from a larger group of similar compounds, was devised. Mass spectra for 32 alkyl aryl sulfides are provided for future reference work, and analytical correlations used in producing the analytical scheme are discussed. Some of the correlations show that base peaks are either the same mass as the parent peaks or may be derived from alpha cleavage to the sulfur atom with migration of one hydrogen to the sulfur atom. Other spectral consistencies provided means of separating ortho-, meta-, and para-tolyl arrangements in an overall analytical scheme.

RI 7605. Fabrication and Cost Evaluation of Experimental Building Brick From Waste Glass, by M. E. Tyrrell, I. L. Feld, and J. A. Barclay. 1972. 33 pp. 8 figs. The Bureau of Mines produced building brick of good quality in an investigation designed to explore the possible utilization of high-glass fractions of municipal incinerator residues in the manufacture of building products. Common clays, lime, and sodium silicate were used as binders for the nonplastic residues. Test bricks were formed by dry pressing, soft-mud molding, and stiff-mud extrusion. A run of standard-size face brick, dry-pressed and fired in the West Virginia University Coal Research Bureau pilot plant, demonstrated that SW-grade glass-clay face brick can be produced on a commercial scale without difficulty. A cost evaluation made for production of the brick showed an estimated cost of \$42.13 per thousand bricks for a shuttle kiln plant and \$28.70 per thousand for a tunnel kiln plant.

RI 7606. The Effect of Atmospheric Pressures on the Oxygen Level in a Sealed Mine, by N. N. Moebs and C. E. Chamberlain. 1972. 19 pp. 14 figs. The atmosphere in part of an air-sealed coal mine was monitored continuously through a drill hole for oxygen content to determine (1) the effectiveness of sealing a mine against the entrance of air and (2) the major force that caused the phenomenon of mine breathing through the overburden. The differential pressure across the seal and the barometric pressure on the outside also were recorded. A general correlation, obtained between the oxygen level, differential pressure, and barometric pressure, indicates that changes in air pressure are the cause for periodic replenishment of the oxygen in the mine. Mine effluent quality was determined by conditions in many sections of the mine and could not be related to the oxygen level at the drill hole.

RI 7607. An Experiment in Seismic Holography, by G. L. Fitzpatrick, H. R. Nicholls, and R. D. Munson. 1972. 20 pp. 7 figs. Preliminary results of an experiment in seismic holography indicate that the techniques of acoustical holography may be successfully used with seismic waves to determine the size and general shape of underground objects.

This experiment was carried out under field conditions on a moderately large scale compared with the typical laboratory experiments in acoustical holography. The object to be mapped was a 100-foot-diameter, spherical, low-velocity zone of explosively fractured rock in oil shale at an average depth of 80 feet. The seismic wavelength of the Fourier component wave used in making the seismic holograms was 50 feet at a frequency of 140 cps. The hologram sampling aperture was 226 feet square and was sampled by 441 geophones in a 21 by 21 rectangular array.

RI 7608. Washability Examinations of Core Samples of San Juan Basin Coals, New Mexico and Colorado, by A. W. Deurbrouck. 1972. 26 pp. 1 fig. This re-

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port describes the washability characteristics of 18 coal samples taken from 11 drill hole cores from the San Juan Basin area of New Mexico and Colorado. The ash content of these coals could generally be substantially reduced by removing the heavy impurities. The coals were characteristically low in sulfur content; only one sample contained more than 1 percent sulfur after removing the sink-1.50 specific gravity material.

The coals ranged in rank from subbituminous C to high volatile C; 11 of the samples were subbituminous A.

RI 7609. Mercury in Some Coals of the United States, by M. D. Schlesinger and Hyman Schultz. 1972. 11 pp. Mercury exists in coal in minute quantities, but the large tonnages of coal consumed could represent relatively large amounts of mercury entering the environment. Limits have not been placed on the emission of mercury, and it is important that reliable analytical methods be available to the chemist.

The Bureau of Mines has evaluated analytical techniques used by a number of laboratories; most used vapor phase atomic absorption as the final detection method. Neutron activation was used by some of the laboratories. All of the methods described could be applied, but they require careful manipulation to prevent loss or mercury contamination. In the samples analyzed, the mercury content ranged between 0.05 ± 0.01 and 0.41 ± 0.06 part per million.

RI 7610. Electrostatic Separation with Photoelectric Charging, by Foster Fraas. 1972. 14 pp. 4 figs. In this Bureau of Mines report, the use of the photoemission of electrons to produce electric charges for the electrostatic separation of sonic dispersed minerals, which had previously been ground to pass a 43μ -opening sieve, is demonstrated. It appears that many of the oxides, carbonates, sulfides, and arsenides will respond to photoemission. Minerals least responsive are the oxides of silicon, the oxides of aluminum, and minerals that have a high concentration of these oxides. Although several synthetic ore mixtures did not yield to complete separation in a one-stage operation, it is probable that preliminary neutralization of the initial electric charges produced by powder dispersion will provide complete separation. That the separation can be carried out in air and without the use of reagents or heating, which are required in the present practice of electrostatically separating coarse granular feeds, is of special significance.

RI 7611. Evaluation of a Radioisotopic X-Ray Drill Hole Probe: Delineation of Lead Ores, by Harold E. Marr III and William J. Campbell. 1972. 28 pp. 7 figs. The Bureau of Mines evaluated two drill-hole probes for the delineation of Missouri lead ores. The battery-powered, portable instruments, weighing less than 30 pounds, were designed for logging holes of 1.8 inches in diameter or larger. These probes have dual scintillation detectors, balanced filters with a pass band for lead $K\alpha$ radiation, and a cobalt-57 source of radiation. The results of field tests in Missouri confirm laboratory tests indicating that probe response can be correlated to lead ore grade using counting times of 10 seconds or less at any selected depth in the hole.

RI 7612. Effect of Preheating Upon Metallization of Iron Ore Pellets, by R. B. Schluter and P. L. Ruzzi. 1972. 22 pp. 14 figs. Drying and pre-

heating (partial induration) of green, unfired iron ore pellets is a means of reducing the energy required to produce metallized pellets. The Bureau of Mines processed three magnetite and two hematite concentrates through the unit operations of pelletizing, preheating in air, and reduction to metal to determine the effects of preheating upon the properties of the metallized pellets.

The pellets were prepared in a 16-inch-diameter laboratory balling drum. Preheating and metallization were carried out in an externally heated 4-inch-ID by 4-inch-long stainless steel drum using air for the preheating atmosphere and lignite char as a reductant. The results varied considerably; two of the magnetites spalled when preheated in air at temperatures of 900°C and above, and the third magnetite and the hematite flotation concentrate required complete induration at $1,300^\circ\text{C}$ to produce satisfactory pellets. The earthy hematite ore yielded excellent pellets at all preheat temperatures.

RI 7613. High-Speed Photography Studies of Laboratory Cratering in Tennessee Marble Plates, by Joseph L. Condon and Dennis V. D'Andrea. 1972. 18 pp. 13 figs. High-speed movies were taken of crater experiments in two-dimensional plates of Tennessee marble to study craters being formed primarily by stress-wave action. The contribution of gas action to the cratering process was minimized because the two-dimensional models did not contain the expanding gases from the explosive. Four burdens were studied for solid plates and one burden for a segmented plate. After cratering, the plates were reassembled for dye penetrant studies of the fracturing. Flyrock velocities were calculated and related to the degree of fracturing, and compared with those from quarry shots. In general, the smallest burdens produced the highest flyrock velocities and the least amount of fracturing. Flyrock velocities compared favorably with initial flyrock velocities in quarry blasts, but did not show step accelerations owing to gas effects as did the quarry blasts. The test with a segmented plate was used to simulate cratering in a jointed material and showed that stress-wave effects can be important for crater formation in jointed rocks.

RI 7614. Selective Oxidation of Automobile Scrap, by R. E. Peterson and Charles Prasky. 1972. 19 pp. 10 figs. Scrap iron is partially oxidized at elevated temperatures in the selective oxidation process to produce iron oxide and a dense residual metal of high purity. Investigation of the process was confined to converting automobile hulks into useful products. In one test series, compressed, sheared automobile scrap was processed at $1,000^\circ\text{C}$ in a 36-foot-long rotary kiln at feed rates ranging from 300 to 1,200 lb/hr. Less fuel was required to maintain the temperature at the higher feed rates because of the heat generated from the burning of the combustibles and the oxidation of the iron. The bulk density of the residual metal exceeded 75 pounds per cubic foot.

In an attempt to lower the quantity of contaminants in the residual metal, another test was designed using automobile hulks that had been prepared by ripping, a low-cost method of scrap fragmentation. Before oxidizing the ripped scrap, approximately 62 percent of the total copper was removed in a tumbling, screening, magnetic separation, and hand-sorting system. Cast iron made from the residual metal obtained by selective oxidation contained 0.15 percent copper; iron oxide scale obtained from the kiln averaged 0.13 percent copper. Pellets made from the scale demonstrated compres-

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sive strengths necessary for blast furnace reduction; lead and zinc were removed by volatilization when the induration was performed in a reducing atmosphere.

RI 7615. An Experimental Study of Particle Size and Size Distribution of Minerals Crushed by Impact, by Hillary W. St. Clair and Raymond E. Brown. 1972. 19 pp. 6 figs. This report gives the results of an experimental study of the progressive changes that occur in particle size and size distribution when a homogeneous and isotropic mineral is subjected to crushing by impact. The mineral used in the study was uniformly sized quartz, which was crushed in a simple drop-weight machine that applied impact energy up to about 100 kg-cm per g. Screen analyses of the crushed products were effected by the method of moments to determine the mean size, variance, skewness, and kurtosis.

Analysis of the data from these experiments shows that the mean size of the crushed product is a function of the energy input and the initial size. The size distribution is functionally related to the degree of size reduction. As the mean particle size is decreased, at first there is a corresponding increase in the variance and decrease in the skewness. But, as size reduction is carried further, each tends eventually to approach a steady value, and the form of the size distribution becomes stable.

RI 7616. Preparation Characteristics of Coal From the Ohio Coalfield, by John E. Zeilinger. 1972. 72 pp. 3 figs. This Bureau of Mines report describes the preparation characteristics of the significant coalbeds of the Ohio coalfield. Washability analyses were made on 39 coalbed samples collected from a 14-county area. None of the samples were of metallurgical quality as received. Nine of the samples could be sufficiently upgraded to produce metallurgical-grade products, and the remaining 30 samples could not be upgraded to this quality because their sulfur contents could not be lowered to meet the standard. For steam or power generation, 10 of the samples were of medium sulfur content as received and one could be upgraded to a low sulfur content. Of the 29 samples having a high sulfur content as received, 18 could be upgraded to a medium sulfur content. The original sulfur content of the other 11 samples having a high sulfur content as received can be appreciably reduced by removal of the sink 1.58 specific gravity material; however, these coals would be classified as high sulfur coals both before and after removals of the sink 1.58 specific gravity material.

RI 7617. Recovery of Aluminum, Base, and Precious Metals From Electronic Scrap, by T. A. Sullivan, R. L. de Beauchamp, and E. L. Singleton. 1972. 16 pp. 8 figs. The processing of sweated aluminum electronic scrap was investigated to develop methods for recovering the aluminum and concentrating the other metals, including copper, lead, gold, and silver, into a product that can be separated by known methods. Two molten-salt electrolytic processes were developed and tested. The first process utilized a three-layer refining cell with a $\text{BaCl}_2\text{-NaF-AlF}_3$ electrolyte, which operated at 750° to 850° C. The second process used an all-chloride electrolyte of NaCl-KCl-AlCl_3 at 750° to 800° C, with separate anode and cathode compartments. High-quality aluminum that averaged 99.8-percent pure in the three-layer cell and 99.6-percent pure in the compartment cell was recovered. Over 94 percent of the aluminum was recovered with cathode current efficiencies of approximately 90 percent in both methods. The

copper, lead, tin, silver, gold, and other metals were concentrated threefold in an anode product. Separation of lead and part of the tin by liquation from this product seemed feasible. The anode product was smelted to prepare a 96-percent copper bullion that contained 690 ounces of silver and 65 ounces of gold per ton, with 98 percent recovery of these values.

RI 7618. Effect of Tapioca Flour on the Anionic Flotation of Gangue From Iron Ores, by A. F. Colombo. 1972. 18 pp. 7 figs. The differences in starch demands that occur between ore types subjected to the anionic flotation of calcium-activated gangue and the range of residual starch contents expected to give the best metallurgical response were evaluated on a batch and pilot plant basis. A phenol-sulfuric acid procedure was used to determine the residual starch contents in the iron ore slurries.

Three pilot plant campaigns on samples from a group of orebodies located on the Marquette Range, Michigan, showed that in the rougher flotation pulp, a residual carbohydrate range of 25 to 100 ppm, which is equivalent to a 0.5-lb/short ton spread, yielded optimum results. Concentrates assaying at least 65 percent Fe and less than 6.0 percent SiO_2 and containing more than 80 percent of the recoverable iron were obtained. Both batch and continuous research indicated that starch adsorption is calcium modulated and relatively unaffected by the fatty acid additions employed. Residual starch level is not a critical control factor, but the addition must be adjusted to about 25 to 50 ppm residual starch and kept in this range for most effective utilization of the added tapioca flour.

RI 7619. Skid-Resistance and Durability of Fly Ash-Rubber Mixtures, by John P. Capp and Leo Makovsky. 1972. 11 pp. 5 figs. Addition of sintered fly-ash/bottom-ash mixtures to rubber formulations failed to increase the skid resistance of the resulting products. Wear, tensile and hot-tear strengths, and resilience of the ash-rubber material, as determined in laboratory tests, were significantly less than that of comparable rubber. The material appeared unsatisfactory for automobile and truck tire manufacture, but might prove suitable as a filler in other rubber goods. Raw fly ash could not be satisfactorily compounded with rubber.

RI 7620. Thermal Degradation of Green River Kerogen at 150° to 350° C—Rate of Product Formation, by J. J. Cummins and W. E. Robinson. 1972. 15 pp. 6 figs. Green River oil shale previously extracted by benzene was heated at 150°, 200°, 250°, 300°, and 350° C for 0.5 to 360 days to determine the rate at which kerogen degrades to thermal products, the types of thermal products formed, and the effect of prolonged low-temperature heating (preheating) upon subsequent assay yields. Thermal decomposition of kerogen at 150° to 350° C is treated as a first-order reaction. The specific reaction rate for kerogen decomposition increases from 2.2×10^{-4} per day at 150° C to 2.0×10^{-1} per day at 350° C. The calculated kerogen activation energy is 19 kcal. Variations in the rate of formation of individual type components of the pyrolytic products were found. Carbon balances show an increase in the amount of kerogen converted to bitumen and oil (from assay of preheated oil shale) as the temperature of preheating increased from 150° to 350° C. The total product from shale preheated at temperatures of 150° and 200° C gave less than 100 percent of Fischer assay yields while the total products from

shale preheated at temperatures of 250° to 350° C gave greater than 100 percent of Fischer assay yields.

RI 7621. Numerical Methods for Determining Streamlines and Isopressures for Use in Fluid Flow Studies, by R. V. Higgins and A. J. Leighton. 1972. 60 pp. 9 figs. A numerical method is presented to calculate the isopressure (isobar) lines and streamlines for an oilfield from the pressure distribution. A knowledge of these lines is useful in the study of the flow of fluids in underground reservoirs, especially for those containing gaseous and/or liquid hydrocarbons. This work was done primarily to enable determination of the shape factors needed in the calculation of petroleum reservoir performance. However, it has application for the flow of water in aquifers, or electricity or heat in odd-shaped geometry. Techniques previously developed were used to calculate the pressure distribution. From this pressure distribution, the isopressure lines were calculated accurately by the method presented in this paper. Then by successively projecting orthogonal lines from one isopressure line to another, the streamlines are determined. From the coordinates of the isopressures and the streamlines, the shape factors can then be determined by a published method.

Computer methods are presented to calculate the streamlines and isopressures for any well-spacing pattern existing within a field with multiple wells. The method reproduces the flow net for several well configurations having extensive geometrical variations. Such information provides the petroleum engineer with data from which he can compute oil recoveries for different patterns and thereby maximize the recovery of hydrocarbons from the reservoir.

RI 7622. Continuous Gaseous Direct Reduction of Low-Grade Iron Ore in a Fluid-Bed Reactor, by E. G. Davis, J. O. Crabtree, and I. L. Feld. 1972. 19 pp. 6 figs. The gaseous direct reduction of low-grade iron ore concentrates in a continuous fluid-bed reactor was investigated. These studies were made in a 4-inch-diameter fluid-bed reactor using hydrogen alone, and oxygen- or air-reformed natural gas as the reductants. The percent reduction was directly dependent on the mole ratio of hydrogen in the reducing gas to the oxygen associated with the iron oxide in the ore.

Two- and three-stage fluid-bed tests were simulated by repeated continuous tests. The results showed that percent reduction of the final product was dependent on the mole ratio of the quantity of hydrogen in the gas of each stage to oxygen in the iron oxide of the initial ore feed.

Reduction as high as 87 percent in the single stages and as high as 94 percent in the multistages was obtained when either hydrogen or reformed natural gas was used as the reducing gas.

RI 7623. Photoelectric Concentrator for the Wet Concentrating Table, by R. A. Welsh and A. W. Deurbrouck. 1972. 7 pp. 3 figs. The Bureau of Mines has developed a photoelectric concentrator apparatus which is capable of collecting incremental products from the discharge of wet concentrating tables. The instrument uses photoelectric cells as sensors to differentiate between two products which have differences in color or reflectivity. The photocells provide a signal that controls a mobile splitting device that separates the products. Tests conducted on a wet table demonstrated the ability of the apparatus to separate a product containing 81.5 percent pyrite from a lower grade product containing only

68.8 percent pyrite. The photoelectric concentrator should have a broad application for collecting concentrates with visible color or reflectivity differences from wet concentrating tables. Work done under an agreement with the Office of Air Programs of the Environmental Protection Agency.

RI 7624. A Thousand-Ton Capacity Stiff Testing Machine, by F. G. Horino, B. T. Brady, W. I. Duvall, and V. E. Hooker. 1972. 19 pp. 9 figs. This report presents the theory and design of a stiff loading machine used by the Bureau of Mines. The machine incorporates three high-strength steel columns as the restraining member in parallel with the specimen. The theory presented gives the basis of design and the dimensions of component parts of the machine. Laboratory verification of the theoretical stiffness is described using three different setups involving a hydraulic jack and spacers and confirms the stiffness calculations to within 1 percent. Experimental techniques, testing procedures, and special equipment designed for determining the complete stress-strain behavior of NX cores of both hard and soft rock are described. Typical test data are presented as force-displacement curves for two rock types, a marble and a granite.

RI 7625. Flame Spread Evaluation of Ventilation Cloth, by E. M. Murphy. 1972. 9 pp. 5 figs. Comparative data from ASTM method of test E-162 and large-scale trials in the Experimental Mine show that the flame-spread quality of brattice cloth and other ventilation control materials can effectively be evaluated by either method. Materials having a flame spread index of 25 or less, as determined by the simpler and more economical laboratory test ASTM E-162, do not present a serious fire hazard when used in coal mines.

RI 7626. A Least Squares Method for Improving Rock Noise Source Location Techniques, by Fred Leighton and Wilbur I. Duvall. 1972. 19 pp. 7 figs. The least squares method of rock noise source location presented is shown to be more accurate and reliable than standard direct solution methods. This method is particularly effective in improving solutions from rock noise locations outside of geophone array boundaries. A least squares solution for a medium in which the seismic velocity is the same in all directions is also presented. In this special case, one can solve for both the source coordinates and the velocity.

RI 7627. Flash Reduction of Iron Ore in a Coil Reactor, by E. G. Davis and I. L. Feld. 1972. 10 pp. 1 fig. The flash reduction of fine iron ore in a dilute-phase system was investigated at 500° to 900° C within a heated stainless steel tubular coil. Alabama brown iron ore and Mesabi semitaconite ore were fed into the coil concurrently with reducing gases of hydrogen and reformed natural gas, so that the velocity of the gas at the reaction temperature was sufficient to entrain and pneumatically transport the solids through the coil. Reduction is very rapid with retention time of the ore in the coil varying from 4 to 15 seconds. Variables affecting reduction are temperature, ore feed rate, and gas flow or velocity. Results of the studies show that a partially reduced product (10- to 25-percent reduction) can be made which, on subsequent magnetic concentration, yields a concentrate containing 64 to 70 percent iron with a 90- to 94-percent iron recovery. Maximum reduction of 77 percent was obtained when hydrogen was used in a four-stage reduction test to yield a product containing 61 percent metallic iron. Work done in cooperation with the University of Alabama.

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RI 7628. Use of Steam To Control Respirable Coal Dust at the Point of Generation, by A. J. Strazisar, R. L. Stein, and T. F. Tomb. 1972. 8 pp. 4 figs. The Bureau of Mines conducted a laboratory investigation to study the effectiveness of low-pressure steam and water spray in suppressing respirable dust at the tips of a saw-type cutting wheel. Suppression efficiencies were found to be proportional to the amount of the water or steam applied at the cutter tips. For equivalent water output rates, a maximum efficiency of approximately 80 percent was reached for both steam and water spray. Results from the steam and water spray tests showed an increase in suppression efficiency with an increase in particle size of 1 to 8 micrometers. The data indicate no advantages for using steam as a dust suppressant.

RI 7629. Electrolytic Preparation of Beryllium-Copper Alloys, by D. E. Kirby, D. A. O'Keefe, and T. A. Sullivan. 1972. 14 pp. 8 figs. In the preparation of beryllium-copper alloys by fused-salt electrolysis, beryllium was electrowon from beryllium oxide dissolved in fluoride electrolytes and deposited on copper cathodes. At 870° to 1,030° C, deposition was on solid cathodes. Beryllium deposited on the copper, forming a liquid alloy that dripped from the cathode. Dripping alloys containing 3 to 4 weight-percent beryllium were produced with as high as 90 percent cathode current efficiency, by electrolysis at 910° C. To prepare alloys of higher beryllium content, attempts were made at depositing beryllium on liquid copper cathodes. These efforts were generally unsuccessful, although alloys containing as much as 12 percent beryllium were prepared by this method. At temperatures of 1,100° to 1,300° C, requisite to maintaining beryllium-copper compositions as liquids, the beryllium reacted with cell structures.

RI 7630. Use of Preheated Coal in Carbonization, by D. E. Wolfson. 1972. 8 pp. 1 fig. The Bureau of Mines investigated the use of preheated coal in carbonization operations. Liquor yields and coking times were reduced, coke quality was improved, and smokeless pipeline charging to coke ovens should eliminate a serious source of pollution. Work done in cooperation with the National Steel Corp.

RI 7631. Pulverizing Lignite in a Ring Roller Mill, by Robert C. Ellman, Leroy Dockter, and John W. Belter. 1972. 25 pp. 7 figs. The Bureau of Mines studied lignite pulverization in a laboratory ring-roller mill. Both moisture content and the source of lignite were found to be important factors in pulverizer operation. Reduction of moisture content increased capacity and reduced power consumption, but predrying is more effective than in-the-mill drying in improving pulverizer operation. A combination predrier-crusher system produced significant improvements but other efforts to improve in-the-mill drying in the test mill were unsuccessful. Pulverization of frozen lignite was found to seriously reduce pulverizer capacity and increase power requirements.

RI 7632. Contribution of Some Carbonyl, Phenol, and Hydrocarbon Components to Diesel Exhaust Odor, by James W. Vogh. 1972. 11 pp. The report covers initial findings in an experimental program to identify diesel exhaust odorants and determine their contributions to diesel odor. The approach was to isolate selected component groups from exhaust and to evaluate the contribution of each group to exhaust odor. Results were obtained for those carbonyls and phenols that could be isolated from exhaust through intermediate conversion to oxime derivatives. Unsaturated aliphatic aldehydes and sterically hindered carbonyls were not

included. Hydrocarbons intermediate in the diesel range were also evaluated and an odor contribution was found from those of the aromatic group. The evaluated carbonyls, phenols, and hydrocarbons were found to account for about 20 percent of the total odor in exhaust from an indirect-injection engine during idle. For exhaust from the indirect-injection engine operating under load and from a direct-injection engine at no load, these compounds were found to have no significant levels of odor. Work done under an agreement with the Bureau of Air Pollution Sciences of the Environmental Protection Agency.

RI 7633. Sulfur Reduction Potential of the Coals of the United States, by A. W. Durbrouck. 1972. 289 pp. 122 figs. This report presents the results of a washability study of 322 coal mine samples showing the sulfur forms and distribution in the coals. The samples were collected from mines which were principally utility coal producers. Generally, the data show that the total sulfur content of the coals evaluated could be significantly reduced by some combination of stage crushing and specific gravity separation. However, few coals could be upgraded to a final product containing 1 percent or less total sulfur. The complete washability data are presented for each sample processed. A statistical evaluation is included for the coalbeds from which more than 10 samples were collected and for the geographical coal producing regions. A graphical summation is presented for the coal producing regions and selected coalbeds. Work done under an agreement with the Office of Air Programs, Environmental Protection Agency. (Out of print.)

RI 7634. A Field Survey of Emissions From Aircraft Turbine Engines, by F. W. Cox, F. W. Penn, and J. O. Chase. 1972. 28 pp. 7 figs. Exhaust emissions were measured from 25 aircraft turbine engines using Jet A fuel. Analytical apparatus, procedures, and results are described. Carbon monoxide, carbon dioxide, nitric oxide, nitrogen dioxide, and aldehydes were measured at engine operating modes representing power levels used in airline operation. Carbon monoxide, hydrocarbon, and aldehyde emissions were highest at idle and lowest at takeoff; oxides of nitrogen were lowest at idle and highest at takeoff. Of the total oxides of nitrogen emitted, nitrogen dioxide constituted from 10 to 100 percent, depending on the exhaust gas temperature. Engines retrofitted with smoke-reducing burner cans produced less carbon monoxide, hydrocarbon, and aldehyde emissions, and slightly more oxides of nitrogen than engines with standard burner cans. Work done under an agreement with the Office of Air Programs of the Environmental Protection Agency.

RI 7635. Identification and Analyses of Copper-Base Alloys by Fluorescent X-Ray Spectrography, by William J. Campbell and Harold E. Marr III. 1972. 30 pp. 21 figs. Three types of X-ray analytical instrumentation were compared for applications in the secondary brass and bronze industry. The instruments were a conventional X-ray spectrograph, a portable X-ray spectrograph, and a radioisotopic X-ray analyzer using balanced filters. The following two general applications were considered: Rapid identification for sorting scrap metals and quantitative analyses to provide guidance in the melting and casting of alloys. Twenty-three analyzed copper-base alloys were used as standards. Although the alloys varied widely in composition, matrix correction procedures were not necessary except for copper. The conventional X-ray spectrograph provides positive identification of the alloys and quantitative values for the six elements investigated—aluminum, copper, iron, lead, tin, and zinc. Equivalent results were obtained with the portable X-ray spectrograph for

those elements whose characteristic X-rays are in the wavelength range of the instrument. The radioisotopic X-ray analyzer distinguishes certain groups of alloys and provides quantitative determinations for copper, lead, tin, and zinc. The sensitivity of the analyzer was marginal for the determination of small concentrations of elements of atomic number 26 or lower.

RI 7636. The Effect of Pulsation Damping on Respirable Dust Collected by Coal Mine Dust Personal Samplers, by J. A. Lamonica and Harry N. Treafis. 1972. 23 pp. 19 figs. The Bureau of Mines studied two types of approved coal mine dust personal samplers to determine the effect of decreasing the amplitude of airflow velocity fluctuations on cyclone performance. Results indicate that more dust is collected when pulsation free flow is used. Velocity fluctuations were reduced by means of a pulsation damper; damper efficiency of about 85 percent was needed to reduce the fluctuations to an acceptable level. The data were obtained employing both pulsating and nonpulsating flow. A comparison was made of (1) the masses of respirable coal dust as determined by weighing and of (2) the particle size distributions as determined by an electronic counter. An empirical relationship is given between the ratio of masses collected using pulsating and nonpulsating flow (M') and the ratio of the maximum air velocity to the minimum air velocity (V') as measured in the cyclone entrance channel.

RI 7637. Recovery of Zinc, Copper, and Lead-Tin Mixtures From Brass Smelter Flue Dusts, by H. E. Powell, H. Fukubayashi, L. W. Higley, and L. L. Smith. 1972. 8 pp. 3 figs. The smelting of brass and bronze generates a dust composed primarily of zinc oxide, with lesser amounts of other metal oxides, such as copper, lead, and tin. The small quantity of this waste generated by individual smelters and the relatively low unit value of the contained metals, suggests the desirability of reclaiming the metals onsite or at some nearby point. The Bureau of Mines has developed a process that fits these requirements. The technique consists of (1) dissolving zinc and copper from the dust with sulfuric acid, (2) recovery of copper by cementation, (3) recovery of zinc as zinc sulfate crystals, and (4) recovery of lead and tin as a salable residue. Alternatively, zinc may be recovered by electrodeposition. Free acid is recycled and no major pollution problems are generated by the process.

RI 7638. Kinetics of Thermal Decomposition of Copper (II) Sulfate and Copper (II) Oxy-sulfate, by I. D. Shah and S. E. Khalafalla. 1972. 21 pp. 10 figs. Thermal decomposition of copper (II) sulfate (CuSO_4) and copper (II) oxy-sulfate ($\text{CuO} \cdot \text{CuSO}_4$) are important steps in the overall oxidative roasting of covellite (CuS) and chalcocite (Cu_2S). Nonisothermal thermogravimetric techniques were used to investigate the decomposition reactions in flowing N_2 and air. Thermal decomposition of CuSO_4 and $\text{CuO} \cdot \text{CuSO}_4$ followed "linear" kinetics with an apparent activation energy of 55 ± 2 and 66 ± 3 kcal per mole decomposed, respectively. These apparent activation energies comply with those previously reported when isothermal kinetic techniques were used. The addition of oxygen decreased the rate of decomposition, while small amounts of iron which were admixed with $\text{CuO} \cdot \text{CuSO}_4$ did not have a significant effect. Neither oxygen nor iron had any appreciable effect on the apparent activation energy of the decomposition reaction.

RI 7639. Compressibility Data for Helium, Nitrogen, and Helium-Nitrogen Mixtures at 0°, 25°, and 50° C and at Pressures to 1,000 Atmospheres, by Ted C. Briggs and Alvin R. Howard. 1972. 194 pp. 7 figs. A special high-pressure Burnett-type compressibility apparatus was constructed and used to determine

compressibility factors for pure helium, pure nitrogen, and nine helium-nitrogen mixtures containing 89.47, 79.04, 69.69, 60.09, 49.24, 41.02, 30.99, 20.53, and 10.67 mole-percent helium. A total of 161 runs were made consisting of 2,355 observed pressures. Data were obtained at 0°, 25°, and 50° C at pressures to 1,000 atmospheres. A power series in the reciprocal volume, commonly called a Leiden series, is used to represent the compressibility factors. Three parameters in the series are required to represent helium, five parameters to represent nitrogen, and from three to five parameters to represent the mixtures. Compressibility factors are believed to be accurate to better than 0.1 percent over the entire pressure, temperature, and composition range. GPO Stock No. 2404-1103. \$2.00.

RI 7640. Methane and Dust Control by Water Infusion. Pittsburgh Coalbed (Fairview, W. Va.), by Abdurrahman Cetinbas, R. P. Vinson, Joseph Cervik, and M. G. Zabetakis. 1972. 17 pp. 13 figs. The effect of water infusion on the flow of methane and on the production of dust was investigated at an active face in the Pittsburgh coalbed. The average total flow of methane at the face decreased by approximately 79 percent, whereas the flow from the ribs increased about 24 percent after infusion. On the day after infusion, dust concentrations appear to have been reduced; however, the presence of large quantities of rock dust obscured the results on the following days.

RI 7641. Ultrafine Grinding of Several Industrial Minerals by the Attrition Grinding Process, by Martin H. Stanczyk and I. L. Feld. 1972. 25 pp. 8 figs. Ultrafine grinding of the industrial minerals, mica, pyrophyllite, talc, marble, barite, and fluorite was accomplished using the Bureau-developed and patented attrition-grinding process. The materials, representing minerals of diverse physical characteristics, were batch ground in a 10-inch-diameter machine using statistically designed experimental test programs. The tests were made to determine large effects of variables such as feed pulp density, grinding medium size, and quantity of the electrical energy consumed during grinding on product particle size and bulk density. In designing the test programs, it was assumed that there was no interaction between the variables. Relatively coarse commercial flotation concentrates of mica, barite, and fluorspar and mine-run products of pyrophyllite, talc, and marble were readily ground into sub sieve size ranges. Considering the great amount of particle size reduction obtained, the electrical energy requirements for grinding were very low. In general, the test results indicated that the best conditions for particle size reduction were approached when grinding with the coarser fraction of sand grinding media, the higher sand-to-mineral weight ratio, and the higher feed pulp density. Work done in cooperation with the University of Alabama.

RI 7642. Dispersal of Coal and Rock Dust Deposits, by J. M. Singer, E. B. Cook, and J. Grumer. 1972. 32 pp. 8 figs. The objective of this investigation was to determine minimum air velocities and entrainment rates for coal and rock dust dispersion in wind tunnel experiments under conditions that simulate dispersion from surfaces in coal mines where airflows are induced by weak gas explosions. Dust deposits were bed- or ridge-shaped; particle sizes were 6 to 80 microns (cohesive deposits) or 100 to 150 microns (free-flowing deposits); and wind tunnels were 7.62 cm wide by 5.08 cm high by 300 cm long, and 2.4 m wide by 1.5 m high by

215 m long. The investigation showed that minimum air velocities (directed at midheight) of separate, layered, or mixed piles of coal dust and rock dust were within the range 5 to 30 m/sec, independent of size of wind tunnel. This finding considerably facilitates scaling of data to mine-size passageways. Free-flowing deposits dispersed relatively slowly by single-particle detachment; cohesive dusts dispersed faster by the breaking and lifting of large clumps along weak failure flames; particle dispersion occurred in flight. Layered or mixed deposits of coal and rock dust did not disperse selectively. Semi-empirical expressions were derived relating minimum air velocities and dispersion rates to dust-pile geometry, cohesion, porosity, and bulk density.

RI 7643. Creep and Other Properties of Zinc-Copper-Titanium Alloys Annealed After Rolling, by L. A. Neumeier and J. S. Risbeck. 1972. 31 pp. 9 figs. The Bureau of Mines evaluated creep properties of Zn-Cu-Ti alloys that were annealed after finish rolling, either cold or at 480° F (249° C). Compositions ranged up to 1.25 pct Cu and 0.36 pct Ti. Most data are for sheet annealed after finish rolling to 92-pct total reduction. Annealing times were varied at temperatures between 320° and 560° F (160° and 293° C). For a number of the alloys, annealing after hot rolling at 480° F affects creep properties very differently in longitudinal and transverse sheet directions. The detrimental result is that the anisotropy in creep properties between the two directions can be vastly increased. Conversely, specific annealing treatments of certain heavily cold-rolled alloys result in surprisingly low anisotropy in creep properties and the low anisotropy coincides with excellent creep resistance for both directions. Supplemental data are presented on tensile, hardness, and thermal expansion properties and microstructures.

RI 7644. Strongly Caking Coal Gasified in a Stirred-Bed Producer, by P. S. Lewis, A. J. Liberatore, and J. P. McGee. 1972. 11 pp. 4 figs. Shortage of natural gas is reviving interest in low-Btu fuel gas made by gasifying coal in fixed-bed producers. The Bureau of Mines gasified strongly caking Pittsburgh bed coal over test periods lasting 4 days in an experimental gas producer located at Morgantown, W. Va. Mechanical stirring throughout the fuel bed was effective for keeping the fuel moving and this stirring made the operation successful; hence, the gas producer was named the stirred-bed producer. Nuclear density gages were applied as control instruments to indicate coal flow and fuel level and to record the frequency and location of void spaces in the bed. The gas, of nominal 140 to 165 Btu/scf calorific value, could be burned in a boiler for generating steam.

RI 7645. A Method for the Prediction of Stresses in an Isotropic Inclusion or Orebody of Irregular Shape, by Martin S. Oudenhoven, Clarence O. Babcock, and Wilson Blake. 1972. 36 pp. 20 figs. This report describes the results of a Bureau of Mines investigation in which the stress concentrations and distributions caused by inclusions in a strained elastic plate were determined. Finite element analyses were made for 168 models containing single inclusions of elliptical, ovaloidal, and rectangular shape. The variables studied included the following: horizontal-to-vertical loading ratios, (S_h/S_v) of 0, 0.33, 0.5, and 1.0; width-to-height ratios (w/h), of 0.25, 0.5, 2, and 4; and Young's modulus of inclusion to Young's modulus of plate ratios (K ratios) of 0.33, 0.5, 2.0, and 5.0. The results show that the theory for ellipti-

cal inclusions can accurately predict the average stress along the x and y axes of symmetry for circular, ovaloidal, and rectangular inclusions from the width-to-height and K ratios. The actual inclusion shape was insignificant, suggesting that the average stresses in other inclusions of irregular shape (orebodies) can be estimated with the theory for an elliptical inclusion. An application of this technique to mining problems is presented. The stresses in the elliptical inclusions were uniform throughout the inclusion for all the models studied.

RI 7646. Blending Crushed Coal by Recycling Through a Bin Equipped With a Particle Distributor, by James L. Konchesky. 1972. 10 pp. 7 figs. Crushed coal, consisting of a wide range of sizes, was effectively blended by recycling it through a bin equipped with a particle distributor. Vertical blending was accomplished by simply recycling the coal; it was not significantly influenced by the horizontal blending that was achieved by the distributor. The method was effective, even though the coal was wet and possessed poor flowing characteristics. Recirculation appears capable of providing uniform blends of solids that can be more efficiently processed. Recirculation also appears useful, preceding packaging operations, to insure for blending of solids into specification products. Continuous measurement of the bulk density of the coal by a gamma ray meter proved to be an effective monitor of vertical blending effectiveness.

RI 7647. Activity Patterns in the Catalytic Reduction of SO_2 on Some Transition Elements in Alumina, by L. A. Haas, T. H. McCormick, and S. E. Khalafalla. 1972. 14 pp. 4 figs. SO_2 reduction with CO was studied in an integral flow reactor at a nominal flow of 0.5 liter per minute. Reactant gas contained 3 percent SO_2 , 6 percent CO, and the balance He. SO_2 conversion was determined for three different types of catalysts. The first consisted of 16 commercial catalysts used for various chemical syntheses. Only the commercial catalysts which contained transition metals in alumina removed more than 30 percent SO_2 at temperatures below 510° C. Two other types of catalysts were prepared in the laboratory either by pelletizing equal amounts of powdered alumina and transition metal oxides or by impregnating commercial alumina tablets with transition metal ions. Regardless of preparation techniques, Cr and Fe in alumina were the two best catalysts. The observed results suggest that an intermediate (SCO) is formed by the interaction of surface metal sulfides and carbonyls. Alumina then catalyzes the interaction of SCO with SO_2 to form the end products (sulfur and carbon dioxide). Over 80 percent SO_2 was removed at 460° C with 2 grams alumina impregnated with 2.5 percent iron.

RI 7648. Use of Composite Diaphragms in the Electrowinning of Titanium, by O. Q. Leone and D. E. Couch. 1972. 12 pp. 4 figs. Composite diaphragms were used in the investigation of electrowinning Ti from $TiCl_4$ in a fused $LiCl-KCl-TiCl_4$ electrolyte. Composite diaphragms tested were of two general classes—those consisting of two or more solid materials and those which contained, in addition, a loose material. An electrowinning cell using a flat diaphragm is described. The maximum current density for these diaphragms was 300 amp per ft^2 . Lower currents permitted longer operation times. The composite diaphragms gave electrode efficiencies that averaged approximately 60 percent, and the electrowon titanium was of good quality—some Brinell hardnesses were as low as 68.

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RI 7649. **Methane Flows in the Pocahontas No. 3 Coalbed**, by Fred N. Kissell. 1972. 19 pp. 7 figs. Methane-flow and pressure data taken from a mine in the Pocahontas No. 3 coalbed are compared with flow rates from lump coal obtained in laboratory experiments. From this, it is concluded that the main source of gas is the intact coalbed rather than a "crushed zone" near the working face. The permeability and sorption capacity of the intact coalbed are calculated and gas emission rates are theoretically accounted for.

RI 7650. **A Chemiluminescence Detector for Ozone Measurement**, by H. Carroll, B. Dimitriadis, and R. M. Ray. 1972. 17 pp. 12 figs. An ozone detector was built and evaluated for its applicability in smog-chamber studies. The detection method is based on the reaction of ozone with ethylene and the measurement of resultant chemiluminescence. In the first phase of evaluation, the detector's response to ozone was studied as a function of several instrument parameters, and optimum conditions were defined for the maximum and most stable responses to ozone. In subsequent evaluations, the method was checked for sensitivity, precision, and interferences and was compared with two alternative methods. Results showed the chemiluminescence method to be acceptably sensitive and precise for smog-chamber studies and superior to the Mast ozone meter and KI (colorimetric 1-percent neutral potassium iodide method) methods in that it is specific for ozone. Work done under an agreement with the Environmental Protection Agency.

RI 7651. **Recovery of Feldspar and Glass Sand From South Carolina Waste Granite Fines**, by W. H. Eddy, E. W. Collins, J. S. Browning, and G. V. Sullivan. 1972. 11 pp. 1 fig. The Bureau of Mines conducted laboratory batch and continuous flotation processing tests on waste granite fines from South Carolina to determine the possibility of recovering high-quality feldspar and glass sand. Three flotation systems were used for removal of the iron-bearing biotite. Two employed an alkaline anionic-cationic circuit and the third employed an acid cationic circuit. Commercial-grade products were obtained when the remaining biotite was magnetically removed from the feldspar and quartz concentrates. Continuous flotation processing yielded a feldspar concentrate containing, in percent, 3.60 Na₂O, 5.60 K₂O, and 2.25 CaO, with recoveries of 75.3, 66.6, and 72.6 percent, respectively. The feldspar tailing was high quality glass sand containing 98.0 percent SiO₂ and 0.025 percent Fe₂O₃; about 60 percent of the quartz was recovered. Work done in cooperation with the University of Alabama.

RI 7652. **Evaluation of The Sulfatization-Reduction Process for Recovering Manganese and Iron Oxide Pellets**, by John J. Henn, Robert A. Clifton, and Frank A. Peters. 1972. 27 pp. 9 figs. A process is evaluated for recovering metallurgical-grade manganese ore from the low-grade manganiferous iron ores of the Cuyunga Range, Minnesota. The process, developed by the Bureau of Mines, employs high-temperature sulfatization of the ore to form manganese sulfate and reduction of the ore to convert the iron to a magnetic oxide. The roasted ore is water-leached to dissolve the manganese sulfate, which is then separated from the leach residue, crystallized, and calcined to produce the manganese product. Iron is recovered from the leach residue by magnetic separation, and is pelletized and calcined to produce byproduct iron ore pellets. The fixed capital cost for a plant yielding a product containing 100 tons of

manganese per day is \$19.6 million; on a mid-1970 basis, when the raw ore contains 4.84 percent manganese. The estimated operating cost of the plant is \$211 per ton of contained manganese. Graphs are included to show the effects of ore cost and varying manganese content of the raw ore on the estimated operating cost.

RI 7653. **Ground Vibrations From Tunnel Blasting in Granite—Cheyenne Mountain (NORAD), Colo.**, by James J. Olson, David E. Fogelson, Richard A. Dick, and Arlo D. Hendrickson. 1972. 25 pp. 7 figs. The Bureau of Mines recorded peak particle-velocity levels and vibration frequencies to determine the nature and intensity of ground vibrations for tunnel blast rounds at the NORAD Complex, Colorado Springs, Colo. Previous Bureau of Mines studies in quarries and underground mines had shown that scaling (dividing) the distance from the blast by the square root of the charge weight removed the effect of the various charge weights on vibration amplitudes. The analysis of variance tests performed on the NORAD vibration data, however, indicated that the cube rather than square root scaling exponent grouped the data more effectively. The empirical propagation equation $V = 560 (D/W^{1/3})^{-2.04}$, where V is the maximum peak particle velocity in inches per second, D is the distance from the blast in feet, and W is the zero-delay charge weight in pounds described the attenuation, with distance, of the particle velocities from the tunnel blasts in the Pikes Peak Granite of the NORAD Complex.

RI 7654. **In Situ Determination of Stresses in Mountainous Topography**, by Verne E. Hooker, David L. Bickel, and James R. Aggson. 1972. 19 pp. 11 figs. Stress relief measurements were made at three underground test sites associated with the Henderson project, American Metal Climax, located in the rugged, mountainous region between Loveland Pass and Berthoud Pass on the Continental Divide in Colorado. Sufficient data were obtained to determine the three-dimensional stress ellipsoid for each site. The measurements were made at hole depths greater than one diameter of the mined opening; thus, calculated stresses are representative of premining in situ conditions. The vertical components of stress are in good agreement with overburden depth including the influence of mountain topography. Horizontal components of stress substantially increase with depth. These components are believed to be influenced by stresses presumably of tectonic origin. The largest measured principal stress was 5,900 psi at a depth of 3,708 feet. The predominant orientation of maximum principal stress for the determinations at greatest depth is in the NW-SE quadrants. The work upon which this report is based was done under a cooperative agreement between the Bureau of Mines, U.S. Department of the Interior, and American Metal Climax, Inc., Henderson project.

RI 7655. **Ternary Phase Diagram For the System Tetrabromoethane/Water/2-Propanol**, by John P. Gooch, E. K. Landis, and James S. Browning. 1972. 11 pp. 5 figs. Data for the ternary phase diagram for the system 1,1,2,2-tetrabromoethane/water/2-propanol at 25° C have been obtained. Experimental methods used are described, and the complete ternary phase diagram is presented. A simple example is given to review the use of the ternary diagram. Work done in cooperation with the University of Alabama.

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RI 7656. **The Solubility of 1,1,2,2-Tetrabromoethane in Water as a Function of Temperature**, by John P. Gooch, E. K. Landis, and James S. Browning. 1972. 18 pp. 3 figs. The solubility of 1,1,2,2-tetrabromoethane (TBE) in water was determined from 1.0° to 97.0° C. The solubility (S) of TBE in grams of solute per 100 grams water was correlated with

$$S = 1,920.55 \left[\exp \left(\frac{1,407,921.7}{T^2} - \frac{10,737.577}{T} + 9.9239624 \right) \right]$$

where T is in degrees Kelvin. A thermodynamic analysis conducted on a system consisting of a TBE phase and a water phase in equilibrium with a vapor phase led to the calculation of the activity coefficient, vapor-liquid equilibrium distribution coefficient, relative volatility, and heat of mixing for saturated solutions of TBE in water. Data required for these calculations were the solubility of TBE in water and the vapor pressures of TBE and water as a function of temperature. Work done in cooperation with the University of Alabama.

RI 7657. **Effect of a Surface Borehole on Longwall Gob Degassification (Pocahontas No. 3 Coalbed)**, by T. D. Moore, Jr., and M. G. Zabetakis. 1972. 9 pp. 4 figs. The use of a partially slotted 6.5-inch-inside-diameter vertical pipe to remove methane from a longwall gob area at a depth of 2,260 feet in the Pocahontas No. 3 coalbed was investigated. The value of gas removed by such a pipe under free-flow conditions was found to equal the cost of the installation in this case. Approximately 25 percent of the available methane passed through the pipe without the use of an exhaustor; an additional 10 percent was removed when an exhaustor was employed.

The diversion of methane through a vertical slotted pipe to the surface permitted the use of increased mining rates and decreased the ventilation air requirements.

RI 7658. **Methane Emission in Coal Mines—The Effects of Oil and Gas Wells**, by M. G. Zabetakis, T. D. Moore, Jr., A. E. Nagel, and J. E. Carpetta. 1972. 9 pp. 5 figs. The method of moving averages was found useful in assessing the nature of methane emission in coal mines. Emission rates were influenced markedly by the presence of abandoned oil and gas wells in the vicinity of the mine. Such wells appeared to increase the flow rate of methane into the mine by a factor of 2 to 30 in an active mine in the Pittsburgh coal seam.

RI 7659. **Lowering the Tin Content of Secondary Lead-Tin Bronze by Replacement With Lead or Zinc**, by E. R. Cole, L. W. Higley, and J. L. Holman. 1972. 12 pp. 3 figs. Laboratory heats of an 80 percent copper, high-leaded, tin-bronze alloy, similar to Brass and Bronze Ingot Institute (BBII) alloy 3A, were made with reduced tin content to determine whether an alloy comparable to BBII alloy 3A could be produced using less tin to aid in conserving this strategic metal. The tin content was lowered from 10 percent to 8 percent and 5 percent (nominal values), respectively, and the reduction in tin was offset by either increasing the lead content or adding zinc. Mechanical properties, machinability, and corrosion characteristics of the resultant alloys were investigated, and the mechanical properties were compared with BBII typical values and American Society for Testing and Materials (ASTM) minimums for high-leaded, tin-bronze alloy. Results indicate that the tin content of this alloy could be reduced approximately

1 percent (the difference between the 8.4 percent actual tin composition obtained and the 9.3 percent BBII minimum) without seriously affecting the desired properties. Results also show that the tin content can be reduced without significantly increasing the chances of rejects for mechanical property failures, which might result from normal variations in the casting process.

RI 7660. **Recovery of Silver and Mercury From Mill Tailings by Electrooxidation**, by B. J. Scheiner, D. L. Pool, and R. E. Lindstrom. 1972. 9 pp. 3 figs. Extraction of silver from silver mill tailings by an electrolytic oxidation procedure was investigated by the Bureau of Mines. Various parameters affecting silver extraction, such as electrolysis time, particle size, and dissolution of the silver as the tetrachloro or cyanide complex, were studied at 30° C with an electrolyte concentration of 20 weight-percent sodium chloride. Resulting silver extractions ranged from 77 to 90 percent, depending on the tailings being treated. Concomitant extraction of mercury ranged from 90 to 95 percent. Power consumption was 52 to 90 kilowatt-hours per ton for the tailings investigated. Comparative experiments using direct cyanidation resulted in the extraction of 46 to 82 percent of the silver and 20 percent of the mercury. Cyanide consumption ranged from 3.3 to 9.4 pounds per ton of tailings, depending on the tailings being treated. Silver and mercury were recovered from leach solutions by precipitation on iron powder, followed by conventional distillation and fire refining steps.

RI 7661. **Force Distribution in the High-Intensity Wet Magnetic Separator**, by Foster Fraas. 1972. 18 pp. 8 figs. A comparison has been made between cubes and spheres in the matrix of the high-intensity wet magnetic separator. For two inclined plane surfaces, such as may occur with cubes, the maximum force value, $H \frac{dH}{dx}$, is at the point of nearest approach

and is much higher than the force resulting from adjacent spheres. Although the maximum force value for cubes is higher, it decreases more rapidly at increasing distances. The maximum force for spheres is at an appreciable distance from the point of nearest approach. At field intensities for magnetic saturation of the iron spheres, the force extends to further distances with greater uniformity approximating that of the constant force or isodynamic field. The force is also independent of the sphere diameter, which permits the scaling of the sphere diameter to provide changes in particle migration distances without changes in force gradient.

RI 7662. **Recovery of Phosphates and Metals From Waste Phosphate Sludge by Solvent Extraction**, by Howard E. Powell, Lawrence L. Smith, and Andrew A. Cochran. 1972. 12 pp. 4 figs. A solvent extraction procedure was developed on a laboratory scale for recovering trisodium phosphate, zinc, and iron from waste phosphate sludge as separate products. The sludge was dissolved in hydrochloric acid, and iron was extracted as ferric chloride by isopropyl ether. Zinc was extracted by di-2-ethylhexyl phosphoric acid in kerosene. The efficiencies of the one- and two-stage extractions ranged from 98 to nearly 100 percent. Trisodium phosphate was recovered by crystallization from the raffinate. The value of the two marketable products is considerably more than the costs of the major reagent. The process was devel-

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oped to permit recycling of values in this waste and to consequently reduce stream pollution from this source.

RI 7663. Extraction Process for Upgrading Sm_2O_3 Using Selective Stripping Techniques, by D. J. Bauer, L. E. Schultze, and R. E. Lindstrom. 1972. 9 pp. 3 figs. A solvent-extraction system employing selective stripping of a preloaded organic phase was investigated for recovering Sm_2O_3 from a light-group rare-earth mixture. The samarium concentrated in the organic phase, and a >99-pct-pure samarium oxide product was obtained at 76-pct recovery in a 20-stage operation using di(2-ethylhexyl) phosphoric acid (EHPA) as the organic phase. The stripping agent was a 1.5-pct hydrochloric acid solution containing 200 g NH_4Cl per liter.

RI 7664. Synthesis and Characterization of Dawsonite, by J. Jackson, Jr., C. W. Huggins, and S. G. Ampian. 1972. 14 pp. 7 figs. Synthetic dawsonite [$\text{NaAl}(\text{OH})_2\text{CO}_3$] has been prepared with crystallinity similar to that of dawsonite found in oil shale deposits of the Piceance Creek area of Colorado. Optimum experimental conditions were as follows: Na/Al atomic ratio, 43; temperature, 175° to 200° C; pCO_2 , 15 psig; and reaction time, 5 hr. Chemical and spectrographic analysis revealed that the synthetic dawsonite was of high purity and was essentially stoichiometric. Similarity of the synthetic to natural dawsonite, demonstrated by X-ray diffraction, infrared spectrophotometry, and electron microscopy, suggests its suitability as a standard.

RI 7665. The Solution of Ventilation Problems With Analog and Digital Computers, by Richard J. Kline and Stanley C. Suboleski. 1972. 15 pp. 9 figs. The underground mining industry is presently using the fluid network analyzer and digital computer to analyze ventilation systems. The availability of the digital computer and ventilation programs to mining companies has escalated its use, permitting the design and modification of new or existing mine ventilation systems to be projected completely and thoroughly with consistent precision. Because the analog computer has been analyzing ventilation systems accurately for many years, a comparison of the analog and digital methods was warranted. This report summarizes a detailed comparison for one mine, based on parallel analyses by the two computer systems.

RI 7666. Pressure Distribution in Irregularly Bounded Reservoirs, by R. V. Higgins and A. J. Leighton. 1972. 15 pp. 2 figs. A numerical method is presented to calculate the pressure distribution in a petroleum reservoir that has irregular boundaries. The computer program is straightforward and requires minimal data preparation. The method can also be used to determine pressure distribution in many other types of underground reservoirs. In this method, the grid solution of the fluid-flow equations in a reservoir that has regular boundaries (previously published) was expanded to handle irregular boundaries. The computer program locates grid points at the irregular boundaries. The method of mirror images is then used to form a special stencil to determine the pressure at each of these points. Two examples are presented to demonstrate the applicability of the method for virtually any reservoir configuration.

RI 7667. The Methane Migration and Storage Characteristics of the Pittsburgh, Pocahontas No. 3, and Oklahoma Hartshorne Coalbeds, by Fred N. Kissell. 1972.

22 pp. 9 figs. Methane flows and pressures were measured in mines in the Pittsburgh, Hartshorne, and Pocahontas No. 3 coalbeds. From the data, the permeability of each of these coalbeds was computed. It was found to depend strongly on the type of coal and on the amount of water in the coalbed, and it was found to increase with time. All of the coalbeds had a high-permeability zone adjacent to the face or rib, and the Pittsburgh bed exhibited directional anisotropy. Surprisingly, little or no overburden effect was observed.

RI 7668. An In Situ Diffusion Parameter for the Pittsburgh and Pocahontas No. 3 Coalbeds, by Fred N. Kissell and R. J. Bielicki. 1972. 13 pp. 3 figs. In this report the importance of diffusion in controlling the emission of methane in mines is examined. An in situ diffusion parameter is defined and calculated for a hypothetical unfractured lump of coal in the Pittsburgh and Pocahontas No. 3 coalbeds. The values obtained are similar to those obtained with lump coal in laboratory experiments.

RI 7669. Analysis of Fracture Orientations for Input to Structural Models of Discontinuous Rock, by M. A. Mahtab, D. D. Bolstad, J. R. Alldredge, and R. J. Shanley. 1972. 76 pp. 18 figs. This report presents a new procedure for analyzing the orientations of rock fractures in an engineering site. This procedure, coded in a computer program, identifies clusters or groupings among the fracture orientations and calculates (1) the mean orientation of the fractures within each cluster and (2) the dispersion or scatter among these fracture orientations. Data points are represented by intersections of joint normals with the upper hemisphere, which is divided into 100 equal-area quadrilateral patches. The points in adjacent patches where the Poisson distribution test shows significant concentrations are assigned to a single cluster. For a cluster whose fracture orientations follow Arnold's hemispherical normal distribution, a confidence interval for the fracture orientation mean is calculated by applying Fisher's estimates. The technique is applied to the treatment of three examples.

RI 7670. Bureau of Mines Instrumented Impact Tester, by K. R. Becker, C. M. Mason, and R. W. Watson. 1972. 21 pp. 15 figs. The addition of a force gage and a reaction detector to the Bureau of Mines drop-weight impact apparatus made it possible to examine the details of the force exerted on the specimen and make estimates of the time to reaction. With the current setup the force was found to be oscillatory and not reproducible. However, single, well-defined pressure pulses can be delivered to the explosive sample by modifying the drop-weight tools. With a modified test arrangement, the time to reaction and the peak force and energy at the time of reaction were determined as a function of drop-weight height for several different explosives. All these parameters were found to decrease as the rate of force application was increased. The same parameters were also found to vary with the thickness of the test sample. The implications of these results are discussed in terms of practical drop-weight testing.

RI 7671. Separation of Columbium, Tantalum, Titanium, and Zirconium From Titanium Chlorination Residues, by C. C. Merrill and D. E. Couch. 1972. 8 pp. 3 figs. Columbium, tantalum, titanium, and zirconium are present in solid-waste products generated by the chlorination of the rutile used in the production of titanium tetrachloride (TiCl_4). The columbium and

tantalum were separated from titanium and zirconium by liquid-liquid extraction techniques using a secondary amine. Salts of these elements are in a leach liquor produced by water leaching of mineral waste from the chlorination of rutile. This waste, produced at the rate of approximately 50,000 tons per year, is about 40 wt pct water soluble. Leach liquors, separated by filtration, were further separated into a solid fraction and a liquid fraction by pressure hydrolysis. The solid fraction containing Nb, Ta, Ti, and Zr was dissolved in HCl-HF and used as a feed solution. Columbium and tantalum were removed from the organic extractant with 1 N HCl. A miniature 10-stage reactor showed that the columbium and tantalum present in solution could be separated with a continuous flow.

RI 7672. Emission Characteristics of Propane as Automotive Fuel, by J. R. Allsup and R. D. Fleming. 1972. 34 pp. 13 figs. Air pollutants in exhaust gas produced from LP-gas (propane) were studied using both laboratory engines and vehicles. The objective of the study was to evaluate engine parameters relating to the advantageous use of propane as a low-pollution fuel. Some comparisons are made between gasoline, natural gas, and propane.

Results show that engines can operate over a wider range of A/F with minimum carbon monoxide and hydrocarbon emission when using propane than when using gasoline. Mixture enrichment using propane is unnecessary during cold starts, thereby eliminating the emission penalty during warmup. Carbon monoxide and hydrocarbon emission using propane are unaffected by ambient temperature. The photochemical reactivity of hydrocarbon emission is considerably lower with propane than with gasoline. Work done in cooperation with the National LP-Gas Association.

RI 7673. Performance Characteristics of Coal-Washing Equipment: Dense-Medium Cyclones, by A. W. Deurbrouck and J. Hudy, Jr. 1972. 34 pp. 3 figs. The separations achieved by eight conventional cyclone washers have been evaluated to determine their performance when processing intermediate size coal of 28-mesh bottom size. The dense-medium cyclones provided efficient, sharp separations in treating feeds of up to 44 percent of near-gravity material at separating specific gravities ranging from 1.42 to 1.55 (one separation of a secondary feed was made at 1.63). Complete washability analyses are shown by sizes of the composite feed to these cyclones. The magnetite losses per ton of coal processed ranged from 0.6 to 2.0 pounds; however, of the eight plants reporting losses, seven indicated magnetite losses were 1.1 pounds or less per ton of coal processed.

RI 7674. Detection of Rubble Zones in Oil Shale by the Electrical Resistivity Technique, by John W. Brown and Richard C. Repsher. 1972. 17 pp. 8 figs. Electrical resistivity surveys were conducted at three sites in Wyoming in an attempt to detect underground rubble zones in oil shale and to determine their size and resistivity contrast. The zones were detected at Rock Springs sites 4 and 5, but none were detected at Green River site 1. The resistivity of the rubble zones at sites 4 and 5 is greater than that of the surrounding rock. The zones at sites 4 and 5 are concluded to be roughly ovaloid in shape, with a horizontal diameter of 33 m and a vertical thickness of 24 m. Both rubble zones and the blasting that created them are considered to be centered at a depth of 24 m.

RI 7675. Oxygenates in Automotive Exhaust Gas: Estimation of Levels of Carbonyls and Noncarbonyls in Exhaust From Gasoline Fuels, by D. E. Seizinger and B. Dimitriades. 1972. 27 pp. 5 figs. The Bureau of Mines has developed analytical methods, primarily gas chromatographic, for measurement of exhaust oxygenates produced from selected simple fuels. The resulting data were used to estimate levels of carbonyls and noncarbonyl oxygenates in exhaust from gasoline fuels. Estimated noncarbonyl oxygenates in gasoline exhaust may comprise as much as 30 percent of total oxygenates which include unsaturated carbonyls and noncarbonyls believed to be significant potential pollutants. Work done under an agreement with the Coordinating Research Council, Air Pollution Research Advisory Committee.

RI 7676. A Solid-State Amplifier for the Bridge Circuit of a Mercury Detector, by C. Melvin Lepper. 1972. 10 pp. 6 figs. A solid-state amplifier for the bridge circuit of an atomic-absorption mercury detector is presented and described. Operational advantages over previously used circuitry include improved time and temperature stability, increased measurement accuracy, and simplified setup, calibration, and operation.

RI 7677. Sample Preparation Variability in Diamond-Drill Core From the Homestake Mine, Lead, S. Dak., by George S. Koch, Jr., and Richard F. Link. 1972. 15 pp. 2 figs. In preparing diamond-drill core samples for assay at the Homestake mine, Lead, S. Dak., 5-foot intervals of core are processed through three stages, crushing, grinding, and pulverizing, and portions of the core material are discarded after splitting at each stage of preparation. Then two 1-assay-ton fractions are taken from the pulverized material and assayed. This report investigates alternative methods of sample preparation. The consequences of crushing, grinding, and pulverizing all rather than part of the core are appraised through the statistical analysis of assay results from 118 5-foot intervals of core. Evidently, a substantial improvement in precision at small additional expense is obtained by grinding most or all of the core before splitting. Pulverizing all of the core would be desirable only if doing so would cost less than assaying five random splits from each interval. Graphs and tables detail appropriate procedures to obtain specified precisions. The experimental design and methods can be applied to similar problems in preparing core and other geological samples.

RI 7678. Measurement and Reduction of Noise From Detonating Cord Used in Quarry Blasting, by Andris Viksne. 1972. 29 pp. 16 figs. A series of tests were conducted by the Bureau of Mines to determine the best means of reducing noise generated by the detonating cord that is utilized for trunklines in quarry blasting. Ten different types of detonating cord were tested and evaluated for their acoustic qualities. The results of the investigation showed that noise levels produced by "low-core-load-per-foot" detonating cord "not covered" were lower than those produced by "high-core-load-per-foot" detonating cord covered with 6 inches of unconsolidated material.

RI 7679. The Statistical and Spatial Evaluation of Sulfur in Coal Seams, by Manuel Gomez, Donald J. Donaven, and Kathleen Hazen. 1972. 46 pp. 31 figs. The mean and the standard deviation were used to describe general sulfur and ash populations as well as specific populations of these variables from one coal seam. Both the mean and the standard deviation were incorporated in the exploration process to de-

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termine the number of drill cores necessary for seam evaluation and to guide the sequential drilling plan. Probability regions were computed to establish a basis for predicting probable ranges of average sulfur and ash concentrations that may be expected upon continued or future drilling.

A computerized plot program was utilized to interpolate sulfur and ash concentrations between grid points. The plot program, which is essentially a moving average technique, permits a rapid evaluation of sulfur, sulfur forms, and ash spatial distributions as a drilling program progresses sequentially. This information, in the form of contour plots, can be made available to both the mining engineer and the fuel technologist in advance of mining to outline reserves, to improve selective mining, and to anticipate preparation facilities.

RI 7680. Forecasting the Properties of Coal Seams in Place, by Manuel Gomez and Donald J. Donaven. 1972. 53 pp. 25 figs. A computerized, interpolative mapping technique based on the moving average method was shown to be adequate to estimate the between-drill-hole values of coal-seam variables. The forecasting of the spatial distribution of coal properties along the seam was of three kinds: (1) Estimation of the variable of interest on a regional basis, from widely spaced sample points, (2) prediction of coal properties for product control from closely spaced data, and (3) prediction of coal properties for specified benches, or layers of the coal seam, from closely spaced sample points. Estimates obtained with the computerized, interpolative mapping procedure were useful in the delineation of seam thickness, elevation, and overburden and in the estimation of sulfur and ash concentrations during the early phases of exploration. This grid interpolation technique was found adequate to adjust between-drill-hole values for trends resulting from the combined effect of several variables on a measured response. This information, coupled with statistical and geologic data that can be obtained in the exploration phase of mining, enlarges the information base available for coal-mine development planning, energy forecasts, and environmental control associated with fossil fuel power generation.

RI 7681. Oil Yields and Stratigraphy of the Green River Formation's Tipton Member at Bureau of Mines Sites Near Green River, Wyoming, by George F. Dana and John Ward Smith. 1972. 46 pp. 4 figs. Oil yields, lithology, and stratigraphy have been evaluated for 15 cored wells and two sampled wells representing 10 square miles of the Tipton Member of the Green River Formation near Green River, Wyo. The area evaluated is being used by the Bureau of Mines for experimental production of oil from the oil shales in place. Lithology and oil yields were correlated to produce a stratigraphy diagram for the in situ study area, permitting precise designation of comparable sections. Because of lateral uniformity of oil shale, oil yields from eight cores and two sets of drill-cutting samples within a quarter section show the range of variation in average oil yield arising from experimental error. Variation in average oil yields from the seven cores representing the 10-square-mile study area lies within the expected experimental error. No difference in oil-shale richness across the study area is indicated.

Average oil yields for three Tipton sections in the study area were determined as follows: (1) The entire Tipton Member oil shale (about 145 feet thick), 13.3 gallons per ton; (2) the 40-foot upper rich zone, 21.0 gallons per ton; and (3) the 21-foot zone in which the Laramie Energy Research Center is con-

ducting in situ experiments, 22.4 gallons per ton. One acre of the 21-foot experimental section represents 34,300 barrels of oil in place, and 1 acre of the Tipton's 40-foot rich upper layer represents 62,000 barrels.

RI 7682. Reducing Surface Hot Shortness of Copper-Bearing Steels, by M. I. Copeland and J. E. Kelley. 1972. 19 pp. 15 figs. A study was conducted to determine if commonly used alloying additions or coating materials can prevent the formation of a liquid-copper phase during the reheating of copper-containing steels. If so, the tendency of such steels to surface crack during hot working might be eliminated. Steel specimens were scaled by heating them either isothermally or in a programmed manner that simulated industrial furnace practice. Metallographic examination of the heated specimens showed that molten fayalite (Fe_2SiO_4) completely prevented the formation of liquid copper at the surface. Fayalite, which melts at $2,200^\circ\text{F}$ ($1,205^\circ\text{C}$), was formed by internal oxidation of the silicon contained in the steel. By forming complex molten oxides, coatings of borax glass were also effective in preventing the occurrence of liquid copper at the steel surface.

RI 7683. Recovery of Precious Metals From Electronic Scrap, by R. O. Dannenberg, J. M. Maurice, and G. M. Potter. 1972. 19 pp. 8 figs. The Bureau of Mines investigations described in this report were undertaken to devise a process to economically recover precious metals and copper from low-grade, complex electronic scrap generated in large quantities by military and civilian electronic operations. Leaching with various media is applicable to certain selected items of electronic scrap but cannot be practically applied to complex mixtures of scrap.

A process comprising incineration, caustic leaching to remove aluminum, smelting with a siliceous slag, and electrolysis recovered 99.9-percent-pure copper metal and anode slimes assaying more than 7,000 ounces per ton of combined precious metals. Silver, gold, and copper recoveries were 93, 95, and 87 percent, respectively. Cost analysis indicated that an alternative process using direct smelting of the scrap to make assayable products for sale to a custom smelter would provide better overall financial returns.

RI 7684. Drillability Studies. Percussive Drilling in the Field, by R. L. Schmidt. 1972. 31 pp. 11 figs. One of a series published by the Bureau of Mines covering research investigations in rock drillability, this report of field drilling results extends earlier laboratory findings and provides a relatively simple procedure for predicting percussive drilling rates with reasonable accuracy.

Two percussive drills mounted on a truck were used to drill a total of 25 rock types, and the results were used to develop a prediction equation. The equation was tested on a set of unrelated laboratory percussive drilling data, and the comparison between predicted and actual rates is shown in tabular form.

RI 7685. A Computer Program for Pit Slope Stability Analysis by the Finite Element Stress Analysis and Limiting Equilibrium Method, by F. D. Wang, M. C. Sun, and D. M. Ropchan. 1972. 53 pp. 7 figs. The Bureau of Mines has developed a computer program for evaluating pit slope stability by the finite element stress analysis and limiting equilibrium method. The program includes the finite element method of stress analysis using triangular elements, finite-element model mesh generation, plotting of the model mesh

and stress contours, calculation of a factor of safety along a circular or a plane failure surface, and location of a critical circular failure surface. Instructions for preparation of input data, an example problem, and the program listing are presented.

RI 7686. Dispersion Strengthening of Internally Oxidized Iron-Aluminum Alloys, by M. I. Copeland and W. C. McBee. 1972. 17 pp. 11 figs. The formation of Al_2O_3 dispersoids 0.1μ and less in size in dilute iron-aluminum alloys by internal oxidation in wet hydrogen and dispersion strengthening of iron by application of the technique to iron powder were found to be feasible by the Bureau of Mines. In flowing H_2 -1.5 H_2O gas, Al_2O_3 dispersoids 0.1μ and less in size formed (at 650° to 750° C) in Fe-1 and 2 Al sheet material but not in Fe-3 or 4 Al alloys. With higher temperatures and/or higher H_2O/H_2 volume-ratio gases, Al_2O_3 and $FeAl_2O_4$ dispersoids $>0.1\mu$ in size formed in all the sheet materials. Minus 100-mesh Fe-2 Al powders were internally oxidized under conditions that promoted formation of fine Al_2O_3 particles in sheet material, and then the oxidized powders were hydrogen reduced, sintered, extruded, and evaluated. During internal oxidation, fine Al_2O_3 dispersoids formed within the powder grains, and coarse $FeAl_2O_4$ particles formed on the powder surfaces and grain boundaries. The $FeAl_2O_4$ content was essentially eliminated during sintering by reacting with the unoxidized aluminum that remained in the center of the larger internally oxidized powders. The tensile strength at 800° C depended upon the aluminum-oxygen weight ratio of these elements in the extrusions and reached a maximum of 17,000 psi. The stress-rupture strengths at 800° C of the better alloys were comparable with those of type 310 stainless steel.

RI 7687. A Comparison of Borer, Ripper, and Conventional Mining Products in Illinois No. 6 Seam Coal, by R. L. Schmidt, W. H. Engelmann, and R. R. Fumanti. 1972. 18 pp. 14 figs. The Methane Control and the Respirable Dust Groups at the Twin Cities Mining Research Center (TCMRC) cooperated recently in obtaining production samples of approximately 1 ton each, from the loading conveyors of a ripper, a borer, and a loading machine in conventional development headings. These samples were sized, in four stages, from plus 4 in to minus 10μ . The conventional product had the least fines of the three production methods. The borer product had more fines than did the ripper product, but it also had a greater amount of large pieces. All three products, as sampled, had essentially the same amount of minus 10μ particles. Photomicrographs and surface-area comparisons were made. Gas-adsorption, surface-area determinations on particles under 37μ give essentially the same value. Surface-area calculations, assuming spherical particles and no porosity, give a smaller area to the conventional product.

RI 7688. Oilfields and Crude Oil Characteristics Cook Inlet Basin, Alaska, by Donald P. Blasko, Welton J. Wenger, and J. C. Morris. 1972. 44 pp. 7 figs. The first well that produced commercial quantities of oil in the Cook Inlet Basin of Alaska was completed in 1957. Since that time oil production in the basin has increased rapidly and by the end of 1969 had reached an annual rate of 74 million barrels. Five major oilfields had been developed, and two additional discoveries awaited development. Estimated amounts of recoverable oil by primary and secondary recovery methods total 2.7 billion barrels, or 36 percent of the estimated oil originally in place.

Repressurization by injecting gas or water in formations containing undersaturated oil has significantly increased the volume of recoverable oil. All production has been from formations of the Tertiary age; that much of it is from depth of 10,000 feet or more is unusual for Tertiary formations. The oils are low in sulphur and contain low to moderate amounts of asphalt.

RI 7689. Estimating Nahcolite and Dawsonite Content of Colorado Oil Shale From Oil-Yield Assay Data, by John Ward Smith, Thomas N. Beard, and Paul M. Wade. 1972. 24 pp. 3 figs. Methods for estimating the amounts of nahcolite, dawsonite, and the sum of these two sodium carbonate minerals from oil-yield assay data are developed and evaluated for Green River Formation oil shales from the saline section of Colorado's Piceance Creek Basin. Derived statistically, these estimation methods depend on the fact that these minerals yield water and gas measured during oil-yield assay. The estimation procedures yield values for nahcolite and nahcolite-plus-dawsonite of sufficient accuracy for stratigraphic plotting and correlation, whereas estimates for dawsonite are more generalized. However, resource estimates and reserve computations for both nahcolite and dawsonite accurate within 10 percent of the real value are readily available by assuming the mineral amounts calculated by the procedures presented. These estimation procedures are applicable to oil-yield assay data on core samples from more than 30 coreholes which have penetrated the saline section of the Green River Formation in Colorado. Work done in cooperation with the University of Wyoming.

RI 7690. Hydrocarbon Gases Produced in a Simulated Swamp Environment, by A. G. Kim and L. J. Douglas. 1972. 15 p. 11 figs. Coal formation begins in peat swamps or bogs, in which microorganisms alter plant material and initiate the formation of carbonaceous sediments. Methane, which constitutes about 98 percent of the hydrocarbon gas in coalbeds, is known to be a product of anaerobic microbial metabolism. To determine if other hydrocarbon gases could be produced in an environment similar to that of a swamp, samples of wood cellulose and lignin were inoculated with soil microorganisms and incubated anaerobically. The resultant gases included methane, ethylene, propane, propylene, butanes, pentanes, and carbon dioxide. Hydrogen was also produced from the wood samples during the first month of incubation. Over 90 percent of the produced gas was methane; CO_2 was the other predominant component. Concentrations of all other hydrocarbon gases ranged from 1 to 20 parts per million, approximately 0.1 percent of the total hydrocarbons, which was less than the concentration in coalbeds. Therefore, although higher hydrocarbons could be produced in a swamp environment, subsequent mechanisms, either concentration by adsorption or formation during geochemical reactions, must affect the final concentration of higher hydrocarbons in coalbeds.

RI 7691. Low-Temperature Heat Capacities and High-Temperature Enthalpies of Sodium Chromate, by M. J. Ferrante, J. M. Stuve, and M. P. Krug. 1972. 12 pp. 2 figs. Low-temperature heat capacities and high-temperature enthalpies were determined calorimetrically for Na_2CrO_4 . A reversible transition was found at 700° K with an isothermal heat of transition of 2,263 cal/mole. High-temperature X-ray diffraction analysis showed that the transition was a crystal change from the low-temperature orthorhombic

bic form to the high-temperature hexagonal form. At 795° K the hexagonal form had the parameters $a_0 = 5.691$ and $c_0 = 7.478$ Å. Powder diffraction data for the high-temperature form are given and possible structures discussed. The melting point was determined to be 1,065° K with a heat of fusion of 5,810 cal/mole. Enthalpy and entropy increments from this investigation were combined with other data from the literature to calculate enthalpies of formation, free energies of formation, and equilibrium constants for formation from 298° to 1,400° K. Equations that represent enthalpies above 298° K are given. Work done under an agreement with the U.S. Atomic Energy Commission.

RI 7692. Percussive Drilling With Independent Rotation, by Harold F. Unger and Robert R. Fumanti. 1972. 21 pp. 16 figs. The Bureau of Mines conducted drilling experiments in the laboratory with a commercially available percussive drill that has an independent rotational system. Eight rock types with a wide range of physical properties were drilled under several combinations of rotational speed, drilling thrust, and operating pressure. Penetration rates and energy per unit volume correlated well with the coefficient of rock strength as shown graphically. Size-distribution analyses of some of the drill cuttings show how particle size varies with rotation speed and rock hardness. In general, changing the rotational speed has a greater influence on the penetration rate in softer rocks, with penetration rate increasing with increasing rotational speed.

RI 7693. Oil Yields and Characteristics of Green River Formation Oil Shales at Wosco EX-1, Uintah County, Utah, by John Ward Smith, Laurence G. Trudell, and William A. Robb. 1972. 145 pp. 11 figs. Detailed oil yield, lithologic, and mineral distribution data are presented for core and drill-cutting samples from the Western Oil Shale Corp. Project Utah EX-1 Corehole (WOSCO EX-1), drilled to sample a deeply buried oil-shale sequence in the Green River Formation of Utah's Uinta Basin. Drilling of this corehole was part of the evaluation of this site for possible oil-shale development by nuclear explosion. Sections sufficiently thick for nuclear development average 15 gallons per ton or less and consist predominantly of low-grade shales. Some properties of low-grade shales may be advantageous to a nuclear experiment by facilitating breakage, fracture development, and in situ retorting. The formation correlates precisely with the well-studied oil shales 25 miles east near the Colorado border. A 235-foot mineralized section containing nahcolite, shortite, and searlesite whose bottom lies 300 feet above the Mahogany zone is described. Work done in Cooperation with the University of Wyoming.

RI 7694. Stability Constants of Metal Coordination Compounds. Complexes of N-Ethylethylenediamine and 2-(Ethylthio)-Ethylamine, by David J. MacDonald, Alexander May, and E. G. Baglin. 1972. 19 pp. 5 figs. Stability constants, that is, equilibrium constants for complex-formation reactions, have been determined by a titrimetric method for complexes formed by the transition metal ions Ni^{2+} , Cu^{2+} , Zn^{2+} , and Cd^{2+} with the structurally analogous bidentate ligands N-ethylethylenediamine and 2-(ethylthio)-ethylamine. The sulfur containing ligand was found to be the weaker of the two chelating agents for each of the four metals. Absorption spectra of the individual complexes have been determined in order to calculate their crystal field stabilization energies. The combined results suggests a linear relation between free energy of chelation and ionic radius of the metal ion.

RI 7695. Extraction of Manganese From Georgia Umber Ores by an Acid-Ferrous Sulfate Process (in Two Parts). 2. Cocurrent Extraction and Centrifuge Tests, by H. P. LeVan. 1972. 19 pp. 3 figs. The Bureau of Mines has developed a technically feasible continuous single-stage leaching and thickening system for extracting manganese from umber by a sulfuric acid-ferrous sulfate process; the cocurrent leaching and thickening system proved simpler to operate and control than the countercurrent leaching and thickening system developed earlier. Related tests investigated the use of a centrifuge to replace thickeners for separating the product liquor from ore residues and compared several chemical agents for removing iron from the pregnant manganese leach solutions. Results of some exploratory autoclaving tests are also given. Work done in cooperation with the University of Alabama.

RI 7696. A Three-Minute Gas Chromatographic Analysis of the Main Constituents of Mine Atmospheres, by Helen W. Lang and Robert W. Freedman. 1972. 7 pp. 3 figs. The Bureau of Mines has developed a very rapid gas chromatographic method for routine determination of oxygen, nitrogen, methane, and carbon dioxide in mine atmosphere samples. Analysis is accomplished in 3 min; readout appears on a single strip chart. The gas sample is split between two columns contained in separate chromatographs. A 5-Å molecular sieve column separates oxygen, nitrogen, and methane; a porous polymer column separates carbon dioxide from an air peak. Direct selective analysis of methane from this unresolved air peak is accomplished using a hydrogen flame ionization detector (FID). Carbon dioxide is catalytically converted to methane and detected by FID.

RI 7697. Methane Diffusion Parameters for Sized Coal Particles—A Measuring Apparatus and Some Preliminary Results, by R. J. Bielicki, J. H. Perkins, and Fred N. Kissell. 1972. 12 pp. 7 figs. A sorption apparatus for measuring the equilibrium sorption isotherm and the rate of diffusion of methane from fine-sized coal was designed and constructed. Preliminary work that used Pittsburgh and Pocahontas No. 3 coal shows that the diffusion coefficient varies with pressure and that the fracture spacing in these two coals is substantially different.

RI 7698. Optimizing Decomposition of Carbonyl Sulfide in an Electrical Discharge, by Larry A. Haas, Carl F. Anderson, and Sanaa E. Khalafalla. 1972. 17 pp. 10 figs. Carbonyl sulfide (COS) was decomposed to sulfur and CO in a silent electrical discharge. A threshold of about 4 kv at 60 Hz was required to dissociate the gas in a laboratory ozonizer at 790 torr with electrode gaps between 1 and 5.5 mm. Above the threshold value, the reaction rate increased with increasing voltage with helium or nitrogen diluent. With the latter diluent, higher voltage had to be applied to obtain the same yield in the 4- to 12-kv range. The COS decomposition rate increased with COS concentration, but a saturation value was reached at about 10 pct COS. The reaction rate decreased at low linear gas velocities as obtained at lower gas flows, larger electrode gaps, or larger reactor volumes. Increasing gas temperature also decreased the decomposition rate. The presence of solid adsorbents such as quartz wool, bauxite, or charcoal had no significant effect on the reaction rate. The addition of SO₂ did not affect the COS decomposition rate, but small amounts of water decreased the reaction rate. Over 50 pct of the COS was decomposed at room temperature and atmospheric pressure in a 17-kv ozonizer using a gas

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containing 0.9 pct COS in helium flowing at a rate of 0.3 liter/min. The average current was less than 5 ma. This method has possible application in eliminating the toxic air pollutant, COS, which is generated in petroleum refineries and in processes involving reactions between sulfurous and carbonaceous materials. Carbon monoxide that is formed can be further oxidized to CO₂ after the collection of elemental sulfur.

RI 7699. Experimental Investigations of an Open-Cycle Vortex MHD Generator, by G. J. Conroy, R. C. Kurtzrock, R. B. Snedden, J. J. Demeter, D. Bienstock, and W. F. Hughes. 1972. 28 pp. 13 figs. Electrical power generation was studied in a laboratory-scale, open-cycle vortex MHD generator, which offers several advantages over straight-channel generators that require separate combustors. Compactness, lower capital cost, and high-energy release are obtained by combining the combustor and generator into one unit in the vortex generator. In addition, the vortex generator uses a simple solenoid rather than the more complex and expensive saddle magnet required for straight-channel generators. Although the vortex generator must utilize combustion gases with a low Hall coefficient in order to be efficient in direct comparison to the linear generator, the primary motivation for this experimental device in terms of ultimate objective was to investigate the vortex generator with applications to direct coal firing and with combustion taking place in specially designed expansion nozzles. The vortex device offers one decided advantage over the linear device in this regard because slag deposits do not degrade or short-circuit the coaxial electrodes as is the case for a linear machine. The experimental vortex generator consists of a modified cyclone burner 7½ in ID by 21 in long, with the inner wall used as one electrode together with a coaxial center electrode. Power was obtained by impressing an axial field of 3,000 G from an air core solenoid magnet. Tests were conducted by seeding natural gas seeded with potassium acetate and burning with preheated oxygen-enriched air. Power generation was lower than calculated because theoretical plasma velocities were not achieved.

RI 7700. Interpretation of Gas Chromatographic Spectra in Routine Analysis of Exhaust Hydrocarbons, by B. Dimitriadis, C. J. Raible, and C. A. Wilson. 1972. 19 pp. 1 fig. Experimental work has been done to refine and to confirm an analytical procedure by which gas-liquid chromatographic (GLC) spectra are interpreted from retention time data alone. The rationale of this spectra interpretation technique involves whether or not a given peak invariably represents the same component or component mixture; if not, what factors influence changes in peak identifications. To answer these questions, peak-identification procedures, based mainly on the use of subtractive columns, were developed and applied to interpret GLC spectra of several exhaust (and fuel) samples. Work done under an agreement with the Bureau of Air Pollution Sciences, Environmental Protection Agency.

RI 7701. Waste Glass as a Flux for Brick Clays, by M. E. Tyrell and Allen H. Goode. 1972. 9 pp. 1 fig. Work in this investigation was undertaken by the Bureau of Mines to demonstrate how waste glass might be utilized to lower the required firing temperature and firing time of structural clay products. Mixtures of waste glass and common clays were formed by stiff-mud extrusion and fired to the temperature required to produce a body having 6 to

7 percent absorption. Substitution of glass for one-half of the clay in a red body reduced the firing temperature 500° F, which made possible a 30-percent increase in production; in a tan body, the firing temperature was reduced 400° F, which made possible a 23-percent increase in production.* Work done in cooperation with the University of Alabama.

RI 7702. Dispersing Antiferromagnetic Precursors To Prepare Magnetic Fluids, by George W. Reimers and Sanaa E. Khalafalla. 1972. 16 pp. 6 figs. Metastable pyrophoric wüstite (Fe_xO, with x between 0.89 and 0.95) was found to be much easier to grind to colloidal state than were its stable disproportion products, magnetite or iron. The grinding of polycrystalline magnetite appears to be complicated by the magnetic flocculation arising from interparticle attraction. This is superimposed on the attraction of a fluctuating electric dipole for a neighboring induced dipole. More than 85 percent of the tumbling time was saved by grinding antiferromagnetic wüstite instead of the ferrimagnetic oxide of iron (Fe₃O₄). Disproportionation of colloidal wüstite to the stable ferromagnetic and ferrimagnetic colloidal particles of alpha-iron and magnetite, respectively, was accomplished rapidly at temperatures above 250° C but below 570° C, the eutectoidal stability point of the wüstite phase.

RI 7703. Methane Emission Rate Study in a Deep Pocahontas No. 3 Coalbed Mine in Conjunction With Drilling Degasification Holes in the Coalbed, by Stephen Krickovic and J. D. Kalasky. 1972. 12 pp. 5 figs. A degasification experiment was conducted in a Pocahontas No. 3 coalbed mine in Virginia. It involved (1) drilling holes in the coalbed in the outside headings of a set of five being developed in virgin area and (2) conducting a methane emission rate study as mining progressed and additional holes were drilled. Degasification from all drill holes except the longest in each of the outside headings and the first three drilled (excluding the in situ pressure hole) was erratic and inconsequential in methane emission rates. The two longest holes liberated 66 and 79 cfm of methane, which is significant for the coalbed, but such quantity lasted a relatively short time; the first three were uniform but low in methane emission.

RI 7704. A Study of Fragmentation From Bench Blasting in Limestone at a Reduced Scale, by Richard A. Dick, Larry R. Fletcher, and Dennis V. D'Andrea. 1973. 24 pp. 7 figs. Eight blasts were fired in a 2½-ft bench in the Stewartville member of the Galena Limestone formation in an aggregate quarry near Stewartville, Minn. The shots were dimensionally proportional to production-size bench blasts and were about 5 to 10 percent of full scale. The effects of site, timing of initiation, and burden-to-spacing ratio were studied in a 2 x 2 x 2 factorial experiment, using three boreholes, each containing a ½-in charge diameter of high-density ammoniac dynamite, in each blast. Detonation velocity measurements indicated that the dynamite detonated satisfactorily in the ½-in charge diameter. The effects of the three experimental variables were analyzed by weight for the percentage of oversized material produced and for size distributions determined by screening the entire muckpiles. The bench faces were painted before each shot in an effort to determine the origin of the oversized material. The square pattern (burden and spacing = 15 in) produced finer overall fragmentation and less oversized material than the rectangular pattern (burden = 15 in; spac-

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ing = 22½ in). Sites 1 and 2 were about 15 ft. apart. Although site 2 produced slightly better overall fragmentation than site 1, the amounts of oversized material produced showed no significant difference. The timing of initiation (instantaneous or delayed) did not significantly influence the overall fragmentation or the amount of oversized material produced.

RI 7705. Autogenous Smelting of Copper Sulfide Concentrate, by Robert B. Worthington. 1973. 21 pp. 9 figs. This investigation was undertaken to develop a more efficient copper smelting practice that would help meet the increasingly stringent anti-pollution standards. Continuous smelting to copper and a 0.8- to 5-percent copper slag using pure oxygen has been demonstrated for several hours at a time in a unique double furnace, which was devised to overcome the heat losses inherent in a laboratory furnace. The use of pure oxygen to effect the smelting and conversion of copper sulfide concentrate in a single unit to produce blister copper and a very high SO₂ concentration provides a much reduced gas volume for more economical and thorough sulfur recovery. Although the process was successfully demonstrated for several hours at a time, extended test work using longer runs will be required to balance the system and to obtain test data for adequately demonstrating its technical feasibility.

RI 7706. Determination of Paleotectonic Principal Stress Direction, Including Analysis of Joints by Optical Diffraction, by Robert C. Steckley. 1972. 18 pp. 5 figs. A study of joints in Marathon County, Wis., was made to determine the orientation of regional paleotectonic stresses and to develop a method of using optical diffraction analysis (ODA) in studying joint orientations and spacings. Standard geologic and petrofabric techniques employing the use of a geologic compass and a Schmidt net were used in gathering, describing, and reducing joint orientation data. Analysis of selected outcrops with ODA indicates that ODA can be applied to study both joint orientations and spacings. ODA is shown to be a rapid method that can be used to complement standard petrofabric techniques, especially in the study of joint spacings.

RI 7707. Effect of Fuel Front-End and Midrange Volatility on Automobile Emissions, by B. H. Eccleston and R. W. Hurn. 1972. 70 pp. 19 figs. Experimental work is reported showing the effects of gasoline characteristics on auto emissions. Fuel volatility is shown to influence evaporative losses, with the higher losses associated with higher volatility. Fuel front-end olefin is shown to contribute significantly to reactivity of emissions. Large vehicle-to-vehicle differences were found. The study was conducted by the Bureau of Mines at its Bartlesville Energy Research Center in cooperation with the Coordinating Research Council Air Pollution Research Advisory Committee. The work was done using 15 1968-70 model autos and eight fuels were tested at ambients ranging from 20° to 95° F. Data on emissions from each vehicle-fuel-temperature combination are presented. Also included are calculated photochemical reactivity data and the distribution of hydrocarbon and nitrogen oxides during the test cycle. Work done under an agreement with the Coordinating Research Council Air Pollution Research Advisory Committee.

RI 7708. Glass Wool From Waste Glass, by Alan H. Goode, M. E. Tyrrell, and I. L. Feld. 1972. 16 pp. 5 figs. Glass wool meeting requirements for commercial use was made from glassy fractions of urban solid wastes by the Bureau of Mines. This research was a part of the Bureau's program to develop building products and other usable materials from reclaimed urban waste materials. Mixes of molten glass were fiberized into glass wool during laboratory studies by impingement of a jet of compressed air on a stream of the molten glass. The principal test variable studied was composition of the melt; this was varied by adding dolomite and alumina to obtain molten glass with the handling characteristics required for producing final wool products of the desired composition and physical characteristics. When no charge is made for the waste glass and approximately \$75 per ton can be obtained for the wool product, an interest rate of return on investment after taxes of about 12 percent can be obtained. If a charge of \$5 per ton is required for the waste glass, a selling price of about \$78 per ton would be necessary to obtain a 12-percent-interest rate of return on investment after taxes.

RI 7709. Adhesion at Crystalline Interfaces in Rock, by George A. Savanick, and Donald I. Johnson. 1972. 16 pp. 7 figs. The objective of this research is to develop a method for measuring the tensile strength at the interface between minerals in rock. These measurements reflect the strength of the attractive forces operating at crystalline interfaces in rock. Since these forces act in opposition to the forces set up in various rock fragmentation processes, measuring their strength may help in designing more efficient methods of rock fragmentation. The method developed for measuring the strength of intergranular adhesion in rock involves separating a bicrystal from the rock and determining the tensile strength at its solid-solid interface. This technique has been successfully applied to the study of quartz-feldspar interfaces separated from massive pegmatites, graphitic granite, and the Rockville granite, yielding average tensile strengths of 5.86, 8.62, and 10.65 meganewtons per meter squared (MN/m²) (850, 1,250, and 1,524 psi, respectively). The data this technique provides indicate that the members of these bicrystals are strongly adherent. Examination of bicrystals broken at the crystalline interfaces indicates that the bonds responsible for this adhesion operate over only a portion of the interfacial area. This work conclusively demonstrates that tensile strength tests can be conducted on small selected areas; for example, grain boundaries in rock. The small-scale zones of strength or weakness determined in this way can be related to the overall strength of the rock.

RI 7710. Purification of Yttrium by Electrorefining, by D. C. Fleck, E. K. Kleespies, and D. G. Kesterke. 1973. 12 pp. 2 figs. Electrorefining yttrium from selected low-melting yttrium-base alloys is investigated, and various halide systems are studied as potential electrolytes for use in preparing low-oxygen yttrium by electrorefining unalloyed yttrium. Yttrium cathode products having significantly less metallic impurities than the anode materials were prepared from alloys containing nickel, iron, and manganese by electrorefining in LiCl-YCl₃ electrolytes at 900° to 1,000° C. Yttrium-copper and yttrium-magnesium alloys are not suitable as anode feed materials. An evaluation of chloride, fluoride,

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bromide, and mixed chloride-fluoride electrolytes showed that cathode products containing much less oxygen than the anode material can be obtained in the fluoride and mixed chloride-fluoride systems. Initial cathode current density has no apparent effect on the purity of the products obtained in both phases of the investigation.

RI 7711. Cleaning Titanium Alloy Chips, by O. Q. Leone and D. E. Couch. 1973. 18 pp. 12 figs.

A processing unit was developed for the complete cleaning of titanium alloy chips. The process uses solvent degreasing, magnetic separation, and anodic solution of nonmagnetic impurities in 10 weight-percent sulfuric acid. Vacuum arc-melted ingots weighing approximately 10 pounds each were prepared from cleaning chips according to ingot specifications.

RI 7712. Analyses of Tipple and Delivered Samples of Coal (Collected During Fiscal Year 1972), by J. B. Janus and B. S. Shirley. 1973. 17 pp. This report,

the 22d in a series, gives analytical data showing composition and quality of tipple and delivered samples of coal collected during fiscal year 1972. This coverage lists mines located in 20 States. Ultimate analyses are given for most of the coalbeds listed. Tipple samples were collected by Bureau of Mines engineers at tipples as coal was being loaded into railroad cars or trucks. The deliveries were sampled in accordance with instructions issued by the Bureau of Mines, and the samples were analyzed in the Bureau laboratory at Pittsburgh. GPO Stock No. 2404-0126, Catalogue No. I28.23:7712, 45 cents.

RI 7713. Testing of Coal Cutter Materials for Incendivity and Radiance of Sparks, by R. A. Blickensderfer, J. E. Kelley, D. K. Deardorff, and M. I. Copeland. 1972. 17 pp. 7 figs. The sparking and gas-

igniting tendency of steels and alloys were evaluated by measuring the radiance of spark showers produced by grinding a sample on an abrasive wheel in air, the time required for a spark shower generated on an abrasive wheel to produce an ignition in an explosive gas mixture, and the energy and speed required for impacts between various materials to ignite an explosive gas mixture. Mixtures of air-methane were found quite resistant to ignition by showers of sparks. A mixture of air-9.5 pct hydrogen was used to increase the sensitivity of the tests and to thereby extend the range of materials that could be evaluated. The results of the spark-shower tests indicate that carbon steels and the alloy steels found in coal-cutter tools are among the most sparking and most incendive of any materials tested. Stainless steels, nickel alloys, and tungsten carbide are among the least sparking and least incendive. The brightness of the spark showers depended upon the degree of oxidation of the abraded particles. Impact tests against hard rocks such as solid quartz and sandstone, showed that high-carbon steel was more incendive in the hydrogen mixture than were the softer steels or the alloy steels found in coal cutters. Ignitions were found much less likely to occur at speeds somewhat lower than the speeds currently in use in continuous mining machines.

RI 7714. Analysis of Trace Elements in Coal by Spark-Source Mass Spectrometry, by T. Kessler, A. G. Sharkey, Jr., and R. A. Friedel. 1973. 8 pp. 2 figs.

As part of a respirable mine-dust research program at the U.S. Bureau of Mines, spark-source mass

spectrometry has been used for the semiquantitative determination of trace elements (200 ppm weight or less) in raw coals. In addition, several minor and major elements have been determined using this technique. Sixty-four elements ranging in concentration from 0.01 to 41,000 ppm weight were determined in one anthracite, two mvb, four lvb, and six hvab raw coal samples. The samples represented 10 coal seams located in Pennsylvania, West Virginia, Virginia, Utah, and Colorado.

RI 7715. Analysis of the Geometry of Fractures in San Manuel Copper Mine, Arizona, by M. A. Mahtab, D. D. Bolstad, and F. S. Kendorski. 1973. 24 pp. 14 figs.

This report presents the geometric parameters (attitude, spacing, extent, and aperture) of fracture patterns in a selected portion (study area) of San Manuel copper mine, Arizona. The geometric parameters are quantified for input to structural analyses for studies of the influence of fractures on cavability of ores. Using an orientation analysis procedure developed earlier by the Bureau, three prominent and nearly orthogonal sets of fracture orientation were delineated in the study area. Sets 1 and 2 dip nearly vertically, and generally strike east-west and north-south, respectively, whereas set 3 is nearly horizontal. Both a horizontal rotation (of 14° to 26° for sets 1 and 2, respectively) and a tilt (of 20° for set 3) is shown to occur between the 1415 and 2015 levels of the mine. Comparison of the three major rock types present in the study area (quartz monzonite, monzonite porphyry, and rhyolite) show that the rhyolite is characterized by short extent, small spacing, and tightness of fractures as well as the general absence of fracture set 3, which may account for its generally observed strong resistance to caving.

RI 7716. Use of Cryogenics To Reclaim Nonferrous Scrap Metals, by E. G. Valdez, K. C. Dean, and W. J. Wilson. 1973. 13 pp. 5 figs. Three cryo-

genic systems that utilized liquid nitrogen, Dry Ice, and methanol with Dry Ice were investigated in conjunction with crushing and classifying techniques. The systems were used to aid in separating and reclaiming the metallic components contained in insulated wires, shredded automobile nonferrous metal concentrates, small motors, generators, and rubber tires. Wire strands, 2 to 6 inches long and insulated with polyvinyl chloride and neoprene, were chilled at -60° and -195° C, then roll-crushed and processed by water elutriation; this procedure resulted in two products—a sink fraction that was 99 percent metallic and a float fraction that was 99 percent nonmetallic. Excellent separation of zinc die-casting alloys from copper and aluminum contained in shredded automobile nonferrous metal concentrates was attained by chilling at -72° C for 1 minute, crushing in a grateless hammer mill, and screening. From the screened products, 97.2 and 100 percent of the copper and aluminum, respectively, were recovered in the plus 1-inch fraction, and 100 percent of the zinc was recovered in the minus 1-inch fraction of over 97 percent zinc die-cast purity. Laboratory experimental results comparing direct and indirect chilling indicated that a sufficiently low temperature could be attained by indirect chilling to permit use of a liquid CO₂-Dry Ice system on insulated wires and mixed nonferrous metallic concentrates.

RI 7717. Economics of Mixed Potassium-Cesium Seeding of an MHD Combustion Plasma, by P. D. Bergman and D. Bienstock. 1972. 12 pp. 5 figs. The high

price of pollucite ore, its limited availability, and the need to provide stack removal of SO_2 present formidable obstacles to the use of pure cesium as a seeding material in MHD power generation. Cost estimates indicate that mixed potassium-cesium seeding is preferable to the use of either pure cesium or pure potassium. Cheaper electricity and higher open-cycle MHD operating efficiencies result from the use of mixed seed. Savings of \$3,000,000 per year in power costs for a 1,000-MWE open-cycle MHD powerplant are envisioned if the mixed seeding technique is adopted.

RI 7718. Better Coke by Using Antifissurants: Results for Illinois No. 6 and High Splint Coals, by M. J. Kovalik, D. E. Wolfson, and L. Mafrika. 1973. 20 pp. 2 figs. Illinois No. 6, a high-volatile B coal of low fluidity, was blended with fluidized-bed char and coke breeze to improve the strength of the coke obtained from carbonizing this coal. Twenty-one tests, selected from those made in the small-scale Hanson carbonizer, were carbonized in the BM-AGA 13-inch-diameter, cylindrical retort, with a coal charge of about 90 pounds; the strength of the cokes was determined by the standard ASTM tumbler test. Using the same procedure, 10 tests were made with High Splint, a high-volatile A coal from Harlan County, Ky. Carbonization of the blends produced larger and stronger cokes than did the Illinois No. 6 coal singly. The optimum blend contained 6 percent each of char and coke breeze. Further improvement in coke strength was realized by either preheating this blend prior to carbonization or by adding a small proportion of a premium blending coal. The former method could possibly eliminate the use of premium coking coals in blends with Illinois No. 6 coal to make an acceptable metallurgical coke. Except for no improvement in coke strength by preheating, results for High Splint coal showed behavior similar to that of the Illinois No. 6 coal.

RI 7719. Conversion of Ilmenite to Rutile by a Carbonyl Process, by A. Visnapuu, B. C. Marek, and J. W. Jensen. 1973. 20 pp. 16 figs. High-grade synthetic rutile has been produced in the laboratory from domestic ilmenite concentrates by a new carbonyl process. The ilmenite was first reduced to convert the iron oxides to metal and then treated at temperatures over 100°C in high-pressure carbon monoxide (CO) to convert the iron to the pentacarbonyl. Rapid carbonylation was achieved in the presence of small quantities of selected promoters. Maximum iron removal occurred at temperatures between 110° and 130°C at CO pressures from 1,000 to 1,400 psig. Iron pentacarbonyl appeared as liquid and vapor in the reactor and could be removed by gravity flow and vapor transport. More than 90 pct of the iron was extracted in 2-hr experiments at pressures of 1,000 psig and above. The TiO_2 product is porous owing to the removal of the iron, has the rutile crystal structure, and is suitable for chlorination. Waste disposal problems associated with the process would be minimal because the iron pentacarbonyl can be decomposed to produce iron powder or pellets for sale and CO for recycling.

RI 7720. Kinetics of CO Reduction of Hematite to Magnetite and the Effect of Silica, by J. C. Nigro, T. D. Tiemann, and Charles Prasky. 1973. 43 pp. 25 figs. Hematite-to-magnetite reduction kinetics were investigated mainly in CO-CO_2 atmospheres at tem-

peratures ranging from 500° to $1,000^\circ\text{C}$. Reduction rates were measured with a thermobalance, which recorded the weight loss as the specimen was reduced. Reduction data on both synthetic and natural hematite spheres showed good linearity of $r_0 [1 - (1 - R)^{1/3}]$ with time, t , up to over 85 pct conversion to magnetite; the rate coefficient (k_L , cm/min) obtained from the linear portion of the plot was used to characterize the penetration rate of the hematite-magnetite interface. Gas composition, porosity, and silica content were major factors affecting the rate. Temperature dependency of the reaction rate was small, yielding a mean activation energy of about 3 kcal/mole. Silica additions increased the reaction rate, probably through an increase in the effective surface area and diffusion; however, above 900°C , silica can react to form fayalite. Experimental data showed that the linear thickening rate of the magnetite layer, normally evidence of a chemically controlled reaction, can also be indicative of a reaction controlled by both mass transfer and diffusion. Evidence from this study indicates that the dominant rate-controlling factor in the reduction of hematite to magnetite at high temperatures is transport in the gas phase.

RI 7721. Phase-Contrast Enhancement Without Spatial Filters for Seismic Holography, by G. L. Fitzpatrick. 1973. 17 pp. 5 figs. Future applications of seismic holography to "seismically transparent phase objects," such as rock inclusions, fracture zones, liquid-filled cavities, etc., will require techniques to improve the poor image contrast generally characteristic of these objects. Although conventional phase-contrast enhancement techniques could be used, these methods involve additional optical elements such as quarter-wave spatial filters. Owing to the anticipated practical difficulties of properly aligning such optical devices and properly locating poorly defined image planes and filter planes, this approach is not considered to be well-suited to the case of seismic holograms and their laser reconstructions. Results similar to those achieved with spatial filters may be obtained without filters by specially processing the seismic hologram data. The new process, which is an extension of Gabor's subtraction holography, achieves an improvement in contrast by an interferometric technique. The process involves adding a "before" hologram without an object present to a 90° phase-shifted "after" hologram with the object present. Then, the combination is reconstructed with a laser or by computer. Not only is the image contrast improved in such processed holograms, but the images are also phase-contoured. In general, the latter feature is not to be expected when conventional phase-contrast enhancement techniques are employed. The new technique is experimentally verified by examining computer-generated synthetic seismic holograms rather than by examining actual seismic field data. However, results of this study are directly applicable to real seismic data and should prove useful in future applications of seismic holography.

RI 7722. Molten Salt Electrowinning of Magnesium-Yttrium Alloys, by E. Aamlund, D. J. MacDonald, and D. G. Kesterke. 1973. 11 pp. 5 figs. Preparation of high-purity magnesium-yttrium alloys by electroreduction of Y_2O_3 dissolved in a $\text{YF}_3\text{-LiF}$ bath and the subsequent deposition of yttrium in a molten magnesium cathode was investigated in laboratory-

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scale apparatus. Parameters such as temperature, current density, and electrolyte density were studied. Electrolysis was conducted in a specially designed MgO diaphragm cell at temperatures ranging from 780° to 970° C. Alloys containing up to 55 weight-percent yttrium were prepared at cathode current efficiencies of 21 to 60 percent. Cell design and operation are described, and some of the limiting conditions pertaining to the method are discussed.

RI 7723. Chemical Flame Inhibition Using Molecular Beam Mass Spectrometry Bromotrifluoromethane in Low Pressure Methane-Oxygen-Argon Flames, by Joan C. Biordi, Charles P. Lazzara, and John F. Papp. 1973. 39 pp. 16 figs. A molecular beam-mass spectrometer-low pressure flat flame apparatus has been constructed for the purpose of examining the chemical microstructure of normal methane-oxygen-argon flames and those inhibited with Halon extinguishants. Details of construction and performance of this apparatus and of related flame temperature measurements are given. Particular attention is paid to the empirical characterization of the perturbation to the flame caused by the sampling probes. The composition profiles obtained for normal flames are compared to those of flames inhibited by CF_3Br . In addition to the unusual stable species (CH_4 , O_2 , CO , CO_2 , H_2O , H_2 , and H_2CO), the inhibitor, its products and intermediates associated with its reactions could be followed. In particular, hydrogen bromide, bromine atoms, hydrogen fluoride, and carbonyl fluoride were observed. The relatively rapid disappearance of inhibitor and early appearance of fluorinated reaction products suggest a short lifetime for the CF_3 radical in this system. Observation of COF_2 suggests that CF_3Br is effective as an inhibitor, at least in part, by virtue of its interference with the oxygen containing species of the normal chain reaction. Profiles of the 17^+ peak at low electron energy suggests that the hydroxyl radical may also be sampled, but the profiles obtained are not yet sufficiently accurate to determine the effect of inhibitor on this important flame radical.

RI 7724. Continuous Heavy Liquid Concentration of High-Clay Potash Ores, by K. J. Liles, J. W. Brown, and G. V. Sullivan. 1973. 14 pp. 4 figs. The Bureau of Mines conducted laboratory semi-continuous and continuous heavy liquid tests to determine the feasibility of producing commercial-grade products from the high-clay sylvinitic ores of the Permian Basin in New Mexico. Continuous test operations demonstrated that concentrates containing 59.9 percent K_2O and recoveries of over 75 percent of the contained potash can be obtained.

The organic heavy liquid was effectively recovered by vaporization, condensation, and absorption methods. Less than 5 parts per million of heavy liquid vapors were released to the atmosphere. This loss represents only 0.02 pound of heavy liquid per ton of ore treated.

RI 7725. Solid-Liquid Flow in Noncircular Pipes, by R. C. Wang and J. J. Seman. 1973. 31 pp. 25 figs. Solid-liquid flow in different pipe geometries was investigated. This investigation was conducted by measuring delivered solids concentration and head loss. The delivered solids concentration was measured to study the effect of pipe geometry on the minimum carrying velocity above which solids do not lag behind the fluid. Head loss was measured

to study the effect of pipe geometry on the friction loss. A mathematical formula was developed for determination of the minimum carrying velocity. Darcy-Weisbach's equation and Durand's equation were used for comparison of head losses of pipe shapes. Of the different pipe shapes studied, each having the same interior cross-sectional area, the rectangular pipe with the wide side oriented as the base yielded the lowest minimum carrying velocity at high solids concentrations. The minimum head loss at low velocity and high solids concentration also was attained with this pipe. Although the circular section is known to be the best for transporting liquid only, the present study suggested that pipe geometry is a factor in lowering the operating velocity and reducing head loss in solid-liquid flow.

RI 7726. Characterization of the Valence State of Iron in Coal Dust, by D. A. Doughty and C. W. Dwiggins, Jr. 1973. 17 pp. The Bureau of Mines developed two methods for determining iron II and iron III in 2- to 5-mg samples of coal using electron paramagnetic resonance (EPR) spectrometry. One method used solid coal samples; the other method used aqueous solutions. The method using solid samples was more simple, technically, but required the use of X-ray fluorescent analysis, or another independent method, for determining total iron in the samples, and the results were subject to some uncertainty. The method using aqueous solutions appeared capable of greater certainty and did not require additional methods of total iron analysis but was more involved procedurally. The coals analyzed were found to contain much more iron II than iron III.

RI 7727. Aragonite and the Genesis of Carbonates in Mahogany Zone Oil Shales of Colorado's Green River Formation, by John Ward Smith and William A. Robb. 1973. 21 pp. 4 figs. Aragonite, co-occurring with calcite and dolomite as matrix minerals, has been discovered in Mahogany zone oil shales of Colorado's Eocene Green River Formation, posing puzzles on the geochemical patterns of their separate origins, reasons for their simultaneous existence, and their interrelation. The presence of aragonite is demonstrated by X-ray diffraction. Amounts of aragonite and dolomite are significantly and inversely related, but the calcite quantity is essentially independent of either aragonite or dolomite quantity. A geochemical pattern outlining the deposition conditions that created the Green River Formation oil shale is postulated from characteristics of the oil shale. The development of the three separate carbonates—aragonite, calcite, and dolomite—the inverse relationship between aragonite and dolomite, and the independence of amounts of calcite and the other two carbonates are shown to be natural consequences of this oil-shale genesis pattern.

RI 7728. Phosphorus Removal From Birmingham, Ala., Calcareous Iron Ores, by W. E. Lamont, T. N. McVay, C. E. Spruiell, Jr., and I. L. Feld. 1973. 15 pp. 2 figs. The Federal Bureau of Mines conducted research to develop methods of removing phosphorus from the earthy, calcareous hematite ores of the Birmingham, Ala., iron district while simultaneously improving the grade and recovery of the iron values prior to furnacing. An attempt was also made to identify the phosphorus minerals present in the ores. The ores contained about 36

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percent iron, 12 to 16 percent CaO, 15 to 20 percent hydrochloric acid insolubles, and 0.30 to 0.36 percent phosphorus. Fractions containing 5 to 15 percent phosphorus were isolated from the ores. Collophanite, $\text{Ca}_3\text{P}_2\text{O}_7 \cdot n\text{H}_2\text{O}$, a member of the apatite group, was the only phosphate mineral identified. Beneficiation methods using flotation and reduction roasting with magnetic separation yielded good grade iron concentrates, but were not as effective for reducing the phosphorus content of concentrates. Reduction roasting followed by fine grinding, magnetic separation, and acid leaching gave iron concentrates containing 62.5 percent iron and 0.04 percent phosphorus with an iron recovery of 82.9 percent and a phosphorus rejection of 93.7 percent. Reoxidation of reduced magnetic concentrates followed by acid treatment gave iron concentrates 58.1 percent iron and 0.02 percent phosphorus with 89.6 percent recovery of the iron and 96.5 percent rejection of the phosphorus.

RI 7729. Methods and Evaluation of Explosive Fracturing in Oil Shale, by J. S. Miller and H. R. Nicholls. 1973. 22 pp. 9 figs. The Bureau of Mines developed methods for fragmenting oil shale formations with chemical explosives to prepare oil shale for in situ retorting and to evaluate the extent of fragmentation by various methods. A combination of three methods of explosive fracturing was used: (1) The displacement and detonation of a liquid chemical explosive in a natural fracture system; (2) the use of 60-pct dynamite to relieve stress conditions of the rock around the wellbore; and (3) the use of pelletized TNT in a series of wellbore shots to fragment the oil shale. An attempt was made to seal or grout around the fragmented oil shale by drilling 67 holes and displacing approximately 200 bbl of neat cement in the fracture system to aid in evaluating the fragmented zone. Seven methods were used to evaluate the fragmented zone. The primary evaluation method was the recording of seismic waves to delineate the fragmented zone with results based on arrival time, amplitude, and record quality. The data from the seismic measurements indicated the extensively fragmented zone was approximately 95 ft in diameter and 70 ft thick. Results of the remaining methods of evaluating fractures—including airflow tests, coring of the expected fragmented zone, elevation measurements to indicate overburden crowning, and surveys with high-speed camera, impression packer, and down-hole camera—agreed with and supported the data from seismic measurements. Further field application of explosive fracturing and evaluation methods is needed to determine when a zone of oil shale is effectively fragmented for efficient in situ retorting.

RI 7730. Beneficiation of Calico District, California, Silver-Barite Ores, by W. W. Agey, J. Vance Batty, Hugh W. Wilson, and Wayne J. Wilson. 1973. 15 pp. The Calico silver-barite deposits near Barstow, Calif., are a potentially important resource. Exploration performed by two major mining companies outlined large tonnages of ore that assayed at 2 to 3 ounces of silver per ton and 7 to 15 percent barite. Laboratory beneficiation work was done by the Bureau of Mines on four samples to develop methods for recovering the silver and/or barite. Cyanidation recovered from 47 to 60 percent of the silver from

ore ground to approximately 100 percent minus 325 mesh. Salt roasting minus 10-mesh material, followed by regrinding and cyanidation, recovered 75 to 85 percent of the silver.

From 75 to 90 percent of the barite was recovered in a plus 92-percent barite product from either the natural ore or from cyanidation residues. Salt roasting before cyanidation precluded recovery of the high-grade barite concentrate from the leach tails.

RI 7731. Materials Handling Research: Shear Properties of Several Granular Materials, by G. A. Wancheck and R. S. Fawkes. 1973. 36 pp. 25 figs. Shear tests were performed on several prepared samples of granular and powdery bulk materials to investigate the following parameters: Particle size and distribution, particle movement, moisture content, consolidation of material, bulk density, void ratio, porosity, volume change, and strain rate. A series of shear tests was performed with weight-percent ratios of minus 0.185-inch tertiary sand and 1½- by ½-inch tertiary gravel mixtures, and weight-percent ratios of minus 200-mesh limestone (rock dust) and minus 200-mesh bituminous float coal dust. A comparison was made for shear test results obtained with rectangular and circular shear cells utilizing the large and small direct shear testers. Specifically, the shear results obtained include the angle of internal friction or shear strength of the tested material under known consolidating pressures, and the kinematic angle of friction or coefficient of friction between the interface of a bulk material and a sample wall material. The experimental procedure, tests, and results are given for each parameter investigated.

RI 7732. Removal of Pyrite From Coal by Dry Separation Methods, by W. T. Abel, M. Zulkoski, G. A. Brady, and J. W. Eckerd. 1973. 26 pp. 16 figs. The difficulties associated with wet-processing fine size coal led the Bureau of Mines to investigate a dry process for removing pyrite from coal pulverized to powerplant fineness. The dry process that was investigated consists of two cleaning steps: First, centrifugal separation is used to remove a fine, pyrite-depleted portion as a product; second, the remaining coarser, pyrite-enriched portion is taken to electrostatic separation in which pyrite is concentrated and rejected. Ball milling and Hardgrove milling were used to pulverize the coal. Three coals from the Pittsburgh seam were treated by the dry-removal process. Over 55 percent of the pyrite, which amounted to 70 percent of the available pyrite, was removed in a reject of 10 to 20 percent from one of the coals. Similar treatment of the other two coals removed about 35 to 50 percent of the pyritic sulfur, which amounted to about 70 percent of the available pyritic sulfur from these coals. Both centrifugal and electrostatic separations were more efficient when pyrite particles were as large as possible. Separation efficiency was improved by confining the particle size of the feed to a relatively narrow range and by avoiding excessive amounts (more than 10 percent) of dust in the electrostatic range. The removal efficiency was increased with the use of stage grinding.

RI 7733. Solvent Extraction of Nitrate From Titanium Leacher Effluent, by J. R. Ross, S. R. Borrowman, and D. R. George. 1973. 12 pp. 8 figs. The extraction and recovery of nitrate from waste solutions

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generated in the production of titanium were investigated using solvent extraction techniques. Laboratory studies and continuous tests in a small solvent-extraction system showed that up to 98 percent of the nitrate can be selectively extracted by a solution of tributyl phosphate in kerosene. The extracted nitrate can be recovered as nitric acid, at concentrations suitable for reuse, by stripping the loaded organic with water.

RI 7734. An Automatic Data Acquisition System for Underground Measurements, by J. R. McVey and T. O. Meyer. 1973. 10 pp. 9 figs. A 10-channel automatic data acquisition system has been designed and environmentally packaged for use with underground strain-gage applications and associated instruments. The system uses commercially available components and is assembled in two plastic enclosures. Environmental control is provided through a specially designed (compressed-air) air-conditioning system and water-resistant cabling. Accuracies of 0.01 pct and resolution of 1 μ V have been obtained in underground tests.

RI 7735. Emission Characteristics of an Aircraft Auxiliary Power Unit, by F. W. Penn and W. F. Marshall. 1973. 13 pp. 8 figs. An aircraft auxiliary power unit (APU) was used as an exhaust source for evaluation and refinement of sampling and analytical procedures for gas turbine engines. The unit was also used to determine the emission characteristics of APU's in service and to study the effect of fuel composition and combustor design on exhaust emissions. Carbon monoxide, carbon dioxide, oxides of nitrogen, hydrocarbons, aldehydes, particulate loading, and odor were measured at engine operating modes representing the duty cycle encountered in airline operation. Analyses showed good repeatability, and adequate sensitivity was attained in these experiments. Smoke opacity measurements were not taken owing to the lack of a high-sensitivity smoke meter. Results showed that the minimum emission levels occurred with the standard combustor and Jet A fuel. Emission rates were highly dependent on test mode, but emission patterns as a function of test mode were similar for all fuels and combustors tested. A comparison of three identical design production combustors showed a variation in average emission rates of less than 5 pct.

RI 7736. Extraction of Silver From Refractory Ores, by B. J. Scheiner, D. L. Pool, J. J. Sjoberg, and R. E. Lindstrom. 1973. 11 pp. 4 figs. Silver ores from the Candelaria District, Nevada, and Round Mountain District, Colorado, were investigated mineralogically and metallurgically. Silver minerals of four distinct groups were identified: (1) Silver sulfide; (2) argentobarrosite; (3) silver contained in the iron oxide; and (4) manganese carbonate-oxide minerals. Electrooxidation and acid-chloride leaching techniques were investigated as means of altering silver minerals, and their effects on subsequent silver extraction were determined. Application of the knowledge obtained from mineral leaching studies resulted in development of a sulfur dioxide-sodium chloride leaching sequence for extracting silver from these types of ores. Silver extractions of 80 to 85 percent were obtained by leaching the ores with a

sulfurous acid-sodium chloride system. This was an increase of 9 to 61 percent silver extraction over that obtained by conventional cyanidation techniques.

RI 7737. Geochemical Aspects of the Saturated Hydrocarbon Constituents of Green River Oil Shale-Colorado No. 1 Core, by D. E. Anders and W. E. Robinson. 1973. 23 pp. 6 figs. Saturated hydrocarbons from 60 selected samples of a 2,300-foot Green River Formation oil-shale core (Piceance Creek Basin, Colo.) were analyzed by gas-liquid chromatography techniques. Emphasis was placed upon the distribution of normal alkanes and 15 key-branched and cyclic alkanes. The latter compounds consisted of the C₁₅, C₁₆, C₁₈, C₁₉, and C₂₀ chain isoprenoids, the 5- α and 5- β C₂₇, C₂₈, and C₂₉ steranes, three C₃₀ pentacyclic triterpanes, and perhydro- β -carotene. The results showed definite evidence of maturation of both the *n*-alkanes and the branched and cyclic alkanes; however, most if not all of the changes were limited to the indigenous soluble extract and were not the result of additional soluble extract generation from the insoluble kerogen. Source material and environmental variations were important factors in some of the observed differences in the branched plus cyclic alkane compositions. Work done in cooperation with the University of Wyoming.

RI 7738. Hydrogenating Shale Oil at Low Space Velocity, by C. M. Frost and P. L. Cottingham. 1973. 9 pp. 1 fig. Crude shale oil prepared by gas-combustion retorting of Colorado oil shale was hydrogenated over a cobalt molybdate catalyst at an operating pressure of 1,000 psig, temperatures of 781° F and 761° F, and liquid hourly space velocities of 0.10 and 0.05 V_o/V_c/hr, respectively. The yields of total liquid products and the amounts of nitrogen and sulfur removed were comparable with those obtained at an operating pressure of 3,000 psig and a liquid hourly space velocity of 1.0 V_o/V_c/hr. Approximately 1.5 times as much gasoline was produced at the lower pressure and space velocities. Work done in cooperation with the University of Wyoming.

RI 7739. Materials Handling Research: Penetration of Selected Granular Materials by Wedge-Shaped Tools, by R. S. Fowkes, D. E. Frisque, and W. G. Pariseau. 1973. 19 pp. 8 figs. A study was made by the Bureau of Mines of the penetration of selected granular materials in an unconfined state by wedge-shaped tools having dimensions comparable with the dimensions of the particles composing the materials. The output force for larger particles fluctuated radically. A custom-designed integrator was used to obtain work as a function of depth of penetration in the form of smooth curves. The influence of wedge angle, depth of penetration, penetration rate, entry angle, compaction state, and particle size on the force required and the work performed was ascertained. Empirical equations describing force and work as a function of penetration were obtained for each set of experiments.

RI 7740. Refining Improvement of Shale Oil Naphtha, by L. K. Barker and P. L. Cottingham. 1973. 15 pp. 7 figs. The purpose of this research was to determine how much, if any, improvement would be made by subjecting hydrogenated shale-oil naphtha to a catalytic reforming process. Preselected ranges of temperature and pressure within the com-

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mercial reforming ranges were chosen for investigation and other possible variables were held constant. All tests were made with a liquid hourly space velocity of 3 volumes of liquid feed per volume of catalyst per hour ($V_L/V_C/hr$) and a hydrogen feed rate of 3,000 scf/bbl. Operating temperatures of 850°, 875°, and 900° F were used at pressures of 200, 400, and 600 psig. The greatest octane improvement in the naphtha was obtained at a temperature of 900° F and pressure of 200 psig. The reformed naphtha had a clear research octane number of 89, a liquid yield of 80 vol-pct, and a yield-octane number of 71.1. The data indicate that a higher temperature could have produced a higher yield-octane number. Work done in cooperation with the University of Wyoming.

RI 7741. Development of a Portable Radon Detector, by H. L. Gibbs and J. H. Bilbrey, Jr. 1973. 9 pp. 6 figs. A portable radon monitoring instrument capable of making on-the-spot measurements of the radon gas content of uranium mine atmospheres was designed and constructed. The monitor was tested in the laboratory and in operating uranium mines. Good correlation was obtained between the monitor readings and radon measurements made on mine atmosphere samples taken in radon bottles.

RI 7742. Studies on Recovering Rutile From Titanium-Enriched High-Iron Smelter Slag, by Laurance L. Oden, D. H. Sumner, and J. Howe, Jr. 1973. 10 pp. 3 figs. Titanium-enriched smelter slag produced commercially by Quebec Iron and Titanium Corp., Sorel, Quebec, was evaluated as feed material for a process developed by the Bureau of Mines to prepare rutile. Glass-forming agents including P_2O_5 , B_2O_3 , and two binary mixtures were added individually to the as-received and preoxidized smelter slag, and the nonferrous tramp oxides were effectively partitioned into the resulting noncrystalline phase. Iron in the ferrous oxidation state was moderately soluble in the glass of reduced specimens but less soluble under oxidizing conditions. The solubility of iron oxide in phosphate glass exceeded the solubility of iron oxide in borate glass. Effective conversion of titanium oxide to rutile was not achieved in the high-iron commercial smelter slag, and 20 to 30 pct of the titanium remained as pseudobrookite, a mixed iron-titanium oxide.

RI 7743. Liquid State Spectral Emissivities of Titanium, Vanadium, Zirconium, Molybdenum, and Platinum in an Electron Beam Furnace, by R. K. Koch, J. L. Hoffman, and R. A. Beall. 1973. 25 pp. 8 figs. The normal spectral emissivities of liquid Ti, V, Zr, Mo, and Pt were determined at the fusion temperatures in an electron-beam furnace using a water-cooled copper hearth. The normal spectral emissivities were estimated above the melting points by using adjusted two-color temperatures as approximations of the true temperatures for substitution in Wien's equation. Simultaneous brightness temperatures were determined with a micro-optical pyrometer. The true temperature ranges covered were 1,668° to 1,885° C for Ti; 1,919° to 2,013° C for V; 1,855° to 2,367° C for Zr; 2,610° to 2,751° C for Mo, and 1,772° to 1,990° C for Pt. The spectral emissivities for titanium and zirconium decreased with increasing temperature. At an effective wavelength (λ) of 658 $m\mu$ the emissivity

of titanium ranged from 0.51 to 0.45 and zirconium, from 0.47 to 0.41. The emissivities of vanadium ($\lambda = 658 m\mu$) and molybdenum ($\lambda = 657 m\mu$) were constant at 0.41 ± 0.02 and 0.33 ± 0.01 , respectively. The spectral emissivity of platinum ($\lambda = 658 m\mu$) was constant at 0.39 ± 0.02 up to 1,900° C; above that temperature anomalous data were obtained. A mass spectrometric study indicated that platinum was reacting with backstreaming silicon vapors from the diffusion pump when the ambient pressure was greater than 2×10^{-5} torr.

RI 7744. Properties of Natural Zeolites, by Ronald A. Munson. 1973. 13 pp. 8 figs. Samples of the naturally occurring zeolites phillipsite, clinoptilolite, erionite, and chabazite have been surveyed for their gas adsorption, ion exchange, and other characteristics. Chabazite and erionite, which are generally more stable, also have higher methane adsorption capacities than do the other natural zeolites. Both natural erionite and natural chabazite are classified as small-pore zeolites on the basis of their inability to adsorb chlorotrifluoromethane. In the range of 8 to 100 mesh, the adsorptive capacity of natural zeolites is improved only slightly by a decrease in particle size. The capacity of natural clinoptilolite to adsorb methane is increased by cation replacement by the hydrogen ion and decreased by exchange with calcium ion. Natural phillipsite, which is easily decomposed by heat, adsorbed methane to a limited extent.

RI 7745. Beneficiation of Idaho Kyanite-Bearing Materials, by A. R. Rule and R. S. McClain. 1973. 12 pp. 3 figs. Research was conducted by the Bureau of Mines to develop a process for utilization of Idaho kyanite. A continuous gravity-flotation separation process was applied successfully to recover kyanite-group minerals from an Idaho ore containing about 21 percent combined kyanite, andalusite, and sillimanite. Dry magnetic separation of the concentrate resulted in a product containing about 90 percent kyanite at a recovery of 63 percent of the kyanite-group minerals in the ore. Alumina and silica analyses were within the range generally accepted for conversion to mullite, and the finished products had a pyrometric cone equivalent of more than 38. A recovered garnet coproduct may be of commercial value.

RI 7746. Alternating Current Matrix-Type Magnetic Separator, by Foster Fraas. 1973. 13 pp. 10 figs. This report describes the application of pulsed magnetic fields derived from alternating and intermittent magnetizing currents. Application of such pulsed magnetic fields to the matrix-type separator permits (1) the complete discharge of the magnetic fraction with wet feeds and (2) the dry separation at particle sizes down to 325 mesh. At smaller particle sizes, indications are that frequencies above 60 hertz will be required. Applications of intermittent magnetizing current to the crossbelt separator give the crossbelt separator an advantage over the conventional constant-field crossbelt and induced roll separators; the intermittent current enables the crossbelt separator to separate matted fibrous and magnetically coagulating feeds, a type of feed that occasionally occurs with mineral, industrial, and secondary materials.

RI 7747. Ionic and Neutral Reactions in Glow Discharges of a He- SO_2 -CO Mixture, by D. G. Kuehn,

S. E. Khalafalla, and L. M. Chanin. 1973. 18 pp. 9 figs. Mass spectrographic studies have been conducted on the positive ions and neutral species of glow discharges containing 1.0 pct SO₂ and 1.0 pct CO in helium. Measurements were conducted for gas pressures from 3.5 to 10.1 torr using both dc and 60-Hz ac excitation. The ion species that were observed included S⁺, SO⁺, SO₂⁺, O⁺, O₂⁺, C⁺, CO⁺, and CO₂⁺ with less amounts of SO₃, (CO)₂⁺, SCO⁺, and (SO·CO)⁺ or CS₂⁺. Interpretation of the functional dependence of the various ionic and neutral species on pressure and applied power showed that CO reacted with the SO formed in the discharges to produce CO₂ and sulfur. Deposition of elemental sulfur was observed in the plasma container.

RI 7748. **Effects of Specimen Radius on the Stress State Near a Roof Bolt Anchor: A Finite Element Determination**, by L. V. Wade and P. A. Stahl. 1973. 24 pp. 14 figs. This Bureau of Mines work was performed to theoretically determine the effects of specimen radius and specimen boundary conditions on the stress state in the rock near the anchor for rock specimens used to investigate expansion anchor behavior. Finite element analyses were performed on mathematical models of varying radius and boundary conditions. A review of the results of these analyses revealed a definite convergence of all stress measures considered as the specimen radius increased. There was, however, a significant variation in all stress measures as the specimen diameter increased from 8 to 12 inches.

RI 7749. **Sulfatization-Reduction of Manganiferous Iron Ore**, by F. E. Joyce, Jr., and Charles Prasky. 1973. 17 pp. 4 figs. This paper describes the development of a process for producing manganese and iron pellet concentrates from low-grade manganiferous iron ores of the Cuyuna Range by a two-stage sulfatization-reduction roast. First, the manganese minerals (7.5 percent manganese) were converted to water-soluble manganese sulfate by roasting in sulfur oxide gases at 700° C, then, the hematitic iron minerals (31 percent iron) in the hot sulfatized ore were reduced to magnetite with simulated reformed natural gas in the temperature range of 350° to 425° C. Batch tests were made in a 3-inch-ID by 6-inch-long, gas-heated, stainless steel retort, and continuous countercurrent experiments were performed in a 2-inch-ID by 10-foot-long, electrically heated shaft furnace. Manganese sulfate was removed from the roasted product by leaching with water, and over 90 percent of the manganese was recovered in an oxide product (65 percent manganese) obtained by precipitation, drying, and thermal decomposition of the sulfate. An iron oxide concentrate (60 percent iron) with an iron recovery of 75 percent was obtained from the water-insoluble residue by magnetic separation.

RI 7750. **Recovery of Mercury From Cinnabar Ores by Electrooxidation**, by B. J. Scheiner, R. E. Lindstrom, and D. E. Shanks. 1973. 14 pp. 9 figs. The Bureau of Mines investigated an electrolytic technique for oxidizing ore slurried with brine to determine its effectiveness in extracting mercury from ores. Optimization experiments conducted on a 2.5-pound-mercury-per-ton ore resulted in 95 percent mercury extraction with operating conditions of 30° C, a current density of 0.5 ampere per square inch, and a treatment time of 3.5 hours. Corresponding power consumption amounted to 38 kilowatt-hours per ton of ore treated. Amenability

experiments conducted on 62 different mercury ores resulted in 90 to 99 percent mercury dissolution from ores containing 0.6 to 20 pounds of mercury per ton of ore. Treatment time ranged from 1 to 7 hours in 4- to 20-percent sodium chloride solutions, and power consumption was in the range of 10 to 50 kilowatt-hours per ton of ore. Pilot mill experiments in a 100- to 200-pound-per-hour extraction plant have been in progress to quantify power and reagent requirements. These data will be reported in a subsequent publication.

RI 7751. **Rock Damage From Small Charge Blasting in Granite**, by James J. Olson, Robert J. Willard, David E. Fogelson, and Kenneth E. Hjelmstad. 1973. 44 pp. 25 figs. The Bureau of Mines used microfracture density analysis of quartz grains in thin sections and diametric pulse velocity measurements along preblast and postblast cores to determine the nature and extent of rock damage produced by small (0.25-, 0.50-, 1.0-, and 2.0-kg) charges of high intensity explosive (C-4) in granite. Pulse velocities from the postblast cores were significantly lower than velocities from the preblast cores and, with the core logs, provided clear identification of the upper and sometimes the lower limits of most severe damage. These zones ranged from about 1.68 ft for the 0.25-kg blast to 4.16 ft for the 2.0-kg blast. Microfracture densities from postblast cores were significantly higher and more variable than densities measured from preblast cores. The microfracture density measurements showed that microscopic damage was present far past the zones of most severe damage as delineated by the pulse velocity logs and core logs. An exponential relationship was observed between the microfracture density levels and the charge weight.

RI 7752. **Detonation of a Flammable Cloud Following a Propane Pipeline Break: The December 9, 1970, Explosion in Port Hudson, Mo.**, by D. S. Burgess and M. G. Zabetakis. 1973. 26 pp. 15 figs. This report summarizes the incidents that preceded the December 9, 1970, propane-air explosion in Port Hudson, Mo., and then attempts to establish the nature of the explosion from the ensuing events. Special emphasis is given to possible ignition sources, the distribution of flammable vapors, and the analysis of blast damage. Both near- and far-field damage indicated that this explosion may be attributed to the detonation of propane in air with an energy release equivalent to that from about 50 tons of detonating TNT.

RI 7753. **Fracturing in the Zone Around a Blasthole, White Pine, Mich.**, by David E. Siskind, Robert C. Steckley, and James J. Olson. 1973. 20 pp. 9 figs. The Bureau of Mines has studied the fracturing and associated damage occurring in the vicinity of blastholes from five shots fired in the shale pillars in the White Pine copper mine, White Pine, Mich. Four types of explosives (AN-FO, commercial extra dynamite, ammonia gelatin dynamite, and a low-density, low-velocity permissible) were used. Cores were taken from the blast region and examined by ultrasonic and petrographic techniques. Pulse wave velocities were measured across the core diameters, and thin sections showing cracks and changes in lithology were examined in an attempt to establish zones of damage. Cores from the blast regions and areas near pillar free faces were found to have abnormally low pulse velocities. Petrographic study of the thin sections showed that the

negative velocity anomalies were caused by cracks in the cores. Crushing and extensive fracturing prevented meaningful measurements on core fragments from the immediate blast vicinities. Compositional changes and other rock nonuniformities, such as joints and preexisting fractures, tended to mask detailed damage differences among the four explosives; however, the two most energetic explosives (extra dynamite and ammonia gelatin dynamite) produced damage zones two to three times as large as the AN-FO and low-velocity permissible explosives.

RI 7754. Recovery of Zinc, Copper, Silver, and Iron From Zinc Smelter Residue, by H. E. Powell and L. W. Higley. 1973. 15 pp. 6 figs. This Bureau of Mines study describes two processes for recovering zinc, copper, silver, and iron from the magnetic fraction of a waste generated by the primary smelting of zinc in horizontal retort distillation furnaces. The laboratory-scale procedures include reduction melting to produce a high-copper iron and matte smelting to produce a copper-silver-iron matte and metallic iron. Zinc is fumed in each process and recovered as the oxide. Direct reduction melting yields a metallic iron high in copper and a small rich matte from the sulfur contained in the waste. The products of the second process are a matte containing essentially all of the silver, about 80 percent of the copper and 37 percent of the iron, and an iron-copper alloy containing all of the remaining copper. Extraction with metallic lead or sodium sulfate recovers essentially all of the copper from the molten high-copper iron and yields an acceptable foundry iron.

RI 7755. Strengthening of Fractured Rock Pillars by the Use of Small Radial Reinforcement Pressures, by B. T. Brady and W. I. Duvall. 1973. 20 pp. 11 figs. Results of a study of the effect of low radial reinforcement pressure on the postfailure characteristics of two types of granite, a sandstone, and marble are presented. The low radial reinforcement pressure is applied to the rock surface by a gooch rubber sleeve. The gooch rubber sleeve provides a radial pressure of less than 1 psi pressure to the rock surface. This method of support gives an average strength increase of approximately 8 percent to the fractured rock sample.

RI 7756. The Association of Automotive Fuel Composition With Exhaust Reactivity, by Basil Dimitriadis, B. H. Eccleston, G. P. Sturm, Jr., and C. J. Raible. 1973. 51 pp. 14 figs. The association of automotive fuel composition with exhaust reactivity was studied in an experimental program that involved testing with different automotive engines and with gasolines of varied composition. Results showed clearly the exhaust reactivity to increase with increasing levels of polyalkylbenzenes in the fuel. No other systematic patterns of high significance were detected in the association of exhaust reactivity with several broadly defined groups of fuel components. For the purpose of this study, had it been possible, fuel composition should have been defined and expressed in terms of component groups such that the potential for exhaust reactivity would be the same within each group and different from group to group. Classification of fuel components in terms of the paraffins-olefins-aromatics groups does not meet the latter requirements. For appropriate classification of fuel components more information is needed on the combustion of hydrocarbons in the multicylinder internal combustion engine. Statistical analysis of the mass emissions data showed significant car and fuel

effects on hydrocarbon, carbon monoxide, nitric oxide, total aldehydes, and formaldehyde emission levels and on total photochemical reactivity. Car-fuel interactions were not significant at the 90-pct level. Correlations were found between mass emission parameters and fuel composition.

RI 7757. Hazard From Engines Rebreathing Exhaust in Confined Space, by W. F. Marshall and R. W. Hurn. 1973. 16 pp. 18 figs. The Bureau of Mines conducted a series of experiments to determine the influence of exhaust rebreathing on emissions from various gasoline and diesel engines. Tests were conducted that simulated operation of engines in nonventilated spaces as well as in spaces with partially restricted ventilation. Results of these tests showed that exhaust rebreathing can have a marked effect on exhaust emissions and thus on the composition of the air in the working space. For the case of restricted ventilation, unacceptably high (greater than 50 ppm) levels of CO in the air of the working space resulted from exhaust rebreathing rates as low as 8 pct exhaust in the engine's intake. Operation in a nonventilated space resulted in highly critical CO levels (fatal in a few minutes) at times corresponding to 1 to 3 pounds of fuel consumed per 1,000 cu ft of space. Tests involving space of various sizes showed that volume of the air spaces per se is not important—the primary variable is fuel consumed per unit volume of air space.

RI 7758. Methods for Producing Alumina From Clay: An Evaluation of a Sulfurous Acid-Sulfuric Acid Process, by Paul J. Barrett, Paul W. Johnson, and Frank A. Peters. 1973. 40 pp. 11 figs. The Bureau of Mines evaluated a sulfurous acid-sulfuric acid process for recovering alumina from clay, in which clay is leached successively with sulfurous acid and sulfuric acid. The resulting aluminum sulfite and aluminum sulfate solutions are combined and heated to produce a basic aluminum sulfate and sulfur dioxide. Alumina is extracted from the basic aluminum sulfate as sodium aluminate by leaching with dilute sodium hydroxide. After desilication, sulfuric acid is used to precipitate alumina as alumina trihydrate, which is then calcined to alpha-alumina. The estimated fixed capital cost for a plant producing 1,000 tons per day of alumina is about \$74 million on a 1971 basis. For comparison with previous alumina-from-clay evaluations, the estimated fixed capital cost for the plant is about \$67 million on an M and S Chemical Equipment Index basis of 240.0, which is equivalent to a 1960 cost level. Because the operating cost is highly dependent on fuel and electric power costs, graphs are included to show the effect of these items on the operating cost. On a 1971 basis, with natural gas costing 35 cents per million Btu and operating labor costing \$4 per hour, the estimated operating cost is about \$100 per ton of alumina. On a 1960 basis, with labor costing \$2.30 per hour and natural gas costing 25 cents per million Btu, the estimated operating cost is about \$86 per ton of alumina.

RI 7759. Correlations of Phase-Boundary Pressures of Condensate Fluid Systems With Compositions Modified by Added Butane, by Byron A. Baker and C. Kenneth Eilerts. 1973. 56 pp. 28 figs. The Bureau of Mines used a windowed cell to measure the phase-boundary pressures of two related series of gas-condensate fluid mixtures. Normal butane was added to the mixtures incrementally to determine its effectiveness for lowering phase-boundary pressure. All the experimental data were correlated, so that the pressure required to maintain light oils mixed with

natural gas in the single phase may be computed for secondary recovery applications. The heavy hydrocarbon parts of the mixtures were distillation fractions of a gulf coast condensate. Intermediate normal hydrocarbons in the butane-heptane range and natural gas were added to the fractions in selected proportions, so that phase-diagram pressures of 26 fluids were actually studied. The experimental range of temperatures was 50° to 280° F. Two correlations were developed to represent phase-boundary pressures by means of a polynomial. Independent variables represent natural gas content, disparity of properties of components comprising the mixtures, and temperature. A fourth variable, for one correlation only, was the quantity of normal butane added to the original mixtures. The latter correlation with four independent variables contains 15 coefficients and is estimated to be accurate to 135 psi.

RI 7760. Resource Recovery From Raw Urban Refuse, by P. M. Sullivan, M. H. Stanczyk, and M. J. Spendlove. 1973. 28 pp. 16 figs. At its College Park Metallurgy Research Center in Maryland, the Bureau of Mines has installed and is operating a 5-ton-per-hour pilot plant for continuous mechanical separation of values contained in raw urban refuse. The entire system was assembled using commercially available equipment. The process relies on multistage processing including shredding, air classification, screening, gravity concentration, and electrostatic separation. Compactor trucks deliver raw refuse collected along typical routes in metropolitan Washington, D.C., to the pilot plant. The loads are separated into concentrates of light-gage iron, massive metals, glass, putrescibles and waste combustibles, paper, and plastics. While some refinements remain to be made in the processing system flowsheet, the data obtained to date have been highly encouraging, indicating favorable economics for commercial-size plants.

RI 7761. Physical Aspects of Copper Cementation on Iron, by Walter W. Fisher and Rees D. Groves. 1973. 9 pp. 5 figs. A study of copper cementation on iron was initiated to determine the effect that deposited copper has upon subsequent cementation. A microscopic investigation of cementation on an iron surface showed that cupric ion precipitates predominately on a growing copper deposit attached to the iron surface. A kinetic study of the cementation process in a revolving drum showed that the cementation rate is enhanced by the copper deposit attached to the iron surface and by the discrete copper particles of a cement-copper slurry. The kinetic study also indicated that the character of the deposit is affected by the major anion in the solution. The cementation process is visualized to occur as a series of electrochemical cells in which cupric ion precipitates on copper dendrites attached to the iron surface.

RI 7762. The Composition of Coalbed Gas, by Ann G. Kim. 1973. 9 pp. Samples of gas were obtained directly from the coalbed during drilling of horizontal and vertical boreholes in six different formations. The samples were analyzed by gas chromatography for C₁ to C₅ hydrocarbons and for O₂, N₂, H₂, He, and CO₂. Methane in the gas varied from 63 to 99 percent; carbon dioxide from 0.1 to 15 percent. The CH₄/CO₂ ratio varied and showed no apparent correlation with age, rank, or bed. The majority of samples contained ethane, propane, and butane; hydrogen and helium were found in some

samples. Oxygen and nitrogen were usually present, possibly as a result of air contamination. A more extensive sampling program would be necessary to establish a relationship between the amount and composition of the gas in the coalbed and other factors.

RI 7763. Procedures Used for Sampling Fracture Orientations in an Underground Coal Mine, by D. D. Bolstad, J. R. Alldredge, and M. A. Mahtab. 1973. 9 pp. 3 figs. The Bureau of Mines has developed procedures for sampling the geometry of fractures in underground coal mines. Stratified cluster sampling and the unit area concept are applied to the collection of fracture orientation data. The use of unit area mapping, stratification, and site delineation is made to assure collection of representative data. The procedures developed here help to isolate sources of variability in the fracture patterns.

RI 7764. Mine Roof Vibrations From Underground Blasts, Pilot Knob, Mo., by David E. Siskind, James J. Snodgrass, Richard A. Dick, and John N. Quiring. 1973. 21 pp. 14 figs. The Bureau of Mines recorded particle accelerations in the mine roof produced by three types of explosives in the Pilot Knob Pellet Co. mine, Pilot Knob, Mo. Examined were the effectiveness of cube root, square root, and two-thirds power scaling in grouping the underground blast vibration data, and the effects of mine geometry, rock type, explosive type, and charge size on blast vibration levels. A propagation law for this mine was determined. The scaling factor of the square root of the charge weight was developed from previous Bureau studies of vibrations from quarry blasts, and in underground blasting both square root and cube root scaling were found applicable for scaling particle vibration data. The vibrations from the Pilot Knob blasts were best grouped by a square-root scaling factor. The empirical propagation equation $AW^{1/2} = 76,250 (R/W^{1/2})^{-2.61}$ where A is the peak acceleration in g's, W is the charge weight in pounds, and R is the distance from the blast in feet, may be used to describe vibration amplitudes from charges fired with zero delay caps or with a single cap at Pilot Knob.

RI 7765. Respirable Dust Adhering to Run-of-Face Bituminous Coals, by L. Cheng and P. P. Zukovich. 1973. 10 pp. 6 figs. This Bureau of Mines report summarizes an investigation of the amount of respirable dust adhering to the surfaces of seven run-of-face broken bituminous coals. The number of respirable-size (0.9 to 10 micrometers) particles adhering to the run-of-face coal ranged from 10¹¹ to 10¹² particles per pound of coal and was approximately inversely proportional to the mean lump size of the coal sample. Otherwise it did not vary significantly with the coal seam, mining method, or winning machine. Based on these results, about 16 pounds of ordinary run-of-face broken coal would have enough respirable-size adhering dust to contaminate 1 million cubic feet of air up to the 2 mg/m³ level, if this adhering dust should become airborne. Although brief studies here suggest that a negligible amount of new respirable dust is formed owing to fracture of the broken coal during dropping, dislodging of old adhering particles during secondary handling operations is a potentially dangerous source of airborne respirable dust.

RI 7766. Radical Species Profiles for a Methane-Oxygen-Argon Flame, by Charles P. Lazzara, Joan C. Biordi, and John F. Papp. 1973. 10 pp. 4 figs. Concentration profiles of low-pressure, slightly lean

CH₄-O₂-Ar flames have been measured in situ for the following unstable species: oxygen atom, hydrogen atom, hydroxyl radical, methyl radical, and formyl radical. The observed maximum mole fractions were 2.0×10^{-2} for H, 1.1×10^{-2} for OH, and 0.8×10^{-2} for O; the maxima occurred in the recombination zone. Methyl and formyl radicals have maximum mole fractions in the reaction zone of 2.2×10^{-3} and 6×10^{-5} , respectively.

RI 7767. The Direct Method of Determining Methane Content of Coalbeds for Ventilation Design, by F. N. Kissell, C. M. McCulloch, and C. H. Elder. 1973. 17 pp. 7 figs. The applicability of the "direct method" for determining the methane content of virgin coalbeds was tested. Preliminary results indicate that the direct method, when applied to exploration cores, can be successfully used to estimate coalbed gas content and also approximately predict the total gas emission from a prospective mine located in the coalbed at the exploration site.

RI 7768. Gases Desorbed From Five Coals of Low Gas Content, by A. G. Kim and L. J. Douglas. 1973. 9 pp. 1 fig. Methane and other hydrocarbon gases, byproducts of coalification, are emitted from coal at widely varying rates and often present ventilation problems during mining. The air in some coal mines apparently contains no methane. To determine if coals from mines which had no history of detectable gas emission contained adsorbed methane, samples of coal at the shaft bottom and at an active face were obtained and placed in sealed metal cylinders. The atmosphere around the coal was sampled and analyzed by gas chromatography. Methane, ethane, ethylene, propane, propylene, and butane were found to have been desorbed from these coals. Hydrogen and helium were also detected. An estimate of the amount of residual gas per ton of coal indicated that coal samples from the active face generally contained more adsorbed gas than coal samples obtained from the shaft bottom.

RI 7769. Geologic Factors Causing Roof Instability and Methane Emission Problems. The Lower Kittanning Coalbed, Cambria County, Pa., by C. M. McCulloch and Maurice Deul. 1973. 25 pp. 15 figs. A geologic study of Mines 32 and 33 in Cambria County, Pa., was conducted as part of a methane control research program. Areas of high methane emission and roof instability are encountered; these are related to the structural and stratigraphic features that characterize the geologic setting of these mines. Locally the folds trend N 20° E $\pm$ 2°, the direction of the butt cleat in the Lower Kittanning coal. The face cleat strikes at N 69° W $\pm$ 2° and the systematic rock joint in the surface bedrock strikes N 67° W $\pm$ 2. This suggests that a directional stress oriented N 70° W produced the folds and influenced the directions of coal cleat and systematic joint sets. Analysis of side-look airborne radar (SLAR) indicates three directions of prominent regional lineation: N 39° E, N 31° W, and N 70° W. Little gas was encountered during development mining; large volumes of gas are encountered when roofs fall. Most of the gas comes from strata above the mined coal; therefore, to control methane, roof instability must be controlled. Roof falls and high rates of methane emission are most likely where less than 30 feet of many thin layers of limestone, shale, and sandstone occur between the Lower Kittanning coal and the next coal and in zones along the margins of a sandstone channel.

RI 7770. Compound Type Separation and Characterization Studies for a Gash Saran, Iran, 370° to 535° C Boiling Distillate, by J. E. Dooley, R. L. Hopkins, D. E. Hirsch, H. J. Coleman, and C. J. Thompson. 1973. 25 pp. 10 figs. To process and use the heavy ends of petroleum effectively, the development of suitable separation and characterization procedures not currently available was required. A systematic procedure was developed by the Bureau of Mines using such techniques as isothermal and molecular distillation, chemical treatment, silica-alumina gel chromatography, gel permeation chromatography, and spectrometry. Using these techniques, the Bureau achieved a detailed separation and characterization of a 370° to 535° C distillate from Gash Saran, Iran, crude oil. Such a systematic procedure and the semi-quantitative data resulting therefrom should be of value in selecting feedstocks and in optimizing petroleum processing operations.

RI 7771. Large-Scale Continuous Attrition Grinding of Coarse Kaolin, by E. G. Davis, E. W. Collins, and I. L. Feld. 1973. 22 pp. 7 figs. Large-scale ultrafine grinding tests of a coarse kaolin were made using the Bureau of Mines-developed attrition grinding process in continuous open- and closed-circuit systems. A 20-inch-diameter attrition grinder, designed and constructed at the Tuscaloosa Laboratory, was used. Studies included single- and multiple-stage open-circuit grinding, and also continuous grinding tests in closed-circuit with a 6-inch-diameter solid bowl centrifuge. Clay feed, containing 9.0 percent minus-2-micrometer esd, was used at rates up to 840 pounds per hour. Multistage grinding tests gave better results than single-stage treatment when equivalent clay feed rates were used. Closed-circuit grinding tests yielded ground products containing slightly more minus-2-micrometer-esd clay than the open-circuit grinding when using the same clay feed. Energy consumption was lower in closed-circuit grinding than in batch or open-circuit grinding. A modified two-stage closed-circuit grinding system gave the best grade of product and amount of minus-2-micrometer-esd clay produced per pound of clay feed. The ground product from this test contained 88.5 percent minus-2-micrometer-esd material and electrical energy consumption was 327 kilowatt-hours per ton of minus-2-micrometer-esd material produced. Work done in cooperation with the University of Alabama.

RI 7772. Comparison of Respirable Dust Concentrations Measured With MRE and Modified Personal Gravimetric Sampling Equipment, by Thomas F. Tomb, H. N. Treafis, R. L. Mundell, and P. S. Parobeck. 1973. 29 pp. 2 figs. Past experience has shown that the penetration characteristics of the 10-mm nylon cyclone used on approved personal sampling equipment are significantly different from those determined in the laboratory using a nonpulsating flow source. The Bureau of Mines has developed and recommended a modification to presently approved equipment that will alleviate this difference. However, as a result of this modification, a new relationship for converting respirable dust concentrations measured with approved personal sampling equipment to equivalent concentrations as measured with an MRE instrument will have to be established.

This Bureau of Mines report describes the underground sampling program conducted to establish a new factor for converting respirable dust concentrations measured with personal sampling equipment, modified with a recommended pulsation damping device, to an equivalent concentration as measured with an MRE gravimetric dust sampler.

- RI 7773. Determination of Eight Minor Elements in Low Alloy Steels by Fluorescent X-Ray Spectrography**, by William J. Campbell and David L. Neylan. 1973. 13 pp. This analytical method development and evaluation was undertaken by the Bureau of Mines to provide accurate determinations of eight minor elements in low-alloy steels prepared from ferrous scrap. Fluorescent X-ray spectrography was the principal method investigated. Confirming analyses were made by conventional instrumental and chemical methods. All X-ray data were processed by a timesharing computer. No corrections were found necessary for interelement effects or overlapping spectral lines. Concentrations were calculated from the least-square fit of a linear calibration equation derived from measurements on three sets of standard steels. These studies show that X-ray spectrographic analysis of lathe-finished surfaces provides accurate determinations of aluminum, copper, chromium, manganese, nickel, phosphorus, silicon, and tin.
- RI 7774. Sulfur Dioxide Emission Control by Hydrogen Sulfide Reaction in Aqueous Solution. The Citrate System**, by J. B. Rosenbaum, W. A. McKinney, H. R. Beard, Laird Crocker, and W. I. Nissen. 1973. 31 pp. 17 figs. Prolonged laboratory and limited pilot plant tests have shown that the Bureau of Mines buffered SO_2 - H_2S process is capable of removing 95 to 99 percent of the SO_2 from industrial waste gases. Most of the SO_2 is converted to elemental sulfur; only about 1 percent is converted to sulfate. The process comprises (1) washing the flue gas to remove particulates and SO_3 , (2) absorption of the SO_2 in citric acid or other carboxylate solution, (3) reaction of the loaded solution with H_2S in a closed vessel to precipitate the absorbed SO_2 as elemental sulfur, and (4) separation of the sulfur from the regenerated solution by oil flotation and melting. Two-thirds of the molten sulfur is converted to H_2S for use in the sulfur precipitation step by reacting sulfur vapor with natural gas and steam in the presence of an alumina catalyst. The chemistry and mechanism of the process are described, initial laboratory and pilot plant data are summarized, and second-generation laboratory operation and pilot plant design are reviewed. Preliminary cost estimates are presented for recovering sulfur from copper smelter gas, powerplant flue gas, and Claus plant tail gas.
- RI 7775. Geology of Eocene Rocks and Oil Yields of Green River Oil Shales on Part of Kinney Rim, Washakie Basin, Wyoming**, by Laurence G. Trudell, Henry W. Roehler, and John Ward Smith. 1973. 151 pp. 8 figs. Geology and oil-yield data are presented for a 58-square-mile area encompassing the U.S. Department of the Interior oil-shale leasing program tracts in the western Washakie Basin, Sweetwater County, Wyo. Lithology and oil yields of samples from three Bureau of Mines coreholes are evaluated and correlated with Kinney Rim surface sections measured and sampled by the U.S. Geological Survey. Minable sections of oil shale averaging up to 25 gallons of oil per ton crop out on Kinney Rim in the Laney Member of the Green River Formation. Thick oil-shale sections in the Laney Member that average 15 gallons per ton represent 155 million barrels of oil in place per square mile. In the lower part of the Green River Formation the Tipton Shale Member contains a 20- to 40-foot section averaging 15 gallons per ton. Beds of high-volatile C bituminous coal up to 6 feet thick are present in intertongued parts of the lower Green River Formation and upper Wasatch Formation. GPO Catalog No. I28.23:7775. Stock No. 2404-01429. \$2.90.
- RI 7776. Reducing Copper and Tin Impurities in Ferrous Scrap Recovered From Incinerated Municipal Refuse**, by L. L. Oden, A. Adams, and A. D. Fugate. 1973. 11 pp. 3 figs. The purpose of this research was to develop a method to remove copper and tin from the magnetic fraction of incinerated municipal refuse, as recovered by the Bureau of Mines pilot plant in College Park, Md. Copper, present in the scrap in a metallic form bonded to ferrous objects, was amenable to leaching in cupric ammonium carbonate solution. Copper levels in small 5- to 10-pound lots of treated scrap were reduced from the initial level, 0.5 to 0.6 percent, to 0.1 to 0.2 percent. Larger lots of scrap (100 lb) were treated less effectively because of poor contact of solution and scrap. Oxidation in the air or in aerated aqueous solution was applied to liberate tin from the dilute solid solution present on the surface of incinerated tinplate. Shredding of air-oxidized scrap or caustic leaching of scrap oxidized in solution reduced tin levels from the initial 0.25-percent level to about 0.1 percent.
- RI 7777. Effect of Copper and Silicon on Selected Mechanical Properties of Hot-Rolled Medium-Carbon Steels**, by Mark I. Copeland. 1973. 19 pp. 11 figs. The Bureau of Mines investigated the effect of up to 1 wt-pct of copper and silicon on the heat treatment response and hardness, tensile, and impact properties of hot-rolled medium-carbon steels. The steels were prepared by induction melting and fabricated into plates by forging and rolling. The tensile strength of 0.2-wt-pct carbon steels containing 0.3 wt-pct silicon was affected significantly by copper in both the hot-rolled and heat-treated (600°C) conditions, whereas the tensile strength of the 0.3-wt-pct carbon steels was less affected. A 600°C treatment was considered optimum as a post-rolling treatment to strengthen the steels by copper precipitation. Strengthening of 0.2-wt-pct carbon steels by silicon was reduced by increasing copper contents. Optimum impact strengths occurred at about 0.3 wt-pct silicon in 0.2-wt-pct carbon steels containing 0.6 and 0.8 wt-pct copper. The impact strengths were lowest for 0.2-wt-pct carbon steels containing over 0.8 wt-pct copper and greater than 0.3 wt-pct silicon, especially in the heat-treated condition. Copper and silicon solutes and copper precipitates strengthened the steels. This effect was augmented slightly by strengthening through grain refinement by these solutes.
- RI 7778. Thermodynamic Properties of Three Sodium Titanates**, by K. O. Bennington and R. R. Brown. 1973. 13 pp. Enthalpies of formation of three sodium titanates were determined by hydrofluoric acid solution calorimetry. The values obtained for formation from the elements at 298.15°K are -370.9 ± 0.5 kcal/mole for Na_2TiO_3 , -832.1 ± 0.9 kcal/mole for $\text{Na}_2\text{Ti}_3\text{O}_7$, and $-1,510.9 \pm 1.7$ kcal/mole for $\text{Na}_2\text{Ti}_6\text{O}_{13}$. Tables of enthalpies of formation and Gibbs energies of formation are given as a function of temperature both from the elements and from the component oxides for Na_2TiO_3 and $\text{Na}_2\text{Ti}_3\text{O}_7$.
- RI 7779. The Spectral Growth of Expanding Flames: The Infrared Radiance of Methane-Air Ignitions and Coal-Dust-Air Explosions**, by M. Hertzberg, C. D. Litton, W. F. Donaldson, J. M. Kuchta, and A. L. Furno. 1973. 38 pp. 21 figs. Results of a comprehensive study of the absolute spectral radiance of the infrared emissions from methane-air explosions are reported. The spectral growth of these expanding

flames were recorded with a time resolution of 1 msec in the spectral range of 1.7 to 5.0 μm . Time-resolved spectra were obtained for methane-air mixtures as a function of stoichiometry, nitrogen dilution, and Halon dilution, in a 9-liter vessel under different venting conditions. Data are also presented for coal dust-air explosions. Temperatures, obtained from the absolute radiances and from a band ratio technique for methane-air, are internally consistent and are generally 50° to 200° K below adiabatic flame temperatures. All near limit mixtures gave essentially the same flame temperatures (1,500° to 1,600° K) regardless of whether the limit was obtained by dilution with excess air, excess methane, excess nitrogen, or Halon. The coal dust explosion spectrum is essentially a blackbody continuum at 1,500° K with some selective emission at 4.4 μm from hotter CO_2 . The data are analyzed in terms of the radiative dynamics of a spherically expanding flame zone. The importance of radiative transport is assessed. An equation is derived which relates the instantaneous fraction of combustion power radiated to adiabatic variables.

RI 7780. Decomposition of Hydrogen Sulfide in an Electric Discharge, by L. A. Haas and S. E. Khalafalla. 1973. 22 pp. 14 figs. Hydrogen sulfide was decomposed to elemental sulfur in an electrical discharge. With He, N_2 , or Ar diluents, a threshold voltage between 1 and 3 kV was required for the decomposition reaction to occur in a laboratory ozonizer. Above the threshold voltage, the H_2S decomposition rate increased with increasing voltage, but the increase was more pronounced with argon diluent than with either nitrogen or helium. In common with other reactions in an electrical discharge, the H_2S decomposition decreased with increasing temperature in the range of -41° to +61° C. The reaction did not appear to be rate controlled by a solid-gas sorption step because the introduction of activated charcoal into the electrical discharge zone did not significantly affect the decomposition yield. In the presence of polymeric chlorofluorocarbon oil, 90 percent conversion of the 3-percent H_2S in helium was obtained at 14 kV, 60 Hz, a 2-mm electrode gap, and a gas-residence time greater than 1 min. Under the same experimental conditions in the absence of oil, the conversion was only about 50 percent.

RI 7781. Evaluation of Methods for Determining Nahcolite and Dawsonite in Oil Shales, by Charles W. Huggins, Thomas E. Green, and T. L. Turner. 1973. 21 pp. 13 figs. To determine the nahcolite and dawsonite content in oil shales, the Bureau of Mines compared X-ray diffraction, infrared spectroscopy, thermal methods, and a previously published method by Smith and Young based on the selective solubility of sodium compounds. The Smith and Young method and a new method based on the weight of carbon dioxide produced by thermal decomposition are recommended for determining nahcolite. X-ray diffraction and the Smith and Young method are recommended for determining dawsonite. X-ray diffraction, infrared spectroscopy, and differential thermal analysis were useful for identifying other minerals in the samples.

RI 7782. Minimum Extinguishant and Maximum Oxygen Concentrations for Extinguishing Coal Dust-Air Explosions, by Joseph Grumer, L. F. Miller, A. E. Bruszak, and L. E. Dalverny. 1973. 6 pp. In addition to nine powder and gaseous extinguishants of propagating Pittsburgh seam coal dust-air explosions earlier evaluated, 10 other powders have similarly been evaluated under like conditions such that wall

quenching of the coal dust-air flames was virtually absent and the dust concentration was temporally and spatially uniform to within about ± 5 percent. None of the newly examined extinguishants was better than Purple-K (potassium bicarbonate); the 10 of this report are anhydrite (calcium sulfate), monobasic (4 types) and dibasic ammonium phosphate, natural and synthetic cryolite (sodium fluoaluminate), sodium sulfate, and tricalcium phosphate. Except for anhydrite, sodium sulfate, tricalcium phosphate, and the cryolites, these materials were about equally effective, when present in relatively low concentrations (weight-percent of the coal dust-extinguishant mixture). The maximum oxygen concentration for the extinguishment of otherwise uninhibited coal dust explosions and the influence of coal dust particle size and the volatile content of the coal were also explored. For the present, the choice of the inhibitor among the good ones evaluated is not as critical as the system to be used to deploy the extinguishant against a coal dust explosion.

RI 7783. In Situ Retorting of Oil Shale—Results of Two Field Experiments, by E. L. Burwell, T. E. Sterner, and H. C. Carpenter. 1973. 41 pp. 26 figs. Application of the in situ recovery process to oil shale was tested during two field experiments near Rock Springs, Wyo. The results of these tests demonstrate that a self-sustaining combustion zone can be created in an oil shale body, that this zone can be moved through the oil shale, and that the process will produce shale oil. Evaluation of the combustion process by monitoring produced fluids for physical and chemical properties and volumes is described. The material and energy balance obtained is compared with a second evaluation based on extensive coring of the test area after the test was terminated. Several side results of the research are noted such as ground surface heating by underground burning and production of low- to medium-Btu gas during retorting. Work done in cooperation with the University of Wyoming.

RI 7784. Preparation of Samarium-Cobalt Permanent Magnets, by J. W. Walkiewicz, J. S. Winston, and M. M. Wong. 1973. 18 pp. 14 figs. Studies were conducted by the Bureau of Mines to develop a method for fabricating Sm-Co permanent magnets. This method consisted of arc-melting, crushing and grinding the alloy, alining and pressing the powder, and sintering the green compacts. Results indicated that the optimum composition was 36.7 ± 0.3 weight-percent Sm and 63.3 ± 0.3 weight-percent Co. This composition was obtained by blending together Sm_2Co_7 and SmCo_5 . The maximum values experimentally obtained were $MH_c = 27.4 \text{ KOe}$, $BH_c = 7,510 \text{ Oe}$, $B_r = 7,810 \text{ G}$, and $(BH)_{\text{max}} = 15.1 \text{ MGOe}$. The optimum sintering temperatures and grinding times for maximum MH_c and $(BH)_{\text{max}}$ were determined. Lowering the grinding temperature from 0° to -60° C resulted in a significant increase of magnetic properties.

RI 7785. The $\text{K}_2\text{HfF}_6\text{--K}_2\text{ZrF}_6\text{--}1.25$ Percent HF System at 40° C With Other Solubility Curves From 25° to 70° C, by Stanley C. Rhoads. 1973. 20 pp. 10 figs. The Bureau of Mines investigated the complete ternary system $\text{K}_2\text{HfF}_6\text{--K}_2\text{ZrF}_6\text{--}1.25$ weight-percent HF at 40° C. In addition, solubility curves have been established at 25°, 30°, 50°, 60°, and 70° C. These solubility data implemented a study of hafnium enrichment in feed solutions for liquid-liquid extraction processes. Selected $\text{K}_2\text{HfF}_6\text{--K}_2\text{ZrF}_6\text{--}1.25$ weight-percent HF mixtures were equilibrated in a constant temperature bath. Compositions of the equilibrated

solutions and wet residues were established from combined hafnium and zirconium oxide and total fluorine analyses. All solubility curves were essentially parallel on triangular coordinates. At 40° C, the solid phase of the K_2HfF_6 - K_2ZrF_6 -1.25 percent HF system is a series of solid solution hydrates with $K_2HfF_6 \cdot H_2O$ and $K_2ZrF_6 \cdot 3H_2O$ segments existing at the respective extremes. Since this system contains $K_2HfF_6 \cdot H_2O$ and $K_2ZrF_6 \cdot 3H_2O$ segments, it is not ideal for simple separation of high-purity K_2HfF_6 from K_2HfF_6 - K_2ZrF_6 mixtures by recrystallization. However, it would be useful for producing hafnium-enriched feed solutions from zircon concentrates for liquid-liquid extraction of hafnium from zirconium.

RI 7786. An Algorithm for Calculating Multiphase Chemical Equilibrium, by F. E. Spencer, Jr., and A. A. Orning. 1973. 42 pp. 1 fig. This Bureau of Mines report provides a complete mathematical description of the algorithm employed by a general multiphase chemical equilibrium program developed particularly for the purpose of studying problems in coal combustion, although the generality of the program will allow its application to any equilibrium system in which an appreciable gas phase is present. When applied to coal combustion problems, the program predicts composition and quantity of slag and unconsumed carbon phases as well as calculates accurately the composition of the gas phase including trace species such as free electrons and ions which are important for predicting electrical properties.

RI 7787. Tunneling Machine Research—Development of an Experimental Full-Scale Research Rock Cutting Device, by Parviz F. Rad and Robert L. Schmidt. 1973. 18 pp. 12 figs. The increased use of tunnel boring machines (TBM) has stimulated laboratory research to optimize the cutting parameters of these machines with the objective of increasing machine efficiency and penetration rate. Laboratory-scale rock cutting experiments have succeeded in identifying many of the important parameters involved in rock-cutter interaction. Although scaling factors may be required to apply the results directly, the concepts developed can be used qualitatively as design guidelines for boring machines. The Bureau of Mines Twin Cities Mining Research Center has recently developed a large-scale rock cutting device (RCD) that will simulate many of the operating parameters of the tunnel boring machines in the laboratory under a controlled environment. The results of the experiments with this device will be directly applicable to the design of TBM's.

RI 7788. Evaluation of a Machine-Mounted Dust Collector, by T. F. Tomb, J. F. Martonik, and C. D. Taylor. 1973. 15 pp. 7 figs. This paper describes field and laboratory investigations conducted on a dust-collection system recently designed for integral use with a continuous mining machine. The results of the field study showed that the average respirable dust concentration measured at the machine operator's position was reduced by about 60 percent (from 8.7 to 3.5 milligrams per cubic meter), and total and respirable dust concentrations in the return air were reduced by approximately 70 percent. The data indicated that approximately 20 percent of the dust generated at the face was not passed through the scrubber. The laboratory results showed that the overall efficiency (by particle count) was approximately 80 percent for total dust concentrations (minus 20 micrometers in size) typical of those encountered underground. Calculations based on total dust concentrations measured during the underground study indicated that the respirable mass

concentrations of the effluent from the scrubber would still exceed acceptable levels even if scrubbing of all the air at the face were possible.

RI 7789. Establishing Standards for Effective Wire Rope Clip Installation, by Robert I. Fujimoto. 1973. 20 pp. 16 figs. The work described was conducted to develop standards for the application of wire rope clips on wire rope. These standards include optimum number of clips and clip nut torques for wire rope sizes $\frac{1}{4}$ through $2\frac{1}{4}$ inches, when used for forming an eye attachment in wire rope. Wire rope test specimens with clip attachments were load tested on tensile testing machines to determine an effective combination of clip nut torques and number of clips for each size of wire rope to develop efficiencies above 90 percent of the catalog ultimate rope strength.

RI 7790. Methane Control by Isolation of a Major Coal Panel—Pittsburgh Coalbed, by Charles Findlay, Stephen Krickovic, and J. E. Carpetta. 1973. 11 pp. 9 figs. As one of its projects for degasification of major panels of coal prior to mining within them, the Bureau of Mines conducted methane emission studies during development of a set of three headings 1,800 feet in a major coal panel (2,700 by 3,500 feet) which had been completely isolated by sets of main headings for 12 months in the Federal No. 2 mine (Pittsburgh coalbed) in northern West Virginia. Similar emission studies were conducted in the development of two sets of main headings in virgin coal areas nearby. Comparing the two sets of data indicated that the isolated coal panel had been degasified by approximately 70 percent. Work done in cooperation with the Eastern Associated Coal Corp.

RI 7791. Radioactive Tracer Pulse Method of Evaluating Fracturing of Underground Oil Shale Formations, by Philip B. Lorenz. 1973. 33 pp. 17 figs. A Bureau of Mines feasibility study on the use of tracer pulses to assess the degree of fracturing in an underground formation consisted of three phases:

1. A laboratory study on sand packs and open tubes, which developed a correlation between dispersion of the pulse and size of the flow channels.

2. A test on a retort, 11 feet in diameter and 45 feet high, packed with shale rubble. Void volume was measured, but evaluation of channel size was not possible because of interference from the space unoccupied by the matrix.

3. A field test on an explosively fractured shale formation. Pressure, flow, and transit time led to qualitative estimates of fracture pattern, but quantitative detection of dispersion in the formation was overwhelmed by dispersion effects in the well.

RI 7792. Structural Design Data for Concrete Drift Linings in Block Caving Stopes, by J. D. Dixon. 1973. 73 pp. 112 figs. The Bureau of Mines has developed structural design data for unreinforced concrete tunnel linings for drifts used in block caving stopes. Design data are given that consist of moment, thrust, and deformation coefficients from which bending, axial, boundary stresses, and structural deformations can be determined at any point on the lining. Data is given for circular, horseshoe, and rectangular linings, each with two different thicknesses and subjected to eight different loading conditions for drifts excavated in hard and soft rocks. The structural analyses performed are based on procedures that account for both the structural behavior of the lining and that of the drift and take into con-

sideration deformational interaction that occurs between them.

RI 7793. Nuclear Gages for Monitoring the Coalbed of Commercial-Scale Pressurized Gas Producers, by G. R. Friggens and A. W. Hall. 1973. 9 pp. 4 figs. A nuclear method for continuously monitoring the coalbed and ash levels and void formation in commercial-scale, fixed-bed, pressurized gas producers is proposed. Measurement of gamma ray transmission through the coalbed is the basis of the method. The coalbed level is monitored by detecting the transmission of gamma rays from a 1 to 2 Ci Co-60 source positioned on the outside wall of the vessel. Coal bridging or, alternatively, ash level is monitored by a 10 Ci Co-60 source at the center of the coalbed. Source activities and geometries are calculated for a 12-foot-ID producer designed to operate at 350 psi. Source capsule and detector specifications and operational safety are also discussed.

RI 7794. Oxidation of Cement Copper by Flash Roasting, by Walter W. Fisher and Rees D. Groves. 1973. 11 pp. 5 figs. Cement copper was flash roasted in a vertical tube furnace to convert the copper to acid-soluble oxides as part of a postulated process for refining cement copper by oxidation roasting, acid leaching, and electrowinning. The results of the study showed that the oxidation was a linear function of oxygen concentration between 0 and 20 percent, but above 20 percent oxygen there was no further increase in oxidation. Therefore, air was the optimum oxidizing atmosphere in this flash roasting system. The oxidation followed a parabolic rate law as the roasting temperature was increased from 400° to 800° C. Extrapolation of the data, based on the parabolic law, indicated that at 400°, 500°, 600°, 700°, and 800° C, the roasting times required for complete conversion to soluble oxides were 75, 37, 21, 7.7, and 4.6 seconds, respectively. Cyclic-roasting test results did not substantiate the predictions obtained through data extrapolation.

RI 7795. Determining Explosive Oil in Dynamites Using High-Pressure Liquid Chromatography, by T. Christos and L. Spinetti. 1973. 5 pp. 2 figs. The explosive oils, nitroglycerin (NG) and ethylene glycol dinitrate (EGDN), were extracted from dynamites by a halocarbon solvent and were then determined by high-pressure liquid chromatography. Separation was achieved by liquid-liquid chromatography on a column packed with Durapak-Carbowax 400/Corasil II and the eluted NG and EGDN were detected with a double-beam ultraviolet detector.

RI 7796. An Economic Evaluation of MHD-Steam Powerplants Employing Coal Gasification, by P. D. Bergman, K. D. Plants, J. J. Demeter, and D. Bienstock. 1973. 33 pp. 10 figs. To assess the efficacy and economics of producing power from coal, four open-cycle magnetohydrodynamic (MHD) processing schemes were selected for study. Each involved a different mode of coal combustion and level of gas cleanliness. The options considered were the following: (1) Coal burned in a slagging combustor; (2) suspension gasification with slag removal prior to combustion; (3) parallel cyclone combustors, one operating fuel rich and the other operating with excess air; and (4) suspension gasification by the hot exhaust gases from the MHD duct with ash removed prior to combustion. Option 1 has the highest ash content in the combustion plasma and as a result would have the greatest operational difficulties associated with it. Options 2

and 4 have the cleanest MHD combustion plasma. For coal priced at \$4/ton, the power generating cost of Option 4, 11.78 mills/kW-hr, is the highest, with Option 1, at 9.04 mills/kW-hr the lowest. These costs may be compared with a conventional power cost of 9.92 mills/kW-hr for the late seventies. Capital costs of three of the four options were competitive with those of conventional thermal powerplants employing stack gas SO₂ cleanup systems. Option 2 has the most favorable combination of operating characteristics and power cost. It was concluded that a clean, high-temperature working fluid can probably be produced from coal without leading to depressed system efficiencies and exorbitant capital costs.

RI 7797. Effects of Thermal Treatments Upon Concentratibility of a Nonmagnetic Iron Ore, by J. J. Drost and W. M. Mahan. 1973. 15 pp. 6 figs. This Bureau of Mines investigation studied the effect of thermal treatments upon concentratability of a western Mesabi Range nonmagnetic taconite ore and is a sequel to Bureau of Mines RI 7567. Magnetic tube tests were used to develop the data needed to calculate separation efficiency, the primary measure of concentratability. A horizontal tube furnace was employed to heat treat and reduce the hematitic ore samples. The two variables studied were roasting temperature and cooling method. The manner of cooling, either by slow cooling or quenching in water, produced no significant difference in concentratability. Roasting temperatures employed ranged from 500° to 1,000° C, and a temperature of 650° C effected the best concentratability. The temperature of 650° C correlated with the most effective roasting temperature for grindability.

RI 7798. Microseismic Source Locations Around Block Caving at the Climax Molybdenum Mine, by Martin S. Oudenhoven and Robert E. Tipton. 1973. 13 pp. 8 figs. This Bureau of Mines report presents the results of a microseismic study conducted in the Climax block cave mine at Climax, Colo. Rock noises created by caving were monitored and their sources located during a 3-month period. A planar array of seven accelerometers, located above the block of ore being caved, detected the rock noise. A computer was used to calculate the location of the microseismic activity, using a traveltime difference method. The accuracy of these locations was estimated to be ±20 feet. An analysis of the data taken during the recording period showed a concentration of microseismic events located in the wall of the cave panel. This concentration of events was found to occur in a "high-silica" geologic formation that cut across the caving panel approximately 200 feet behind the undercut.

RI 7799. Elastic Plane Frame Analysis of Semisymmetric Cabs and Canopies Used on Underground Electric Face Equipment, by Stephen Gerard Sawyer and Darryl K. Brogan. 1973. 40 pp. 31 figs. The Bureau of Mines developed a method for analyzing elastically certain types of protective cabs and canopies used on underground electric face equipment. The method is based on plane frame theory, and to be amenable to analysis by this method, cabs and canopies must contain symmetry about one plane. Additionally, protective structures with one or more top members in the long direction that do not frame into the columns should be approximately twice as long as they are wide and have two or more internal top members in the short direction. The assumptions and limitations of the plane frame method as regards analysis of three-dimensional cabs and can-

opies are discussed. A step-by-step procedure for application of the plane frame method is given, and three example canopies are analyzed following this procedure. Elastic strengths calculated for the three example canopies compare within 10 percent of those computed by the more complicated space frame analysis. Formulas employed in plane frame analysis of cabs and canopies are given in the appendixes.

RI 7800. Degasification of Virgin Pittsburgh Coalbed Through a Large Borehole, by H. H. Fields, Stephen Krickovic, Albert Sainato, and M. G. Zabetakis. 1973. 27 pp. 19 figs. The Bureau of Mines is in the process of degasifying a virgin area in northern West Virginia from the base of an 839-foot-deep vertical borehole. An in situ gas pressure hole 199 feet long, and seven degasification holes ranging in depth from 500 to 850 feet (average 618 feet) were drilled in an 8-foot-thick virgin Pittsburgh coalbed from the enlarged (14-foot-diameter) bottom of this borehole. The in situ pressure at the back end of the hole and the range of gas and water flows from degasification holes as they were completed and closed off were 203 psi, 79,000 to 257,000 cfd (average 160,000 cfd), and 5 to 8 gpm per hole (average 6.8 gpm), respectively. Twenty-four hours after the seven holes were connected through individual water traps to a common collector for natural venting of the gas through pipes to the atmosphere, the total gas and water flows and the in situ pressure dropped, respectively, to 971,000 cfd, 1.3 gpm, and 18 psi. Eighty days later the corresponding values dropped to 529,000 cfd, 0.50 gpm, and 13 psi. After 180 days of degasification, 91 million cubic feet of gas had been removed from the affected virgin area. This represents 60 to 70 percent of the gas calculated to be contained in the area of coal affected by the holes.

RI 7801. Reactions of Copper Sulfide Minerals With Chlorine in an Aqueous System, by Rees D. Groves and Paulette B. Smith. 1973. 10 pp. 1 fig. The Bureau of Mines conducted research on reactions of copper sulfide minerals with chlorine in an aqueous system. Selected samples of covellite, chalcopyrite, chalcocite, bornite, and pyrite were leached with aqueous chlorine solutions. The mineral samples were sized to minus 100- plus 325-mesh, individually mixed with precleaned sand and leached in an enclosed percolation column. Each mineral was leached in stages to achieve about 90 percent mineral dissolution. The chlorine leaching solutions were produced by reacting sodium hypochlorite with hydrochloric acid within the closed system. The study showed that when the mineral dissolution was complete, the reaction products (copper, iron, and sulfur) were in their highest oxidation states and a stoichiometric amount of chlorine was consumed. Although elemental sulfur formed as an intermediate product, it was oxidized to sulfate during the leach.

RI 7802. Extraction of Molybdenum and Rhenium From Concentrates by Electrooxidation, by R. E. Lindstrom and B. J. Scheiner. 1973. 12 pp. 5 figs. Electrooxidation techniques were investigated on a bench scale by the Bureau of Mines to determine the applicability of the process for extracting molybdenum and rhenium from low-grade molybdenite concentrates. Parameters affecting the extraction, such as pulp density, power consumption, reagent requirements for pH control, and electrolytic cell configuration, were studied. Molybdenum and rhenium extractions of 98 to 99 percent were

achieved from several concentrates containing 4.76 to 28.6 percent molybdenum and 180 ppm to 1,000 ppm rhenium. Optimum results were obtained by maintaining pH values between 5.5 and 7.0 during electrolysis and allowing the final pH to rise to about 8.2. Reagent consumption was 4 to 6 pounds of sodium carbonate per pound of molybdenum extracted. The power consumption declined from a range of 12 to 25 kilowatt-hours per pound of molybdenum extracted with immersion electrodes to 9.7 kilowatt-hours with a bipolar flow-through cell; however, molybdenum extraction was independent of cell configuration.

RI 7803. Smog Chamber Reactivities of Emissions From Leaded and Lead-Free Fuels, by G. P. Sturm, Jr., and Basil Dimitriadis. 1973. 14 pp. 2 figs. This work was undertaken by the Bureau of Mines in cooperation with the Environmental Protection Agency to determine photochemical specific reactivities of emissions from automobiles using leaded-premium- and regular-grade fuels and prototype lead-free fuels of comparable octane quality. Emissions were photoirradiated in a 100-ft³ environmental (smog) chamber constructed of aluminum and Pyrex glass at three sets of initial hydrocarbon (HC) and oxides of nitrogen (NO_x) concentrations. Reactivity was measured and expressed in terms of rate-of-NO₂ formation (^hNO₂) and dosages of oxidant, peroxyacetyl nitrate (PAN), peroxypropionyl nitrate (PPN), and formaldehyde (HCHO). The results indicate that the evaporative emission samples and the evaporative plus exhaust emissions samples from the lead-free fuels have, in general, higher reactivities per gram than those from the leaded fuels. For the samples containing only exhaust emissions, the only trend observed was the lower specific reactivity exhibited by the leaded premium fuel exhaust. These differences in specific reactivity are taken to reflect the differences in hydrocarbon composition of the fuels and their evaporative and exhaust emissions rather than any difference in lead content per se. Work done under an agreement with the Environmental Protection Agency.

RI 7804. Subsurface Disposal of Pickle Liquor, by Abdo F. Bayazeed, and Erle C. Donaldson. 1973. 31 pp. 23 figs. A survey of the underground injection of steel processing waste pickle liquor (WPL) was made by Bureau of Mines engineers. Hydrochloric and sulfuric acids WPL are being injected into deep wells completed in the Cambrian age Mt. Simon Sandstone Formation in Illinois and Indiana. The Mt. Simon Formation ranges up to 1,800 feet in thickness. The average depth of WPL injection wells is 4,000 feet, and injection is mostly by gravity flow at rates as high as 4,000 barrels per day. The details of the design and operating history of a WPL well located near Gary, Ind., are discussed. Laboratory tests showed that the Mt. Simon Sandstone is sensitive to fresh water. The adsorption of iron and neutralization of acids by sandstone cores from deep wells and an outcrop were determined.

RI 7805. Bleeder System in Virgin Area in a Pittsburgh Coalbed Mine, by Stephen Krickovic, T. D. Moore, Jr., and J. E. Carpetta. 1973. 8 pp. 2 figs. Air quantity-pressure and methane concentration surveys were conducted by the Bureau of Mines in accessible portions of an area being pillared in a Pittsburgh coalbed mine in West Virginia. These included two mined-out and three active butt headings and a bleeder system. The particular mine

workings were started in virgin coal directly from a set of main headings; the main reason for the study was the difficulty usually encountered in adequately bleeding the gobbs under such conditions. Although the two separate return airways in each active butt heading and the North and 1 Left bleeders contained acceptable methane concentrations (0.01 to 0.78 percent in the butts and 0.73 to 1.0 percent in the bleeders) with significant total methane removal (109 cfm in butts and 631 cfm in bleeders), there were relatively large areas in the gobbs with possible minimal airflows. This condition appears to have developed from lack of systematic regulation of the airflow across the gobbs and appears to indicate the existence of considerably more methane in the probably low flow areas in the gob.

RI 7806. Natural Gas as an Automotive Fuel, an Experimental Study, by R. D. Fleming and J. R. Allsup. 1973. 26 pp. 5 figs. A study was conducted by the Bureau of Mines to evaluate natural gas as an automotive fuel and to provide guidelines for optimum engine adjustments for low exhaust emissions. The study was conducted using a single-cylinder engine, a multicylinder engine, and a total of eight vehicles. Results from single-cylinder engine tests showed that the light-load, lean-limit misfire region for natural gas begins at an air-fuel ratio between 150 and 160 pct of stoichiometric. Changes in ignition timing significantly influenced emissions of nitrogen oxides and hydrocarbons, but had little effect on carbon monoxide emission. Low emissions can be achieved with current-design engines by adjustment of engine parameters, but only with heavy penalty to engine performance. Emissions from vehicles fueled with natural gas are virtually unaffected by ambient temperature change within the range 20° to 100° F. The organic emissions from engines fueled with natural gas were estimated to be 22 to 25 pct as reactive as the emissions produced using gasoline. Levels of exhaust emissions from vehicles fueled with natural gas were unchanged over 10,000 miles of normal driving.

RI 7807. Continuous Monitoring of Coal by a Neutron Moisture Meter, by A. W. Hall, J. L. Konchesky, and R. F. Stewart. 1973. 18 pp. 10 figs. A nuclear method was developed for continuously and automatically determining the moisture content of coal flowing through a bin. Fast neutrons from a 1 curie americium-beryllium source penetrate the coal, are thermalized (slowed down) by hydrogen in the moisture, and are counted by a thermal neutron detector. The difference between the number of these thermal neutrons and those thermalized by dry coal (in a reference drum) is a measure of the moisture content of the coal. A materials handling system was developed and in tests at a commercial coal preparation plant, moisture in coal was monitored continuously within 0.2 percent of values determined by conventional means. The meter responded rapidly to change in moisture content, making it adaptable to automatic process control, and was operated for 1 year without malfunction or recalibration. Shielding of the source by the coal kept the neutron flux level at the bin wall less than 1 milliroentgen per hour, a safe level for personnel. Work done in cooperation with the U.S. Steel Corporation.

RI 7808. Secondary Pig Iron From Shredded Auto Scrap, by Jack E. Tress and Willard L. Hunter. 1973. 9 pp. 1 fig. The Bureau of Mines has been involved for several years in the development of processes for the recycling of solid wastes. As part

of this program, a project was initiated to determine the feasibility of producing secondary pig iron from auto scrap. During the test period, 86,000 pounds of shredded auto scrap, along with petroleum coke and fluxing agents, was charged to a submerged-arc furnace of 1 ton nominal capacity. Eighty-eight thousand pounds of pig iron, with an average carbon content of 3.90 percent and an average copper content of 0.2 percent, was produced at an electrical consumption of 512 kW-hr per net ton. A cost estimate of the process showed that the pig iron might be produced at a cost of \$57 per ton.

RI 7809. Separation of Copper From Scrap by Preferential Melting. Laboratory and Economic Evaluation, by Vance G. Leak, M. M. Fine, and Henry Dolezal. 1973. 48 pp. 10 figs. A technique for recovering copper and steel from metallic scrap has been developed by the Bureau of Mines based on preferential melting in molten salt baths at 1,150° to 1,250° C. The molten salt, preferably barium chloride or calcium chloride, both minimizes oxidation of the metals and promotes heat transfer. Cleanest separations (0.01 percent copper remaining in iron) have been achieved by pretreatment (dipping or spraying) with sodium sulfate or sodium silicate, which alters and coats the surface of the iron to inhibit the alloying or brazing with copper. An economic evaluation of the process was carried out on six combinations of sweating media and inhibiting reagents. On the basis of the postulated model, a cost of about \$0.20 per pound of copper recovered has been determined for the sweating treatment operation.

RI 7810. Response Variations of a Microphone Worn on the Human Body, by Terry L. Muldoon. 1973. 42 pp. 26 figs. The Bureau of Mines conducted an investigation to quantify microphone response variations that could result when the microphone is worn by a worker, as with a personal noise dosimeter, and to suggest an optimum placement and orientation of the microphone for noise exposure measurements. Previous studies have shown no significant variations in a diffuse field. This investigation, therefore, was conducted in the free-field conditions of an anechoic chamber using an anthropometric dummy as a subject, and broad band noise as the acoustic stimulus. This investigation established that, in a free field, the wearer's body does significantly affect microphone response; the response variations are a function of azimuth, and location and orientation of the microphone. Results suggest that locating the microphone on top of the subject's shoulder, oriented parallel to the body axis, should yield data comparable to that obtained using a sound-level meter.

RI 7811. Accuracy and Precision of Several Portable Gas Detectors, by H. B. Carroll, Jr., and F. E. Armstrong. 1973. 42 pp. 34 figs. This Bureau of Mines report evaluates the performance of commercially available portable instrumentation for the detection of carbon monoxide, carbon dioxide, oxygen, and methane at conditions simulating an industrial work atmosphere. Portable instrumentation included in the study was gas-detection tubes (length-of-stain and color intensity), catalytic detector, liquid absorption detectors, paramagnetic oxygen detector, galvanic detector, and "pelement" or hot-wire methane detectors. Evaluation of the instruments was in atmospheres with 50 and 80 percent relative humidities at 75° F and containing test gas concentrations of 0.1, 0.25, 0.50, 1.0, 1.5, and 2.0 times the threshold limit value. Correlation of the results from the portable gas analyzer with measurement from the stand-

ard instruments was made by calculating and plotting an estimated line of regression, prediction, and confidence limits and the correlation coefficient for each detector system. Relative humidity in the 50- to 80-percent range did not appear to contribute to instrumental uncertainties in either performance or operation. Considerable deviation in detection precision between the portable gas-detection systems and the standard systems was established, especially at the lower gas concentration levels. The main difference or inconsistency in toxic gas concentrations determined with length-of-stain tubes resulted from the observer's interpretation of the results rather than difference in the tubes themselves.

RI 7812. Iron Oxide Superconcentrates by Caustic Leaching, by R. E. Green and A. F. Colombo. 1973. 11 pp. 10 figs. The removal of silica from commercial iron oxide concentrates by dissolution with sodium hydroxide was investigated by the Bureau of Mines as a means for producing supergrade concentrates. The effects of strength of solution, temperature, and digestion time on the extraction of silica were evaluated using eight iron oxide concentrates. Silica extraction from the eight concentrates was enhanced by autoclave leaching in the temperature range of 150° to 250° C and varied from 70 to 95 pct depending on the concentrate used. Superconcentrates containing less than 2 pct SiO₂ and more than 69 pct Fe were made only when magnetite concentrates were leached in the autoclave. The investigation showed that it is not difficult to obtain a super-grade product if the gangue is mainly quartz.

RI 7813. Analysis of Factors Influencing Fracture Initiation and Orientation in Oil Reservoir Sandstone, by C. A. Komar and K.-H. Frohne. 1973. 22 pp. 11 figs. Laboratory-scale hydraulic fracture tests were conducted by the Bureau of Mines on directionally oriented sandstone material, along with measurements of directional rock properties such as tensile strength, permeability, ultrasonic velocity, and dynamic elastic constants. In these tests, fracture orientation was determined as a function of various combinations of stress, rock saturation, rate of borehole pressurization, and direction of minimum tensile strength relative to minimum horizontal compressive stress. The objective of the experiment was to investigate whether horizontal stresses always controlled the orientation of induced vertical hydraulic fractures, or if under conditions of small differences in stress and/or slow borehole pressurization rates, the induced fracture direction was influenced by directional properties of the rock matrix. The study shows that the expected influence of horizontal earth stress on the orientation of an induced hydraulic fracture becomes negligible whenever the magnitude of the difference between the compressive stresses is 200 psi or less. When this occurs, fracture orientation is controlled by the directional properties of the rock—primarily permeability and tensile strength.

RI 7814. Shear Testing of Simulated Lunar Soil in Ultrahigh Vacuum, by B. V. Johnson, W. W. Roepke, and K. C. Strebig. 1973. 18 pp. 11 figs. The Federal Bureau of Mines has conducted research in support of the National Aeronautics and Space Administration's (NASA) Apollo program to acquire fundamental scientific and engineering knowledge of lunar-mineral resources for NASA's Office of Advanced Research and Technology. Equipment and techniques were developed to conduct soil shear tests in a simulated lunar environment. Shear tests performed with this equipment in ultrahigh vacuum and

controlled laboratory atmosphere showed that simulated lunar soil increased in strength in the simulated lunar environment. Work done under a contract with National Aeronautics and Space Administration.

RI 7815. Suppression of Coal-Dust Explosions by Passive Water Barriers in a Single-Entry Mine, by I. Lieberman and J. K. Richmond. 1974. 34 pp. 17 figs. A Bureau of Mines study is in progress to determine the effectiveness of passive water barriers in suppressing coal-dust explosions. A 2.9-ft³-capacity water-filled plastic tub was found effective in suppressing dust explosions propagating at speeds of 250 to over 1,000 ft/sec. Work directed at determining the limitations of water barriers showed that the passive water barrier technique is also feasible for the suppression of weak dust explosions propagating at speeds of 100 to 250 ft/sec. For relatively slow accelerating flames, dynamic wind forces appear to be the important quantity governing fragmentation of the plastic tub and subsequent water release and dispersion, whereas dynamic impulse appears to be the significant quantity for rapidly accelerating flames. The acoustic approximation (relation between static pressure and flame or wind speed) is shown to be valid in a long single mine entry. This relationship appears to be useful in predicting the regions within a long single entry where passive water barriers are effective in quenching a dust explosion.

RI 7816. Electrophoresis and Coagulation Studies of Some Florida Phosphate Slimes, by Oleg Terichow, and Alexander May. 1973. 8 pp. 2 figs. Electrophoretic mobility measurements were made on samples of Florida phosphate slimes to determine the optimum conditions of coagulation and precipitation in aluminum sulfate solutions. The addition of silica sand and other selected materials as mutual coagulants has demonstrated the practicability of coagulating two dissimilar particle systems by elimination of the repulsive double layers. By proper selection of the solution and its concentration, the reduction of the double layer to a zero point of charge causes coagulation and rapid precipitation of both particle systems. Confirmation was found in filtration tests and sedimentation tests. Work done in cooperation with the University of Alabama.

RI 7817. Use of Char To Improve Physical Quality of Coke From Sunnyside (Utah) Coal, by Charles C. Boley, M. M. Fegley, and R. B. Porter. 1973. 30 pp. 8 figs. Using bench- and pilot-scale coking facilities, the Bureau of Mines produced experimental coke from blends of char with Sunnyside coal (high-volatile A bituminous) from Carbon County, Utah. At bench scale, additions of char made from lignite improved resultant cokes when concentrations of up to 60 percent were used in the blends. At pilot scale (500-pound movable-wall oven), four chars made by entrained-bed carbonization techniques from the parent Sunnyside coal and from a North Dakota lignite were used in two-component blends with the Sunnyside coal. Chars from Sunnyside coal had volatile matter contents of 5.8, 9.8, and 16.0 percent, moisture-free basis; the char from the lignite had 16.6 percent. In 25 500-pound tests, improvement in coke quality was observed from all blends at char concentrations to 17.5 percent. The best coke, produced from a concentration of 12.5 to 15 percent of 5.8-percent volatile char, exhibited physical properties approaching those of an industrial coke produced.

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from Sunnyside coal blended with three higher rank blending coals. Studies were also made of the effects on coke quality of char source, of particle size, of comparative use of char and of a blending coal, and of prolonged coal storage.

- RI 7818. Evaluation of Instrumentation for Measuring Behavior of Aerosols in Smog-Chamber Studies**, by H. B. Carroll, Jr., and R. M. Ray. 1973. 23 pp. 8 figs. The Bureau of Mines investigated the adaptability of the Meteorology Research Inc. (MRI) nephelometer and the Sinclair-Phoenix smoke meter for use in routine, analytical, smog-chamber experiments. The sampling systems of both instruments were modified—smaller size sample input systems were studied using the nephelometer and a secondary sample system was added to the smoke meter to allow measurement of Aitken or condensate nuclei. Both instruments were easily adapted for use with small smog chambers and both displayed good precision and sensitivity to aerosols. A correlation was shown to exist between the responses of both instruments to aerosol. This correlation makes it possible to report the Sinclair-Phoenix measurements in visibility and/or mass units if desired. Work done under an agreement with the Office of Air Programs of the Environmental Protection Agency.
- RI 7819. Collection of Airborne Coal Dust by Steam**, by L. Cheng, J. E. Emmerling, and T. F. Tomb. 1974. 13 pp. 9 figs. This report describes a laboratory investigation of the effectiveness of low-pressure steam and a steam-water spray sequence for the collection of airborne respirable ($<10\ \mu\text{m}$) coal dust. Comparison of present results to previous results obtained with water spray alone indicates that the use of steam in a steam-spray sequence increases the collection efficiency by about 14 percent over that obtained by water spray alone. However, the use of steam to collect airborne dust requires cooling the steam-dust mixture in order to achieve condensation of the steam, and steam does not appear to be an attractive approach for collecting airborne dust in underground coal mining operations.
- RI 7820. Compositional Variations of Organic Material From Green River Oil Shale. Wyoming No. 1 Core**, by W. E. Robinson and G. L. Cook. 1973. 32 pp. 12 figs. Oil-shale samples selected from a core of the Green River Basin (Wyoming) were studied to ascertain differences in the composition and/or chemical structure of the organic material in the samples relative to stratigraphic position within the Green River Formation. This involved a systematic study of the soluble organic material and the insoluble kerogen present in the samples. Emphasis was placed upon the distribution of the alkanes (normal and isoprenoid compounds) in the soluble extract and upon the aromaticity of the kerogen. In general, it was concluded that significant differences exist in the chemical structure of the oil-shale organic material from various strata within the Green River Formation of Wyoming. Most of the compositional and structural changes were not related to burial depth but were related to source material variations, environmental differences, or other factors. Work done in cooperation with the University of Wyoming.
- RI 7821. Compound-Type Separation and Characterization Studies for a 370° to 535° C Distillate of Swan Hills (South Field), Alberta, Canada, Crude Oil**, by J. E. Dooley, D. E. Hirsch, H. J. Coleman, and C. J. Thompson. 1973. 30 pp. 10 figs. An analytical procedure developed by the Bureau of Mines was applied to the separation and characterization of a 370° to 535° C distillate from Swan Hills (south field), Alberta, Canada, crude oil. Investigators determined the general characteristics of the crude oil by the Bureau's routine method for crude oil analysis. Suitable fractions were prepared for instrumental analyses by utilizing such techniques as isothermal and molecular distillations, chemical treatment, silica-alumina gel chromatography, and gel permeation chromatography (GPC). A detailed characterization of the 370° to 535° C distillate was possible by the application of GPC-mass spectrometry, correlations and nuclear magnetic resonance spectrometry. Semi-quantitative data based on mass Z series distributions were determined and are shown. The data will be valuable in developing future processing techniques and in calculating yields for converting high-boiling distillates into more useful energy forms.
- RI 7822. Flotation of Pyrite From Coal: Pilot Plant Study**, by Kenneth J. Miller. 1973. 15 pp. 3 figs. Pittsburgh bed and Lower Freeport bed coals were tested in the U.S. Bureau of Mines two-stage froth flotation pilot plant, which utilizes a new flotation process to remove pyritic sulfur. The process consists of a first-stage coal flotation step to remove coarse, free pyrite and other refuse in the tailings. The clean coal froth concentrate is then repulped and treated with a coal depressant, a pyrite collector, and a frother to selectively float the remaining pyrite in a second stage. Results in the pilot were excellent, comparing well with those obtained in laboratory batch tests. That is, about 70 percent of the pyrite present in the Pittsburgh bed coal and about 90 percent of the pyrite present in the Lower Freeport bed coal were removed with excellent final clean coal recoveries.
- RI 7823. Initial-Stage Sulfuric Acid Leaching Kinetics of Chalcopyrite Using Radiochemical Techniques**, by J. P. Baur, H. L. Gibbs, and M. E. Wadsworth. 1974. 38 pp. 23 figs. The sensitivity of radiochemical techniques makes possible the study of the initial-stage sulfuric acid leaching kinetics of chalcopyrite and other copper sulfide minerals. This Bureau of Mines study of the initial leaching of chalcopyrite used techniques to evaluate the molecular and electrochemical processes. High-grade Transvaal chalcopyrite was neutron-irradiated to produce radioisotopes copper-64, iron-59, and sulfur-35. Dissolution rates were measured in the time interval zero to 60 minutes, during which time significant anomalies were observed. First was an initial period of rapid dissolution lasting a few minutes; second, an arrest or "plateau" region usually lasting from 6 to 10 minutes; third, a second period of dissolution of lesser rate than the first. The effects of solution variables such as pH, oxygen partial pressure, and ferric iron concentration at different temperatures were measured.
- RI 7824. Detection and Delineation of Faults by Surface Resistivity Measurements. Gas Hills Region, Fremont and Natrona Counties, Wyo.**, by Robert Lee Stahl. 1973. 28 pp. 13 figs. Comprehensive field tests were made in the Gas Hills, Wyo., to determine whether surface geophysical techniques could be used to detect and delineate faults in marginal uranium deposits. The tests were made on property owned by Federal American Partners, Gas Hills, Wyo., and included seismic refraction, self-potential, induced polarization, magnetometer, electrical resistivity, airborne infrared thermal scanning, and airborne photography.

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Of the several geophysical techniques tested in the field, horizontal resistivity profiling with electrode spacings in the range of 25 to 50 feet was most diagnostic of faults. The method is quick, cheap, accurate, and one that can be easily used by personnel employed by mining companies to detect and delineate faults.

RI 7825. Stability Constants of Metal Coordination Compounds. Complexes of Diethylenetriamine, 2-Aminoethyl Sulfide, Triethylenetetramine, and 1,8-Diamino-3,6-dithiaoctane, by Alexander May and David J. MacDonald. 1974. 12 pp. 2 figs. In this Bureau of Mines publication stability constants for complexes of diethylenetriamine, 2-aminoethyl sulfide, triethylenetetramine, and 1,8-diamino-3,6-dithiaoctane with copper, nickel, zinc, and cadmium were determined. The amine complexes were found to be much more stable than the analogous thio complexes. The results are interpreted in terms of possible molecular structure of the complexes.

RI 7826. Flotation of Marquette Range Nonmagnetic Taconite Using Innovative Procedures, by D. W. Frommer, P. A. Wasson, and D. L. Veith. 1973. 30 pp. 8 figs. Processing of nonmagnetic taconites by selective flocculation-desliming and anionic flotation of calcium-activated silica has been investigated using innovative procedures as a means of improving operating costs. Areas chosen for cost-cutting evaluation were grinding, fine screening, and water conservation and reclamation. The investigation was performed on Marquette Range nonmagnetic taconites in the Bureau of Mines Twin Cities Metallurgy Research Center flotation pilot plant, at feed rates ranging between 900 and 1,100 lb/hr. With fully integrated water reclamation, flotation concentrates containing 65.8 percent Fe and 3.4 percent SiO₂ were made in the best operating period, with accompanying weight and iron recoveries of 40 and 74 percent, respectively. During this same period, the estimated cost of both flotation and water reclamation reagents was only \$0.80 per ton of concentrate (1968 pricing basis). This cost is about 15 percent lower than obtained previously at this Center for flotation reagents only. The investigation demonstrated additional potential savings in operating costs of approximately \$0.96 per ton of concentrate through autogenous grinding as a substitute for ballmilling. Fine screening of intermediate concentrates was employed advantageously, but the frequency of blinding may be a factor militating against use of the screen in this flotation system. Work done in cooperation with the Cleveland-Cliffs Iron Co.

RI 7827. Distribution of Sulfur and Ash in a Part of the Pittsburgh Seam and Probable Mode of Deposition, by Manuel Gomez, Donald J. Donaven, and Bion H. Kent. 1974. 44 pp. 28 figs. Areal distributions for ash, total sulfur, and sulfur forms were developed for the top 12 inches, the middle section, the bottom 8 inches, and the total seam of Pittsburgh coal in southwestern Pennsylvania. The sulfur and ash exhibit an apparent high local variability. As a general rule, both the sulfur and ash show high concentrations in the top 12 inches and in the bottom 8 inches of the seam relative to the concentrations observed in the middle section of the seam. The high-low sulfur and ash concentrations in the top 12 inches of the seam are not coincident with the high-low sulfur and ash concentrations in either the middle section or the bottom 8 inches of the seam. With respect to sulfur and ash, it is suggested that the

top and bottom sections of the Pittsburgh coal may reflect both a syngenetic and epigenetic origin. Present data support the belief that paleotopography controlled Pittsburgh seam deposition. Evidence is presented to show that channels were cut at various times into the semilithified sediments that buried the Pittsburgh seam. In this channeling process, portions of the Pittsburgh coal may have been eroded away. Following channel development, the lower part of the Pittsburgh sandstone filled the complex system of braided channels to produce the "want areas" encountered in present mining operations. In localized areas of the Pittsburgh seam, impingement of Pittsburgh sandstone may be responsible for the lateral displacement of the coal. Information of this type becomes important in the assessment of exploration data, in the development of a quality control system for mine output, and in mine life planning. Work done in cooperation with the U.S. Steel Corp.

RI 7828. Design of an Underground Mine Layout, by William R. Sharp. 1974. 45 pp. 7 figs. This Bureau of Mines report details a technique for aiding the engineer with the long-range design of an underground mine. The method is based upon the assumption that sufficient data are available to assign numeric values to some finite number of mineralized blocks; assignment of numerical values is problem dependent. By assigning appropriate weighting schemes, the algorithm developed in this report may be used to solve the optimal end-of-life underground mine layout, design least-cost electrical layout networks and efficient material handling networks, find least risk escape routes in the event of an accident, etc. The method is based upon the assumption that sufficient cost and geologic data is available to build a detailed mineral block inventory of the mineral deposit. It is further assumed that the cost assigned to any minable unit is independent of the neighboring blocks. The basic approach relies upon concepts and ideas from the theory of networks. To make the approach user oriented, a computer program is included and discussed. The computer code is written for an orthogonal, three-dimensional set of blocks. Computational costs and experience indicate that the program could be of great benefit in evaluating large complex mineral properties from the viewpoint of predesigning an underground mine layout.

RI 7829. Utilization of Phosphorus Furnace Slag in Ceramic Wall and Floor Tile, by E. G. Valdez, K. C. Dean, and L. L. Warner. 1974. 12 pp. 3 figs. Laboratory research demonstrated that ceramic wall and floor tile can be produced from electric furnace phosphorus slags composed of calcium silicates. Grinding the slag in a pebble mill, followed by magnetic removal of deleterious magnetite, produced a raw material that could be compounded and formed into wall tile by dry pressing, sintering, and glazing. The effects of process variables such as forming pressure and sintering temperature were investigated. Wall tile bodies produced by this method were comparable to commercial tile. The tiles were readily glazed to a smooth shiny finish and met ASTM Specifications C34-62 for structural clay load-bearing tile. The estimated cost of producing wall tile by this method compared favorably with the retail market value for similar wall tile. Addition of borax or other additives to the ground slag followed by dry pressing and firing likewise produced a commercial grade of floor tile.

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RI 7830. Preparation Characteristics and Desulfurization Potential of Iowa Coals, by J. A. Cavallaro and O. J. Van Eck. 1973. 32 pp. 3 figs.

This Bureau of Mines report describes the preparation characteristics of 10 coal samples collected from the significant coal-producing mines of Lucas, Mahaska, Marion, Monroe, and Wapello Counties in Iowa, with emphasis on physical desulfurization. All 10 samples were of high sulfur content as received, ranging from 4.2 to 10.4 percent; the organic sulfur content ranged from 0.8 to 3.8 percent. The pyritic sulfur content of the samples could be appreciably reduced by crushing and washing and provided pyrite sulfur reductions ranging from 36 to 75 percent. Crushing to 3/8-inch top size and removing the sink 1.60 specific gravity material would provide float coal products containing 3.5 to 6.0 percent sulfur. However, these coals could be burned at utility plants utilizing SO₂ removal processes with efficiencies ranging from 70 to 88 percent and still be in compliance with the current Federal SO₂ emission regulation for stationary sources.

RI 7831. Statistical Comparison of the Pulse and Resonance Methods for Determining Elastic Moduli, by Richard E. Thill and Syd S. Peng. 1974. 24 pp. 9 figs.

Elastic wave velocities and moduli were determined by both the pulse and resonance methods in a large number of specimens of St. Cloud Gray Granodiorite and Tennessee marble under the same moisture, temperature, and stress environment. Long cylinders were first tested by the resonance method to obtain longitudinal bar and torsional wave velocity. The cylinders were then sectioned in half and tested by the pulse method to obtain the transient pulse velocity. These velocities were later used to obtain various moduli for comparison. Statistical comparisons between the Young's, shear, and bulk moduli and Poisson's ratios obtained independently by the pulse and resonance methods indicate that the methods do not give equivalent results in nearly isotropic rock. The amount of difference varies for each modulus, with the least difference (less than 5 pct) occurring in the shear modulus and the greatest difference (as high as 34 pct) in the bulk modulus. Moduli determinations in aluminum show much closer agreement between the pulse and resonance methods than in rock. The discrepancy in pulse and resonance results probably is caused by frequency dispersion effects and by differences in error sensitivity in the various formulas used to calculate the moduli.

RI 7832. Undulatory Conveyor Tests and Evaluation, by W. K. Kleysteuber and A. J. Miscoe. 1974. 16 pp. 11 figs.

This report covers the design and testing of a novel bulk materials conveying device by the Bureau of Mines. The transport concept of the device is to create a traveling wave with a steep front so that the bulk material slides and cascades down the front of the wave with some horizontal motion. Ideally, the front should act like a continuous chute. The concept of moving bulk materials along a belt without any forward movement of the belt itself was demonstrated. The conclusions reached were that the mechanism as designed could not overcome the inherent major disadvantages that would make the undulatory conveyor suitable for practical applications.

RI 7833. The Rapid Growth of Metallic Fibers by Partitioning Sulfur in a Copper-Iron-Sulfide Mineral, by H. W. Leavenworth, Jr., B. W. Dunning, Jr., R. C. Gabler, Jr., and C. E. Goldsmith. 1974. 16 pp. 8 figs. Research was conducted by the Bureau of

Mines to develop a technique to grow metallic fibers from a sulfide mineral. In this research, chalcopyrite (CuFeS₂) was made sulfur deficient, and the remaining sulfur partitioned to the iron in the mineral to liberate metallic copper, or to the copper to liberate metallic iron. The metals formed on the surface as fibers and in the interior as spherical particles. Fiber growth is very fast. Lengths of 3 to 4 cm form in a matter of minutes, and the diameter of individual fibers is less than 1 μ m. The mechanism of fiber growth is explained, and the reactions are reversible as predicted. Copper fibers can be made to grow from the surface at 400° C or to dissolve back onto the solid surface and be replaced by iron fibers at 625° C. Growth and dissolution can also be controlled to form copper/iron duplex fibers.

RI 7834. Low-Temperature Heat Capacity and High-Temperature Enthalpy of TiAl₃, by J. M. Stuve and M. J. Ferrante. 1974. 9 pp. 2 figs.

Thermodynamic properties were determined by the Bureau of Mines for the intermetallic compound, TiAl₃. Heat capacities were obtained from 5 to 303 K by adiabatic calorimetry. The derived value of S_{298.15} is 22.08 ± 0.07 cal/deg-mole. Enthalpies relative to 298 K were obtained from 298 to 1,413 K by copper-block drop calorimetry. No anomalous thermal behavior was noted in the temperature ranges investigated. Low- and high-temperature data were combined with a known enthalpy of formation at 298 K to give values of enthalpy of formation and Gibbs energy formation, 0 to 1,400 K.

RI 7835. Some Effects of Pressure on the Hydrocracking of Crude Shale Oil Over Cobalt Molybdate Catalyst, by C. M. Frost and P. L. Cottingham. 1973. 11 pp. 9 figs.

Crude shale oil produced by gas combustion retorting of Green River oil shale was hydrocracked over a cobalt molybdate catalyst at operating pressures of 500, 1,000, 1,500, and 3,000 psig, an operating temperature of 890° F, and a liquid hourly space velocity of 1.0. Hydrogen feed rate was maintained at 6,000 scf/bbl. The volume-percent yields of total liquid product were directly proportional to the operating pressure. Weight-percent conversion and volume-percent yields of gasoline were directly proportional to the log of the operating pressure. Catalyst deposit percentages were inversely proportional to the log of the operating pressure. Nitrogen and sulfur removal rates as well as saturation of the liquid products increased as the operating pressure was increased.

RI 7836. Polymeric Materials for Underground Support, by J. C. Franklin, J. E. Fraley, R. E. Burnham, and L. W. Brandt. 1974. 16 pp. 5 figs.

The Spokane Mining Research Center of the Federal Bureau of Mines is placing major emphasis on chemical stabilization as part of the ground support program. Development of polymeric material suitable for bonding rock fractures around the mine opening is one phase of the program. Some of the problems that must be considered are viscosity, applicability, adhesion, cure times, strength, toxicity, and flammability. Epoxies and polyesters were investigated, but shrinkage in polyesters caused redirected effort toward epoxies. Test results with the latter showed that bonded fractures in mine-roof strata were stronger than in the virgin rock. Further tests showed that polymeric materials have good potential for bonding, and in conjunction with polymer roof bolts, are expected to result in an economic and useful new support concept.

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RI 7837. Oxygenates in Automotive Exhausts. Effect of an Oxidation Catalyst, by D. E. Seizinger and B. Dimitriades. 1973. 21 pp. 4 figs. Analytical methods for oxygenates in exhaust gases were studied, and emissions of these compounds from automotive engines were measured with and without an oxidation catalyst in the exhaust system. Hydrocarbons, simple mixtures of hydrocarbons, and a single gasoline were used as fuels. With the more complex gasoline, successful analysis was possible *only* with exhaust from the catalytic system which preferentially converted and thus removed interfering hydrocarbon species. However, it was shown that an estimate of the oxygenate yield from gasoline used in a noncatalytic system can be synthesized from data obtained with simple fuels. Such synthesized data were used for comparison of noncatalytic with catalytic systems. Compared with those of previous studies, results of this work indicate that the action of the catalyst introduced no new oxygenates and reduced both the carbonyl and the total of oxygenates. It is concluded that the compositional character and class distribution of oxygenates in exhaust from catalytic systems may differ significantly from the composition and distribution for oxygenates not subjected to catalytic conversion. The findings also support previous estimates that noncarbonyls may constitute a significant fraction of exhaust oxygenates and may warrant attention in procedures for measurement of the oxygenates. Work done under an agreement with the Coordinating Research Council, Air Pollution Research Advisory Committee.

RI 7838. A Geometric Method for the Prediction of Stresses in Inclusions, Orebodies, and Mining Systems, by Clarence O. Babcock. 1974. 35 pp. 17 figs. This report describes the results of a Bureau of Mines investigation in which an elastic inclusion, orebody, or mining system is replaced for purposes of analysis with an imaginary effective inclusion of rectangular shape that encloses the region. This effective inclusion has averaged physical properties that are directly related to the average inclusion stresses. The results were in excellent agreement with those predicted by Donnell's theory for an isotropic elliptical inclusion in a state of plane strain for all height-to-width ratios and for all degrees of inclusion hardness from very soft to very hard. The results are exact for an isotropic circular inclusion and provide an easy method of evaluating the stresses obtained by cylindrical inclusions in boreholes when the Poisson's ratio for both host and inclusion equals 0.25 for plane strain or 0.333 for plane stress. The practical usefulness of the method is given by treating a variety of mining problems: (1) The average stresses in an orebody of irregular shape; (2) the average stresses in single-level room-and-pillar mining systems; (3) the average stresses in multiple-level room-and-pillar mining systems; (4) the effect of mining sequence on the average stresses produced during mining; (5) the stresses in cylindrical borehole plug related to host rock stresses as a function of plug hardness; and (6) methods for simplifying finite-element analysis of complex structures.

RI 7839. Constant-Volume Flame Propagation, by H. E. Perlee, F. N. Fuller, and C. H. Saul. 1974. 24 pp. 11 figs. Mathematical expressions are derived for the histories of the pressure, flame radius, mass fraction burned, and burned and unburned gas temperatures associated with a spherical flame propagating concentrically in a spherical vessel. The equations are solved numerically for a

9.5 pct CH₄/air mixture using the best available information for the burning velocity, expansion ratio, and specific heat ratio. Calculated histories are in complete accord with experimental measurements. The accuracy of calculated histories is determined relative to errors in the system parameters, and it is found that a 10-pct error in either the burning velocity or the expansion ratio results in a 40-pct error in the pressure history. A 10-pct error in burned or unburned specific heat ratio results in a 22-pct error in the pressure history. It was further established that the usual assumption of constant specific heat ratio is unacceptable, but equating the burned and unburned specific heat ratios results in no apparent error in the histories. The cubic law ($P = Kt^3 + P_0$) is derived and discussed, and it is found that the law is valid only during the early period ($P < 2$ atm) of flame growth.

RI 7840. Sensitivity of Some Ammonium Nitrate-Based Explosive Compositions, by R. W. Watson, J. E. Hay, and K. R. Becker. 1974. 8 pp. This Bureau of Mines report summarizes some recent results on the sensitivity of various explosive systems using ammonium nitrate (AN) as the oxidizing agent. The sensitivity survey included drop-weight and friction testing and sensitivity to initiation by projectile impact and a No. 8 blasting cap. It was found that certain types of AN prills can result in cap-sensitive mixtures when combined with No. 2 diesel fuel (FO); prilled AN mixed with nitromethane also result in cap-sensitive mixtures. Mixtures of AN prills and neat 1- and 2-nitropropane were not cap-sensitive, and the use of powdered or grained aluminum in AN-FO did not adversely affect the sensitivity except possibly to increase its sensitivity to friction.

RI 7841. Catalytic Activity of Rare-Earth Oxides for the Oxidation of Hydrogen, by Larry J. Nicks and D. J. MacDonald. 1973. 9 pp. 4 figs. The Bureau of Mines is investigating the catalytic activity of rare-earth compounds to develop a catalyst for the cathode reaction of a hydrogen-oxygen fuel cell. This report presents the results of studies of the catalytic activities of lanthanide oxides for the oxidation of hydrogen at 150° to 250° C. Preliminary activity tests were made with approximately stoichiometric mixtures of hydrogen and oxygen diluted with helium. A series of tests was also run under oxygen-rich conditions in which specific rate constants and activation energies were determined. Variations in rate constants up to 2,000 times were observed for the various lanthanide oxides. The three most active catalysts were oxides of Ce, Pr, and Eu, having specific activities of 6.93×10^{-7} , 4.88×10^{-7} , and 4.06×10^{-7} moles H₂ • sec⁻¹ • m⁻², respectively, at 200° C.

RI 7842. Forecasts of Chemical, Physical, and Utilization Properties of Coal for Technical and Economic Evaluation of Coal Seams, by Manuel Gomez and Donald J. Donaven. 1974. 127 pp. 57 figs. A computerized moving average technique was developed to interpolate coal seam characteristics between sample points. The interpolative method coupled with multivariate regression analysis and simulation procedures was used to forecast coal properties not readily obtained from an analysis of drill core samples. Coal property forecasts were of two kinds: (1) Specific mine property forecasts that are suitable for mine product control and yield a good approximation of the local variation along both the vertical and horizontal axes of the seam, and (2) regional

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estimates where much of the local seam variation is smoothed out, but the general trends are maintained. Forecasts of the volatile matter, ash, total sulfur, and the heating value for part of the Pittsburgh seam located in Ohio, Pennsylvania, and West Virginia were in good agreement with independent evaluation data. Spatial configuration for preparation characteristics, particularly, the effect of crushing on sulfur release, low- and high-temperature carbonization properties, the Hardgrove grindability index, the coal hardness index, gasification variables, and hydrogenation factors were constructed for the same area of the Pittsburgh seam. These forecasts may be developed from drill core data collected in the exploration phase of mining. The results, which may take the form of a series of maps, are useful to mining, chemical, and combustion engineers, to economists and mine managers, as well as to coal users for mine design, economic analyses, energy forecasts, utilization studies, mine product control, and environmental control and programming.

RI 7843. Partial Devolatilization of Coal in Two Entrained-Bed Carbonizers, by Daniel C. Boteler and Charles C. Boley. 1973. 20 pp. 2 figs. Data from 68 entrained-bed carbonization tests were treated statistically by the Bureau of Mines, and several useful relationships were developed among the major variables. Nine coals, ranging in rank from lignite A to high-volatile A bituminous, were carbonized in two entrained-bed carbonization pilot plants. The carbonizing reactors employed were vertically mounted cylinders, internally heated, refractory-lined, and 10 inches ID. The range of carbonization temperatures was from 825° to 1,600° F. Using a regression-analysis computer program, empirical equations were developed by which carbonization temperature, air-to-coal ratio, devolatilization of coal, char yield, and volatile matter content of product char may be predicted.

RI 7844. Methods for Refining Crude Shale Oil Produced by In Situ Retorting, by C. M. Frost and P. L. Cottingham. 1974. 21 pp. 5 figs. Crude shale oil produced during in situ retorting by the Bureau of Mines at Rock Springs, Wyo., was refined by three schemes. In the first, the crude oil was fractionated to raw naphtha and a residuum boiling above 400° F. The residuum was hydrogenated over cobalt molybdate catalyst at 815° F and 1,100 psig. The blended raw and 160° to 400° F hydrogenated naphthas were hydrogenitrified and then catalytically reformed. The hydrogenated oil boiling above 400° F was catalytically cracked. In the second scheme, the crude was hydrogenated over nickel-tungsten catalyst at 800° F and 1,500 psig. The hydrogenated fractions were processed by methods used in the first scheme. The third scheme resembled the second, but, prior to hydrogenation, the crude was "hydrostabilized" over cobalt molybdate at 500° F and 500 psig. Yields of reformat and cat-cracked gasoline as volume-percent of the crude, and research-method octane numbers (with 3 ml tetraethyllead) for the three methods were as follows: First method, 32 pct reformat, 90 octane; 19.5 pct cracked gasoline, 99.2 octane. Second method, 29 pct reformat, 81.1 octane; 21.3 pct cracked gasoline, 99.6 octane. Third method, 28.2 pct reformat, 86 octane; 28.7 pct cracked gasoline, 95.9 octane.

RI 7845. Structural Analysis of a Coal Mine Opening in Elastic Multilayered Material, by F. D. Wang, D. M. Ropchan, and M. C. Sun. 1974. 36 pp. 36

figs. Finite-element structural analyses were performed to determine the stress distribution and displacements around a single rectangular coal mine opening in a multilayered rock system. The effects of changes in mechanical properties of roof and coal layers, roof layer and mine opening geometry, horizontal-to-vertical load ratio, and structural geologic features on the stress distribution about the opening were studied. Variability in the stiffness and relative thickness of the immediate roof layers can produce a considerable difference in the stress distribution about the opening as compared with that of a homogeneous material. Changes in opening width and horizontal-to-vertical load ratio have different effects on the stress distribution about the opening depending on the composition of the roof layers. In general, where a stiff layer exists in the roof at the surface of the opening, the stresses are higher in the roof and ribs around the opening. Horizontal changes in facies in the roof layers produced by structural geologic features can also greatly alter the stress distribution about the opening compared with the simple layered cases.

RI 7846. Effect of Specimen Volume on Apparent Tensile Strength of Three Igneous Rocks, by Laxman S. Sundae. 1974. 26 pp. 7 figs. A Bureau of Mines investigation was conducted to determine the effect of specimen volume on the apparent tensile strength of disks of St. Cloud Gray Granodiorite, Lithonia granite, and Rockville granite. The investigation used a technique developed by the Bureau to determine apparent tensile strength.

RI 7847. Formation of Surface Sulfides on Iron Through Reaction With Sulfur, by L. A. Haas and S. E. Khalafalla. 1974. 21 pp. 8 figs. In this Bureau of Mines investigation, conditions were determined to form an iron sulfide adherent coating with a metallic golden luster on steel upon anaerobic heat treatment with sulfur. The sulfide formation rate was determined in the temperature range of 105° to 500° C with reaction times up to 68 hours. The optimum temperature and time to form an adhering decorative coating on mild steel was in the range of 105° C for about 70 hours to 285° C for 1 hour. The golden coating consisted of an inner layer of pyrrhotite and an outer layer of pyrite. At temperatures higher than about 300° C, the outer layer thickness decreased owing to the decomposition of pyrite to pyrrhotite. Small quantities (<0.5 wt-pct) of petroleum oil accelerated the sulfide growth rate. The sulfide coating decreased the corrosion rate of steel in a neutral aqueous medium by a factor of two. The dissolution of pyrite in water was dependent on particle size and surface area with the flat pyrite coatings exhibiting the lowest dissolution rate.

RI 7848. Analyses of Tipple and Delivered Samples of Coal Collected During Fiscal Year 1973, by J. B. Janus and B. S. Shirley. 1973. 15 pp. In connection with the purchase of coal under specifications for Government use, the Bureau of Mines in this report has compiled data on 81 mines located in 15 States. This annual report lists analytical data on the composition and quality of tipple and delivered samples of coal collected during fiscal year 1973. Tipple samples were collected by Bureau of Mines engineers at tipples as coal was being loaded into railroad cars or trucks. Ultimate analyses are given for most of the coalbeds listed. The deliveries were sampled at destination in accordance with instruc-

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tions issued by the Bureau of Mines. All samples were analyzed in the Bureau laboratory at Pittsburgh, Pa. GPO Catalog No. I28.23:7848. Stock No. 2404-01501. 50 cents.

RI 7849. Methane and Dust Controls for Longwalls: Pocahontas No. 3 Coalbed, Grundy, Va., by Abdurrahman Cetinbas, R. P. Vinson, Joseph Cervik, and M. G. Zabetakis. 1974. 16 pp. 13 figs. The periphery of longwall panels in the Pocahontas No. 3 coalbed is characterized by a zone of reduced permeability that inhibits the natural drainage of methane. A residual gas pressure of 105 psig was measured after 1 year in an isolated block of coal measuring 340 by 1,100 feet. The buildup of gas pressure within such large blocks causes methane problems during plowing operations. However, natural drainage holes drilled during development have been found to reduce the gas content of the coal in this coalbed by over 90 percent. The effect of water infusion on dust during plowing operations was investigated using existing methane drainage holes. These holes were cleaned of debris and a pipe was grouted into the hole for water infusion of the panel. Both total and respirable dust levels were reduced by 40 to 79 percent. Water infusion of the panel proved more effective than did the use of a plow-mounted spray system. Work done in cooperation with the Island Creek Coal Co.

RI 7850. Support Performance of Hydraulic Backfill: A Preliminary Analysis, by J. R. M. Hill, M. McDonald, and L. M. McNay. 1974. 12 pp. 5 figs. The Bureau of Mines performed elastic-plastic, finite-element analyses to investigate the support performance of hydraulic backfill. A mathematical model was developed for two vertically adjacent stopes separated by a sill pillar. An exact duplicate of a working stope was not intended; however, the model did simulate a working stope to the extent that field measurements from an active stope could be used for comparative purposes. Using a predetermined mining sequence, the computer analysis simulated the mining operation as a series of incremental cut-and-fill steps. Computer results included a complete history of stope closure and pillar stresses throughout the mining sequence. With the mining sequence and rock properties held constant, three separate analyses were made using varying backfill properties. These cases included no fill, low-to-medium quality fill, and medium-to-high-quality fill. Results of these analyses show decreases in stope closure and pillar stresses as the backfill quality increases, thus reducing the possible occurrence of rock bursts. Predicted stresses within the backfill compare favorably with field measurements. A relationship between maximum stress normal to the stope wall and the ratio of relative fill stiffness to relative rock stiffness was also indicated.

RI 7851. Enthalpy of Formation of Malachite [$\text{Cu}_2(\text{CO}_3)(\text{OH})_2$], by D. W. Richardson and R. R. Brown. 1974. 5 pp. This Bureau of Mines publication provides the enthalpy of formation of malachite [$\text{Cu}_2(\text{CO}_3)(\text{OH})_2$] as determined by hydrochloric acid solution calorimetry. At 298.15 K the enthalpy of formation from the component oxides is -15.10 ± 0.30 kcal/mole and from the elements -251.9 ± 0.5 kcal/mole.

RI 7852. Superconcentration of Commercial Magnetic Taconite Concentrates by Cationic Flotation, by David L. Veith. 1974. 12 pp. 3 figs. Caustic scrubbing followed by silica flotation with cationic

ether primary amine proved effective in upgrading commercial magnetic concentrates to supergrade products containing 2 percent SiO_2 or less. Samples representing 41 million long tons per year of commercial magnetic concentrates from the Lake Superior region were tested by the Bureau of Mines. Bench-scale and pilot plant research indicated an estimated potential of 32 million long tons per year of superconcentrates to be available. Two pilot plant investigations yielded superconcentrates containing 1.1 and 1.9 percent SiO_2 that were derived from commercial concentrates containing 7.0 and 4.2 percent SiO_2 , respectively. Corresponding iron recoveries were 90 and 93 percent at reagent costs of just over 33 cents per long ton of superconcentrates produced. Additional sources evaluated on a bench scale resulted in iron recoveries of 72 to 95 percent in products containing 1.7 to 2.0 percent SiO_2 . Although reagent cost ranged up to 60 cents per long ton of superconcentrate, it is probable that these costs would be reduced in plant applications where benefits are derived from material and reagent recycle.

RI 7853. Phase Relations in the Alkaline Earth Fluoride-Yttria Systems (In Three Parts). 3. The $\text{SrF}_2\text{-Y}_2\text{O}_3$ Phase Diagram and Information on the $\text{SrF}_2\text{-SrO}$ System, by Laurence L. Oden, Herbert R. Babitzke, and Philip E. Sanker. 1974. 9 pp. 4 figs. The Bureau of Mines is developing melting data for binary combinations of the alkaline earth fluorides and yttria to facilitate the formulation of slag compositions. The present report deals with the $\text{SrF}_2\text{-Y}_2\text{O}_3$ system for which liquidus and solidus temperatures and solid solubilities were determined. The information is presented as the phase diagram. The phase diagram was constructed from information obtained by ceramography, X-ray diffraction, thermal analysis, and electron probe microanalysis of small specimens encapsulated in platinum-20 percent rhodium or molybdenum ampoules. The data indicate a simple eutectic system with limited terminal solid solubilities. The eutectic temperature is $1,457 \pm 5^\circ \text{C}$, and the eutectic composition is 4 ± 1 mole-pct Y_2O_3 . Strontium fluoride containing up to 2 wt-pct O_2 was studied to determine the effects of oxygen contamination. Oxygen levels in excess of 0.2 wt-pct resulted in eutectic formation between SrF_2 and SrO . The eutectic composition is between 0.2 and 0.7 wt-pct O_2 , and the eutectic temperature is $1,447 \pm 5^\circ \text{C}$.

RI 7854. Dispersion of Dust in a Channel by a Turbulent Gas Stream, by C. C. Hwang, J. M. Singer, and T. N. Hartz. 1974. 29 pp. 11 figs. The Bureau of Mines formulated a method for calculating the concentration of entrained dust from a dust deposit by a turbulent gas stream. In particular, a diffusion equation is used to calculate dust concentrations in a channel following an explosion. Dust leaving the channel walls was treated as originating from stationary or moving, and single or multiple material sources. Formulas and sample computations for various types of dust sources in circular and rectangular channels are given, based on experimental entrainment rates. The analysis predicts the dust concentration as a function of time and channel space. The results appear to agree with the physical characteristics of explosion-driven dust dispersion in a 0.6-m-diameter, 50-m-long explosion tunnel. The analysis is also applied to simultaneous and consecutive dispersion of coal and rock dust from simulated coal mine surfaces (walls, floor, roof, and ribs).

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- RI 7855. NX Borehole Jack Modulus Determinations in Homogeneous, Isotropic, Elastic Materials**, by Thomas O. Meyer and James R. McVey. 1974. 50 pp. 25 figs. Laboratory test results are presented for the determination of elastic modulus made with the NX borehole jack. Determinations were made in massive pieces of aluminum so as to satisfy conditions of linear elasticity, homogeneity, and isotropy. Results indicate a large discrepancy (approximately 200 percent) between material modulus as determined by laboratory block-loading tests and that indicated by the jack under relatively ideal circumstances. Effects due to interface friction, finite block size, incomplete plate-bore contact, and other factors were examined and found not to be significant. Finite element results indicate that assumed loading conditions for the jack differ from those actually occurring, at least in materials of high elastic modulus (approximately 10 million psi), such as quartzite.
- RI 7856. Steam-Cured Bricks From Industrial Mineral Wastes**, by P. G. Pigott, E. G. Valdez, and K. C. Dean. 1974. 13 pp. 1 fig. This investigation by the Bureau of Mines demonstrated that building bricks can be produced by the steam-curing process from various types of industrial mineral wastes. Wastes, utilized to produce bricks, consisted of copper mill tailings, roofing granule fines, asbestos fines, and zinc mill tailings. Bonding of the wastes with either $\text{Ca}(\text{OH})_2$ or portland cement resulted in building bricks that met ASTM specification C73-67 for grade SW and MW bricks when evaluated in accordance with ASTM designation C67-66 on sampling and testing of brick. An economic evaluation of the process indicates the total operating cost per 1,000 bricks to be about \$36.
- RI 7857. Potential Uses for 400-Hz Electrical Power Systems in Mining**, by G. J. Conroy. 1974. 10 pp. 3 figs. This Bureau of Mines study was initiated to determine whether or not a large-scale investigation of 400-Hz applications in coal mines was justified as a means of increasing safety in operations due to size and weight reductions in portable and other mining machinery. Potential uses for 400-Hz power in mining operations are explored, and cost and size comparisons with 60-Hz systems are made. The use of variable-frequency motor drive is suggested for conveyors. The conclusion was reached that there is no significant potential safety increase due to a general size and weight reduction, since the fact of such general reduction cannot be demonstrated.
- RI 7858. Chemical Analysis of Slickensides From Coal Mine Roof Shale**, by George A. Savanick and Raymond W. Cabaniss. 1974. 13 pp. 5 figs. Coal mine roof shales fracture preferentially as slickensided surfaces because of weak or nonexistent adhesion between two slickensided rock surfaces. The purpose of this Bureau of Mines research was to characterize chemically the thin film of smooth, glossy material that makes up the slickenside. This material was analyzed by electron spectroscopy and ion scattering spectrometry while in place on the rock surface and by standard methods of quantitative chemical analysis on concentrate removed from the rock. These analyses showed that the chemistry and mineralogy of the slickensides are similar to that of the adjacent shale.
- RI 7859. Controlled-Atmosphere System for Testing Gas Monitors**, by H. B. Carroll, Jr., R. M. Ray, and F. E. Armstrong. 1973. 10 pp. 6 figs. The Bureau of Mines has designed and built a controlled-environment test chamber specifically for instrument evaluation in simulated work atmospheres. The atmosphere inside the 300-liter stainless steel chamber can be controlled at any selected temperature and relative humidity in the range of 2° to 93° C and 20 to 95 percent, respectively. Instruments placed inside the test chamber are subjected to an atmosphere at a present temperature and humidity containing various concentrations of toxic gases such as CO , CO_2 , NO , NO_2 , SO_2 , and H_2S . Toxic gas losses resulting from wall reactions, monitoring instruments, and instruments under evaluation are compensated by the use of a dynamic gas blending system.
- RI 7860. Permeability Changes and Compaction of Broken Oil Shale During Retorting**, by Edward L. Burwell, Samuel S. Tihen, and Harold W. Sohns. 1974. 16 pp. 11 figs. The Bureau of Mines conducted laboratory experiments to determine the change during retorting in the apparent permeability and the degree of compaction of beds of broken oil shale. Grades of oil shale studied ranged from 20.6 to 46.7 gallons of oil per ton (gpt), and the simulated overburden pressures applied to the shale were from 300 to 900 psi. Linear regression analysis of the data produced equations describing the response of the oil shale. Oil shales of approximately 20 gpt experience only minor apparent permeability reductions under test conditions, but richer shales (30 to 50 gpt) lose essentially all permeability. The permeability reductions were accompanied by corresponding decreases in bed height that ranged up to 37 percent of the original bed height. Work done in cooperation with the University of Wyoming.
- RI 7861. Atomic Absorption Methods of Analysis of Oilfield Brines: Barium, Calcium, Copper, Iron, Lead, Lithium, Magnesium, Manganese, Potassium, Sodium, Strontium, and Zinc**, by Gordon E. Fletcher and A. Gene Collins. 1974. 14 pp. 1 fig. This Bureau of Mines report outlines the atomic absorption analysis of oilfield brines for barium, calcium, copper, iron, lead, lithium, magnesium, manganese, potassium, sodium, strontium, and zinc, using the method of additions. The advantages of using atomic absorption are discussed. The method of additions was chosen to overcome large matrix interferences usually found in brines; techniques of overcoming chemical, ionization, and background interferences are also described. The method was used to analyze several hundred oilfield brines and found to be rapid and reasonably accurate. A solvent extraction method was used to concentrate lead, copper, zinc, and iron in low-level samples.
- RI 7862. Thermal Characteristics of Shortite**, by Donald R. Johnson, John Ward Smith, and William A. Robb. 1974. 9 pp. 3 figs. Apparatus developed by the Bureau of Mines for thermal analysis of oil shale was used to determine the thermal properties of shortite. Dissociation of shortite near 470° C occurs as an endothermic reaction that could consume significant quantities of heat in the oil-shale retorting process that produces shale oil. The shortite dissociation products undergo other thermal reactions that would not affect the retorting process. These reactions include crystal inversions near 365° C and 425° C and melting and decomposition endotherms

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above 500° C. Two separate reaction routes for fusion and decomposition of the shortite decomposition products are dictated by the presence or absence of CO₂ around the sample. Work done in cooperation with the University of Wyoming.

RI 7863. Effects of Jointing and Bedding Separation on Limestone Breakage at a Reduced Scale, by William C. Larson and Joseph M. Pugliese. 1974. 13 pp. 8 figs. A study was conducted by the Bureau of Mines to provide quarry operators with information regarding (1) the effects of jointing and bedding on rock fragmentation when bench blasting in two small-scale (2.5-ft) limestone benches and (2) the successful use of inexpensive equipment and field techniques to determine the orientation and spacing of joints and bedding separations within the quarry. Using inexpensive equipment, such as a pocket transit and steel and paper tapes, joint and bedding separations were mapped and their frequencies measured. Results from two small-scale bench blasts in the Stewartville member of the Galena limestone formation showed that when the row of vertical blastholes was oblique to the vertical joint orientations, the backface expression was outlined by two relatively large triangular protrusions (joint surfaces). In this blast, part of the rock burden was unbroken. When the line of vertical blastholes paralleled a predominant joint set, all of the rock burden was broken and displaced. The thickness of fragments that had been displaced by a blast correlated with the observed bedding thickness in the bench.

RI 7864. Flotation of Carbonate Minerals From Unaltered Phosphate Ores of the Phosphoria Formation, by A. R. Rule, C. W. Clark, and M. O. Butler. 1974. 18 pp. 6 figs. A flotation process was developed by the Bureau of Mines for separation of carbonate and phosphate minerals occurring in unaltered phosphate ores of the Phosphoria formation. The process involves depression of phosphate minerals with fluosilicic acid and flotation of carbonate minerals with fatty acid emulsions. In individual laboratory tests, selective removal of carbonates was achieved with phosphate recoveries ranging from 60 to 80 pct P₂O₅. In continuous-circuit testing, sizing and separate treatment of coarse and fine fractions was necessary to achieve 65-pct P₂O₅ recovery. Concentrate grade ranged from 26 to 33 pct P₂O₅. The flotation tailings containing primarily carbonate and phosphate minerals are a potential fertilizer material. When reacted with H₃PO₄, concentrated superphosphate containing approximately 40 pct available P₂O₅ was obtained.

RI 7865. A Standard Rock Suite for Rapid Excavation Research, by Warren W. Krech, Frank A. Henderson, and Kenneth E. Hjelmstad. 1974. 29 pp. 16 figs. Rock property data is needed over a wide range of parameters for the optimum execution of rapid excavation research. Eight rock types were chosen by the Bureau of Mines for a standard rock suite for such research. Large rock blocks were quarried and the standard physical and mechanical properties measured and documented. The eight rock types that comprise the rock suite are Barre Granite, Berea Sandstone, Dresser basalt, Holston Limestone, Salem Limestone, Sioux Quartzite, St. Cloud Gray Granodiorite, and Westerly Granite. Geologic, petrographic, physical-property, and mechanical-property test data are reported for each

rock type. The information is the first step in the building of a comprehensive property listing for the eight rock types. A limited number of rock cubes are available from the Bureau of Mines Twin Cities Mining Research Center for use by researchers to broaden the information available on the suite.

RI 7866. Recovery of Fluorine From Low-Grade Calcareous Fluorspars: Preliminary Studies, by A. R. Rule and H. E. Blake, Jr. 1974. 6 pp. This report describes preliminary studies by the Bureau of Mines to develop a procedure for extracting the fluorine from low-grade fluorspar ores in which the CaF₂ particles are finely locked in the calcite matrix. A combination of flotation beneficiation and pyrohydrolysis is applied to recover and to liberate the fluorine. Flotation of a finely locked high-calcite fluorspar ore containing only 11.7 pct CaF₂ recovered over 92 pct of the fluorspar at a grade of 51 to 52 pct CaF₂. Pyrohydrolysis of the flotation concentrate liberated nearly 90 pct of the fluorine as aqueous HF. By this procedure over 80 pct of the fluorine contained in the original ore was extracted.

RI 7867. Toxic Fumes From Explosives. Ammonium Nitrate-Fuel Oil Mixtures, by R. F. Chaiken, E. B. Cook, and T. C. Ruhe. 1974. 24 pp. 11 figs. The Bureau of Mines has carried out experimental and theoretical studies with prilled and pulverized ammonium nitrate-fuel oil (AN-FO) mixtures containing varying amounts of fuel oil in an attempt to quantify the effects of stoichiometric composition, nonideal detonation behavior, and expansion volume on the production of CO, NO, and NO₂ fumes. Experimental fume measurements were obtained in the Bureau's large closed gallery facility (7.2 × 10⁴ liter expansion chamber) and in the standard Crawshaw-Jones apparatus (90-liter expansion chamber) using a prepackaged charge configuration containing about 450 g of explosive. The theoretical calculation of toxic fumes was achieved with an equilibrium detonation code called "TIGER." Contrary to initial expectations, the NO_x (= NO + NO₂) fumes from the large gallery test were found to be in essential agreement with the Crawshaw-Jones results. It was also concluded that (1) "TIGER" calculations offer a good approach to the prediction of toxic fumes; (2) there is a basic problem in extrapolating laboratory measurements of CO fumes to mine conditions—this being due to postdetonation oxidation of CO to CO₂; and (3) the detonation velocity decay rate of an explosive is a useful experimental parameter for correlating toxic fumes production with nonideal detonation behavior.

RI 7868. Recovering Copper From Mill Tailings. Selected Studies, by Jack C. White, Andrew J. Ferguson, and Thomas N. Goff. 1974. 21 pp. 8 figs. The purpose of this Bureau of Mines work was to develop information useful in improving copper recovery during copper milling operations. Eleven copper mill tailings from the Western United States were subjected to froth flotation and cyanide leaching to provide an experimental basis for comparing their beneficiation response. Recoveries in flotation concentrates made from mill tailings ranged from 65 to 15 percent, at copper grades of 13 and 2.2 percent, respectively. Liberated copper sulfide minerals present in two samples were readily recovered by laboratory froth flotation. Nine of the samples were less amenable to froth flotation because of physical locking between copper sulfide minerals and gangue.

Correlations among tailings indicated that recovery of sulfide copper by flotation was directly related to the sulfide copper content. Empirical equations derived from flotation data provided average values for unrecoverable copper and for recovery efficiency. Flotation response of copper mill tailings may be predicted from the equations. Data from cyanide leaching provides an equation describing the limiting high values for removal of copper by this method.

RI 7869. Geologic Structure Analysis Using Radar Imagery of the Coal Mining Area of Buchanan County, Va.,

by C. H. Elder, P. W. Jeran, and D. A. Keck. 1974. 29 pp. 19 figs. An analysis of the geologic structure of an area of Buchanan County, Va., was made by the Bureau of Mines using imagery from an airborne AN/APQ-97 side-looking radar system to evaluate that mapping technique for delineating structural features that may cause mining problems. Side-looking airborne radar (SLAR) was found to be a useful remote sensing tool for geologic structural analysis. Fault and joint systems identified by lineaments and linear patterns in the imagery were verified by surface and in-mine observations. Little Paw Paw fault was extended 10 miles by SLAR lineament analysis. A 22-mile fault, here named the Bishop-Bradshaw Creek fault, was mapped by lineament analysis and verified by observation of the fault on the Bishop Coal Co. mine map and on offset patterns of commercial gas production and surface observation of lineament along the fault. Three major superimposed joint sets and several fault or fractured zones were identified by SLAR lineament analysis, showing more complex structure than earlier mapping indicated. SLAR imagery accurately delineated structural features that are known to affect gas migration and accumulation and that weaken the rock forming the immediate roof to mine workings, causing mining problems and potentially hazardous environment in the mines.

RI 7870. The Influence of Manganese Additions Upon Properties of Iron Ore Pellets,

by R. B. Schluter and B. W. Carriere. 1974. 17 pp. 10 figs. The objective of this Bureau of Mines investigation was to determine the effects of adding manganese compounds and ores to iron ore pellets. Manganese dioxide, carbonate, sulfate, and chloride, plus six manganese ores from the Minnesota Cuyuna Range were tested as additives to increase the manganese content of iron ore pellets. One to 5 percent manganese, as a compound or ore, was added to five magnetite concentrates and one hematite concentrate. These concentrates were balled, indurated (1,300° C), and tested for reducibility. Manganese sulfate and chloride were unsatisfactory additives causing cracking and degradation of the pellets during reduction. Manganese dioxide, carbonate, and the ores were satisfactory additives. The additives increased pellet compression strengths with a corresponding loss of reducibility, as compared with the pellets without manganese additions. The changes in compression strengths and reducibility were caused by the formation of jacobite spinel and slag within the pellets. However, when the induration temperature was lowered from 1,300° to 1,200° C the reducibility and compression strengths were comparable with the pellets without manganese additions indurated at 1,300° C.

RI 7871. Determining the Effects of Gasoline Price on Use of Metals in Automobile Manufacture,

by N. Yasnowsky and Donald S. Colby. 1974. 15 pp. 1 fig. The thrust of this Bureau of Mines report is to relate the size of automobiles to the price of gasoline, and the use of minerals in automobile manufacture to the size of automobiles. Only one of the many plausible scenarios of public reaction to higher gasoline prices, a switch to economy size automobiles, is developed. No account is taken of other potential impacts such as improvements in public transportation or increased occupancy per vehicle. Furthermore, a gasoline price increase is the only incentive to the greater utilization of economy cars that is considered. A gasoline price increase to \$0.60 per gallon would reduce the amount of minerals required to produce the automobiles sold in the United States by an estimated 15 percent. Gasoline prices of \$0.80 and \$1 per gallon would cause declines in mineral requirements for U.S. automobile sales estimated at 26 percent and 35 percent, respectively.

RI 7872. Coal Mine Combustion Products: Identification and Analysis,

by Arthur M. Hartstein and David R. Forshey. 1974. 12 pp. 2 figs. The Bureau of Mines, through contract with Ultrasystems, Inc., obtained data on the oxidative degradative behavior of a number of materials used in coal mines. Tests were performed using a stagnation burner arrangement. Materials examined included those used in typical coal mining operations such as (1) polyvinyl chloride-containing materials, (2) neoprene compositions, (3) rigid foams (urethanes/isocyanates), (4) miscellaneous materials (including jute, fiber glass, and polyethylene), (5) coal, (6) fluids (phosphate esters, organic esters, oil-water emulsions), and (7) composites. The composite comprised a mixture of a phosphate ester fluid with (1) coal, (2) a representative polyvinyl chloride sample, or (3) a neoprene-type composition. A number of decomposition products are identified that could represent a potential health hazard to miners including HCl, CO, SO₂, and H₂S, if they were generated to exceed toxic levels. The work upon which this report is based was done by Ultrasystems, Inc., under Contract No. H0122009.

RI 7873. Use of Centrifugal Measurements of Wettability To Predict Oil Recovery,

by P. B. Lorenz, E. C. Donaldson, and R. D. Thomas. 1974. 26 pp. 11 figs. Wettability measurements and laboratory waterflood tests were compared under a wide variety of conditions. Experiments were conducted with synthetic and natural crude oils, treated and untreated outcrop and oilfield sandstone cores, and synthetic brines with and without caustic, detergent, or phosphate additives. Measurements were made on equilibrated and unequilibrated systems at 77° and 150° F. Wettability was evaluated by the Bureau of Mines method from capillary pressure curves determined with a centrifuge. The waterflood data were fitted by empirical curves; the parameters of the curves characterize primary and subordinate production and also give the ultimate oil recovery. Results showed that wettability measurements at 77° F were useful predictors of recovery efficiency in waterflood tests run at both temperatures. Oil recovery in the early stages of waterflooding increased with increasing water wettability; however, the ultimate recovery was highest at a slightly oil-wet condition. The oil displaced at highest speed in the centrifuge was correlated with ultimate recovery in waterflood tests. Chemical additives to the brine sometimes lowered wettability and also sometimes improved waterflood recovery, but wettability and recovery were

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not correlated with additives present. The effect of additives on recovery in waterflooding was best seen in water-oil ratio curves.

RI 7874. Fracturing Oil Shale With Explosives for In Situ Oil Recovery, by J. S. Miller, C. J. Walker, and J. L. Eakin. 1974. 100 pp. 40 figs. This report presents a complete coverage of results from Bureau of Mines preliminary research and the field application of explosive fracturing techniques to prepare oil shale for in situ recovery of shale oil. Small-scale surface tests were conducted to determine the feasibility of using a nitroglycerin-base explosive for creating rock fractures. Prior to underground testing, surface and near-surface tests with liquid explosives showed that explosions in sheetlike layers simulating underground fractures would propagate effectively. Successful surface experiments were conducted using layers of explosive placed between glass plates and explosive-saturated sand confined in small-diameter metal tubes. The tests in glass-plate reservoirs and metal tubes demonstrated that nitroglycerin would detonate and the explosion would propagate in cracks as thin as 1/32 inch and through distances up to 12 feet. In a shallow field test, nitroglycerin was detonated in a vertical crack in limestone and produced extensive fracturing. Explosive fracturing tests were performed in oil shale formations on seven sites near Rock Springs, Wyo. The procedures included (1) displacing and detonating nitroglycerin in natural or hydraulically induced fracture systems; (2) detonating nitroglycerin in wellbore shots; (3) displacing and detonating nitroglycerin in induced fractures followed by wellbore shots using pelletized TNT; and (4) detonating wellbore charges using pelletized TNT. The research on oil shale formations demonstrated that nitroglycerin displaced in a natural or hydraulically induced fracture would detonate, and the explosion would propagate through the explosive-filled fracture. Shooting a pattern of wells in oil shale at 100-foot depth with wellbore charges of pelletized TNT developed a satisfactory interwell fragmented zone. Tests performed on other sites at depths to 385 feet caused fragmentation of rock around the wellbore and provided interwell communication. Fourteen methods used to evaluate the extent and degree of fragmentation in the explosively fractured oil shale are discussed.

RI 7875. Correlations of Basic Gel Permeation Chromatography Data and Their Applications to High-Boiling Petroleum Fractions, by D. E. Hirsch, J. E. Dooley, and H. J. Coleman. 1974. 77 pp. 9 figs. The Bureau of Mines, as a part of American Petroleum Institute Research Project 60, Characterization of the Heavy Ends of Petroleum, has made extensive use of gel permeation chromatography (GPC). Data developed in this study were used to develop several correlations that greatly expanded the usefulness of GPC and the data have been used as an aid in the interpretation of mass spectra (MS). GPC retention volume data on pure compounds were used with molecular structure to develop correlations that can be used to accurately predict retention volumes, molecular volumes, densities, chain lengths, and ring numbers of many components of petroleum without resorting to further laboratory experimentation. Conversely, the correlation can be used to select or reject some compounds from several possible compounds that are indicated on the basis of MS analysis. The utility of these correlations in compound type characterization is demonstrated by showing their application to 330° to 550° C fractions from a low-sulfur and a high-sulfur crude oil.

RI 7876. Noise Dosimeter Performance, by Kenneth C. Stewart and Timothy Y. Yen. 1974. 39 pp. 49 figs. Eight brands (three samples of each kind) of commercially available audiodosimeters were performance tested. Each unit was placed in an anechoic chamber and subjected to various acoustic signals to measure its A-weighting response and overall integration accuracy. All units met the A-weighting tolerance for type II sound level meters, and six brands were within the Bureau's overall accuracy requirements of ± 2 dB referred to input.

RI 7877. Development and Application of the Waste-Plus-Waste Process for Recovering Metals From Electroplating and Other Wastes, by Andrew A. Cochran and Lawrence C. George. 1974. 18 pp. 9 figs. Laboratory-scale research was conducted by the Bureau of Mines to develop a new process for treating electroplating and other wastes. Various acid and alkaline cyanide wastes were combined under controlled conditions to neutralize the wastes and to almost completely precipitate the metals and cyanides. The metals were subsequently recovered for recycling; the cyanides can also be easily recycled. The process was successfully used to treat the major types of electroplating and etching wastes, containing Cd, Cr, Cu, Ni, and Zn, and to treat both concentrated and dilute wastes. The economic aspects of treating concentrated electroplating, etching, and anodizing wastes are especially attractive because of the low cost of mixing two wastes, the high value of the recovered metals, and the simplicity of the recovery procedures. The filtrates from the waste-plus-waste step were relatively harmless compared with the original wastes and met Public Health Service standards for free cyanide content. Free cyanide ions were not detected in most of the filtrates; the limit of detection was 0.03 ppm. Only small amounts of HCN were produced during the neutralization; the HCN was collected and neutralized.

RI 7878. Rapid Identification of Copper-Base Alloys by Energy Dispersion X-Ray Analysis, by Harold E. Marr III. 1974. 15 pp. 3 figs. Energy dispersion X-ray analysis was evaluated for possible application in the secondary metals industries for the rapid analysis and identification of copper-base alloys. Laboratory investigations of standard brass and bronze samples indicate that X-ray methods are capable of separating standard alloys into 10 general classes with analytical times of less than 3 seconds per sample for clean, flat samples. A radioactive source of americium-241 with a secondary fluorescer was used as an excitation source, and a lithium-drifted silicon semiconductor detector was utilized for energy discrimination of X-rays.

RI 7879. Method for Rapid Particle Size Analysis by Hydrosizing and Nuclear Sensing, by C. B. Daelenbach, W. M. Mahan, and F. E. Armstrong. 1974. 16 pp. 4 figs. A prototype particulate size analyzer system was developed that would rapidly determine size distributions of homogeneous and two-mineral materials in the 74-micrometer (200-mesh) to 7-micrometer size range. The system sizes particles in a series of hydrocyclone elutriation steps and senses the weight of the five sized fractions by nuclear attenuation techniques. Size distribution of materials was determined from experimentally developed mathematical relationships that existed between particulate weight and the measured transmittance of gamma rays from an americium-241 source. In the developmental phases, size distributions of three minerals (quartz, magnetite, and hematite) and a

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laboratory prepared two-mineral mixture of quartz and magnetite were accurately determined by the prototype system. In later stages of the investigation, semiconcentrates, an intermediate magnetic product from a taconite plant, were evaluated. Using 25-gram feed samples of this industrial material, the analyzer system was found to predict weight percentages for individual size fractions with an accuracy of ± 0.85 percent or better at a 95-percent confidence level.

RI 7880. Recovery of Zinc and Lead From Brass Smelter Dust, by H. H. Fukubayashi and L. W. Higley. 1974. 10 pp. 4 figs. This Bureau of Mines report describes the development of a pyrometallurgical process for the recovery of the zinc and lead contained in brass smelter flue dusts, which constitute a recycling or disposal problem. Tests on brass flue dust from several sources were made in a quartz tube, heated by an electric furnace to temperatures as high as 1,050° C. The dusts were mixed with carbon and heated in an oxygen-free atmosphere. It was demonstrated that 98 pct of the zinc and 12 to 25 pct of the lead, both in the metallic state, could readily be removed from the dusts. It was also found that 75 pct of the zinc could be recovered, with less than 0.1 pct of the lead, in the absence of chlorides. Pelletization techniques were investigated and 0.6-inch pellets were found to be optimal.

RI 7881. Tunneling Machine Research—Interaction Between Disk-Cutter Grooves in Rocks, by Parviz F. Rad and Richard C. Olson. 1974. 21 pp. 12 figs. The Bureau of Mines conducted groove cutting experiments in marble, limestone, granite, and quartzite with a 7-inch disk cutter under a normal thrust of 7,000 lb. The values of muck weight per unit length, specific energy, cutting coefficient, and groove depth for each of these rocks were determined for groove spacings ranging from 0.1 to 4 inches, and from these results the values of optimum and critical spacing were computed. The results indicate that compressive strength may be used to predict some of the cutting characteristics of the independent grooves. Considering all the cutting characteristics, particularly those for the interacting grooves, Shore hardness, coefficient of rock strength, and torsional velocity correlate with cutting characteristics better than do other physical properties. Some of the field applications of the principles established in this report are identified.

RI 7882. Tunneling Machine Research: Size Distribution of Rock Fragments Produced by Rolling Disk Cutters, by Parviz F. Rad and Richard C. Olson. 1974. 40 pp. 17 figs. The Bureau of Mines used a linear cutting apparatus equipped with a 7-inch disk cutter to cut grooves in marble, limestone, granite, and quartzite under a normal force of 7,000 lb. The size distribution of the muck for various grooves was determined through sieve analysis. A statistical search showed that Weibull distribution describes the size distribution better than other available functions. Results indicate that fineness modulus, chip population, and dimension of the largest chip can be used as indicators of cutting efficiency. The results correlate with those obtained from the boring machines and other laboratory experiments. Application of the principles established through this work to the operation of boring machines is explained.

RI 7883. Correlation of Laboratory Cutting Data With Tunnel Boring Machine Performance, by Parviz F.

Rad. 1974. 19 pp. 19 figs. The Bureau of Mines conducted rock-cutting experiments under constant normal force and constant penetration in an effort to correlate laboratory data with those obtained in the field. Both independent and interacting groove spacing regions were studied, and optimum and critical cutter spacings were determined. For the laboratory work, the effects of specific energy, muck weight, groove depth, cutting coefficient, and size distribution of the muck for both independent and interacting grooves were studied. For field operations, forward thrust, torque, advance rate, and muck size distribution were the parameters studied. Satisfactory correlation is obtained between laboratory cutting results and field performance data.

RI 7884. Waste Lubricating Oil Research. An Investigation of Several Re-refining Methods, by M. L. Whisman, J. W. Goetzinger, and F. O. Cotton. 1974. 26 pp. Several commercial processes for reclaiming used lubricating oil were duplicated on a laboratory bench scale. Laboratory tests were selected and in some instances modified to determine the physical properties of each oil produced. In addition, the hydrocarbon composition of some samples was determined using a liquid chromatographic technique and compared with the composition of new oil to determine the severity of the re-refining technique. Selected samples of reprocessed oil were reformulated with an additive package for further estimates of quality as determined by wear, corrosion, foaming, and oxidation stability tests. Additionally, several samples of commercially re-refined oil and new oil were obtained, and physical properties were determined for comparative studies.

RI 7885. Peak Methane Concentrations During Coal Mining. An Analysis, by Fred N. Kissell, J. L. Banfield, Jr., R. W. Dalzell, and M. G. Zabetakis. 1974. 17 pp. 7 figs. Methane concentration peaks were measured by the Bureau of Mines at coal mine working faces during entry development. The statistical distribution of peaks was found to be normal or log normal depending on how well the methane was being mixed into the ventilation airstream. A normal distribution indicated good mixing, whereas a log-normal distribution indicated that mixing was poor. In addition, the "highest" peaks over selected intervals were found to fit a type I extreme-value distribution, a result similar to that obtained while mining longwall faces.

RI 7886. Field Studies on an Unsupported Roof, York Canyon Coal Mine, Raton, N. Mex., by Raymond M. Stateham. 1974. 18 pp. 12 figs. Infrared and displacement studies were made of an unsupported roof in Kaiser Steel Corp.'s York Canyon coal mine, Raton, N. Mex. Monitoring of the roof continued until the roof over the area was caved. Loose slabs in the roof, about 6 inches thick, were detected by means of associated thermal anomalies, using remote-sensing infrared instruments. Displacement measurements taken during the study indicate that roof movement was cyclic in nature; the cycles appear to have been related to the mine work cycle (work days to idle days).

RI 7887. Laboratory Determination of Factors Affecting Storage of North Dakota Lignite: Computer Simulation of Spontaneous Heating, by Everett A. Sondreal and Robert C. Ellman. 1974. 83 pp. 59 figs. Material and energy balances for stockpiled lignite were calculated by computer simulation techniques to deter-

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mine the occurrence of spontaneous heating. Data on properties of lignite which affect spontaneous heating were required. In some cases, best values from reported data were utilized; in other cases, new data were developed. These include specific studies on the rate and conditions that influence oxidation, heat of oxidation, heat of wetting, specific heat, thermal conductivity, and permeability of stockpiles to air. These data are presented and discussed in detail for possible application to other studies. Results of computer simulations confirm past field experience on the storage of lignite containing as-mined moisture, and predict a greater risk of heat occurrence in stockpiles of dried lignite where experience is lacking. Successful storage was predicted for dried lignite of 20 pct moisture content, if it were cooled after drying and compacted to an interparticle void fraction of 9 pct (bulk density of 67 lb/cu ft) compared to 10 pct void fraction (72 lb/cu ft) for as-mined lignite.

RI 7888. X-Ray Study of the Structure of Cokes Carbonized at Different Temperatures, by R. R. Schehl and R. A. Friedel. 1974. 12 pp. 7 figs. The Bureau of Mines analyzed the structure of a high-grade metallurgical coke, carbonized at different temperatures in the range 500° to 1,000° C, through X-ray diffraction studies. Growth in the crystallite size with increasing coking temperature was calculated from profile analysis and compared with values obtained from the radial distribution function. The carbonization temperature appeared to have little influence upon the stack height, whereas the layer diameters more than doubled in size between 500° and 1,000° C. These results are comparable with those obtained from other studies of poorer quality cokes.

RI 7889. Second-Order Effects in the Kinetics of Oil Shale Pyrolysis, by Donald W. Fausett, John H. George, and Harry C. Carpenter. 1974. 21 pp. 6 figs. This Bureau of Mines publication presents a system of thermal decompositions providing an adequate description of the mechanism of oil shale pyrolysis. Specific rate constants for systems of thermal decompositions studied are estimated via a least-squares procedure. The estimates thus obtained provide a mathematical model of the corresponding thermal decomposition system. A model that generates a good fit to published Bureau of Mines experimental data, in comparison with other models studied, is based on a thermal decomposition system consisting of two first-order reactions and three second-order reactions. Values computed for the specific rate constants corresponding to this system are shown to exhibit a temperature dependence that is in good agreement with the Arrhenius equation. Work done in cooperation with the University of Wyoming.

RI 7890. Combination Model for Simulating Transient Gas Flow in a Vertically Fractured Reservoir, by W. K. Sawyer and C. D. Locke. 1974. 44 pp. 7 figs. In this Bureau of Mines investigation, one- and two-dimensional gas reservoir simulators were combined in such a manner that pressure distributions, both in an induced vertical fracture and in the surrounding formation, could be determined as a function of time for any specified well production rate. The technique used consisted basically of the alternate use of one- and two-dimensional algorithms for obtaining new pressure distributions in the fracture and in the reservoir, respectively. The pressures at adjacent reservoir and fracture nodes were used to calculate

flow rates from the formation into the fracture, which provided source terms for both algorithms. The combination model developed provides the only known means of simultaneously simulating transient gas flow in a vertical fracture and the surrounding formation. Thus, the technique developed would be useful in locating wells in a gas storage field in that the effects of both fracture length and conductivity could be considered prior to drilling and fracturing operations. In addition, it will be helpful in analyzing pressure drawdown tests in a vertically fractured gas well since the entire test can be readily simulated for a wide range of reservoir and fracture properties.

RI 7891. Performance Characteristics of Coal-Washing Equipment: Hydrocyclones, by Albert W. Deurbrouck. 1974. 22 pp. 5 figs. The performance characteristics of five hydrocyclone coal washers were evaluated to determine the sharpness and efficiency of separation that might be anticipated in commercial operation. The hydrocyclone overflows contained generally good clean coal products that would require little re-treating to remove misplaced high-gravity material. The underflows, however, contained from 63.6 to 36.7 percent of misplaced low-gravity material, which would require secondary cleaning to provide acceptable clean coal yields. Work done in cooperation with the University of Wyoming.

RI 7892. Laboratory Experiments in Electrokinetic Densification of Mill Tailings (in Two Parts). 1. Development of Equipment and Procedures, by R. H. Sprute and D. J. Kelsh. 1974. 72 pp. 42 figs. This report describes Bureau of Mines laboratory test results in electrokinetic dewatering and consolidation of metal-mine tailings. Tailings were placed in 0.3-ft³ plexiglass models, and dc potential was applied until dewatering ceased. Time-oriented measurements of water removal, changes in resistivity, and power consumption were recorded during the dewatering process. Dewatered material was tested for moisture content and density. Equipment and procedures were developed to optimize the method for unclassified mill tailings from a particular mine in the Coeur d'Alene, Idaho, district. Results indicate the method to be highly effective in dewatering and consolidating this material.

RI 7893. Compound-Type Separation and Characterization Studies for a 370° to 535° C Distillate of Wilmington, Calif., Crude Oil, by D. E. Hirsch, J. E. Dooley, H. J. Coleman, and C. J. Thompson. 1974. 28 pp. 10 figs. A systematic procedure for separation, characterization, and semiquantitative analysis of high-boiling petroleum distillates was developed by the Bureau of Mines and applied to a 370° to 535° C distillate of Wilmington, Calif., crude oil. Separation procedures employed were isothermal and molecular distillation, chemical treatment, silica-alumina adsorption, and gel permeation chromatography. Characterization and analysis were accomplished by gel permeation chromatography correlations and mass and nuclear magnetic resonance spectrometry. These data should be useful in improving petroleum processing and utilization and in achieving the energy conservation inherent therein.

RI 7894. Improvements in the Three-Component Borehole Deformation Gage and Overcoring Techniques, by Verne E. Hooker, James R. Aggson, and David L. Bickel. With an appendix on stress relief by center

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hole, by Wilbur I. Duvall. 1974. 29 pp. 20 figs. This Bureau of Mines report summarizes the results of modifications in the borehole deformation gage design and subsequent changes in the overcoring techniques. Modifications in the borehole deformation gage have greatly improved the creep characteristics and enhanced the versatility of the gage. In situ field tests in competent rock near St. Cloud, Minn., provided sufficient data to compare the reliability between gages and new techniques in obtaining good engineering estimates of stresses. Near-surface horizontal stresses at the test sites are compressive and biaxial in nature.

RI 7895. Thermodynamics of the Al-Si System, by Seth C. Schaefer. 1974. 15 pp. 7 figs. The Bureau of Mines studied thermodynamic properties of liquid Al-Si alloys with the high-temperature galvanic cell $\text{Al(l)}/\text{Al}^{+3}(\text{AlCl}_3 \text{ in } \text{NaCl} \cdot \text{KCl})/\text{Al-Si alloy(l)}$. Activities of aluminum and silicon (referred to pure liquid metals) show a pronounced negative deviation from Raoult's law in liquid Al-Si alloys containing 0.9 to 35.2 atomic-percent silicon. Activity coefficients and the properties ΔG , ΔG° , ΔH , ΔG , ΔG° , and ΔS have been derived from the experimental data and are summarized in tables and illustrations.

RI 7896. Methods and Costs for Stabilizing Fine-Sized Mineral Wastes, by K. C. Dean, Richard Havens, and M. W. Glantz. 1974. 26 pp. 4 figs. Fine-sized mineral wastes discarded by ore milling plants require stabilization to prevent air and water pollution. Stabilization has been attained by physical, chemical, vegetative, and combination procedures. Vegetative reclamation is preferred to physical and chemical stabilization but is difficult to achieve because the wastes are sterile, contain deleterious inorganic salts, and lack the essential nutrients and physical characteristics required for sustaining vegetative growth. Methods now have been developed for attaining vegetative growth on all but excessively acidic, basic, or saline tailings at costs ranging from \$120 to \$650 per acre. The cost for stabilizing tailings requiring more intensive treatment techniques may range upward to \$1,750 per acre. This report summarizes procedures developed by the Bureau of Mines and industry for vegetating amenable tailings, lists costs for the various processes, and suggests procedures that may be applicable for stabilizing saline and pyrite-containing tailings. Ridged planting beds, drip irrigation, and deep-furrow planting techniques are suggested for stabilizing saline wastes. A combination of mill tailings and sewage sludge can be used for producing synthetic soils, and layers of sewage sludge buried under a layer of tailings offer promise of inhibiting acid formation from oxidation of sulfides in mineral wastes.

RI 7897. Geochemistry of Liquids, Gases, and Rocks From the Smackover Formation, by A. Gene Collins. 1974. 84 pp. 22 figs. The Bureau of Mines conducted a research study of the geochemistry of the Smackover Formation to determine what geochemical relationships are useful in exploration for and production of oil and gas. Samples of oil, gas, brine, and rock were collected and analyzed. The oilfield brines were analyzed by methods recommended by the American Petroleum Institute and by tentative methods of the American Society for Testing and Materials. The crude oils were analyzed by Bureau of Mines methods; the gas, by Bureau of Mines methods; and the rocks, by wet-chemical, atomic

absorption, and neutron activation methods. The results were correlated and interpreted, and several geochemical relationships useful in exploration and production were found. These include the type and class of brine, organic constituents in the brine, redox potential, in situ temperature and pressure of brine, degree of sulfate and carbonate saturation of brine, and halide concentrations in the brine.

RI 7898. Corrosion of Commercial Alloys in Three Environments Simulating Phosphate Rock Acidulation, by Laurance L. Oden and Boyd D. Nash. 1974. 10 pp. 3 figs. The Bureau of Mines conducted corrosion tests of 18 commercial alloys in H_3PO_4 -phosphate rock or Al_2O_3 slurry, in 10 pct HF, and in 25 pct H_2SiF_6 to simulate three environments anticipated in a Bureau process to extract fluoride values from phosphate rock. Small alloy coupons were rotated in duplicate tests at 4.4 to 21 fps in the slurry at 170° C to determine rates of erosion-corrosion. At 4.4 fps the lowest rates, in mils penetration per year (mpy), were measured for Hastelloy C-276 (<20), Hastelloy B (30), and Inconel 625 (150); the rates increased at 21 fps to 55 mpy, 45 mpy, and 1,000 mpy, respectively. The corrosion rate for all alloys exceeded 40 mpy in either the equilibrium vapor or liquid phases of aqueous solutions containing 10 pct HF or 25 pct H_2SiF_6 at 100° C. Uniform corrosion in 10 pct HF at 50° C was observed only for Inconel 625 (22 mpy), Hastelloy C-276 (43 mpy), and Ilium 98 (17 mpy). Inconel 625 (0.75 mpy), Hastelloy C-276 (1.3 mpy), Ilium 98 (1.7 mpy), and Inconel 825 (0.45 mpy) were attacked uniformly in 25 pct H_2SiF_6 at 50° C.

RI 7899. The Error in Gas Drive Calculations Caused by Ignoring Compressibility and Solution Effects, by F. M. Carlson and C. S. Land. 1974. 18 pp. 6 figs. Comparisons are made between the results of the Buckley-Leverett and Kern solutions, which describe immiscible displacement of oil by gas in a linear system and the results obtained from a less restrictive numerical model. This model takes into account the effect of compressibility of the oil and gas and the effect of allowing changes in the amount of gas in solution in the oil. These effects are best exemplified by imposing large pressure drops across the system. With these large pressure drops, comparison of the model solution with the Buckley-Leverett solution reveals that the Buckley-Leverett solution provides estimates of recoveries at breakthrough of the gas that are too low. In contrast to the model, the Kern solution predicts breakthrough recoveries that are too high. A modification to the Kern solution is presented to facilitate more accurate predictions of recovery at gas breakthrough for gas injection at pressures higher than the saturation pressure of the oil.

RI 7900. Laboratory Experiments in Electrokinetic Densification of Mill Tailings (In Two Parts). 2. Application to Various Types and Classifications of Tailings, by R. H. Sprute and D. J. Kelsh. 1974. 43 pp. 27 figs. This report describes Bureau of Mines laboratory test results in electrokinetic dewatering and consolidation of metal-mine mill tailings from five mines in the Coeur d'Alene, Idaho, district. Classified (coarse) tailings, slimes, and unclassified material were separately tested. Tailings were placed in 0.3-ft³ plexiglass models, and dc potential was applied until dewatering ceased. Time-oriented measurements of water removal, changes in resistivity, and power consumption were recorded during the dewatering

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process. Moisture content and density of the de-watered material at test end indicated the method to be generally effective for all materials examined, but best results were achieved with well-mixed unclassified tailings.

RI 7901. Blast-Produced Fractures in Lithonia Granite, by David E. Siskind and Robert R. Fumanti. 1974. 38 pp. 23 figs. The Bureau of Mines has studied the fracturing produced in the vicinity of large-diameter blastholes in Lithonia granite. Cores were taken from the vicinity of AN-FO production blasts and examined using a total of seven laboratory and field measurement techniques to delineate zones of damage and to evaluate the effectiveness of the seven diagnostic tests for fracture-state determination. Laboratory measurements of acoustic pulse velocity, porosity, permeability, compressive strength, and Young's modulus indicated the extent of fracturing, with the acoustic techniques providing the best means of distinguishing between fractured and unfractured core. A severely fractured zone was found to extend approximately 25 inches (64 cm) from the center of the 6½-inch blastholes, equivalent to 8 blasthole radii. A second zone, characterized by a lesser degree of fracturing, extended from 25 to 45 inches (64 to 114 cm) or 8- to 14-blasthole radii. Beyond 45 inches (114 cm) the rock was undamaged.

RI 7902. Spark-Shower Radiance of Metal Grinding Sparks, by John E. Kelley and Robert Blickensderfer. 1974. 25 pp. 12 figs. A method for measuring the spark-shower radiance of metals when abraded on a grinding wheel was developed by the Bureau of Mines for evaluating the sparking tendency of metals. The radiance was measured in units of emissive power per solid angle per area of the detector. Over 100 metals were tested and rated relative to commercially pure iron. The metals tested included elemental metals, iron binary and ternary alloys, iron-carbon ternary alloys, commercial steels, nonferrous alloys, and a few hard-metal compounds. Some alloys were synthesized; others were obtained commercially. Alloys that possessed good strength properties were emphasized for selection. The results indicate that the spark-shower radiance of plain carbon steels and carbon alloy steels was greater than that of pure iron. Certain elements, particularly vanadium and chromium, reduced the sparking tendency of iron. Stainless steels and particularly nickel alloys displayed low spark-shower radiance. Some metallic elements had much lower radiance than iron; others, much greater. Plain carbon steels, heat treated to a variety of hardnesses, gave radiance values that generally increased with increasing hardness. The effect on sparking tendency of an increase in hardness of an alloy steel was studied. The sparking tendency increased with an increase in hardness to a maximum, then decreased with a further increase in hardness.

RI 7903. Gas Chromatographic Method for Analyzing Gases Associated With Coal, by Ann G. Kim and Louise J. Douglas. 1974. 9 pp. 3 figs. Gas samples containing O₂, N₂, H₂, He, CO₂, CO, CH₄, and trace amounts of C₂ to C₅ hydrocarbons are analyzed by a gas chromatographic method that utilizes both thermal conductivity and flame ionization detectors. A porous polymer support and molecular sieve columns are used with argon as the carrier gas. A column selector valve makes it possible to perform a complete analysis either on one 1-ml sample in 40 minutes or on two samples in 20 minutes, one sample for each detector. Samples are introduced

either by on-column injection or through a gas sampling valve. By varying operational parameters, the speed, sensitivity, and accuracy of analysis may be modified to suit a particular situation.

RI 7904. Detecting and Sorting Disseminated Native Copper Ores, by Vernon R. Miller, Robert W. Nash, and Alfred E. Schwaneke. 1974. 14 pp. 4 figs. The Bureau of Mines developed and evaluated a detector-sorting device to separate the copper-bearing portion from the barren portion of native copper ores. Small-scale sorting tests were run on minus 1-inch plus ½-inch size materials from the following Michigan samples: Winona, Kingston, and Centennial ores, and "poor" rock from the Champion mine dump. Results showed that 60 to 85 pct of the copper was recovered in 9 to 19 wt-pct of the sorted fraction. About 90 pct of the copper recovered was obtained in the first pass through the sorter. For the Kingston and Centennial ores, combinations of sorter concentrates and fines generated during crushing resulted in recoveries of 93 and 94 pct, respectively, of the total copper in the samples. The combined products constituted about 66 wt-pct of the total sample and allowed the balance to be discarded with only a 6 to 7 pct copper loss.

RI 7905. Detonation Calculations With a Percus-Yevick Equation of State, by John C. Edwards and Robert Chaiken. 1974. 15 pp. 5 figs. Chapman-Jouguet detonation calculations were carried out for pentaerythritol tetranitrate (PETN), TNT, and ammonium nitrate-fuel oil (AN-FO) explosives using the compressibility form of an equation of state of hard spheres based upon Percus-Yevick (PY) theory, and a chemical equilibrium detonation code called TIGER. Similar calculations were also carried out with the Becker-Kistiakowsky-Wilson (BKW) equation of state. For PETN, the BKW equation gives somewhat better agreement with experimental values of detonation velocity and pressure. However, in terms of experimental temperatures and concentrations of the minor product species (NO), the predictions of the PY equation are shown to be more satisfactory. Similar comparisons of experimental and theoretical results for TNT and AN-FO indicate that the PY equation has general utility in predicting the detonation properties of condensed explosives at moderate loading densities ($\rho_0 < 1.3 \text{ g/cm}^3$).

RI 7906. Reduction of Tetravalent Cerium and Its Application to Stripping From Tri-*n*-Butyl Phosphate, by L. E. Schultze, D. J. Bauer, and R. E. Lindstrom. 1974. 8 pp. 7 figs. The Bureau of Mines conducted bench-scale studies to develop techniques for stripping tetravalent cerium from tri-*n*-butyl phosphate solutions. Experiments were conducted in a constant-temperature bath using beakers and mechanical stirring. In 15 minutes at 50° C, 95 percent of the cerium was stripped from a 50-pct tri-*n*-butyl phosphate-50-pct kerosene solution containing 0.18 M cerium, using 0.11 M aqueous formaldehyde.

RI 7907. Mine Roof Reinforcement by Specifically Designed Epoxy Resin Systems, by R. V. Subramanian, Helen Austin, R. A. V. Raff, and J. C. Franklin. 1974. 14 pp. 8 figs. This Bureau of Mines project investigated the use of polymers to achieve rock bonding and reinforce coal mine structures for better or permanent ground support. Support was achieved by pumping the polymers into the rock interstices to bond the mass together for increased structural competence. Holes were drilled in the mine roof, after which the polymers were injected at about 100 psi to

permeate the cracks. Initial laboratory work indicated that, of all the resin systems tested, the epoxy resins could most likely be modified to be suitable for rock injection. This was confirmed when several potentially suitable resin systems underwent intensive evaluation. In a series of three field-tests, two conducted in a copper mine with coal mine-type shale and the third in a coal mine, it was shown that the polymers penetrated cracks less than 0.005 inch wide. The fast-setting epoxy systems, cured out in thin films under mine conditions, produced a bond exceeding the strength of the uncracked virgin rock. Work done in cooperation with Washington State University.

RI 7908. Mathematical Study of a Propagating Flame and Its Induced Aerodynamics in a Coal Mine Passageway, by Donald N. H. Chi and Henry E. Perlee. 1974. 51 pp. 18 figs. The unsteady, one-dimensional, compressible-flow equations have been solved numerically for a deflagration propagating through a gallery of finite length closed at the ignition end and open at the opposite end. These equations were solved for two situations wherein (1) the propagating flame was extinguished after 0.1 sec or before the return of aerodynamic disturbances reflected from the open end, and (2) the flame was allowed to propagate a full 0.8 sec until it was extinguished. It was found that the process of sudden flame extinguishment creates rarefaction waves that, upon entering the burned zone, produce resonance within the burned cavity. For the relatively small value of the product of the expansion ratio (8.5) and the effective burning velocities of 7.4 m sec⁻¹ for the first experiment and 4.9 m sec⁻¹ for the second experiment, it was found that the acoustic approximation provides an adequate estimate of the pressures developed ahead of the flame during the system's early history.

RI 7909. Fast Pulse Processing for Gamma-Ray Spectroscopy, by George E. Fasching and George H. Patton. 1974. 11 pp. 6 figs. The Bureau of Mines has developed a pulse counting system with improved energy resolution and having dual channels to process pulses at different rates and a pulse pileup detector for channel selection. Pulse input is delayed until the detector determines if any pulse is so closely followed by a second pulse as to constitute pulse pileup. If no pulse pileup is detected, the slower channel is selected; this clips the pulse to a relatively wide pulse width to retain good energy resolution. If pulse pileup is predicted, the fast channel, with correspondingly shorter pulse width, is selected to improve resolution with respect to time. Output of the two channels is transmitted to a pulse height analyzer for interpretation. The pulse processing system can process count rates above 300,000 counts per second with little loss in energy resolution.

RI 7910. Cleat in Bituminous Coalbeds, by C. M. McCulloch, Maurice Deul, and P. W. Jeran. 1974. 25 pp. 13 figs. The natural vertical fracture system in bituminous coalbeds is called cleat. Cleat orientation commonly controls the direction of mining with major development paralleling the face cleat. Previous researchers have categorized the origin of cleat as endogenetic, relating the origin of cleat to compaction and coalification, and exogenetic, relating the origin of cleat to tectonic forces. In the coalbeds studied for this report it was found that tectonic forces were the controlling factor of

cleat formation. Face cleats were formed as extension fractures during structural deformation, and butt cleats, as release fractures during erosion and uplift. The face cleat of the Pittsburgh coalbed rotates from N 80° W in northwestern West Virginia to N 57° W in southwestern Pennsylvania; the face cleat maintains a perpendicular orientation to the shifting axial trend of local structures. Cleat orientation in other bituminous coalbeds in Virginia, Utah, Oklahoma, and central Pennsylvania showed a similar relationship to local structure. Directional permeability of coal is directly related to cleat. Holes drilled perpendicular to the face cleat yield from 2.5 to 10 times the amount of gas released as compared with holes drilled perpendicular to the butt cleat.

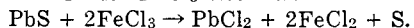
RI 7911. The Optimum Gas Saturation for Maximum Oil Recovery From Displacement by Water, by Carlton S. Land and Francis M. Carlson. 1974. 28 pp. 21 figs. The Bureau of Mines investigated the influence of a free gas saturation on oil recovery by water drive. A digital computer was used to calculate the combined oil recovery from solution-gas drive to various states of depletion. Results of these calculations are compared and optimum conditions for the maximum oil recovery are found for various fluid-rock systems. For most of the fluid-rock systems, the calculations show an optimum gas saturation other than zero. Using fluid and rock properties as parameters, graphs are plotted showing the optimum gas saturation and increase in oil recovery brought about by the gas saturation. The effects of fluid properties and relative permeability on the optimum gas saturation are seen in these graphs. The graphs can be used as guides in connection with other considerations in determining the optimum time to start a waterflood. They should also be helpful in determining the MER of a water-drive reservoir. The effects of compressibility and solubility of the trapped gas saturation are investigated for select cases using a backward difference scheme to solve the partial differential equation of three-phase flow. From these calculations, it is observed that some benefit of a gas saturation remains for injection pressures up to 1.5 times the original bubble-point pressure.

RI 7912. Deformation Monitoring of Underground Openings by Photographic Techniques, by James R. McVey, Samuel R. Lewis, Elmer E. Guidice, and James R. Powell. 1974. 26 pp. 16 figs. A new method for measuring deformations of rock surfaces in underground excavations has been suggested by Dr. James Powell of Brookhaven National Laboratories (BNL) and subsequently developed and successfully demonstrated in a mining environment by the Federal Bureau of Mines Spokane Mining Research Center (SMRC) and Brookhaven National Laboratories. The system uses 35-mm photography of targets strategically located on surfaces of interest, such as across the roof and on the sides of a mine drift or tunnel. The optimum target, as determined in this investigation, consists of a white "X" made with 1/8-inch-wide reflective tape on a black 6-inch square. Photographs, taken in pairs from two separated camera positions and at regular time intervals, were analyzed at the Bureau by hand and at Brookhaven National Laboratories using techniques and equipment similar to those used in cloud chamber film analysis. Test results show that deformation-measurement accuracies of better than ±0.020 inch in a drift that is 20 feet wide can be expected. This degree of accuracy, plus providing displace-

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ment data in the X, Y, and Z directions (rather than the one direction formerly possible), makes this a noteworthy and useful tool for industry as well as for mining research.

RI 7913. Recovery of Lead From Galena by a Leach-Electrolysis Procedure, by J. E. Murphy, F. P. Haver, and M. M. Wong. 1974. 8 pp. 3 figs. A method is being developed by the Federal Bureau of Mines for recovering lead metal from galena without the generation of SO₂. Lead chloride is obtained by leaching lead concentrate at a temperature of approximately 100° C with FeCl₃ solution:



Electrolysis of the PbCl₂ product in a fused-salt bath results in deposition of molten lead metal at the cathode and evolution of chlorine at the anode. The chlorine can then be absorbed in the spent leach solution to regenerate FeCl₃ for recycling. Optimum electrolyte composition was a PbCl₂-LiCl eutectic containing 7.6 wt-pct LiCl. The PbCl₂-NaCl eutectic also proved satisfactory. Electrolysis in the PbCl₂-LiCl bath 450° C yielded 99 pct current efficiency at current density of 5 amp/in² with an energy requirement of only 0.24 kW-hr/lb metal produced. This compares with 98 pct current efficiency and 0.26 kW-hr/lb metal produced for the PbCl₂-NaCl bath. A typical lead deposit contained less than 100 ppm total detectable metallic impurities. At the low temperature employed for electrolysis, there was essentially no vaporization of Pb or PbCl₂.

RI 7914. Copper Removal From Molten Ferrous Scrap. A Pilot Plant Study, by H. V. Makar and R. E. Brown. 1974. 11 pp. 1 fig. The Bureau of Mines successfully demonstrated, on a pilot plant scale, a sodium sulfate (Na₂SO₄) refining process for removal of copper from molten ferrous scrap. Previous tests established technical feasibility on a bench scale for achieving low copper concentrations and determining the principal factors controlling process efficiency. The pilot plant study involved a 1-ton arc furnace for melting ferrous scrap and a 1½-ton treatment ladle. Results of these tests showed that copper removals obtained in laboratory tests (approximately 40 relative percent copper removal with 10 weight-percent surface addition of sodium sulfate) could be achieved on the pilot plant scale when excess carbon was added with the sodium sulfate compacts. Data were obtained on temperature losses and carbon consumption related to Na₂SO₄ treatment.

RI 7915. Dielectric Constants and Dissipation Factors of Simulated Lunar Rocks, by Russell E. Griffin. 1974. 19 pp. 16 figs. Dielectric constants and dissipation factors were measured by the Bureau of Mines for 13 simulated lunar rocks over the 20- to 100-megahertz frequency range by means of the susceptance-variation method. Measurements were made at room temperature and normal atmospheric pressure. Results are presented and some comparison is made with data reported by others. The rocks used include a broad range of physical characteristics and chemical compositions from the large areas of volcanism in Oregon and northern California, and two nonvolcanic types. These rocks make up a suite of rock standards used by a group of laboratories engaged in lunar research. The data presented will add to the basic scientific and engineering knowledge needed to utilize extraterrestrial mineral resources for support of future space missions.

RI 7916. Using Sulfur Hexafluoride as a Gaseous Tracer To Study Ventilation Systems in Mines, by E. D.

Thimons, R. J. Bielicki, and F. N. Kissell. 1974. 22 pp. 14 figs. The Bureau of Mines found sulfur hexafluoride (SF₆), released from a lecture bottle, to be an ideal gaseous tracer for studying mine ventilation systems. Air samples were collected in glass syringes and analyzed by electron-capture gas chromatography. In these studies, the lower limit of detection was about 1 part per billion by volume (ppb) of SF₆ per part of air. Experiments conducted in a Pennsylvania limestone mine showed this technique useful in evaluating the effectiveness of auxiliary fans, measuring low flow velocities, probing the air circulating near a working face region where ventilation appeared to be poor, and estimating volumetric flow rates in airways of large cross-sectional area and having low flow velocities. This technique was also used in a western vein-type metal mine to measure the amount of return air being recirculated into the intake air due to leakage through old stoped areas.

RF 7917. Tracer Gas as an Aid in Mine Ventilation Analysis, by E. D. Thimons and F. N. Kissell. 1974. 17 pp. 13 figs. The Bureau of Mines has successfully used sulfur hexafluoride (SF₆) as a tracer gas to measure mine air flows under conditions where conventional methods have failed. SF₆ was employed experimentally to measure accurately recirculation of return into intake air caused by leakage through an old stoped area, to check for potential leakage from an adjacent mine, to trace 10,000 cfm of "lost" air from an intake airway, and to measure transit air time through uranium mines. It proved useful as a means of accurately measuring airflow volumes in airways of large cross section and very low flow velocity and in determining the recirculation resulting from underground cooling plants.

RI 7918. Identification of γ-Valerolactone in Waste Water From an Oil-Shale In Situ Retort, by F. R. McDonald. 1974. 8 pp. 5 figs. The compound γ-valerolactone has been identified in an acid fraction isolated from waste water collected from an in situ oil-shale retort. Infrared, nuclear magnetic resonance, and mass spectrometry were used by the Bureau of Mines to confirm the identification of a subfraction collected from a gas chromatograph. Work done in cooperation with the University of Wyoming.

RI 7919. Electrochemical Kinetics of the Reaction of Titanium Metal With Titanium Subchlorides in Molten Sodium Chloride, by D. J. MacDonald, A. E. Raddatz, T. A. Henrie, and E. K. Kleespies. 1974. 16 pp. 5 figs. Rates of electrooxidation and electrodeposition of titanium metal in a bath of molten sodium chloride containing dissolved TiCl₂ and TiCl₃ were measured by Bureau of Mines investigators as a function of current density, temperature, and TiCl₂ and TiCl₃ concentrations. The rates were found to be nearly linear functions of current density, but their dependence on temperature and on TiCl₂ and TiCl₃ concentrations are more complex. A rate equation that adequately describes the anodic electrooxidation at a single temperature (860° C) is

$$\text{Unit mass rate} \times 10^4 \text{ (g} \cdot \text{cm}^{-2} \cdot \text{sec}^{-1}) = 2.39 \text{ CD} + 0.11 \times \text{mole-percent TiCl}_3.$$

Similarly, the cathodic deposition of titanium at 860° C can be described by the rate equation:

$$\text{Unit mass rate} \times 10^4 \text{ (g} \cdot \text{cm}^{-2} \cdot \text{sec}^{-1}) = 1.65 \text{ CD} - 0.06 \text{ (CD} \times \text{mole-percent TiCl}_3).$$

The average number of electrons transferred per titanium atom dissolved anodically ranged from 0.84

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to 2.7, the exact number being a function of current density and of TiCl_3 and TiCl_4 concentrations. In the cathodic experiments, from 2.6 to 6.3 electrons were transferred per titanium atom deposited, and the ratio was found to be a function only of TiCl_3 concentration. The results are interpreted in terms of a reaction mechanism involving adsorption.

RI 7920. Evaluation of Plastic Scintillators for Detection of Prompt Gamma Rays in Continuous Analysis of Bulk Materials, by A. W. Hall and G. R. Friggens. 1974. 11 pp. 3 figs. Cylindrical plastic scintillators were investigated for efficiency in detecting neutron-induced prompt gamma rays. Scintillator performance was compared on the basis of half-resolution and peak-to-trough ratios for gamma spectra obtained from Co-60 (1.17 and 1.33 MeV), Th-228 (2.62 MeV), and PuBe (4.43 MeV). Various sizes of Pilot Chemical scintillators (types B, F, M, and Y) were tested. The best half-resolution, 7.7 percent for PuBe, was achieved with a 5- by 5-inch Pilot Y-scintillator and dual photomultipliers. Comparison with sodium iodide (NaI) scintillators and the use of plastic scintillators for on-stream analysis of sulfur in coal is discussed. Plastics were found to be unsuitable for on-stream analysis of materials having complex prompt gamma ray spectra; however, they could conceivably be used for those yielding simpler spectra.

RI 7921. Retorting Indexes for Oil-Shale Pyrolyses From Ethylene-Ethane Ratios of Product Gases, by I. A. Jacobson, Jr., A. W. Decora, and G. L. Cook. 1974. 22 pp. 7 figs. In a closely controlled laboratory retorting system for oil shale, a relationship was developed by the Bureau of Mines between the temperature in the retort and the weight ratio of ethylene to ethane in the gases produced. Reciprocal temperature was shown to be directly proportional to the log ([ethylene]/[ethane]). From this relationship a number, called retorting index, was developed. The retorting index has the dimension of temperature, but its magnitude depends on both temperature and residence time for the reactants in the heated zone in the oil-shale retort. The slopes of the lines relating reciprocal temperature and the logarithm of the ethylene-ethane ratios are nearly constant for each of the retorting processes for which data have been presented. The retorting index should be a valuable tool to control the operation of oil-shale retorts, either aboveground or in situ. If an optimum operating condition can be established, the maintenance of the optimum or the departure from it should be easily monitored by use of the index. Work done in cooperation with the University of Wyoming.

RI 7922. Steam Pyrohydrolysis of Hydrous Magnesium Chlorides, by John L. Reuss and Joan T. May. 1974. 9 pp. 3 figs. A laboratory study was conducted by the Bureau of Mines to investigate the technical feasibility of decomposing hydrous magnesium chlorides by using a steam pyrohydrolysis technique. This procedure consisted of injecting steam into the atmosphere of a decomposition furnace containing samples of hydrous magnesium chloride and then determining the rate of hydrolysis by measuring the rate of chloride evolution. The variables investigated were temperature, amount of water vapor in the decomposition atmosphere, and hydration stage of magnesium chloride. The application of steam was shown to accelerate both the rate

and completeness of magnesium chloride decomposition reactions. For example, when magnesium chloride hexahydrate is exposed to a furnace temperature of 600° C in an air atmosphere for 20 minutes, the decomposition is 37 percent. Under identical conditions in a steam atmosphere, the decomposition is in excess of 70 percent. The magnesium oxide produced by the steam pyrohydrolysis of magnesium chloride dihydrate at 800° C contained 98 percent magnesium oxide. Based on magnesium oxide composition, this is equivalent to that of burned magnesite produced at temperatures in excess of 1,300° C. To demonstrate the quality of the product on a practical basis, metal reduction tests have shown it to be equivalent to reagent-grade magnesium oxide as a carbothermic reduction feed material.

RI 7923. Properties of Utah Tar Sands—Threemile Canyon Area, P. R. Spring Deposit, by L. C. Marchant, L. A. Johnson, and C. Q. Cupps. 1974. 14 pp. 6 figs. Results of detailed analyses of four cores from the Threemile Canyon area in the P. R. Spring tar sand deposit in Utah are reported by the Bureau of Mines. The cores were obtained by the Utah Geological and Mineralogical Survey as part of a 17-corehole evaluation program in the P. R. Spring, Hill Creek, and Rim Rock tar sand deposits. Average properties of the oil zone in the Threemile Canyon areas as determined from these cores are as follows: Oil saturation, 67.4 pct of pore volume; porosity, 29.2 pct; permeability before oil extraction, 133 millidarcies; and permeability after oil extraction, 2,855 millidarcies. Average net thickness of oil zone is 23.8 ft, and average depth to the top of the oil zone is 189 ft. Work done in cooperation with the University of Wyoming.

RI 7924. Thermal Degradation of Green River Kerogen at 150° to 350° C. Composition of Products, by J. J. Cummins, F. G. Doolittle, and W. E. Robinson. 1974. 18 pp. 5 figs. The Bureau of Mines heated Green River oil shale that had been previously extracted by benzene to provide information on in situ processing conditions, to determine the effect of low temperature heating on the unconverted kerogen, and to determine the composition of benzene-soluble thermal products. Tests were conducted at 150° to 350° C for 0.5 to 360 days. The methods used in determining the composition of the soluble thermal products consisted of fractionation of the soluble material, elemental analysis of the soluble products, fractionation of the polar resins by ion-exchange chromatography, gas chromatographic analysis of *n*-alkanes, and mass spectral analysis of the branched plus cyclic alkanes and aromatic oils. The methods used to determine the effect of low-temperature heating on the unconverted kerogen remaining in the oil shale heated residues consisted of carbon-hydrogen analysis, volatile material determination, carbon residue determination, and oxidation rate determination. In general, it was concluded that significant increases in the degradation of kerogen to oil occurred between the temperature range of 250° to 350° C; that the composition of the soluble products depends upon the temperature at which they are formed; and that the *n*-alkanes are pyrolytically degraded from the kerogen structure. In particular, the 250° C heating temperature is beneficial to the formation of branched plus cyclic alkanes. Also, the heated and unconverted oil shale kerogen and the soluble thermal products become more aromatic as the temperature increases from 150° to 350° C. Work done in cooperation with the University of Wyoming.

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RI 7925. Waste Lubricating Oil Research. Some Innovative Approaches To Reclaiming Used Crankcase Oil, by M. L. Whisman, J. W. Goetzinger, and F. O. Cotton. 1974. 20 pp. The Bureau of Mines developed and laboratory tested several innovative techniques for reclaiming used lubricating oil. These processes included percolation through both chemically treated clay and ion-exchange resins, distillation through batch and continuous wiped-wall vacuum apparatus, treatment with solvent extraction systems, and chemical removal of impurities with chelating agents. In each treatment, the criteria of evaluation were oil recovery and reduction of acidic and metallic components. Both vacuum distillation and solvent treatment ranked high in their abilities to remove acidic and metallic components of the used oil with good oil recoveries. A combination of the two techniques gave the best overall results in terms of quality evaluations made by established bench tests. The methods were not ranked according to economic practicability.

RI 7926. Vapor Phase Reduction of Lead Sulfide, by E. R. Cole, Jr., W. M. Dressel, and M. M. Fine. 1974. 11 pp. 3 figs. A lead smelting process that appears to present minimal pollution problems has been developed at the Bureau of Mines Rolla Metallurgy Research Center. Ten- and 100-g samples of PbS mill concentrates were vaporized at 1,000° to 1,100° C in a furnace with an inert gas atmosphere during a 2-hour period. The PbS vapor was transported by the inert carrier gas to the reduction zone of the furnace where it was reduced at the same temperature with excess hydrogen to metallic lead. Lead of 99.9-pct purity was produced. The H₂S formed can be decomposed into elemental sulfur and water vapor by a modified Claus process. Approximately 90 pct of the Cu and 70 pct of the Ag and Zn remain in the residue and are potentially recoverable. More than 98 pct of the lead in the concentrates was extracted.

RI 7927. Removal of Lead and Zinc and the Production of Prereduced Pellets From Iron and Steelmaking Wastes, by W. M. Dressel, P. G. Barnard, and M. M. Fine. 1974. 15 pp. 3 figs. Over 2 million tons of steel furnace dust containing approximately 100,000 tons of zinc and 10,000 tons of lead are produced each year. Recycling of the dusts would conserve mineral resources, lessen land area requirements for disposal, decrease pollution problems, and aid in solving the balance of payment problem. Steelmaking dusts can be pelletized and thermally treated to remove lead and zinc and to reduce the iron oxide to form metallized pellets. In laboratory tests, more than 99 pct of the zinc and 85 pct of the lead was volatilized from the dust by roasting at 1,000° C in carbon monoxide. The volatilized material can be collected and treated further for lead and zinc recovery. Reduction and volatilization of over 95 pct of the zinc and most of the lead were achieved by roasting self-reducing mixtures of steel furnace dusts and high-carbon steelmaking wastes in an inert atmosphere at 1,100° C. Over 80 pct of the iron in the resulting pellets was metallized.

RI 7928. Recovery of Feldspar and Glass Sand From Georgia Waste Granite Fines, by W. H. Eddy, E. W. Collins, and G. V. Sullivan. 1974. 11 pp. 1 fig. The Bureau of Mines conducted laboratory batch- and small-scale continuous flotation processing tests on waste granite fines from Georgia to determine the feasibility of recovering usable feldspar and quartz products by flotation. Two flotation methods were

utilized for the removal of biotite and other iron-bearing minerals: one was in an acid-cationic circuit, and the other, in an alkaline-anionic-cationic circuit. Feldspar was recovered using an acid-cationic method. To produce commercial-grade feldspar and quartz products, it was necessary to employ either two sequential froth flotation circuits or one froth flotation circuit supplemented by wet-magnetic separation techniques to remove iron contaminants. Continuous flotation processing yielded a commercial-grade feldspar concentrate containing, in percent, 3.8 Na₂O, 5.4 K₂O, and 1.10 CaO, with recoveries of 77.8, 70.3, and 64.4, respectively. The feldspar tailing was high-quality glass sand containing 98.2 percent SiO₂ and 0.024 percent Fe₂O₃. About 42 percent of the quartz was recovered at glass sand specifications. An effective separation of potash feldspar from the bulk feldspar concentrate was achieved by batch flotation in a mineral separation cell. Work done in cooperation with the University of Alabama.

RI 7929. Thermal Energy Recovery by Basic Oxygen Furnace Offgas Preheating of Scrap, by J. J. Drost, C. B. Daellenbach, W. M. Mahan, and W. C. Hill. 1974. 8 pp. 3 figs. The feasibility of basic oxygen furnace (BOF) offgas heat recuperation by preheating scrap was investigated on a pilot plant scale by the Bureau of Mines. In this study, offgases generated during the oxygen blowing of a molten pig iron and scrap charge were passed through a static bed of shredded auto scrap. Scrap quantities ranging from 100 to 180 pounds and representing from 22 to 40 percent of the 450-pound BOF metallic charge were preheated in this manner. Average scrap bed temperatures of 1,650° F for 100 pounds of scrap and 1,150° F for 180 pounds of scrap have been achieved during the blows. Compared with cold scrap used in the normal BOF practice, it was found that by preheating scrap, usage could be increased by 43 percent. The thermal energy recovered by this preheating method can account for up to 44 percent of the energy necessary to melt the scrap.

RI 7930. Incendivity of Some Coal-Cutter Materials by Impact-Abrasion in Air-Methane, by R. Blickensderfer, D. K. Deardorff, and J. E. Kelley. 1974. 20 pp. 5 figs. Test equipment that simulated frictional impacts between coal-cutter bits and mineral inclusions at a coal face during operation of a continuous coal mining machine was used by the Bureau of Mines in the laboratory to study the incendivity of impacts between various rocks, metals, and hard-metal alloys in an explosive mixture of air-7 pct natural gas. Quartzitic sandstone was found to be the most incendive of several rocks tested. Limestone concretions from a coal seam, known locally as "sulfur balls," sparked furiously but were not incendive. Among the metals tested, the type of steel used in commercial coal-cutter tools was the most incendive material tested. A 17-4PH stainless steel was less incendive and appears to be the most promising high-strength steel alloy for use in coal-cutter bits. Some hard-metal alloys, primarily titanium and zirconium diboride composites, were also evaluated as possible replacements for the conventional cobalt-bonded tungsten carbide used in the tip of coal-cutter bits. The metal-bonded diborides were generally less incendive but more brittle than the conventional tungsten carbide. Carbonitride coatings on tool bits were also tested but found to have no advantage. The source of ignition during frictional impact between metal and rock was studied. Immediately after impact, a yellow flash was observed and a smear of metal near its melting

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point occurred on the rock. This hotspot on the rock, rather than the yellow flash or sparks or metal fragments, were observed to be the cause of the ignition.

RI 7931. Hydrogen Peroxide Precipitation of Uranium, by M. Shabbir and K. E. Tame. 1974. 13 pp. 5 figs. A study was made to determine the optimum conditions for precipitation of uranium from mill solutions using hydrogen peroxide. Precipitation tests were made on both synthetic and actual mill solutions. Parameters studied included the amount of hydrogen peroxide, initial pH, reaction pH, time, and temperature. Also investigated was the effect of varied amounts of vanadium, molybdenum, and sulfate in the test solution on uranium precipitation and product quality. The optimum conditions for complete precipitation and high product quality were (1) the use of 150 percent of the stoichiometric requirement of hydrogen peroxide, (2) initial pH of 1.0, (3) reaction pH between 3.4 and 5.0, (4) 4 hours reaction time, and (5) ambient reaction temperature. The excess hydrogen peroxide requirement is partially dependent on the amount of impurities present in the feed solution. The hydrogen peroxide process appeared applicable to treatment of the several mill eluate and strip solutions tested. The experimental studies also indicated that the hydrogen peroxide technique gives substantially better product quality than that produced by ammonia precipitation.

RI 7932. Recovering Vanadium From Dolomitic Nevada Shale, by P. T. Brooks and G. M. Potter. 1974. 20 pp. 6 figs. A process for extracting 69 percent of the vanadium from weathered Nevada dolomitic shale containing about 1 percent V_2O_5 was developed on a laboratory scale by the Bureau of Mines. The process essentially consists of salt roasting, leaching with dilute sulfuric acid, solvent extraction, and precipitation of vanadium as ammonium metavanadate. Carbonaceous unweathered shale was less amenable to treatment. A preliminary cost estimate for mining and processing 1,500 tons per day of weathered shale indicated a production cost of about \$1 per pound of V_2O_5 . Considering recent sales at nearly \$1.75 per pound of contained V_2O_5 , larger scale testing to obtain more definitive process design and evaluation data may be warranted.

RI 7933. Source and Control of Nitride Inclusions in Titanium, by Jack L. Henry, S. D. Hill, W. E. Anable, and J. L. Schaller. 1974. 48 pp. 24 figs. A laboratory- and a pilot plant-scale investigation has been conducted by the Bureau of Mines to examine possible sources of nitride defects in the production of magnesium-reduced titanium sponge. The production of alpha-stabilized nitride inclusions in hot-rolled titanium plate from air contamination of sponge during its manufacture has been experimentally demonstrated. Magnesium-reduced sponge prepared from air-contaminated magnesium or when contaminated by an air leak during reduction, vacuum distillation, or inert gas sweep shows very large variations in nitrogen content. Refractory nitrides, delta TiN , and epsilon Ti_2N have been identified in this sponge. The highest incidence of inclusions resulted from sponge that was reduced by air-contaminated magnesium and from sponge subjected to air contamination during the vacuum distillation cycle and during helium sweep. Air contamination of sponge during the reduction cycle was not nearly as effective in producing inclusions. Tests showed that color and texture may not be reliable criteria for locating defects during sponge inspection. Maintenance of good vacuum-tight integrity, filtration of

molten magnesium prior to charging into the reduction retort, and mechanical attrition of sponge to pulverize and disperse nitrides are suggested as practices to lower inclusion incidence in commercial titanium ingots.

RI 7934. Pioneering Experiments on the Coreduction of Titanium, Aluminum, and Vanadium Chlorides To Produce Titanium Alloy Sponge, by Jack L. Henry, Wallace E. Anable, and John L. Schaller. 1974. 21 pp. 15 figs. The Bureau of Mines conducted seven pioneering experiments in a 12-inch-diameter Kroll reduction reactor to examine the feasibility of coreducing the chlorides of Ti, Al, and V to produce a homogeneous titanium alloy sponge. The coreduction studies proceeded in a normal manner, and the yields of sponge were comparable with those of pure titanium sponge made in the same reactor. Vanadium concentration was very uniform throughout the sponge cake when VCl_4 in solution in $TiCl_4$ was fed into the molten magnesium. More difficulty was encountered in feeding solid VCl_2 and $AlCl_3$. Vanadium and aluminum concentration in the sponge was not uniform, and mechanical difficulties were experienced with the small-scale screw feeder. Although the sponge varied in composition from region to region, the ingots prepared from it were uniform in composition.

RI 7935. Drilling and Sampling Tertiary Gold-Bearing Gravels at Badger Hill, Nevada County, Calif., by Russell R. McLellan, Richard D. Berkenkotter, Richard C. Wilmot, and Robert L. Stahl. 1974. 50 pp. 20 figs. As part of an effort to develop new or improved placer mining technology in the Tertiary gold-bearing channel gravel of northern California, the Bureau of Mines conducted investigations at the old Badger Hill placer mine in Nevada County, Calif., to collect data and information regarding drilling and sampling methods and deposit characteristics. Sampling studies involved the collection and processing of 400 tons of large- and small-volume samples from drill holes, underground workings, surface pits, and blasthole rounds. A total of 355 samples averaging 2,296 pounds per sample provided reasonably accurate data for analysis of the gold distribution. These studies indicated that the bulk of the gold is within 40 feet of bedrock in stacked, lenticular zones of cemented gravel that are largely confined to the relatively narrow, meandering course of the deepest portion of the bedrock channel. Drilling studies involved the testing of truck-mounted rotary, bucket, and vibratory drills, none of which proved to be a completely versatile tool for sampling quickly and reliably both consolidated and unconsolidated gravel.

RI 7936. Reducing Surface Hot Shortness of Copper-Containing Steels Using Silicon Additions and Controlled Reheating Conditions, by Mark I. Copeland. 1974. 20 pp. 7 figs. This study was conducted by the Bureau of Mines to determine the effect of steel reheating practices in burning natural gas on the amount of silicon required to prevent the formation of copper on steels containing up to 1 wt-pct Cu. Formation of copper, which causes surface hot shortness, was readily prevented by as little as 0.3 wt-pct Si and by 2 vol-pct excess oxygen in the furnace atmosphere when reheating steels containing up to 0.8 wt-pct Cu. Up to 0.8 wt-pct Si content and careful control of reheating conditions were necessary for steels con-

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taining 1 wt-pct Cu. Best conditions for these steels were reheating to 2,200° F (1,205° C) in burning gases containing 2 vol-pct excess oxygen, and then to higher temperatures in gases of 6 vol-pct excess oxygen. Slag and mold wash were not detrimental on steels reheated for 8 hr by a soaking-pit-type furnace schedule, but they were problematical on steel heated for 2 hr by a pusher-type furnace schedule. The effect of silicon contents on scaling rates also was determined.

RI 7937. Vibrations From Underground Blasting, by James J. Snodgrass and David E. Siskind. 1974. 31 pp. 22 figs. The Bureau of Mines has investigated vibration levels produced by blasting at four underground sites to establish how such factors as type of explosive, delay blasting, charge weight, and geology affect amplitudes of ground motion. A summary of the work is presented, and the results of further analysis of the data are discussed. Square root scaling was found applicable to two of the underground sites and could be applied with minor error to all the sites. Comparison of empirical propagation equations in the different rock types indicates that although the site effect is apparent, the combined data may be used as a basis for engineering estimates of vibration amplitudes from subsurface blasting in many different rock types. Recommendations for predicting and minimizing vibration amplitudes from underground blasts are given.

RI 7938. Processing High-Resolution Mass Spectrographic Plates With a Comparator-Microdensitometer-Programmable Calculator System, by J. H. Weber, D. G. Earnshaw, D. W. K. Severin, and A. W. Decora. 1974. 14 pp. 4 figs. This Bureau of Mines publication describes the hardware system and software package for the semiautomatic acquisition and automatic processing of high-resolution mass spectrographic plates. The semiautomatic data acquisition allows a tenfold saving of time compared with manual data acquisition. Automatic processing of the high-resolution data to yield exact masses, intensity, and the corresponding empirical formulas is accomplished by efficient programming on a small, inexpensive, programable calculator system.

RI 7939. Seepage-Environmental Analysis of the Slime Zone of a Tailings Pond, by C. Daniel Kealy, Richard A. Busch, and Michael M. McDonald. 1974. 89 pp. 18 figs. Dissolved and suspended solids are present in the free water of tailings ponds. This Bureau of Mines study was designed to identify the influences of the slime zone in preventing these solids from reaching the environment outside the tailings pond. The finite-element method was used to determine the rate of discharge of subsurface water from the Van Stone tailings pond in northern Washington. The slime zone was sampled and tested for the first time, and results were interpreted and incorporated into the mathematical model. Computer results were verified by installing and monitoring piezometers in the field and by a simulated (16- by 1/2- by 3-foot) laboratory model. Output from the numerical model defined critical seepage zones and revealed that proper pond design and maintenance can reduce pond seepage losses to a minimum. Minimization of seepage requires maintaining the pond water level over the slime zone. Sufficient physical, chemical, and limnological data were collected and analyzed to conclude that the only realistic reflection of synergistic effects is obtained by study of the

indigenous biota in combination with quantitative chemical and physical data. Proper planning and management of the milling and waste disposal operations are the key to minimal pollution.

RI 7940. Low-Temperature Heat Capacities of Sphalerite and Wurtzite, by J. M. Stuve. 1974. 8 pp. 2 figs. Low-temperature adiabatic heat-capacity determinations were made by the Bureau of Mines in the temperature range from 5 to 300 K for the two crystalline modifications of zinc sulfide, sphalerite (β) and wurtzite (α). The entropy at 298.15 K of sphalerite was evaluated as 14.02 ± 0.04 cal/deg mole, and that of wurtzite, at 14.06 ± 0.04 cal/deg mole.

RI 7941. Tube-Wall Methanation Reactors With Combined Diffusion and Kinetic Resistance, by T. D. Ralston, W. P. Haynes, A. J. Forney, and R. R. Schehl. 1974. 15 pp. 6 figs. This Bureau of Mines report presents a mathematical model for heterogeneously catalyzed chemical reactors operating under turbulent conditions. The model includes reaction kinetics on the catalyst surface as well as diffusion of the reacting components within the reactor. Three applications of the model to tube-wall methanation reactors are discussed. The first application is a computation of catalyst activity from measured reactor data. This result is then used in a reactor sizing problem and a problem of reactor simulation with recycle. In addition to the reactor model, a novel approach to solving the recycled reactor problem is given.

RI 7942. An Improved Electrical Resistivity Field System for Shallow Earth Measurements, by C. Melvin Lepper and James H. Scott. 1974. 20 pp. 10 figs. The Bureau of Mines has developed an improved earth resistivity field system that employs a novel technique for obtaining null measurements. The instrument is designed to operate reliably in high-noise environments such as those found in the vicinity of operating mines. The system consists of a low-frequency transmitter, a sensitive receiver, and an external battery pack, each in its own case to provide protection from the elements. The receiver and transmitter units have self-contained rechargeable batteries to supply power to the circuitry and separate built-in battery charges that operate on standard 115 Vac power. The system is portable and simple to operate. Measurement accuracy, reliability, and dynamic range are superior to most commercially available equipment even though less time and effort is required to make null readings. Unlike some commercial systems, long integration times are not required to enhance signal-to-noise ratio in areas of high background noise.

RI 7943. Phases and Interdiffusion Between Titanium and Its Mononitride, by F. W. Wood, P. A. Romans, R. A. McCune, and O. G. Paasche. 1974. 40 pp. 27 figs. The Bureau of Mines has sought clarification of the Ti-TiN system by studying the phases formed by diffusion reactions between titanium and titanium nitride. Reaction couples were prepared by embedding pockets of TiN powder in arc-melted buttons of titanium. Specimens were vacuum annealed at nominal temperatures of 800°, 950°, 1,200°, and 1,500° C. Metallographically mounted cross sections from reacted specimens and from some that were not annealed were examined optically, with an electron microprobe, with an elec-

tron microscope, and by X-ray diffraction. Each annealed specimen contained a segregated core primarily of δ -phase material, an ϵ -phase diffusion layer, an α -phase diffusion layer, and host metal. On the basis of corresponding microprobe analyses, and considering results of certain other research, a new phase diagram is proposed. It contains no qualitative innovations, only quantitative adjustments. Results were also analyzed from the viewpoint of diffusion behavior. Diffusion coefficients calculated for the ϵ -phase were sufficiently scattered that the parameters are very tentative. Nevertheless, the diffusion behavior reported is in reasonable agreement with one of two prior studies if it is assumed that the earlier investigators were mistaken in their identification of the nitride phase in which the diffusion occurred.

RI 7944. Multiple-Orifice Feeder for Fine Particles, by H. G. Lucas and N. S. Smith, Jr. 1974. 5 pp. 5 figs. A feeder screw supplied at constant pressure by a hopper-orifice arrangement was developed for feeding solids in size ranges up to several hundred micrometers at constant flow rates. Performance of the feeder was evaluated by measuring the flow rates obtained with 3- to 7-micrometer coal ash, 70 percent through 200-mesh coal, and minus 325- plus 400-mesh coal ash. Constant feed rates within a few percent of set values were achieved for half-hour periods for the larger particles and for 5-minute periods for the finer particles. Suggestions are given for feedstock preparation and feeder operation for optimum performance.

RI 7945. Compound-Type Separation and Characterization Studies for a 370° to 530° C Distillate of Recluse, Wyo., Crude Oil, by D. E. Hirsch, J. E. Dooley, J. W. Vogh, and C. J. Thompson. 1974. 25 pp. 10 figs. The Bureau of Mines has developed a systematic procedure for separation, characterization, and semiquantitative analysis of high-boiling (350° to 550° C) distillates of crude oils. Isothermal and molecular distillation were used to prepare the 370° to 530° C distillate of Recluse, Wyo., crude oil. The distillate was separated into fractions by chemical treatment, silica-alumina gel adsorption, and gel permeation chromatography (GPC). The fractions were analyzed by use of GPC correlations and mass and nuclear magnetic resonance (NMR) spectrometry. The increased knowledge of petroleum composition obtained from the data will contribute to improved petroleum processing and utilization and energy conservation.

RI 7946. Coal Mine Dust Incombustibles Content Analyzer Using a Gamma-Ray Backscatter Technique, by F. E. Armstrong. 1974. 10 pp. 5 figs. An instrument using a gamma-ray backscatter technique for determining the weight-percent incombustibles content of coal dust and rock dust mixtures in coal mines has been built and tested. The unit gives a direct readout in percent incombustibles for coal mine dust mixtures containing between 50 and 100 percent incombustibles. Calibration of the device requires using a sample of the rock dust employed; the sample is usually limestone but is occasionally dolomite or gypsum. A small americium-241 source is used with a scintillation detector, the output of which feeds a rate meter. The source-detector geometry used was chosen to reduce the effects of variation in bulk density. Accuracy of the system is within ± 3 percent for most mixtures. The instrument is portable and completely self-contained; the rechargeable batteries supply power for 300 to 400 determinations.

RI 7947. Removal of Hydrogen Sulfide From Hot Producer Gas by Solid Absorbents, by W. T. Abel, F. G. Shultz, and P. F. Langdon. 1974. 23 pp. 13 figs. The Bureau of Mines tested 48 materials for their ability to absorb H₂S from hot simulated producer gas (1,000° to 1,500° F). The material found best from the standpoint of absorption capacity, durability, and amenability to regeneration was sintered pellets of 75 percent fly ash-25 percent Fe₂O₃. The performance of this absorbent under simulated and actual conditions is described. The effect of absorbent composition, absorbent temperature, steam content of the gas, and tar vapors and dust in producer gas is discussed.

RI 7948. Continuous Heavy Liquid Concentration of Brucite, by T. O. Llewellyn and G. V. Sullivan. 1974. 7 pp. 1 fig. The Bureau of Mines investigated the use of a heavy liquid in combination with fluid cyclones to separate brucite from a Nevada ore on a continuous basis, using a mixture of dibromomethane and trichloroethylene having a density of 2.44 grams per cubic centimeter. Single-stage cyclone separation produced a concentrate that contained 84 percent of the total magnesia at a grade, on a calcined basis, of 95.6 percent MgO. Work done in cooperation with the University of Alabama.

RI 7949. Room Temperature Tensile Properties of Titanium and Seven Titanium Alloys Prepared by Skull Casting, by E. D. Calvert and Ronald R. Lowery. 1974. 26 pp. 6 figs. The room temperature tensile properties of commercially pure titanium and seven titanium alloys prepared by skull casting were determined in the as-cast and heat-treated conditions. Data were compared with property data from tensile tests on wrought alloys of the same compositions in the as-worked and heat-treated conditions. The alloys evaluated were Ti-5Al-2.5Sn, Ti-6Al-4V, Ti-6Al-4V-1Si, Ti-6Al-2Sn-4Zr-2Mo, Ti-6Al-6V-4Zr-4Mo, Ti-6Al-6V-2Sn, and Ti-11.5Mo-6Zr-4.5Sn. Test specimens were prepared from both static and centrifugal castings and from plate fabricated by forging and rolling vacuum-melted ingots. The data indicate that the alpha and alpha-beta alloys have strength properties in the as-cast condition that are reasonably close to the strength properties of their wrought counterparts in the as-worked condition. An exception to this was the Ti-6Al-6V-4Zr-4Mo alloy for which insufficient data were available to form any firm conclusions. Fine-grained cast structures of Beta III (Ti-11.5Mo-6Zr-4.5Sn) were shown to be generally stronger in the as-cast condition than the wrought alloy in the as-worked condition except for the yield strength of one structure that was unusually low. Heat treatment of this alloy produced properties that were unpredictable. Indications are, however, that optimization of heat treatment parameters for each cast structure could produce strength properties equal to that of wrought materials.

RI 7950. Preliminary Investigation of Desilication of Minerals With Sulfur and Carbon, by H. O. Poppleton and T. T. Campbell. 1974. 8 pp. 8 figs. This Bureau of Mines study was made to investigate a possible method for selectively removing the SiO₂ component of silicate minerals and ores. Of specific interest were aluminum ores and zircon. Methods are described for removing SiO₂ from these ores as volatile silicon sulfides by treating the ore with sulfur and carbon; with sulfur, carbon, and a reducing

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gas; or with sulfur compounds and carbon. Comparative results are also given for the desilication of some of the ores with carbon alone to form volatile silicon monoxide. The silica component can be removed partially from bauxites at temperatures above the sublimation temperature of SiS (940° C) by treatment with carbon, sulfur, and methane; however, it is more difficult to remove the silicon from kyanite, manganese silicate, red muds from aluminum processing, kaolinite, lateritic nickel ores, and zircon. Complete desilication requires temperatures ranging from 1,100° C for bauxite to 1,450° C for zircon. Although the high temperatures required and the undesirable metal sulfides produced eliminate practical application of this method using present technology, the Bureau is reporting this data so that they will be available to future investigators.

RI 7951. A Continuous-Recording Methanometer for Exhaust Fan Monitoring, by M. C. Irani, A. Tall, B. M. Bench, and P. W. Jeran. 1974. 18 pp. 10 figs. The Bureau of Mines, in cooperation with the Mine Safety Appliances Co., has developed a continuous-recording methanometer utilizing a catalytic combustion detector. The methanometer, which is presently operating at 22 exhaust fans at 14 mines in the Eastern coalfields, is reliable and simple to install, operate, and maintain. The instrument and the details of its installation and calibration are described. Analytical data obtained by infrared spectrophotometer and gas chromatograph are presented to substantiate its reliability.

RI 7952. Relationships of Earth Fracture Systems to Productivity of a Gas Storage Reservoir, by W. K. Overbey, Jr., W. K. Sawyer, and B. R. Henniger. 1974. 133 pp. 102 figs. The Bureau of Mines conducted surface joint and stress measurements, airborne remote sensing imagery studies, compass-oriented borehole televiwer surveys, numerical simulation of fractured wells, and well productivity studies in a four-quadrangle study area of Ohio, to determine the effects of earth fracture systems on the deliverability of gas storage fields. The results of these studies indicate that much useful information about a gas storage reservoir can be obtained and put to practical use by studying (1) oriented cores for fractures and directional permeability, (2) orientation of induced hydraulic fractures for alignment of well patterns, and (3) aerial photos and multi-spectral scanner imagery for general surface geology comparison and to determine if some development patterns can be generated by such results. The absence of known tectonic elements associated with flat-lying sediments, such as faults or fracture zones that can be seen on the surface, indicates that the use of remote sensors such as radar or aerial photography is not likely to be useful in picking well locations for drilling. Studies similar to those discussed here should be conducted in gently folded and strongly folded sedimentary formation areas to determine if the increased knowledge of earth fracture systems under these conditions might be beneficial in gasfield and gas storage reservoir development. Work done in cooperation with the American Gas Association.

RI 7953. Aqueous Reduction of Chalcopyrite Concentrate With Metals, by M. B. Shirts, J. K. Winter, P. A. Bloom, and G. M. Potter. 1974. 18 pp. 16 figs. Bench-scale studies were made on a reductive hydrometallurgical procedure to convert chalcopyrite flotation concentrate to copper metal or a

readily leachable sulfide. Reductive conversion of chalcopyrite and dissolution of iron and sulfur were accomplished in hydrochloric or sulfuric acid solution by the addition of metallic copper, iron, or lead. Use of metallic copper as the reductant enabled extraction of 95 and 46 percent of the iron and sulfur, respectively. The products were ferrous iron, hydrogen sulfide, and a copper sulfide. Use of metallic iron or lead as the reductant enabled extraction of 95 percent of both the iron and sulfur. The products obtained with metallic iron or lead were ferrous iron, hydrogen sulfide, and metallic copper.

RI 7954. Thermal Diffusivity of Six Igneous Rocks at Elevated Temperatures and Reduced Pressures, by D. P. Lindroth. 1974. 33 pp. 12 figs. The thermal diffusivity above 298 K, up to 400 K and at pressures from ambient down to 10^{-10} torr was measured for the following six igneous rock types: tholeiitic basalt, obsidian, rhyolite, granodiorite, gabbro, and dunite. The thermal diffusivity data were obtained by the laser flash method. Extreme values range from a low of 5.3×10^{-3} cm²/sec for rhyolite at 383 K and 2×10^{-7} torr to a high of 13.4×10^{-3} cm²/sec for dunite at 298 K and 760 torr. Data are also included on a commercial fused silica, which was used as a standard.

RI 7955. Recycling of Plastics From Urban and Industrial Refuse, by J. L. Holman, J. B. Stephenson, and M. J. Adam. 1974. 44 pp. 26 figs. The Bureau of Mines, at its Rolla Metallurgy Research Center, has devised methods for separating and reusing the major portion of waste plastics discarded in urban and industrial refuse. Waste plastic concentrates from a local collection drive, recycling center collections, urban refuse pilot plants, and the secondary metals industry were separated into three major thermoplastic families—polyolefins, styrenes, and vinyls—based on differences in density using a Bureau-designed sink-float-elutriation hydraulic separator. Other separation methods and systems such as air classification, jigging, liquid media, screening, and electrostatics were studied. Vinyl plastics contain up to 50 percent HCl. It was found that over 90 percent of the HCl in vinyls can be recovered as usable hydrochloric acid by pyrolysis at 350° C. The remaining pyrolysis products, which had heats of combustion in excess of 12,000 Btu/lb, could become valuable as a future source of energy. A characterization study conducted on eight chopped wire insulation wastes from secondary copper and aluminum processors showed that most wastes contained 2 to 7 percent residual metal and large percentages of vinyl. The residual metal content of some of these wastes was lowered to 0.1 percent and the vinyl portion segregated using various separation techniques. The research also suggests ways in which reclaimed thermoplastics may be fabricated into useful products.

RI 7956. Ultraviolet-Visible and Infrared Emission Spectra of Propagating Methane-Coal-Dust Inhibitor Flames, by Z. J. Fink, L. E. Dalverny, and J. Grumer. 1974. 56 pp. 29 figs. Ultraviolet-visible and infrared emission spectra from propagating methane-coal-dust inhibitor mixtures have been obtained in a 0.2- by 0.2- by 5.3-m vertical duct over a range of flame speeds from 2 to 100 m/sec. Results serve as a basis for the design and evaluation of thermal radiation detectors for triggered barriers that suppress ongoing mine explosions. Of particular significance is the large continua superimposed on the methane-air spectra when small amounts of coal dust are present

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and the variation of emissivity with infrared (IR) wavelength in dust flames. In conjunction with the spectral measurements, studies of flame speed, particle size, gas sampling plus thermodynamics, and dust sampling are presented and discussed to gain insight into the more fundamental aspects of propagating explosions. Sampling results have shown that only a near-stoichiometric amount of dust is consumed in the flames studied even though initial concentrations are five times stoichiometric. Difficulty in propagating coal-dust inhibitor flames of realistic mine characteristics in a cold-walled laboratory duct has been encountered. A simplified analysis of the flame zone utilizing spectral and sampling results indicates that the stability of slowly propagating flames is more dependent upon thermal radiation than upon convection losses to the walls. It is predicted that thermal radiation losses will make any measurements of coal dust burning velocities, "quenching diameters," or flammability limits more apparatus dependent than those corresponding to gaseous fuels.

RI 7957. Cost of Producing Copper From Chalcopyrite Concentrate as Related to SO₂ Emission Abatement—An Evaluation of Five Smelting Procedures, by Masami Hayashi, Henry Dolezal, and J. H. Bilbrey, Jr. 1974. 87 pp. 10 figs.

Cost evaluations were made for five processes for producing 100,000 tons of electrorefined copper per year from a chalcopyrite concentrate. The processes were (1) conventional smelting with all furnace gases vented to the atmosphere; (2) conventional smelting with converter gases routed to an acid plant and reverberatory gases vented to the atmosphere; (3) conventional smelting with converter gases routed to an acid plant and reverberatory gases to a citrate system plant; (4) conventional smelting with all furnace gases routed to a citrate system plant; and (5) a modified smelting process in which the concentrate is roasted before being charged to the reverberatory furnace, with roaster and converter gases routed to an acid plant. The total fixed capital costs of the plants were estimated as (1) \$56.7 million, (2) \$77.4 million, (3) \$87.2 million, (4) \$73.9 million, and (5) \$77.0 million, respectively. Total SO₂ removal from stack gases as sulfuric acid or sulfur for each process was (1) none, (2) 66 percent, (3) 99 percent, (4) 98 percent, and (5) 78 percent. Assuming no credit for byproduct sulfur or sulfuric acid, total operating costs per pound of electrorefined copper produced were estimated as (1) \$0.081, (2) \$0.103, (3) \$0.119, (4) \$0.111, and (5) \$0.103, respectively.

RI 7958. Strengthening Molybdenum by Powder Metallurgical Internal Oxidation of ZrMo₂, by W. L. O'Brien and R. Blickensderfer. 1974. 14 pp. 7 figs.

Molybdenum alloys with good strength properties at elevated temperatures were produced by the powder metallurgical internal oxidation method previously applied to tungsten and known as oxyreaction strengthening. Commercial molybdenum powders were blended with 0 to 10 pct of a reactive powder, ZrMo₂. The effects of composition, blending procedure, and sintering conditions on strength properties at elevated temperatures were studied. Strengthening was attributed to zirconium, in solid solution with molybdenum and to the presence of submicrometer particles of ZrO₂. Several alloys had tensile strength and stress-rupture properties comparable with those of the best commercial alloys. The maximum tensile strengths obtained were 92 kpsi at 1,200° C and 53 kpsi at 1,316° C. The maximum stress-rupture life at 30 kpsi and 1,200° C was 145 hours.

RI 7959. Waterflooding of Oilfields in Colorado, by Paul Biggs and Charles A. Koch. 1974. 92 pp. 16 figs.

This Bureau of Mines report contains information on 63 waterflood projects in Colorado. Water was injected in 10 formations located in 58 oilfields. Specific field data presented include location, discovery, development, water supply, fluid injection, oil and water production, oil reserves, and oil recoveries by primary and secondary methods. An estimated 3.5 billion barrels of water has been injected to recover approximately 533 million barrels of oil, a ratio of 6.57 to 1. Most of the injection water is from alluvial deposits, although produced water is used in many fields. Injection water treatment is not a major problem. Appraisal of project success or failure in this report is based on technical, rather than economic, information.

RI 7960. Evaluation of a Novel Electrophoretic Separation Method To Remove Pyritic Sulfur From Coal, by K. J. Miller and A. F. Baker. 1974. 14 pp. 6 figs.

Electrophoretic mobility measurements of coal and pyrite particles in distilled water revealed a difference between the migration speeds of the two materials toward the anode in a dc electric field. This information led to the development of a laboratory electrophoresis column for separating fine pyrite from coal by utilizing the electrokinetic and the specific gravity differences between coal and pyrite. The study demonstrated on a laboratory scale that pyrite and other impurities can be separated from fine coal by electrophoresis using a stage separation technique. In a cost analysis, electrical power for electrophoresis was extrapolated to about \$1 per ton of clean coal product. But, since the only successful tests ever made were in the laboratory with pre-washed samples of minus 100- plus 325-mesh coal in distilled water, the cost figure derived is not representative of conditions prevalent in commercial coal cleaning operations. True conditions would reflect costs many times as great. In the course of the work, several scale-up techniques were considered, but their feasibility became academic in view of the physical and economic problems associated with electrophoretic separation of pyrite from coal. Although the process and apparatus were finally deemed impractical for commercial coal preparation, the electrophoresis column may have some application as a laboratory device. Work upon which this report is based was funded by the Office of Air Programs of the Environmental Protection Agency.

RI 7961. Tunnel Boring Technology: Disk Cutter Experiments in Metamorphic and Igneous Rocks, by Roger J. Morrell and David A. Larson. 1974. 50 pp. 25 figs.

Bureau of Mines laboratory experiments with reduced scale cutter and cutter forces were performed to (1) define the fundamental relationships governing disk cutter performance and (2) to develop a method of predicting disk cutter performance in soft, medium, and hard rocks. The rock cutting experiments were performed in four igneous and metamorphic rocks that ranged in compressive strength from 38,000 to 67,000 psi. A special testing machine called a linear cutter apparatus (LCA) was used to load and traverse a free rolling disk cutter across a smooth rock surface. Each pass of the disk produced a single crater, and runs were spaced to avoid breakage between craters. During each run the normal and tangential cutter forces were measured and recorded. The soft and medium rock data were obtained from previous Bureau experiments with disk

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cutters. Crater depth, tangential cutter force, crater volume, specific energy versus normal cutter force, and crater width versus depth are defined within this study. With the use of standard physical properties, performance prediction equations were developed using stepwise linear regression analysis techniques. A method of using these prediction equations to calculate the boring rate, the cutter spacing, and the torque and energy requirements of a full-scale boring machine was also developed.

RI 7962. In Situ Determination of Rock Behavior by Overcore Stress Relief Method, Physical Property Measurements, and Initial Deformation Method, by Eugene H. Skinner, Galen G. Waddell, and John P. Conway. 1974. 87 pp. 41 figs. This Bureau of Mines report describes the fieldwork and subsequent analysis to determine physical properties, stress distribution, and several aspects of rock behavior as a necessary evaluation for a typical mine opening. All work was done at a test site on the 3300 level, Crescent mine, Coeur d'Alene mining district, Idaho. Free field stress beyond the influence of the opening was also determined. Conventional overcore technique with the three-component borehole deformation gage developed by the Bureau of Mines was used in three drill holes. Three field verification tests were performed using a gage newly developed by the Spokane Mining Research Center in an approach herein termed "initial deformation method." Use of this method validated that aspect of overcore theory which predicts that similar deformation effect occurs in the wall rock around the perimeter of an opening in rock under stress. Also described are all drilling procedures and performances. Physical property determinations were made on rock samples obtained from the three overcore drill holes. Twelve physical properties with a total of 532 values were obtained at various drill hole orientations and depths. Exhaustive statistical tests were utilized in the analysis of these physical properties. Further elaborated are statistical inferences based on these analyses. Extensive analysis and interpretation of Crescent mine geology are also described.

RI 7963. Infrared Spectra of Compounds of Importance in Lead Sulfide Flotation, by Roy L. Wilfong and Edwin E. Maust, Jr. 1974. 65 pp. 24 figs. Infrared reference spectra are presented of compounds of importance in lead sulfide flotation research. Included are the spectra of several short chain alkyl xanthates of lead and zinc, the corresponding dixanthogen compounds, and the common oxidation products of lead sulfide and their sodium analogs. The spectra of several frequently used industrial flotation reagent xanthates are also presented. A thorough, well-documented discussion is given of the various corrections made to correct the as recorded absorption band data to near absolute values.

RI 7964. Physical Property Data on Coal Waste Embankment Materials, by Richard A. Busch, Ronald R. Backer, and Lynn A. Atkins. 1974. 142 pp. 22 figs. Inadequate engineering design criteria for coal refuse embankments has allowed hazardous impoundment structures in coal mining areas to be created. A necessary first step to develop adequate design criteria is the determination of basic, representative physical property data on the materials that constitute typical refuse embankments. An extensive field and laboratory program was undertaken by the Fed-

eral Bureau of Mines. Much physical property data was generated. Additional petrographic analysis and large-scale triaxial compression testing was performed by others. The data presented here should aid in establishing design parameters for coal refuse embankments.

RI 7965. Low-Temperature Evolution of Hydrocarbon Gases From Coal, by Ann G. Kim. 1974. 23 pp. 7 figs. Hydrocarbon gases, primarily methane but also the C_2 through C_5 paraffins, the C_2 and C_3 olefins, and possibly the C_4 and C_5 olefins, are byproducts of coal formation. Although it is generally believed that coal formation occurred at temperatures below 200° C, most experimental work on gas formation from coal has been performed at temperatures between 200° and 1,000° C. The objective of this Bureau of Mines experiment was to determine if observable changes in the gases from coal could be produced at temperatures below 200° C in relatively short periods of time. The experiment involved heating coal samples from six coalbeds at constant temperatures and analyzing evolved gases. The composition of the gases at three temperatures was compared. At 35° C, over 99 pct of the gas is methane; at 125° and 150° C, methane constitutes approximately half of the hydrocarbon gas. Isobutane and pentane are the predominant higher hydrocarbons at temperatures between 100° and 150° C.

RI 7966. The Effect of Impurities and Additives on the Electrowinning of Zinc, by Harold H. Fukubayashi, Thomas J. O'Keefe, and William C. Clinton. 1974. 26 pp. 18 figs. The effect of various zinc electrowinning solution impurities on the surface morphology of deposited zinc was investigated. Impurities studied included Al, Ag, Cd, Co, Cr, Cu, Ge, Mn, Ni, Sb, Sn, Ti, PbO_2 , $PbSO_4$, and HCl. Also, the effect of animal glue, gum arabic, and Na_2SiO_3 additives on the deposited zinc surface structure was studied. Results were compared with deposits from a pure electrolyte consisting of H_2SO_4 and Zn^{+2} , 200 and 65 gpl, respectively. Zinc was deposited on an Al cathode, 99.9 pct pure, using Pt anodes. Time, temperature, current density, and impurity concentrations were controlled. The bulk of the tests were conducted at 40° C and 75 A/ft² (82 mA/cm²). A scanning electron microscope (SEM) was used to examine the surface morphology. X-ray diffraction techniques were used to determine crystal orientation, and nondispersive X-ray spectrometer analyses were employed in an attempt to locate impurity concentrations on the zinc deposit when pitting or re-solution occurred. The impurities were categorized by their effect on current efficiency, morphology, and apparent mechanism of H_2 evolution from the cathode.

RI 7967. A New Method of Analysis To Obtain Exact Solutions for Stresses and Strains in Circular Inclusions, by Clarence O. Babcock. 1974. 40 pp. 6 figs. This Bureau of Mines report presents the initial development of a two-dimensional method of analysis for inclusions in plates in which the deformed shape of an open hole and the separate structural behavior of inclusion and plate with hole are used to obtain the stresses and strains in the inclusion only. In this report, the solution for a circular inclusion is presented because a direct verification of the results with previous solutions was possible. The numerical results were in exact agreement with those obtained with the equations of Sezawa and Donnell. The equations developed are

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less complex than those of Sezawa and more general, for a circular inclusion, than those of Donnell. Stresses and strains in the inclusion are in terms of the elastic constants of the inclusion and the plate and the biaxial stress field applied far away. The elastic constants can be all different. An important conclusion from this work is that a difference in Poisson's ratios between inclusion and plate may be as important as a difference in Young's moduli between inclusion and plate in producing the inclusion effect. Many problems in mining and rock mechanics can be treated as inclusion problems. The understanding of inclusion behavior on a physical basis should provide the solutions to some of these problems.

RI 7968. Degasification of the Mary Lee Coalbed Near Oak Grove, Jefferson County, Ala., by Vertical Borehole in Advance of Mining, by C. H. Elder and Maurice Deul. 1974. 21 pp. 9 figs. A 5-hole pattern was drilled from the surface at a site near Oak Grove, Jefferson County, Ala., to degasify the gassy Mary Lee coalbed in advance of mining. Gas and water production was monitored for 1 year, 4 months to allow gas flow to stabilize fully. A thickened water stimulation treatment was designed and applied in 1 hole of the pattern to evaluate this degasification technique for the Mary Lee coalbed. A gas production rate of 70,000 ft³/day after stimulation treatment indicates that the use of vertical boreholes coupled with hydraulic fracturing in advance of mining the Mary Lee coalbed would provide for more rapid degasification and could provide a possible source of natural gas.

RI 7969. Methane in the Pittsburgh Coalbed, Washington County, Pa., by Ann G. Kim. 1974. 16 pp. 3 figs. Methane in coal constitutes a serious hazard during mining. Draining the methane from large blocks of coal in advance of mining is an effective method of improving the safety and efficiency of coal mining. Because of the similarity of the two gases, drained methane can be recovered and added to pipeline supplies of natural gas. To effectively apply advance drainage techniques and recover drained gas, a gross estimate of the methane content of coal is necessary. Using data from previous investigations, the virgin reserves of the Pittsburgh coal in the central and southwestern parts of Washington County, Pa., are estimated at over 1.5 billion tons, with a methane content of 50 to 100 ft³/ton. The Pittsburgh bed in this area of approximately 265 mi² contains over 130 billion ft³ of methane.

RI 7970. Oxidation of Mixed Iron and Copper Chlorides, by G. L. Hundley, R. S. Olsen, and T. T. Campbell. 1974. 16 pp. 4 figs. An anhydrous chlorination process has been developed by the Bureau of Mines for the production of copper, ferric oxide, and sulfur from chalcopyrite. The first part of the process is a chlorination step in which elemental sulfur and a mixture of iron-copper chlorides are produced. This paper describes the second step of the process in which the copper and iron chlorides are reacted with oxygen to selectively convert the iron chloride to ferric oxide and chlorine leaving the copper in the chloride form. The chlorides are pulverized and dropped countercurrent to a flow of oxygen in a vertical 20-cm-diam reactor at 800° C. By leaching with brine, the copper chloride may be separated from the insoluble iron oxide and reduced to copper powder by electrowinning. It has been

demonstrated that 70 to 80 pct of the iron can be converted to oxide in a single-stage operation with a chlorine content in the offgas of 80 pct. After removal of the oxygen, this chlorine could be recycled to the chlorination step. A two-stage operation will convert 98 to 99 pct of the iron in the mixture to insoluble oxides. The offgas from the second stage contains 70 pct chlorine.

RI 7971. Mine Roof Simulator: Definition and Discussion of Parameters, by Lewis V. Wade. 1974. 18 pp. 13 figs. This report provides background information concerning a mine roof simulator currently being considered by the Bureau of Mines. The simulator is a mechanical device with the ability to simulate the forces and displacements associated with mine roof over an area 20 by 20 feet. The topics covered in the report include a conceptual description of the system, definition of system capabilities, discussion of how such capabilities were decided upon, description of available control modes, and a comparison between the mine roof simulator facility and similar facilities existing elsewhere.

RI 7972. Development of Titanium Load Cells for Support Load Determination, by Michael J. Beus and Earl L. Phillips. 1974. 35 pp. 25 figs. This Bureau of Mines report describes the development of load cells for measuring compressive loads in timber and rock-bolt support systems commonly used in coal, metal, and nonmetal mines. Design and evaluation is covered in detail to insure a reliable, accurate, and practical instrumentation scheme. The load cells are relatively inexpensive and adaptable to various size support systems. User-oriented procedures are emphasized, and design equations were reduced to a series of nomographs. Laboratory evaluation, destructive testing, environmental testing, and tests to determine the effect of extraneous loads were conducted. Field performance was evaluated in conjunction with ongoing Bureau projects at a metal mine in North Idaho and a coal mine in Utah. Load cells utilizing a titanium alloy as the cell body and weldable strain gages as the strain-sensing components satisfied the basic design and performance criteria, and with minor design modifications, the load cells can be adapted to many mining applications.

RI 7973. Waste Lubricating Oil Research: A Comparison of Bench-Test Properties of Re-refined and Virgin Lubricating Oils, by M. L. Whisman, J. W. Goetzinger, and F. O. Cotton. 1974. 18 pp. Three samples of waste lubricating oil were re-refined by processes developed by the Bureau of Mines and reformulated with additives to meet designated requirements for viscosity and service. Quality-defining bench-scale tests were used to compare and evaluate the quality of these three motor oils, eight commercially re-refined lubricating oils, and three new lubricating oils. Most of the re-refined oils studied could not be distinguished from new oils by the bench tests used to define quality. There was some evidence, however, that one and perhaps more of the re-refined products investigated might not meet all of the quality standards of new lubricating oil, suggesting the need for better quality controls by re-refiners.

RI 7974. Qualitative Characterization of 370° to 535° C Aromatic Concentrates of Crude Oils From GPC Analyses, by D. E. Hirsch, J. E. Dooley, H. J. Coleman, and C. J. Thompson. 1974. 26 pp. The

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types of compounds present in aromatic concentrates derived from high-boiling petroleum distillates can be estimated from a gel permeation chromatographic (GPC) analysis by the use of tables developed from extensive GPC and mass-spectral analyses on fractions from four crude oils. For a fraction from the GPC analysis, the retention volume and the molecular weights (from mass spectrometer) suffice to indicate the types of compounds that predominate. The tables that show these qualitative analyses were developed through the use of pure compounds as well as the extensive analyses on Prudhoe Bay (Alaska), Gachsaran (Iran), Swan Hills (Canada), and Wilmington (California) crude oils. These tables provide a rapid method for determining which types of compounds are present in a GPC fraction before attempting to develop quantitative data.

RI 7975. Detection and Delineation of Faults by Surface Resistivity Measurements. Schwartzwalder Mine, Jefferson County, Colo., by Robert Lee Stahl. 1974. 27 pp. 15 figs. Comprehensive field tests were made by the Bureau of Mines at the Schwartzwalder mine near Golden, Colo., to determine whether surface geophysical techniques could be used to detect and delineate faults in uranium deposits. The tests included seismic refraction, magnetometer, electrical resistivity, airborne infrared thermal scanning, and airborne photography. Of the several geophysical techniques tested in the field, horizontal resistivity profiling with electrode spacings in the range of 10 to 15 feet was most diagnostic of faults. The method is quick, inexpensive, and accurate and can be easily used by mining company personnel to detect and delineate faults.

RI 7976. Mine Pager to Public Telephone Interconnect System, by Howard E. Parkinson. 1974. 14 pp. 6 figs. The mine pager phone to public telephone interconnect system permits mine paging telephones to be interconnected with the public phone system, thereby providing emergency and off-hours communications. The system, a push-to-talk, push-to-listen system, is compatible with any mine paging system utilizing dc voltage on the line to enable paging. A tone generator of the proper frequency enables an outside caller to page over mine pager system loudspeakers. A caller inside the mine can make an outgoing call to a preselected, preprogrammed number with the use of a proper frequency tone generator. The system includes an automatic hangup timer that restricts the time off-line due to a wrong number or incorrect hangup to 20 seconds and 6 minutes, respectively.

RI 7977. Coal Mine Combustion Products: Neoprenes, Polyvinyl Chloride Compositions, Urethane Foam, and Wood, by Arthur M. Hartstein and David R. Forshey. 1974. 25 pp. 13 figs. The Bureau of Mines, through contract with Ultrasystems, Inc., obtained gram per gram data of products formed on thermal oxidative degradation of selected compositions, both under dynamic and static conditions. Four broad classes of materials were studied: Polyvinyl chloride compositions, neoprene compositions, rigid urethane foams, and variously treated woods. Whenever possible, comparisons between pure components and composites were attempted. Thermogravimetric and differential thermal analyses were performed to gain understanding of the processes occurring and to explore the feasibility of using these analyses as a method of material

identification. The toxic products detected and quantitated included HCl, H₂S, CO, SO₂, CS₂, COS, HCOOH, CH₃COOH, formaldehyde, acrolein, C₆H₆, chloroprene, chloroethanol, benzyl chloride, aniline, and furfural.

RI 7978. Solvent Stimulation in Two California Oilfields, by H. J. Lechtenberg, G. L. Gates, W. H. Caraway, and O. C. Baptist. 1974. 23 pp. 12 figs. This Bureau of Mines report investigates solvent injection as a means of increasing oil production from low-gravity oilfields; thus, wells in two California oilfields that produce from reservoirs having low-gravity oil were injected with highly aromatic solvents to increase their oil recovery. The wells were either allowed to soak or the solvent was circulated for a period of time. In some of the wells, the solvent was followed by a slug of water. The post-stimulation production rate was considerably higher than the prestimulation rate of the wells. Wells in which the solvent was not followed by water showed an immediate increase in oil production, and essentially all of the solvent was recovered. The wells in which solvent was followed by water essentially showed a delay in the increase in oil production, thus indicating a temporary water block. The results show that the production rate is usually increased by the injection of solvent, and the method may prevent early abandonment of marginal producers. Cumulative post-stimulation oil production indicates that cyclic solvent injection treatment can be an economic success.

RI 7979. Microdetermination of Volatile Matter and Rock Dust Concentration of Airborne Coal Mine Dust, by C. Edward Chamberlain and Robert W. Freedman. 1974. 8 pp. 4 figs. A Bureau of Mines procedure was developed for the analysis of volatile matter in airborne coal dust-rock dust mixtures prior to, and resulting from, coal mine fires and explosions. Dust in the 10- to 20-mg weight range can be analyzed. Volatile matter is determined by a greatly scaled-down version of the empirical macroscale method used by the Bureau. The alkaline earth carbonates in the rock dust are dissolved in acid prior to the volatile matter determination of the residue, and the rock dust content is calculated from the analysis of calcium and magnesium by atomic absorption.

RI 7980. Increasing Fluosilicic Acid Evolution From Phosphate Rock by Digestion With Phosphoric Acid, by Henry E. Blake, Jr., and Boyd D. Nash. 1974. 16 pp. 1 fig. The Bureau of Mines has been engaged in a continuing research effort to develop processes for increasing the recovery and utilization of fluorine from low-grade resources. This current research has shown that over 98 percent of the fluorine in phosphate rock is extracted when the ore is treated with excess phosphoric acid in the presence of water vapor at 150° to 180° C. More than 80 percent of the fluorine can be recovered as fluosilicic acid, which can then be converted to commercially useful hydrogen fluoride or fluorspar by previously developed Bureau processes. Extraction of P₂O₅ from the ore was about 98 percent in batch tests and 90 percent in semicyclic tests.

RI 7981. Carbon Steel From Prereduced Pellets—Acid Practice, by W. L. Hunter, J. E. Tress, and W. A. Stickney. 1974. 7 pp. 2 figs. Eleven steel-making heats are described in this Bureau of Mines report in which acid practice was used to produce carbon steel from prereduced iron ore pellets. Fur-

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nace slags obtained with no flux addition to the charge became quite viscous as they cooled, which precluded pressure casting from a ladle. Lime was added to the furnace charge at two levels to eight of the heats to modify slag characteristics in the furnace, and to the ladle in two heats to further modify the ladle slag cover. Selected ingots from nine heats were successfully rolled on a commercial mill to produce No. 10 reinforcing bar.

RI 7982. Washing Fine-Size Coal in a Dense-Medium Cyclone, by Albert W. Deurbrouck. 1974. 6 pp. Dense-medium cyclone tests in 4- and 8-inch-diameter units have shown the ability of cyclones to make sharp separations down to 100 mesh when washing coals of a finer top size than normally fed to dense-medium cyclones. The reduced top size of the feed apparently allows the finer size particles to report to the proper product by reducing the effect of very coarse particles in the congested separation zone of the dense-medium cyclone.

RI 7983. Compression Testing of Rock in Simulated Lunar Environment, by John O. Atkins and Syd S. Peng. 1974. 21 pp. 14 figs. Experiments were conducted by the Bureau of Mines on five types of simulated lunar rock (dacite, tholeiitic basalt, vesicular basalt, pumice, and Duluth Gabbro) to study the effects of various simulated lunar environments on their strength and deformational properties. Specimens were tested in an ultrahigh vacuum (UHV) system at pressures ranging from atmospheric down to 10⁻¹¹ torr and at temperatures of -130°, 20°, and 135° C. All tests were conducted with a servocontrolled testing machine. Rock specimens tested at 20° C in UHV exhibited significantly higher compressive strength and Young's modulus than those tested at 20° C in atmospheric pressure. The magnitudes of increase are related to the porosities and permeabilities of the rock specimens; high porosity and permeability allow better outgassing and thus improve surface cleanliness in UHV. The compressive strength generally increases but Young's modulus decreases as test environments change from 20° C in UHV to 135° C in UHV. No significant difference was observed in the physical properties measured at 20° C in UHV and -130° C in UHV. Anisotropy in strength and Young's modulus exist both in UHV and at atmospheric conditions with the same symmetry pattern. The orientations of the principal axes may, however, change from the atmospheric to UHV condition. The results indicate that rock fragmentation in lunar environment will require more energy than that at 20° C in atmospheric pressure. Work done under an agreement with the Office of Advanced Research and Technology, National Aeronautics and Space Administration.

RI 7984. Pulsed Nuclear Magnetic Resonance Studies of Oil Shales—Estimation of Potential Oil Yields, by F. P. Miknis, A. W. Decora, and G. L. Cook. 1974. 47 pp. 12 figs. Previous studies at the Bureau of Mines have shown that broad-line nuclear magnetic resonance (NMR) techniques have potential applications for rapid evaluation of oil-shale deposits. In a continuation of this study, the techniques of pulsed NMR have been applied in a similar manner. The basis for the pulsed NMR oil-shale assay method lies in the assumption that the free induction decay (FID) amplitude following a 90° pulse is proportional to the potential oil yield. This assumption was

tested on two groups of oil-shale samples, numbering 141 and 263 samples, from two different oil-shale cores. For both groups of samples, a small number were selected as calibration samples. Free induction decay amplitude measurements were made on the 141 and 263 samples. The best least-squares regression line was obtained for the calibration samples, and the oil yields of the remaining samples were calculated using the slopes and intercepts obtained in the regression analyses. The agreement between measured and calculated oil yields was good; the indexes of determination were 0.93 and 0.89 for the groups of 141 and 263 samples, respectively. Work done in cooperation with the University of Wyoming.

RI 7985. Synthesis of Rutile From Domestic Ilmenites, by G. W. Elger, D. E. Kirby, S. C. Rhoads, and W. A. Stickney. 1974. 19 pp. 7 figs. Bureau of Mines laboratory tests show that ilmenite concentrates with titanium dioxide contents as low as 33 wt-pct can be beneficiated to produce a crystalline substitute for natural rutile suitable for direct chlorination. The synthesized product prepared by a three-step procedure was comparable with natural rutile in titanium content. Reduction smelting of ilmenite removes iron as a pig iron byproduct, and the remaining slag phase is greatly enriched in titanium. Oxidation of the slag in the presence of phosphorus-bearing slag additive converts the titanium-bearing phases to discrete rutile crystals and a glass phase containing most of the associated impurities. Rutile is separated from the glassy impurities by attrition scrubbing ground slag in dilute phosphoric or sulfuric acid solutions. Tests made in a laboratory fluid-bed reactor show that synthetic rutile responds to chlorination at the same rate as natural rutile and that more than 95 pct of the titanium contained in the feedstock was extracted as titanium tetrachloride.

RI 7986. Electrochemical Anodic Reaction Rate of Vanadium Metal With Molten VCl₃-VCl₄-NaCl Mixtures, by A. E. Raddatz and D. J. MacDonald. 1974. 9 pp. 1 fig. The Bureau of Mines has determined the electrochemical rate of anodic dissolution of vanadium metal in a VCl₃-VCl₄-NaCl electrolyte at 860° C for the purpose of elucidating the reaction mechanism. Rate measurements were carried out with the help of specially designed equipment capable of continuously recording the weight loss experienced by a cylindrical vanadium anode immersed in the molten salt electrolyte while a constant current is maintained through it. The rate is expressed as a function of current density and VCl₃ concentration, and the reaction is interpreted in terms of an adsorption mechanism. Multiple regression analysis of the data gave the following rate equation: Rate $\times 10^4$ (g·cm⁻²·sec⁻¹) = -0.38 + 2.64 current density (amp·cm⁻²) + 0.69 log₁₀ (mole-percent VCl₃).

RI 7987. Statistical Analysis of Methane Concentration Fluctuations Produced by Incomplete Mixing of Methane and Air at a Model Coal Mine Working Face, by Richard J. Bielicki and Fred N. Kissell. 1974. 21 pp. 10 figs. Poor mixing of methane and air at coal mine working faces causes fluctuating methane concentrations. If these fluctuations are large enough, methane levels can periodically exceed safe limits, even though the time average methane concentration may be satisfactory. Concentration fluctuations measured underground can result both from variations in methane emission rate and poor mixing. The present paper reports on a statistical analysis of fluctuations at a constant methane emis-

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sion rate, that is, on fluctuations due only to poor mixing. A full-scale model of a working face was used. Both peak heights and elapsed times between peaks were evaluated. Good mixing was indicated by normal, Poisson, and exponential distributions, and poor or incomplete mixing was indicated by log-normal or gamma distributions.

RI 7988. Emission Characteristics of a Prime Mover for Hybrid Vehicle Use, by J. R. Allsup and R. D. Fleming. 1974. 32 pp. 13 figs. The Bureau of Mines studied a conventional spark-ignition engine as a prime mover for use in a hybrid system. The study involved both steady-state and transient engine operation with ignition timing, air-fuel ratio, exhaust gas recirculation, oxidizing-type catalytic converters, engine speed, and power output as variables. Data were obtained from two 1971 model 350-cubic-inch-displacement engines mounted on engine dynamometer stands. When the hybrid engine was operated with an oxidizing catalyst at power output levels required for a 4,000-lb curb weight hybrid vehicle, carbon monoxide and hydrocarbon emissions could be reduced to approximately 2.0 grams and 0.3 gram per brake horsepower-hour, respectively. With exhaust gas recirculation, oxides of nitrogen emission levels could be reduced to approximately 1.2 grams per brake horsepower-hour.

RI 7989. A Mathematical Model To Guide the Discovery of Ore Bodies in a Coeur D'Alene Lead-Silver Mine, by George S. Koch, Jr., John H. Schuenemeyer, and Richard F. Link. 1974. 43 pp. 26 figs. A mathematical simulation model has been devised to guide the layout of underground mine workings, drill stations, and drill holes that are established in order to search for tabular ore bodies. Developed and tested for elliptical ore shoots in fissure veins in the Galena mine, Coeur d'Alene district, Idaho, the model can also be applied to ore bodies contained within sedimentary beds (for instance, many types of uranium, copper, and gold ore bodies) or other tabular structures. Programmed for a time-shared digital computer, the model contains both stochastic and deterministic variables. Stochastic or natural variables include the number of ore shoots and their sizes, orientations, locations, and values. Deterministic or controllable variables include (1) locations and costs of workings; (2) drill-station locations and costs; and (3) drill hole azimuths, inclinations, lengths, and deflections, if any. For various assumptions about the stochastic variables, the model is run while the controllable variables are changed deliberately. Thus, layouts are devised to determine the percentages of the total number of assumed ore shoots found at different costs.

RI 7990. Recovery and Separation of Rare-Earth Elements, Barium, and Strontium From Bastnäsite With Sulfuric Acid, by J. A. Eisele and D. J. Bauer. 1974. 10 pp. 1 fig. The Bureau of Mines conducted a bench-scale investigation of a concentrated H_2SO_4 reaction for recovering and separating rare-earth elements, barium, and strontium from a bastnäsite ore and byproduct. Barium and strontium were dissolved in the concentrated acid and precipitated as a mixed product by water dilution. Separation of strontium from barium was effected by reaction with Na_2CO_3 solution, followed by a dilute acid leach of the $SrCO_3$ formed. After removing the barium and strontium from bastnäsite ore, the rare-earth elements were roasted to water-soluble sulfates.

The rare-earth sulfate solution was subsequently processed by solvent extraction to produce rare-earth oxides low in lead and magnesium.

RI 7991. Ventilation Eddy Zones at a Model Coal Mine Working Face, by Fred N. Kissell and Richard J. Bielicki. 1974. 14 pp. 8 figs. Tracer gas decay curves were experimentally obtained in a full-scale model coal mine working face area. The concentration of tracer gas was found to decay in exponential fashion but with a change in slope. This change in slope is attributed to eddy zones in the face area. A simple theory was developed that allows one to calculate the approximate amount of gas in the eddy zones and thus estimate the size of the eddy zones.

RI 7992. Elemental Composition of Coal Mine Dust, by T. C. Wesson and F. E. Armstrong. 1974. 25 pp. 3 figs. The need for elemental-analysis information on coal mine dust for use in health and safety research prompted this study by the Bureau of Mines. Neutron-activation and X-ray fluorescent techniques were used to obtain five-element analysis (silicon, aluminum, iron, calcium, and magnesium) on 444 samples from 68 coal mines in 10 States. From these analyses, the average composition of the dust in coal mines was determined.

RI 7995. Oil Shale Retorting in a 150-Ton Batch-Type Pilot Plant, by A. E. Harak, L. Dockter, A. Long, and W. H. Sohns. 1974. 31 pp. 26 figs. To determine the retorting characteristics of a column of mine-run, ungraded oil shale ranging in size from fines to 5-ton pieces, a 150-ton batch-type retort was designed and constructed at the Bureau of Mines Laramie Energy Research Center, Laramie, Wyo. The retort vessel is 45 feet high by 11½ feet inside diameter and is supported in a 95-foot-high steel superstructure. Mine-run shale from the Bureau of Mines facility near Rifle, Colo., assaying about 25 gallons of oil per ton, was used as the test shale. To date, 11 runs have been completed, and the results of the last 10 of these are reported. The effects of oxygen content of the retorting gas and the superficial gas velocity of the retorting gas on oil recovery from a column of mine-run oil shale were studied. In one run, the average particle size of the shale was substantially increased to determine its effect on oil yield. Oil recoveries ranged from a low of 39.3 to a high of 65.8 volume-percent of Fischer assay.

RI 7998. Noise Abatement of Pneumatic Rock Drill, by C. R. Summers and J. N. Murphy. 1974. 45 pp. 45 figs. In response to the Coal Mine Health and Safety Act of 1969, mandatory noise standards have been developed that specify time-noise limits of mine personnel exposure. Most affected by elevated noise levels is the pneumatic roof bolter operator, both in terms of levels near or in excess of 115 dbA and in terms of length of exposure. Therefore, the principal emphasis of this Bureau of Mines report is on pneumatic drill noise control. It is not the intent of this report to suggest any drill redesign; instead, methods are suggested to reduce the noise level by complementing existing machines. An integral muffler system and a separate muffler system were tested in an attempt to lower pneumatic drill noise levels. Pneumatic drills, when new, operate at about 115 dbA when drilling in sandstone. Using the drill muffler systems, it was possible to decrease the noise level of a 115-dbA stopec drill to approximately 100 dbA.

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IC 8434. Supply and Demand for Energy in the United States by States and Regions, 1960 and 1965.

Integrated Energy Balances and Energy Flows (Prepared From Four Parts), by R. F. Zaffarano, P. N. Yasnowsky, L. H. Crump, and W. Y. Mo. 1970. 546 pp. 13 figs. Integrated energy balances and energy flows were constructed and quantified for State, regional, and national levels from four separate supply and demand commodity balances for coal, dry natural gas, petroleum and natural gas liquids, and utility electricity. These commodity balances were integrated by source and sectors through conversion and aggregation of their components to energy equivalents expressed in British thermal units (Btu). A summarization of the total gross energy components of supply and demand for commercial energy derived from direct fuels, hydropower, and nuclear power based on individual States and regions, is tabulated for 1960 and 1965. Pertinent computerization details and more than 500 individual State and regional printout tables, in both original commodity units and Btu's, are shown. Using these data, energy flows between States and regions were calculated to identify surplus and deficit energy areas. Report emphasis is on the conceptual aspects of integrated energy balances, rather than on the development of missing State energy data. (*Out of print.*)

IC 8439. Bismuth in the United States, by Franklin H.

Persse. 1970. 26 pp. 7 figs. Domestic bismuth supply was projected from production figures for the ores in which it occurs—copper, lead, zinc, and tungsten. Published and unpublished data concerning host ores were examined to determine bismuth reserves and resources, and mine production. Potential recoverable bismuth occurring with reserves and resources of copper, lead, and zinc was estimated to be 36.3 million pounds. A bismuth availability diagram was developed from quantity estimates and ratios of production cost to value for these host ores. Additional recoverable bismuth occurring with domestic tungsten reserves was estimated to be 1.5 million pounds. Domestic byproduct production of bismuth will approximate 1.3 million pounds annually by 1980. This quantity will provide about 37 percent of the 3.5-million-pound estimated requirement for that year. Known world supply of bismuth appears to be sufficient for world demand to the end of this century. The study indicates that bismuth reserves and potential resources in the rest of the world have not been adequately reported. (*Out of print.*)

IC 8440. Estimated Cost of Steel Slag Disposal, by E. C. Baker. 1970. 18 pp. 5 figs. Costs of disposing of steel slag are estimated based on the present method and a proposed alternate method for a steel mill in the Pittsburgh area. Estimated cost data were calculated by the Bureau of Mines and do not reflect the investment and operating costs and credits of a specific steel mill and processing plant. The alternate method of steel slag disposal would result in an appreciable cost saving to the mill and concurrently supply the industrial

and commercial markets with low-cost, high-quality construction materials. (*Out of print.*)

IC 8441. Natural Gas Liquids, A Review of Their Role in the Petroleum Industry, by Richard F. Zaffarano.

1970. 22 pp. 5 figs. The Bureau of Mines compiled information for the nonspecialist about natural gas liquids recovery from hydrocarbon streams in natural gas processing plants. Attention is directed to the impact of the technology of processing and the quality of gas processed in view of the increased availability of natural gas for processing. Significant changes in product and market trends within the natural gas processing industry are highlighted. Fixed capital-plant costs for grassroots, refrigerated-oil absorption and conventional adsorption schemes, adapted from published studies, are presented giving ranges of cost estimates for medium-sized plants. Marketed products of the natural gas processing industry are briefly discussed in relation to automotive air pollution problems and approaches to their control. (*Out of print.*)

IC 8442. Research and Technologic Work on Explosives, Explosions, and Flames. Fiscal Year 1968, by

Staff, Safety Research Center. January 1970. 33 pp. 6 figs. The principal activities of the Bureau of Mines Explosive Research Center (now Safety Research Center) during fiscal year 1968 (July 1, 1967, to June 30, 1968) are reviewed in part 1. Part 2 presents short abstracts of the publications issued during this period in the Bureau series and in other media. Part 3 describes a short study on the thermal decomposition of RDX and HMX not destined for publication elsewhere.

IC 8443. Analyses of Natural Gases, 1968, by L. E. Cardwell and L. F. Benton. 1970. 169 pp. This

Bureau of Mines publication contains routine analyses and related source data for 495 natural gas samples from 21 States and three foreign countries. Of this total, 376 samples were collected during calendar year 1968. The remaining 119 analyses are of samples collected during previous years, but releases granting permission to publish the results were not received until 1968. All samples were collected as a part of a continuous survey of the free world for occurrences of helium in natural gas. This survey has been conducted in the United States by the Bureau of Mines since 1917 and in late 1965 was expanded to include foreign gasfields. The analyses published herein were made by mass spectrometer and a special helium analysis apparatus which are described in Bureau of Mines Bulletins 486 and 576. Ten previous publications have presented results of 8,165 gas analyses made by the Bureau of Mines Helium Activity prior to 1968. The first three, Bulletins 486, 576, and 617, contain analyses and related source data on 5,218 gas samples collected from 1917 through 1960. The other seven publications, which were published as Information Circulars, supplement the three Bulletins and contain 2,947 analyses of samples collected since 1960. This publication is the

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eighth publication supplementing the three Bulletins. (*Out of print.*)

IC 8444. Unit Train Transportation of Coal, Technology and Description of Nine Representative Operations, by T. O. Glover, M. E. Hinkle, and H. L. Riley. 1970. 109 pp. 60 figs. The Bureau of Mines surveyed unit train loading and storage installations in the midwestern, eastern, and southeastern coalfields. Nine individual operations were studied in detail as a representative cross section of unit train operations in these areas. Of the nine operations studied, three were in Illinois, two in Kentucky, and one each in West Virginia, Tennessee, Ohio, and Pennsylvania. Information was obtained from coal producers, coal sale agencies, railroads, construction and equipment companies, and power companies. (*Out of print.*)

IC 8445. Impact of Technology on the Commercial Secondary Aluminum Industry, by Donald L. Siebert. 1970. 76 pp. 18 figs. This profile study of the commercial secondary aluminum industry examines not only the elements that form the industry but also the technological contributions of each toward industrial growth. Concise descriptions of processing methods trace aluminum scrap from generating sources to marketable industrial and consumer goods. Economic and marketing appraisals are used to illustrate the impact that recent technology has had upon the secondary aluminum industry. Price, supply, demand, competition, and substitutes are selected as components of an economic model of the secondary industry and are used to illustrate the aggregate effects of technological changes. The final section is a conceptual look at the future in which sensitive economic indicators (such as die casting in the automotive and appliance industries) are examined as well as the problems of conserving mineral resources by retrieving secondary aluminum from solid waste. (*Out of print.*)

IC 8446. Demand and Supply of Molybdenum in the United States, by Carl L. Bieniewski. 1970. 61 pp. 24 figs. U.S. molybdenum production increased from 18.2 million pounds in 1946 to 90.5 million pounds in 1966 and constituted 87.3 percent of the total free world supply in the 1946-66 period. Mining development in other free world countries in the next few years may reduce the magnitude of the U.S. position, although similar development planned for the United States may counteract some of the relative gains by those countries. In 1966 two-thirds of the reported molybdenum consumption in the United States by end uses was an alloying element in steel. Molybdenum also has important use as an alloying element in iron and high-temperature alloys. Consumption of molybdenum metal for making fabricated parts has increased in the past few years, especially in the space and nuclear industries. Molybdenum compounds are used mainly for making pigment, catalysts, and lubricants. Based on producer reports of shipments of primary products to domestic customers, U.S. consumption of molybdenum increased from 16.5 million pounds of molybdenum in 1946 to 65.6 million pounds in 1966. Molybdenum reserves are now estimated to be 5.9 billion pounds of recoverable molybdenum, an increase of 2.1 billion pounds above previous estimates. Molybdenum ores account for 71.4 percent of the reserves, copper ores for 22.3 percent, and copper-molybdenum, tungsten, and uranium ores for 6.3 percent.

Several methods for predicting future demand are illustrated and estimates of demand using these methods were made for 1975. Estimates of annual production were made for 1967 through 1975 for the United States, Canada, Chile, Peru, and the free world. These data indicate that molybdenum production in 1975 for the free world is expected to be 246 million pounds with the United States producing 68.2 percent and Canada, Chile, and Peru 30.3 percent. (*Out of print.*)

IC 8447. Secondary Gold in the United States, by Staff, Bureau of Mines. 1970. 30 pp. 7 figs. The Bureau of Mines analyzed the cycle of secondary gold to determine the quantity of gold not being recovered from scrap, and to identify areas for research to increase the supply of gold from scrap. Secondary gold in 1967 was estimated to be 2.4 million troy ounces; this excludes secondary gold which is recycled within consuming plants. Firms contacted included consumers using about 41 percent of the gold in 1967, and refiners that recovered about 90 percent of the secondary gold. Results of the study indicate that loss of gold is small, and refiners and consumers are accelerating programs designed to reduce recovery costs. With the increasing generation of low-grade industrial scrap, research is needed to improve present recovery techniques and to develop methods to accelerate the flow of secondary gold back to supply. (*Out of print.*)

IC 8448. Petroleum and Oil-Shale Research of the Bureau of Mines, Fiscal Years 1967-68, by Bill Linville and Staff, Bureau of Mines—Petroleum Research. February 1970. 162 pp. 61 figs. During fiscal years 1967-68, the Bureau of Mines produced 185 technical papers and reports about petroleum and oil-shale research, which were published either by the Bureau or by others as referable scientific literature. Numerous other reports were prepared for Government agencies, State agencies, and organizations of the petroleum and natural gas industry engaged in cooperative research programs with the Bureau. Research performed during the reporting period by the Bureau on petroleum, natural gas, and oil shale was classified by 71 active projects. A basic appropriation of \$3,575,000 was supplemented by \$1,300,000 in fiscal year 1967, and that of \$4,043,000 by \$1,402,000 in fiscal year 1968, making the appropriated-to-supplemental fund ratios about 2.8 to 1 for fiscal year 1967 and 2.9 to 1 for fiscal year 1968. In fulfillment of the mission of the Bureau, through planned research programs, methods for producing and utilizing petroleum were improved. The continued conservation of this natural resource of petroleum, including crude oil, natural gas, and oil shale, was pursued through research performed by some 350 personnel at two petroleum research centers and two petroleum research laboratories supervised and supported by administrative personnel of the Bureau and the Department of the Interior.

IC 8449. A Review of the Curve-Fitting Method of Least Squares as Applied to Petroleum Engineering, by R. E. Cerullo and M. K. Romeo. 1970. 27 pp. 4 figs. Many computer programs have been written which are capable of performing a least squares fit, both linear and nonlinear, to data gathered by the petroleum researcher. However, when the petroleum engineer tries to program methods of analysis he has used manually in the past, such as forecasting production by decline-curve analysis,

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more than a knowledge of the use of existing least squares programs becomes necessary. It is the intent of the authors to report the techniques used in the development of such a decline-curve program. (*Out of print.*)

IC 8450. A Review of Proposed Processes For Making Rutile Substitutes, by John J. Henn and James A. Barclay. 1970. 27 pp. As part of U.S. Department of the Interior programs on rutile, authorized by the Office of Emergency Preparedness in June 1967 under provisions of the Defense Production Act, the Bureau of Mines reviewed available literature on major proposed processes for producing rutile substitutes. The processes are grouped according to the major processing step, and important operating features are described. Sixty-one references are cited. (*Out of print.*)

IC 8451. A Quantitative Economic Analysis and Long-Run Projections of the Demand for Steel Mill Products, by William Y. Mo and Kung-Lee Wang. 1970. 54 pp. 14 figs. This study presents the preliminary results of an investigation of the quantitative characteristics of U.S. demand for steel mill products and major end-use components. The end uses studied were construction, automobiles, producer durables, and consumer durables. The main objectives of the research underlying this study are (1) to formulate and estimate the empirical demand relations for steel and the four major end uses, (2) to measure and calculate the responsiveness of per capita steel consumption with respect to the changes in steel and nonferrous metals prices, (3) to determine and quantify the relative importance of the demand explanatory factors which contribute to the average year-to-year changes in per capita steel consumption, (4) to adapt and use the estimated demand relations in projecting future demand for steel and the major end-use components. Three versions of simple linear demand relations were selected and estimated using data for the period 1947-65 by means of ordinary least squares method. Direct and cross price elasticities of demand are computed for each major end use. The relative importance of demand explanatory factors in contributing to the average year-to-year changes in per capita steel consumption are also calculated. (*Out of print.*)

IC 8452. Physical and Explosion Characteristics of Hydrazine Nitrate, by Harry K. James, Yael Miron, and Henry E. Perlee. March 1970. 22 pp. 13 figs. Experimental studies of the physical and explosion characteristics of pure hydrazine nitrate and multicomponent systems containing hydrazine nitrate, supplemented with an extensive literature survey, are presented. Such properties as melting point, heat of fusion, density, viscosity, surface tension, thermal stability, decomposition process, detonation velocity, impact sensitivity, and TNT equivalence are included.

IC 8453. Microfilming Maps of Abandoned Anthracite Mines, Mines in the Lackawanna Basin, Northern Anthracite Field, by G. B. Gait. March 1970. 11 pp. 4 figs. This report is the third in a series concerning the Bureau of Mines program for microfilming maps of abandoned mines in the Pennsylvania anthracite region; a catalog of the microfilmed maps of mines in the Lackawanna basin of the Northern anthracite field is presented. Previous reports in the series IC 8274 and IC 8379 were catalogs of microfilmed maps of mines in the Eastern Middle anthra-

cite field and Wyoming basin, Northern anthracite field, respectively. Additional catalogs will be published as the microfilming of significant mining areas is completed.

IC 8454. A Computer Program for the Stereographic Analysis of Coal Fractures and Cleats, by P. W. Jeran and J. R. Mashey. March 1970. 34 pp. 7 figs. The Stereonet Analysis Program (SNAP) is a mathematics tool which, by means of a computer, reproduces mathematically the manual techniques of preparing stereograms. This computer program was developed to provide a fast, accurate, and economical means of analyzing fracture orientation data. It is written in FORTRAN IV for use on a UNIVAC 1108 operating under an Exec II system, but can be adapted to other systems. SNAP is currently being used to aid in the analysis of cleats and other geologically induced fractures associated with coalbeds that are being mined underground. Methane flows through the coalbed and into these mine workings predominantly through the fracture system. Therefore, knowledge of fracture orientation is an invaluable aid in the development of methane control technology.

IC 8455. Potential Oil Recovery by Waterflooding Reservoirs Being Produced by Primary Methods, by Staff, Offices of Mineral Resources. 1970. 53 pp. 32 figs. As part of a continuing program of evaluating the Nation's crude-oil resource, this report presents information pertaining to resource, primary reserve, and potential waterflood reserve for 3,209 selected reservoirs contained in 24 oil-producing States, as of January 1, 1968. To that date the selected reservoirs had not been subjected to pressure-maintenance or secondary-recovery operations. These reservoirs also met the following parameters: (1) A minimum of five oil-producing wells on January 1, 1968, (2) a minimum of 50 acres areal extent, (3) a minimum of 50,000 bbl of oil ultimate primary recovery, and (4) the principal reservoir energy was other than active water encroachment. The selected 3,209 reservoirs produced 527 million bbl of oil in 1967, about 17 pct of U.S. total production. Primary oil reserve was 4,983 million stb; in addition, there was 6,043 million stb of potential waterflood oil reserve. Oil resource in the selected reservoirs was 59,547 million stb. A brief history and outlook of waterflooding are presented for each State. Depth and producing rate statistics and geologic distributions of production, resource, reserve, and potential waterflood reserve for the selected reservoirs are presented by States in the appendix. Also included in the appendix are description, history, and technique modifications of waterflood, and a preliminary cost estimate of a closed-system water-injection project. (*Out of print.*)

IC 8456. Surface Mine Reclamation, Moraine State Park, Pennsylvania, by Lewis M. McNay. 1970. 28 pp. 23 figs. Description of methods employed and cost data are given for surface-mined land reclamation in Moraine State Park, Butler County, Pa. This project was conducted under the authority of the Appalachian Regional Development Act; a total of 177 acres of land was rehabilitated for specific land use purposes. The use of large equipment expedited the project work, and similar results could be anticipated on similar reclamation programs. (*Out of print.*)

IC 8457. Mineral Materials for Chemical Manufacturing. A Survey of Supply and Demand by the Chemical Industry in the Ohio River Basin of Ohio, Pennsylvania, and

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West Virginia, by M. C. Irani and J. W. Hartwell. 1970. 86 pp. 6 figs. This study is a survey of supply and demand for minerals, metals, alloys, and compounds used by the chemical industries in the Ohio River basin area of Ohio, Pennsylvania, and West Virginia during 1967. Data for the study were obtained from completed questionnaires received from chemical manufacturers and from interviews with officials of chemical companies and mineral producers and distributors. The information includes, kind, quality, quantity, values, sources, specifications, uses, and methods of transportation. Results of the study show that of the total value of mineral materials consumed by the chemical industry, manufacture of inorganic chemicals consumed 46 percent; fertilizers, 22 percent; and soaps and detergents, 19 percent. Fifteen commodities accounted for 91 percent of the total value of mineral materials consumed. Five of these—phosphates, potash, salt, sulfur, and titanium dioxide—accounted for 59 percent of the total. (*Out of print.*)

IC 8458. Proceedings of the Symposium on Respirable Coal Mine Dust, Washington, D.C., November 3-4, 1969, compiled by Richard M. Gooding. 1970. 297 pp. As a part of its continuing program in protecting the health and safety of U.S. coal miners, the Bureau of Mines presented on November 3-4, 1969, a Symposium on Respirable Coal Mine Dust. Cosponsored by the American Mining Congress, the National Coal Association, and the National Independent Coal Operator's Association, this symposium dealt with the various engineering methods of controlling dust in underground coal mines including ventilation, water suppression, machine design, and dust collection, and a discussion of respirators and life support systems. The merits of these various procedures and their potential application to underground coal mining were examined. (*Out of print.*)

IC 8459. The Phosphate Industry in the Southeastern United States and Its Relationship to World Mineral Fertilizer Demand, by John W. Sweeney and Robert N. Hasslacher. 1970. 76 pp. 25 figs. The southeastern phosphate industry is investigated to determine its role in supplying the United States and world phosphate demand. The report shows that the southeastern (Florida, Tennessee, and North Carolina) phosphate industry is the leading domestic and world producer of phosphate rock. The report emphasizes size and organization, production capacity, transportation, and marketing of the southeastern phosphate product. Factors affecting the supply-demand relationship of the southeastern phosphate industry and world phosphate production-consumption relationships are analyzed and related to the southeastern phosphate industry.

Past trends are projected and the future role of the southeastern phosphate industry is analyzed to determine its ability to supply the United States and rest-of-the-world phosphate requirements in 1985 and 2000. The projections show that southeastern resources are ample to supply domestic and export requirements at the projected rates of consumption well beyond the year 2000. (*Out of print.*)

IC 8460. Bureau of Mines Research and Accomplishments in Utilization of Solid Wastes, by F. J. Cservenyak and C. B. Kenahan. March 1970. 29 pp. 12 figs. The Bureau of Mines Solid Waste Program is directed toward three main areas of research: (1) extraction of mineral,

metal, and energy values from urban refuse; (2) recovery of mineral and metal values from wastes generated in the industrial extraction, processing, and utilization of raw materials and mineral-base products; and (3) upgrading and utilization of automotive scrap. The Bureau also has a contract and grant program which supplements the in-house research and aids in the training of personnel in the proper management of mineral- and metal-based solid wastes. (*Out of print.*)

IC 8461. Transportation of Iron Ore, Limestone, and Bituminous Coal on the Great Lakes Waterway System, With Projections to 1995, by James H. Aase. 1970. 61 pp. 19 figs. This study provides data on the physical and hydrological makeup of the Great Lakes waterway system and forecasts quantities, traffic patterns, and shipping cost of prospective bulk mineral commerce projected to be transported upon it. Factors affecting the shipping cost of iron ore, bituminous coal, and limestone were quantified and integrated into a computer program that can be used to estimate costs under varying sets of conditions. Combined shipments of iron ore, bituminous coal, and limestone in 1995 were estimated at 276.5 million tons. The cost of operating the U.S. vessel fleet for transporting an indicated 80 percent of this traffic tonnage was projected to be \$163.5 million. (*Out of print.*)

IC 8462. Gold Placer Mining. Placer Evaluation and Dredge Selection, by C. M. Romanowitz, H. J. Bennett, and W. L. Dare. 1970. 56 pp. 7 figs. This report deals with the factors which should be considered in evaluating a placer deposit and selecting a dredging system for mineral recovery. Overall dredging feasibility and the design of dredging systems are reviewed. Excavation methods, each with its advantages and disadvantages, are compared. Direct operating costs, both original and updated, of gold dredges with bucket capacities of 6 to 18 cubic feet are included. Costs vary with digging depth, changes in environmental conditions, and physical characteristics of the placer, all of which affect excavation rate and recovery. The costs, updated with appropriate indexes, should be used only as guidelines to evaluate potential dredging projects with similar characteristics. The relation of direct dredging costs to annual production is graphically illustrated by a family of curved envelopes that span dredge sizes from 2½ to 18 cubic feet. A curve fitted to the data expresses the relation of direct costs to annual production. (*Out of print.*)

IC 8463. Permissible Mine Equipment Approved by the Bureau of Mines During 1967-68. A Supplement to Bulletin 543 and Information Circulars 8220, 8299, and 8372, by F. R. Lee. May 1970. 25 pp. This publication lists permissible equipment approved by the Bureau of Mines during 1967 and 1968 (calendar years), except breathing apparatus and explosives. The purpose of this publication is to inform the public about approved equipment for use in underground mines.

IC 8464. Silver Potential and Economic Aspects of the Leadville District, Lake County, Colo., by Henry C. Meeves and Richard P. Darnell. 1970. 105 pp. 16 figs. The Bureau of Mines investigated the silver production potential of the Leadville (California) mining district, Lake County, Colo., in 1966-67. The mining history of the district, the ground conditions encountered in mining, and the mine-support methods used are reviewed. The

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drainage problem is discussed in detail. An initial objective was to establish the existence of potential silver resources minable by low-cost open pit methods, particularly in the silver-bearing manganese halos surrounding the major deposits. The report concludes that under present conditions, development of the deposits in the area is not economically feasible; however, a pioneer rotary noncore drilling program demonstrated that this type of exploration is technically feasible. Potential reserves of silver and associated metals are estimated. Possible mining methods for recovery of the reserves are discussed. Future production possibilities from the various subareas of the district are analyzed, considering optimum operating size. Consolidation of small individual holdings for unit operation is recommended. Type of operation, amount of rehabilitation, size and type of concentrating plants required, drainage and other mining problems, and metal price trends are discussed as they bear on economic feasibility of development. (*Out of print.*)

IC 8465. Availability of U.S. Chromium Resources, by Gary A. Kingston, Robert A. Miller, and Fred V. Carrillo. 1970. 23 pp. 2 figs. Chromium resources in the United States are estimated at 1.8 million tons of recoverable chromium contained in 22.5 million tons of chromite-bearing material. Additional resource is presumed existent in large, but as yet undetermined, quantities of material containing less than 10 percent Cr₂O₃. No domestic resources are being mined presently (1969).

Excluding transportation charges to domestic consuming areas, the total 1.8 million tons of chromium is estimated to be available, in ore or concentrate, at costs up to \$0.64 per pound; 63 percent of the total is available under \$0.11 per pound; and 38 percent under \$0.08 per pound. It is judged that transportation from the resource areas to the existing market centers would add nearly \$0.05 to the cost of a pound of chromium contained in ore or concentrate.

Technically effective beneficiation methods have been developed for much of the known domestic resource, and further development might reduce costs of processing these materials. However, at present, domestic chromium resources are noncompetitive with foreign sources. (*Out of print.*)

IC 8466. Economic Potential of Mineral-Based Insulating Materials in Combating the Noise Problem in Residences, by Franklin D. Cooper and Lucille M. Langlois. 1970. 24 pp. Three model dwelling units were redesigned to achieve specific levels of noise reduction above that provided by conventional construction. Using 1968 prices, the added costs of materials and installation were found to range from \$500 to \$5,000 depending upon the size of the dwelling unit and the degree of insulation. The potential aggregate expenditures for sound insulation materials are projected to reach \$617 million in 1975, including about \$408 million for the mineral-based materials, in 1968 constant dollars. The report includes a brief review of the mechanics and effect of sound. (*Out of print.*)

IC 8467. Helium: Bibliography of Technical and Scientific Literature, 1963, Including Papers on Alpha-Particles, by Philip C. Tully, Billy Joe King, and Emily Dowdy. 1970. 831 pp. This bibliography contains

3,062 different citations to technical and scientific literature about helium and alpha-particles abstracted by 13 abstract service publications during 1963. Multiple subject classification has increased the total number of entries to almost 5,000. Helium citations are listed by 23 major classifications. The number of subclassifications has been greatly increased to minimize the time required for literature search. The use of automatic data processing has been extended in compiling the bibliography. (*Out of print.*)

IC 8468. Methods for Studying, Improving and Optimizing Electric-Furnace Smelting Processes, by Victor R. Spironello. 1970. 27 pp. 7 figs. Applications of three experimental design techniques to smelting operations are explained. The report describes a factorial design using three variables at two levels, a fractional factorial design which investigates seven variables, and response-surface methodology for optimization of electric-furnace smelting processes. These methods may be applied with a minimum of trials and at little expense. Further, the writer knows of no reasons why the same methods could not be applied to other operations as well, such as steel-making. (*Out of print.*)

IC 8469. Availability of U.S. Primary Nickel Resources, by Gary A. Kingston, Fred V. Carrillo, Jerry J. Gray, and Paul McIlroy. 1970. 57 pp. 6 figs. Domestic nickel resources are costed to develop a contingency supply curve of U.S. nickel availability at various costs. It is estimated that 4.3 billion pounds of nickel is potentially recoverable from 698 million tons of ore at prices ranging up to \$6.36 per pound of nickel. Over 95 percent of the total is estimated to be available at a price of less than \$4.00 per pound. (*Out of print.*)

IC 8470. Computer Program for Plotting Data Points From a Multichannel Analyzer Via a Remote Teletype, by Bruce D. Sartwell, Paul B. Needham, Jr., and Richard S. Graham. May 1970. 14 pp. 6 figs. A program was written which utilizes a remote teletype input to a time-sharing computer to plot charged particle or X-ray energy spectra which are stored in the memory of multichannel analyzers. The program, written in FORTRAN V, accepts the data printed out by the pulse height analyzer on paper tape and then, after reading these data tapes into the computer, plots on the teletype the desired energy spectra on a scale automatically adjusted for the maximum number occurring in the data. The program is flexible enough so that the researcher can subsequently expand or contract the vertical (intensity) or horizontal (energy) scales. With a slight modification, the program will accept data, printouts from scalars or analog to digital converters. The program also includes a feature for integrating the energy peaks obtained by pulse height analysis.

IC 8471. Technology and Use of Lignite. Proceedings: Bureau of Mines-University of North Dakota Symposium, Grand Forks, N. Dak., May 1-2, 1969, by James L. Elder and Wayne R. Kube. 1970. 174 pp. 79 figs. The 1969 Lignite Symposium was held at Grand Forks, N. Dak., on May 1-2, 1969. Cosponsored by the University of North Dakota and the Department of the Interior, Bureau of Mines, the meeting was the fifth in this series. Registrants from many States and Canadian Provinces attended the meeting representing many energy-oriented

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companies, State and Federal Governments, and universities. At 2-year intervals, these symposia provide a common meeting place where recent research and developments in technology and utilization of energy resources with emphasis on solid fuels (lignite) are presented. Proceedings of the previous symposia including a forum held in 1958 have been published. Fifteen technical presentations were made including papers on electrical power generation, combustion, lignite ash deposition, handling, utilization and analysis, mining, spoil bank rehabilitation, carbonization, oil shale, and relationship of coal, gas, and oil to the total energy concept. (*Out of print.*)

IC 8472. Changing Investment Patterns of the U.S. Petroleum Industry, 1950-68, by Harry R. Johnson. 1970. 23 pp. 8 figs. Domestic expenditures by the U.S. petroleum industry have exhibited distinctive shifts in emphasis over the past 20 years. From the end of World War II to 1955, expenditures for all phases of the industry expanded. Although over one-half of all expenditures was for production, the relative emphasis was changed after 1956-58 from production toward processing and marketing. The period 1967-69 marked the beginning of a return to emphasis on exploration and production. These trends in expenditure patterns are logical and rational when related to domestic and international economic conditions and to the widespread application of improved production technology. As the immense job of developing the oil resources of Alaska and other regions begins, the petroleum industry will continue to turn to external sources for working capital. Long-term debt will probably be the principal method of external financing through 1970, but a definite shift toward new common and preferred stocks will be made. Higher product prices may be sought by the petroleum industry, but the economics of crude-oil production, changes in the tax structure, and possible changes in the oil imports control program make the price structure of crude oil and crude-oil products unpredictable at the present time. (*Out of print.*)

IC 8473. Lithologic Descriptions of Appalachian Area Oil-Producing Formations, by R. L. Rough and W. K. Overbey, Jr. June 1970. 133 pp. 24 figs. The Bureau of Mines obtained samples of oil-reservoir rock from wells in Ohio, Pennsylvania, and West Virginia as part of an investigation of the susceptibility of petroleum reservoirs to secondary-recovery techniques. Illustrations and tables showing the geographic and stratigraphic sequence of the cored reservoirs and 40 tables of detailed lithologic descriptions of the reservoirs are presented. Information relevant to geologic surroundings, oilfield history, coring and well logging operations, and reservoir core analyses are referenced throughout the report.

IC 8474. Calculation Procedure for Heat Transfer to a Gas-Solid Suspension From an Externally Heated Tube, by M. B. Bransford and J. H. Holden. August 1970. 29 pp. 11 figs. A calculation procedure was evolved by the Bureau of Mines for determining the heat-transfer characteristics of dilute gas-solid mixture in an externally heated tube. The procedure accounts for differences in gas and particle velocities and covers a range of particle sizes. Heat transfer coefficients obtained by the calculation procedure are compared with values reported in the literature.

IC 8475. Analyses of Natural Gases, 1969, by L. E. Cardwell and L. F. Benton. 1970. 134 pp. This publication contains routine analyses and related source data for 390 natural gas samples from 22 States and five foreign countries. Of this total, 385 samples were collected during calendar year 1969. The remaining five analyses are of samples collected during previous years, but releases granting permission to publish the results were not received until 1969. All samples were collected as part of a continuous survey of the free world for occurrences of helium in natural gas. This survey has been conducted in the United States by the Bureau of Mines since 1917. In late 1965, the survey was expanded to include foreign gasfields. The analyses published in this report were made by mass spectrometer and a special helium analysis apparatus which are described in Bureau of Mines Bulletins 486 and 576. Eleven previous publications have presented the results of 8,660 gas analyses made by the Bureau of Mines Helium Activity prior to 1969. (*Out of print.*)

IC 8476. The Rare-Earth Elements, Yttrium, and Thorium. A Materials Survey, by John G. Parker and Charles T. Baroch, with a chapter on resources by John W. Adams. 1971. 92 pp. 9 figs. This materials survey on the rare-earth elements, yttrium, and thorium is part of a series prepared by the Bureau of Mines, under the sponsorship of the Office of Emergency Preparedness, to give comprehensive information on metals and minerals that are essential to national security. This publication summarizes the supply-demand position in the United States for the rare-earth elements, yttrium, and thorium and includes information on their properties, resources, industry structure, production, consumption, trade, strategic factors, and pertinent history. (*Out of print.*)

IC 8477. Socioeconomic Aspects of Mining in Selected Cities. Urbanization and Surface Mining, Atlanta, Ga., by R. R. French, A. W. Stuart, and D. H. White. 1970. 50 pp. 18 figs. The industrial minerals industry in the Atlanta, Ga., area was studied in order to better understand problems associated with exploiting mineral resources in and near metropolitan areas. A method for delineating the Atlanta urban area and its component parts was developed so that the factors affecting the location of the minerals industry could be viewed more objectively in the urban context. Major attention is focused on the area's dominant crushed stone subindustry. Demographic and socioeconomic analysis of the Atlanta, Ga., area shows that expansion of the metropolis and its environs will probably eliminate potential mineral resources from the mineral resource base in the area, and that the expanding metropolis will be the primary determinant of future mining sites. Competition for land is accentuated to varying degrees by the incompatibility of mining operations with residential and other environmental requirements. Areas of consideration are suggested to provide maximum development of land and resources for greatest economic benefits at minimum social cost. Further research is recommended to determine market locations in urban areas, optimum operating levels for industrial minerals plants, and alternatives to surface mining. (*Out of print.*)

IC 8478. Bibliography of Investment and Operating Costs for Chemical and Petroleum Plants, January-December 1969, by Sidney Katell and John R. Duda. 1970. 162 pp. This report, covering the period January 1969

through December 1969, is the 11th in a series of reports prepared in cooperation with the American Association of Cost Engineers. The abstracted articles are concerned with all phases of cost engineering in the field of chemical and petroleum plants and related subjects. (*Out of print.*)

IC 8479. Review of Bureau of Mines Coal Program, 1969, by John D. Spencer. July 1970. 106 pp. 50 figs. Projects aimed at achieving the least disturbance to the Nation's air, water, and land resources in the mining and utilization of coal continued to be a feature of the Bureau of Mines coal program. This reflects the current concern about damage inflicted on the environment by our growing and increasingly affluent society. Mine health and safety research, along with investigations related to all other aspects of coal extraction and use, also continued to be implemented and expanded. The overall research efforts seek the dual objective of increasing coal tonnage yet facilitating pollution abatement, and control in achieving maximum public benefit from our coal resources. Appendix A lists the Bureau of Mines research centers and laboratories. Publications issued during 1969 are cited with the projects and in appendix C. Organizations that cooperated with the Bureau in the work described in this report are cited in appendix B.

IC 8480. Evaluating the Economic Availability of Mesabi Range Taconite Iron Ores With Computerized Models, by R. W. Michelson, H. J. Polta, and Orin Peterson. 1970. 99 pp. 32 figs. The Bureau of Mines developed computerized mathematical models to estimate the economic availability of Mesabi Range taconite concentrates; these are a quality model, a cost model, and an economic availability model. The quality model evaluates metallurgical test data; the cost model determines iron unit cost from mining and processing cost data; and the economic availability model determines quantity from geologic and ore quality data. By correlating all of the physical resource quality factors and dimensional characteristics with the economic cost factors associated with producing iron ore pellets, these three models combine to establish a final relation between iron ore reserve quantities and iron unit cost. (*Out of print.*)

IC 8481. Injury Experience in the Nonmetallic Mineral Industries (Except Stone and Coal), 1964-65, by Forrest T. Moyer and Mary B. McNair. August 1970. 131 pp. The safety record of the nonmetal mining industry during 1965 was worse than that of 1964 in all general measures of injury experience except for a slight improvement in the number and frequency rate of non-fatal injuries. Work fatalities in 1965 totaled 31 and occurred at a frequency rate of 1,711 per million man-hours of worktime. The fatality total was seven higher than in 1964 and the injury rates increased 32 and 28 percent, respectively. The total of 2,472 nonfatal injuries in 1965 was 14 less than in 1964 and the frequency rate per million man-hours worked declined 2 percent to 22.73 from 23.14 in 1964. However, the 1965 nonfatal severity rate of 1,339 per million man-hours worked was 15 percent over the 1964 rate of 1,160. This increase was largely attributable to two more permanent total and nine more permanent partial injuries in 1965 than in the preceding year. The average severity of all injuries in 1965 was 132 days lost or charged per injury or 25 days more than in 1964. Injury experience in the non-metal mining industry, including and excluding office

workers, for the 5-year period 1961-65 is shown in a table. The average number of men working on active days in 1965 was 48,429, or 625 fewer than in 1964. However, mines and mills were active an average of 5 days more for a total of 277 in 1965, and each worker averaged 2,245 hours compared to 2,190 hours in 1964. As a result, aggregate worktime of 108.7 million man-hours increased 1 percent over the 1964 total of 107.4 million hours.

IC 8482. Summary of Mining and Petroleum Laws of the World (in Five Parts). 1. Western Hemisphere, by Northcutt Ely. 1970. 159 pp. This volume summarizes mining and petroleum legislation in 30 jurisdictions of the Western Hemisphere. Within these jurisdictions, primary attention is given to requirements that must be met in each country for acquisition of rights to permit development of mineral resources. Coverage includes: First, identification of the controlling laws or statutes governing minerals acquisition and reference to the administrative authority; second, analysis of the laws governing mines and quarries and their products; and third, analysis of laws applicable to natural gas, petroleum, and related materials. Where pertinent, sections dealing with historical background or administration have been added. In countries where minerals are subject to control of states or provinces, those areas are considered separately from the central government. (*Out of print.*)

IC 8483. Fly Ash Utilization. A Summary of Applications and Technology, by John P. Capp and John D. Spencer. 1970. 27 pp. 23 figs. Information is summarized on the major uses of fly ash and prospects for utilization in agriculture and in brick and mineral-wool manufacture. Technological aspects of utilization are discussed and references are given to the work of many of the leaders in the fields of fly ash production, processing, and utilization. (*Out of print.*)

IC 8484. Respirable Dust Sampling Requirements Under the Federal Coal Mine Health and Safety Act of 1969, by Donald P. Schlick and Robert G. Peluso. July 1970. 35 pp. 2 figs. Respirable dust provisions of the Federal Coal Mine Health and Safety Act of 1969 are designed to protect the most important resource of the coal mining industry—its workers. The Act imposes two respirable dust standards of 3.0 milligrams per cubic meter of air after June 30, 1970, and 2.4 milligrams per cubic meter of air after December 30, 1972.

Under Federal regulations, each operator is required to carry out a dust sampling program established by the Secretary of the Interior and the Secretary of Health, Education, and Welfare. This program features the sampling of "high risk" face workers to establish that the exposure of each miner is below the dust standard. Mining sections, continuously in compliance with the regulations, may sample at less frequent intervals. In addition to requiring the mining company to take respirable dust samples, the Bureau of Mines will perform in-depth dust inspections twice a year, as well as frequent "spot inspections." The Bureau has established a semiautomatic computerized operation capable of processing over 1 million samples per year. This facility will be linked to various Bureau offices by a telecommunications system to provide automatic data printouts within hours after samples have been weighed.

IC 8485. A Method for Extinguishing and Removing Burning Coal Refuse Banks, by Frank C. Andreuzzi. 1970. 29 pp. 21 figs. The Division of Environmental

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Activities, conducted a solid waste demonstration project on a burning coal refuse bank. The primary objective of this project was to develop and evaluate an efficient method of extinguishing burning coal refuse and moving it. A series of tests were performed using water monitors and related apparatus to quench the burning material and, at the same time, using earth-moving equipment to transport, spread, and compact the extinguished material.

The method found to be most effective consisted of water-quenching the surface material to a workable depth, ripping, and removing the quenched material with a bulldozer and tractor-scraper. The total cost was estimated to be \$0.44 per cubic yard. (*Out of print.*)

IC 8486. Two-Phase Equilibria of Analytical Binary Solutions Near the Critical Point, by B. J. Dalton. September 1970. 11 pp. Several relationships between coexisting phases for analytical binary solutions near the critical point are given. These relationships were developed from a consideration of a (G, u, P) surface at constant temperature and a (G, u, T) surface at constant pressure, where G is the molal Gibbs free energy, u is the concentration of component 1 expressed as a mole fraction, P is the pressure, and T is the temperature. These formulas should facilitate the calculation of some of the quantities useful in making thermodynamic consistency checks on phase equilibria data about the critical point.

IC 8487. The United States Position and Outlook in Potash, by Staff, Bureau of Mines. 1970. 47 pp. 11 figs. This Bureau of Mines report reviews the development of the world potash industry. The trends leading to the present market situation of oversupply and low prices, which threaten the domestic potash industry, are presented and analyzed. Because the major threat to the domestic industry comes from Canadian imports, the report focuses on the comparative economics of United States and Canadian production. The study resulted in these major conclusions: (1) Balance of world supply and demand is foreseeable in 1975, but it could be delayed by planned expansion. (2) Balance of U.S. supply and demand could occur as early as 1974-75 or as late as 1981. (3) Nearly all U.S. production capacity vis-a-vis Canadian competition is now uneconomic. Prices cover out-of-pocket costs for only 30 percent of U.S. production. (4) U.S. producers will be undersold by Canadians in 60 to 90 percent of the U.S. market. Canadians also will have the edge over United States and European producers in export markets. (5) U.S. firms have invested in 60 percent of the planned 1971 Canadian production, and they have large holdings in Saskatchewan. (6) The decline in the U.S. potash industry probably reduced personal income in Carlsbad, Eddy County, N. Mex., the chief potash-producing area in the United States, about \$21.5 million between 1966 and 1969. (*Out of print.*)

IC 8488. Ash Utilization. Proceedings: Second Ash Utilization Symposium. Sponsored by National Coal Association, Edison Electric Institute, American Public Power Association, National Ash Association, and Bureau of Mines, Pittsburgh, Pa., March 10-11, 1970, compiled by John H. Faber, Neil H. Coates, and John D. Spencer. 1970. 351 pp. More than 400 academic, government, and industry representatives attended the second symposium on ash utilization and technology. The symposium featured 24 formal presentations by leading experts from Europe and the United States on all major phases of ash pro-

duction, utilization, and research. Abstracts of all the papers and the full symposium proceedings are presented. Biographical sketches of the representatives are given in an appendix. (*Out of print.*)

IC 8489. Helium: Bibliography of Technical and Scientific Literature, 1964. Including Papers on Alpha-Particles, by Philip C. Tully, Emily Dowdy, and Betty G. Noe. 1970. 946 pp. This bibliography contains 3,655 different citations to technical and scientific literature on helium and alpha particles, abstracted by 13 abstract service publications during 1964. Multiple subject classification increases the total number of entries to more than 5,800. Helium citations are listed by 23 major classifications, alpha particles by 12. (*Out of print.*)

IC 8490. Respirable Dust Control in the Mines of West Germany, by D. P. Schlick. September 1970. 16 pp. 5 figs. The German experience in dealing with the health hazard of respirable dust in underground mines is reported from first-hand observation in this Bureau of Mines paper. The report covers—(1) The control of dust by water infusion, water spraying, and ventilation. (2) The sampling devices (tyndalloscope, konimeter, and BAT-I) and methods used to determine the dust concentrations in mines. (3) The systems of classifying hazardous and safe dust levels in mines. (4) The research facilities devoted to theoretical and applied work on mine dust and pneumoconiotic disease. The major research projects on dust and disease now underway in West Germany are outlined in an appendix.

IC 8491. A General Computer Program for Use in the Reduction of Burnett Compressibility Data, by B. J. Dalton, R. Leroy Moffitt, Robert E. Barieau, and D. R. Smith. 1970. 278 pp. The Bureau of Mines Helium Activity has developed a computer program for use in the reduction of pressure-volume-temperature (PVT) data obtained with a Burnett compressibility apparatus. This program includes important modifications and extensions of some of the methods currently used for treating these types of data and yields statistical information that cannot be obtained from any other published work.

The methods of calculation make use of a general nonlinear least-squares technique developed at the Helium Research Center. Because of a need to investigate different functional forms of representing the compressibility factor isotherm, Z , the computer program has been written in such a way that the only additional coding required is the so-called compressibility function subroutine. The subroutine defines the analytical form of Z and certain of its partial derivatives. The program described herein is believed to be the most advantageous for use in treating isothermal Burnett compressibility data. (*Out of print.*)

IC 8492. Research and Technologic Work on Explosives, Explosions, and Flames: Fiscal Year 1969, by Staff, Safety Research Center. October 1970. 28 pp. 1 fig. The principal activities of the Bureau of Mines Explosives Research Center during fiscal year 1969 (July 1, 1968, to June 30, 1969) are reviewed in part 1 of this report. Part 2 presents short abstracts of the publications issued during this period in the Bureau series and in the outside press. These publications are referenced in part 1 by underlined numbers in parentheses. Other publications, which are not abstracted, are cited in footnotes throughout the paper.

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IC 8493. Active List of Permissible Explosives and Blasting Devices Approved Before July 1, 1970, by P. A. Richardson and C. M. Mason. October 1970. 8 pp. The current Bureau of Mines active list of permissible explosives includes 76 brands. Eleven are gelatinous and the rest are the granular type. The list of permissible blasting devices comprises five Cardox models.

IC 8494. Impact of Changing Technology on Refractories Consumption, by David J. Kusler and Robert G. Clarke. 1970. 68 pp. 4 figs. The Bureau of Mines reviewed current technology in the refractories consuming industries and evaluated the impact of changes in technology on the supply and demand of refractories. Literature was searched and contacts were made with leading consumers and producers of refractories. The distribution of refractories by value of shipments to users was surveyed.

The report shows that the percentage distribution of refractories sales to the consuming industries has remained essentially constant during the last decade but that substantial changes have occurred in the relative distribution of types of refractories. The trend in pyro-processing technology in recent years has been toward higher temperatures, which require more costly refractories. This fact is reflected in the impressive gain in the dollar value of refractories sales, which in 1968 was about one-third greater than in 1960, and the rapid growth of refractories based on high-alumina, magnesia, zirconia, carbon, and other materials, at the expense of fire clay, silica, and chrome-based refractories.

An appendix to the report contains refractories value and shipment data tabulated in a manner by which trends in the distribution of refractory types can be observed from 1955 to 1968. In addition, unit values are presented on a per-ton basis for comparison. (*Out of print.*)

IC 8495. Financial Evaluation of Mineral Deposits Using Sensitivity and Probabilistic Analysis Methods, by Harold J. Bennett, Jerrold G. Thompson, Herbert J. Quiring, and Joseph E. Toland. 1970. 82 pp. 27 figs. This study was undertaken to develop a computer program for use in evaluating an investment in a mineral deposit when uncertainty may exist in the input data. The program developed can be used to perform sensitivity and/or probabilistic financial analyses. Included in the report are techniques that may be used to select the best alternative investment opportunity, mining and processing methods, and production rate. The criterion used to measure the relative advantages of these investment and operating alternatives is the discounted-cash-flow rate of return. The theory and methods used in the probabilistic analysis approach, which is based on the premise that the expression of a range of values is more realistic than the choice of a single value, are described. The sensitivity analysis method is also described; it is combined with the probabilistic analysis to interrelate mineral reserves, capital investments, operating costs, and production rates. The computer program was written in FORTRAN II and should run without modification on most computers having 8K (8,000-word) core memory, a card reader, and printer (120 characters per line). (*Out of print.*)

IC 8496. The Implications of Urban Growth and the Minerals Industry in the Huntsville, Ala., Area, by

Donald E. Ralston and Ronald P. Hollenbeck. 1970. 24 pp. 10 figs. The Huntsville study area in northeastern Alabama consists of Jackson, Limestone, Madison, and Marshall Counties. Major emphasis was placed on the Huntsville urban area in Madison County to analyze the relationship of urban growth and the minerals industry. Huntsville was delineated into its component urban, suburban, and rural parts for 1964, and the primary area of growth was predicted for 1990. Population estimates were made for the four-county area as a unit and Madison County separately, and projected to 1990. Demand estimates for crushed stone and sand and gravel were made for the same area units and projected to 1990. Analysis of quarry sites in the Huntsville area was made for the present and for the future. The mineral operations of the study area are all located in rural areas; in the case of Huntsville, the mineral sites are located in areas defined as "rural" in the component urban-suburban-rural system.

IC 8497. Coal Production From the Uinta Region, Colorado and Utah. Cost Analysis for Proposed Underground Mining Operations, by D. H. Hileman, Bruce A. Collins, and S. R. Wilson. 1970. 11 figs. Economic investigations indicate that bituminous coal can be mined underground in the Uinta region and marketed at a cost competitive with that of other energy sources in the West. A selling price of \$3.90 per ton of coal was calculated from a cost analysis of a projected coal mine in the Emery coalfield of Utah. Although some mines in some of the coalfields have extremely difficult mining conditions and cannot compete in the energy market at this price level, at least two other coalfields in the Uinta region contain coal reserves that could be mined and sold at a price of approximately \$3.90 per ton. Projections by power companies and other coal-consuming industries indicate a strong future market for the large coal reserves in the Uinta region. (*Out of print.*)

IC 8498. Case Studies of Municipal Waste Disposal Systems, by H. W. Sheffer, E. C. Baker, and G. C. Evans. 1971. 36 pp. 14 figs. Technical and economic aspects of community refuse disposal systems and their effects on the environment are identified and described. Seven landfills and two incineration systems, located throughout the United States, are reviewed. 45 cents.

IC 8499. A Simplified Oil and Gas Well Information System, by Jerry G. Craig. 1971. 22 pp. 2 figs. The Bureau of Mines has developed a computerized oil and gas well data retrieval system from studies of the water-flood potential of a producing reservoir. This system stores pertinent information about each well completed in a reservoir and facilitates selection and manipulation of large volumes of data. Use of the system enables reservoir information to be supplied rapidly, accurately, and at less expense. (*Out of print.*)

IC 8500. Availability of Tungsten at Various Prices From Resources in the United States, by L. P. Larson, R. L. Lowrie, and G. R. Leland. 1971. 65 pp. 14 figs. In this Bureau of Mines evaluation of the domestic supply position of tungsten, certain tungsten resources in the United States are estimated as to quantity and grade and then are systematically costed in detail (excluding exploration costs). A supply curve is developed which depicts the quantity of tungsten (WO₃) up to about 15.5

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million short ton units that is producible at calculated price levels ranging from about \$13 to \$125 per short ton unit. About 10.4 million short ton units are available at a calculated price that is less than the present market price (\$40). Total known resources amount to about 40.2 million short ton units. A very large portion of that quantity was not costed due to inadequate information on either resources or processing methods. Further exploration and research would have a significant effect on the availability of tungsten in the United States. (*Out of print.*)

IC 8501. Availability of Uranium at Various Prices From Resources in the United States, by Carl L. Bieniewski, Franklin H. Persse, and Earl F. Brauch. 1971. 92 pp. 16 figs. In a Bureau of Mines supply evaluation, the known uranium resources in the United States are estimated to have a total recoverable uranium oxide (U_3O_8) content of 3,132,400 tons at prices up to \$69.32 per pound. Only those resources were evaluated for which sufficient quantity data are available and process technology exists for recovering uranium. A total of 160,800 tons of U_3O_8 is available at \$8 per pound from ore deposits presently mined and an additional 244,700 tons is available at prices up to \$30 per pound from similar but usually lower grade deposits. A total of 2,726,900 tons of U_3O_8 is available from four other resources: copper leach solutions, wet-process phosphoric acid, Florida phosphate rock leached zone, and Chattanooga Shale. These resources contain from 30,000 tons of recoverable U_3O_8 at a price of \$7.52 per pound as a by-product of copper leach solutions to 2,557,300 tons at a price of \$69.32 per pound from Chattanooga Shale. (*Out of print.*)

IC 8502. Metallurgical Application of Solvent Extraction (In Two Parts). 2. Practice and Trends, by Joe B. Rosenbaum, D. R. George, and Joan T. May. January 1971. 19 pp. 4 figs. New applications and concepts of solvent extraction as a unit operation in extractive metallurgy have been developed in the last decade. Wider use is being made of established solvent extraction techniques in processing spent nuclear fuel elements and in winning columbium-tantalum, hafnium-zirconium, thorium, tungsten, uranium, and vanadium. Commercial application has been extended to recovery of beryllium, boron, bromine, copper, molybdenum, phosphorus, rare-earth metals, and rhenium. Systems in use and proposed typically extract metals or salts as anion, cation, or neutral species from aqueous media by reaction with a recycleable organic reagent.

IC 8503. Sampling and Evaluating Respirable Coal Mine Dust: A Training Manual, by Staff, Pittsburgh Field Health Group. February 1971. 47 pp. 12 figs. The Federal Coal Mine Health and Safety Act of 1969 requires that each operator of a coal mine shall take accurate samples of the amount of respirable dust in the mine atmosphere to which each miner is exposed, a measure designed to prevent the development of coal workers' pneumoconiosis. This textbook manual is designed to be used in the training of personnel to operate respirable dust sampling devices and to conduct sampling programs. It contains the portions of the act applicable to respirable dust standards, the procedures to be followed to insure compliance with Federal regulations, and descriptions of sampling devices.

IC 8504. Computerized Programming of Respirable Dust Sampling Data, by Donald P. Schlick and Kenneth R. Werner. March 1971. 28 pp. 1 fig. The Federal Coal Mine Health and Safety Act of 1969 requires each mine operator to implement the respirable dust sampling program established by the Secretary of the Interior and the Secretary of Health, Education, and Welfare. This program requires frequent sampling of "high-risk" face workers and periodic sampling of other underground workers. Dust samples are collected by the coal mine operator and weighed at the Bureau's Pittsburgh Field Health Group, and the results are processed by the Bureau's Automatic Data Processing Section located in Denver, Colo. This paper presents the system employed by the Bureau to weigh the dust samples and to process and store the data.

IC 8505. Materials Substitution Study. General Methodology and Review of U.S. Zinc Die-Casting Markets, by N. S. Peterson, F. W. Carrillo, and R. Charles Vars. 1971. 42 pp. 1 fig. As part of the Demand Evaluation Program of the Bureau of Mines to determine future needs for minerals, a study was instituted to develop and describe a methodology for approaching the problem of substitution between mineral commodities and between mineral commodities and other materials. The report comprises three sections: A review of general factors relative to substitution, a case study of the effect of substitution on zinc die-casting markets in recent years, and a general methodology for reviewing materials substitution with specific emphasis derived from reviewing substitution in the domestic zinc die-casting markets. (*Out of print.*)

IC 8506. Causes and Prevention of Transportation Accidents in Bituminous Coal Mines, by Ernest A. Curth. 1971. 107 pp. 44 figs. Statistics for 1956-66 show that mine transportation accidents accounted for 19 percent of fatalities in bituminous coal mines, second only to roof deficiencies as a cause of death. Productivity per man-shift increased from 10.2 tons in 1956 to 18.4 tons in 1966, but the fatalities per million man-hours of exposure also increased from 0.19 to 0.21 during that same period, indicating that transportation hazards still persist. The data were processed by computer to find what constitute hazardous conditions and unsafe actions as well as to correlate occupation and age of victims, transportation type, and mine production. Findings show that unsafe actions of personnel and hazards created by environmental deficiencies or equipment malfunction contribute equally in causing transportation accidents. Accordingly efforts should be directed toward improving working conditions, equipment maintenance, and education and training of employees. The trend is toward using safer modes of transportation, notably conveyors. More attention should be given to track haulage operation, railroad yards, and nondestructive field testing of materials. \$1.

IC 8507. Mine Subsidence—Extent and Cost of Control in a Selected Area, by William Cochran. 1971. 32 pp. 6 figs. The Bureau of Mines investigated mine subsidence caused by recent underground mining, estimated the extent of damages, and formulated a procedure for evaluating subsidence costs. On the basis of the quantity of material removed from beneath the surface, bituminous coal mining currently causes more extensive subsidence problems than mining of other minerals; costs

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are highest in areas such as western Pennsylvania where urban and suburban development and related types of land use conflict with mineral recovery.

The Bureau of Mines estimated subsidence costs, including surface damages and control costs, for a 12-county area in western Pennsylvania for 1968. Total surface damages attributable to the underground production of bituminous coal in the 1-year period were \$295,000; in addition, 12.4 million tons of coal, valued at \$4.3 million, was left in place to minimize potential surface damage. Of the total subsidence cost (\$4.6 million), \$2.7 million was classified as external or social costs, not reflected in the market value of bituminous coal; this averaged \$0.05 per ton of production, or slightly less than 1 percent of the market value. (*Out of print.*)

IC 8508. Gulf Coast Export-Import of Mineral Commodities, by Frank B. Fulkerson. 1971. 90 pp. 11 figs.

The Bureau of Mines gathered data on origin-destination patterns by mineral commodity, quantity and value moved, method of transportation, and methods of handling. The largest areas for export were found to be Western Europe, Latin America, and Asia, other than Japan. The importance of our Latin American neighbors was emphasized by the fact that they supply over 80 percent of gulf coast imports of ores and raw materials. Gulf coast export of mineral commodities is projected to increase from 22.9 million tons in 1968 to 40.0 million tons in 1980. Larger tonnages are forecast mainly for phosphate rock with lesser gains for fertilizers, sulfur, and petroleum coke. Tonnage of gulf coast imports of mineral commodities is projected to increase from 26.6 million tons in 1968 to 33.7 million in 1980. Tonnage gains are forecast for alumina, bauxite, fluorspar, iron ore, and residual fuel oil. Metals will probably continue to dominate the imports. (*Out of print.*)

IC 8509. Approved Dust Respirators for Coal Mines, by Robert H. Schutz. May 1971. 7 pp. This

publication lists and describes devices approved jointly by the Secretary of the Interior and the Secretary of Health, Education, and Welfare, under the provisions of § 70.300-1, Part 70, Subchapter O of Chapter I, Title 30, Code of Federal Regulations (35 F.R. 5548, April 3, 1970), for use as respiratory protection against respirable pneumoconiosis-producing dusts. Included are type C supplied-air respirators approved under Bureau of Mines Schedule 19B and dust, fume, and mist respirators approved under Bureau of Mines Schedule 21B.

IC 8510. A Computer Program for Generating Finite Element Models of Mine Structures, by F. D. Wang,

M. C. Sun, and J. Wolgamott. May 1971. 56 pp. 6 figs. This report presents a structural-mesh-generating program for the two-dimensional finite-element method of mine structural analysis of single and multiple openings in nonhomogeneous rock mass. This program greatly reduces the amount of input data required and the chances of error which otherwise are large owing to the large amounts of data and the complex mesh involved. The program description, a user's guide, example problems, and program listing are included.

IC 8511. Economic Evaluation of California-Nevada Iron Resources and Iron Ore Markets, by Lyman Moore.

1971. 207 pp. 50 figs. This Bureau of Mines report describes and evaluates iron ore resources in California and Nevada and analyzes the California and Japanese

iron ore markets in which these resources will be used. The competitive position of California-Nevada ores, in these markets, was estimated by comparing regional iron ore prices, production costs, and transportation costs with those of foreign suppliers. Resources were determined to be sufficient to produce the equivalent of 585 million tons of 64-percent iron pellets at a price of less than \$15 per ton delivered at California ports. Much higher tonnage could be produced at higher prices. Iron ore requirement of the California iron and steel industry will increase to an estimated 15.9 million tons by the year 2000. A study of the iron ore production potential of California-Nevada deposits and of out-of-State sources indicated that this ore requirement can be supplied most economically by California-Nevada ores. Iron ore import requirements of the Japanese iron and steel industry will increase to an estimated 150.0 million tons by the year 2000. A study of price trends in this market indicated that very little California-Nevada iron ore will be sold in Japan after 1973 when existing sales contracts expire. Iron ore exports might be economically possible if ore could be transported from California to Japan at ballast rates as backhaul on existing petroleum shipping. \$2.

IC 8512. Mesabi Range Iron Ore Transportation: Feasibility and Estimated Cost of Pipelining, by Harold J.

Polta. 1971. 46 pp. 19 figs. This Bureau of Mines publication considers the feasibility of augmenting the present transportation system by pipelining taconite concentrates from the Mesabi Range to the Chicago area. The cost of pipelining in the hypothetical system using water as the carrier is estimated to be between \$3.66 and \$3.97 per long ton. This appears competitive with the 1970 rail-vessel transportation rate of \$4.08 even after allowing a few cents per ton for barging from the terminal to existing furnaces. Political obstacles requiring solution before such a pipeline could be built and the feasibility of using crude oil as the carrier fluid are also discussed.

FORTAN routines used to calculate unit transportation cost for specific estimated values of cost items and for a range of values are presented. The effect of deviations from estimated values of cost items on the total unit transportation cost are shown graphically. (*Out of print.*)

IC 8513. Computer Program for Economic Evaluations of Underground Bituminous Coal Mines, by Robert

A. Miller. 1971. 42 pp. This computer program determines the price per ton of coal needed to obtain a profit of 12 percent discounted cash flow.

From a predetermined equipment and manning list, the program calculates all costs and prints seven tables, including the equipment and manning tables and the discount cash-flow table. Forty-four of the input variables may be readily changed to study their effects upon the final price per ton of coal or upon individual cost items.

The method is adaptable for any type of mining and, with additions, for beneficiation processes.

This program was written in FORTRAN IV for use on the IBM 1130 and with few modifications can be used on other computers. 85 cents.

IC 8514. Summary of Mining and Petroleum Laws of the World (in Five Parts). 2. East Asia and the Pacific, by Northcutt Ely. 1971. 104 pp. This volume

summarizes mining and petroleum legislation in 25 juris-

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dictions of East Asia and the Pacific. Within these jurisdictions, primary attention is given to requirements that must be met in each country for acquisition of rights to permit development of mineral resources. Coverage includes the following: First, identification of the controlling laws or statutes governing minerals acquisition and reference to the administrative authority; second, analysis of the laws governing mines and quarries and their products; and third, analysis of laws applicable to natural gas, petroleum, and related materials. Where pertinent, sections dealing with historical background or administration have been added. In countries where minerals are subject to control of states or provinces, those areas are considered separately from the central government. \$1.

IC 8515. Coal Refuse Fires, an Environmental Hazard, by Lewis M. McNay. 1971. 50 pp. 10 figs. The Bureau of Mines located and examined 292 burning coal refuse banks throughout the Nation's coal-producing regions in 1968. These coal waste fires, extending over 3,200 acres, produce poisonous, acrid gases and particulate matter that pose a threat to health and safety in the surrounding areas, damage vegetation, and cause the deterioration of nearby structures and buildings. Methods of extinguishing coal fires are discussed, and an approach to eliminating future occurrences of these fires is presented. (*Out of print.*)

IC 8516. A Practical Approach to Cutoff Sampling for Repetitive Surveys, by Katherine Harding and Arthur Berger. June 1971. 17 pp. 7 figs. This Bureau of Mines publication describes a practical approach to sampling that does not require elaborate statistical techniques. Simple steps are given for finding a cutoff point in the response from a repetitive survey. This procedure can be used to estimate the aggregate value of the characteristic being measured without waiting for a complete count from the survey. This is a useful technique when the reference periods are repeated at frequent intervals, such as monthly and quarterly, and when the statistical collecting agency is engaged in publishing timely data which must be accurate economic indicators.

IC 8517. How To Mine and Prospect for Placer Gold, by J. M. West. 1971. 43 pp. 6 figs. Increased leisure time and increased interest in the out-of-doors is leading more and more families to experiment with placer mining of gold, and sometimes even to going on into small-scale production. This Bureau of Mines report supplies basic information on areas of occurrence, equipment needed, prospecting, sampling, mining, and regulations concerning the possession and sale of gold. Selected references are given for further study. \$1.05.

IC 8518. Analyses of Natural Gases, 1970, by L. E. Cardwell and L. F. Benton. 1971. 130 pp. This publication contains routine analyses and related source data for 377 natural gas samples from 19 States and two foreign countries. Of this total, 373 samples were collected during calendar year 1970. The remaining four samples were collected during previous years, but releases granting permission to publish the analyses were not received until 1970. All samples were collected as part of a continuous survey of the free world for occurrences of helium in natural gas. This survey has been conducted in the United States by the Bureau of Mines since 1917. In

late 1965, the survey was expanded to include foreign gas-fields. The analyses published herein were made by mass spectrometer and a special helium analysis apparatus, which are described in Bureau of Mines Bulletins 486 and 576.

Twelve previous publications have presented the results of 9,050 gas analyses prior to 1970. The first three, Bulletins 486, 576, and 617, contain analyses and related source data on 5,218 gas samples collected from 1917 through 1960. Nine other publications, which were issued as Information Circulars, supplement the three Bulletins and contain 3,832 analyses of samples collected since 1960. This publication is the 10th publication supplementing the three bulletins. (*Out of print.*)

IC 8519. Microfilming Maps of Abandoned Anthracite Mines. Mines in the Western Middle Anthracite Field, by G. B. Gait. August 1971. 11 pp. 4 figs. This report is the fourth in a series concerning the Bureau of Mines program for microfilming maps of abandoned mines in the Pennsylvania anthracite region; a catalog of the microfilmed maps of 76 mines in the Western Middle field is presented. Previous reports were catalogs of microfilmed maps of mines in the Eastern Middle field and in the Wyoming and Lackawanna Basins of the Northern anthracite field. Additional catalogs will be published as the microfilming of significant mining areas is completed.

IC 8520. Respirable Mine Dust Sample Processing Laboratory, by Murray Jacobson and Paul S. Parobeck. August 1971. 13 pp. 10 figs. The Federal Coal Mine Health and Safety Act of 1969 established mandatory dust sampling of coal mines according to procedures prescribed in the Mandatory Health Standards, Title 30, Code of Federal Regulations, Part 70, published in the Federal Register on April 3, 1970. A laboratory was established in the Pittsburgh Field Health Group of the Bureau of Mines to process the coal mine dust samples collected by the mine operators. This paper describes the laboratory and presents the equipment and procedures used in processing these samples.

IC 8521. Analysis of Free Silica in Respirable Dust, by Robert W. Freedman. August 1971. 8 pp. The Bureau of Mines investigated methods of analysis of free silica in respirable dust, including both work done at the Bureau of Mines and work done elsewhere. The review covers both coal dust and noncoal dust, taking into account both existing and proposed chemical and spectroscopic procedures.

IC 8522. Reuse and Subsurface Injection of Municipal Sewage Effluent. Two Case Histories, by Erle C. Donaldson and Abdo F. Bayazeed. 1971. 20 pp. 8 figs. Bureau of Mines engineers examined the chemical and biological treatment of sewage water designed in one case for reuse and in another for subsurface injection. In the first case discussed, approximately 6 million gallons per day of sewage are treated by the activated sludge process followed by tertiary treatment that includes ion exchange. The renovated water is used in the industrial complex. Liquid industrial waste is sent to a waste disposal facility where it is treated for injection into a deep subsurface formation. In the second case, a community of 3,000 people is using a lagoon sewage treatment system, followed by subsurface injection of the treated

effluent. Subsurface disposal is used to avoid growth of algae and weeds in a nearby lake to which the treated effluent was originally discharged.

The renovation of municipal water for reuse provides a source of water for industries in a semi-arid region and may also provide a source for domestic use in densely populated regions where domestic water requirements have priority over industry needs. In addition, both waste treatment systems provide examples of the use of subsurface waste disposal to avoid pollution of surface streams. (*Out of print.*)

IC 8523. Helium: Bibliography of Technical and Scientific Literature, 1965. Including Papers on Alpha-Particles, by Phillip C. Tully, Emily Dowdy, and Betty G. Noe. 1971. 760 pp. This bibliography contains 3,990 different citations to technical and scientific literature about helium and alpha particles, abstracted by 12 abstract service publications during 1965. Multiple classification increases the total number of entries to more than 6,300. Helium citations are listed by 23 major classifications, alpha particles by 13. (*Out of print.*)

IC 8524. Three Mine Fire Control Projects in Northeastern Pennsylvania, by H. A. Dierks, R. H. Whaite, and A. H. Harvey. With Appendix, "Helium Tracer Study," by B. J. Moore. 1971. 53 pp. 36 figs. The work and costs involved in controlling three large fires in abandoned mines in the anthracite region of Pennsylvania are presented in detail. The work was done under authority of Public Law 89-4. Three basic control techniques were successfully employed by the Bureau of Mines: (1) Forming underground fire-containing barriers by systematically flushing incombustible material into mine voids, (2) excavating an isolation trench around the fire area, and (3) complete excavation of hot and burning material in the fire area. When methods 2 and 3 were used, the excavations were subsequently backfilled with incombustible material. Preliminary location of fire perimeters by the standard use of patterned 6- and 8-inch-diameter boreholes is discussed. Investigations into airborne infrared scanning, shallow subsurface thermal anomalies, and the use of helium to trace the movement of mine air currents are covered. Although they are costly and time consuming, boreholes have proven to be the most efficient means to date of obtaining necessary subsurface fire data. Infrared scanning was ineffective in delineating fires under more than 30 feet of cover. Helium tracing was shown to have a good potential for determining possible hazards to adjacent residential areas from traveling mine fire gases. (*Out of print.*)

IC 8525. Petroleum and Oil-Shale Research of the Bureau of Mines, Fiscal Year 1969, by Bill Linville. 1971. 117 pp. 35 figs. During fiscal year 1969, the Bureau of Mines was engaged in 66 projects to improve methods for producing and utilizing petroleum. Programs directed toward the continued conservation of this natural resource, including crude oil, natural gas, and oil shale, were carried out through research performed at four laboratories supervised and supported by administrative personnel of this Bureau of the Department of the Interior. Over 100 technical papers and reports were published by the Bureau or others based on this research, and numerous other reports were prepared for U.S. Government agencies, State agencies, and organizations of the petroleum and natural gas industry engaged in cooperative research programs with the Bureau.

IC 8526. Review of Bureau of Mines Energy Program, 1970, by Bill Linville and John D. Spencer. 1971. 111 pp. 44 figs. Producing oil, gas, and coal in sufficient amounts to satisfy U.S. demands for fuels, electrical power, and chemicals promises to be one of the country's major challenges during the 1970's. Adding significantly to this challenge is the urgent task of satisfying soaring fuel and power demands without destroying the natural environment or jeopardizing long-range requirements for resources.

The Bureau of Mines is engaged in a comprehensive program of research to help industry meet this challenge. This report reviews the aims of the research program and accomplishments in 1970; the first 11 sections cover coal programs, nine sections are then devoted to petroleum, and the concluding five sections deal with oil shale research. Figure 1 shows the nationwide distribution of Bureau of Mines energy research installations; full addresses are given in appendix A. Many of the publications resulting from the Bureau's energy research efforts are discussed throughout the report; others are listed in appendix B. (*Out of print.*)

IC 8527. Control of Sulfur Oxide Emissions in Copper, Lead, and Zinc Smelting, by Staff, Bureau of Mines. 1971. 62 pp. 21 figs. Air pollution control regulations already implemented or being considered for implementation require substantial investment of capital to remove the sulfur oxides from copper, lead, and zinc smelter gases. As a result, there will be an attendant increase in production costs and possibly an associated increase in the price of these metals to the consumer. The total investment and any resulting metal price increase will depend upon the control regulations that ultimately will be adopted by the individual States.

Controversy has arisen between the metals industry and governmental control agencies regarding the status of stack gas desulfurization technology and the ability of industry to control sulfur oxide emissions to the degree proposed by some of the more stringent regulations currently under consideration. This paper evaluates the problems involved in achieving various degrees of control over smelter sulfur oxide emissions and the technology available to accomplish the task of assuring clean air. The estimated cost of compliance is reviewed for the copper, zinc, and lead industries, but principal attention is given to the copper situation.

IC 8528. Coal Mine Dust Standards of the United States and Other Countries, by Donald P. Schlick, G. G. Morgis, and David B. Booker. 1971. 25 pp. 4 figs. This Information Circular presents a brief historical digest of the early attempts of the Bureau of Mines and the U.S. Public Health Service to establish coal mine dust exposure standards. It reviews current, accepted standards of the United States as well as available standards of other countries. (*Out of print.*)

IC 8529. Bureau of Mines Research Programs on Recycling and Disposal of Mineral-, Metal-, and Energy-Based Solid Wastes, by Charles B. Kenahan and Einar P. Flint. 1971. 53 pp. 24 figs. A summary of Bureau of Mines research on the utilization and disposal of solid wastes is presented, accompanied by an extensive bibliography of related publications. The Bureau's Solid Waste and Materials Recycling Program is directed toward the four following areas of research, development, and demonstration: (1) Extraction of mineral, metal, and

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energy values from urban refuse; (2) upgrading and recycling of automotive and related ferrous and nonferrous scrap; (3) utilization and stabilization of mine, mill, and smelter wastes; and (4) recovery and reuse of values from industrial waste products. A contract and grant program that supplements the in-house research and aids in the training of manpower in management of mineral-, metal-, and energy-based solid wastes is also discussed.

This publication updates Bureau of Mines Information Circular 8460 issued March 1970.

IC 8530. Satellite Monitoring of Open Pit Mining Operations, by William C. Henkes. 1971. 28 pp. 15 figs. Anticipating the availability of space-altitude imagery from the Earth Resource Technology Satellites (ERTS), the Bureau of Mines investigated the possibilities of using such imagery in its activities in solid waste disposal, reclamation of mine workings, and mineral resource inventory. The study indicates that monitoring open pit and strip-mining operations can be done using conventional techniques if the sharpness of the imagery is sufficiently high. Possibilities also exist for semi-automated processes for change detection. Additional experimentation is needed for multispectral discrimination and identification of mine-related phenomena. 35 cents.

IC 8531. Strippable Reserves of Bituminous Coal and Lignite in the United States, by Staff, Bureau of Mines. 1971. 148 pp. 6 figs. The strippable reserves of bituminous coal and lignite in the United States were calculated in accordance with the prevailing conditions of seam thickness and depth of overburden in each of the several coal-producing areas of the Nation. Within defined limits of seam thickness and depth of overburden, it is estimated that there was a remaining strippable resource of 118 billion tons of raw bituminous coal and lignite as of January 1, 1968. Because of topography, natural and manmade features, and other limitations, only 45 billion tons of the resource are strippable reserves. Of this, 32 billion tons is considered low-sulfur (less than 1 percent), 4 billion tons is medium-sulfur (1 to 2 percent), and 9 billion tons is high-sulfur (over 2 percent) coal. Owing to a cleaning loss affecting that portion of strip coal that is mechanically cleaned, the 45 billion tons of strippable reserves are reduced to 39.6 billion tons of marketable coal.

A brief discussion is given for each coal-producing State, summarizing past and present production, historical background, and outlook. Appendix A contains reserve data by State, county, seam, and sulfur content. Appendix B contains the general information and requirements necessary to comply with the current strip mining laws covering 20 States. \$2.05.

IC 8532. A Survey of the Secondary Titanium Market, by Jerry J. Gray and Paul McIlroy. 1971. 17 pp. 1 fig. The utilization of secondary titanium was determined in a study by the Bureau of Mines. A 10-year statistical table showing supply and distribution patterns is presented in this report. Over the total 10-year period, estimated scrap consumption is larger than estimated scrap supply. Trends from the estimated data indicate that titanium is in short supply and probably will continue to be in the future. Because of higher processing costs for recycled scrap, scrap will tend to migrate to the

steel and aluminum industries and to ferrotitanium production and exports. Nonrecoverable losses of titanium metal during processing was determined to be a potential area for research. (*Out of print.*)

IC 8533. Cost Evaluation of a Metal and Mineral Recovery Process for Treating Municipal Incinerator Residues, by John J. Henn and Frank A. Peters. 1971. 41 pp. 9 figs. An evaluation is presented of the Bureau of Mines process for the recovery of metal and mineral values from municipal incinerator residues. This process employs standard mineral beneficiation techniques and is operating on a pilot-plant scale of 1,000 pounds of incinerator residue feed per hour. Products from this separation process include ferrous, aluminum, and copper-zinc scrap and colorless and colored glass.

Cost estimates were prepared for four plant sizes. It is assumed that the separation plant is located adjacent to a municipal incinerator. Provision is made, however, for part of the residue feed to be delivered by truck so that one large separation plant can be used for residue from more than one incinerator. 50 cents.

IC 8534. Selected List of Bureau of Mines Publications on Petroleum and Natural Gas, 1961-70, by V. Vern Hutchison. 1972. 139 pp. This selected list contains 829 entries with citations to Bureau of Mines publications related to petroleum and natural gas, which were released during the 1961-71 period. Some entries are multiple in nature, resulting in a total of 881 citations. Work done in cooperation with the State of Oklahoma. GPO Stock No. 2404-1050. \$1.75.

IC 8535. Cost Analysis of Model Mines for Strip Mining of Coal in the United States, by Staff, Bureau of Mines. 1972. 116 pp. 1 fig. This study estimates costs of producing bituminous coal and lignite by stripmining methods in 12 hypothetical mines. Basic costs are developed by geographic area, rank of coal, and output capacity. Seam thickness and depth and type of overburden are considered typical for the area in which the hypothetical mine would be located. The cost analyses are based on the use of new equipment, the prevailing union wage scales, and the payment of all miscellaneous costs including royalties, contributions to the miners' welfare fund, and license and permit fees. All model mines are considered to have a life span of 20 years. GPO Stock No. 2404-1048. \$1.25.

IC 8536. Effect of Coal Mine Health and Safety Act of 1969 on Respirable Dust Concentrations in Selected Underground Coal Mines, by Murray Jacobson, Paul S. Parobeck, and Mona E. Hughes. 1971. 9 pp. 5 figs. The respirable dust standard in the Federal Coal Mine Health and Safety Act of 1969 is designed to prevent disability and death from coal workers' pneumoconiosis. Beginning June 30, 1970, the operators of coal mines were required to maintain the average concentration of respirable dust in the active workings at or below 3.0 milligrams of dust per cubic meter of air. The standard is reduced to 2.0 milligrams per cubic meter after Dec. 30, 1972.

This paper presents the equipment and procedures used by the coal mine operators in implementing the respirable dust sampling program established by the Secretary of the Interior and the Secretary of Health, Education, and Welfare and shows the effect of the law, during the first year, on the reduction of dust levels in

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selected mines. The system employed by the Bureau of Mines for analyzing and processing the dust samples is also presented.

IC 8537. Strippable Lignite Reserves of North Dakota. Location, Tonnage, and Characteristics of Lignite and Overburden, by Benjamin C. Pollard, Joseph Blake Smith, and Clinton C. Knox. 1972. 37 pp. 19 figs. The location and production potential of a large block of strippable reserves in North Dakota were determined by using published data as a base and adding new drill hole data or other data contributed by companies that presently own or lease coal lands. Only beds exceeding 5 feet in thickness, under less than 120 feet of overburden, and in large blocks of 5 million tons or more were included in the estimates. All such reserves are in the Fort Union Formation of western North Dakota and are lignite in rank. Sixteen large blocks of reserves evaluated in this study are estimated to contain a total of 4.1 billion tons of strippable lignite. GPO Stock No. 2404-1063. 65 cents.

IC 8538. Strippable Coal Reserves of Wyoming. Location, Tonnage, and Characteristics of Coal and Overburden, by Joseph Blake Smith, Maynard F. Ayler, Clinton C. Knox, and Benjamin C. Pollard. 1972. 51 pp. 14 figs. Coal resource data from published sources and company files were used by the Bureau of Mines to determine the location and extent of strippable coal reserves in Wyoming. Total strippable reserves of 23 billion tons were estimated in seven major coal areas. Seven large strip mining operations were active in 1969, and their production totaled 4½ million tons of coal. Cutoffs used to define strippable reserves were (1) minimum coalbed thicknesses of 5 feet; (2) overburden-to-coal ratios of less than 10 cubic yards of overburden per ton of coal, and (3) total overburden thicknesses of less than 120 feet, except where reserves occur in multiple beds or a single thick bed. Tertiary rocks along margins of the Powder River basin contain most of the strippable coal reserves in Wyoming. The Wyodak beds ranging in combined thickness from 30 to 130 feet, crop out on the east flank of the basin and contain an estimated 19 billion tons of strippable subbituminous C-rank coals under less than 200 feet of overburden. Partings between these beds total less than 60 feet. The 100- to 200-foot-thick Healy bed on the western flank of the basin and the 35-foot-thick School and 20-foot-thick Badger beds on the south also contain large strippable reserves. Elsewhere in Wyoming, strippable deposits are subbituminous coal of Late Cretaceous and Tertiary ages, mostly in the Hanna and Great Divide basins in the south-central portion of the State and in the Kremmerer-Hamms Fork region in the southwestern corner. GPO Stock No. 2404-1066. \$1.

IC 8539. Bureau of Mines Safety Research Center, Research and Development Activities: Fiscal Year 1970, by Staff, Safety Research Center. 1972. 38 pp. 2 figs. On July 1, 1969, the Explosives Research Center merged with the Health and Safety Research and Testing Center to form the Safety Research Center, with facilities at Pittsburgh and Bruceton, Pa. Subsequently, passage in December of the Federal Coal Mine Health and Safety Act of 1969 had a major influence on the activities of the new center. These activities, which were conducted under two main programs, Coal Mine Safety Research and Explosives Research, are described in this publication.

IC 8540. Availability of Rutile as a Byproduct From Sand-Washing Plants in the Southeastern United States, by William Cochran and Robert L. Smith. 1972. 27 pp. 6 figs. Data on the cost and quantity available were developed for rutile (TiO₂), which is potentially recoverable as a byproduct at sand-washing plants in the Southeastern States of Alabama, Georgia, North Carolina, and South Carolina. Based on 1969 production data, an estimated 4,300 tons of rutile could be recovered annually from plants that process more than 25,000 tons of sand per year. Rutile prices at which this resource would be available ranged upward from \$262 per ton, compared with the current market value of \$185 per ton. GPO Stock No. 2404-1077. 35 cents.

IC 8541. Methods for Evaluating Explosives and Hazardous Materials, by C. M. Mason and E. G. Aiken. 1972. 48 pp. 25 figs. The methods currently used by the Bureau of Mines to evaluate the sensitivity, strength, incendiarity, gaseous products, and physical properties of explosives and hazardous chemicals are described. Included are the tests used to evaluate explosives which are certified as permissible for use in underground coal mines. GPO Stock No. 2404-1085. 55 cents.

IC 8542. Analyses of 169 Crude Oils From 122 Foreign Oilfields, by E. P. Ferrero and Dorothy T. Nichols. 1972. 113 pp. Crude oils from fields throughout the world are analyzed by the Bureau of Mines to determine the characteristics of the oils and their contribution to the petroleum resources of the world. Analyses are reported for 169 foreign crude oil samples from 122 oilfields in Africa, Asia, Australia, the Caribbean, Europe, North America, and South America. Tables show the geographic and geologic origin of the samples, names of companies that supplied the samples, annual production for the fields, general characteristics and analytical and computed data, hydrocarbon-type data, cumulative production of the larger fields, and references to sources of geological and field development information. The analyses were made by the Bureau of Mines routine method and comparisons may be made with more than 8,000 other such analyses.

IC 8543. Technology and Use of Lignite. Proceedings: Bureau of Mines-University of North Dakota Symposium, Bismarck, N. Dak., May 12-13, 1971, compiled by Wayne R. Kube and James L. Elder. 1972. 145 pp. 52 figs. This Bureau of Mines report contains the proceedings of a symposium cosponsored by the Bureau of Mines and the University of North Dakota concerning utilization and technology of Western coals and lignites. The symposium, the sixth in a series, comprised 12 papers. GPO Stock No. 2404-1101. \$1.50.

IC 8544. Summary of Mining and Petroleum Laws of the World (in Five Parts). Part 3. Near East and South Asia, by Northcutt Ely. 1972. 82 pp. This volume summarizes mining and petroleum legislation in 22 jurisdictions of the Near East and South Asia. Within these jurisdictions, primary attention is given to requirements that must be met in each country for acquisition of rights to permit development of mineral resources. Coverage includes: First, identification of the controlling laws or statutes governing minerals acquisition and reference to the administrative authority; second, analysis of the laws governing mines and quarries and their products; and third, analysis of laws applicable to natural gas, petroleum, and related materials. Where pertinent, sections dealing with historical background or administration have been added. In countries where

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minerals are subject to control of states or provinces, those areas are considered separately from the central government. GPO Stock No. 2404-1114. 75 cents.

IC 8545. Bureau of Mines Procedure for Evaluating Quartz Content of Respirable Coal Mine Dust, by Samuel A. Goldberg and Murray Jacobson. 1972. 10 pp. 5 figs. The Federal Coal Mine Health and Safety Act of 1969 delegated to the Bureau of Mines a yearly program of health inspections. Respirable coal mine dust concentrations are measured by Bureau inspectors. Samples of respirable coal mine dust are weighed to determine dust concentration and then analyzed for ash and quartz content. This paper describes the laboratory procedure for determining the percent quartz in the respirable coal mine dust samples.

IC 8546. A Computer Program for the Structural Analysis of Space Frame Type Protective Canopies, by Stephen Gerard Sawyer. 1972. 53 pp. 3 figs. This report presents a Fortran IV computer program for the structural analysis of space-frame protective canopies used in underground mines to protect equipment operators from falls of roof, face, or rib. This program entitled CANOPY permits rapid calculation of the elastic strength of a canopy for a variety of static loading conditions. Stresses in, and displacements of, each structural member are computed and printed out. Additionally, identification of all members that have commenced yielding, weight of the canopy, total loads on the canopy, and maximum loads that the canopy can sustain elastically are output. Program description, input instructions, program listing, and two example problems are included.

IC 8547. Trends in the Minerals Industry, 1970, by Staff, Bureau of Mines. 1972. 89 pp. 19 figs. The Bureau of Mines annually publishes statistical data reflecting technological trends in the minerals industry (metals and nonmetals except fuels). This report outlines recent developments and trends and the technology outlook for mining practices and metallurgical processing based on a review of the minerals industry during the past 2 years. A historical statistical series which indicates trends in the minerals industry has been extended with 1970 data. In addition, data are given from a 5-year Bureau of Mines cyclic canvass of froth flotation plants. Data for 1970 are compared with those of 1960 and 1965. GPO Stock No. 2404-1146. \$1.00.

IC 8548. Instruments for Detecting Gas in Underground Mines and Tunnels, by B. I. Ferber and A. H. Wieser. 1972. 16 pp. 2 figs. Toxic and explosive atmospheres are discussed, along with some of the instruments commercially available for their detection. No attempt has been made to evaluate the accuracy of any one device. This circular has been prepared primarily to aid mine inspectors in selecting suitable instruments for underground gas detection.

IC 8549. Energy Potential From Organic Wastes: A Review of the Quantities and Sources, by Larry L. Anderson. 1972. 16 pp. 3 figs. Enormous quantities of organic wastes are produced each year in the United States. The total amount is in excess of 2 billion tons and at least 880 million tons of this is moisture- and ash-free organic material (dry organic solids), representing a potential energy source of significant magnitude that is not being utilized. Bureau of Mines scientists have developed methods for converting these wastes to

convenient energy forms. This report itemizes and evaluates for the first time in detail the quantities and sources of moisture- and ash-free organic material contained in manure, urban refuse, industrial wastes, sewage solids, and agricultural wastes in the United States. Furthermore, estimates are presented for amounts of organic wastes collected or concentrated. The potential for fuel, either oil or gas, from both the total organic wastes generated and those collected or concentrated is also estimated. GPO Stock No. 2404-1112. 55 cents.

IC 8550. Designing Blast Patterns Using Empirical Formulas. A Comparison of Calculated Patterns With Plans Used in Quarrying Limestone and Dolomite, With Geologic Considerations, by Joseph M. Pugliese. 1972. 33 pp. 2 figs. This work was done by the Bureau of Mines to provide quarry operators with an uncomplicated, first-approximation method for designing blast patterns, considering geologic structure, and to show the valid use of the technique by comparing drill and blast pattern dimensions used in the quarry with those determined by the presented method. The author visited 12 limestone and dolomite quarries in Ohio (Adams, Crawford, and Highland Counties), Wisconsin (Milwaukee, Racine, and Waukesha Counties), and Minnesota (Fillmore, Olmsted, and Wabasha Counties); observed the blasting practices; studied the major geologic features; and after discussion with the quarry managers, foremen, and blasters, compared the quarry blasting patterns with those as calculated by the empirical formulas (after R. L. Ash), with geologic structural considerations. When geologic structure such as bedding, jointing, folding, and caves, as well as explosive properties and field performance characteristics are accounted for in a manner suggested by the research, the presented empirical formulas may be used as a good first approximation. The included steps in planning a blast design and generalized blast patterns should be of help to the quarry operator. Design changes are recommended for those quarries where problems are occurring. GPO Stock No. 2404-1145. 45 cents.

IC 8551. Review of Bureau of Mines Energy Program, 1971, by John D. Spencer and Bill Linville. 1972. 102 pp. 44 figs. Clean energy production from coal, oil, and gas, and the development of these and other energy sources continued to be a major objective of the energy research program of the Bureau of Mines. In 1971 increased emphasis was placed on the production of fluid fuels and chemicals from coal. Advances were achieved in the development of the Synthane and Hydrane gasification processes for producing pipeline gas from coal, and progress was made in research on solid wastes utilization, and on liquid fuels production from coal. Coal mine safety, solid waste disposal and utilization, coal preparation and transport, and fundamental research on coal and related products also continued to be the subject of extensive research.

This report is the second in a series; the first report, published in 1971, was Information Circular 8526.

IC 8552. Bin Hopper Engineering and Bulk Materials Flow: A State-of-the-Art Report on Empirical and Theoretical Analyses, by W. G. Pariseau and R. S. Fowkes. 1972. 36 pp. 16 figs. This Bureau of Mines report is an evaluation of the state of knowledge about gravity flow from bin hoppers, the most commonly used method of handling bulk materials where the

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force of gravity is used. The requirements for flow to be initiated and to continue, formulas developed experimentally or mathematically from various assumptions to describe the materials flow, and the question of whether or not a material will flow over the entire cross sectional area of the bin hopper according to the flow regime developed are the primary areas discussed.

The work of A. W. Jenike, whose pioneering investigations raised bin hopper design from the trial and error state, is examined in depth and its limitations and assumptions are pointed out. Bin hopper design depends heavily upon prior experience, and suggestions for further studies of bin hopper flow to include the effects of feeders are made. GPO Stock No. 2404-01167. 45 cents.

IC 8553. Mathematical Smoothing of Digitized X-Ray Spectra, by Harold E. Marr, III. 1972. 15 pp. 2 figs. A simple algorithm is presented for processing digitized X-ray spectra obtained with a Si(Li) or Ge(Li) semiconductor detector coupled to a multichannel analyzer. The simplified least-squares procedure is used to smooth out the statistical fluctuations in the spectrum by repeatedly fitting a quadratic equation to a predetermined number of channels and performing a traveling smooth across the spectrum. A logarithmic transform is applied to the raw data to minimize the distortion of the gaussian-shaped peak profiles. The efficacy of the technique is evaluated by observing the distortion of several gaussian-shaped peaks that have been subjected to the smoothing operation. The locations of maximums and minimums in the spectrum are predicted in the process as well as the values of the peak heights. The convolution integrals from a least-squares fit of a quadratic equation are calculated as part of a FORTRAN subroutine. The building-block approach to computer programming in a small laboratory is discussed.

IC 8554. Analyses of Natural Gases, 1971, by L. E. Cardwell and L. F. Benton. 1972. 163 pp. This publication contains routine analyses and related source data for 475 natural gas samples from 17 States and two foreign countries. Of this total, 454 samples were collected during calendar year 1971. The remaining 21 samples were collected during previous years, but releases granting permission to publish the analyses were not received until 1971. All samples were collected as part of a continuous survey of the free world for occurrences of helium in natural gas. This survey has been conducted in the United States by the Bureau of Mines since 1917. In late 1965, the survey was expanded to include foreign gasfields. The analyses published here were made by mass spectrometer and a special helium analysis apparatus, which are described in Bureau of Mines Bulletins 486 and 576. Thirteen previous publications have presented the results of 9,427 gas analyses prior to 1971. The first three, Bulletins 486, 576, and 617, contain analyses and related source data on 5,218 gas samples collected from 1917 through 1960. The other 10 publications, which were issued as information circulars, supplement the three bulletins and contain 4,209 analyses of samples collected since 1960. This publication is the 11th publication supplementing the three bulletins. GPO Stock No. 2404-1147. \$1.75.

IC 8555. Injury Experience in Coal Mining, 1967, by Forrest T. Moyer and Mary B. McNair. 1972. 112 pp. 1 fig. Injury experience at coal mines and mechanical-cleaning plants (excluding offeworkers)

in 1967 was 222 fatal and 10,115 nonfatal disabling work injuries during an exposure time of 241.8 million man-hours. These injuries occurred at a frequency rate of 42.75 per million man-hours worked; the severity rate was 7,699 days lost or charged per million man-hours. Each of these general measures of injury experience was lower than similar data recorded for 1966.

Employment at 6,885 coal mines and 569 mechanical-cleaning plants, excluding offeworkers, averaged 139,312 men in 1967. The average number of days worked was 220. Coal production totaled 560.8 million short tons, at rates of 2.32 tons per man-hour and 18.32 tons per man-day.

A total of 2,779 onsite offeworkers at coal mines and mechanical-cleaning plants worked 5.2 million man-hours in 1967 without a disabling work injury.

IC 8556. Injury Experience in Coal Mining, 1968, by Forrest T. Moyer and Mary B. McNair. 1972. 107 pp. 1 fig. The safety record of the coal mining industry in 1968 worsened appreciably in fatality experience but was slightly better in nonfatal injury experience. Work fatalities in 1968 totaled 311 and occurred at a frequency rate of 1.33 per million man-hours or worktime. The fatality total was 89 higher, and the rate of occurrence was 45 percent higher than the corresponding figures of 222 fatal injuries with a frequency rate of 0.92 in 1967. The worsened fatality record in 1968 resulted primarily from two major disasters (a single accident which results in the death of five men or more) which killed 87 men, nine in one and 78 in the second. The total of 9,639 nonfatal injuries was the lowest annual figure in complete records since 1930. The frequency rate of 41.12 nonfatal injuries per million man-hours of worktime for 1968 was the second lowest annual rate of occurrence. The severity rate of all injuries, 10,513 days lost or charged per million man-hours, and the average severity, 248 days lost per injury, in 1968 were the worst annual data in the series started in 1944. Total worktime of 234.4 million man-hours and coal output of 553.3 million tons in 1968 were, respectively, 3 and 1 percent lower than in 1967.

IC 8557. Offshore Petroleum Studies. Composition of the Offshore U.S. Petroleum Industry and Estimated Costs of Producing Petroleum in the Gulf of Mexico, by L. K. Weaver, H. F. Pierce, and C. J. Jirik. 1972. 168 pp. The objective of this study is twofold. The first is to present the composition of the offshore petroleum industry in terms of lease bonuses and the value of hydrocarbons produced from Federal offshore tracts. The second is to present costs of producing petroleum (oil and condensate) in the Gulf of Mexico with a financial analysis of an offshore operation. To prepare a financial analysis of an offshore operation, a model was derived to show the costs necessary to explore, acquire, develop, produce, and abandon a 5,000-acre block and the estimated income from the sale of the hydrocarbons produced. To establish cost and income guidelines for the model, a group of seven oilfields in the Gulf of Mexico ranging from 7 to 75 miles from shore and in water 20 to 130 feet deep was selected for study. A net profit or loss statement was prepared for each field and a discounted cash flow rate of return was calculated. Discounted cash flow rates of return for the seven fields range from 1.1 to 19.5 percent. Under the two specified conditions set up for the model (a 20-year and a 30-year oil de-

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pletion model), the rates of return are 17.2 and 13.7 percent, respectively. To January 1, 1969, the top four operators in the Federal offshore areas had paid approximately 40 percent of the amount spent on all lease bonuses and produced about 56 percent of the total hydrocarbons. GPO Catalogue No. I 28.27:8557. GPO Stock No. 2404-01205. \$1.75.

IC 8558. Methane Emission From U.S. Coal Mines. A Survey, by M. C. Irani, E. D. Thimons, T. G. Bobick, Maurice Duel, and M. G. Zabetakis. 1972. 58 pp. 12 figs. This survey was conducted to determine the magnitude of the methane emission and control problem in U.S. bituminous coal mines. The resultant data indicate that the emission rate for any given coalbed depends primarily on the coal production rate and on mine depth, as well as on the nature of the coalbed and the surrounding strata. An excellent correlation was found between (1) the methane emission rate and (2) the product of coal production rate and mine depth for the mines in the Pittsburgh, Pocahontas Nos. 3 and 4, and the Illinois Nos. 5 and 6 coalbeds.

The highest total emission rates found in U.S. bituminous coal mines were as follows, in million cubic feet per day: Monongalia County, W. Va., 39; Marion County, W. Va., 30.4; McDowell County, W. Va., 13.1; Washington County, Pa., 11.9; Greene County, Pa., 11.4; Buchanan County, Va., 21.6; Jefferson County, Ala., 10.3; and Franklin County, Ill., 6.6.

IC 8559. Respirators Approved by the Bureau of Mines as of May 24, 1972. A Revision of Information Circular 8436, by E. J. Kloos and Robert H. Schutz. 1972. 12 pp. This publication lists devices approved jointly by the Secretary of Interior and the Secretary of Health, Education, and Welfare, as of May 24, 1972, under provisions of Section 11.2, Part 11, Subchapter B of Chapter 1, Title 30, Code of Federal Regulations (37 F.R. 6244, Mar. 25, 1972), for use in mines as respiratory protection in oxygen-deficient atmospheres, and in gases, vapors, dusts, fumes, and mists. Included are self-contained breathing apparatus, gas mask, and supplied-air, dust, fume, mist, and chemical-cartridge respirators. Names and addresses of manufacturers appear in the appendix.

IC 8560. The Impact of Blasting Agents and Slurries on Explosives Technology, by Richard A. Dick. 1972. 44 pp. 15 figs. This Bureau of Mines report describes the evolution of modern-day blasting-agent and slurry products and the state of the art of the usage of these products as it exists today. The steadily increasing consumption of blasting agents and slurries at the expense of cartridged high-explosive usage is related. Although safety is not covered in depth, reference is made to pertinent safety literature available. Product formulations, detonation reactions, and detonation products are discussed. Product terminology is defined and the significant differences between the relatively insensitive modern-day dry blasting agents and slurries and cap-sensitive high explosives are described. Blasting agent and slurry properties are discussed, as well as methods of determining and describing these properties, and specific types of products are also discussed with reference to their ingredients, properties, and field applications. Increasing consumption of slurries, particularly in small-diameter boreholes, and the development of more cap-sensitive varieties of slurries are

forecast although dry blasting agents should continue to dominate the market. The consumption of cartridged high explosives will level off or gradually decrease. 50 cents. GPO Stock No. 2404-01218.

IC 8561. An Engineering Cost Study of Development Wells and Profitability Analysis of Crude Oil Production, by T. M. Garland and W. D. Dietzman. 1972. 134 pp. 11 figs. This report presents a more extensive perspective of the calculated profitability of developing and producing crude oil and associated natural gas by primary methods from selected onshore areas of the United States. Estimates were made for cost of drilling, completing, equipping, and producing oil wells at four depths in seven onshore producing areas. A computer program was developed for calculating the discounted cash flow rate of return for the 64 different models in each area resulting from varying the oil-producing rate and production decline rate. The results of these calculations provide data that vividly illustrate the change in rate of return to changes in well depth, initial producing rate, and production decline rate, as well as to variations in development cost and operating expense. Cost per barrel of oil produced in terms of annual cost and total cost is also discussed. Included in the report are explanations of the methods of determining costs and the procedure used for profitability analysis. Summaries of all cost estimates and results of profitability analyses are presented in the appendix in tabular form for each of the seven producing areas. GPO Stock No. 2404-01248. \$2.

IC 8562. Injury Experience in Quarrying, 1961-63, by Forrest T. Moyer, George E. Fish, Jr., and Mary B. McNair. 1972. 184 pp. Quarry accidents in 1963 caused 61 fatal and 3,468 nonfatal injuries which occurred at respective frequency rates of 0.31 and 17.91 per million man-hours of worktime. The fatality record in 1963 was better than in 1962 but was appreciably worse than in 1961. For nonfatal injuries, the 1963 record was slightly worse than in 1962 but was better than in 1961. The injury-severity rate of 2,913 days lost or charged per million man-hours in 1963 was better than that of 3,046 in 1962, the first year for which such data became available. The average severity of all injuries in 1963 was 160 days lost or charged per injury, 15 less than in 1962. An average of 91,960 men were at work on active days in 1963 and these men had an aggregate worktime of 193.7 million man-hours during the year.

IC 8563. WAVE—A Computer Program for One-Dimensional Stress Wave Analysis in a Time-Dependent Inelastic Rock Using a Generalized Voigt Model, by Stephen Gerard Sawyer. 1972. 31 pp. 6 figs. A Fortran IV computer program entitled WAVE, which employs an explicit finite difference scheme for solving the one-dimensional wave equation for a time-dependent inelastic rock has been developed. The viscoelastic properties of the rock are represented in terms of a generalized Voigt model. The theory on which the computer program is based is rederived and a short description of the program is given. The computer program input instructions, a listing of the computer program, and example problems with required input and subsequent printed output are presented in appendices. In the example problems, calculated results are free of spurious oscillations which occur in certain other methods of numerical calculation, notably the extended Ritz method.

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IC 8564. Hearing Conservation for the Mineral Industry, by Raymond Derzay. 1972. 42 pp. 9 figs. This publication is intended to be of value to the mineral industry in establishing and maintaining effective programs for preventing noise-induced hearing loss. Factors involved in this loss and the need for and the requirements of an effective hearing conservation program are discussed. The legal and legislative history of compensation for hearing loss is briefly reviewed. A review of statutes is not attempted since several States have recently modified, or are in the process of modifying their laws regarding permissible noise exposures, required hearing protection, and/or compensation for hearing loss. A review of other aspects of the problem of industrial noise in terms of medical, physiological, and psychological frames of reference is included. A hearing conservation program is described in detail. Appendixes detailing the names and addresses of a few equipment suppliers are included. References are provided for those who may wish to delve more deeply into the medical, technical, and scientific considerations of noise and its effect on man.

IC 8565. Demand for Platinum To Reduce Pollution From Automobile Exhausts, by David J. Kusler. 1973. 32 pp. 10 figs. This Bureau of Mines study is an appraisal of the demand for platinum, should this strategic metal be used as a catalyst in the National abatement of automobile exhaust pollution. The Clean Air Act of 1970, as amended, requires that automobiles produced in 1975 and thereafter be provided with antipollutive measures to control automotive exhaust emissions. The study considers the need for automobile pollution control, the methodology for such control, the annual primary (new) platinum demand for automobiles produced from 1975 to 1990, primary platinum availability, and supply-demand forecasts and outlook. The correlative demand for platinum for the production of the required unleaded gasoline is also considered. Methodology for the study included a forecast of new automobile production from 1975 to 1990, development of automobile survival and retirement data, estimates of new platinum demand under various conditions of salvage, and data on recycling the precious metal from the catalytic converters of scrapped vehicles and existing vehicles when their spent converters are exchanged for replacement units. The new platinum demand for automobile exhaust converters, based on a converter service life of 50,000 miles, is estimated to be 1.41 million troy ounces initially in 1975, rising to 1.68 million in 1980, and declining curvilinearly to 0.94 million in 1990. The platinum demand for converter longevities other than 50,000 miles can be derived from the tabular data presented. An appendix to the report presents a comparison between longevities of 50,000 miles and 25,000 miles. The petroleum industry's demand for new platinum for the production of lead-free gasoline could total as high as 1 million troy ounces between 1972 and 1981, just for expansion of isomerization and reforming capacity, and is in addition to normal operating demand for this metal. GPO Stock No. 2404-01212, Catalogue No. I28.27:8565. 65 cents.

IC 8566. Economic Availability of Byproduct Fluorine in the United States (In Two Sections) 1. Utilization of Byproduct Fluosilicic Acid in the Manufacture of Aluminum Fluoride. 2. Utilization of Byproduct Fluosilicic Acid in the Manufacture of Calcium Fluoride, by Robert C. Johnson,

John W. Sweeney, and Walter C. Lorenz. 1973. 97 pp. 5 figs. Domestic byproduct fluorine (in fluosilicic acid) availability at various price levels of aluminum fluoride were determined and a contingency availability curve developed. The supply of byproduct fluosilicic acid is restricted in amount to certain geographic regions, where plants processing phosphate rock are located, and the byproduct can be collected. The maximum possible U.S. annual supply, based on potential plant capacities, is 373,400 tons of fluosilicic acid containing 295,400 tons of fluorine. Based on inputs of 5, 10, 25, 50, and 100 thousand tons per year, five levels of producing aluminum fluoride from fluosilicic acid (100 percent) were costed. Based on a 12-percent discounted cash flow rate, including the cost of salvaging the fluosilicic acid, the calculated selling price of aluminum fluoride ranged from \$233 per ton to \$448 per ton. At the higher price, 98 percent of the potential supply of byproduct fluosilicic acid could be used profitably; at the lower price only 46 percent could be used profitably. GPO Catalogue No. I28.27:8566. Stock No. 2404-01293. \$1.25.

IC 8567. Economic Studies of Uses of the Glass Fractions From Municipal-Incinerator Residues, by Paul W. Johnson and James A. Barclay. 1973. 44 pp. 10 figs. Economic studies of four processes for using the glass fractions obtained from processing municipal incinerator residues are presented. Three processes—brick production, floor tile production, and glass wool production—use the colored glass fraction from an incinerator residue separation plant, and the fourth process, glass spheres production, uses the colorless glass fraction.

The value of the product obtained from each of the plants was calculated on the basis of the interest rate of return method. Each of the processes appears economically attractive when comparing the product values with estimated selling prices. However, the effect of the products on market size and price must be determined. GPO Catalogue No. I28.27:8567. Stock No. 2404-01294. 75 cents.

IC 8568. Coal Mine Health Seminar. A Joint Staff Conference of the Bureau of Mines and the National Institute for Occupational Safety and Health, compiled by Marilyn K. Hutchison, M. D. 1972. 44 pp. 7 figs. Senior staff representatives of the Bureau of Mines and the National Institute for Occupational Safety and Health (NIOSH) met in Washington on September 6, 1972, to review and evaluate their cooperative accomplishments to date and to consider the planning and conduct of future coordinated activities. The six presentations given at this joint staff seminar are published here for the benefit of those concerned with the problems of coal mine health, and especially those with responsibilities in administering the Coal Mine Health and Safety Act of 1969.

IC 8569. The Economics of Byproduct Metals. (In Two Parts).

1. **Copper System,** by Alfred Petrick, Jr., Harold J. Bennett, Karl E. Starch, and Robert C. Weisner. 1973. 105 pp. 44 figs. This study gives an analysis of the copper system byproducts and discusses the identification and classification of byproduct metals and their supply systems. Arsenic, platinum-group metals, silver, gold, selenium, tellurium, molybdenum, rhenium, uranium, aluminum, magnesium, and byproduct copper, lead, and zinc from complex ores are covered. The report describes

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several metallurgical systems, the marginal and incremental products costs of byproduct subsystems, industry structure and organization, and the historical data on price, consumption, and supply. Supply curves are presented for about one-half of the byproduct metals studied.

The study develops a conceptual framework for analysis by reviewing the present concepts of byproduct supply and the related price theory. It gives the sources of supply of the individual byproduct metals to indicate the importance of the byproduct supply to the total supply. Mills, smelters, and refineries processing byproduct materials for their metal content are identified by geographic location and company ownership. The study also includes information on the reserves-resource base supporting byproduct output, reserve estimates, and the demand aspects of each byproduct metal. GPO Catalogue No. I28.27:8569. Stock No. 2404-01341. \$1.50.

IC 8570. The Economics of Byproduct Metals (in Two Parts).

2. **Lead, Zinc, Uranium, Rare-Earth, Iron, Aluminum, Titanium, and Lithium Systems**, by Alfred Petrick, Jr., Harold J. Bennett, Karl E. Starch, and Robert C. Weisner. 1973. 99 pp. 41 figs. This report analyzes the byproducts systems of lead, zinc, uranium, rare earths, iron, aluminum, titanium, and lithium. Specific byproduct metals covered are cadmium, germanium, indium, and thallium from the zinc system; antimony and bismuth from the lead system; vanadium, radium, and scandium from the uranium system; rare-earth oxides from the rare-earth system; and cobalt, gallium, hafnium, and rubidium from other systems. The report discusses various metallurgical systems, marginal and incremental production costs of byproduct subsystems, industry structure and organization, and historical data on price, consumption, and supply. GPO Catalogue No. I28.27:8570. Stock No. 2404-01342. \$1.50.

IC 8571. Subsidence Due to Underground Mining (In Two Parts). 1. Theory and Practices in Predicting Surface Deformation, by Gerhard Braeuner. 1973. 56 pp.

36 figs. The report gives a review of the methods of predicting mine subsidence; these methods are used particularly in European coalfields. The methods are subdivided into two groups, based on mathematical expressions either for the trough profile or for the influence of infinitesimal extraction elements. The fundamental relationships common to all methods described herein are the principles of superposition and of equivalent extraction areas. The involved parameters are derived from field observations. For calculating horizontal displacements, their relation to the slope of the subsidence profile is applied. The time-dependent development of the subsidence process is characterized by the empirical "time factor." Modifications for the case of inclined strata are considered. A brief review of experimental and theoretical model investigations is given. GPO Catalogue No. I28.27:8571. Stock No. 2404-01329. 85 cents.

IC 8572. Subsidence Due to Underground Mining (in Two Parts). 2. Ground Movements and Mining Damage, by Gerhard Braeuner. 1973. 53 pp. 29 figs.

The present knowledge on ground movements and mining damage is mainly based on observations made when mining seamlite deposits. The studies, rules, and regulations in different countries agree in that the differential ground movements, especially the strain, account for the damage to structures. Accordingly, large buildings are particularly sus-

ceptible. The opinions on what amount of ground deformation induces what degree of structural damage are not quite uniform.

Mining damage can be reduced or prevented by structural and/or underground precautions. The latter comprise measures for generally reducing the ground movements (leaving pillars, filling, partial extraction) and for reducing temporary movements (rapid extraction, specially arranged workings). Because the differential movements decrease with increasing depth of mining, safety pillars are largely dispensable at greater depths. Shafts are mainly affected by the vertical derivatives of rock displacements, but extraction in the vicinity of shafts is feasible even under difficult conditions. The theoretical concept of the ground movement process established in part 1 of this work is in qualitative agreement with the facts herein observed. As a quantitative approach, it should be applied to calculating ground surface movements rather than rock movements about underground openings. It can be extended by introducing more detailed strata characteristics. GPO Catalogue No. I28.27:8572. Stock No. 2404-01338. 85 cents.

IC 8573. Availability of Rhenium in the United States, by

K. Shimamoto. 1973. 35 pp. 1 fig. This study has been prompted by the anticipated demand for rhenium by the petroleum industry and the concern for an adequate supply of rhenium to meet the demand. The present and projected outlook for rhenium relative to its distribution and occurrences, the recovery factors involved in ore beneficiation, capital and operating costs, changing technology, and the projected uses and market growth of rhenium are presented in this report as part of the Bureau of Mines program to determine the availability of recoverable rhenium in a developing market. GPO Catalogue No. I28.27:8573. Stock No. 2404-01299. 55 cents.

IC 8574. Iron: A Materials Survey, by Horace T. Reno and Francis E. Brantley. 1973. 117 pp.

16 figs. This information circular surveys the iron ore industry of the world. It presents a comprehensive statistical record through 1970 of the U.S. iron ore industry and world trade patterns. The supply position of the United States and the other principal industrial countries of the world is summarized; detailed information is given on iron ore production, consumption, imports, exports, mine capacities, substitutes, properties, and uses. There is a generalized discussion of the technology of mining and smelting iron ore, with a selected bibliography on the current state of these arts. The circular contains a summary economic account of world iron ore resources, and discussions of the structure of the domestic and principal foreign mining industries, iron ore mine employment and labor productivity, research and development, legislation, government programs, and strategic factors. GPO Catalog No. I28.27:8574. Stock No. 2404-01339. \$2.10.

IC 8575. Offshore Petroleum Studies. Historical and Estimated Future Hydrocarbon Production From U.S. Offshore Areas and the Impact on the Onshore Segment of the Petroleum Industry, by L. K. Weaver, C. J. Jirik, and H. F. Pierce. 1973. 30 pp. 10 figs.

The purposes of this Bureau of Mines report are to review the history of the domestic offshore hydrocarbon production; to project offshore oil and lease condensate production from 1971 through 1985; and

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to show the impact of offshore development on the onshore segment of the petroleum industry.

Since 1954, offshore production has provided an increasingly larger portion of the domestic oil production. Domestic offshore oil and lease condensate production has increased from about 2.0 pct of the U.S. total in 1954 to 16.7 pct in 1970. Likewise, marketed gas production has increased from 1.0 pct of the U.S. total in 1954 to 15.0 pct in 1970. The past performance of exploration, leasing, development, and production of the offshore petroleum industry was used to make projections of offshore oil production. A comparison between onshore and offshore operations was also made. Assuming a tentative Department of the Interior offshore leasing schedule is completed by 1980, the authors estimate that by 1985, about 30 pct of domestic crude oil and lease condensate production from the lower 48 States will come from offshore areas. Currently, leasing of Federal offshore areas has been delayed owing to environmental considerations. The rate at which offshore hydrocarbons will enter the energy market will depend, to a large extent, on how soon environmental considerations are resolved. Assuming that offshore leasing will resume in the near future, U.S. offshore production of crude oil and lease condensate should be about 934 million barrels in 1985. GPO Catalogue No. I28.27:8575. Stock No. 2404-01300. 65 cents.

IC 8576. Methods and Costs of Coal Refuse Disposal and Reclamation, by Staff, Bureau of Mines. 1973. 36 pp. 22 figs. The Bureau of Mines is active in programs pertaining to solid waste disposal and land reclamation. Nine reclamation projects of mining companies and six projects of the Commonwealth of Pennsylvania were investigated to provide information on the procedures, costs, and results obtained from reclamation projects of bituminous coal-waste disposal areas. Refuse disposal costs of mining companies ranged from 9 to 28 cents per ton-mile, and quantities disposed of ranged from 600 to 4,500 tons per day. Spreading and compacting the refuse at the dump site ranged from 3 to 20 cents per ton. Cost of covering with soil and planting ranged from \$750 to \$1,646 per acre. Total costs of reclamation for the Pennsylvania projects ranged from about \$1,800 to more than \$15,000 per acre. Refuse preparation costs ranged from \$772 to \$5,550 per acre. Soil covering and planting costs ranged from \$1,083 to \$5,086 per acre. The best results were obtained by soil preparation and conditioning prior to planting. The type and depth of soil and effect of climate were also factors. GPO Catalogue No. I28.27:8576. Stock No. 2404-01289. 70 cents.

IC 8577. The Application of Remote Sensing to Air Pollution Detection and Measurement, by Brian M. Harney, Donald H. McCrea, and A. J. Forney. 1973. 21 pp. 7 figs. The technique of remote sensing, used for many years by earth scientists, is being applied to the detection and monitoring of air pollution. Instrumentation being developed is of a very diverse nature and is effective, in varying degrees, at ranges from 1,000 meters to the altitude of a space satellite. This paper describes a number of the recent developments in this new field. Instruments based on spectroscopic, laser, and photographic systems are discussed. Sensors are being developed which utilize correlation spectrometry, interferometry, Raman scattering, Mie scattering, laser line absorption, and simple photographic detection. GPO Catalogue No. I28.27:8577. Stock No. 2404-01308. 60 cents.

IC 8578. How To Find Abandoned Wells: A Manual, by Kenneth H. Johnston, Herbert B. Carroll, R. J. Heemstra, and F. E. Armstrong. 1973. 51 pp. 25 figs. This guide was written to furnish the coal industry with a description of techniques, instruments, and clues on how to find abandoned oil and gas wells that have penetrated coal seams. The report includes specific information on searching techniques currently in use by several coal mining companies, gas-transmission companies, and water-flood operators, as well as information on State agencies responsible for the enforcement of laws and the preservation and distribution of data pertaining to the drilling, development, and abandonment of oil and gas wells. Comparative tests were performed with several commercial electronic metal detectors to determine the feasibility of using them to aid in the search for abandoned wells and to determine the instrument most suited for that particular use. The role of methane detectors to locate abandoned wells is described, including a case history. Tests were made to develop an efficient procedure to follow in systematically searching an area for metallic clues or hydrocarbon evidence to abandoned wells. The guide describes, in detail, a search sequence, including the collection of basic data, preparation of the selected area, and the physical search. Methods are given for evaluating the results. GPO Catalogue No. I28.27:8578. Stock No. 2404-01314. 75 cents.

IC 8579. Radiation Halos and Hydrocarbon Reservoirs: A Review, by F. E. Armstrong and R. J. Heemstra. 1973. 52 pp. 8 figs. This Bureau of Mines publication reviews 237 papers on radiometric prospecting, which is the measurement of naturally occurring radioactivity in the earth's surface and its application to petroleum and natural gas exploration. Many theories and documented surveys are listed in both support and refutation of this reported phenomenon, and the Bureau of Mines is conducting research to obtain direct field information in order to determine the statistical credibility of a radiometric method of predicting petroleum accumulation. GPO Catalogue No. I28.27:8579. Stock No. 2404-01346. 80 cents.

IC 8580. Materials Handling Research: The Bucket-Wheel Excavator, by G. C. Price, C. B. Manula, and Rajaraman Venkataramani. 1973. 79 pp. 15 figs. This study traces the development of the bucket-wheel excavator, points out the differences in the German- and American-type wheels, and gives the major design criteria and the advantages and disadvantages of bucket-wheel operations. A computer program, written in FORTRAN IV for use with an IBM 360 computer, simulates the operation of the digging components of a bucket-wheel excavator. By supplying certain mining dimensions, soil characteristics, and machine design specifications, this program will print out a time study of the various components of an operation, power calculations for the operation, and production data. This program, when combined with a truck, belt, or rail program, should be helpful in planning a complete mining system in material suitable for a bucket-wheel excavator operation. GPO Catalogue No. I28.27:8580. Stock No. 2404-01355. \$1.00.

IC 8581. Technologic Trends in the Minerals Industry, 1971, by Staff, Bureau of Mines. 1973. 61 pp. 8 figs. This report, the second in an annual series, summarizes information on latest technological de-

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velopments and advances, and identifies trends in mining and metallurgy based on a review of activities in the minerals industry in 1971. Exploration and mining data obtained from an annual canvass are presented for 1971 and are compared with similar data obtained over the past decade. GPO Catalogue No. I28.27:8581. Stock No. 2404-01328. 90 cents.

IC 8582. Procedures for Evaluating Hazards to Coal Mining Operations From Hydrocarbon Reservoirs, by James A. Wasson and Charles E. Whieldon, Jr. 1973. 42 pp. 13 figs. Because of the danger to life and property in a coal mine if an oil or natural gas well should be accidentally intersected during mining operations, certain precautionary measures should be carried out prior to entering previously unmined areas. The locations of all wells both at the surface and at the depth of the coalbed should be accurately determined. The condition of the well should be learned from surface observations, and more importantly, from subsurface examination by geophysical logging devices where possible. It is also desirable to learn the physical properties of the hydrocarbon-bearing rock formation and the hydrocarbon fluids. The major hazard presented by oil or natural gas wells to mining operations is that of explosion and fire owing to the rapid release of gas into the mine atmosphere. Wellbore pressure, the principal index of danger, should be determined by one or more of the methods described and by a service company such as those listed in the appendix. Because of high pressures involved and the consequent hazard, much emphasis has been placed on underground storage of natural gas in areas containing minable coalbeds. Maps of the principal coal producing areas and the locations of currently active gas storage reservoirs are shown. A checklist has been included of factors to be considered when mining coal in an area where oil or gas wells exist. GPO Catalogue No. I28.27:8582. Stock No. 2404-01356. 75 cents.

IC 8583. Effects of Direct Reduction Upon Mineral Supply Requirements for Iron and Steel Production, by Richard J. Leary and Gary M. Larwood. 1973. 94 pp. 13 figs. The technologies of contemporary iron and steel production and of direct reduction processes have been studied to identify and estimate the potential effects of direct reduction on mineral consumption and the problems raised thereby for the Nation's mineral supply to the iron and steel industry. Contemporary patterns of mineral raw material and energy consumption were determined from a study of the 1964-70 period. Major changes were observed in requirements for 14 of 20 principal commodities. Average practice in 1970 was compared to best practice to estimate the potential effects of implementing existing technology without recourse to direct reduction. Potential effects of direct reduction were estimated by comparing the mineral requirements for 95 percent reduced pellets with 1970 best practice technology for two cases of use: (1) Complete substitution for hematite pellets in blast furnace burdens and (2) partial substitution (40 percent) for scrap in electric furnace steel charges. Effects upon mineral supplies are described; important collateral factors are analyzed, and the principal metallurgical, industrial, and environmental consequences of implementing direct reduction are discussed. Major effects of direct reduction on the domestic steel industry and its mineral supply system are foreseeable. Direct reduction will (1) cre-

ate a large demand for low-gangue iron ore, (2) relieve the dependence of the steel industry on coking coal, and (3) permit great increases in furnace productivity, both in blast furnace ironmaking and electric arc furnace steelmaking. GPO Catalogue No. I28.27:8583. Stock No. 2404-01383. \$1.25.

IC 8584. Mechanical Properties and Cutting Characteristics of Coal, by Parviz F. Rad. 1973. 46 pp. 47 figs. This Bureau of Mines report reviews laboratory and in-mine techniques for determining mechanical properties of coals, with special emphasis on the relationship between these properties and the minability of coal. An extensive bibliography is included. GPO Catalogue No. I28.27:8584. Stock No. 2404-01369. 75 cents.

IC 8585. Rock Mechanics Instrumentation for Mine Design. Proceedings: Bureau of Mines Technology Transfer Seminar, Denver, Colo., July 25, 1972, compiled by the Technology Transfer Group, Office of the Assistant Director—Mining. 1973. 76 pp. 49 figs. This report contains the papers presented at the Technology Transfer Seminar on Rock Mechanics Instrumentation for Mine Design held by the Bureau of Mines on July 25, 1972, in Denver, Colo. Seminar attendance consisted of representatives from coal, metal and nonmetal mining industries, universities, mining consultants, instrument manufacturers, and other Government agencies. The purpose of this meeting, the first in a series of seminars, was to present the philosophy and mode of operation of the Technology Transfer Program, to give an overview of the Bureau's progress in mine structural design methods, and to describe their latest instrumentation developed for rock mechanics investigations in coal and metal mines. The report includes the opening remarks by the Bureau of Mines Deputy Director—Mineral Resources and Environmental Development, who discussed the new Technology Transfer efforts; three papers on mine design; four papers on instrumentation; and a summary.

IC 8586. Historical Injury Experience in Quarrying (in Three Parts). 1. 1964-65, by Donald E. Redmon and Leonard P. Larson. 1973. 164 pp. 1 fig. This Bureau of Mines report examines the injury experience in the quarrying industry for the years 1964-65. Twenty-eight tables for each year are presented in which disabling work injuries are summarized by department, source of injury, extent of disability, part of body injured, and nature of injury. Correlative information on employment, worktime, and operating activity is also presented.

IC 8587. Historical Injury Experience in Quarrying (in Three Parts). 2. 1966-67, by Donald E. Redmon and Leonard P. Larson. 1973. 174 pp. 1 fig. This Bureau of Mines report examines the injury experience in the quarrying industry for the years 1966-67. Twenty-eight tables for each year are presented in which disabling work injuries are summarized by department, source of injury, extent or disability, part of body injured, and nature of injury. Correlative information on employment, worktime, and operating activity is also presented.

IC 8588. Historical Injury Experience in Quarrying (in Three Parts). 3. 1968-69, by Donald E. Redmon and Leonard P. Larson. 1973. 174 pp. 1 fig. This Bureau of Mines report examines the injury experience in the quarrying industry for the years 1968-69. Twenty-eight tables for each year are-

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presented in which disabling work injuries are summarized by department, source of injury, extent of disability, part of body injured, and nature of injury. Correlative information on employment, worktime, and operating activity is also presented.

IC 8589. Historical Injury Experience in the Metallic Mineral Industries (in Two Parts) 1. 1966-67, by Donald E. Redmon and Leonard P. Larson. 1973. 122 pp. 1 fig. This Bureau of Mines report reviews injury experience in the metallic mineral industries for 1966-67. For each of the years, 27 tables summarize disabling work injuries by department, source of injury, extent of disability, part of body injured, and nature of injury. Correlative information on employment, worktime, and operating activity is also presented.

IC 8590. Historical Injury Experience in the Metallic Mineral Industries (in Two Parts) 2. 1968-69, by Donald E. Redmon and Leonard P. Larson. 1973. 120 pp. 1 fig. This Bureau of Mines report reviews injury experience in the metallic mineral industries for 1968-69. For each of the years, 27 tables summarize disabling work injuries by department, source of injury, extent of disability, part of body injured, and nature of injury. Correlative information on employment, worktime, and operating activity is also presented.

IC 8591. Historical Injury Experience in the Nonmetallic Mineral Industries (Except Stone and Coal) (in Two Parts) 1. 1966-67, by Donald E. Redmon and Leonard P. Larson. 1973. 128 pp. 1 fig. This Bureau of Mines report reviews injury experience in the nonmetallic mineral industries (except stone and coal) for 1966-67. For each of the years, 23 tables summarize disabling work injuries by department, source of injury, extent of disability, part of body injured, and nature of injury. Correlative information on employment, worktime, and operating activity is also presented.

IC 8592. Historical Injury Experience in the Nonmetallic Mineral Industries (Except Stone and Coal) (in Two Parts) 2. 1968-69, by Donald E. Redmon and Leonard P. Larson. 1973. 122 pp. 1 fig. This Bureau of Mines report reviews injury experience in the nonmetallic mineral industries (except stone and coal) for 1968-69. For each of the years, 23 tables summarize disabling work injuries by department, source of injury, extent of disability, part of body injured, and nature of injury. Correlative information on employment, worktime, and operating activity is also presented.

IC 8593. Determining Discounted Cash Flow Rate of Return and Payout Time for Onshore Development Wells. A Graphical Method, by T. M. Garland, W. D. Dietzman, and J. G. Thompson. 1973. 8 pp. 2 figs. A nomographical approach is proposed as a fast, easy-to-use, and reasonably accurate method for estimating expected discounted cash flow rate of return and payout time for onshore development drilling and oil production. All costs pertaining to drilling, completing, and equipping development wells, annual expenses of operation, maintenance, and taxes incurred in producing properties, and crude oil prices were considered in developing the nomographs. This report briefly outlines the origin, derivation, and use of the nomographs.

IC 8594. A Method for Calculating Mine Ventilation Pressure Losses Using Computers and Desk-Top Calculators.

A Supplement to Information Circular 7809, by E. J. Harris, R. W. Dalzell, R. J. Kline, and E. J. Miller. 1973. 22 pp. 6 figs. Data obtained from mine ventilation pressure and quantity surveys are required to accurately diagnose ventilation problems, project future air quantity needs, and locate conditions adversely affecting the efficiency of a mine ventilation system. A method for making mine ventilation pressure surveys with aneroid altimeters was presented in Bureau of Mines Information Circular 7809, and a description of field calculation technique is presented. This report supplements Information Circular 7809 by developing the information obtained during a mine ventilation pressure survey into a single equation suitable, with appropriate modification, for use with desk-top calculators and digital computers. The equation can be used to calculate the ventilation pressure from the base station to any underground station, or between any two underground stations, and can be programmed for semiautomatic sequential calculation using a desk-top calculator. An example of application to a programmed desk-top calculator is provided in the appendix.

IC 8595. Bureau of Mines Research Programs on Recycling and Disposal of Mineral-, Metal-, and Energy-Based Wastes,

by C. B. Kenahan, R. S. Kaplan, J. T. Dunham, and D. G. Linnehan. 1973. 54 pp. 27 figs. A summary of Bureau of Mines research on recycling, reuse, and disposal of mineral-, metal-, and energy-based wastes is presented, accompanied by an extensive bibliography of related publications. The Bureau's waste recycling and disposal program is directed toward the following four main areas of research and development: (1) extraction of mineral, metal, and energy values from urban refuse; (2) upgrading and recycling of automotive and related ferrous and nonferrous scrap; (3) recovery, utilization, and stabilization of mine and mill processing wastes; and (4) recovery and reuse of values from industrial waste products.

This publication updates Bureau of Mines Information Circular 8529, which was issued August 1971.

IC 8596. An Economic Analysis of the Junk Automobile Problem,

by Robert Louis Adams. 1973. 168 pp. 38 figs. A general discussion of the structure of the junk automobile recycling system shows that the generation of stripped automobile hulks and scrapped automobiles is price inelastic. As a result, it is extremely difficult for the price mechanism to automatically achieve an equilibrium that will prevent the accumulation of excessive automobile wrecker inventories and vehicle abandonment by the last owners of scrapped cars. The new shredder processing technology and the new portable flattener technology have altered the structure of the junk automobile recycling system. The shredder technology has increased the demand for processed automobile scrap. This increased demand is reflected in higher prices paid for hulks by scrap processors. The portable flattener has reduced the transportation cost of shipping hulks to processors. The two new technologies have eliminated, at least potentially, the net cost of shipping stripped hulks so frequently incurred by wreckers in the past. The elimination of this cost eliminates the economic incentive for excessive wrecker inventories. Unfortunately, the incentive for last owners to abandon their cars does

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not appear to have been eliminated by the new technologies. The last owner of an automobile with no spare parts value is still likely to incur a cost by delivering his automobile to the recycling system. Although a subsidy payment is probably unnecessary to reduce excessive wrecker inventories, such a payment might be one solution to the problem of automobile abandonment. However, there are a wide variety of subsidy programs that could be introduced. Before any Federal subsidy program is introduced to reduce automobile abandonment, it is recommended that the program be tested on a limited basis in many different parts of the country. Catalogue No. I28.27:8596. Stock No. 2404-01405. \$2.35.

IC 8597. Active List of Permissible Explosives and Blasting Devices Approved Before December 31, 1972. Supersedes Information Circular 8493, by J. Ribovich and R. W. Watson. 1973. 10 pp. The current Bureau of Mines active list of permissible explosives includes 71 brands. Eleven are gelatinous, 56 are the granular type, and four are water-gel explosives, an entirely new type of ammonium nitrate-based explosive for use in coal mines. The list of permissible blasting comprises five Cardox models.

IC 8598. An Economic Appraisal of the Supply of Copper From Primary Domestic Sources, by Harold J. Bennett, Lyman Moore, Lawrence E. Welborn, and Joseph E. Toland. 1973. 156 pp. 35 figs. This study was performed by the Bureau of Mines to evaluate the potential supply of primary copper from domestic resources. A tonnage-price relationship was developed indicating the quantity of copper that could be produced economically from known deposits at various copper prices and at various rates of return on the required capital investment. Costs of production are based on estimated capital and operating costs for mining, concentrating, smelting, and refining the copper. Total known recoverable copper resources are 189 million short tons of which 83 million tons could be economically recovered assuming a price of \$0.50 per pound of copper, credit for the recovery of byproducts, and a 12-percent rate of return on capital investment. The quantities of recoverable byproducts associated with the 83 million tons of recoverable copper are molybdenum, 1.8 million tons, gold, 43 million troy ounces, and silver, 740 million troy ounces. GPO Stock No. 2404-01416; Catalog No. I28.27:8598. \$2.10.

IC 8599. Injury Experience in Coal Mining, 1969, by Forrest T. Moyer and Mary B. McNair. 1973. 113 pp. 3 figs. In 1969, the number of fatal injuries in the coal mining industry was lower than in any previous year and the number of nonfatal injuries was lower than in any preceding year except 1968. Fatal injuries in 1969 totaled 203 with frequency rates of 0.85 per million man-hours of worktime and 0.36 per million tons of coal. These rates were new annual lows. Nonfatal injuries totaled 9,917 with frequency rates of 41.76 per million man-hours and 17.42 per million tons. The severity rate for fatal and nonfatal injuries combined was 7,359 days lost or charged per million man-hours. The average severity was 173 days lost or charged per injury. These statistics represent the injury experience of an average of 133,302 employees per day, working an average of 225 days in 5,955 coal mines for a total of 237.5 million man-hours worked and a coal output of 569.2 million tons.

IC 8600. Methane Control in United States Coal Mines—1972, by M. G. Zabetakis, Maurice Deul,

and M. L. Skow. 1973. 23 pp. 16 figs. This Bureau of Mines report presents a brief summary of the explosion trends in United States coal mines for the past 160 years. These trends show that in spite of the overall improvements in mine safety, the number of fatalities from ignitions of methane has actually increased in recent years. Suggestions are made of procedures that can be utilized to reverse this trend.

IC 8601. Corrosion Resistance of Metals in Hot Brines: A Literature Review, by Lloyd H. Banning and Laurance L. Oden. 1973. 39 pp. With the ever-increasing demand for energy in all forms, electrical energy generated from geothermal resources could become an important energy source in the next few decades. Geothermal fluids, which contain appreciable quantities of dissolved salts and gases, are generally corrosive to materials of construction. Since data on corrosion of materials in geothermal brines is limited, the literature was surveyed through February 1972 to obtain a compilation of information on corrosion resistance of aluminum and its alloys, copper and copper-base alloys, carbon steel and cast iron, stainless steels, chromium-iron alloys, nickel- and cobalt-base alloys, and titanium in heated brines including sea water. GPO Stock No. 2404-01435; Catalog No. I28.27:8601. 70 cents.

IC 8602. Estimated Costs To Produce Copper at Kennicott, Alaska, by R. P. Maloney and R. G. Bottge. 1973. 35 pp. 3 figs. The economic viability of four depleted mines near Kennicott, Alaska, was determined by the Bureau of Mines to assess their profitability if they were developed today and thus estimate cost data for a medium-sized mine, mill, and town complex. This information should help the State and Federal Governments appraise the potential development of similar-sized mining operations in Alaska. Modern conventional mining and milling techniques were assumed, and capital and operating costs were derived using flowsheets and standard costing methods. A total capital investment of \$37.6 million was necessary to install a 1,000-ton-per-day shrinkage stope mine, flotation-type mill, and support facilities; capital requirements were divided about evenly among the three components. Operating costs, including labor, supplies, power, water, and indirect and fixed costs, totaled \$42.79 per ton of ore; the mining accounted for nearly one-half the cost. To obtain a 12-percent discounted cash flow rate of return on investment, the analysis showed that the ore could be mined and milled, and the concentrate could be trucked via public roads to a dock facility in Valdez, Alaska, barged to Tacoma, Wash., and smelted and refined for 34.7 cents per pound for copper and 104.0 cents per ounce for silver. The average May 1972 price was 52.6 cents for copper and 158.3 cents for silver. The same set of data was used to examine the economic viability of the mine with the cost of constructing a private road from McCarthy, Alaska, to Valdez, Alaska. The 148-mile road added \$53.3 million to the original capital costs and raised the required price of copper to 57.4 cents per pound and the required price of silver to 172.0 cents per ounce. The additional cost of building, maintaining, and paying taxes on a private road from McCarthy, Alaska, to Valdez would make this venture uneconomical. GPO Catalog No. I28.27:8602. Stock No. 2404-01431. 45 cents.

IC 8603. Technologic and Related Trends in the Mineral Industries, 1972, by Staff, Bureau of Mines.

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1973. 44 pp. 19 figs. This report, the third in an annual series, outlines recent trends and developments in the minerals industry. Discussed are new methods, equipment, techniques, and systems used to more effectively extract and process minerals and fuels. Environmental considerations, reduced ore grades, and the related increased quantities of material handled were the dominant concerns of the minerals industry in 1972. Productivity increased in most mineral commodities as equipment became more mobile, versatile, and sophisticated. Increasingly, equipment designs incorporated health and safety features. There was considerable interest in the field of energy and in pollution-free metallurgy processes. GPO Catalogue No. I28.27:8603. Stock No. 2404-01388. 75 cents.

IC 8604. Gold-Lode Deposits, Fairbanks Mining District, Central Alaska, by Bruce I. Thomas. 1973. 16 pp. 4 figs. The Fairbanks mining district forms an arc 40 miles long and 8 miles wide on the north side of the Tanana Valley in central Alaska. This is a region of broad valleys and rounded hills that range in elevation from 600 to 2,600 feet. Lode-gold production started in 1910 and has continued sporadically to the present, but the largest single mine produced only 40 tons per 24-hour day. Total recorded lode-gold production of the district is 241,000 fine troy ounces of gold from ore that averaged 1.32 fine ounces per ton. The ore was mined chiefly from narrow veins and veinlets aligned along anticlinal folds at Ester Dome and the Pedro Dome-Cleary area. The only proven reserves are reported to be at the Ryan Lode at Ester Dome and at the Keystone Mines, Inc., holdings in the Pedro Dome-Cleary area. An inferred lode-gold resource for the district of approximately 4 million ounces is considered to indicate only the order of magnitude of the lode-gold potential because of the absence of detailed data needed to evaluate the numerous deposits.

IC 8605. Card-Gap and Projectile Impact Sensitivity Measurements, A Compilation, by Richard W. Watson. 1973. 12 pp. Card-gap and projectile impact sensitivity data are presented for a wide variety of explosive compositions tested at the Bureau of Mines in more or less standard test geometries. The results of both tests are in good agreement in that they provide the same sensitivity ordering for different subclasses of explosives. Least sensitive were homogeneous liquids that did not exhibit a tendency to undergo low-velocity detonation, ammonium nitrate-fuel oil, and most cast military explosives. Of intermediate sensitivity were pressed and powdered military explosives, cast pentolite, permissible and non-permissible water-based explosives, and one commercial two-component explosive. The most sensitive were permissible and nonpermissible dynamites and explosives susceptible to low-velocity detonation.

IC 8606. Computer Program for Calculating Equilibrium Composition of High-Temperature Combustion Products, by Michael W. Redifer and John S. Wilson. 1973. 42 pp. 10 figs. A Fortran IV computer program was developed to calculate the composition at equilibrium of products from a set of high-temperature gas combustion reactions. The program was used to develop high-temperature equilibrium concentration profiles for various constituents as a function of temperature and oxygen concentration. The computer program was specifically applied to reactions pertaining to the corrosion of superheater tubes in pulverized coal-fired boilers; however, it is

useful for any multicomponent, multireaction scheme in which equilibrium constant data can be obtained and is comprised of gaseous reactants along with finely dispersed solids or liquids. General applicability of the computer program, including its limitations, are discussed along with detailed instructions for using the program. GPO Catalogue No. I28.27:8606. Stock No. 2404-01441. 80 cents.

IC 8608. Sulfur Dioxide: Its Chemistry as Related to Methods for Removing It From Waste Gases, by Larry A. Haas. 1973. 19 pp. 1 fig. The chemistry of current or potential SO₂ removal processes can be placed into four categories: (1) reduction, (2) liquefaction, (3) direct dissolution, and (4) oxidation. Methods that involve reducing SO₂ to elemental sulfur appear promising since this product can be easily handled, shipped, and stockpiled. Unfortunately, SO₂ cannot always be reduced directly when other oxidizing agents are present. Thermodynamic data indicate that some oxidizing reagents will also consume reductant at the reduction temperature. A two-stage process can be applied to waste gases that contain excessive quantities of oxygen, nitrogen oxides, and water vapor. The best sorbent for the first stage appears to be a nonalkali or nonalkaline earth medium since this medium more readily releases the SO₂ for reduction in the second stage.

IC 8607. Analyses of Natural Gases, 1972, by L. E. Cardwell and L. F. Benton. 1973. 104 pp. This publication contains routine analyses and related source data for 299 natural gas samples from 22 States and three foreign countries. All of the samples were collected during calendar year 1972 as part of a continuous survey of the free world for occurrences of helium in natural gas. This survey has been conducted in the United States by the Bureau of Mines since 1917. In late 1965, the survey was expanded to include foreign gasfields. The analyses published herein were made by mass spectrometer and a special helium analysis apparatus, which are described in Bureau of Mines Bulletins 486 and 576. GPO Catalogue No. I28.27:8607. Stock No. 2404-01433. \$1.25.

IC 8609. Offshore Petroleum Studies: Nomograph for Estimating Hydrocarbon Lease Bonus Bids in the Gulf of Mexico. Supplement to Bureau of Mines IC 8557, by L. K. Weaver, H. F. Pierce, C. J. Jirik, and J. G. Thompson. 1973. 12 pp. 2 figs. The objective of this Bureau of Mines publication is to present a nomograph that provides a fast, convenient method for estimating hydrocarbon lease bonus bids for offshore acreage in the Gulf of Mexico. Discounted cash flow analyses were computed from a model derived to show the costs necessary to explore, acquire, develop, produce, and abandon a 5,000-acre block of offshore acreage, and the estimated income from the sale of the hydrocarbons produced from the block. The range of the variables in the financial analyses used to construct the nomograph are prices of oil, \$2.50 to \$5.00; recoverable hydrocarbon reserves, 44,651,476 to 127,575,645 barrels; and discounted cash flow (DCF) rates of return, 5.0 to 57.2 percent. A total of 1,234 sets of DCF data were used to construct the nomograph. The range of bonus bids shown on the nomograph is from 2 to 90 million dollars (\$400 to \$18,000 per acre). GPO Catalogue No. I28.27:8609. Stock No. 2404-01467. 40 cents.

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IC 8610. Summary of Mining and Petroleum Laws of the World (in Five Parts). 4. Africa, by Northcutt Ely. 1974. 205 pp. This volume summarizes mining and petroleum legislation in 45 African jurisdictions. Within these jurisdictions, primary attention is given to requirements that must be met in each country for acquisition of rights to permit development of mineral resources. Coverage includes: First, identification of the controlling laws or statutes governing minerals acquisition and reference to the administrative authority; second, analysis of the laws governing mines and quarries and their products; third, analysis of laws applicable to natural gas, petroleum, and related materials; and fourth, mention of laws regulating offshore operations. Where pertinent, sections dealing with historical background or administration have been added. In countries where minerals are subject to control of states or provinces, those areas are considered separately from the central government. GPO Catalog No. I28.27:8610. Stock No. 2404-01528. \$2.55.

IC 8611. Thermodynamic Data for Air Preheaters in Direct Coal-Fired Magnetohydrodynamic Power Generation Systems, by F. E. Spencer, Jr., and J. C. Hendrie, Jr. 1973. 53 pp. Calculated equilibrium data are presented for three phases in the flue gas stream from a hypothetical open-cycle magnetohydrodynamic (MHD) generator. A typical coal is "burned" with 1.0 gram-mole K_2O seed per kilogram coal and with 101 percent of stoichiometric air. Tables of composition and the overt thermodynamic properties, enthalpy and entropy, are given for the temperatures 2,200 down to 1,100 K in decrements of 100 K, at pressures of 1.0 and 1.5 atmospheres, and slag rejection figures of 90 and 75 percent. GPO Catalog No. I28.27:8611. Stock No. 2404-01490. 85 cents.

IC 8612. Bureau of Mines Energy Program, 1972, by Bill Linville and John D. Spencer. 1973. 107 pp. 53 figs. During calendar year 1972, the Bureau of Mines was engaged in some 20 major areas of research for the development of new and improved efficient methods of conservation and utilization for petroleum and natural gas, oil shale, and coal. Made up of numerous projects described in this report, the program was carried out through research performed at research centers and laboratories in the field supervised and supported by administrative personnel of this Bureau of the Department of the Interior. Based on this research, 186 technical reports were published by the Bureau or others, and numerous other reports were prepared for Federal agencies, State agencies, and organizations engaged in cooperative research programs with the Bureau.

IC 8613. Injury Experience in Coal Mining, 1970, by Forrest T. Moyer and Mary B. McNair. 1973. 135 pp. 8 figs. All general measures of the safety record of the coal mining industry worsened appreciably in 1970. Injury experience for the year was 260 fatal and 11,552 nonfatal injuries at respective frequency rates of 1.00 and 44.40 per million man-hours of worktime. The fatality total was 57 higher and the rate of occurrence was 18 percent higher than the corresponding figures of 203 fatal injuries with a frequency rate of 0.85 in 1969. The worsened fatality record in 1970 resulted primarily from a major disaster (a single accident which results in the death of five men or more) on December 30, 1970, that killed 38 men. There were no major disasters in 1969. The total of 11,552 nonfatal in-

juries in 1970 was the highest annual total since 1960. It was 1,635 higher and the frequency rate was 6 percent higher than the corresponding totals for 1969 of 9,917 nonfatal injuries occurring at a rate of 41.76. The injury severity rate of 8,308 days lost or charged per million man-hours was 13 percent worse than that of 7,359 in 1969. Similarly, the average severity of 183 days lost or charged per injury in 1970 was 10 days or 6 percent higher than in 1969. Aggregate worktime of 260.2 million man-hours and production of 609.8 million tons in 1970 were, respectively, 10 and 7 percent higher than in 1969.

IC 8614. Comparative Transportation Costs of Supplying Low-Sulfur Fuels to Midwestern and Eastern Domestic Energy Markets, by P. H. Mutschler, R. J. Evans, and G. M. Larwood. 1973. 54 pp. 16 figs. The Bureau of Mines studied the costs of transporting fossil fuels, coal, and residual fuel oil from areas of production to consumer regions. Transportation data were stratified by type of carrier, size of shipment, and distance to determine what general effects these variables have upon transportation costs. Economies of haul for coal exist for longer versus shorter distances, and for larger versus smaller trainload sizes. Tanker and barge transportation of residual fuel oil does not show economies of haul for longer distances. It is shown that tanker size and seasonal variation are primary factors influencing the cost of shipping. Railroad transportation data show that coal from western coalfields could be competitive with foreign residual fuel oil in selected midwestern fossil fuel markets. However, the western coal would not be competitive in the New England and the eastern seaboard energy markets. GPO Catalog No. I28.27:8614. Stock No. 2404-01502. 85 cents.

IC 8615. Determination of Attitudes of Joints Surveyed With a Borescope in Inclined Boreholes, by M. A. Mahtab, D. D. Bolstad, and R. R. Pulse. 1973. 12 pp. 5 figs. This report describes the procedures used by the Bureau of Mines for obtaining attitudes of joints surveyed with a borescope in inclined boreholes. An algorithm for computing the dips and azimuths of the observed joints is presented. The algorithm is used to solve an example problem. A computer program based on the algorithm is listed. It is hoped that the procedures described here will be useful in treating large quantities of data obtained from comprehensive borehole surveys.

IC 8616. Recent Developments in Coal Mine Fire and Explosion Prevention Research, by Joseph Grumer. 1973. 21 pp. 22 figs. Reported fiscal year 1973 studies of fires and explosions seek to develop capabilities during mining operations to detect and quench ignitions of gas in the face area, to detect and quench by means of passive or triggered barriers explosions propagating in rock-dusted coal dust, and to detect incipient fires early enough for easy extinguishment. Research discussed includes minimum air velocities to lift coal or rock dusts, surveys to determine adequacy of rock dusting, chemical agents to quench gas or coal dust explosions and their relative efficacies, spectra radiated by explosions, and nozzle sprays of extinguishants.

IC 8617. A Bureau of Mines Direct-Reading Azimuth Protractor, by D. D. Bolstad and M. A. Mahtab. 1974. 7 pp. 4 figs. This report describes the construction and use of a direct-reading azimuth pro-

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tractor (DRAP) by the Bureau of Mines for measuring fracture orientations in mines, tunnels, or other excavations having a magnetic environment. The DRAP allows a rapid and simultaneous measurement of dip and azimuth of dip of a fracture plane. The instrument is rugged, lightweight, and easily constructible from standard hardware items. The DRAP can measure dip to within $\pm 0.5^\circ$ and azimuth of dip to within $\pm 5^\circ$ of corresponding values obtained with a Brunton compass.

IC 8618. Overcoring Equipment and Techniques Used in Rock Stress Determination, by Verne E. Hooker and David L. Bickel. 1974. 32 pp. 29 figs. Stress-relief techniques and instrumentation have been developed through many years of research in the Federal Bureau of Mines and successfully used to determine the in situ state of stress in rock. This paper describes the drilling equipment and accessories for use with the Federal Bureau of Mines three-component deformation borehole gage. Operation and calibration procedures for the deformation gage are discussed in detail. Site selection and overcoring procedures are included to provide a complete working knowledge for surface or underground applications.

IC 8619. Technique To Improve Fuel Extraction For Coal Seams Intersected by Oil and Gas Wells, by Richard David Haynes. 1973. 19 pp. 7 figs. Coal, gas, and oil in many geological formations of the Eastern United States are intimately associated but have traditionally been recovered independently of each other. Oil and gas wells, however, are often spaced sufficiently close to cause the subsequent loss of up to 50 percent of the recoverable coal in the form of pillars or barriers left for mine safety purposes. A long-range planning technique was devised for exploiting oil and gas wells simultaneously with the mining of coal to recover the maximum fuel potential of the formations. Planned plugging of oil and gas wells, determined partly from production predictions via decline curve analysis, is coordinated with a mine development plan to achieve maximum coal recovery and reduce overall production losses of gas and oil due to plugging of the wells. Catalog No. 128.27:8619. Stock No. 2404-01498. 50 cents.

IC 8620. Control of Fires in Abandoned Mines in the Eastern Bituminous Region of the United States. A Supplement to Bulletin 590, by M. O. Magnuson. 1974. 53 pp. 45 figs. This publication describes abandoned-mine fire-control work administered by the Bureau of Mines under cooperative agreements with State and local governments. The work was done by private contractors under the supervision of Bureau engineers. The work is authorized by Public Law 738, approved August 31, 1954, and Public Law 89-4, approved March 9, 1965. Earlier work was authorized by Interior Department Appropriations Acts for fiscal years 1949-55. A total of 70 fires have been controlled under this program in the eastern bituminous region. The nature and extent of the abandoned-mine fire problem in the bituminous region is discussed, and the methods used for controlling these fires are described. The methods that have been used, either singly or in combination, include loading out and cooling the burning material, installing fire barriers, surface sealing, and water and pneumatic flushing. GPO Catalog No. 128.27:8620. Stock No. 2404-01546. 90 cents.

IC 8621. Methane Control in Eastern U.S. Coal Mines. Proceedings of the Symposium of the Bureau of Mines/Industry Technology Transfer Seminar, Morgantown, W. Va., May 30-31, 1973, by Staff—Mining Research. 1973. 96 pp. Research workers from the Bureau of Mines and industry met with other government and industry representatives at the Mont Chateau Lodge, Morgantown, W. Va., on May 30-31, 1973, to discuss the current status of methane control in eastern U.S. coal mines. The opening remarks, the eight technical presentations, and the discussions of the members of a government-industry panel are published here for the benefit of those concerned with the control of methane in coal mines.

IC 8622. Recovery of Secondary Copper and Zinc in the United States, by Fred V. Carrillo, Mark H. Hibpshman, and Rodney D. Rosenkranz. 1974. 58 pp. 8 figs. Of the total quantity of secondary copper and zinc that became obsolete in the United States from 1961 through 1970, more than 11 million tons of copper and 10 million tons of zinc were not recovered. These estimates are based on a study of the flow and recovery of old copper and zinc scrap by consumption end-use. This report describes (1) where copper and zinc are being used; (2) when they become obsolete and available as secondary metal; (3) how they are being collected for recycling; and (4) how much might be recovered from scrap that presently is not being recycled. GPO Catalog No. 128.27:8622. Stock No. 2404-01555. \$1.

IC 8623. Theoretical and Experimental Studies on the Packing of Solid Particles: A Survey, by R. S. Fowkes and J. F. Fritz. 1974. 30 pp. The degree and manner of packing of bulk materials influences all phases of their loading, such as by a front-end loader or a dragline, and their mechanics of flow, such as through a binhopper or an ore pass. The most important quantity in analyzing the handling of a bulk material is its shear strength, which depends primarily on the same parameters as those that determine the packing state. Some of these are size, size distribution, moisture content, particle shape, particle orientation, and cohesion. The variables that affect the packing state are vibration, pressure, intensity of deposition, velocity of deposition, and, when the material is confined, container used. The analysis of packing by a number of investigators has been done almost entirely with spherical particles. Most of these studies have dealt with monosized spheres. There is scant information on particles with angular shapes. Since most of the investigations by far have been concerned with ceramics and powder metallurgy, the particle sizes and ranges of size distribution have been small compared with those generally found in mining after fragmentation.

IC 8624. A Computer Program for Clustering Data Points on the Sphere, by Robert J. Shanley and M. Ashraf Mahtab. 1974. 58 pp. 3 figs. The computer program, HYBMODE, has been developed to meet the need for a fast and economical method for clustering data points on the sphere. The algorithm used in this development is an extension of D. Wishart's one-level mode analysis. The program can be used to cluster either vectorial or axial data; it is currently being used by the Bureau of Mines to cluster fracture orientations.

IC 8625. Rapid Wet Chemical Methods for the Analysis of Blast Furnace Slags, by R. H. Jefferson and

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E. A. Hattman. 1974. 15 pp. 2 figs. This Bureau of Mines report describes a series of rapid wet chemical methods for the analysis of blast furnace slags. A "complete" analysis for total iron, manganese, silica, lime (calcium oxide), magnesia (magnesium oxide), sulfur, and mixed oxides (R_2O_3) can be routinely performed in less than 3 hours. These methods were employed as the analytical control procedures for the Bureau's experimental blast furnace operations and have been satisfactorily applied to the analysis of other slags and calcareous materials.

IC 8626. Mineral Resources of the Trans-Alaska Pipeline Corridor, by John J. Mulligan. 1974. 24 pp. 9 figs. The Bureau of Mines investigated reports of mineral deposits within 10 miles of the route of the proposed pipeline from Prudhoe Bay to Valdez. No producing lode deposits or lode prospects of possible national economic significance were found. Measured placer deposits in the route are of slight value except possibly some deeply buried gold placer deposits in the Fairbanks and Livengood Quadrangles. The pipeline corridor crosses five belts of minerals, having potential economic value: (1) The north slope of the Brooks Range (oil, gas, oil shale, coal, phosphate); (2) the south slope of the Brooks Range (copper, gold); (3) the Livengood area (gold); (4) the Fairbanks area (gold, lead-silver, antimony); and (5) the Wrangell Mountains-Denali copper belt (copper-gold). The Jarvis Creek coalfield, an eastern extension of the Nenana coalfield, is on the north side of this belt. Scattered along the corridor across the Chugach Mountain and in the vicinity of Valdez are a wide variety of metallic deposits that make up the eastern margin of the Chugach gold belt but do not seem to constitute a well-defined zone. GPO Catalog No. I28.27:8626. Stock No. 2404-01558. \$3.10

IC 8627. Well-Logging Techniques for Mineral Deposit Evaluation: A Review, by James H. Scott and Benton L. Tibbetts. 1974. 45 pp. Well-logging techniques that have been used to evaluate various types of mineral deposits are discussed briefly, and many pertinent references are cited. Information is categorized by mineral commodity to make it easy to determine what logging techniques have been used for evaluating specific metals and nonmetals. Part 1 discusses logging techniques applied to deposits of the following metals: Aluminum, antimony, beryllium, boron, copper, iron, lead and zinc, manganese, mercury, nickel, silver and gold, tin, tungsten, and uranium. Part 2 covers the following nonmetals: Coal, evaporites, fluor spar, oil shale, rock salt, and sulfur. Separate bibliographies are given for English and foreign language references. GPO Catalog No. I28.27:8627. Stock No. 2404-01589. 90 cents.

IC 8628. Bureau of Mines Test Procedures for Rocks, ed. by W. E. Lewis and S. Tandanand. 1974. 223 pp. 101 figs. This Bureau of Mines report is a reference manual of procedures used by the Bureau's Twin Cities Mining Research Center for obtaining rock properties. Included in the report are discussions on the usage of each property, descriptions of the general test methods for obtaining the properties, and instructions for performing the tests. The instructions embrace details of the specimen configuration, test apparatus, test procedure, test conditions, and calculations needed to achieve satisfactory results. Although the procedures presented in this reference manual generally conform to recommenda-

tions of the ASTM Administrative Committee on Standards, they are not purported to be standards. GPO Catalog No. I28.27:8628. Stock No. 2404-01681. \$2.95.

IC 8629. The U.S. Zinc Industry: A Historical Perspective, by A. D. McMahon, C. H. Cotterill, J. T. Dunham, and W. L. Rice. 1974. 76 pp. 9 figs. Changes in world mine and smelter supply sources of zinc have led to changes in zinc supply patterns in the United States during the past 3 years, 1970-72. The result has been a growing reliance on foreign sources of zinc metal to furnish an ever-increasing portion of expanding domestic requirements. This review of fundamentals and historical developments is intended to provide background in order to place the future of the U.S. zinc industry in perspective. The properties and uses of zinc are described. A new study on U.S. reserves is presented with description by geographical region and comparisons with older reserve data. The technology of the zinc industry from prospecting through refining is described with emphasis on the metallurgy involved in the various methods of smelting. Production, consumption, and imports are discussed and illustrated with graphs and tables to review the past and present patterns. Government actions affecting the industry are shown. Catalog No. I28.27:8629. Stock No. 2404-01527. \$1.10.

IC 8630. Ground Control Aspects of Coal Mine Design. Proceedings: Bureau of Mines Technology Transfer Seminar, Lexington, Ky., March 6, 1973, by Staff—Mining Research. 1974. 138 pp. 71 figs. This report contains the papers presented at the Technology Transfer Seminar on Ground Control Aspects of Coal Mine Design held by the Bureau of Mines on March 6, 1973, in Lexington, Ky. Seminar attendance consisted of representatives from the coal mining industry, universities, mining consultants, instrument manufacturers, and local, State, and Federal Governments. The purpose of this meeting, one of a series of Technology Transfer seminars, was to provide the coal mining industry with detailed information about recently developed techniques, equipment, and instruments that can be used in the solution of coal mine design problems, and to discuss results and direction of research in mine design. The report includes opening remarks by Joseph J. Yancik, Acting Assistant Director—Mining; an overview of the Federal Bureau of Mines approach to mine design; three papers on problems associated with the design of panels; five papers on coal mine roof problems; three papers on longwall problems; and the comments made by the participants on the Bureau-industry panel discussion.

IC 8631. Summary of Mining and Petroleum Laws of the World. (In Five Parts). 5. Europe, by Northcutt Ely. 1974. 86 pp. This volume summarizes mining and petroleum legislation in 18 European jurisdictions. Within these jurisdictions, primary attention is given to requirements that must be met in each country for acquisition of rights to permit development of mineral resources. Coverage includes (1) identification of the controlling laws or statutes governing minerals acquisition and reference to the administrative authority; (2) analysis of the laws governing mines and quarries and their products; (3) analysis of laws applicable to natural gas, petroleum, and related materials; and (4) mention of laws regulating offshore operations. Where pertinent, sections dealing with historical background or

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administration have been added. In countries where minerals are subject to control of States or Provinces, those areas are considered separately from the central government. GPO Catalog No. I28.27:8631. Stock No. 2404-01559. \$1.25.

IC 8632. Basic Estimated Capital Investment and Operating Costs for Underground Bituminous Coal Mines. Mines With Annual Production of 1.06 to 4.99 Million Tons From a 72-Inch Coalbed, by Sidney Katell and E. L. Hemingway. 1974. 41 pp. 1 fig. This study estimates capital investment, operating costs, and selling prices for four underground bituminous mines producing coal with annual production ranging from 1.06 to 4.99 million tons. It is assumed that the mines have a 20-year life. Wages and union welfare payments are considered as of November 12, 1973, under the Bituminous Wage Agreement of 1971, and costs for material and equipment are based on 1973 indexes. Initial capital investment ranges from \$12,540,700 for the 1.06-million-ton-per-year (MM tpy) mine to \$44,720,500 for the 4.99 MM tpy mine. Total capital investment ranges from \$21,850,700 to \$75,693,500 for the same mines. Corresponding selling prices for the coal range from \$8.76 to \$7.53 per ton, assuming a 12-percent discounted cash flow rate of return after Federal income taxes. GPO Catalog No. I28.27:8632. Stock No. 2404-01514. 85 cents.

IC 8633. Potential Solid Waste Generation and Disposal From Lime and Limestone Desulfurization Processes, by R. J. Evans. 1974. 22 pp. 5 figs. The generation and disposal of solid waste from electric utility plants using a lime or limestone wet-scrubbing system and the potential effects on the environment were estimated for 1975 and 1980. The study indicated that in 1975 approximately 5.8 million tons of desulfurization solid waste (50 percent solids) will be generated. In 1980, when it is estimated that desulfurization will become commercially accepted, approximately 17.4 million tons of this material will be generated for disposal and/or utilization. The desulfurization waste material, when combined with lime, fly ash, and water, may have potential for use as a roadbase material, in landfill reclamation, and as synthetic aggregate. GPO Catalog No. I28.27:8633. Stock No. 2404-01578. 65 cents.

IC 8634. Assessment of U.S. Petroleum Supply With Varying Drilling Efforts, by T. M. Garland, M. Carrales, Jr., and J. S. Conway. 1974. 36 pp. 12 figs. This report presents a Bureau of Mines assessment of crude oil and associated gas production and reserves that would result from different drilling efforts in the contiguous 48 States during the 1972-85 period. The drilling effort was based upon five growth rate assumptions from the 1971 level. Additions to crude oil reserves were computed for nine cases resulting from the use of three equations for findings per foot drilled and three constant revision factors. The results indicate that the United States will not become self-sufficient in crude oil production by 1985 and also illustrate the lead time required to reverse the decline in oil production. Discussion is limited to three of the nine cases to provide high, intermediate, and low results. More emphasis is on the intermediate case because it is indicative of the most probable trends. The methodology and statistical data are included in the appendixes. GPO Catalog No. I28.27:8634. Stock No. 2404-01537. 75 cents.

IC 8635. Mine Communications. Proceedings: Bureau of Mines Technology Transfer Seminar, Bruceton, Pa., March 21-22, 1973, by Staff—Mining Research. 1974. 86 pp. 71 figs. The Technology Transfer Seminar on Mine Communications held on March 21-22, 1973, at the Pittsburgh Mining and Safety Research Center, Bruceton, Pa., presented information about recently developed equipment, instruments, and techniques for use in mine communications systems. All of the basic ideas presented in the seminar are operational in the Bureau of Mines Safety Research Mine in Bruceton, Pa.

IC 8636. Subsurface Waste Injection in the United States: Fifteen Case Histories, by Erle C. Donaldson, Rex D. Thomas, and Kenneth H. Johnston. 1974. 72 pp. 27 figs. Subsurface injection of liquid and slurry-type industrial waste is being used as a means of waste disposal. This survey conducted by the Bureau of Mines shows that the method can be economically and environmentally attractive if the proper precautions are taken, especially when the alternative is cursory treatment and discharge at the surface. Attention is called to petroleum technology and experience that can be applied to subsurface waste injection. Part 1 of this report is a discussion of the general aspects of subsurface waste-injection systems. Part 2 is a general discussion and review of the literature concerning the geologic formations available for injection in the United States. Part 3 is a discussion of 15 case histories including information on the source and nature of the waste and the geology, surface equipment, well completion, and operation of the systems. GPO Catalog No. I28.27:8636. Stock No. 2404-01581. \$1.15.

IC 8637. Evaluation of Waterfloodability of Oilfields by Pilot Flooding, by James A. Wasson. 1974. 21 pp. 11 figs. This Bureau of Mines report summarizes the application of pilot flooding in the evaluation of a potential waterflood project. Aspects of pilot flooding discussed include choice of pilot location, confined and unconfined waterfloods, operational precautions, and comparison of predicted with observed performance. Summaries of published methods of pilot flood data analysis for determination of full-scale waterflood feasibility are presented and their use illustrated for example pilot flood data. GPO catalog No. I28.27:8637. Stock No. 2404-01580. 65 cents.

IC 8638. Extracting Minerals From Geothermal Brines: A Literature Study, by Rolland L. Blake. 1974. 25 pp. The Bureau of Mines is concerned with extracting minerals from residual geothermal brines after their heat content and some demineralized water have been recovered. This literature study is based on a survey of the literature and discussions with individuals knowledgeable on various aspects of the subject. This report examines the potential of the domestic geothermal mineral resources, considers the technical problems involved, and outlines possible effects on the environment from reservoir fluid withdrawal and reinjection. Geothermal resources in the Western United States were extensively explored during the 1960's. Limited development operations included exploratory drilling and operating wells producing hot brine, separating steam for experimental electric power generation, and recovering minerals in solar evaporation ponds or in extraction plants. Interest in the recovery of minerals and salts from geothermal fluids waned because of corrosion and scaling problems

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and low or no market value of the mineral products. Most of these problems can be controlled with existing technology and careful planning of processes and equipment. Extracting geothermal minerals is technically feasible, but the problem of low or no market value for major mineral products, and insufficient amounts of more valuable minor products, make mineral recovery uneconomical at present.

IC 8639. *Proceedings of the Symposium on Talc, Washington, D.C., May 8, 1973*, compiled by Aurel Goodwin. 1974. 102 pp. 55 figs. A symposium on the health hazards of respirable dust in the mining and milling of talc was held on May 8, 1973, in Washington, D.C. The results of medical effects on both human and animal subjects were presented. Methods for identification and classification of talc minerals were also presented. Analytical techniques discussed included X-ray diffraction, scanning electron microscope observation, electron probe, and optical microscopy.

IC 8640. *Ash Utilization—Proceedings: Third International Ash Utilization Symposium*, compiled by John H. Faber, William E. Eckard, and John D. Spencer. 1974. 317 pp. 89 figs. More than 400 academic, Government, and industry representatives attended the third symposium on ash utilization and technology held in Pittsburgh, Pa., March 13-14, 1973. Sponsored by the American Public Power Association, Edison Electric Institute, National Coal Association, National Ash Association, and Bureau of Mines, the symposium featured 26 formal presentations by leading experts from Europe and the United States on all major phases of ash production, utilization, and research.

IC 8641. *Basic Estimated Capital Investment and Operating Costs for Underground Bituminous Coal Mines: Mines With Annual Production of 1.03 to 3.09 Million Tons From a 48-inch Coalbed*, by Sidney Katell and E. L. Hemingway. 1974. 31 pp. 1 fig. This Bureau of Mines study estimates capital investment, operating costs, and selling prices for three underground bituminous mines producing coal with annual production ranging from 1.03 to 3.09 million tons. It is assumed that the mines have a 20-year life. Wages and union welfare payments are considered as of November 12, 1973, under the Bituminous Wage Agreement of 1971, and costs for material and equipment are based on 1973 indexes. Initial capital investment ranges from \$12,938,200 for the 1.03-million-ton-per-year (MM tpy) mine to \$31,435,500 for the 3.09 MM tpy mine. Total capital investment ranges from \$21,607,200 to \$51,982,000 for the same mines. Corresponding selling prices for the coal range from \$9.11 to \$8.06 per ton, assuming a 12-percent discounted cash flow rate of return after Federal income taxes. GPO Catalog No. I28.27:8641. Stock No. 2404-01579. 70 cents.

IC 8642. *Land Utilization and Reclamation in the Mining Industry, 1930-71*, by James Paone, John L. Morning, and Leo Giorgetti. 1974. 61 pp. 51 figs. Land utilized by the mining industry from 1930 through 1971 amounted to 3.65 million acres, or 0.16 percent of the land mass in the United States. Land reclaimed during the same period was 1.46 million acres, or 40 percent of the land utilized. This report includes data on land use for wastes from underground and surface mining, for wastes from mill

operations, and on subsidence. Data on land use and reclamation were obtained from operating companies, mining organizations, appropriate State agencies, and others concerned with such activities. The 10 leading States in land used for mining in 1971 were, in decreasing order, Kentucky, Pennsylvania, Arizona, Ohio, California, Florida, West Virginia, Illinois, Minnesota, and Indiana. Mineral commodities accounting for a major portion of land use are, in decreasing order, bituminous coal, sand and gravel, stone, copper, phosphate rock, iron ore, and clay; for coal, these commodities are produced principally by surface mining operations. Reclamation over the 42-year period was largely on lands utilized for surface mining of bituminous coal. New surface mining methods, particularly for coal, incorporate some form of land restoration. GPO Catalog No. I28.27:8642. Stock No. 2404-01601. \$1.05.

IC 8643. *Technologic and Related Trends in the Mineral Industries, 1973*, by Staff, Bureau of Mines. 1974. 52 pp. 27 figs. This report, the fourth in an annual series, outlines recent trends and developments in the minerals industry. Discussed are new methods, equipment, techniques, and systems used to more effectively extract and process mineral products. Environmental considerations, health and safety standards, price controls, inflation, material shortages, and more dependence on foreign imports were problems faced by the minerals industry. Although productivity increased for most mineral commodities, the annual rate of increase has slowed in recent years, indicating a maturing technological situation. Growing concern for energy resulted in increased interest and research in alternative fuel sources. The primary concerns of metallurgists were pollution control and improved efficiency and performance of metallurgical processes, especially for reduction of energy consumption. GPO Catalog No. I28.27:8643. Stock No. 2404-01609. 95 cents.

IC 8644. *Bureau of Mines Pittsburgh Mining and Safety Research Center Research and Development Activities: Fiscal Year 1971*, by Staff, Pittsburgh Mining and Safety Research Center. 1974. 25 pp. The principal activities of the Bureau of Mines Pittsburgh Mining and Safety Research Center during fiscal year 1971 (July 1, 1970, to June 30, 1971) are reviewed in part 1 of this paper. Part 2 summarizes publications during fiscal year 1971.

IC 8645. *Coal Mining Techniques in the Federal Republic of Germany—1971*, by Ernest A. Curth. 1974. 54 pp. 31 figs. A 3-month study in 1971 of the Essen Roof Support and Rock Mechanics Research Center's program of roof and support evaluation included 25 mine trips. German miners must adopt mining methods and environmental control measures involving methane drainage and water infusion to improve productivity under severe natural conditions. Pressing problems in ground control must be solved, such as cavities in front and above the supports at longwall faces and excessive convergence in gate roads. The Center developed automatic data processing methods to quantify the results of roof and support surveys and to establish criteria. Another approach to ground control is the study of mine models. The Center's laboratory has the facilities to test elements of powered roof support and whole assembled units. Face automation and roof control by powered shields are novel developments that are under close scrutiny in the field as well as in the laboratory. Though the Essen Center's roof and support evaluation techniques are tailored to

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the needs of the coal mining industry of the Federal Republic of Germany under conditions vastly different from those in the United States, some application may be found here, for instance, monitoring faces and roadways and preventive maintenance of hydraulic systems. GPO Catalog No. I28:27:8645. Stock No. 2404-01642. \$1.35.

IC 8646. Availability of U.S. Primary Lead Resources, by Paul McIlroy, J. S. Coffman, W. L. Rice, and M. H. Hibpshman. 1974. 60 pp. 11 figs. Costs of producing lead from various known resources in the United States are developed by the Bureau of Mines to define the future availability of domestic lead at various price levels. It is estimated that 60 million tons of primary lead (75 percent of the total resource) is available at \$0.20 or less per pound; 72 million tons (90 percent of the total) is available at \$0.50 or less per pound; and the 79-million-ton total estimated resource can be obtained at a price of \$1.82 or less per pound. The supply available at \$0.20 per pound or less will meet demand for over 78 years at the 1970 annual consumption rate of 763,000 tons. GPO Catalog No. I28:27:8646. Stock No. 2404-01689. \$1.00.

IC 8647. Fuel and Energy Data: United States by States and Regions, 1972, by Lulie H. Crump and Charles L. Readling. 1974. 82 pp. 8 figs. Salient information on reserves, production, and consumption of fuels and energy, by State, are summarized in this Bureau of Mines publication. The data are broken down by fossil fuels (coal, petroleum, and natural gas) and hydropower and nuclear for the major consuming sectors: Household-Commercial, Industrial, Transportation, Electric Power, and Miscellaneous. In addition, total energy consumption in the Nation in 1972 is compared with consumption in 1971 and 1973 (preliminary data). GPO Catalog No. I28:27:8647. Stock No. 2404-01635. \$1.25.

IC 8648. Revised and Updated Cost Estimates for Producing Alumina From Domestic Raw Materials, by Frank A. Peters and Paul W. Johnson. 1974. 51 pp. 5 figs. With the current renewed interest in advancing the technology for producing alumina from domestic raw materials, revisions of previous cost estimates to provide planning data are urgently needed. Completed new cost estimates on a 1973 basis are included for four alumina-from-clay processes and one alumina-from-anorthosite process. These estimates are based on new or previously calculated material balances, recalculated heat requirements, and new equipment designs. The use of larger and more modern equipment has permitted a significant reduction in labor requirements as well as equipment costs. Chemical prices, labor rates, and utility rates typical of late 1973 are used in these cost estimates. In addition to the revised cost estimates, all 21 previously published alumina evaluations compiled by the Bureau of Mines were updated to show the effect of inflation using an inflation index and late 1973 chemical prices, labor rates, and utility rates.

IC 8649. Computer Program for Nonlinear Regression Using Least Squares, by Robert T. Langland and Norman N. Yabe. 1974. 50 pp. 4 figs. The Bureau of Mines, at its Denver, Colo., research center, has developed a computer program to solve nonlinear regression problems. The program is written in a general form so that regardless of the functional relationship assumed, the unknown param-

eters may be evaluated by the Newton-Raphson method of iteration. Variances and covariances of the parameters are derived, based on the propagation of errors. A creep function is established from shale test data as an example of program utility. Program accuracy is compared with the accuracies of other programs in present-day use.

IC 8650. Technology and Use of Lignite. Proceedings: Bureau of Mines—University of North Dakota Symposium, Grand Forks, N. Dak., May 9-10, 1973, compiled by Gordon H. Gronhovd and Wayne R. Kube. 1974. 262 pp. 139 figs. Sixteen papers concerned with the technology and utilization of low-rank fossil fuels are presented as the proceedings of the 1973 lignite symposium. This symposium, the seventh in a series of biennial meetings, was cosponsored by the Bureau of Mines and the University of North Dakota. GPO Catalog No. I28:27:8650. Stock No. 2404-01684. \$3.30.

IC 8651. Bureau of Mines Energy Program, 1973, by John D. Spencer and Bill Linville. 1974. 73 pp. 47 figs. Research on the development of new and improved methods for the discovery and production of oil and gas and production of fluid fuels from coal, continued to be the major thrust of the Bureau of Mines energy research program during 1973. Crude oil recovery from tar sands and oil shale also retained a high priority in this work. Complementing this program were numerous studies aimed at accomplishing the objective of increased energy output with greater safety and minimum harm to the natural environment. This report summarizes research objectives and results and itemizes formal publications of the Bureau of Mines on energy and related subjects.

IC 8652. Profitability Analysis of Producing Crude Oil by Waterflooding Using a Simulation Technique, by W. D. Dietzman and J. H. Martin. 1974. 78 pp. 7 figs. This Bureau of Mines report presents a profitability analysis of producing crude oil by waterflooding. Included are the estimated costs of installation of water injection and producing equipment for waterfloods at 2,000 and 4,000 feet and the estimated annual operational expenses for each in west Texas. Using these cost estimates as a base for selecting a range of costs that are indicative of producing crude oil by waterflooding, a simulation technique was derived for determining the profitability under various conditions. Because of the large number of combinations of variables used in this study, a high-speed digital computer was utilized for the calculations. The variables include operational expenses, capitalized costs, price of the oil, annual production, and leasehold acquisition cost. The results obtained from the simulations are presented in the appendix. In addition, a nomographical approach was chosen for presentation of the profitability. Five nomographs are presented that can be used for fast estimation of the discounted cash flow (DCF) rate of return that might be expected from a prospective or active operation under various sets of assumed conditions.

IC 8653. Economic Significance of the Florida Phosphate Industry, by Kung-Lee Wang, Barry W. Klein, and Andrew F. Powell. 1974. 51 pp. 7 figs. This Bureau of Mines study illustrates the economic significance of the Florida phosphate industry to the State and to the Nation. Environmental considerations related to phosphate industry activity are discussed briefly. Based on forecasts of Florida phosphate production in 1975 and using 1972 dollars,

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regional and national output value, income, and employment created by the phosphate industry were estimated for 1975. State and Federal Government tax revenues generated by the phosphate industry are also measured. Further, the concentrated impact of the phosphate industry on certain Florida areas and on regional industries is examined. Finally, the phosphate industry's importance to the U.S. balance of payments, U.S. agricultural production, and the Frasch sulfur industry is considered in addition to byproduct fluorine and potential byproduct uranium from fertilizer manufacturing. GPO Catalog No. I28.27:8653. Stock No. 2404-01692. \$1.10.

IC 8654. The Bureau of Mines Minerals Availability System and Resource Classification Manual, by Staff, Bureau of Mines—Mineral Supply. 1974. 199 pp. This Information Circular describes the Bureau of Mines Minerals Availability System (MAS), presents the Resource Classification Manual used for information input to a computer file, and discusses the methods of collecting and assembling background material basic to coding the data. GPO Catalog No. I28.27:8654. Stock No. 2404-01687. \$2.50.

IC 8655. The Reserve Base of Bituminous Coal and Anthracite for Underground Mining in the Eastern United States, by Staff, Bureau of Mines. 1974. 428 pp. 2 figs. The coal reserve base is defined for coalbeds having sufficient thickness for underground mining within a depth range compatible with economic recovery. The reserve data are compiled by the Federal Bureau of Mines by updating and reevaluating previous estimates of the U.S. Geological Survey, State geological surveys, and others. Through the application of computer techniques, the tonnages are compiled by State, county, coalbed, and rank. Coal reserve base is allotted to sulfur categories by a statistical apportionment of data from available Bureau of Mines reports and records. The coal reserve base in those States east of the Mississippi River, minable by underground methods, is estimated to be 169 billion tons in coalbeds greater than 28 inches in thickness to a maximum depth of 1,000 feet. Excluding those coals in reliability categories other than measured and indicated, the underground reserve base includes 162 billion tons of bituminous coal and 7 billion tons of anthracite. Of the total, 27 billion tons contains 1.0 percent or less sulfur. Most of this low-sulfur coal is in the southern Appalachian area. Approximately 16 percent of the underground reserve base is without available analyses. Included in this report is a glossary of terms applicable to a classification system for coal resources and reserves. The purpose of this system is to provide a common yardstick for determining coal resources and reserves. GPO Catalog No. I28.27:8655. Stock No. 2404-01691. \$4.80.

IC 8656. Comparative Porphyry Copper Mining and Processing Costs—Alaska and Arizona, by R. G. Bottge. 1974. 55 pp. 10 figs. To better understand those factors which increase mining costs in Alaska, a Bureau of Mines study was conducted to compare the estimated costs of operating a 100,000-tpd open pit copper mine located on a hypothetical ore body in the Lake Clark area, Alaska, with the costs of mining a similarly sized hypothetical copper ore body near Tucson, Ariz. The information derived should be beneficial to the State and Federal governments in appraising the potential for development of large, low-grade porphyry copper deposits in south-central Alaska. Conventional mining and concentrating methods were assumed, and capital

and operating costs were derived using flowsheets and standard costing methods. The total price required for copper mined in Alaska and Arizona was \$1.12 and \$0.63 per pound, respectively, plus or minus 20 percent. These values were obtained assuming no leaching of low-grade copper, recovery of gold, silver, and molybdenum as byproducts, 100-percent equity financing, and a 12 percent discounted cash flow rate of return. The average domestic and international prices for copper in July 1973 were \$0.60 and \$0.916 per pound, respectively. The existence of a developed transportation and power system in Alaska would have reduced capital and operating costs substantially. The required price for copper would have declined from \$1.12 to \$1.05 per pound, plus or minus 20 percent. GPO Catalog No. I28.27:8656. Stock No. 2404-01703. \$1.20.

IC 8657. The Mine Map Repository—A Source of Mine Map Data, by Curtis D. Edgerton. 1974. 9 pp. 2 figs. The Pittsburgh Mine Map Repository of the Bureau of Mines serves as a basic reference file for the archival preservation of mine map data of mines east of the Mississippi River. About 22,000 of an estimated 500,000 available mine maps have been microfilmed. A computerized index serves as the mechanism for retrieval of any microfilmed mine map. The operation, equipment, and index are described in the report.

IC 8658. Analyses of Natural Gases, 1973, by B. J. Moore. 1974. 96 pp. This publication contains routine analyses and related source data for 278 natural gas samples from 14 States. All of the samples were collected during calendar year 1973 as part of a continuous survey of the free world for occurrences of helium in natural gas. This survey has been conducted in the United States by the Bureau of Mines since 1917. In late 1965, the survey was expanded to include foreign gasfields. The analyses were made by mass spectrometer and a special helium analysis apparatus. GPO Catalog No. I28.27:8658. Stock No. 2404-01695. \$1.65.

IC 8659. Methane Emission From U.S. Coal Mines in 1973, A Survey. A Supplement to IC 8558, by M. C. Irani, P. W. Jeran, and Maurice Deul. 1974. 47 pp. This Bureau of Mines survey of methane emissions indicates that total daily emissions have declined from 227 MM ft³ in 1971 to 214.7 MM ft³ in 1973. The highest average daily emissions in million cubic feet per day observed in U.S. bituminous coal mines were, in decreasing order, Monongalia County, W. Va., 40.7; Marion County, W. Va., 23.1; Buchanan County, Va., 22.1; Washington County, Pa., 12.4; Greene County, Pa., 11.7; McDowell County, W. Va., 11.4; Cambria County, Pa., 9.8; Jefferson County, Ala., 9.5; Wyoming County, W. Va., 6.0; Marshall County, W. Va., 4.8; and Indiana County, Pa., 4.8.

IC 8660. Mineral Resources of the Black Hills Area, South Dakota and Wyoming, by John Paul Gries. 1974. 61 pp. 7 figs. This Bureau of Mines report reviews the mineral industry of the Black Hills area, including Butte, Custer, Fall River, Lawrence, Meade, and Pennington Counties, S. Dak.; and Crook, Niobrara, and Weston Counties, Wyo. It includes discussion of geological occurrence, processing, and potential of 27 commodities that have been produced from the nine-county area. The

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value of mineral production exceeds \$70 million annually. Gold and petroleum account for two-thirds of the total, followed by clays, cement, sand and gravel, and rock. The combined mineral industries annually consume 268 million kilowatts of electrical energy, 933 million cubic feet of gas, and 2 million barrels of fuel oil. Water consumption is about 10,000 gallons per minute. About 2,700 persons are employed on a year-round or significant part-time basis. GPO Catalog No. I28.27:8660. Stock No. 2404-01713. \$1.30.

IC 8661. Basic Estimated Capital Investment and Operating Costs for Coal Strip Mines, by Sidney Katell and E. L. Hemingway. 1974. 31 pp. This Bureau of Mines study estimates typical capital investments, operating costs, and selling prices for two bituminous coal strip mines in the Eastern and Interior provinces and a subbituminous coal operation in the Northern Great Plains province. The annual productions were based on tonnage required to fuel a 250-MM-scf, high-Btu gas plant. The annual tonnage for the Eastern province mine is 4.8 million tons; for the Interior province mine, 6.72 million tons; and for the Northern Great Plains province mine, 9.2 million tons. It is assumed that the mines have a 20-year life. Wages and union welfare payments are considered as of May 12, 1974, under the terms of the Bituminous Wage Agreement of 1971, and costs for material and equipment are based on 1973 and early 1974 indexes. Initial capital investment varies: \$45,358,600 for the 4.8-million-ton-per-year (MM tpy) mine in the Eastern province, \$54,603,000 for the 6.72-MM-tpy mine in the Interior province, and \$29,871,000 for the 9.2-MM-tpy mine in the Northern Great Plains province. Total capital investments for the Eastern province mine, the Interior province mine, and the Northern Great Plains province mine are \$61,070,000, \$76,753,000, and \$56,286,000, respectively. Corresponding selling prices for the coal, per ton, are \$4.79, \$4.23, and \$2.66, assuming a 12-percent discounted cash flow rate of return after Federal income taxes. These studies are considered typical for the areas involved. Costs will vary depending on specific locations in these areas. GPO Catalog No. I28.27:8661. Stock No. 2404-01694. 85 cents.

IC 8662. The Flathead Tunnel. A Geologic, Operations, and Ground Support Study, Burlington Northern Railroad, Salish Mountains, Montana, by Eugene H. Skinner.

1974. 98 pp. 41 figs. The 7-mile Flathead Tunnel, located in the central Salish Mountains of northwestern Montana, was constructed between 1966 and 1969. With the contract awarded April 19, 1966, drill and blast tunnel excavation began September 30, 1966, and was completed June 21, 1968, in 488 tunnel-driving days. Peak advance was 66 feet per day. On June 27, 1969, all tunnel concrete lining was completed. Average wall and arch concrete placing rates exceeded 1,700 cubic yards daily, with nearly half of the concrete placed during a severe winter season. Major cost savings in concrete tunnel lining were achieved through a value engineering clause in the contract. Achieving consistent results and high rates of placement in concrete lining ranked equal to ground control in overall tunnel problems. Ground control problems exceeded expectations and were of continual concern throughout excavation. One support collapse in the tunnel and one portal slide condition developed during construction. Critical surface geologic exposures were largely obscured; only a portion could be accurately projected underground. An instrumentation program to gather basic data on rock deformation near the heading face for support purposes was a pioneering effort. The Flathead Tunnel was placed in service on November 7, 1970. GPO Catalog No. I28.27:8662. Stock No. 2404-01719. \$2.55.

IC 8664. Effects of Urbanization Upon the Availability of Construction Minerals in Southeastern Florida, by Curtis D. Edgerton. 1974. 20 pp. 10 figs. Miami Oolite limestone is the only significant construction mineral in southeastern Florida. Its source area coincides with that of rapid urban expansion. Two-thirds of the existing resource is already unavailable because of development. Land-use conflicts place future availability of limestone in jeopardy. However, a sufficient limestone resource to meet demand for many years is present if its extraction is not restricted. Adverse environmental effects of quarrying Miami Oolite are not severe; land values often increase following quarrying. Future availability depends upon—(1) achieving uniformity of Federal, State, county, and municipality statutory requirements governing quarry operations, (2) setting aside specific land areas for future quarrying, and (3) cooperative planning to provide for land utilization upon completion of quarrying.

TECHNICAL PROGRESS REPORTS

TPR 21. Construction and Testing of a Junk Auto Incinerator, by C. J. Chindgren, K. C. Dean, and J. W. Sterner. February 1970. 8 pp. 3 figs. A refractory-lined, garage-type automobile incinerator with a natural gas afterburner for air pollution control was cooperatively constructed and tested by the Bureau of Mines and the Wasatch Metal & Salvage Co. in Salt Lake City, Utah. The incinerator is capable of relatively smokeless burning of 32 to 60 cars per day, depending upon the degree to which the cars are stripped prior to incineration. Preliminary burning campaigns indicate the cost of incineration to be approximately \$2.75 per car.

TPR 22. Recovery of Heavy Minerals From Alabama Sand and Gravel Operations, by G. B. Sullivan and James S. Browning. April 1970. 14 pp. 3 figs. The Bureau of Mines studied 25 samples from 15 Alabama sand and gravel operations to determine their heavy mineral content. All of the samples contained some heavy minerals (4 to 188 pounds per ton), and 80 percent contained 20 or more pounds of heavy minerals per ton of sand and gravel. Valuable heavy minerals, in order of decreasing amounts, were ilmenite, kyanite, zircon, rutile, and monazite. Large-scale concentration tests were made on samples from three of the State's major producers.

TPR 23. Gas Flood Efficiency Improvement by Polymer Injection, by Edward L. Burwell and Arlen E. Hunt. March 1970. 8 pp. 3 figs. The Bureau of Mines investigated the use of dilute polymer in brine solutions to increase the efficiency of air in gas flooding model oil reservoirs. Slugs (0.23 pore volume) of 500 ppm polyacrylamide were injected into a model, consisting of a high- and a low-permeability core, that had been previously gas flooded in residual oil. Gas flooding was then resumed. Of the total gas volume injected, the percentage entering the high-permeability zone was greatly reduced after polymer injection but remained unchanged when slugs of water without polymer were used.

TPR 24. A Process To Make High-BTU Gas From Coal, by Albert J. Forney, Stanley J. Gasior, William P. Haynes, and Sidney Katell. April 1970. 6 pp. 3 figs. A process for the manufacture of high-Btu gas from coal has been developed by the Bureau of Mines. The process consists of fluid-bed gasification of the coal, followed by the gas treatment steps of gas purification and methanation. Advantages of the system are that caking coals can be used directly, and more than half of the ultimate methane is made in the gasifier. (*Out of print.*)

TPR 25. Conversion of Urban Refuse to Oil, by Herbert R. Appell, Irving Wender, and Ronald D. Miller. May 1970. 5 pp. Urban refuse, cellulosic wastes, and sewage sludge have been converted to heavy oil by heating under pressure with carbon monoxide and steam. Conversions of the organic matter to oil, water, and gas have averaged near 90 percent at temperatures of 250° to 400° C and pressures of 1,500 to 5,000 psi. The yield of oil, based on the dry organic matter of the waste

materials, is usually near 40 percent. This is the equivalent of more than 2 barrels of oil per ton of dry, ash-free waste material. The oil from urban refuse and cellulosic wastes has a sulfur content near 0.1 percent. This low sulfur content makes the oil from refuse a desirable source of fuel oil. (*Out of print.*)

TPR 26. Electrolytic Oxidation of Cinnabar Ores for Mercury Recovery, by B. J. Scheiner, R. E. Lindstrom, D. E. Shanks, and T. A. Henrie. June 1970. 11 pp. 9 figs. Electrooxidation of cinnabar mercury ores (HgS) was investigated as a means of providing an effective and economical hydrometallurgical technique for extraction of mercury from its ores, particularly those too low in grade to allow economical metal recovery by retorting or furnacing techniques. Oxidation was accomplished by electrolysis of ore slurried with brine. Cinnabar was dissolved by oxidation of the insoluble sulfide to soluble mercuric salts. The mercury ion in a brine solution forms a stable tetrachloro complex. Typical laboratory experiments required 1 to 7 hours of electrolysis at 35-percent pulp density in a brine solution that contained 4 to 20 weight-percent sodium chloride (NaCl). Power consumption ranged from 10 to 50 kwhr/ton of dry ore. Mercury extraction values between 90 and 99 percent were obtained with all of the ores investigated. Subsequent mercury recovery from leach solutions was readily accomplished by precipitation on zinc. Pilot mill experiments in a 100- to 200-lb/hr extraction plant are in progress to quantify power and reagent requirements, and extraction and recovery data obtained to date closely parallel those obtained in the laboratory.

TPR 27. Recovery of Metals From Electroplating Wastes by the Waste-Plus-Waste Method, by L. C. George and Andrew A. Cochran. August 1970. 9 pp. 5 figs. Addition of an acid waste to an alkaline cyanide waste was investigated for five different combinations of electroplating wastes. At the optimum final pH values of the mixtures, metals and cyanides were almost quantitatively precipitated. No evolution of hydrogen cyanide was detected. By a few additional processing steps, significant amounts of valuable metals were recovered for recycling. The waste-plus-waste step is attractive, because no reagents are required; metals are concentrated, and a relatively harmless effluent that meets most water quality standards for cyanide content is produced.

TPR 28. Methane Emission Rate Studies in a Northern West Virginia Mine, by Stephen Krickovic, Charles Findlay, and W. M. Merritts. August 1970. 11 pp. 8 figs. Methane emission rates were studied in a Pittsburgh coalbed mine in northern West Virginia. A fullface boring-type continuous miner, equipped with a methane monitor, was used in the development of a set of eight main headings, one side of which was near old workings; the other side abutted virgin coal. Two air splits ventilated the section. Air volumes and methane percentages were recorded, and time studies of the miner were made

during five consecutive operating days, during which a complete cycle of mining the headings and one line of related breakthroughs was accomplished. Methane emission rates increased significantly as mining progressed from the side near old mine workings toward the virgin area, and generally increased with coal extraction. Mining in the heading immediately adjacent to virgin coal was interrupted quite frequently, owing to excessive methane concentrations at the face, despite adequate air volumes and acceptable methane concentrations in the immediate return airway.

TPR 29. A New High-Temperature Soft Solder System, by Alfred E. Schwaneke, Wilbert L. Falk, and Orrin K. Crosser. December 1970. 18 pp. 11 figs. A new high-temperature soft soldering system has been developed by the Bureau of Mines for use on copper, copper alloys, and low-carbon steel; the method is applicable to automobile radiators and home appliances. The system uses a unique sacrificial metal coating method to promote spontaneous wetting and spreading of zinc and zinc alloy solders on metallic substrates. The 10⁻⁵ to 10⁻⁶-cm-thick, electroplated or sputtered, sacrificial nickel coating is absorbed by the molten filler alloy during soldering and produces a direct solder-substrate metallic bond. Preliminary measurements on butt joints with copper members give tensile strengths up to 22,000 psi at room temperature using 95 Zn-5 Al alloy as solder. Spontaneous wetting, spreading, and capillary penetration are extremely rapid and produce joints as easily as 50-50 tin-lead solders. Recrystallization or annealing of the wrought-copper joint members is negligible at the soldering temperatures of 450° to 490° C and lower. A list of fluxes and solder alloys is included in the report. (*Out of print.*)

TPR 30. Some Results From the Operation of a 150-Ton Oil Shale Retort, by A. E. Harak, L. Dockter, and H. C. Carpenter. January 1971. 14 pp. 8 figs. To determine the retorting characteristics of a column of mine-run, ungraded oil shale ranging in size from fines to pieces weighing as much as 5 tons, a 150-ton batch retort was designed and constructed at the Laramie Energy Research Center, Laramie, Wyo. The retort vessel is 45 feet high by 11½ feet in inside diameter and is supported in a 92-foot-high steel superstructure. Mine-run shale from the Bureau of Mines facility near Rifle, Colo., assaying about 25 gallons of oil per ton, is currently being used as the test shale. To date, three runs have been completed. Results of the second and third runs are reported in this paper. The two runs considered in this report are the first of a series of nine to determine operating conditions that will yield maximum oil recovery from a column of mine-run shale. Variables studied are the oxygen content of the retorting gas and the space velocity of the retorting gas expressed as ft³gas/ft²bed/min. Oil recoveries for the two runs reported are 62.2 volume-percent of Fischer assay for the run using higher oxygen and space velocity, compared with the 39.3 volume-percent when less oxygen and a lower space velocity were used. Work done in cooperation with the University of Wyoming.

TPR 31. Recovery of the Nonferrous Metals From Auto Shredder Rejects by Air Classification, by C. J. Chindgren, K. C. Dean, and LeRoy Peterson. April 1971. 11 pp. 3 figs. Two air classification systems were built

and tested as separatory devices for recovering the non-ferrous metal values from shredded automotive non-magnetic reject scrap. A horizontal air system with a capacity up to 16 tons per hour was used to obtain preliminary separations, and a smaller capacity vertical system was used as a cleaning device.

Shredded automobile reject materials containing aluminum, copper, and zinc values of about \$55 per ton were air-classified in the horizontal elutriator. Ninety-six percent of the metal was recovered in a 74-percent metal concentrate. Tandem operation of both classifiers recovered 92 percent of the metal in an 80-percent concentrate while rejecting 87 percent of the nonmetallics. Heavy media separation of the air-classified concentrate produced an overall recovery of 91 percent of the metal in the form of a 99-percent metal concentrate.

TPR 32. An Evaluation of the Respirable Dust Sampling Program in United States Underground Coal Mines, by D. P. Schlick, R. G. Peluso, and W. E. Byers. April 1971. 20 pp. 10 figs. As of June 30, 1970, Federal regulations required the operator of each underground coal mine to maintain the average concentration of respirable dust below legislative standards. As of March 1, 1971, over 152,000 respirable dust samples have been processed by the Bureau of Mines. Approximately 75 percent of underground working sections are being sampled in accordance with Federal regulations. Results indicate that 72 percent of the sections which have completed at least one basic sampling cycle are below 3.0 mg/m³, the standard in effect under the Federal Coal Mine Health and Safety Act of 1969 (Public Law 91-173). Notices of Violation were issued on 1,670 underground mines for failure to begin a sampling program; Withdrawal Orders were issued in 64 of these instances. Notices of Violation were issued on 1,121 sections where applicable dust levels were exceeded; Withdrawal Orders were issued in seven of these instances. There are 381 mining sections currently operating on permits from the Interim Compliance Panel.

TPR 33. Economics of Recycling Metals and Minerals From Urban Refuse, by P. M. Sullivan, and M. H. Stanczyk. April 1971. 19 pp. 7 figs. A physical beneficiation flowsheet was designed by the Bureau of Mines for reclaiming and recycling metal and mineral values contained in municipal incinerator residues, and a continuous processing plant was installed. Residue samples collected from incinerators located in various parts of the country were processed at a rate of one-half ton per hour. Continuous screening, shredding, grinding, magnetic separation, and gravity concentration techniques were applied to produce metallic iron concentrates, clean nonferrous metal composites, clean fine glass fractions, and fine carbonaceous ash tailings.

Research to develop systems for refining and upgrading the reclaimed metals and glass into marketable products is also underway. From the engineering data developed in the continuous processing plant, evaluations of the capital and operating costs for plants with capacities of 250, 400, 670, and 1,000 tons of dry incinerator residues per day were made. Research on a parallel system to separate and recover the metals, minerals, glass, paper, and plastics from raw, unburned refuse is currently underway, as are studies on the use of air classification to separate the refuse into organic and inorganic fractions.

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TPR 34. Preliminary Separation of Metals and Nonmetals From Urban Refuse, by K. C. Dean, C. J. Chindgren, and LeRoy Peterson. June 1971. 10 pp. 4 figs. Horizontal and vertical air classification systems were treated individually and in simulated tandem for the recovery of ferrous and nonferrous metals, and of other noncombustible and combustible products from shredded urban refuse. The horizontal air system with a larger tonnage throughput was used to obtain preliminary separations, and a smaller capacity vertical system was used as a cleaning device.

Air elutriation, magnetic separation, and screening of shredded minus 6-inch municipal refuse recovered 92 percent of the metal in a relatively clean iron product contaminated only by adhering coatings or entrapped materials, recovered 97 percent of the combustibles in a 97-percent combustible product, and rejected 88 percent of the nonmetal noncombustibles. Cleaning of the preliminary combustible fraction produced a 98-percent paper product while rejecting other combustibles (plastics, rubber, textiles, etc.) into a 94-percent combustible product. Retreatment of the preliminary noncombustible fraction produced a relatively clean glass product.

TPR 35. Low-Sulfur Fuel Oil From Coal, by Sayeed Akhtar, Sam Friedman, and Paul M. Yavorsky. July 1971. 11 pp. 1 fig. A high-sulfur bituminous coal suspended in coal tar was hydrosulfurized by continuous processing through a fixed bed of pelletized cobalt molybdate on alumina catalyst, under conditions of a highly turbulent flow of hydrogen to prevent obstruction of the flow fluids and to promote catalytic contact. High yields of low-sulfur oil were obtained. The feed contained 30 percent coal of 3.4 percent sulfur suspended in tar of 0.6 percent sulfur. For process conditions of 4,000 psig and 450° C, the yield of whole liquefied product was 94 percent of the whole feed. The product had 9 percent benzene-insoluble residues and only 0.3 percent sulfur. Most of the sulfur was in the insoluble residues and was organic. By separating the insoluble residues, the whole product gave a 91-percent yield of benzene-soluble fuel oil having only 0.09 percent sulfur. For the milder conditions of 2,000 psig and 450° C, the whole liquefied product was 93 percent of the feed and had 13 percent insoluble residues and 0.4 percent sulfur. By separating the residues this product gave an 87-percent yield of fuel oil having only 0.14 percent sulfur. Commercially, part of the separate oil would be recycled to suspend the feed coal instead of using the tar. Thus, the net product for fuel use would derive entirely from coal and is expected to have sulfur at least as low as reported above. This work presents a method for providing large amounts of low-sulfur fuel.

TPR 36. Recovery of Chromite and Silica From Steel Industry Waste Molding Sands, by P. G. Barnard, R. A. Ritchey, and H. Kenworthy. July 1971. 21 pp. 4 figs. Most foundry molding sands are recycled within their plants until they become unusable through agglomeration or because of excessive coating with deleterious materials. This portion of the sand is then discarded since it no longer has the required properties. To eliminate this waste, a method was developed to clean the sand particles and recover the valuable components by using physical separation techniques. A simple scrubbing followed by an oxidation roast is used to produce a quality sand which can be reused. If the waste sands contain chromite, a magnetic separation will separate this rela-

tively expensive component after the cleaning treatment. A large steel foundry that has recently adopted the process for recovering chromite and silica from its waste molding sand is presently recovering for reuse about 20 tons of chromite and 80 tons of silica sand per day. (*Out of print.*)

TPR 37. Production of High-Purity Synthetic Rutile From a Domestic Ilmenite Concentrate, by Gerald W. Elger and W. A. Stickney. August 1971. 10 pp. 3 figs. A new process under development by the Bureau of Mines for producing synthetic rutile from ilmenite is described. Rutile formation is based on oxidation and fluxing of titania slag produced by electric furnacing of ilmenite. Laboratory tests show that phosphorus pentoxide flux additions to oxidized slag enhance conversion to rutile by forming a phosphate-based glass matrix. This matrix contains most of the major impurities, including the oxides of iron, aluminum, magnesium, manganese, and silicon. Rutile crystals of 5 to 150 microns in size were formed in slags heated to temperatures of 800° to 1,550° C. The synthetic rutile crystals were liberated from ground slag by treating with phosphoric acid to weaken the glass matrix, followed by attrition scrubbing. Rutile fractions analyzed as high as 94 percent titania content. In several instances, more than 90 percent of the titanium in the slag was recovered to yield combined rutile fractions containing 90.2 to 92.6 percent titania.

TPR 38. Natural Gas Storage With Zeolites, by Ronald A. Munson and Robert A. Clinton, Jr. August 1971. 9 pp. 5 figs. Adsorption of methane on high-surface-area materials, especially zeolites, is a potential means for increasing the on-vehicle fuel storage capacity of vehicles using natural gas. Gravimetric methods have been employed to determine the room temperature adsorption capacities of a number of high-surface-area materials at up to 1,000 psig. On all zeolites tested, except one, the initial rates of adsorption, representing better than 80 percent of the total adsorption, are fast. Two techniques for correcting crude high-pressure adsorption isotherms for nonadsorbed gas have been investigated, and it appears preferable to estimate the free volume using a fluid which cannot penetrate the pores of the zeolite. The potential of zeolites for gas storage is discussed.

TPR 39. Rock Burst Research at the Galena Mine, Wallace, Idaho, by Wilson Blake. August 1971. 22 pp. 17 figs. A minewide, automatic rock-burst monitoring system has been developed and field tested. Use of this system by mine personnel should allow rock-burst-prone mine structures to be detected, recognized, and evaluated on a routine basis.

In related research, a burst-prone stope pillar at the Galena mine was successfully destressed by blasting a single line of long holes in the footwall of the vein. As a result of destressing, the pillar was fractured and softened; hence it yielded, releasing a large amount of stored elastic strain energy nonviolently. In addition, the high stress in the pillar was shifted out around the stope walls and in the sandfill. Both broad-band microseismic monitoring and seismic velocity surveys were used to evaluate the destressing test. The mechanics of destressing were determined by finite element computer model studies of destressing. Results of the field destressing test agreed remarkably with the predicted results from the computer model.

TPR 40. Fuel Additives and Automobile Exhaust Emissions, by R. D. Fleming, W. F. Marshall, and J. R. Allsup. August 1971. 12 pp. 1 fig. The influence of fuel additives on automobile exhaust emissions was studied using engines currently found in the U.S. vehicle population. The fuel additives used in the experiment were four multifunctional additives and one lead antiknock additive. Experimental work was done to determine both the direct effect of the additive per se on exhaust emissions and the influence of long-term additive effects on emissions with mileage accumulation. Results showed no significant direct or intermediate effect on exhaust emissions for any additives tested.

In subsequent experimental work concerned with the long-term or indirect effects of additives, the detergent-dispersant additives were found to have little influence on emissions when used in conjunction with high-quality oil and motor fuel. The lead (tetraethyl) antiknock additive increased exhaust hydrocarbons approximately 12 to 7 percent during a 4,000-mile accumulation period using a base fuel containing 2 ml of tetraethyllead per gallon. An unleaded fuel was used during a similar accumulation period with no significant increase in exhaust hydrocarbons with mileage.

TPR 41. Beneficiation of High-Clay Potash Ores by Flotation, by Arthur B. Johnson, Jerome O. Crabtree, Thomas L. McVay, and Paul E. Bennett. September 1971. 12 pp. 2 figs. The Bureau of Mines investigated the concentration characteristics of high-clay sylvanite ores from four potash companies operating in the Permian Basin near Carlsbad, N. Mex. These ores, containing 13 to 22 percent K_2O and 3 to 7 percent clay slimes, cannot be effectively processed by current commercial flotation methods because of their high slime content. A solution to this problem was shown to be the use of two-stage moderate scrubbing conditions and washing of the ore as opposed to strenuous attritioning.

Bench-scale physical beneficiation techniques for recovering potash minerals and the development of ore-dressing systems by flotation resulted in obtaining acceptable product grades and recoveries. By using a coarse grind, emphasis was placed on the production of premium granular and coarse products. Flotation results showed that concentrates of 58.7 to 60.4 percent K_2O with recoveries of 71.0 to 83.4 percent of the K_2O values can be obtained.

TPR 42. Spark-Source Mass Spectrometer Investigation of Coal Particles and Coal Ash, by T. Kessler, A. G. Sharkey, Jr., and R. A. Friedel. September 1971. 15 pp. Spark-source mass spectrometry has been used to determine the amounts of minor and trace elements in coal particles of various sizes, including the respirable range (< 5 microns). Fifty-six elements ranging in concentration from 0.1 ppm wt to 5,000 ppm wt have been determined. The investigation of coal and coal ash has shown that the organic material in coal does not interfere with the spark-source determination of the various elements.

TPR 43. Analysis for Mercury in Coal, by M. D. Schlesinger and Hyman Schultz. September 1971. 4 pp. Mercury exists in coal at very low levels; the structure of coal, the vapor pressure of mercury, and its almost universal occurrence introduce unusual problems into the analytical methods. Round-robin analyses by several laboratories, each using its own techniques, indicate that the

average mercury content of coal is about 0.2 ppm. Some western coals are as low as 0.05 ppm.

TPR 44. Mining and Conversion of Oil Shale in a Gas Combustion Retort, by Sidney Katell and Paul Wellman. October 1971. 11 pp. 2 figs. An economic analysis of one proposed system for the production of synthetic crude oil from oil shale is presented. An oil shale complex for producing 100,000 barrels of semirefined oil per calendar day will require a capital investment of \$426,216,400, a total that includes mining, retorting, intermediate pipelining, and partial refining. A selling price of \$3.74 per barrel of product will be required to maintain a discounted cash-flow rate of 12 percent.

TPR 45. Electronic Color Sorting of Glass From Urban Waste, by F. J. Palumbo, M. H. Stanczyk, and P. M. Sullivan. October 1971. 9 pp. 3 figs. An electronic color-sorting machine was tested for recovering colorless glass concentrates from mixed glass products. The tests were made using glass recovered from unincinerated (raw) urban refuse and residues resulting from the incineration of refuse. The results of the study revealed that concentrates analyzing about 86 percent colorless glass could be recovered from mixed unincinerated glass containing 54 percent colorless glass material. Recovery of the colorless glass was about 62 percent. Color sorting of the incinerated glass was somewhat more difficult. Multiple-stage processing was required to recover 59 percent of the colorless glass material in a product analyzing 89 percent colorless glass. The feed material analyzed 41 percent colorless glass.

TPR 46. Combustion Disposal of Manure Wastes and Utilization of Byproducts, by E. G. Davis, I. L. Feld, and J. H. Brown. January 1972. 9 pp. 1 fig. Agricultural manure wastes were combusted in a fluidized-bed reactor and a small rotary kiln as a method for disposal combined with utilization. As much as 90 percent weight reduction and 85 percent volume reduction was obtained by burning the manures. Dry manure burning in the fluid-bed reactor was self-sustaining, whereas wet manure required drying before it was burned in a rotary kiln using additional heat. Heat balance estimations indicated that preheating would be required to burn wet manure fed directly into the fluid-bed reactor. However, the estimation indicated that no extra heat was needed in the process if the wet manure was predried with exhausted combustion gases before feeding to the fluid bed. The burned residues were pelletized and found suitable for use both as a potassium and phosphorus fertilizer and as a lime soil conditioner.

TPR 47. Extraction of Molybdenum From Ores by Electrooxidation, by B. J. Scheiner and R. E. Lindstrom. January 1972. 9 pp. 5 figs. Extraction of molybdenum from molybdenite ore by an electrolytic oxidation procedure was investigated by the Bureau of Mines. Various parameters affecting molybdenum extraction, such as salt concentration, temperature, treatment rate, current density, and particle size, were studied.

Molybdenum extraction of 95.2 percent was achieved on a laboratory scale from an ore containing 0.35 percent molybdenite. Corresponding power consumption was 24 kilowatt hours per pound of molybdenum extracted with a base consumption of 4.5 pounds of sodium carbonate. Laboratory and pilot plant experiments are in progress

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on low-grade molybdenum concentrates containing rhenium and copper. Preliminary results indicate that molybdenum extractions in the 90 to 99 percent range and rhenium extractions of 95 to 99 percent can be obtained without appreciable oxidation of associated copper minerals.

TPR 48. Clean Automotive Fuel. Engine Emissions Using Natural Gas, Hydrogen-Enriched Natural Gas, and Gas Manufactured From Coal (Synthane), by D. B. Eccleston and R. D. Fleming. February 1972. 13 pp. 3 figs. Natural gas and mixtures of natural gas and hydrogen were used as fuels in a laboratory engine to determine the relationship of emissions to air-fuel ratio and to establish practical lean limits for air-fuel ratio. Synthetic gas manufactured from coal (Synthane) and natural gas were used as fuels in a vehicle to obtain comparative data on emissions and performance. Results showed that the lean limits for air-fuel ratio when using hydrogen-enriched natural gas were extended significantly beyond that of natural gas. Synthane produced exhaust that was significantly less reactive than exhaust from natural gas. With lean air-fuel ratios, the acceleration performance of a vehicle fueled with Synthane was improved compared with its performance when fueled with natural gas.

TPR 49. Clean Automotive Fuel. Laboratory-Scale Operation of the Synthane Process, by A. J. Forney, W. P. Haynes, J. J. Elliott, and R. E. Kenny. February 1972. 6 pp. 4 figs. A high-Btu gas was made at the Bruceton laboratories of the Bureau of Mines to demonstrate the feasibility of using the gas as a nonpolluting fuel for automobiles. The pilot plants at Bruceton had to be revised to combine the processes of coal gasification, gas purification, and catalytic methanation in one overall system. The gas product was tested at Bartlesville, Okla., in their test automobiles. The results showed that the Synthane gas was less polluting than natural gas.

TPR 50. Processing the Plastics From Urban Refuse, by J. L. Holman, J. B. Stephenson, and J. W. Jensen. February 1972. 20 pp. 9 figs. In conjunction with its research program on the separation, recovery, and recycling of metal, mineral, and energy-based materials in urban refuse, the Bureau of Mines is developing means to reuse and recycle plastics discarded in raw municipal waste. Experimental work on plastic waste from a community collection has produced some guidelines for systematic methods of processing, including air classification, cleaning, separation, and use or disposal. Sink-float methods are a practical means of separation into types. Methods for final disposition of the plastic waste include refabrication, thermal decomposition, and incineration.

TPR 51. Flotation of Pyrite From Coal, by K. J. Miller and A. F. Baker. February 1972. 7 pp. A two-stage froth flotation technique was developed in the laboratory to separate fine-size pyrite from coal. The process consists of the initial flotation of a 15-percent solids coal slurry with a minimum of frother; the coarse, free pyrite and other refuse are removed in the tailings. The froth product from this first stage is then repulped and treated with a coal depressant, a pyrite promoter, and a frother to float the remaining fine-size pyrite or pyrite attached to coal particles.

With the two-stage process, the pyrite sulfur content of

a Lower Freeport bed coal sample was reduced from 1.78 percent to 0.75 percent in the first stage, and from 0.75 percent to 0.27 percent in the second stage with good clean coal recovery.

TPR 52. Recycling of Steelmaking Dusts, by P. G. Barnard, A. G. Starliper, W. M. Dressel, and M. M. Fine. February 1972. 10 pp. Methods are described for upgrading steel furnace dusts to produce high-iron pellets for recycling. These dusts contain impurities, such as zinc, lead, and copper, which reflect the character of the feed to the furnace and the operation of the furnaces.

Treatment procedures described include (1) pelletization and reduction roasting to remove lead and zinc, (2) sulfation with sulfuric acid or SO_2 , followed by leaching to remove copper and zinc and pelletization and reduction to remove lead and to metallize iron, (3) pelletization of mixtures of dusts containing carbon, zinc, and lead, followed by roasting to eliminate these elements, and (4) pelletization and roasting of mixtures of blast furnace dusts, basic-oxygen-furnace dusts, and mill scale.

TPR 53. Upgrading Junk Auto Shredder Rejects, by L. J. Froisland, K. C. Dean, and C. J. Chindgren. March 1972. 11 pp. 2 figs. Water classification and heavy-media sink-float methods were investigated for concentrating metallic junk automobile shredder rejects, initially upgraded to about 75-percent metal content in an air elutriation system. An 8-inch-diameter water elutriation column with a feed capacity of 2.7 tons per hour was constructed and operated. The results obtained were compared with those produced by sink-float methods. Tests made on duplicate samples of an intermediate-grade metal product were successful in upgrading the metal content from 75 percent to 98.7 and 99.1 percent with respective recoveries of 95.5 and 98.9 percent for the water classification and sink-float procedures. Tentative flow-sheets for treating junk auto shredder rejects are outlined.

TPR 54. Fate of Trace Mercury in the Combustion of Coal, by R. C. Diehl, E. A. Hattman, H. Schultz, and R. J. Haren. May 1972. 9 pp. 4 figs. Coal, fly ash, and flue gas samples were analyzed for mercury by double gold amalgamation-flameless atomic absorption spectrophotometry. The purpose of the study was to elucidate the fate of the trace mercury in the coal when the coal is burned. Samples were collected from a bench-scale 100-g/hr combustor, a 500-lb/hr combustor, and three coal-burning powerplants. In all cases mercury was found in the fly ash. The amounts ranged from about 9 to about 70 percent of the mercury in the coal that was burned.

TPR 55. Deoxidation of Steel Using Waste Aluminizing Dross (A Feasibility Study), by Harry V. Makar and Patrick J. Gallagher. July 1972. 9 pp. 3 figs. An aluminizing dross which is accumulating as a waste material in substantial quantities was tested for possible use as a steel deoxidizer. This material, consisting mainly of aluminum, silicon, and iron, was used to deoxidize laboratory-scale melts ranging from 7 to 100 pounds. Oxygen analysis showed that the aluminizing dross was effective in reducing oxygen levels in steel. A direct comparison with aluminum wire showed the dross material to be at least as effective. Under similar test conditions with 7-pound melts, 3 grams of aluminum reduced the oxygen concentration from 210 to 175 ppm, while 4 grams of

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aluminizing dross (equivalent to approximately 2 grams aluminum) reduced the oxygen concentration from 250 to 170 ppm. An additional 4 grams of aluminizing dross produced a final oxygen concentration of 140 ppm.

TPR 56. Demonstration of Safety Plugging of Oil Wells Penetrating Appalachian Coal Mines, by G. E. Rennick, J. Pasini III, F. E. Armstrong, and J. R. Abrams. July 1972. 23 pp. 11 figs. An oil well penetrating the Pittsburgh bituminous coalbed in northern West Virginia was plugged and safely mined through 3 months later. A sensitive chemical tracer, introduced into the oil reservoir before the test, was not detected in the mine air following the plugging and during mining of the pillar and penetration of the well. Effectiveness of the plugging in preventing reservoir gas from entering the mine through the well hole was verified by continuous monitoring of the mine air for indications of sulfur hexafluoride, an inert gas detectable in amounts as minute as 0.5 part per billion. Expandable cement and fly ash-gel-water slurry were utilized to seal the well above and below the coal seam. Three other wells were also plugged using various techniques.

TPR 57. Improving Nickel Extraction From Oxide Nickel Ores, by Parkman T. Brooks and George M. Potter. September 1972. 4 pp. A simple and low-cost roasting modification for improving nickel extraction from relatively refractory and low-grade nickel- and cobalt-bearing weathered serpentine was demonstrated on a laboratory scale using the reductive roast-ammonia leach process. Reductive roasting at 750° C of weathered serpentine mixed with only 4 pounds of pyrite per ton of ore enabled extracting 83 percent of the nickel, whereas only 68 percent of the nickel was extracted when pyrite was not used. Improved nickel extraction was achieved with Philippine and Caribbean ores. Little, if any, improvement in cobalt extraction was gained using pyrite.

TPR 58. A Hazard Evasion Program for Mine Planning, by Frank Ruskey and Richard G. Burdick. September 1972. 18 pp. 10 figs. This report describes a computer program devised by the Bureau of Mines to model coal-mining situations where one or more panels encounter oil or gas wells. The program seeks in several hundred trials to evade the wells if possible or to minimize their influence by shifting or skewing the mine plan and/or adjusting the centerline dimensions of the entryways. Upon completion of computations, the program sorts the hundred of models which have been tested, and lists the 10 best with their associated parameters. It also draws a mine plan of the best configuration showing the entryways and crosscuts along with the "lost" coal remaining in the barrier pillars surrounding the various wells.

TPR 59. Preparing Magnetic Fluids by a Peptizing Method, by George W. Reimers and Sanaa E. Khalafalla. September 1972. 13 pp. 6 figs. Agglomeration from matter in the molecular state, rather than long-term grinding and dispersion techniques, was used to prepare magnetic colloids. Under optimum conditions, freshly precipitated iron (II and III) hydrous oxides in an aqueous phase can be extracted into an immiscible hydrocarbon phase by means of a transfer agent. Steric stabilization of the colloidal magnetic particles was

accomplished by a suitable peptizing agent which also acted as a dispersing agent. Rapid preparation of large volumes of magnetic fluids at a substantial saving in cost was accomplished at the Bureau of Mines by the peptization technique.

TPR 60. Solvents and Explosives To Recover Heavy Oil, Bartlett, Kansas, by Larman J. Heath, F. Sam Johnson, and J. S. Miller. September 1972. 11 pp. 4 figs. Preliminary results of an explosive fracturing-solvent injection heavy oil recovery experiment conducted by the Bureau of Mines at a shallow oil reservoir near Bartlett, Kans., are given. Three wells 35 to 50 feet apart were drilled to a depth of 360 feet, and an open hole interval from 300 to 350 feet in the Bartlesville Sandstone Formation was explosively fractured with 3,000 pounds of pelletized TNT in each well. Laboratory tests were made on cores obtained from these wells to confirm the suitability of using an aromatic-type solvent. Injection of a 74 percent aromatic solvent was begun into one well and continued intermittently for approximately 2 months. Crude oil production amounted to 29.6 barrels, or 11.7 percent of the total oil contained within the three-well interwell zone.

TPR 61. Detection of Organic Compounds in Respiratory Coal Dust by High-Resolution Mass Spectrometry, by J. L. Shultz, R. A. Friedel, and A. G. Sharkey, Jr. October 1972. 17 pp. 9 figs. The investigation of organic compounds in respiratory coal dust by high-resolution mass spectrometry has shown that the organic compounds differ (1) with particle size, (2) with rank of coal, (3) in coals of same rank from different coal seams, and (4) in respirable mine dust and respirable coal dust (prepared) from the same mine. The eight respirable mine dusts studied are from coal seams in the Appalachian region where the incidence of coal workers' pneumoconiosis is relatively high. The molecular weights of the major organic components vary greatly among these respirable mine dusts: three show strong concentrations of polynuclear aromatic hydrocarbons.

TPR 62. Field Study of Viscous Oil Production by Solvent Stimulation, Wilmington, California, by H. J. Lechtenberg, G. L. Gates, W. H. Caraway, and O. C. Baptist. November 1972. 12 pp. 4 figs. Preliminary results are given of solvent stimulation of two wells producing viscous oil (14°-17° API) from the Tar zone in the Wilmington field, California. The solvent (coker oil, an intermediate refinery product) was injected into the formation, and after a soak period, the well was returned to production. Data are given on crude oil properties, solvent properties, determination of volume of solvent in the produced oil, rate of oil production before and after stimulation, volume of additional oil produced, and volume of solvent recovered. Although further study and improvement of the method are needed, cyclic solvent stimulation appears to be an unqualified success in one well and a moderate success in one other.

TPR 63. Recovering Plastics From Urban Refuse by Electrodynamic Techniques, by Michael R. Grubbs and Kenneth H. Ivey. December 1972. 6 pp. 2 figs. The Bureau of Mines is currently developing methods for reclaiming the metal and mineral values contained in unburned urban refuse. One important phase of the research deals with recovering plastics from shredded

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refuse using an electrodynamic process. The results of this study have indicated that mixed plastic concentrates analyzing 99.4 percent plastic can be consistently recovered from the light material fraction of shredded refuse, leaving a mixed paper fraction analyzing 99.9 percent paper. Recovery of the plastics exceeds 99 percent.

TPR 64. Tests for Analyzing the Incombustible Content of Coal Mine Dust Using Instruments Employing a Gamma-Ray Backscatter Technique, by F. E. Armstrong and J. R. Abrams. January 1973. 9 pp. 4 figs. A program with the objective of developing a fast, accurate instrumental method of analyzing mine dust for incombustible content has been underway in the Bureau of Mines for several years. Several prototype instruments making use of a gamma-ray backscatter technique have resulted. Although extensive laboratory testing has shown that these instruments are accurate under laboratory conditions, only extensive field testing will prove their ultimate practicality and usefulness. This report shows that under most conditions these devices are at least as accurate as the volumetric method and much faster in use. Other data obtained during the same study concerning mine dust are presented; these concern moisture content, sample bulk density distribution, and some particle size distribution information.

TPR 65. Locating Uncharted Oil and Gas Wells: State-of-the-Art, by F. E. Armstrong. January 1973. 9 pp. 6 figs. The Bureau of Mines has conducted a research program to systematize the art of locating uncharted and lost oil and gas wells that penetrate coal seams; this publication presents a preliminary summary of its findings. Although no method or combination of methods will guarantee finding all uncharted and abandoned wells in a particular area, at least 75 percent of such wells can be located by compiling and applying all information and using modern metal detectors.

TPR 66. Toxic Products From Burning of Fire-Resistant Materials, by Allan F. Smith and Joseph M. Kuchta. February 1973. 19 pp. 12 figs. The Bureau of Mines studied toxic products produced by burning eight fire-resistant mine conveyor belts, a brattice cloth, and an electrical cable insulation obtained from laboratory-scale burning experiments under various air-flow conditions. Generally, CO product concentrations for most materials were noticeably higher than the NO₂ and HCl levels that were measured; also, no phosgene was detected. However, several of the fire resistant belt samples yielded HCl concentrations that were above the reported lethal level for 1/2- to 1-hour exposures, although these data were limited to flow conditions where air dilution effects were small; the belt materials that showed this behavior included samples of polyvinyl chloride, styrene butadiene, styrene butadiene blends, and a British neoprene which yielded the greatest amount of toxic vapor. In addition, some results are presented on the phosphoric acid concentrations that may be produced from the decomposition of ammonium dihydrogen phosphate when dispersed on a burning coalbed.

TPR 67. Copper Recovery From Chalcopyrite by a Roast-Leach Procedure, by P. R. Haskett, D. J. Bauer, and R. E. Lindstrom. March 1973. 12 pp. 4 figs. Sulfation roasting of chalcopyrite concentrates, followed by water or dilute acid leach, was investigated as an alterna-

tive to conventional smelting. Copper sulfation was found to be effectively promoted by the addition of materials such as Fe₂O₃ to the furnace charge. Conversion of the copper to a soluble form was essentially complete after roasting the mixed charge at 400° to 600° C, using an Fe₂O₃-to-chalcopyrite concentrate weight ratio of 1:2.

TPR 68. Detecting Hot Areas in Dumps With Handheld, Infrared Scanners, by Raymond M. Stateham. April 1973. 12 pp. 8 figs. A portable, handheld infrared scanner has been used to detect abnormal surface temperature on dumps of flood-generated trash near Wilkes-Barre, Pa. Three of eight dumps examined had thermal anomalies on the surface, indicating temperature buildup at depth. The anomalies found with the scanner were verified by measurements with a thermocouple probe or a carbon monoxide detector. One week after the investigation was completed, open fire broke out at the site of one of these thermal anomalies; about 6 weeks after the investigation, a thermal anomaly in another dump was verified when a trench was excavated in the dump.

TPR 69. Simulated In Situ Leaching of Copper From a Porphyry Ore, by T. G. Carnahan and H. J. Heinen. May 1973. 11 pp. 7 figs. Extraction of copper from a porphyry ore by simulated in situ leaching techniques was investigated by the Bureau of Mines as a means of recovering copper from deeply buried sulfide deposits. Effects of adding sodium chloride and nitric acid separately to sulfuric acid leaching systems under oxygen pressure were studied on a bench scale to define conditions under which copper could be extracted more effectively from porphyry ores. Charges of ore, crushed to 3/8 inch, were leached under static conditions in the range of 25° to 200° C and in the range of 14 to 400 psig oxygen. Additions of sodium chloride or nitric acid to dilute sulfuric leachants were found to enhance dissolution of chalcopyrite markedly. Addition of 1 weight-percent sodium chloride or 0.25 percent nitric acid increased copper extractions obtained at 80° C with sulfuric acid alone by twofold and eightfold, respectively, under the test conditions. In addition, the Na⁺ ion, along with the Fe³⁺ and SO₄²⁻ ions, forms a crystalline natrojarosite. Precipitation of the codissolved iron as crystalline natrojarosite, or minerals closely related to jarosite, permits continuous contact of the leach solution with the particles of ore, purifies the pregnant solution with respect to iron, and redeposits the ferric iron contents as an innocuous mineral.

TPR 70. Predicting Probable Roof Fall Areas in Advance of Mining by Geological Analysis, by W. K. Overbey, Jr., C. A. Komar, and J. Pasini III. May 1973. 17 pp. 11 figs. Surface fracture trace density, changes in roof rock type, and topographic unloading due to drainage were mapped for the mining areas located in the Blacksville-Osage, W. Va., quadrangles to investigate their influence on mine roof falls. Using these factors, a technique was developed to predict probable roof fall areas ahead of projected mining operations. As a feasibility test of this proposed technique, areas were delineated where one, two, and all three of these factors were operating to formulate a "potential hazard map" for comparison with roof fall observations that were made. The limited evidence suggests that in combination these factors are reliable predictors of where roof falls are likely

to occur. This technique promises to be a useful tool in planning mining operations.

TPR 71. Computerized System for Quantitative X-Ray Diffraction Analysis of Pyrite in Coal, R. R. Schehl and R. A. Friedel. June 1973. 9 pp. 7 figs. The Bureau of Mines has developed a quantitative analysis for pyrite in coal by X-ray diffraction that can be accomplished in little more than 1 hour. To minimize the sample analysis time, data processing has been completely computerized with pertinent output information displayed on a VR12 cathode-ray tube display. Use of this computerized system is not only advantageous during the experimental stages of the pyrite analysis project, but would also be essential if the X-ray diffraction procedure is accepted as a standard method of analysis.

TPR 72. Airborne Asbestos Fiber Concentrations in Asbestos Mines and Mills in the United States, by Leonard Schutz, Walter Bank, and George Weems. June 1973. 15 pp. 12 figs. Personnel of the Bureau of Mines have conducted investigations in the principal asbestos mines and mills in the United States to determine the concentration of airborne asbestos fibers in the workplace, and to establish the exposure of workers to such fibers. The surveys were conducted using the sampling and evaluation method recommended by the National Institute for Occupational Safety and Health. The method consists of collecting the airborne sample on filters and, after appropriate sample preparation, counting the fibers utilizing phase contrast microscopy. The results of the investigation show that fiber concentrations are low in the asbestos mines but high in the asbestos mills, ranging well above 5 fibers/ml of air based on a count of fibers greater than 5 μ m in length.

TPR 73. Directional Properties of Coal and Their Utilization in Underground Gasification Experiments, by C. A. Komar, W. K. Overbey, Jr., and J. Pasini III. November 1973. 11 pp. 9 figs. Renewed interest in the underground gasification of coal evolves from comprehensive studies of earth fracture systems that indicate that the movement of fluids can be controlled in the coalbed. In particular, directional property studies of natural microfracture occurrence, permeability, ultrasonic velocity, tensile strength and orientation of intervals of inherent rock weakness, together with geologic structure setting and fracture trace analysis, can predict the gaseous flow paths in the coalbed. Having this information, the dominant direction in which gases generated and/or liberated by heat would move can be determined so that appropriate well patterns can be developed. Together with advances made in drilling technology that permit long horizontal holes to be drilled through the coal seams, tests can be conducted to determine whether directional control will permit devolatilization of the coalbed and gasification of the remaining hot coke in a systematic manner to produce a low-Btu gas suited for the generation of electricity.

TPR 74. Nuclear Meter for Monitoring the Sulfur Content of Coal Streams, by R. F. Stewart, A. W. Hall, J. W. Martin, W. L. Farrior, and A. M. Poston. 1974. 11 pp. 9 figs. A nuclear meter based on measurement of prompt capture gamma rays is being developed for monitoring the sulfur content of coal streams. Equipment has been built to measure sulfur rapidly, and methods have been devised to compensate for changes in moisture,

ash, and bulk density of coal flowing through a bin. Pilot plant tests of the system with various additives to different coals show a precision and accuracy of 0.02 percent sulfur and 0.04 percent sulfur, respectively. Based on these results, a hardwired meter has been fabricated for testing in a commercial coal preparation plant.

TPR 75. The Dustiness of Different Coal Seams, by R. J. Seibel and F. E. McCall. 1974. 9 pp. 4 figs. A statistical comparison of the dust exposures of coal miners with identical occupations in Pittsburgh, Pocahontas, Freeport, and Kittanning seams was conducted. Results indicated that, in some cases, identical occupations have different dust exposures in different seams. For example, the continuous miner operator in the Pittsburgh and Pocahontas seams is exposed to more dust than the same in the Kittanning seam, but the Kittanning seam has more dust along the haulage roads than the other seams. Also, average dust exposures for similar occupations in continuous and conventional mining operations are similar.

TPR 76. Analysis of Tars, Chars, Gases, and Water Found in Effluents From the Synthane Process, by Albert J. Forney, William P. Haynes, Stanley J. Gasior, Glenn E. Johnson, and Joseph P. Strakey, Jr. 1974. 9 pp. 2 figs. Extensive studies have been made of the various effluents found in the Synthane coal-to-gas process. Analyses have been made of the waters, gases, and trace elements present in some of the streams. Results of analyses show the water effluents are the area where extensive research is needed.

TPR 77. Noncaking Coal Gasified in a Stirred-Bed Producer, by R. V. Rahfuss, G. B. Goff, and A. J. Liberatoro. March 1974. 8 pp. 3 figs. Noncaking 0- by 2-inch subbituminous A coal from New Mexico was gasified with air and steam at 205 psig using a stirred-bed producer to determine coal losses by entrainment in the gas for this low-sulfur, high-ash coal which contained 20 percent particles smaller than 1/16-inch sieve size. The use of fine sized coal has particular importance because most production from mechanized mines is smaller than 2-inch size. This initial attempt showed technical feasibility for gasifying New Mexico subbituminous coal containing small-sized particles in fixed-bed producers without excessive coal loss by entrainment. Dust loss averaged about 2 percent of moisture-free coal, most of which was recovered from the gas. Ash clinkering was controlled by adding 1,010 lb/hr steam to reduce temperatures in the combustion zone. Yield of low-Btu fuel gas, 150 Btu per scf, dry, amounted to 69,800 scfh from 1,490 lb/hr coal (as received) and 3,450 lb/hr air (dry).

TPR 78. Blast Noise Standards and Instrumentation, by David E. Siskind and Charles R. Summers. May 1974. 18 pp. 6 figs. A Bureau of Mines survey of noise from quarry production blasting was conducted at seven crushed-stone quarries, providing information on close-in noise generation, comparative instrumentation, and evaluation of the sound levels as related to blasting parameters and existing State and local noise standards. The results from this preliminary survey will be useful in the design of a complete investigation of the problem of noise from blasting. There exists an immediate need for technical guidelines for noise pollution control agencies presently working on the regulation of impulsive

noise sources. This survey and results from previous work by other researchers are used to derive interim recommendations on weighting scales, generated sound levels, and instrumentation. These recommendations are based on the limited data presently available and may be modified with subsequent investigation of noise generation, propagation, structural damage, and human tolerance.

TPR 79. Effect of Increasing Plastics Content on Recycling of Automobiles, by K. C. Dean, J. W. Sterner, and E. G. Valdez. May 1974. 14 pp. 5 figs. Changes in the types of materials used for the construction of recent automobile models have occasioned a review of the continued applicability of current recycling techniques. Plastics are being used increasingly in late model cars. To evaluate the changes occurring, a 1972 Mercury Montego, furnished by the Ford Motor Co., was completely dismantled and analyzed, and the composition was compared with that of a composite automobile from 15 vehicles ranging in date of manufacture from 1954 to 1965 and designated as a circa 1960 model. The composite vehicle contained about 26 pounds of plastics, while the 1972 model contained over four times that quantity. The increasing use of plastics in automobiles suggests that research to improve the economic potentiality of plastics recycling is warranted. Work done in cooperation with the Ford Motor Co.

TPR 80. Remote Sensing of Potential Spontaneous Combustion in Coal Mines, by Raymond M. Stateham. May 1974. 9 pp. 5 figs. The Bureau of Mines used portable infrared scanners to examine the surface of pillars and faces in the Somerset mine near Somerset, Colo. Zones of temperature buildup, indicative of potential combustion, were detected with the scanners; their existence was verified by temperature measurements with conventional instrumentation. Temperatures of 32° to 62° C were measured on surfaces with normal temperatures of 26° to 35° C. The infrared instruments and techniques appeared to offer a rapid and efficient method for locating potential trouble spots in mines susceptible to fires caused by spontaneous combustion.

TPR 81. An Economic Analysis of Oil Shale Operations Featuring Gas Combustion Retorting, by Sidney Katell and Paul Wellman. September 1974. 18 pp. 1 fig. This report is primarily involved with the economics of producing a high-quality, semirefined shale oil (Syncrude) from oil shale. The study envisions two options

for Syncrude production, 50,000 and 100,000 barrels per calendar day, with an integrated system of underground mining, aboveground processing, and waste handling. The 50,000-barrel-per-day complex will require a capital investment of \$279,450,100 (excluding land cost) and will provide a discounted cash flow (DCF) rate of 12 percent at a Syncrude selling price of \$5.66 per barrel. The larger complex will require a capital investment of \$522,375,400, but the Syncrude selling price declines to \$5.15 per barrel to yield the 12 percent DCF.

TPR 82. Preliminary Evaluation of Underground Coal Gasification at Hanna, Wyo., by G. G. Campbell, C. F. Brandenburg, and R. M. Boyd. October 1947. 14 pp. 9 figs. The Bureau of Mines initiated a field test of underground coal gasification to investigate the technologic feasibility of gasifying a subbituminous coal. The test site is near the town of Hanna, Wyo., about 70 miles northwest of Laramie. Preliminary results of the experiment are described. The coal was ignited in the central well of a 16-well pattern. Both forward and reverse combustion techniques were attempted to prepare a path of sufficient permeability to permit the high air injection rates necessary for gasification. Gasification between linked wellbores was sustained for periods as long as 3 months. Hydrogen-rich gas having a heating value of 100 to 150 Btu/scf was produced. Work done in cooperation with the University of Wyoming.

TRP 83. Cable Whip in Shuttle Car Trailing Cables, by G. J. Conroy and D. Giroux. October 1974. 6 pp. 5 figs. Cable whip occurring during normal movement of a shuttle car can result in a personnel hazard and excessive tensions in the cable. This Bureau of Mines report discusses preferred payout and reel-in torque settings to reduce cable whip. A simplified adjustment procedure is described.

TPR 84. In Situ Combustion of Coal for Energy, by Robert F. Chaiken. November 1974. 12 pp. 3 figs. A concept of efficient thermal energy generation through the in situ combustion of coal and the onsite conversion of that energy to electricity is discussed and shown to offer distinct advantages in the utilization of U.S. coal reserves. Analysis of data from previous underground coal gasification projects suggests that coal can be efficiently burned underground and that the burning process should be maintainable for time periods sufficient to power a commercial electricity generation plant.

INSTRUCTION GUIDES *

IG 1. Coal Mine Ventilation, by Division of Education and Training Services, Bureau of Mines. April 1972. 85 pp. 32 visuals. This course has been developed to increase the miners' knowledge of good ventilation practices in everyday work situations and to instruct them in maintaining adequate face ventilation in accordance with their ventilation plan and the provisions of the Federal Coal Mine Health and Safety Act of 1969.

IG 2. MSA W-65 Self Rescuer, by Division of Education and Training Services, Bureau of Mines. March 1972. 23 pp. 12 visuals. The self rescuer is a device to be used in case of emergency for escape through atmosphere containing carbon monoxide present in the air following a fire or explosion. All personnel in underground mines need to know how to use a self-rescuing device and to be aware of its limitations.

IG 3. Drager 810 Respirator for Self Rescue, by Division of Education and Training Services, Bureau of Mines. March 1972. 20 pp. 10 visuals. The self rescuer is a small gas respirator designed to protect the wearer from carbon monoxide present in the air following a fire or explosion. It is small enough to be carried on one's belt or machine and thus be readily available in case of an emergency.

IG 4. The MSA Hydrogen Sulfide Detector, by Division of Education and Training Services, Bureau of Mines. April 1972. 34 pp. 16 visuals. The purpose of this course is to enable a person who is unfamiliar with the MSA hydrogen sulfide detector to learn the proper operation and care of the instrument. The hazards of hydrogen sulfide are discussed.

IG 5. MSA Nitrogen Dioxide Detector, by Division of Education and Training Services, Bureau of Mines. April 1972. 34 pp. 18 visuals. The purpose of this course is to instruct personnel in the proper use and care of the MSA Nitrogen Dioxide Detector and to acquire a knowledge of nitrogen dioxide and its hazards.

IG 6. G-70 Permissible Methanometer, by Division of Education and Training Services, Bureau of Mines. May 1972. 34 pp. 16 visuals. The purpose of this course is to instruct underground mining personnel in the proper use and care of the G-70 methanometer.

IG 7. Permissible Methanometer M-402, by Division of Education and Training Services, Bureau of Mines. April 1972. 31 pp. 10 visuals. The purpose of this course is to instruct underground mining personnel in the proper use and care of the MSA M-402 methanometer.

IG 8. Hand-Held Permissible Methane Indicating Detector, by Division of Education and Training Services, Bureau of Mines. June 1972. 33 pp. 14 visuals. The purpose of this course is to instruct underground mining personnel in the proper use and care of the Bacharach Permissible Methane Indicating Detector. The guide offers a well-delineated course outline, visual material, and suggestions to the field instructors on methods for an effective course presentation. The use of a training model

of the instrument as well as additional audiovisual materials available from the Bureau of Mines is encouraged.

IG 9. MSA Permissible Methane Spotter, by Division of Education and Training Services, Bureau of Mines. May 1972. 38 pp. 16 visuals. The purpose of this course is to instruct underground mining personnel in the proper use and care of the methane spotter.

IG 10. Fundamentals of Noise Measurement, by Division of Education and Training Services. April 1973. 77 pp. 31 visuals. The purpose of this course is to instruct all mining personnel in the requirements and methods set forth in the Federal Coal Mine Health and Safety Act of 1969 with regard to periodic noise surveys and methods used to combat undesirable environmental noise conditions.

IG 11. Introduction to Courses in Oxygen Deficiency and Methane Detecting Devices, by Division of Education and Training Services, Bureau of Mines. September 1972. 8 pp. The purpose of this course is to train persons involved in testing mine atmospheres in the proper use of oxygen deficiency and methane detecting devices approved by the Bureau of Mines. A goal of the course is to aid miners in developing a basic knowledge of the Federal Coal Mine Health and Safety Act of 1969 regarding oxygen deficiency and methane detection.

IG 12. Riken Gas Indicator (Type 17, 18, and 21), by Division of Education and Training Services, Bureau of Mines. October 1972. 36 pp. 14 visuals. The purpose of this guide is to aid field instructors in training underground mining personnel in the use and care of the Riken Gas Indicator. The course materials are amply supplemented with visual materials.

IG 13. Bacharach Monoxor Carbon Monoxide Indicator, by Division of Education and Training Services. November 1972. 46 pp. 17 visuals. The purpose of this guide is to aid field instructors in the teaching of the proper operation and care of the Monoxor Carbon Monoxide Indicator to underground mining personnel. Included is a course outline and ample visual materials.

IG 14. MSA Explosimeter, Model 2A, by Division of Education and Training Services. October 1972. 27 pp. 9 visuals. The purpose of this instruction guide is to instruct underground mining personnel in the proper use and care of the MSA Explosimeter. A course outline and visuals are included.

IG 15. Koehler and Wolf Permissible Flame Safety Lamps, by Division of Education and Training Services, Bureau of Mines. 52 pp. 24 visuals. The purpose of this training guide is to aid field instructors in their presentation to underground mining personnel the use and care of the flame safety lamp. The lecture materials are amply supplemented with visuals.

* In 1973 responsibility for the Instruction Guides was transferred to the Mining Enforcement and Safety Administration, U.S. Department of the Interior.

INSTRUCTION GUIDES

IG 16. Principles of Mine Rescue, by Division of Education and Training Services. November 1972. 104 pp. 34 visuals. The purpose of this guide is to aid field instructors in the presentation of the principles involved in mine rescue operations to underground mining personnel. The course is well outlined and amply illustrated.

IG 17. Roof and Rib Control, by Division of Education and Training Services. February 1973. 85 pp. 22 visuals. The purpose of this instruction guide is to develop in mining personnel a total awareness to the danger of injuries and fatalities sustained from falls of roof, face, and ribs, and to acquaint these personnel with methods for preventing such falls.

IG 18. MSA Carbon Monoxide Tester, by Division of Education and Training Services. November 1972. 38 pp. 20 visuals. The purpose of this guide is to aid field instructors in the presentation of the proper use and care of the MSA Carbon Monoxide Tester to underground mining personnel. The course is outlined and ample visual materials are included.

IG 19. Mine Emergency Training, by Division of Education and Training Services, Bureau of Mines. September 1972. 47 pp. 15 visuals. This course was devised to instruct miners on how to handle themselves if an emergency occurs in their particular mine. The guide offers a well-delineated course outline, visual material, and suggestions to the field instructors on methods for an effective course presentation.

IG 20. Audiovisual Guide, by Division of Education and Training Services, Bureau of Mines. September 1972. 70 pp. This manual was developed to aid field instructors in the use of audiovisual materials and equipment. It is amply illustrated in addition to being clearly and concisely written.

IG 21. Scott/Draeger BG 174 Mine Rescue Apparatus, by Division of Training and Education Operations, Bureau of Mines. October 1972. 47 pp. 64 visuals.

This Instruction Guide was developed to provide a source of basic information and visual material to assist mining personnel in the training of mine rescue.

IG 22. Auxiliary Rescue Apparatus, MSA Chemox, by Division of Education and Training Services. October 1972. 30 pp. 36 visuals. This instruction guide was developed to provide a source of basic information and visual material to assist mining personnel in the training of mine rescue using the Chemox mine rescue apparatus. The goal is to have adequate personnel in the mining industry capable of conducting rescue and recovery operations following mine fires and explosions.

IG 23. MSA McCaa Mine Rescue Apparatus, by Division of Education and Training Operations. October 1972. 45 pp. 62 visuals. This instruction guide has been developed to provide a source of basic information and visual material to assist mining personnel in the training of mine rescue. The goal is to have adequate personnel in the mining industry capable of conducting rescue and recovery operations following mine fires and explosions using the McCaa mine rescue apparatus.

IG 24. Instructor Training Guide, by Division of Education and Training Services. April 1973. 50 pp. 8 visuals. This is one of a series of instruction guides developed to help health and safety instructors in the presentation of safety training courses to the people of the mineral industry. The purpose of this course is to provide the fundamentals of instruction for potential instructors and to serve as a refresher for experienced instructors.

IG 25. Job Safety Guide. Continuous Miner Operation, by Division of Education and Training Services. April 1973. 34 pp. This job safety course has been developed to provide mining personnel with the necessary knowledge that will enable them to eliminate or control unsafe conditions or acts which contribute to accidents and injuries relative to the operation of a continuous mining machine.

MINERAL INDUSTRY SURVEYS

Mineral Industry Surveys are processed reports that contain statistical and economic data on various mineral commodities. These reports are issued at regular intervals so that information on mineral commodities may be made available quickly and in a convenient form. Most of the data contained in these reports appear in permanent form in the Minerals Yearbook. These reports may be obtained from the Publications Distribution Branch, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213. The list of Mineral Industry Surveys being published in 1974 follows:

WEEKLY

Bituminous Coal and Lignite.
Pennsylvania Anthracite.

MONTHLY

Aluminum Industry.
Cement.
Chromium.
Cobalt.
Coke and Coal Chemicals.
Copper Industry.
District V Petroleum Statement.
Fuel Oils by Sulfur Content.
Gold and Silver.
Iron and Steel Scrap.
Iron Ore.
Lead Industry.
Lime.
Manganese.
Molybdenum.
Natural Gas.
Natural Gas Liquids.
Nickel.
Petroleum Statement.
Sulfur.
Tin.
Tungsten.
Vanadium.
Zinc Industry.
Zinc Oxide.

QUARTERLY

Antimony.
Bauxite.
Bismuth.
Bituminous Coal and Lignite Distribution.
Cadmium.
Carbon Black.
Cobalt Refiners.

QUARTERLY

Copper Sulfate.
Ferrosilicon.
Fluorspar.
Gypsum.
Magnesium, Primary.
Mercury.
Platinum-Group Metals.
Selenium.
Titanium.

ANNUALLY

Abrasive Materials.
Aluminum and Bauxite.
Antimony.
Asbestos.
Asphalt Sales.
Aviation Turbine Fuels (Petroleum Products Survey 84).
 Prepared in cooperation with the American Petroleum Institute.
Barite.
Beryllium.
Bismuth.
Boron.
Bromine.
Burner Fuel Oils (Petroleum Products Survey 86).
 Prepared in cooperation with the American Petroleum Institute.
Cadmium.
Calcium-Magnesium Chloride.
Carbon Black.
Cement.
Cesium and Rubidium.
Chromium.
Clays.
Cobalt.
Coke and Coal Chemicals.
Coke Distribution.
Coke Producers.
Columbium and Tantalum.
Commodity Data Summaries. Preliminary data, in summary form, for most metals, nonmetals, and fuels.
Copper.
Diatomite.
Diesel Fuel Oils (Petroleum Products Survey 87).
 Prepared in cooperation with the American Petroleum Institute.
District V Petroleum Statement.
Explosives.
Feldspar.
Fluorspar.
Fuel Oil Sales.
Gem Stones.
Gold and Silver.
Graphite.
Gypsum.
Iodine.

ANNUALLY

Iron and Steel.
 Iron and Steel Scrap.
 Iron Ore.
 Kyanite.
 Lead.
 Lime.
 Liquified Petroleum Gas Sales.
 Lithium.
 Magnesium and Magnesium Compounds.
 Manganese.
 Mercury.
 Mica.
 Minor Nonmetals.
 Molybdenum.
 Motor Gasolines, Summer (Petroleum Products Survey 83) .
 Prepared in cooperation with the American Petroleum
 Institute.
 Motor Gasolines, Winter (Petroleum Products Survey 85) .
 Prepared in cooperation with the American Petroleum
 Institute.
 Natural Gas.
 Nickel.
 Nitrogen.
 Peat Producers.
 Pennsylvania Anthracite Distribution.
 Perlite.
 Petroleum Refineries in the United States and Puerto
 Rico.
 Petroleum Statement.
 Phosphate Rock.
 Platinum-Group Metals.
 Potash.

ANNUALLY

Pumice.
 Rare-Earth Elements and Thorium.
 Rhenium.
 Salt.
 Sand and Gravel.
 Slag—Iron and Steel.
 Selenium and Tellurium.
 Sodium Compounds.
 Stone.
 Sulfur.
 Talc, Soapstone, and Prophyllite.
 Tin.
 Titanium.
 Tungsten.
 Uranium.
 Vanadium.
 Vermiculite.
 World Crude Oil Production.
 World Mineral Production.
 World Natural Gas.
 Zinc.
 Zirconium and Hafnium.

BIENNIALY

Natural Gas Processing Plants.

TRIENNIALY

Crude Oil and Product Pipeline Mileage in the United States.

FOREIGN MINERAL REPORTS

Foreign mineral reports are issued to assist domestic producers and consumers of mineral commodities to keep abreast of developments in the minerals industries and markets abroad and provide a brief summary of significant information from U.S. Foreign Service offices and other sources, which may otherwise not be made available to the general public. These publications may be obtained from the Publications Distribution Branch, Bureau of Mines, 4800 Forbes Ave., Pittsburgh, Pa. 15213.

International Coal Trade. Issued monthly. Summarizes the latest salient statistical and economic data on worldwide coal trade.

Mineral Trade Notes. Issued monthly. Provides selected news notes and brief economic information on a variety of mineral commodities (except fuels) throughout the world.

International Petroleum Annual. Provides data for nearly all countries outside the Soviet bloc on production; imports and exports, showing countries of origin and destination; refinery runs of crude oil; calculated demand for major refined products; and world retail prices and taxes for refined petroleum products.

COOPERATIVE PUBLICATIONS

WITH THE STATE OF FLORIDA DEPARTMENT OF NATURAL RESOURCES, DIVISION OF INTERIOR RESOURCES, BUREAU OF GEOLOGY

FNR 1-71. *Land Use Conflicts and Phosphate Mining in Florida*, by John W. Sweeney. 1971. 42 pp. 6 figs. Florida Bureau of Geol. Inf. Circ. 72.

WITH THE GEOLOGICAL SURVEY, U.S. DEPARTMENT OF THE INTERIOR

The Wilderness Act (Public Law 88-577, Sept. 3, 1964) and the Conference Report on Senate Bill 4, 88th Congress, direct the Geological Survey and the Bureau of Mines to make mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System. Areas classified as "primitive" were not included in the Wilderness System, but the act provided that each area should be studied for its suitability for incorporation into the Wilderness System. The act also directs the Secretary of the Interior to review roadless areas of 5,000 contiguous acres or more and every roadless island within the national wildlife refuges and game ranges under his jurisdiction, and to report the suitability or unsuitability of each area or island for preservation as a wilderness. The mineral surveys of the primitive areas, wildlife refuges, and game ranges are one aspect of the suitability studies.

GS 1-70. *Mineral Resources of the Emigrant Basin Primitive Area, California*, by E. W. Tooker, H. T. Morris, and Paul V. Fillo, with a section on geophysical studies by H. W. Oliver. 1970. Geol. Survey Bull. 1261-G. 70 pp. 19 figs. 1 pl. \$1.

GS 2-70. *Mineral Resources of the Ague Tibia Primitive Area, California*, by William P. Irwin, Robert C. Greene, and Horace K. Thurber. 1970. Geol. Survey Bull. 1319-A. 19 pp. 3 figs. 1 pl. 65 cents.

GS 3-70. *Mineral Resources of the Jack Creek Basin, Madison County, Montana*, by George E. Becraft, Thor H. Killsgaard, and Ronald M. Van Noy. 1970. Geol. Survey Bull. 1319-B. 24 pp. 3 figs. 2 pl. 65 cents.

GS 4-70. *Mineral Resources of the Gore Range-Eagles Nest Primitive Area and Vicinity, Summit and Eagle Counties, Colorado*, by Ogden Tweto, Bruce Bryant, and

Frank E. Williams. 1970. Geol. Survey Bull. 1319-C. 127 pp. 23 figs. 2 pl. \$1.50.

GS 5-70. *Mineral Resources of the Sawtooth Primitive Area, Idaho*, by Thor H. Killsgaard, Val L. Freeman, and Joseph S. Coffman. 1970. Geol. Survey Bull. 1319-D. 174 pp. 29 figs. 2 pl. \$1.75.

GS 6-70. *Mineral Resources of the Black Range Primitive Area, Grant, Sierra, and Catron Counties, New Mexico*, by George E. Erickson, Helmuth Wedow, Jr., Gordon P. Eaton, and George R. Leland. 1970. Geol. Survey Bull. 1319-E. 162 pp. 16 figs. 2 pl. \$2.25.

GS 1-71. *Mineral Resources of the Glacier Primitive Area, Wyoming*, by H. C. Granger, E. J. McKay, R. E. Mattick, Lowell L. Patten, and Paul McIlroy. 1971. 113 pp. 17 figs. 2 pl. Geol. Survey Bull. 1319-F. \$1.75.

GS 1-72. *Mineral Resources of the Pasayten Wilderness Area, Washington*, by Mortimer H. Staatz, Paul L. Weis, Rowland W. Tabor, Jacques F. Robertson, Ronald M. Van Noy, Eldon C. Pattee, and Dean C. Holt, with a section on aeromagnetic interpretation by Gordon P. Eaton and Mortimer H. Staatz. 1971. 255 pp. 66 figs. 3 pl. Geol. Survey Bull. 1325. \$2.25.

GS 2-72. *Mineral Resources of the Wilson Mountains Primitive Area, Colorado*, by Calvin S. Bromfield and Frank E. Williams, with a section on geophysical interpretation by Peter Popenoe. 1972. 79 pp. 11 figs. 2 pl. Geol. Survey Bull. 1353-A. \$1.25.

GS 3-72. *Mineral Resources of the Popo Agie Primitive Area, Fremont and Sublette Counties, Wyoming*, by Robert C. Pearson, Thor H. Killsgaard, and Lowell L. Patten. 1971. 55 pp. 10 figs. 2 pl. Geol. Survey Bull. 1353-B. \$1.25.

GS 4-72. *Mineral Resources of the Salmon River Breaks Primitive Area, Idaho*, by Paul L. Weis, Leonard J. Schmitt, Jr., and Ernest T. Tuckek, with a section on aeromagnetic survey by W. E. Davis. 1972. 91 pp. 33 figs. 2 pl. Geol. Survey Bull. 1353-C. \$1.50.

GS 1-73. *Mineral Resources of the Idaho Primitive Area and Vicinity, Idaho*, by F. W. Cater, D. M. Pinckney, W. B. Hamilton, R. L. Parker, R. D. Weldin, T. J. Close, and N. T. Zilka, with a section on the Thunder Mountain district by B. F. Leonard, and a section on aeromagnetic interpretation by W. E. Davis. 1973. 431 pp. 126 figs. 2 pl. Geol. Survey Bull. 1304, GPO Catalog No. I19.3:1304, Stock No. 2401-02434. \$4.65.

GS 2-73. *Geology and Mineral Resources of the Northern Part of the North Cascades National Park, Washington*, by Mortimer H. Staatz, Rowland W. Tabor, Paul L. Weis, Jacques F. Robertson, Ronald M. Van Noy, and Eldon C. Pattee. 1972. 132 pp. 20 figs. 2 pl. Geol. Survey Bull. 1359, GPO Catalog No. I19.3:1359, Stock No. 2401-2135. \$2.00.

GS 3-73. *Mineral Resources of High Sierra Primitive Area, California*, by James G. Moore and Lawrence

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Y. Marks, with a section on aeromagnetic interpretation by H. W. Oliver. 1972. 40 pp. 11 figs. 1 pl. Geol. Survey Bull. 1371-A. GPO Catalog No. I19.3:1371-A. Stock No. 2401-2132. \$1.00.

GS 4-73. Mineral Resources of the Salmon-Trinity Alps Primitive Area, California, by Preston E. Hotz, Horace K. Thurber, Lawrence Y. Marks, and Robert K. Evans, with a section on aeromagnetic survey and interpretation by Andrew Griscom. 1972. 267 pp. 56 figs. 2 pl. Geol. Survey Bull. 1371-B. GPO Catalog No. I19.3:1371-B. Stock No. 2401-2199. \$3.75.

GS 5-73. Mineral Resources of the Cloud Park Primitive Area, Wyoming, by Thor H. Kiilsgaard, George E. Ericksen, Lowell L. Patten, and Carl L. Bieniewski.

1972. 60 pp. 10 figs. 2 pl. Geol. Survey Bull. 1371-C. GPO Catalog No. I19.3:1371-C. Stock No. 2401-00219. \$1.75.

GS 6-73. Mineral Resources of an Area Near the Popo Agie Primitive Area, Fremont County, Wyoming, by Robert C. Pearson, Lowell L. Patten, and David L. Gaskill. 1973. 18 pp. 1 fig. 1 pl. Geol. Survey Bull. 1391-A. GPO Catalog No. I19.3:1391-A. Stock No. 2401-02403. \$1.30.

GS 1-74. Mineral Resources of the Chiricahua Wilderness Area, Cochise County, Arizona, by Harald Drewes and Frank E. Williams, with a section on aeromagnetic interpretation by Gordon P. Eaton. 1973. 53 pp. 13 figs. 1 pl. Geol. Survey Bull. 1385-A. GPO Catalog No. I19.3:1385-A. Stock No. 2401-02425.

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OFR 1-70. Stability of Nitroparaffins. Progress Reports 1-16, March 1955 to February 1959, by J. A. Herickes and J. Ribovich. 1959. The primary objective of this program was to determine the possibility of desensitizing commercial nitroparaffins to such stimuli as high velocity impact, high temperature, and adiabatic compression of gases. The program involved two main areas of research: (1) the study of the shock sensitivity of nitromethane and nitromethane plus additives including higher nitroparaffins and (2) the study of the thermal stability of nitromethane and nitromethane plus additives. In the shock sensitivity study 62 additives were evaluated; 35 additives were selected for detailed study to determine the effect of concentration, and in some cases, the effect of temperature and confinement of the system. The best desensitizers and most effective sensitizers of those tested were determined. Suitable equipment and instrumentation were developed for the thermal stability study. Both purified 99-percent grade and commercial 96-percent grade nitromethane were used in decomposition studies made at temperatures from 300° to 600° F. The effects of selected additives were determined. The direction of further research is briefly considered. Available for inspection at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 2-70. The Price Behavior of Nonfuel Mineral Commodities, by C. McCuiston, E. Battison, and A. M. Lago. Prepared for the Bureau of Mines by Resource Management Corporation. Jan. 15, 1970. 146 pp. The report initiates and develops statistical methodology for studying the price behavior of nonfuel minerals, conducts an empirical analysis of price variation within and between mineral commodity groups, and presents the results of case studies showing the effects of price variation on selected economic indicators in the mining industry. Available for inspection at the Bureau of Mines libraries at Bartlesville, Okla., Denver, Colo., Minneapolis, Minn., Pittsburgh, Pa., and San Francisco, Calif.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 3-70. Testing for Downward Vein Extensions of Gold-Silver Mineralization in the Wolf Creek-Fairbanks Creek Divide Area, Fairbanks, Alaska, by Robert S. Warfield. 1970. 20 pp. 4 figs. During the summer field season of 1967, the Bureau of Mines core drilled two holes on the Keystone properties near the Fairbanks Creek-Wolf Creek divide in the Pedro Dome-Cleary Summit area; this location is about 20 miles northeast of Fairbanks. The purpose of the drilling was to test at depth the continuity of gold, silver, and base metal (mainly lead and antimony) mineralization that has recently been mined by open cut and relatively shallow underground methods. The two holes were drilled vertically to depths of 716.6 and 690 feet. Assays of samples from each hole established that gold, silver, and base metal mineralization is present at depth, although grade was fairly low. Available for inspection at the State Historical Library, Juneau, Alaska; at the Division of Mines and Geology, Alaska Department of Natural Resources, College and Juneau, Alaska; at the University of Alaska, College, Alaska; at the Public Inquiries Office, Geological Survey,

U.S. Department of the Interior, Anchorage, Alaska; at the Geological Survey offices in Juneau and Fairbanks, Alaska, and Menlo Park Calif.; at the Bureau of Mines Offices Mineral Resources in Anchorage and Fairbanks, Alaska; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 4-70. Mine Rescue and Survival. Final Report, prepared for the Bureau of Mines by the Committee on Mine Rescue and Survival Techniques, National Academy of Engineering, Washington, D.C. March 1970. 81 pp. The National Academy of Engineering Committee on Mine Rescue and Survival Techniques was established in March 1969 at the request of the Bureau of Mines to "conduct a study program to assess the technological capabilities that can be applied to survival and rescue techniques following mining disasters." The Committee agreed with the Bureau of Mines (1) to define a mine rescue and survival system that could be developed in approximately 1 year from existing technology, (2) to plan a more advanced system that could be realized with a 5- to 7-year research and development program, and (3) to plan the research and development program that would implement the advanced system. The first part of the report describes the interim system of mine rescue that uses the existing technology including emergency breathing devices, refuge chambers, telephone and electromagnetic communications, seismic communications, and drilling and rescue-team techniques. The second part of the report gives recommendations for a research and development program that will provide the needed data for planning an advanced system of survival and rescue techniques in mine disasters. Available for reference at the Bureau of Mines libraries at Denver, Colo., Minneapolis, Minn., and Pittsburgh, Pa.; at Coal Mine Safety District A Office and Subdistrict Offices, Pittsburgh, Wilkes-Barre, and Johnstown, Pa., and St. Clairsville, Ohio; at Coal Mine Safety District B Office and Subdistrict Office, Mount Hope and Morgantown, W. Va.; at Coal Mine Safety District C Office, Norton, Va.; at the Alaska Field Operation Center, Juneau, Alaska, the Eastern Field Operation Center, Pittsburgh, Pa., the Intermountain Field Operation Center, Denver, Colo., and the Western Field Operation Center, Spokane, Wash.; at the Mines Systems Engineering Group, Denver, Colo.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 5-70. Changing Patterns in Expenditures for Supplies in the U.S. Bituminous Coal and Lignite Industry—1958 and 1963. Preparation and Cleaning, by Franklin D. Cooper. 1969. This report relates to the actual costs of 78 classes of purchases made by the U.S. bituminous coal and lignite industry for its processing activities during 1958 and 1963. These purchases, or inputs, are separated into two broad classes comprising operating supplies excluding fuels and electricity and those parts and materials, having a service life less than 3 years, which were used for repair and maintenance activities. Also included in this report are descriptions of the major processes and methods employed in the 1958-63 period, trends in operating practices, the shift in the mix of processes employed, and the actual costs of inputs

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for specific activities and processes. Inputs for which no detailed cost data are available are listed as areas for future research. This study provides a better understanding of the impact on the supplying industries by the changing demands for inputs and their interrelationship to other sectors of the national economy. Available for reference at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 6-70. Changing Patterns of Expenditures for Supplies in the U.S. Copper Industry—1958 and 1963. Mining, Beneficiation, and Hydrometallurgy, by Franklin D. Cooper. 1969. This report compares the cost of operating supplies and parts and materials for repair and maintenance used by the U.S. copper industry in 1958 and 1963. Mining, beneficiation, and hydrometallurgical activities only are included. This evaluation brings together for the first time detailed cost data for different years. It provides a better understanding of the impact on the supplying industries of the changing demands for inputs and the interrelationship of other sectors of the national economy. It also permits discussion of the changing pattern in the demand for inputs as a result of the gradual adoption of new technology and its effects on operating practices. It allows broader implications to be drawn about rates of technologic progress in mining activities. Available for reference at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 7-70. Physical Properties of Sulfur Compounds. Literature Review Through 1955 (C_1 to C_{13}), by W. E. Haines, R. V. Helm, and Janice L. Stephens. October 1969. These tables of physical properties are the result of an extensive literature search that has been continued as part of the Bureau of Mines study of sulfur compounds in petroleum. This study, carried on cooperatively with American Petroleum Institute Research Project 48, was concerned with the types of sulfur compounds that have been found in petroleum, namely the thiols, sulfides, disulfides, and thiophenes. The tables include all of these compounds from C_1 through C_{13} except those compounds that have atoms other than carbon, hydrogen, and sulfur. The literature from 1840 through 1955 was searched for physical property data. Some previously unpublished data obtained by the Bureau of Mines are included. Available for reference at the Petroleum Research Centers at Laramie, Wyo., and Bartlesville, Okla., and the Morgantown Petroleum Research Laboratory, Morgantown, W. Va.

OFR 8-70. Physical Properties of Sulfur Compounds. A Literature Review Through 1955 of the Higher Molecular Weight Compounds (C_{14} and up), by R. V. Helm. October 1969. The tables of physical properties are the result of an extensive literature search that has been continued as part of the Bureau of Mines study of sulfur compounds in petroleum. This study, carried on cooperatively with American Petroleum Institute Research Project 48, is concerned with the types of sulfur compounds that have been found in petroleum, namely the thiols (mercaptans), sulfides (thioethers), disulfides, and thiophenes. The tables in this paper include all of these compounds from C_{14} to C_n which are composed only of carbon, hydrogen, and sulfur atoms. The values in these tables are from the literature through 1955. Two

other papers include the literature through 1955 for the compounds from C_1 through C_{13} and the literature from 1956 through 1960 for the compounds from C_1 to C_n . Available for reference at the Petroleum Research Centers at Laramie, Wyo., and Bartlesville, Okla., and the Morgantown Petroleum Research Laboratory, Morgantown, W. Va.

OFR 9-70. Physical Properties of Sulfur Compounds. A Literature Review (C_1 to C_n), by R. V. Helm. 1969. This volume updates OFR 7-70 and 8-70 by tabulating the values for physical properties of sulfur compounds found in petroleum as published in the literature from 1956 through 1960. The tables in this paper include all of the compounds from C_1 to C_n which are composed only of carbon, hydrogen, and sulfur atoms. Available for reference at the Petroleum Research Centers at Laramie, Wyo., and Bartlesville, Okla., and the Morgantown Petroleum Research Laboratory, Morgantown, W. Va.

OFR 10-70. Underground Coal Mining in the United States—Research and Development Programs, prepared for the Office of Science and Technology by TRW Systems Group. June 1970. In this study the problems of underground coal mining in the United States were examined, and recommendations were developed for a 5-year integrated research and development program to resolve the problems by improved technology. The specific objectives of the study were (1) to identify the existing inadequacies that adversely affect the health, safety, external environment and productivity of underground coal mining; (2) to identify opportunities for technological advances to correct these inadequacies; and (3) to develop an integrated research and development program designed to accomplish the advances identified. Many clearly long-range projects are recommended. Available for reference at the Bureau of Mines libraries at Denver, Colo., Minneapolis, Minn., and Pittsburgh, Pa.; at the Spokane Mining Research Laboratory, Spokane, Wash.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 11-70. The Impact of Corporate Diversification on the Mineral Industry, by D. F. Klyce and R. Sulentrop. 1970. 45 pp. 9 figs. In this report the Bureau of Mines studies the structure of the mineral industry; reasons, history, and legal aspects of mergers; merger activity in the mining industry; and the effects of mergers on industry structure, profits, and production. Most mineral mergers occurred in the crude petroleum, natural gas, and petroleum refining sectors. Before 1967 horizontal mergers were predominant in the mineral industry. Since that time, the conglomerate merger has been most popular. This study indicated that mineral-oriented companies that merged frequently did no better in areas such as stock prices and earnings per share than did those which relied on internal growth. Available for reference at the Bureau of Mines libraries at Albany, Oreg., Bartlesville, Okla., Denver, Colo., Minneapolis, Minn., and Pittsburgh, Pa.; at the Western Field Operation Center, Spokane, Wash., and Alaska Field Operation Center, Juneau, Alaska; at the Mineral Supply Field Offices at Knoxville, Tenn., Dallas, Tex., Socorro, N. Mex., Tucson, Ariz., Laramie, Wyo., Salt Lake City, Utah, San Francisco, Calif., Reno, Nev., and Anchorage and Fairbanks, Alaska; and

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at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 12-70. Working Documents Prepared for the Advisory Conference on Tunnelling of the Organization for Economic Co-operation and Development, Washington, D.C., June 22-26, 1970. The results of a questionnaire on tunnelling distributed by the Organization for Economic Co-operation and Development to its member nations in April 1969 along with findings and conclusions were compiled in six reports for use at the OECD Advisory Conference on Tunnelling. The reports were entitled (1) Demand for Tunnelling, 1960-1980; (2) Inadequacies and Needed Improvements in Technology for Rock Tunnelling, rapporteur: T. E. Howard; (3) Present-Day Inadequacies and Needed Improvements in the Technology of Cut-and-Cover Construction, rapporteur: Prof. Dr.-Ing. Schnidbauer; (4) Inadequacies and Needed Improvements in the Technology of Immersed Tunnels, rapporteur: H. C. Wentink; (5) Present-Day Inadequacies and Needed Improvements in the Technology of Soft Ground Tunnelling, rapporteur: Jacques Deschamps; and (6) Research and Development in the Field of Tunnelling.

OFR 13-70. Advisory Conference on Tunnelling of the Organization for Economic Co-operation and Development Proceedings, June 22-26, 1970, Washington, D.C., August 1970, 203 pp. This volume contains a preliminary text of the proceedings of the Conference. Included are all addresses, statements and reports presented at the plenary sessions, together with the recommendations of the conference. The appendix contains the prepared comments of certain national delegations and official observers, as well as other items of general interest. The working documents contained in OFR 12-70 are not included; however, highlights of those documents and of the technical sessions are summarized in various presentations.

NOTE: OFR 12-70 and OFR 13-70 are available for reference at the Denver Mining Research Center, Denver, Colo., the Spokane Mining Research Center, Spokane, Wash., the Twin Cities Mining Research Center, Fort Snelling, Minn., and the Pittsburgh Mining Research Center and the Safety Research Center, Pittsburgh, Pa.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 14-70. Reconnaissance of the Gold-Bearing Quartz Veins in the Tibbs Creek Area, Goodpaster River, Big Delta Quadrangle, Central Alaska, by Bruce I. Thomas. 1970. 12 pp. 5 figs. Gold-bearing quartz veins at Tibbs Creek, Goodpaster River, about 54 miles N 60° E of Delta Junction, Central Alaska, were examined by the Bureau of Mines to determine the production potential and extent of the metalliferous lode area. The reconnaissance work was only 50 percent completed and an appraisal of the area on the basis of accumulated data would be misleading. Work was confined to sampling of pits and trenches. Underground workings at the Blue Lead, Blue Lead Extension, Grizzly Bear, and Grey Lead are iced but cursory inspection reveals they would be safe for entry after removal of ice barriers.

Bureau of Mines records show a scant 150 tons of ore, averaging 0.88 ounce of gold per ton, was produced from

the Blue Lead, Blue Lead Extension, and Grizzly Bear. The amount of subsurface mining in this remote area is not explained by the surficial sampling and related work that was completed during the reconnaissance. Continuance of surface sampling and removal of ice barriers for entry underground to permit mapping and sampling is recommended. Available for inspection at the Bureau of Mines offices in Anchorage and Fairbanks, Alaska, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 1-71. Impact of Environmental Controls on the Southeastern Ohio Coal Industry, by Patricia A. Malin and Annette P. Graham. April 1970. 102 pp. This study, done under contract for the National Air Pollution Control Administration, is one of a series of investigations conducted by the Bureau of Mines in order to develop a statistical model which will measure the cost of air pollution regulation in terms of income and employment in regions that produce high-sulfur coal. Possible regulations are not discussed. The study is based on the assumption that SO₂ emission regulation results in a drop in high-sulfur coal production. The Southeastern Ohio region was selected for analysis because most of its coal reserves are high in sulfur. The model examined is a simple application of regression analysis using county income data available from the Department of Commerce. The model develops a general regional picture. Also discussed are the composition of the regional industry, and the various sectors of the regional economy and employment in them. Two sets of conclusions are drawn. The first concerns the reliability and limitations of the regression model. (Its major shortcoming is the short time span covered by the data available from the Department of Commerce.) The second has to do with the impact of a reduced coal output on the Southeastern Ohio region and the implications for other high-sulfur coal regions. (The impact on Southeastern Ohio will be great in terms of employment and income due to the lack of industrial diversification in the region where most employment is in manufacturing, which is a sector of the economy with sluggish growth and which is probably indirectly dependent upon coal for power.) Available for reference at the Bureau of Mines libraries at Denver, Colo., Pittsburgh, Pa., and Morgantown, W. Va.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 2-71. A Seventy-Eight Sector Interindustry Model of the Pacific and Mountain States for 1963, by M. Zaki Yakouk and Jona S. Bargur. Prepared by the Sanitary Engineering Research Laboratory, University of California, Berkeley, Calif., for the Bureau of Mines. June 1970. 54 pp. The regional input-output model reported was developed as part of the Bureau's resource allocation investigations. The economies of the 11 Pacific and Mountain States are highly interrelated, and in periods of growth they tend to become increasingly dependent on regional resources and less dependent on the more industrialized East. This study attempted to quantify these flows as precisely as possible and to analyze the productive potential of the region as a whole in the light of its known resources and possible comparative trade advantages. Major difficulties encountered were a lack of standardized accounting procedures, a lack of implicit agreement on economic sectoral units of disaggregation,

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problems of secondary transfers, and the absence of gross trade flow data from primary sources. The study can be considered to have concentrated on the problems of standardization in sectoring and of disaggregating at the regional level. The 1963 78-sector input-output model for the Pacific Mountain States is based on the 1958 U.S. national coefficients. Available for reference at the Bureau of Mines library, Denver, Colo., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 3-71. Comprehensive Analysis and Action Alternatives for Northeastern Pennsylvania, 3 Volumes, by R. J. Buck, L. Radner, M. Rifkin, and R. B. Shaller. Prepared by The MITRE Corporation for the Bureau of Mines. October 1970. This report briefly summarizes the 6-month first phase of a comprehensive study of the anthracite region of Pennsylvania. Purpose of the study is to develop a comprehensive view of the critical factors that influence economic growth in mining communities there, with special emphasis on the total quality of the community environment. This first phase report defines and describes the area and analyzes its infrastructure (land, transportation, and public utilities), economy, government, development plans, and certain specific community characteristics. Volume I, Executive Summary, presents the principal observations, insights, and recommendations developed by the study. Volume II, The Current Situation, contains a geographical definition of the area, a description of the general physical environment, an analysis of the effects of the decline of the anthracite industry in terms of the community characteristics of Scranton, Carbondale, and five other metropolitan areas, a discussion of the economy of the area, a discussion of the role of government in improving environmental quality and sustaining economic growth in the area, an identification and summary of the roles of the key organizations influencing development planning in the area, and identification and summary of the roles, alternative strategies, candidate programs, and planning suggestions for the area. Available for reference at the Bureau of Mines Environmental Affairs Field Office, Wilkes-Barre, Pa., and Division of Environment, Washington, D.C., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 4-71. A Comprehensive State-of-the-Art Evaluation for All Types of Dust Collection Equipment That May Be Applicable in Underground Coal Mines, prepared by Garrett Research and Development Company, Inc., for the Bureau of Mines. Dec. 1, 1970. 43 pp. Pilot-plant tests were conducted on a variety of dust collectors in order to demonstrate that dust collection technology is sufficiently advanced that the performance of various collection mechanisms on coal dust can be explained. The merits of the individual collectors were not determined. The procedures for determining results and the test results are set forth in this report. The collectors, selected to provide a variety of collection mechanisms, were operated according to manufacturers' recommendations. The report shows that, although dust collection mechanisms are available to clean the coal-laden air of a coal mine to 2 milligrams per cubic meter, no commercial dust collector is available which can meet the air quality specifications under the physical constraints of the mine environment. Available for reference at the

Bureau of Mines libraries, Pittsburgh, Pa., Denver, Colo., Minneapolis, Minn., and Spokane, Wash., at the office of the Assistant Director—Mining, Washington, D.C., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 5-71. Preliminary Investigation of a Low-Grade Gold Deposit in Custer County, Idaho, by D. W. Lockard and W. L. Rice. 1970. 58 pp. 36 figs. The Bureau of Mines conducted a research program on the feasibility of recovering gold from the Golden Sunbeam mine, Custer County, Idaho. This mine produced significant quantities of gold prior to 1920. The research program consisted of diamond drilling, geological mapping, assaying, computer analysis of assay data, metallurgical research, and ore testing. Preliminary evaluation of the deposit infers about 82 million tons of submarginal gold and silver resources with an average value of \$1.07±\$0.11 per ton. This report presents the physical and historical aspects of the deposit as well as a detailed analysis of the Bureau's work, including the design of a hypothetical open pit. Available for reference at the Western Field Operation Center, Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 6-71. Strippable Reserves of Bituminous Coal and Lignite in the United States, by Staff, Bureau of Mines. June 1971. 229 pp. 6 figs. The strippable reserves of bituminous coal and lignite in the United States were calculated in accordance with the prevailing conditions of seam thickness and depth of overburden in each of the several coal-producing areas of the Nation. A brief discussion is given for each coal-producing State, summarizing past and present production, historical background, and outlook. Appendix A contains reserve data by State, county, seam, and sulfur content. Appendix B contains the general information and requirement necessary to comply with the current strip mining laws covering 20 States. Available for reference at the Eastern Field Operation Center, Pittsburgh, Pa., and at the Central Library, U. S. Department of the Interior, Washington, D.C.

OFR 7-71. An Attitudinal Survey of Area Residents Toward Indiscriminate Trash Dumping and Possible Causes of Anthracite Mine Fires, Pennsylvania Anthracite Region. In Two Volumes, prepared by Resource Management Corporation for the Bureau of Mines. Dec. 18, 1970. Volume I: Analysis, 59 pp. Volume 2: Appendices. A study was performed to determine the attitudes of residents of the anthracite coal region of northeastern Pennsylvania toward mine-related fire and attendant environmental problems and to review current solid-waste-disposal practices. Particular attention was given to the indiscriminate disposal of solid wastes in abandoned strip mines, a known contributor to mine-fire ignition. Community leaders, 500 residents, and representative waste collectors were interviewed. It was concluded that means should be developed to prevent access to abandoned stripping areas and that an environmental awareness educational program among both adults and school-aged youth should be developed using television, newspapers, and school curricula adaptations. Available for inspection at the Bureau of Mines Division of Environment Field Office, Wilkes-Barre, Pa.; at the Bureau of

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Mines library at Pittsburgh, Pa.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 8-71. Investigations of Gossans of Hot Springs Dome, Near Manley Hot Springs, Alaska, by Raymond P. Maloney. May 1971. 28 pp. Prominent gossans on the summit of Hot Springs Dome were investigated during 1953-54 to determine whether commercially valuable metal sulfides were below the zone of oxidation. The gossan-capped zones are 100 to 500 feet long and 20 to 50 feet wide in metamorphosed sedimentary rocks near their contact with a large body of granitic intrusives. The gossans had been explored superficially and two claims on the strongest gossans had been patented. Various Government geologists and engineers reported the presence of small amounts of lead, zinc, copper, and cobalt sulfides or oxides, but in general the pits and adits had disclosed iron and manganese oxides only.

The Bureau of Mines drilled eight diamond drill holes in 1954 that varied in length from 243 to 515 feet. The objective was to penetrate to the zone of primary sulfides but oxidation was practically complete to a vertical depth of slightly more than 400 feet, which was the limit of the equipment; however, a small amount of galena in relatively unfractured rock was intersected by one hole. Most of the drill hole intersections were in strongly brecciated rock that was traversed by numerous seams of limonite, goethite, or siderite; some of these seams were several feet wide. Available for reference at Bureau of Mines offices in Juneau, Anchorage, and Fairbanks, Alaska, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 9-71. Wire Rope Applications and Practices Associated With Underground Coal Mining in the United States, by C. H. Larsen, R. A. Egen, R. D. Jones, and H. A. Cress. September 1971. 261 pp. A 9-month study of the uses of wire rope associated with U.S. underground coal mining is reported. Rope applications are broken down into hoisting and nonhoisting applications where "hoisting" refers to transport in vertical and inclined shafts. The former receives the greatest emphasis since it represents the most critical rope application from the standpoint of production and safety. The discussion of hoisting practice includes aspects related to the mine operators as well as those related to the equipment builders and wire rope manufacturers. U. S. State and Federal laws regulating hoisting and wire rope use are also presented and discussed. Canadian and other foreign hoisting practice and laws are included. Available for reference at Bureau of Mines libraries in Denver, Colo., Twin Cities, Minn., Pittsburgh, Pa., and Spokane, Wash., and at the Central Library, U. S. Department of the Interior, Washington, D.C.

OFR 10-71. Foam Suppression of Respirable Coal Dust, by I. O. Salyer, S. M. Sun, J. L. Schwendeman, and A. L. Wurster. December 1970. 55 pp. 14 figs. With the objective of suppressing the respirable dust in coal mines by foam application, a formulation was developed for making a water-based, high-expansion, and limited stability foam. A horizontal boring machine was used as a laboratory coal mining model for generating coal dust. A modified laboratory foam generator was built. Foam was applied directly to the point at which dust

was being formed by the cutter of the boring machine working against a block of coal. Coal dust was sampled with an impinger and analyzed for the particle count and particle size distribution. Coal dust suppression test results on freshly generated dust have demonstrated very clearly that, in laboratory scale experiments, over 90 percent of the respirable coal dust can be suppressed by foam. These tests were run when initial coal dust concentrations were 10 and 70 million particles per cubic foot. Available for reference at the Intermountain Field Operation Center, Denver, Colo., at the Spokane Mining Research Center, Spokane, Wash., at Bureau of Mines libraries in Twin Cities, Minn., and Pittsburgh, Pa., and at the Central Library, U. S. Department of the Interior, Washington, D.C.

OFR 11-71. Designing and Planning Open Pit Mining Operations With Computer Simulation Solutions, by Y. L. Su, Charles B. Manula, and Thomas V. Falkie. Mar. 15, 1971. 227 pp. Deterministic and stochastic simulation were combined to develop a computer model of an open pit mining system using bucket wheel excavators and related materials-handling equipment. The model is closed and dynamic in the sense that information is fed back to control activities at various levels and reservoirs. The results of interaction between unit operations in one time interval determine overall system behavior for the next interval. Equipment-performance curves and system-profile characteristics rather than time studies are applied to determine the operation of each activity at any time period. For that part of the system where performance is dictated by a random variable, subjective probabilities are employed. Available for reference at Bureau of Mines Mining Research Centers in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U. S. Department of the Interior, Washington, D.C.

OFR 1-72. Methane Control Program Study. Prepared by The Service Bureau Corporation for the Bureau of Mines. Dec. 30, 1970. 43 pp. Evaluations reflected in this paper are the result of an independent investigation, by The Service Bureau Corporation, of methane considerations during coal mining. The study is oriented toward a systematic analysis of methane-control problems during coal mining. An attempt has been made to ensure considerations consistent with the recently enacted Federal Coal Mine Health and Safety Act of 1969. Available for inspection at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U. S. Department of the Interior, Washington, D. C.

OFR 2-72. Program of Acoustic Research for Underground Coal Mining Operations. Prepared by Damon C. Gray, Donald L. Hathway, and John F. Snuggs for the Bureau of Mines. Hydrospace Research Corp. Tech. Rept. 319, June 15, 1971, 78 pp. This report contains a recommended program of acoustic research to be conducted by the Bureau of Mines. The program is directed toward the abatement and control of machinery noise in underground coal mining operations. The study conclusions and specific problem areas which led to the definition of the recommended program are also briefly described. Available for inspection at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and

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Spokane, Wash., and at the Central Library, U. S. Department of the Interior, Washington, D. C.

OFR 3-72. Development of Improved Ventilation for Non-Coal Mines and Other Underground Excavations, prepared by J. R. Haskins and C. E. Gregory for the Bureau of Mines. University of Idaho Bureau of Mining Research, Oct. 30, 1970, 67 pp. This report details the present conditions of vein-type multilevel mine ventilation technology, with respect to practices, equipment, planning, and needs. Included are conditions and recommendations to guide future programs of research in order to ultimately upgrade operational technology. The main long-term objective was to improve the utilization of air in these particular metal-mining excavations as a means of maintaining a safe and healthful atmosphere, conducive to efficient work output, within an economical framework of mining operations, both present and future. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U. S. Department of the Interior, Washington, D.C.

OFR 4(1)-72. Industrial Engineering Study of Hazards Associated With Underground Coal Mine Production. Volume 1, Analysis of Underground Hazards and Fatal Accidents, prepared by Theodore Barry and Associates for the Bureau of Mines. Dec. 10, 1971, 298 pp. This report covers a 1-year industrial engineering study of working-face hazards in underground bituminous coal mines. The field data were accumulated from observations in 50 underground mines in all parts of the United States. Supporting data for the analysis was derived primarily from Bureau of Mines fatal accident reports from 1966 through 1970. A strong relationship was found to exist between fatal accident occurrences and low task experience. This led to a recommendation for formalized training, certification, and supervision programs for miners. Analysis of roof fall variables revealed a fatal propensity on the part of the miners to work under unsupported roof or under support conditions that are marginal. The report also covers 12 fatality reduction projects that focus on highly hazardous areas identified through fatal accident report analyses and underground industrial engineering observations. Recommendations are evaluated in terms of estimated annual cost to the industry and estimated potential lives saved. The report discusses temporary and permanent support installations, maintenance and repair accidents, operator protection on face equipment, shuttle haulage, machine loading roof fall accidents, and auger-type continuous mining accidents.

OFR 4(2)-72. Industrial Engineering Study of Hazards Associated With Underground Coal Mine Production. Volume 2, Data and Charts, prepared by Theodore Barry and Associates for the Bureau of Mines. Dec. 10, 1971, 241 pp. Volume 2 describes basic mining techniques and production operations associated with underground bituminous coal mining. The report covers conventional mining, including undercutting the face, drilling, shooting the face, loading and hauling the coal, and supporting the roof; continuous mining, including use of the continuous mining machine, hauling the coal, and supporting the roof; and auger mining. Charts and illustrations depict the style of mining employed and its basic operations, the mining cycle involved, and the equipment and

crew work cycles and their work elements. The report covers work element times for the various categories of seam height, production tonnage, and mining style. Work elements commonly subject to hazardous exposure are noted for each cycle along with a percentage estimate of the total cycle time subject to such exposure. Both parts of OFR 4-72 are available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 5-72. A Study of Radar Exploration of Coalbeds, prepared by John C. Cook for the Bureau of Mines. Teledyne Geotech, Dallas, Tex., Tech. Rept. 71-8, June 1971, 83 pp. This report describes a 1-year program of exploratory research to determine the feasibility of radar exploration in advance of coal mining. Advance detection of obstructions including faults, clay veins, abandoned wells, and pyrite concretions would improve the safety and efficiency of mining. Using a proprietary, experimental, VHF short-pulse "mining radar" system, two cycles of field testing and equipment improvement were completed. Measurements were made in three bituminous coal mines, a quarry, and a salt mine. Comparisons were made with ground-penetrating radar equipment previously developed for salt dome exploration and for military tunnel detection. The proprietary mining radar equipment and techniques used were found to be the most effective known for coal exploration. However, further improvements were needed. The results and experience gained during the project affirmed the feasibility of the method. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 6-72. Design and Development of Horizontal Borehole Packers for Use in Coal Beds, prepared by James H. Cobbs Engineering for the Bureau of Mines. Tulsa, Okla., February 1972, 26 pp. This report describes the development and testing of a new horizontal borehole packer for use in coal beds and evaluates commercially available packers. Gas pressure measurements and other testing procedures in horizontal holes may require as many as 30 packers in a 300-foot hole. These packers must be set simultaneously. The cost of the only commercially available packer suitable for this service is quite high, and the repair and replacement of expendable parts are quite expensive. A new hydraulic packer, which was developed, manufactured, and tested, demonstrated superiority over previously existing packers. This superiority was achieved while reducing cost about 60 percent over the best of the other packers and reducing weight almost as much. Because of a unique piston design, this new packer cannot suffer a sealing element rupture. It can be easily disassembled for maintenance in the field using inexpensive expendable parts. It is now on the commercial market, and other applications, variations, and improvements can be expected with increased usage. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

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OFR 7-72. Economic Aspects of Surface Subsidence Resulting From Underground Mineral Exploitation, by Jan Zwartendyk. Ph.D. Thesis, Pennsylvania State Univ., University Park, Pa., March 1971, 412 pp. This study is directed toward providing an understanding of the economic complexities associated with subsidence damage to the surface resulting from underground mining. Some of the pertinent theories on the physical stresses involved are reviewed, and both remedial measures and relevant laws in various countries are discussed. Part I (Chapters 1-3) is an historical overview of various aspects of subsidence problems (theoretical, remedial, and legal) during pre-World War I, between World Wars, and post-World War II, respectively. Part II (Chapters 4-9) presents a comprehensive analysis of the economic aspects of subsidence in relation to (1) carrying out the lowest cost mining method without regard for any surface subsidence, (2) special mining techniques, (3) partial mining, (4) full recovery with stowing, and (5) sterilization or leaving the mineral unmined beneath selected areas. These alternatives are evaluated in terms of their measurable expenses. Available for reference at the Bureau of Mines Office of Mineral Supply and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 8-72. Investigation of the Adsorption Process in Coal Using X-Ray Diffraction, prepared by Shih-Chi Chang and Peter F. Brown for the Bureau of Mines. Duquesne University, Pittsburgh, Pa., March 1972. 14 pp. An exploratory research was done on untreated coal using X-ray diffraction techniques. A comparison was made of diffraction data before and after pressurized methane was added to the coal samples. Although only qualitative data were obtained, the following statements about untreated coal seem plausible: There are other materials in coal that are accumulated in layers causing the macroscopic layered structure of coal; the partial graphitization of the fixed carbon in coal assumes random orientations; the methane adsorbed in coal is held in its microspore system, and there is no evidence of bonding to carbon by X-ray diffraction measurements; the methane in coal microspores assumes no structure itself at room temperature; and, finally, some of the other materials in coal are present in the form of hydrated crystallites which have anisotropic growth habits in the layers. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D. C.

OFR 9(1)-72. Coal Mine Rescue and Survival. Volume 1. Survival Subsystem, by Westinghouse Electric Corporation. September 1971. 113 pp. 36 figs. The basic objectives of this program were to develop and test hardware to determine the efficacy of various coal mine rescue and survival techniques and concepts based on the proposal of the Bureau of Mines and a study conducted by the National Academy of Engineering. This volume covers three parts of the survival subsystem from the point of view of design, manufacture, test, and evaluation. They are (1) the personal breathing apparatus (PBA), an emergency unit designed to provide a breathable atmosphere in a contaminated gaseous environment; (2) the auxiliary survival chamber, a portable self-contained 15-man refuge for trapped miners located near the working face; and (3) the large central chamber, a

design for a permanent fixed installation to provide life support for as many as 50 men indefinitely.

OFR 9(2)-72. Coal Mine Rescue and Survival. Volume 2. Communications/Location Subsystem, by Westinghouse Electric Corporation. September 1971. 258 pp. 92 figs. This volume covers electromagnetic and seismic equipment for locating and communicating with workers trapped underground either behind barricades, in refuge chambers, or attempting to escape. The electromagnetic (EM) voice downlink and coded beacon uplink were tested and qualitatively and quantitatively evaluated at five different coal mines. In the voice downlink test, intelligible voice transmission was received using a horizontal wire transmitting antenna terminated in the ground at each end. Coded beacon transmissions were also detectable on the surface. Studies indicate that the EM system could be effectively used in rescue operation in most coal mines, provided that the mines were equipped with subsurface EM transmitters and receivers. Further testing, however, was recommended including operation of the communications/location subsystem in a continuing training program.

OFR 9(3)-72. Coal Mine Rescue Survival System. Volume 3. Rescue Subsystem, by Westinghouse Electric Corporation. September 1971. 62 pp. 23 figs. This volume describes the method by which trapped miners, located by the communications/location subsystem or other means, can be rescued. It is the purpose of the rescue subsystem to complete a probe hole as soon as possible from the surface to the miners' location through which their survival needs can be met until a rescue hole reaches them in the minimum of additional time. The entire operation must be carried out without creating additional hazards for the men trapped underground. Two separate rotary-type drilling rigs, along with their associated drilling equipment, have been assembled to carry out the probe and rescue operations. Drilling industry experience has been applied to the design of equipment and drilling procedures for the small diameter holes of the probe rig and the large diameter holes of the rescue rig.

OFR 9(4)-72. Coal Mine Rescue and Survival. Volume 4. Program Evolution and Management, by Westinghouse Electric Corporation. September 1971. 50 pp. 2 figs. This volume summarizes the development program undertaken by Westinghouse for the Bureau of Mines. Although the contract did not require final design hardware ready for introduction to the coal mining community, components of the coal mine rescue and survival program have some value in disaster situations and are to be kept on standby alert. A test demonstration exercise is described using the equipment and procedures developed during this program.

OFR 9(5)-72. Coal Mine Rescue and Survival. Volume 5. Executive Summary, by Westinghouse Electric Corporation. September 1971. 14 pp. 5 figs. This volume summarizes the contract work performed over a 9-month period by Westinghouse Electric Corp. for the Bureau of Mines. The work of the basic contract was to design, produce, and test hardware which was based technically on recommendations of a study performed by the National Academy of Engineering. This summary volume completes the final report documentation.

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All five volumes of this report are available for inspection at the Bureau of Mines libraries at Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., at the office of the Assistant Director—Mining, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 10-72. A Mathematical Model Simulating Flow of Methane and Water in Coal, by H. S. Price and A. A. Abdalla. Prepared for the Bureau of Mines by Intercomp. Apr. 7, 1972. 39 pp. 3 figs. This report covers the development of a mathematical model that describes the flow of methane only and methane and water in a coalbed during mining operations. The flow of methane gas from a coalbed that is being actively mined cannot be measured accurately and must be predicted from the known properties of the bed. In general most underground structures have water associated with them; the system to be studied may be single phase (methane gas) or two phase (methane and water). Because the geometry is complex and the fluids have variable properties as functions of pressure and concentration, the differential equations describing the system are not amenable to analytic solutions but must be solved numerically using high-speed computers. The model discussed in this report solves the flow equations for one- or two-phase flow in a heterogeneous anisotropic coalbed. Available for inspection at the Bureau of Mines libraries at Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., at the Office of the Assistant Director—Mining, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 11-72. A Current Appraisal of Underground Coal Gasification, prepared by Arthur D. Little, Inc., for the Bureau of Mines. December 1971. 285 pp. 33 figs. This report describes a study made for the Bureau of Mines to reevaluate underground coal gasification technology. The technology was appraised to determine (1) whether the current (1971) state of the technology offers a technically feasible method for gasifying coal underground that is applicable to reserves of bituminous and lower rank coals in the United States; (2) whether a program of research and further development of the technology could ultimately make it a technically feasible alternative to current open pit and underground coal mining operations; (3) what the nature and cost of further research and development work in the technology should be. The study showed that underground coal gasification in the United States is technically feasible, but economic feasibility is yet to be determined; new activity should obtain reliable production-oriented cost estimates for large-scale use of the product gas; technical objectives should include prevention of roof collapse and knowledge of burning face position and temperature. Cost of further work is estimated at \$2.5 to \$3.5 million.

Available for inspection at the Albany Metallurgy Research Center, Albany, Oreg., Bartlesville Energy Research Center, Bartlesville, Okla., Boulder City Metallurgy Research Center, Boulder City, Nev., Denver Mining Research Center, Denver, Colo., Grand Forks Energy Research Laboratory, Grand Forks, N. Dak., Laramie Energy Research Center, Laramie, Wyo., Morgantown Energy Research Center, Morgantown, W. Va., Pittsburgh Energy Research Center, Pittsburgh, Pa., Rolla Metallurgy Research Center, Rolla, Mo., Salt Lake City

Metallurgy Research Center, Salt Lake City, Utah, Spokane Mining Research Center, Spokane, Wash., Tuscaloosa Metallurgy Research Laboratory, Tuscaloosa, Ala., Twin Cities Mining Research Center, Twin Cities, Minn., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 12-72. Development of a Borehole Device To Determine the Modulus of Rigidity of Coal Measure Rocks, by William Hustrulid. December 1971. 119 pp. 54 figs. This report describes a simple borehole device to determine the modulus of rigidity (G) of rock, which was developed and successfully tested in the laboratory and in the field. The mathematical analysis required to interpret the results was also developed. In the laboratory tests very good agreement was observed between the known values of G and those determined experimentally for both metal and rock cylinders. Field testing was done at the Colorado School of Mines Experimental Mine at Idaho Springs, Colo., and at the No. 4 coal mine of the Mid-Continent Coal and Coke Corp. near Carbondale, Colo. Available for inspection at the Bureau of Mines libraries at Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 13-72. Grouting of Horizontal Holes in Coalbeds, by Halliburton Services. March 1972. 35 pp. 21 figs. This report describes research to evaluate materials and develop a new technique for packing holes in which a semiliquid and/or rigid type grout could be placed in the hole to provide satisfactory sealing. Horizontal holes are drilled underground into coalbeds to control methane flow from the ribs and active face areas and to make gas pressure measurements in coal beds. The study recommended that (1) packers set nearest the rib wall should be at least three times the drift width or five times coal thickness from the rib wall, whichever is greater; (2) grouting pressure should not exceed 0.4 psi/ft times feet of overburden; (3) mine water and actual grouting materials to be used should always be checked for setting times before the grout job; (4) the packer system as designed should be used in 3-inch horizontal holes with either the semiliquid or rigid grout materials; and (5) the rigid grout tested using salt-saturated portland-gypsum-cement blend was satisfactory for use in boreholes of coalbeds. Available for inspection at the Bureau of Mines libraries at Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and the Spokane, Wash., at the Office of the Assistant Director—Mining, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 14-72. Investigation of the Use of Shaped Explosive Charges for Increasing the Permeability of Coal, by Ronald R. Rollins, George B. Clark, and Calvin J. Konya. December 1971. 97 pp. 46 figs. The report was prepared under a Bureau of Mines grant to determine the feasibility of using shaped charges in horizontal boreholes to fracture and increase the in situ permeability of coal. The work was exploratory and a review of results after the first phase was completed indicated that increasing the permeability by the use of shaped explosive charges was neither technically feasible nor practically acceptable. Available for inspection at the Bureau of Mines libraries at Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., at the Office of the

Assistant Director—Mining, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 15-72. Solid Sap: A Static Analysis Program for Three Dimensional Solid Structures, by Edward L. Wilson. Structural Engineering Laboratory, University of California, Berkeley, Calif., March 1972, 162 pp. A general computer program is given for the linear elastic static analysis of complex structural systems. These elements have special advantages for the analysis of massive underground structures, such as mine structures, and aboveground structures, such as arch dams. New finite elements which are useful in the analysis of two and three dimensional solids are developed. Examples that illustrate the accuracy of the elements are given. A description on the use of the program and a FORTRAN IV listing are given in the appendixes. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 16-72. Laboratory Coal-Mine-Dust Incombustibles Meter, Prepared for the Bureau of Mines by Harold A. Kurstedt and Ralph S. Lorenz. Industrial Nucleonics Corporation, Columbus, Ohio, Sept. 17, 1971, 82 pp. This report describes work done under contract for the Bureau of Mines on the incombustibles meter—a portable gage that measures the percent of incombustible content in a coal mine dust sample. The gage uses a low-energy gamma-ray backscatter technique that indicates the average atomic number of the sample, and hence, the percent of the incombustible content. For the most part, the results from this instrument checked within plus or minus 3 percent of the laboratory results. When extensively tested with samples prepared by Industrial Nucleonics and when briefly tested with samples constructed of graphite and incombustibles by the Bureau of Mines, the gage measured all samples within the required plus or minus 3 percent. More work on this instrument will be required before it can actually be taken into mines. The weight must be reduced to one-half or less that of the model described in this report. Available for reference at the Bureau of Mines library in Pittsburgh, Pa., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 17-72. Measurement of Temperature Profiles Around Coal Mine Openings, by William F. Martin, Jr., and William A. Hustrulid. Department of Mining, Colorado School of Mines, Golden, Colo., March 1972, 139 pp., 46 figs. This report presents the results of an extensive program of temperature measurement around openings at the No. 4 mine of the Mid-Continent Coal and Coke Co. near Redstone, Colo. Temperature profiles are given for 20 locations in the coal mine. Virgin rock temperatures were determined from measurements made in five long holes. Thermal properties of the coal and shale roof rock were determined. The experimental results were compared to those predicted using steady-state heat flow models. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 18-72. Effective Systems of Scrap Utilization: Copper, Aluminum, and Nickel, by Richard L. Gordon,

Wilfrid A. Lambo, and George H. K. Schenck. Pennsylvania State University, College of Earth and Mineral Economics, University Park, Pa., 1972, 220 pp., 29 figs. This study examines the supply relationships for non-ferrous scrap and secondary metal. The analysis is concentrated on the response of supply to price changes, but the relationship of supply to other economic and technical variables is also examined. The basic hypothesis is that in the United States the supply of nonferrous metal recovered from scrap responds to changes in price and other economic stimuli. In the first part of the analysis, economic and technical factors underlying the supply of nonferrous scrap and secondary metal are examined in general, and a conceptual model of supply is developed. In the second part of the analysis, quantitative analysis is applied to three specific scrap metals to examine and measure relationships discussed in the *a priori* economic analysis. The three metals—copper, aluminum and nickel—furnish a reasonable cross section of conditions in the secondary metal market. Available for reference at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 19-72. The Collection of Nonferrous Scrap—A Literature Review of the Copper and Aluminum Sectors, by Richard L. Gordon, George H. K. Schenck, and Wilfrid A. Lambo. Pennsylvania State University, College of Earth and Mineral Economics, University Park, Pa., 1972, 83 pp., 8 figs. This study seeks to advance understanding of the problem of waste disposal by reviewing one element of the problem, the reuse of nonferrous scrap. The available literature was reviewed and analyzed. The report covers two major nonferrous metals—copper and aluminum. Although they compete in many markets, these two nonferrous metals prove quite different when viewed in the perspective of this study. Aluminum has shown rapid growth and steadily expanded uses in which it could compete. Copper in contrast has shown much less change. The difference in growth is necessarily a major factor in effecting the role of scrap in the total availability of a metal. At least some portion of the scrap consists of material from products that were made many years ago. A rapid growth rate for primary products implies that this scrap will be a much smaller fraction of total availability than a product with lesser growth. In practice, the relationship also depends upon the rate of recovery of this material. Copper recovery proves considerably easier than that of aluminum. Available for reference at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 20-72. Water Pollution Potential of Snowfall on Spent Oil Shale Residues, by J. C. Ward and S. E. Reinecke. Environmental Engineering Program, Department of Civil Engineering, Colorado State University, Fort Collins, Colo., June 1972, 53 pp., 8 figs. The concentration and composition of totally dissolved solids were determined both in surface runoff water and in water which had percolated through a bed of the residue. An empirical equation was developed to predict the concentration of the runoff water as a function of independent parameters. A tendency for saturation of the residue to occur during a period of snowmelt was revealed. The effects of this saturation on the residue were also considered. An overland-flow water quality model was developed and successfully applied to runoff resulting from

rainfall and snowfall on oil shale retorting residue. The surface water runoff from snowfall on oil shale residue has less water pollution potential than the runoff from rainfall. The concentration of dissolved solids in the runoff was a function of the cumulative volume of runoff per unit width, the porosity of the oil shale retorting residue, the soil moisture content, the snowmelt rate, and the fraction of the snowmelt water that is runoff. Available for reference at Bureau of Mines libraries in Denver, Colo., Laramie, Wyo., Bartlesville, Okla., and San Francisco, Calif., and at the Central Library, U.S. Department of the Interior, Washington, D.C. Companion report "Water Pollution Potential of Rainfall on Spent Oil Shale Residues" is available for \$1.25 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. (Catalogue No. EPI.16:14030EDB-12/71; Stock No. 5501 0197.)

OFR 21-72. Reconnaissance of Ugashik Beach Sands, Bristol Bay, Alaska, by Arthur L. Kimball, 1972. 28 pp. 4 figs. This report describes a Bureau of Mines examination of beach deposits on the east shore of Bristol Bay in Alaska. The analytical results obtained on 125 samples from the deposits are presented. These results indicate that gold is associated with the black sands in local concentrations, which occasionally cover areas as large as 1 acre in size. The deposits were seldom more than 6 inches in thickness and the samples never exceeded 0.007 ounce per ton in gold content. Available for reference at the Bureau of Mines Alaska Field Operation Center, Juneau, Alaska, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 22-72. Evaluation of Anemometers for Use in Coal Mines, by J. F. McCoy, June 6, 1972. 63 pp. 23 figs. The purpose of the research described in this report was to evaluate existing instrumentation for measuring air velocities in the speed range under 2,000 feet per minute; to evaluate the method for determining total air volume flow from the velocity measurements; to evaluate new techniques that may be applied to measuring air velocities; and to design a prototype instrument that represents the best technique based on the evaluation. Hot film anemometry was the technique selected for the prototype design. Portable and self-contained, the prototype instrument developed is expected to be approvable for use in gassy mines. The three-phase research program involved (1) a literature and information search, (2) laboratory testing, and (3) instrument design. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 23-72. Rotary Drilling Exploration of the Ryan Lode Properties, Fairbanks Mining District, Alaska, by Robert S. Warfield and Bruce I. Thomas, June 1972. 21 pp. 5 figs. A rotary-drilling exploration system was tested at the Ryan Lode, Fairbanks mining district, Alaska, to determine its application for surface trenching and to evaluate the open-pit mining potential of a wide shear zone that contains gold-bearing gold-quartz veins. The drilling sampling system was verified as a practical substitute for surface trenching that minimized environmental damage; but where tested, the shear zone material does not contain sufficient values, together with individual vein values, for open-pit mining. Available for reference

at the Bureau of Mines Alaska Field Operation Centers in Juneau, Fairbanks, and Anchorage, Alaska, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 24-72. Equipment Operation Safety Study, prepared by Theodore Barry and Associates for the Bureau of Mines, July 18, 1972. 134 pp. 38 figs. This report provides the results of a comprehensive investigation of underground coal mine fatal and nonfatal accidents for the years 1966 through 1970. In terms of defining specific relationships between accidents and 64 equipment models, this report represents a major contribution to improvement in the safe operation of the identified equipment types. Specific hazards associated with each type of equipment have been identified and investigated throughout their unit operations in the mining cycle. Recommendations for improving the safety of these operations are provided in the report. This report supplements Bureau of Mines OFR 4(1)-72 and OFR 4(2)-72. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 25-72. Standardization of Continuous Miner Control Configurations, by William G. Hedling and John D. Folley, Jr. June 28, 1972. 24 pp. 5 figs. Continuous miners are operated in an environment that is extremely hazardous to mining personnel working in the vicinity, including the operator. Every effort should be made to apply modern technology to reduce human error and accidents. Controls for operating continuous miners do not conform to modern principles of human engineering. Although the functions performed by most continuous miners are very similar, the control configurations associated with operator control of these functions differ significantly. Applied Science Associate, Inc., assisted the Bureau of Mines in investigating control configurations of several types of commercially available continuous miners. Problems associated with the lack of standardization of controls on continuous miners were identified and described. From the data compiled, a tentative, standardized continuous miner control configuration was designed with applicable principles and guidelines of human engineering factors. The model was compared to available equipment. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 26-72. Rutile and Associated Heavy Minerals in Florida Phosphate Flotation Plants, by W. E., Lamont, D. R. Brooks, I. L. Feld, and T. N. McVay, December 1968. 35 pp. 6 figs. The Bureau of Mines investigated the potential for recovering rutile and associated valuable heavy minerals from the central Florida pebble phosphate district flotation circuits. Studies were made to determine (1) the type and quantity of valuable heavy minerals present at various points in the flotation circuits and (2) the technical feasibility of producing marketable grade concentrates of the valuable heavy minerals. Results of these studies indicated that the feed to the fine fatty acid flotation circuits contained an average of 0.39 percent heavy minerals. Based on available tonnage estimates the following average quantities of valuable heavy min-

erals should be passing through the district flotation plants annually: rutile, 4.5 thousand short tons; zircon, 14 thousand short tons; opaque (ilmenite), 41.5 thousand short tons; and monazite, 6 hundred short tons. However, heavy mineral recovery was extremely low, ranging from 18 to 23 percent of the rutile, 52 to 63 percent of the zircon, 17 to 29 percent of the ilmenite, and 50 to 56 percent of the monazite. The principal difficulty in achieving high recovery of the valuable heavy minerals was determined to be the fineness of size, which affected both the wet and dry separation techniques used for recovery. Available for reference during working hours at the Tuscaloosa Metallurgy Research Laboratory, Tuscaloosa, Ala., and at the Central Library, U.S. Department of the Interior, Washington, D.C. This report was done under a cooperative agreement between the Bureau of Mines and the University of Alabama.

OFR 27-72. The Miner, His Job and His Environment: A Review and Bibliography of Selected Recent Research on Human Performance, by Charles Fried and others. April 1972. 192 pp. 10 figs. As one of the early steps in carrying out the provisions of the Coal Mine Health and Safety Act passed by Congress in 1969, the Bureau of Mines commissioned the Behavioral Sciences Group at the National Bureau of Standards to conduct a survey of the state of the art in ergonomics (human factors) as it has been applied to mining. The group carried out an extensive search of both foreign and domestic published literature in ergonomics. About 1,200 references were located and 49 were abstracted on the following topics: Effects of environmental stress on health and productivity; accident prevention measures that have been shown to be effective; protective clothing and equipment; the man-machine relationship in the mining situation; effective training programs for safety and work; effect of informal social organization in underground operations; all aspects of the effect of the physical environment upon the miner; and psychological principles that may have been applied to mine problems. The report concludes that little work has been done on the human factors of mining in the United States. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 28-72. Systems Analysis of an Inherently Explosion-Proof Coal Mining Operation, by Westinghouse Defense and Space Center. 1972. 350 pp. 59 figs. The inherently explosion-proof mine (EPM) concept is based upon the non-flammability of certain combustible-oxidant-inert gas mixtures, and the effect of partial pressure of gases on physiological reactions. In a properly controlled underground environment, gas explosions are impossible, men can do work, and relatively high concentrations of methane would be permitted. A systems analysis was performed to examine the physiological, engineering, and economic feasibility of such a concept, and methods and equipment are recommended for maintaining an EPM atmosphere in a bituminous coal mine producing a nominal 2 million tons of clean coal per year. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 29-72. Exploration of Illumination Concepts for Underground Coal Mines, by Rupert O. Yantz. May 26, 1972. 313 pp. 123 figs. The lack of adequate area lighting in the working places of underground coal mines has been a contributing factor to mine accidents involving damage to equipment and serious injury to personnel. This report describes two prototype lighting systems to demonstrate the feasibility of interim lighting equipment and recommends long-term solutions for working place lighting in underground coal mines. Lighting requirements for high and low coal seams were evaluated and found to be similar, eliminating the necessity for unique lighting systems based on coal seam height. A prototype man-portable area lighting system was developed to meet the operational requirements of conventional mining. A prototype machine-mounted lighting system was developed to meet the operational requirements of mechanized mining. An illumination system concept using portable area lights for entry lighting and roof-support mounted lights for face lighting was recommended to meet the operational requirements of longwall mining. Unusual operational conditions would require both machine-mounted and portable luminaires. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 30-72. Evaluation of Mine Electrical Systems With Respect to Safety, Technology, Economics and Legal Considerations, by Robert Stefanko and A. K. Sinha. The Pennsylvania State Univ., Dept. of Min. Eng. August 1971. 56 pp. 14 figs. Field research was directed toward evaluating the effectiveness of existing grounding systems used in U.S. coal mines, and a literature search was carried out to determine the effectiveness of various grounding systems employed in major coal producing countries of the world. Necessary instrumentation has been developed to analyze mine electrical power systems on a dynamic basis. Plans have already been made to develop a simulated mine electrical power system on which studies will be conducted to confirm and further analyze the findings from field research. Some protective devices have been acquired and more will be procured in the near future. Their performance characteristics and effectiveness will be determined in the laboratory with respect to the characteristics of existing mine power systems. The progress made in the various areas of research is presented in this report. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 31-72. An Economic Analysis of a White Nahcolite Installation in Colorado, Option I, Circa 1971, by Staff, Bureau of Mines. July 1972. 69 pp. 15 figs. Option I is concerned only with material from a "white nahcolite bed" in the Piceance Creek basin, Colorado, containing a high concentration of sodium bicarbonate at a nominal depth of 1,900 feet.

A nahcolite mine and processing plant is designed to mine 8,000 tons of nahcolite ore per calendar day yielding 4,071 tons per calendar day of soda ash product. This will require a total capital investment of \$80,213,200 based on 1971 conditions.

The soda ash will yield an annual income of \$52,749,400. Annual operating expenses including labor, materials, maintenance, taxes, insurance, payroll overhead, and depreciation will be \$18,821,900 in 1971 dollars. The discounted cash flow rate of return is equal to 30.74 percent based on a weighted average depreciation life of 12.88 years. Available for reference at Bureau of Mines libraries in Denver, Colo., Laramie, Wyo., San Francisco, Calif., Bartlesville, Okla., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 32-72. An Economic Analysis of an Oil Shale, Nahcolite, Dawsonite Complex in Colorado, Option II, Circa 1971, by Staff, Bureau of Mines. July 1972. 175 pp. 38 figs. Option II concerns mining and processing a nahcolite deposit in the Piceance Creek basin, Colorado, plus an underlying measure of oil shale containing about 25 percent nahcolite and 9 percent dawsonite to yield soda ash, alumina, and shale oil as principal products. Coke, sulfur, and ammonia are also byproducts.

A two-level shaft mining operation, retorting, partial refining, and a minerals processing plant requires a capital investment of \$605,947,700 in 1971 dollars to process 8,000 tons per calendar day of nahcolite ore and 60,000 tons of the mineral containing oil shale. An income of \$268,283,000 requires \$143,188,700 in annual expenditures including labor, materials, maintenance, taxes, insurance, overhead, and depreciation. The discounted cash flow rate of return is 17.20 percent based on a weighted average depreciation life of 13.99 years. The option differs from Option III in depth of the shale bed mined and analysis of the deposit. Available for reference at Bureau of Mines libraries in Denver, Colo., Laramie, Wyo., San Francisco, Calif., Bartlesville, Okla., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 33-72. An Economic Analysis of an Oil Shale, Nahcolite, Dawsonite Complex in Colorado, Option III, Circa 1971, by Staff, Bureau of Mines. July 1972. 176 pp. 39 figs. Option III concerns mining and processing a nahcolite deposit in the Piceance Creek basin, Colorado, plus an underlying measure of oil shale containing 14.8 percent nahcolite and 11.6 percent dawsonite by weight, yielding 37 gallons of shale oil per ton. Principal products are soda ash, alumina, and shale oil. Coke, sulfur, and ammonia are evaluated as byproducts.

A two-level shaft mining operation, retorting, partial refining, and a minerals processing plant requires a capital investment of \$636,973,000 in 1971 dollars to process 8,000 tons per calendar day of white nahcolite ore and 60,000 tons per calendar day of mineral-bearing oil shale. An income of \$257,599,600 based on 1971 prices requires \$151,373,400 annual operating expenditures including labor, materials, maintenance, taxes, insurance, overhead, and depreciation. The discounted cash flow rate of return is 14.45 percent based on a weighted average depreciation life of 14.155 years. This option differs from Option II in depth of the shale bed mined and analysis of the deposit. Available for reference at Bureau of Mines libraries in Denver, Colo., Laramie, Wyo., San Francisco, Calif., Bartlesville, Okla., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 34-72. Evaluation of Horizontal Drilling Techniques in Coalbeds, prepared by T. N. Williamson of Jacobs Associates, for the Bureau of Mines. Oct. 25, 1970. 131 pp. 57 figs. The purpose of this study was to provide guidelines for meaningful research leading toward improved drilling devices and techniques. The evaluation of the technology indicates clearly that those techniques now in use by the Bureau of Mines represent the most advanced state of the art currently available for the Bureau's purposes and conditions. It also shows that much of the advance in the current state of the art in technology has been the result of the Bureau's activities. It indicates that further advances can and should be reached through research by the Bureau and provides guidance for such activity. The first section describes the conditions under which a drill must work. The second section discusses the state of the art of drilling as it relates to the problem. The third section describes the problem. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 35-72. Determination of the Electromagnetic Environment in Coal Mines, by J. H. Crary. Nov. 3, 1972. 139 pp. 37 figs. This report concerns the need for improved communication during and following mine disasters, especially when miners are trapped. A reliable and versatile communication system throughout an entire mine could be adapted to automatic monitoring at a central location of important environmental parameters, such as air temperature, composition, pressure, seismic activity and so forth, throughout the mine. The use of long-wave electromagnetic methods appears to solve the problems. Basic information required consists of (1) a knowledge of the magnitude of frequency both above and below the surface, (2) information on the attenuation of EM signals propagating from surface to subsurface points, and vice versa, and the antenna coupling characteristics which would be involved, and (3) a knowledge of the accuracy with which an underground signal source can be located from the surface and vice versa. The report covers noise environment, attenuation and antenna coupling, determination of optimum frequencies, electromagnetic location, and properties of tunnels as high frequency waveguides. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 36-72. Model Studies To Determine the Optimum Practical Rearrangement of Timberwork to Ensure Minimum Resistance Values for Rectangular Shafts, by J. R. Hoskins and C. E. Gregory. University of Idaho Bureau of Mining Research. Apr. 15, 1972. 26 pp. 12 figs. This research was conducted to determine optimum configurations of rectangular shaft supports, lining, and fixtures to reduce head losses. Model studies in a specially designed wind tunnel provided information useful as a guide to remedial measures on old shafts or to design new ones. The research disclosed that airway resistance could readily be reduced 25 percent by relatively minor modifications in the timber or steel supporting sets. Potential annual savings in power costs are given. The methods described can be applied to reduce airway resistance in mines with severe ventilation prob-

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lems. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 37-72. Development of an Air Quality Simulator for Coal Mines, by G. E. Geiger. Sept. 1, 1972. 299 pp. 47 figs. The purpose of this research was to develop a computer simulator for predicting the air quality in existing coal mines as well as a design aid for developing new mines. In addition to the air quantity flow, other variables or temperature, moisture, methane, and respirable dust are necessary to determine air quality. An additional feature of this simulator allows parametric studies of these variables to explore the effect that these variables have on the air quality of an operating mine system. The report points out areas where more research is needed. It covers the temperature moisture simulator, which gives the temperature and moisture content at any point in a mine; the methane simulator, which gives the methane concentration; and the dust simulator, which gives the dust concentration at any location in a mine. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 38-72. Development of a Porosimeter for Coal Mines, by The University of Tulsa. June 30, 1972. 72 pp. 40 figs. This research concerned choosing fluids and developing techniques for measuring coal porosity. Helium was adopted as the standard test fluid, and measurements made with it taken as the "true values." The Boyle's Law technique was adopted as the standard for measuring total (micro plus macro) porosity. Mercury-injection tests were found to provide significant information on pore-size distribution. Interest in coal porosity stems from its role in methane control in coal mines. An adequate definition of coal porosity and an acceptable method of measurement must provide links with this function. For this purpose, additional mercury-injection tests, studies of continuity of pore structures, coal microscopy, and stress tests were undertaken. Numerous specimens were examined. Porosity was found to be comprised largely of fractures, some undoubtedly caused by mining. Porosities ranged mostly between 2 and 5 percent. The findings provided a more realistic and substantial basis than existed before for involving porosity as a factor in methane control. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 39-72. Evaluation and Feasibility Study of Isolated Electrical Distribution Systems in Underground Coal Mines, by General Electric Co. Apr. 17, 1972. 218 pp. 84 figs. The objectives of the contract were to evaluate the feasibility of isolated electrical distribution systems in underground coal mines and to design, specify, and evaluate such a distribution system. This final report presents a state-of-the-art literature survey on ungrounded and grounded power systems, a report on literature pertaining to human threshold limits of electric shock, an analysis of the performance requirements of isolated systems, and a section on the design and performance

specifications for an isolated system. It was established that there is no ideal underground system due to the effect of inherent distributed capacitance to ground which is present in all components of the system. The conclusion is that a completely ungrounded power system of 480 v or more is no safer than any other system from a human shock standpoint; also, the ungrounded system has no advantage with respect to gas ignition hazards. The contractor indicates that the high resistance grounded power system has personnel safety advantages for underground mining application. Available for reference at Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 40-72. Research in Advanced Power Systems for Mining Health and Safety, by E. S. Chaplin, R. E. Anderson, J. J. Shore, J. L. Smith, D. M. Jassowski, and R. A. Hewitt. Aerojet Liquid Rocket Company, July 20, 1972, 243 pp. 70 figs. Systems analytical techniques have been formulated and applied to quantitatively assess the relative safety merits of four shuttle car power systems for use in underground coal mines. Results from two techniques—forced decision analysis and fault tree analysis—suggest the open-cycle diesel to be the most desirable of the power systems studied, with the closed-cycle diesel being next, followed by the battery-motor and the electric cable-reel. Two basic mine shuttle-car configurations were considered for incorporation of a closed diesel powerplant. Engineering designs, performance parameters, and the logistics of servicing the power systems were formulated. The utilization of the closed diesel shuttle car as an emergency rescue vehicle was discussed. An extensive evaluation was made of the compatibility, sensitivity, and hazards of closed-cycle diesel consumables with materials normally found in a mine environment. The consumables considered were diesel fuel, KOH, and liquid and gaseous O₂. An extensive bibliography of reports on these topics was prepared. Experiments were also carried out to evaluate the time and concentration of gaseous oxygen in a simulated mine entry following a liquid oxygen spill. Available for reference at Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 1-73. Coal Mine Combustion Products, Identification and Analysis, by K. L. Paciork, R. H. Kratzer, and J. Kaufman. December 1972. 158 pp. 27 figs. Little data is available on oxidative degradative behavior of materials used in coal mines under truly dynamic conditions approximating the mine environment. Accordingly, tests were performed on: (a) polyvinyl chloride-containing materials; (b) neoprene compositions; (c) rigid foams (urethanes, isocyanates); (d) miscellaneous materials (including jute, fiber glass and polyethylene) using a stagnation burner arrangement. It was found that the chlorine-containing materials evolved hydrogen chloride very readily, its rate of evolution being strongly temperature dependent. Even at the high air flow rates employed, significant quantities of hydrogen chloride were detected. The fluorocarbon propellant and CO₂ were the main products found on decomposition of the foams, whereas among other products jute compositions

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liberated methyl chloride. The analyses were performed using mass spectrometry and infrared spectroscopy. Available for reference at Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 2(1)-73. A Mineral Slurry Data Bank. Part 1. Report, by R. R. Faddick. Dec. 2, 1972. 115 pp. 66 figs. This study contains slurry pipelining data on 16 materials including coal, coal refuse, ores, concentrates, and tailings. This report comprises the data bank in the form of a computer printout listing system constants and headloss data for each material. These data are useful for designing hydraulic pipeline transportation systems for mined materials. The computer cards are on file with the Bureau of Mines at Pittsburgh, Pa., and with the Basic Engineering Department of the Colorado School of Mines at Golden, Colo. The purpose of the data bank is to assist in the development of a universal headloss correlation for mineral slurries. Present headloss correlations were tested and found to be inconsistent for the various mineral slurries. Thus, a different approach was taken, that of compiling a library of Stanton diagrams relating friction factor and Reynolds numbers for a given slurry in a given pipe diameter. The advantages of the diagrams are demonstrated and discussed. Available for reference at Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 2(2)-73. A Mineral Slurry Data Bank. Part 2. Appendages—Computer Output, by R. R. Faddick. Dec. 2, 1972. 239 pp. Contained in this part of the report is the computer output of the data bank described in OFR 2(1)-73. Available for reference at Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 3-73. Environmental Action Programs for Northeastern Pennsylvania Refuse Bank Removal/Subsidence Monitoring, by The Mitre Corporation. November 1972. 529 pp. 249 figs. This project, sponsored by the U.S. Bureau of Mines, Division of Environment, addresses two major subjects: refuse removal and subsidence monitoring. The refuse removal task consisted of developing a methodology for selecting the most economical combinations of coal mine breaker refuse and rock banks, disposal sites, and material moving systems (trucks, trains, belt conveyers, and pipelines). To prepare plans for moving refuse in the Lackawanna Valley of Northeastern Pennsylvania, refuse banks were inventoried, underground disposal sites identified, and unit cost data prepared for the various material moving systems. The subsidence monitoring task consisted of defining the phenomenon of coal mine induced surface subsidence, establishing operational requirements, cataloging sensors, and techniques to detect and measure subsidence and testing of the most promising techniques (photoelastic patch, tiltmeter, strain gage, microseismic, and precise surveying). A preliminary system for a 700-acre area in Scranton utilizing 267 grid sensors, seven microseismic sensors and precise surveying techniques was designed with initial and annual operating costs determined. Two minor tasks sup-

ported both main subjects: zoning in the Northern Anthracite Field of Pennsylvania and Technology Transfer of subsidence vulnerability prediction techniques. Available for reference at Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., and Twin Cities, Minn., at the Environmental Affairs Field Office in Wilkes-Barre, Pa., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 4-73. Determination and Description of Characteristics Affecting Performance of the Loading Function in Underground Coal Mining, by Thomas V. Falkie and R. Venkataramani. The Pennsylvania State University, University Park, Pa., September 1972, 102 pp. 22 figs. The purpose of this work was to investigate the rate at which coal is delivered from the underground working face by gathering arm type loaders as employed on continuous mining machines, to identify the factors—geometrical, geological, mechanical, or procedural—which affect the delivery rate, and to develop quantitative rate-descriptive equations for the loading function. The mathematical techniques employed were factor analysis and multiple linear regression. It was determined that the coal-cutting function of the continuous mining machine is the factor that primarily influences the loading function. The geometrical factors—the dimensions of the work area in relation to the dimensions of the mining machine—were the factors of secondary influence. Fifty-five percent of the experimental variation in the loading function was explained in terms of the six most prominent independent variables. It is expected that this work will be useful in operations-research studies as applied to underground coal mining, and with refinement will enable mine planners to select equipment based on the operating characteristics of the equipment and the mining conditions. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 5-73. A Numerical Model for the Study of Particle Interactions in Relation to Hydraulic Transport, by Andrew K. C. Wong and T. S. Liu. Carnegie-Mellon University, Pittsburgh, Pa., June 30, 1972, 57 pp. This research is an attempt to develop a numerical method for studying some of the basic relations that govern particle interaction in laminar flow field so as to (1) acquire better understanding of the flow phenomena and (2) extend the knowledge of the derived analytical results for the modification of the existing formulas. The study model consists of two parts. The first part is to investigate the effect of particle spacings (or concentration) and specific gravity on the particle drag coefficients when particles settle in groups in a given fluid. The study is to establish a relation between drag coefficient and concentration in Durand's formula, which at present implies that the former is independent of the latter. The second part attempts to analyze, by solving the non-linear differential equation, the translation, rolling, lifting of circular particles flowing in long horizontal channel in the laminar regime, so as to correlate the geometric parameters with the hydraulic parameters. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

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OFR 6-73. Portable Mine Dust Concentration, by C. E. Lapple and C. F. Schadt. June 27, 1972. 203 pp. 39 figs. To improve mine health and safety conditions, there is need for a portable instrument that mine inspectors can use routinely for rapidly checking concentrations of dust in mine atmospheres. The prime objective of this study was to build, calibrate, and deliver to the Bureau of Mines two prototype instruments based on a design previously developed. The emphasis was to be on providing instruments which would meet certain minimum standards of size, weight, response time, sensitivity, ruggedness, reproducibility, permissibility, and cost (ultimate); optimization of the design was to be considered only insofar as it would not significantly delay the development. One instrument was to be delivered after initial calibration of both instruments with Coal Dust PGH. The second instrument was to be used for further calibration with a number of other coal and rock dusts and for assessing other relevant performance characteristics. This report summarizes the results of this study. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 7-73. Rotary Drilling for Strippable Coal in the Jarvis Creek Coalfield, Alaska, by Robert S. Warfield, Feb. 13, 1973. 32 pp. 4 figs. Twelve relatively short holes were drilled using a CSR (center sample return) drilling system to test the applicability of the drilling system and to test coal continuity in the vicinity of the present mine workings of the Jarvis Creek coalfield. Coal intersections plus geologic evidence indicate depositional continuity over fairly large distances. The CSR drilling system offers an excellent method for determining coal continuity and a system in which a fair (but not quite as good as core) sample may be obtained. Available for reference at the Office of the Assistant Director—Mineral Supply and the Field Operations Centers in Alaska, Colorado, and Pennsylvania, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 8-73. Evaluation of Methanometry in Coal Mines, by Atlantic Research Corporation. July 1972. 106 pp. 30 figs. This report describes a program of research to evaluate methanometry in coal mines. The program commenced by conducting an extensive state-of-the-art survey. Details of the survey which are presented include a rating of various types of instruments that can be used to detect and record methane gas. Laboratory test data on mine instruments tested are presented together with results from a computerized statistical analysis. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 9-73. Accident Analysis by Functional Classification For Bituminous Coal Mines in 4-Foot to 8-Foot Seam Heights, by R. J. Traube and J. E. Hopper. Sept. 11, 1972. 48 pp. 5 figs. This report presents an abbreviated summary of the accident information developed for the Inherently Safe Mining System (ISMS) project. The objective of the report is to provide information on accidents to individuals in the bituminous coal mining industry in a form it is believed is not currently

available from other sources. The hope is that presentation of the information in this manner will enable industry members to focus their accident prevention and safety education efforts on the paramount problems by explicitly and qualitatively defining the problems relative to each other.

The primary objective of the ISMS program is to reduce the occurrence of fatal accidents. A secondary objective is to reduce the frequency of nonfatal accidents. Progress toward one objective leads to programs in the other, which is compatible with the overall objective of increasing safety in underground coal mines. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 10(1)-73. Analysis of Coal Refuse Dam Failure. Middle Fork Buffalo Creek, Saunders, West Virginia.

Volume 1. Text, by W. A. Wahler & Associates. February 1973. On February 26, 1972, a coal refuse dam, owned and operated by the Buffalo Mining Company, failed near Saunders, W. Va. The resulting flooding of the Buffalo Creek Valley had national ramifications. The immediate consequences of the flooding were the deaths of 118 persons and 7 reported missing, the loss of over 500 homes, and extensive flood damage to other property in Buffalo Creek Valley. Several investigations were started immediately after the disaster; some were under Government auspices, while others were initiated by groups of concerned citizens. These investigations relied primarily on personal observations, and eyewitness reports, although the U.S. Army Corps of Engineers and the U.S. Geological Survey undertook limited field and laboratory testing. These original investigations contributed to an understanding of the Buffalo Creek flood. The principal contributions of this report are the presentation of a comprehensive view of the failure with essential data integrated from many sources, and an analysis of the failure based on a thorough program of subsurface exploration and sampling, field and laboratory testing, and engineering analyses. Available for reference at all Coal Mine Health and Safety District Offices, at the Pittsburgh, Pa., and Denver, Colo., Technical Support Centers, the Health and Safety Analysis Center in Denver, Colo., and in the Office of Mineral Information and the Department of the Interior Library, both in Washington, D.C.

OFR 10(2)-73. Analysis of Coal Refuse Dam Failure. Middle Fork Buffalo Creek, Saunders, West Virginia.

Volume 2. Appendices, by W. A. Wahler & Associates. February 1973. On February 26, 1972, a coal refuse dam, owned and operated by the Buffalo Mining Company, failed near Saunders, W. Va. The resulting flooding of the Buffalo Creek Valley had national ramifications. The immediate consequences of the flooding were the deaths of 118 persons and 7 reported missing, the loss of over 500 homes, and extensive flood damage to other property in Buffalo Creek Valley. Basic data were gathered during the investigation of the Middle Fork Valley dams and refuse bank above Saunders during field investigations of the site conducted from the end of March through mid-September 1972. This information consisted of field mapping, subsurface exploration and sampling by means of auger drill holes, field density tests, field permeability

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tests, aerial photography, vane shear tests, and cone penetration tests. Volume 2, the appendices, covers these details. Available for reference at all Coal Mine Health and Safety District Offices, at the Pittsburgh, Pa., and Denver, Colo., Technical Support Centers, the Health and Safety Analysis Center in Denver, Colo., and in the Office of Mineral information and the Department of the Interior Library, both in Washington, D. C.

OFR 11-73. Acoustic Travel Times for the Madison Limestone in the Williston Basin, by L. C. Marchant and E. J. White. February 1973. 15 pp. An attempt was made to devise a simple method for accurately estimating rock matrix acoustic travel time for heterogeneous carbonate samples. Compressional wave travel time was measured for each of several hundred Madison carbonate samples from the Williston Basin and is related to the corresponding sample porosity and bulk density. Least-squares equations for the linear plots of compressional wave travel time versus porosity and bulk density yield rock matrix travel times at zero porosity and bulk density equal to rock matrix density. However, the data are scattered enough for the authors to conclude that these relationships do not provide a reliable method for estimating rock matrix acoustic travel times. Available for reference at Bureau of Mines libraries in Bartlesville, Okla., and Laramie, Wyo., at Energy Research Centers in Morgantown, W. Va., and San Francisco, Calif., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 12-73. Electromagnetic and Seismic Noise and Propagation. A Bibliography for U.S. Bureau of Mines, by Arthur D. Little, Inc. March 1972. 62 pp. This report covers a partial bibliography of the literature concerning electromagnetic and seismic noise and propagation as a result of an abbreviated literature search. The reference sources include the open literature, in-house reference files, and Bureau of Mines contractor reports. The references are organized by major subject categories and arranged alphabetically by author within each subject category. Where multiple references by the same author appear, the references are arranged chronologically. Unauthored papers (Anon.) are listed at the end of each subject category. An asterisk (*) is used to indicate incomplete citation where information was not immediately available at the time the bibliography was assembled. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 13-73. Mine Dust Surveys for Incombustible Content, by Felix duBreuil, David Hauck, and Robert Saltsman. October 1972. 278 pp. 95 figs. The present sampling procedure for evaluating the rock dusting conditions in a coal mine is time consuming. This study considers means by which this procedure could be simplified. Surveys were conducted in six coal mines in Pennsylvania to determine the incombustible content of the deposited dust. Some 2,000 samples were analyzed and statistically evaluated. It is suggested that the mean incombustible content could be obtained with fewer samples and smaller samples without greatly increasing the sampling error. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver,

Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 14-73. A Field Program and Instrumentation System for Electromagnetic Noise Measurements, by Arthur D. Little, Inc. April 1972. 29 pp. 3 figs. Five conclusions reached by this study were: (1) A limited amount of good data has been obtained for characterizing the noise environment for electromagnetic (EM) coal mine operational/emergency communications systems; (2) significant noise data gaps still exist; (3) suitable instrumentation and data analysis methods are available for filling these data gaps; (4) the immediate and most important data gaps should be filled by means of a timely field measurement effort that is purposely limited in scope and duration; and (5) this field measurement effort should preferably be carried out by a team knowledgeable and experienced in coal mine EM noise measurements. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 15-73. Quick Opening Permissible Electrical Enclosures, by Jack Kadlecik and William Hardy. June 2, 1972. 68 pp. 18 figs. The objectives of this research were to develop, design, fabricate, and demonstrate two permissible prototype quick-entry explosion-proof electrical enclosures, one large and one small, for use in coal mines. The decision was made to proceed with a conventional enclosure using a ground explosion-proof joint between cover and body, but with a circular access employing a threaded joint installed in the cover. Using this concept, the circular access would be used for routine maintenance, whereas the entire cover would be separated at the ground joint for initial installation or major equipment replacement. Several different threads were investigated for the circular access. A multiple start thread was the one selected to best suit the mining environment. This thread had the advantage of being comparatively easy to machine, inherently safe as any thread, and self cleaning. This design permitted the elimination of a special inspection device since the locking device designed for the installation would not operate unless the circular cover was properly installed. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 16-73. Preliminary Performance Predictions for Electromagnetic Through-the-Earth Mine Communications, by Arthur D. Little, Inc. March 1972. 58 pp. 35 figs. This report comprises three working memoranda that present preliminary performance estimates for baseband voice and narrowband through-the-earth electromagnetic communications systems of principal interest to the Bureau of Mines for operational/emergency mine communications. The calculations were prepared to obtain early indications of the feasibility and governing parameters of such communications systems. They are based on limited but pertinent coal mine electromagnetic noise data acquired to date by Bureau contractors and on theoretical signal-attenuation characteristics for two transmitter antenna types of interest to the Bureau. Available for reference at Bureau of Mines libraries in Pittsburgh,

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Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 17-73. Assessment of Electromagnetic Noise Measurements Taken by Bureau of Mines Contractors, by Arthur D. Little, Inc. January 1972. 51 pp. As part of its research and development activities concerning coal mine operational/emergency communications systems, the Bureau of Mines commissioned several contractors to conduct electromagnetic noise studies and measurements that would aid the development of improved coal mine operational/emergency communications systems. The bulk of the noise studies and measurements were conducted in 1971. The Pittsburgh Mining and Safety Research Center inherited the responsibility for monitoring the electromagnetic noise activities by mid-to-late 1971, and initiated a review and evaluation of the current and planned electromagnetic noise work. This technical memorandum report presents the findings, conclusions, and recommendations of that review and evaluation of the electromagnetic noise measurements of the five contractors. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 18-73. Investigation of Requirements and Performance of Safety Catches on Wire-Rope-Suspended Man-Carrying Conveyances in United States Coal Mines, by C. H. Larsen, R. A. Egen, and H. A. Cress. Sept. 27, 1972. 160 pp. 36 figs. This report presents the results of a comprehensive investigation of conveyance arrestment devices (safety catches) in U.S. coal mines. Availability and use, performance, inspection, maintenance, testing, procedures, and regulatory requirements were investigated. Information was obtained from equipment manufacturers, mine operators, and regulatory-agency personnel, as well as from studies of domestic and foreign mining safety regulations. Traditional mine hoists and commercial elevators for mine use were investigated. Results of this and an earlier study of wire-rope practice in U.S. coal mines show a continued need for conveyance arrestment devices. Only two types have been proved reliable for stopping a conveyance without injuring passengers or equipment. These are elevator overspeed-actuated wedge-clamp safeties and broken-rope-actuated devices for wooden guides using a single-tooth-dog developed in Ontario as a braking element. Elevators are widely used in U.S. coal mines, and appear to present no major arrestment problems when using ANSI specifications. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 19-73. Aspects of Noise Generation and Hearing Protection in Underground Coal Mines, by the Pennsylvania State University. Nov. 20, 1972. 158 pp. 40 figs. Roof warning signals from 11 underground coal mines (principally in the Pittsburgh seam) were studied and analyzed. The character of individual acoustic warning signals is shown to be dependent on spectral distribution of energy. Reverberation times (pulse decay rates) were found to be usually between 0.1 and 0.5 seconds. Listening tests were conducted to assess the miner's ability to discriminate speech and roof talk signals in noise

and in quiet, with and without ear protectors, and with various levels of hearing loss. The ability to detect roof talk is shown to be generally degraded while wearing ear protection in quiet, although, if ear protectors are worn only when required by high noise levels, the ability to detect roof talk will be preserved at its maximum. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 20-73. Alaska 1/250,000 Scale Quadrangle Map Overlays Showing Mineral Deposit Locations, Principal Minerals, and Number and Type of Claims, by Staff, Bureau of Mines. March 1973. 153 overlays. Subject overlays for the 153 quadrangles of Alaska are clear plastic sheets with numbered circles showing the locations of all mineral deposits recorded in the State of Alaska Kardex files of mineral claim data. Identically numbered tables on the right margin show number of claims, lode or placer, patented or unpatented, and principal minerals. These overlays have been prepared for the Resource Planning Team of the Joint Federal-State Land Use Planning Commission. They are also basic data for the Bureau of Mines Minerals Availability System. Available for reference at the Alaska Field Operation Center office in Anchorage, Alaska.

OFR 21-73. Coal Manpower Projections, 1970-80, by Leo Kramer, Inc. December 1972. 70 pp. This final report gives projections based on a series of assumptions concerning past trends, current developments, and future possibilities. One such trend is that the demand for energy in the U.S. economy will continue to increase each year at a rate sufficient to put a strain on current sources of energy, of which coal is one. A current development is the impact upon the coal industry of the higher health and safety standards which have been required by the Federal Coal Mine Health and Safety Act of 1969. This legislation is significantly increasing the manpower requirements for coal production in underground mines. A future possibility which could drastically alter the manpower requirements in coal is the enactment of Federal legislation regulating or eliminating strip mining. On the manpower side, one trend is practically inevitable, namely, the phasing out of the older workers who have reached or are approaching retirement age and recruitment and training of new workers. Available for reference at Bureau of Mines installations in Pittsburgh, Pa., Mount Hope, W. Va., and Denver, Colo., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 22-73. Fatality Analysis Data Base Development, by Theodore Barry and Associates. June 30, 1972. 253 pp. 71 figs. Except for discussion of behavioral problems, the various fatal accident problem areas were analyzed both in terms of the potential reduction in fatalities and in relation to the implementation cost of the recommendations. The original computerized fatal accident data base helped determine the relative importance of hazardous work elements and hazardous conditions, and thus substantially assisted the fatality reduction estimates in the problem areas listed. The ability to tabulate fatal accident frequencies for literally any desired combination of factors was the key to comprehensive analysis. The staff reviewed all the face mining equipment, made

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field observations of human factors problems, consulted with equipment manufacturers and analyzed in depth all recorded equipment accident reports. This report supplements Bureau of Mines Open File Reports 4 (1) -72 with equipment manufacturers, and analyzed in depth and 4 (2) -72. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 23-73. A Comprehensive Study of Intrinsic Safety Criteria, by Zsuzsanna Zborovszky and Louise A. Cotugno. March 1972. 113 pp. 9 figs. Present status of standardization in "intrinsic safety" approvals is examined and the supporting data are evaluated. It is concluded that present standards differ widely between countries and organizations. These considerations comprise the significant body of the report. Modification of the Electrical Circuit Analysis Program (ECAP) to provide guidance in approval testing is also described. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 24-73. Dust Suppression in Coal Mines, by DeTer Company, Inc. July 18, 1972. 44 pp. 20 figs. The results of these dust suppression tests showed conclusively that the modified DeTer equipment effectively reduced the level of respirable dust in a working coal mine well below the present and future acceptable levels set by the Mine Health and Safety Act of 1969. Fire tests, carried out in a simulated mine entryway erected on the surface, demonstrated the ability of the DeTer equipment in suppressing fires of varying degrees of severity within an acceptably short time. Available for reference at Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 25(1)-73. Experience Survey of Engineering Methods Used to Control Dust in Underground Coal Mines. Volume 1. Report of Contract Performance, by Apt, Bramer, Conrad, and Associates, Inc. August 1972. 142 pp. 7 figs. This manual was prepared to help and guide underground coal mine operators. It details both common and unique engineering methods by which respirable dust, which is generated in coal mines, can be controlled. There are five basic principles that are used to control or reduce respirable coal mine dust: (1) Prevent or limit dispersion; (2) dilute with air; (3) ventilate correctly; (4) prevent generation; and (5) provide seal protection. This manual and the control methods described are concerned with the first three items only. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 25(2)-73. Respirable Dust Control Manual for Underground Coal Mines, Volume 2, by Jerome Apt and Floyd G. Anderson. Apt, Bramer, Conrad, and Associates, Inc. August 1972. 77 pp. 29 figs. The Federal Coal Mine Health and Safety Act of 1969 required each mine operator to continuously maintain the average concentration of dust in the mine atmosphere during each

shift to which every miner is exposed at or below 3.0 mg of dust per cubic meter of air and thereafter at 2 mg/m³ from June 30, 1970, through December 31, 1972. The application of the most successful engineering methods for respirable dust control developed in this country must be utilized by mine operators to maintain dust concentrations within the limits required by law. Work in the past has covered (1) ventilation; (2) water and wetting agents; (3) dust collectors, both dry and wet; and (4) mining equipment design. With the desired goal of reducing respirable dust in all coal operations, it became mandatory that as much information as possible be assembled, evaluated, and consolidated into a format that could be utilized by all coal operators. The scope of the survey includes identifying, defining, evaluating, and assembling in meaningful form, all engineering methods developed to control respirable dust in coal mines in the past 20 years. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 26-73. Computational Aspects of Input-Output Analysis Applied to Resources Management With Special Reference to the U.S. Mineral Industry, by Jona S. Bargur. College of Engineering and School of Public Health, University of California, Berkeley, Calif. September 1970. 104 pp. This study reviews briefly the computational aspects required for the application of input-output analysis to resources management, with special emphasis on the adoption of a national input-output model for structural analysis of specific industries and specific regions. Programs for handling input-output models of the size of the current 1963 U.S. model were formulated, and their empirical application for a detailed analysis of the U.S. mineral industry was tested. The seven mining sectors presented in the National Input-Output Table for 1963 are disaggregated into 44 subsectors, based on data provided by the Bureau of Mines. The input-output information for these subsectors was then incorporated into the national model to constitute a 399-order table. A corresponding "direct requirements" table and a "direct and indirect requirements" table were then computed, applying the computer programs developed for those purposes. The resulting transactions, relations, and the coefficients for the 44 mineral subsectors are presented. Available for reference at Bureau of Mines Field Offices in Pittsburgh, Pa., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 27-73. Finite Element Analysis of Mine Structures, by Department of Civil Engineering, University of California. September 1972. 195 pp. 3 figs. This report presents a computer program for the static load analysis of linear elastic structures. It is the product of a 2-year project to develop an efficient program for the analysis of mine-type structures. The first part of the report explains the general method of analysis, the computer program organization, and the most significant numerical techniques used. The second part is a user manual for the computer program. The program is machine independent and is coded in standard FORTRAN IV. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

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OFR 28-73. Muffler for Pneumatic Drill, by Robert E. Manning. Jan. 24, 1973. 81 pp. 47 figs. A need currently exists for more effective noise control in the coal mining industry. In particular, new muffler designs with the required acoustic performance are needed for percussive pneumatic drills. The specific objective of this research was to design and deliver a prototype muffler that would attenuate the air-exhaust noise to 90 decibels on the A scale (90 dbA). The test drill used in this study was one used for roof-bolting purposes in coal mines. Using the combined approach analysis by digital-computer program and experiment by simulated-noise tests, three prototype mufflers were designed and constructed at U.S. Steel Research. The mufflers consisted of a variety of resonator chambers and expansion-contraction chambers, and were of the following sizes: 3- by 5-inch elliptical cross section and about 8 inches in length, 5 inches in diameter and about 5½ inches in length, and 5 inches in diameter and about 10½ inches in length. All mufflers in laboratory tests reduced the exhaust-noise level by about 25 dbA—from about 115 dbA without a muffler to below 90 dbA with a muffler. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR-29-73. Shaft Drilling: State of the Art, by James H. Cobbs and Louis R. Reeder. March 1973. 169 pp. 45 figs. This report covers bored shaft up to 25 feet in diameter by both blind drilling and raise drilling. Included are discussions on site selection and preparation, drilling equipment and operations, grouting methods, hole lining techniques, and problems unique to shaft boring in coal provinces. The appendix contains a section on novel drilling techniques, a tabulation of mine shafts drilled to date, and a comprehensive bibliography. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 30-73. Extraction of Energy Fuels, by Extraction of Energy Fuels Panel for The Committee on Energy Research and Development Goals. September 1972. 252 pp. 15 figs. This report of the Extraction of Energy Fuels Panel has been prepared for the Office of Science and Technology which has been engaged in directing an extensive assessment of new energy technologies. That assessment is being carried out in response to a request from the President in his Clean Energy Message to Congress of June 4, 1971, and involves the participation of major Federal agencies concerned with energy research. The purpose is to identify and implement the most promising set of research programs in the energy field. The technical assessment contained in this report is an initial appraisal of the following functional areas: (1) Stimulation of petroleum and natural gas production, (2) production of oil from tar sands, (3) development of oil shale, (4) underground gasification of coal, (5) oil and gas production from organic wastes, and (6) primary extraction of coal. The report covers short-term needs (1972-80), intermediate-term needs (1975-85), and long-term needs (1980-2000). Available for reference during working hours only at the following Bureau locations: Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Fort

Snelling, Minn., Bartlesville, Okla., Grand Forks, N. Dak., Laramie, Wyo., Morgantown, W. Va. San Francisco, Calif., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 31-73. Sulfur Coatings for Mine Support, by John M. Dale and Allen G. Ludwig. November 1972. 46 pp. 12 figs. Sulfur is a plentiful, low-cost, unique material whose physical properties can be altered and employed in structural applications. This program was undertaken to develop an optimum sulfur-based formulation for use as a coating to both seal and support mine walls. The initial effort in this research was devoted to a laboratory study of the physical and mechanical properties of a variety of sulfur-base coatings that were specifically formulated for this application. Concurrent with formulation development, laboratory equipment and techniques were developed for spray application of the sulfur-based coatings to the ceiling and walls of a structure that simulated the interior of a mine. One hundred parts of sulfur modified with 10 parts of talc, 3 parts of milled glass fiber, and 2 parts of dicyclopentadiene was found to be a fire-retarded, low odor, low eye irritation, sprayable formulation for sealing and strengthening mine walls. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 32-73. 50-Cap Blasting Machine Development Program, by Magnavox Company. Mar. 29, 1973. 11 pp. 2 figs. Owing to the demands of industry for a permissible 50-cap blasting machine, the Bureau of Mines contracted with Magnavox Company to design such equipment. From the preliminary analysis of the technical requirements of the blasting machine, a new electrical design, which would eliminate the need for mechanical switches to switch high voltage, was conceived. This new design utilized simple, straightforward techniques to overcome several problems identified in the original design and, at the same time, increase inherent reliability of the equipment. The central feature of the new circuit was a transistorized timing generator capable of driving the output silicon controlled rectifiers (SCR's) directly. Approval and testing of this equipment by the Bureau of Mines has not been completed. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 33-73. A Seismic Communications Investigation Employing a Piezoelectric Transducer, by Craig C. Johnson. 1973. 47 pp. 30 figs. The purpose of this effort was to investigate the feasibility of employing a piezoelectric transducer for seismic communications applications in mine environments. The transducer, a government furnished device, incorporated a high Q, spring-mass resonator to load the air side of the piezoelectric crystal. The resonant frequency was seismic load dependent and fell in the range of 300 to 340 Hz. The effort included a mathematical analysis of the transducer, with corroborative laboratory tests, together with actual communications experiments performed first in an open-pit limestone quarry and finally in an operating iron mine. This work showed that the transducer could be coupled efficiently to hard, competent rock media with

power conversion efficiencies of 70 to 80 percent (electrical to mechanical) in typical installations. In the iron mine, when radiating peak power was about 30 W (acoustical) in a gated pulse mode, signals were received at a distance of 760 feet through a massive rhyolite porphyry formation. This represents a 15 percent radiation efficiency with an input of 200 watts. Despite the high ambient noise level due to operating mine machinery, a signal-to-noise ratio of about 20 dB was achieved using a very narrow band filter to process the received signal, and a data rate of about two pulses per second was demonstrated. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 34(1)-73. Standardization of Controls on Front-End Loaders. Volume 1. Data Analyses and Conclusions, by L. D. Marrus. January 1973. 215 pp. 26 figs. Volume 1 includes an introduction to the subject of front-end loader usage in the mining industry and discusses the associated safety problems that led to this study being performed. Also included in this volume are a task analysis; a control criticality analysis; a safety analysis; commonality analyses for control occurrence, location, direction of motion and type of control; and a trade-off study analysis. This volume concludes with an analysis of the various human factors, safety, mining industry, and front-end loader manufacturing industry factors, influencing the standardization of front-end loader controls; recommendations and rationales for front-end loader controls standardization; and a description of the front-end loader mockup. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 34(2)-73. Standardization of Controls on Front-End Loaders. Volume 2. Summaries of Mining Industry and Manufacturers Data, by L. D. Marrus. 277 pp. 45 figs. Volume 2 includes a summary of the data obtained from the mining industry regarding their commentary on the present design of front-end loader controls, the environmental conditions encountered in the use of front-end loaders, the numbers of different makes and models being used and their functional usage, the personnel policies with respect to front-end loader operators, and various comments on the subjects of standardization, safety, and the costs associated with standardization. The report includes summaries of other makes and models of front-end loaders studied, and of the type of control, direction of motion, axial relationship, location, size, displacement, and resistance (force) for each of the separate controls. The report also includes a listing of the human factors and safety principles, requirements and design criteria that were covered in the study, reference sources, and a description of the tradeoff study. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 35-73. Evaluation of Mine Electrical Systems With Respect to Safety, Technology, Economics, and Legal Considerations, by Robert Stefanko, A. K. Sinha, and

L. A. Morley. June 28, 1972. 103 pp. 35 figs. Pennsylvania State University scientists have developed special analyzers and made measurements at various coal mines to acquire basic data regarding mine electrical power distribution. The report covers power analyses for working sections, ground-bed and mine-floor resistance data, and a description of a power-system computer simulation that is being developed. This research was devoted primarily to the acquisition of field data by utilizing a recently designed three-phase ac continuous-power analyzer. Determination of the electrical performance characteristics and development of instrumentation proceeded concurrently. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 36-73. Safety Analysis System Study, by Theodore Barry and Associates. Aug. 31, 1972. 122 pp. The purpose of this study was to develop a plan for the organization and operation of a Bureau of Mines safety analysis center. Before the completion of the study, the Bureau established such a center, the Health and Safety Analysis Center (HSAC), under the direction of the Assistant Director of Health and Safety for Technical Support. This report recommends that this center be organized under four branches: Accident information, special studies, systems evaluation, and programs assurance. For HSAC to fulfill its role, it must provide current, relevant outputs in each of its four output categories, as follows: (1) As rapidly as possible, establish its role within the Bureau and obtain recognition of that role at all management levels, (2) streamline its data collection and publication processes, and (3) maintain continuous contact with users of HSAC outputs to insure the relevancy of those outputs. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 37-73. State-of-the-Art of Down-the-Hole-Tools, by Wendell L. Reich. REICO Industries. November 1972. 11 pp. plus appendixes. This report provides the state-of-the-art of down-the-hole percussive drilling devices and recommendations as follows for research and development:

1. Rather than spend monies on research and development of new equipment, pursue actual drilling programs designed to test the latest equipment and techniques.
2. Allow actual testing programs in themselves to develop new methods and techniques as they progress toward the ultimate program goals.
3. Bring all factors on drilling techniques together in a test program to develop the proper balance, sequence, and procedure to accomplish the desired results. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 38-73. Accident Prediction Investigation Study, by Theodore Barry and Associates. Sept. 30, 1972. 174 pp. 43 figs. The objective of this study was to investigate promising accident factors that historically have not been reported to the Bureau of Mines on non-

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fatal injury accidents. The contractor analyzed existing accident report data for a specific mining area. Each factor was evaluated in terms of its data availability for analysis, its importance, and potential accident predictive value. The contractor developed some significant information concerning accident occurrence, particularly regarding the factors of task experience and job mobility of workers. The study determined that there is a lack of reliable accident prediction potential for all factors tested and an extremely high variance in accident rates both in type and characteristic in the mines studied. The study indicated a considerable amount of randomness in accident occurrence. It also confirmed that much of the basic accident data required for a predictive model is not presently available. Strategic gathering of detailed accident data should be developed. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 39-73. Research and Development on Lithium-Nickel Fluoride Batteries for Mine Life Support Equipment, by C. Lurie and S. Lerner. Gulton Battery Corporation. February 1973. 94 pp. 9 figs. This final report describes the work performed by Gulton Battery Corporation on lithium-nickel fluoride batteries for mine life support equipment. The lithium-nickel fluoride couple was chosen for this investigation because of its high theoretical energy density, its ability to operate at ambient temperature, and the fact that it showed promise as a secondary system. The theoretical energy density of the lithium-nickel fluoride couple is ten times greater than that of the widely used lead-acid battery and three times greater than the silver-zinc battery which has the highest theoretical energy density of the commercially available secondary systems. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 40-73. Investigation of Flexible Materials for Personnel Shield, by General Technologies Corporation. Apr. 25, 1972. 30 pp. 4 figs. Since roof falls in the vicinity of the working face in underground coal mines are a major source of fatalities and injuries in the Nation's coal mines, it is evident that the present systems of temporary support for use in this working area are ineffective. This seems to be chiefly due to the inconvenience of setting up heavy and awkward devices such as jacks and posts, which also interfere with the movement of men and machines in this critical working area. This program was concerned with defining and testing commercially available materials that could be used as support elements in a more convenient flexible personnel shield. Five specific materials were tested. It was recommended that a heavy denier nylon fabric coated with a polyester resin be considered for use as a flexible personnel protective shield in coal mines. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 41-73. The Development of a System To Suppress and Extinguish Fully Developed Coal Dust Explosions. Progress Report, by U.S. Naval Weapons Laboratory.

September 1972. 129 pp. On a project to develop a system to suppress coal dust explosions, a facility has been built and several devices tested. The facility is a 317-foot, 4.5-foot-diameter shock tube. To date 53 tests have been carried out with methane-air and methane-coal dust-air as the explosive mixtures. The suppression of slowly propagating (up to 300 ft/sec) flame fronts has been successfully carried out on two tests using the dry chemical extinguishing agent Purple K. Delivery of the material directly into the flame front seems to be required if effective suppression is to be accomplished. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 42-73. Laser Irradiation as a Rapid Screening Process for the Evaluation of Flame Inhibitors, by Pittsburgh Energy Research Center. Jan. 3, 1973. 7 pp. 3 figs. Inhibitors are used in coal mines as a precaution against accidental dust explosions. Although rock dust is the usual inhibitor many others have been tested. To facilitate testing, a screening process using laser irradiation was proposed. The procedure includes irradiation of a coal-dust mixture followed by mass-spectrometric analysis of the evolved gases and an evaluation of the flammability characteristics of the gases. Carbonate-type inhibitors decreased the percentage of combustibles in the gases generated, and inhibitors like NaCl (thermally stable salts) decreased the total gas generated. A suitable test procedure did not result from the investigation, demonstrating the inadequacy of fast heating, noncombustive techniques in rating inhibitors of coal dust explosions. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 43-73. Portable Bore-Hole Shear Strength Tester for Coal, by R. L. Handy, D. E. Klockow, and E. G. Ferguson. February 1973. 82 pp. 25 figs. The objective of this research was to devise and test an apparatus to rapidly evaluate the cohesive and frictional strength of coal in situ, in order to increase the safety and percentage of coal recovery from underground coal mines. Since it is extremely difficult to obtain large samples of coal for laboratory testing, the borehole shear tester promises to be of significant value to mining engineers and researchers in determining the physical properties of coal and related strata. Such physical properties are essential to the use of finite-element analyses or other techniques of mine design. During the first year, a device was designed utilizing the borehole shear test principle from soil shear strength testing. The opposing corrugated plates were forced outward to exert a controlled contact pressure against the sides of a previously bored hole, and then the plates were slowly pulled along the axis of the hole to cause shearing of coal in contact with the plates. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 44-73. A Case Study of In-Situ Rock Deformation Behavior for the Design of Ground Support System, by Samuel S. M. Chan. Jan. 31, 1972. 130 pp.

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30 figs. The method of in situ deformation measurement used in this research proved to be satisfactory for obtaining initial elastic deformation and long-term deformation of rock masses immediately surrounding underground openings such as a drift. Technical difficulties were encountered during overcoring operation for ground stress determination, and improvements are needed for future application of the technique. The particular unidirectional borehole jacking technique used to determine in situ modulus of deformation was tentatively shown to be unsatisfactory. Laboratory testing data in rock strength and elastic parameters obtained were justified and may serve as close approximation to the actual values when suitable simulations of the actual conditions are met. The finite element methods used in this research proved useful in predicting and confirming field and laboratory data in all phases of this project even through a lot of estimation and personal judgment were still involved. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 45-73. Development of a Boring Machine Cutter Instrumentation Program, by F. W. Gobetz. June 1973. 149 pp. 53 figs. An experimental study was performed in which three disk cutters of a tunnel boring machine were instrumented to measure dynamic forces and moments experienced by the cutters during full-scale boring operations. The boring machine used was an 18-ft-diameter Robbins mole. Strain gages were installed within the fixed shafts about which the cutters rotate, and dynamic force data were recorded as the machine bored a 12-ft length of tunnel in shale. Geological cores were taken in the bored section, tested for strength and hardness, and compared with similar data from other areas of the tunnel. Cutter force measurements were taken in analog form and recorded on magnetic tape. Representative samples of the analog data were subsequently digitized and reduced to statistics that summarize the four channels of dynamic data recorded for each cutter. A review of the conduct of the technical program is provided. The instrumentation approach is described and details of the system components are presented. All results are documented in tabular and/or graphical form. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 46-73. Test Data on Exhaust Emissions From a Proposed Commercial Catalytic Converter, by Staff, Bartlesville Energy Research Center, Bartlesville, Okla. 1973. 2 pp. 1 fig. These test data were obtained in the Bureau of Mines program "Fuels and Engine Systems To Enhance Fuel Economy in Clean Air Cars." The equipment used was a 1973 Chevrolet 350-CID engine modified to 10.25:1 compression ratio and was equipped with a single-bed catalytic converter (sometimes referred to as three-component control catalyst) for control of carbon monoxide, hydrocarbons, and oxides of nitrogen. The catalytic converter used on the engine was furnished by the Universal Oil Products (UOP) Company. Available for reference at Bureau of Mines libraries in Bartlesville, Okla., Laramie, Wyo., Morgantown, W. Va., and San Francisco, Calif.

OFR 47-73. A Study of the Rope-Haulage Systems, by Louis R. Reeder and James H. Cobbs. June 1973. 77 pp. 40 figs. This investigation was conducted to determine whether the installation of rope-hauled Coolie Car systems were likely to improve upon the present methods of moving men, materials, and supplies in underground bituminous coal mines in the United States. The rope-hauled Coolie Car and related rope-hauled systems generally are not adaptable to most bituminous coal mines in the United States that have room-and-pillar operations, the report states. The rope-hauled systems can be integrated into the haulage scheme of longwall and shortwall operations, but the systems are not being applied effectively until seam pitch or roadway gradients are steep enough to limit the use of other methods of traction. Five rope-hauled monorail systems are integrated into the transport systems of three Pennsylvania anthracite mines. Accident frequency rates for the rope-hauled man and material subsidiary systems in British coal mines show them to be 28.9 and 23.9 percent higher than the frequency rates for all underground haulage in the United States during 1966 and 1967, respectively. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 48-73. An Experimental Investigation of Acoustic Precipitation of Aerosols at Moderate Sound Intensity, by Paul S. Schopf. November 1972. 33 pp. 16 figs. Results of an experimental investigation into the possible use medium energy acoustic fields (130 to 140 db) to precipitate 1- to 10-micrometer particles are presented. The aerosol was produced with a commercial generator using oleic acid and nitrogen. The sound field was a sinusoidal standing wave field in an acrylic tube, with light transmission data used for concentration determination. The results showed collection efficiencies of up to 80 percent on 2-micrometer particles with a residence time of 11.8 seconds at a sound pressure level of 139 db re 2×10^{-5} N/m². A discussion of the possible turbulent mechanism is made, as well as review and comparison with others' work. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 49-73. Rapid Major Element Mine Dust Analyzer, by John R. Rhodes and Morris C. Taylor. Sept. 5, 1972. 52 pp. 11 figs. The objective of this project was to investigate the feasibility of analytical techniques potentially capable of determining Mg, Al, Si, S, Ca, and Fe in 1- to 2-mg samples of respirable coal mine dust is that fraction of airborne dust in coal mines minutes per sample, using equipment capable of being truck mounted for field-laboratory operation. Respirable mine dust is that fraction of airborne dust in coal mines that is breathed in and retained in miners' lungs. The particle size distribution so retained is in the range of 0.1 to 5 micrometers, peaking at about 1 micrometer. The techniques investigated were α -particle scattering, neutron activation, electron excitation of characteristic X-rays (using either an electron gun or a radioisotope source), α -particle excitation of characteristic X-rays, and X-ray fluorescence with both radioisotopic and X-ray tube exci-

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tations. Available for reference during working hours only at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 50-73. Physical and Chemical Properties of Respirable Coal Mine Dust, by Morton Corn, Felix Stein, Yehia Hammad, Sarosh Manekshaw, and William Bell. July 31, 1972. 140 pp. 5 figs. The purpose of this investigation was to develop and demonstrate the feasibility of techniques to determine selected properties of respirable coal mine dust. An approved underground horizontal elutriator that samples air at 36 cfm was designed, fabricated, and utilized in this study to collect respirable coal mine dust in three mines representing the Pittsburgh, Lower Freeport, and Lower Kittanning coal seams. Analytical procedures for measurement of respirable dust sample particle size, density, random projected area, total surface area, and chemical composition are presented. Results of analyses of three samples collected in each mine are presented. No improvement in mining technology was expected or achieved. The methods that were developed for the characterization of particles are of doubtful value because of the large mass of dust required for the analyses. The preliminary results for dust from the three mines are useful in that they show the variation that can be expected in the properties of coal dust from different mines and in particle size fractions. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 51-73. Survey of Dust Control Research, by R. D. Saltzman, R. D. Harris, and K. M. Morse. May 1973. 209 pp. This report reviews, from the point of view of selected coal producers, the contributions made by in-house and contract research by the Bureau of Mines and other governmental agencies in meeting the needs of the industry for accurate dust sampling instrumentation and for improved dust control technology. This review, combined with an evaluation of coal industry research, has been utilized to make recommendations for future research to overcome remaining technologic difficulties. The survey includes a review of 17 research projects conducted in-house by the Bureau of Mines involving a 1972 cost of \$1,762,650; 23 contract research projects funded by the Bureau at a 1972-73 cost of \$2,928,000; 17 projects funded by the National Institute for Occupational Safety and Health and other governmental organizations at a cost of \$538,000; and 89 company-funded projects conducted by coal producers. The survey recommends that the Bureau establish an industry advisory group experienced in coal mine health and safety to aid the Bureau in establishing priority research projects. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 52-73. Measurement of Temperature Profiles Around Coal Mine Openings, by Fun-Den Wang, William Hustrulid, William F. Martin, and Manuel Reyes. Dec. 30, 1972. 187 pp. 55 figs. This report presents theoretical studies and experimental work deal-

ing with the detection of dangerous roof and pillar conditions in underground mines through measurement of temperature differences on the surface of the mine opening. The theoretical work is directed at modeling the circumstances where a loose slab of rock might be detected. The experimental work provides input data for the theoretical models. The study produced mathematical models of heat flow in rock around coal mine openings. These models were verified by measurements in coal mines. The study provided data to support the Bureau's research in infrared detection of potential roof falls. The report substantiates that thermal difference techniques can be used effectively in well ventilated underground openings where there is a temperature difference between rock and the mine atmosphere. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 53-73. The Mechanics of Coal Mine Bumps and the Interaction Between Coal Pillars, Mine Roof, and Floor, by S. L. Grouch and C. Fairhurst. Feb. 22, 1973. 88 pp. 26 figs. This report describes research on the mechanics of coal mine bumps done over a 26-month period. The general term "coal mine bump" refers to the sudden and violent failure of in situ coal. The objective of this research was to develop computational procedures for predicting coal mine bumps in particular mining situations. Such procedures would prove beneficial for planning extraction sequences—and perhaps even mining methods—in bump-prone coal deposits. Although no single set of circumstances is solely responsible for causing coal mine bumps, it is generally agreed that at least one of five conditions is necessary in order for them to occur: (1) The depth of cover exceeds 500 feet, (2) the overlying strata are relatively strong and stiff, (3) the coal is structurally strong, (4) the floor does not heave readily, and (5) the mining method produces high stresses over a large area of the seam. Except for the last, these conditions are related to geological factors that are difficult to control. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 54-73. Evaluation of Present Shotcrete Technology For Improved Coal Mine Ground Control, by S. A. Bortz, E. Aleshin, T. B. Wade, and Y. P. Chugh. May 21, 1973. 205 pp. 75 figs. This report presents the results of an extensive laboratory testing program to determine the physical properties of shotcrete including the use of fast-set agents, controlled set cements, and both wet and dry shotcreting equipment. Shotcrete was placed under simulated field conditions using the dry and wet processes. Mechanical properties obtained for accelerated and non-accelerated shotcretes include compressive, flexural, and shear strength; elastic modulus and Poisson's ratio; and shear and tensile properties of shotcrete bonded to coal, sandstone, and shale. Physical properties measured were unit weight and permeability to methane gas. The data show that rapid setting shotcrete has the potential for improved coal mine ground control. There is no clear evidence that either wet or dry process shotcrete is superior to the other; however, indications are that

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regulated set cement is preferred to cement containing fast-setting admixtures. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 55-73. Spontaneous Electrostatic Precipitation of Dust, by Frederick M. Fowkes and Frank H. Hielscher. May 15, 1973. 48 pp. 7 figs. This report provides fundamental research information on the electrostatic behavior of coal mine dust. The results will be used to help determine whether a precipitator should be designed that would function by the spontaneous exchange of electric charge between coal mine dust and polymer surfaces. The following conclusions were reached: (1) Electrification occurs upon contact of materials and rubbing is not required; (2) electrification occurs by electron injection and not by polarization of dipoles; (3) the direction of electron transfer depends on the electron-donor or electron-acceptor character of the outermost surfaces of the materials in contact; (4) some pairs of materials transferred as many as 4×10^{12} electrons/cm; (5) strong electrification of dusts took place in a fraction of a second, but weaker charge transfer took longer; (6) the transfer of charge between an insulated polymer surface and impinging dust particles diminishes as the surface charge builds up on the polymer; and (7) the charge transfer characteristics of polymers were modified by incorporating acidic or basic additives. Available for reference at Bureau of Mines libraries, in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 56-73. Air-Inflatable Temporary Supports for Coal Mine Roofs, by Hauser Laboratories. June 12, 1973. 73 pp. 27 figs. This report covers development of a temporary support system for coal mine roofs involving the use of overhead rigid spanners supported by pneumatically operated telescoping columns. Test data for individual components as well as for the entire system are reported. Data reported show that the system supports 80-100 pounds of thrust against the mine roof per pound of support as contrasted to a system of conventional mine jacks that support 50 pounds of thrust per pound of jack. As individual components, two of the pneumatically actuated telebeams supported a spanner load of 3 psi over an area of 2 by 18 inches. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 57-73. Development of Multiplexed Borehole Inclino-meter Probe, Data Acquisition and Calculation System, by Earth Sciences Research, Inc. Aug. 24, 1973. 22 pp. The purpose of this work was to develop a borehole inclinometer for use in steeply inclined and horizontal boreholes in order to measure lateral displacements of ground. The objective was not achieved. Positive results of the work included a computer and on-line data acquisition and calculation program. The work did not result in any significant improvement in mining technology. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 58-73. Constitutive Relations of Coal, Annual Reports 1972, by Hon-Yim Ko and Kurt H. Gerstle. Sept. 12, 1973. 213 pp. 132 figs. Most of the studies performed during 1972 were done on coal from two sources: the Old Ben Mine #22 in Illinois, and the Bruceton Experimental Mine of the Bureau of Mines in the Pittsburgh seam of Pennsylvania, which may be considered typical of coal sources of economic importance in the midwestern and eastern parts of the United States. While the researchers were restricted to grab sampling within the Old Ben Mine to minimize interference with commercial operations, they received active help in securing material from the Bruceton mine under controlled conditions of location and orientation, which permitted them to attempt a study of the variation of coal properties over the depth of the Pittsburgh seam. The study involved Hoek cell tests of the Old Ben and Pittsburgh coal, cubical tests, zonal testing of the Pittsburgh coal, tests for compressive strength, tests for tensile strength behavior of coal under sustained loads, and petrographic investigation. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 59(1)-73. Feasibility Study of Surface Impregnation Equipment for Chemical Stabilization of Coal-Mine Structures. Final Report, Summary (Phases I and II). Volume 1 of 4, by Eimco Tunneling and Mining Machinery Division of Envirotech Corporation. July 1972. 25 pp. 4 figs. The results of a feasibility and design study of surface impregnation equipment to be used for chemical stabilization of coal mine structures are described in this report. By establishing that production rate polymer impregnation is feasible for underground coal mines and by providing a practical tool for this process, an important step has been taken toward the demonstration and realization of the chemical stabilization concept as a practical method to achieve improvements in mine safety and production. With complete specifications and drawings at hand, the steps from concepts to actual hardware can be taken. With the prototype machine documented in this report, it will be possible for investigators to study chemical stabilization of mine structures under actual mining conditions. In this way, the uncertainties associated with laboratory or small-scale testing of mine structure problems are largely eliminated. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 59(2)-73. Feasibility Study of Surface Impregnation Equipment for Chemical Stabilization of Coal-Mine Structures. Final Report, Phase I. Volume 2 of 4, by Eimco Tunneling and Mining Machinery Division of Envirotech Corporation. July 1972. 94 pp. 51 figs. Phase I of this study was concerned with the following objectives: (1) Investigate, through industry and literature searches and conceptual design studies, the feasibility of techniques for impregnating the roof and ribs of a coal mine for structural stabilization; (2) select concept(s) and prepare preliminary designs for cost and compatibility analysis leading to selection of concept(s) for feasibility demonstration and detailed design. The

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criteria under which Phase I investigation was conducted included environmental, geometric, physical, chemical, and operational limits. Phase I of the program clearly indicated that a machine for stabilization of coal mine structures through surface impregnation with polymer was completely feasible. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 59(3)-73. Feasibility Study of Surface Impregnation Equipment for Chemical Stabilization of Coal-Mine Structures, Final Report, Phase II, Volume 3 of 4, by Eimco Tunneling and Mining Machinery Division of Envirotech Corporation. July 1972. 166 pp. 69 figs. This report discusses the establishment of a complete design for impregnation equipment for chemical stabilization of coal mine structures and determination of the economics of constructing, using, and maintaining the impregnation equipment designed. It covers a general description of the polymer impregnation machine, the meter and feed system, followed by a detailed account of the design selection process for each major subassembly. Most of the design was conducted without benefit of any testing of hardware. Items designed without testing include the drill and nozzle installer mechanism, boom and linkages, roof support system, and vehicle and controls. The report states that these designs are based on similar equipment currently in use and should, therefore, incur minimal problems when fabricated and assembled into a prototype. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 59(4)-73. Feasibility Study of Surface Impregnation Equipment for Chemical Stabilization of Coal-Mine Structures, Assist Technique, Phase III, Volume 4 of 4, by Eimco Tunneling and Mining Machinery Division of Envirotech Corporation. December 1972. 94 pp. 9 figs. This report summarizes the results of this investigation, and concludes that (1) ultrasonic energy is potentially capable of increasing polymer uptake into shale (above that experienced under static pressure); (2) adaptation to the impregnation machine design presented under the earlier contract is practical with minor modification; and (3) equipment and hardware to characterize and demonstrate the mechanism is commercially available. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 60-73. Plastic Liners Extended With Sand and Other Fillers for Use in Coal Mines, by J. L. Schwendeman, S. M. Sun, and I. O. Salyer. October 1972. 115 pp. 22 figs. This research explored the feasibility of using liners containing sand and other fillers as a means of roof support in coal and other mines. Phase I, directed toward determining which state-of-the-art resin systems might have utility as a means of roof support in a coal mine, consisted of a canvass of resin manufacturers to learn which resins were available commercially that might have utility for this application. The resins submitted by the manufactureres were evaluated in a number of simple

tests to define which of them would be most suitable for roof support use. Phases II included experimental work directed toward better defining the utility of selected resins and, finally, extensive evaluation of two resins for usefulness as components of a mine support system. During Phase I, a number of fillers (fibrous and the particulate) were evaluated. In Phase II, all work was done using concrete sand as the major filler along with a minor amount of chopped glass moving as a fibrous filler. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 61(1)-73. The Role of Mine Tailings Ponds in Reducing the Discharge of Heavy Metal Ions to the Environment. 1. Text, by Roy E. Williams and Alfred T. Wallace. Aug. 9, 1973. 110 pp. This study provides an evaluation of the effectiveness of mine tailings ponds as a means of minimizing or reducing the flow of acids, dissolved solids, tailings, and heavy metal ions into the surrounding environment. It also suggests several types of treatments or methods that would reduce the discharge of undesirable materials from the tailings ponds. Samples of tailings pond inflows, outflows, seepages, and stream water above and below the tailings ponds were collected from seven major operating mines in the Coeur d'Alene district. They were analyzed for 13 elements, along with chlorides, fluorides, electrical conductivity, pH, and temperature. Mineral extraction involved a process of selective flotation to concentrate the ore. Tailings ponds for mines 1, 4, 5, 6, and 7 were found to be effective in reducing suspended solids to acceptable limits. The outflows of these ponds did not contain toxic elements above acceptable limits. Tailings ponds for mines 2 and 3 were not effective in reducing concentration of cadmium, iron, manganese, lead, zinc, and fluoride. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 61(2)-73. The Role of Mine Tailings Ponds in Reducing the Discharge of Heavy Metal Ions to the Environment. 2. Appendix, by Roy E. Williams and Alfred T. Wallace. Aug. 9, 1973. 184 pp. 77 figs. This study provides an evaluation of the effectiveness of mine tailings ponds as a means of minimizing or reducing the flow of acids, dissolved solids, tailings, and heavy metal ions into the surrounding environment. It also suggests several types of treatments or methods that would reduce the discharge of undesirable materials from the tailings ponds. The appendix includes illustrations, tabular material, and computer printouts. Samples of tailings pond inflows, outflows, seepages, and stream water above and below the tailings ponds were collected from seven major operating mines in the Coeur d'Alene district. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 62(1)-73. Feasibility of Remote Control and Development of Remote Control Devices and Sensors. 1. Shuttle Car Sensor System, Introduction and Text, by Richard L. Fowler, Gary I. Robin, and William C. Troll. March 1973. 61 pp. 20 figs. Study and development of

sensing techniques and sensors were performed to aid shuttle car drivers in detecting obstacles and in guiding a car along a face haulage route. Microwave, acoustic, and optical sensing techniques were considered as part of the feasibility study for obstacle detection. Various guidance techniques, including wire-following and rib-ranging, were investigated. Active optical sensing was selected for obstacle detection to obtain the beam coverage and sharp angular cutoff characteristics required within the packaging limitations defined by the shuttle car configuration. Rib-ranging guidance was selected to achieve a completely self-contained shuttle car system that responds to the existing mine geometry without need for wires, stripes, or other path defining devices. The obstacle detection and guidance system was designed, fabricated, and installed on a standard shuttle car, satisfying all permissibility requirements. All sensors successfully demonstrated the predicted performance capability during underground face haulage tests. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 62(2)-73. Feasibility of Remote Control and Development of Remote Control Devices and Sensors.

2. Shuttle Car Sensor System. Appendix A—Technical Description, by Richard L. Fowler, Gary I. Robin, and William C. Troll. March 1973. 182 pp. 67 figs. This appendix covers lateral guidance subsystem sensors, obstacle detector sensors, and processing, displays, and control. Microwave, acoustic, and optical sensing techniques were considered as part of the feasibility study for obstacle detection. Various guidance techniques, including wire-following and rib-ranging were investigated. Active optical sensing was selected for obstacle detection to obtain the beam coverage and sharp angular cutoff characteristics required within the packaging limitations defined by the shuttle car configuration. Rib-ranging guidance was selected to achieve a completely self-contained shuttle car system which responds to the existing mine geometry without need for wires, stripes, or other path-defining devices. Extensive hybrid computer simulation runs were performed to evaluate various guidance techniques during the feasibility study. Subsequent simulation runs were performed to establish parameter values for the rib-ranging guidance system. The obstacle detection and guidance system was designed, fabricated, and installed on a standard shuttle car. The system satisfied all applicable permissibility requirements of Schedule 2G. An experimental permit was issued to Bendix for operation in an underground coal mine. Available for consultation at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 62(3)-73. Feasibility of Remote Control and Development of Remote Control Devices and Sensors.

3. Shuttle Car Sensor System. Appendix B—System Tests, by Richard L. Fowler, Gary I. Robin, and William C. Troll. March 1973. 67 pp. 28 figs. This appendix covers above-ground tests and field demonstrations. System evaluation tests were performed first aboveground at the Bendix Research Laboratories. The simulation model was validated by these runs. Final testing was performed under-

ground in an operating mine with an experienced shuttle car driver. All sensors successfully demonstrated the predicted performance capability during underground face haulage tests. Dust did not impair system performance, and lens cleaning was not required during working shifts. Further development is required to achieve the desired obstacle detection performance. Closed loop steering control with manual override is recommended for the lateral guidance system. The guidance system should be an invaluable aid to low-coal shuttle car drivers where continuous mining machines are utilized. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 62(4)-73. Feasibility of Remote Control and Development of Remote Control Devices and Sensors.

4. Continuous Mining Machine Seam Interface Sensors, by Ronald F. Steinberg, John T. Ioannou, and Sarkis Barkhoudarian. August 1972. 102 pp. 36 figs. This report presents the results of the study and experimentation on coal-seam interface sensing using the acoustic pulse-echo technique. The design and construction of acoustic transducers and coupling techniques are discussed and the electronic equipment used in conjunction with the transducers is described. Laboratory coal simulation experiments are described, and the results of acoustic transmission and reflection laboratory experiments, using coal samples from various sources, are presented. Because of difficulties encountered in laboratory experiments, an underground field test was performed for the purpose of evaluating the effectiveness of the technique for measuring coal thickness in situ prior to final hardware design and construction. The results of the field test, which showed that detection of the coal seam interface was difficult using state-of-the-art techniques because of competing signal returns, are discussed. Recommendations are made that further development of the acoustic pulse-reflection technique be shelved and that detailed information be obtained from the British Coal Board regarding the nucleonic (gamma-ray) backscattering probe for measuring coal thickness. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U. S. Department of the Interior, Washington, D.C.

OFR 62(5)-73. Feasibility of Remote Control and Development of Remote Control Devices and Sensors.

5. Continuous Mining Machine Laser Entry Alignment Sensor, by Clive E. Catchpole, Ronald F. Steinberg, and William R. Wyess. February 1973. 21 pp. 10 figs. This report describes the development of a laser entry alignment sensor for guiding a continuous-mining machine. The history of the design from one using two four-quadrant photodetectors with a servo system to one with an array of optical lens elements and sensors is detailed. Principal design features and the design philosophy are also discussed. The components of the final package (slave laser, master transit, sensor unit, display unit) are described in detail. The results of performance tests on the accuracy of the heading and tracking indications are also presented. Finally, recommendations are made for future work. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo.,

and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 62(6)-73. Feasibility of Remote Control and Development of Remote Control Devices and Sensors.

6. Feasibility Study of the Application of Solid State Displays for Underground Mining Machines, by The Bendix Corporation. Aug. 8, 1972. 125 pp. 44 figs. This report discusses an investigation of the application of solid state devices to information displays on underground coal mining machines. The specific purpose of the feasibility study was to consider solid-state devices as replacements for conventional electrical or electromechanical devices, to increase the reliability of the machinery, to increase safety in the explosive mine atmosphere, to decrease maintenance requirements, and to increase adaptability of the machinery to automatic and remote control techniques. Solid-state displays meet the functional, operational, and environmental requirements for use on underground mine equipment, the report states. It is recommended that the light emitting diode (LED) be used as the basic solid-state device for display design. Replacement of conventional displays with solid-state displays is technically feasible, but because of the very limited usage and simplicity of the conventional displays now in use on underground coal mining equipment, the practicality of replacing them with solid-state displays is doubtful. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 62(7)-73. Feasibility of Remote Control and Development of Remote Control Devices and Sensors.

7. Feasibility Study of the Application of Solid State Motor Controllers to Underground Mining Machines, by The Bendix Corporation. October 1972. 72 pp. 15 figs. This work was directed toward a general study of solid-state control devices available, their potential use on electrical machinery used in underground mines, and the general effect that the use of solid-state devices might have on the safe operation of machines. The underground mine environment presents rather severe physical and electrical stresses to machinery. Silicon-controlled rectifiers (SCR) that meet mine requirements are available. Although SCR initial costs appear to be higher than costs for electromechanical contractors, savings should result from reduced maintenance requirements, safer operation, higher reliability, elimination of mechanical transmissions, elimination of rectifier centers, and standardization on ac power. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 62(8)-73. Feasibility of Remote Control and Development of Remote Control Devices and Sensors.

8. Feasibility Study of Remote/Automatic Controls for Continuous Miners, by The Bendix Corporation. October 1972. 54 pp. 7 figs. The objective of this study was to investigate the feasibility of using remote and/or automatic controls for operation of a drum-type continuous-mining machine. Based upon the study, it was concluded that on-site automatic or semiautomatic controls are not feasible for this type of machine since it requires man to be in a high-accident zone (within 25 feet of the face). In addition, such control modes are economically unattractive,

yielding only marginal gains in production efficiency. On-site control for the continuous-miner operations that are associated with shuttle car docking and loading is ruled out for the same reasons. A key conclusion of the study identified visual information as being essential for the mining and dock/load functions. Two system concepts are possible: Director line-of-sight feedback to an operator in an enclosed remote-control station near the face, or a closed-circuit television system with cameras mounted on the continuous miner with the operator located in a distant remote-control station. The latter system was selected for operator safety. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 63-73. Time-of-Flight Mass Spectrometry Studies of Flame Inhibitors, by Pittsburgh Energy Research Center. Bureau of Mines. Apr. 19, 1973. 19 pp.

Gaseous products resulting from rapid pyrolysis of coal and coal/inhibitor mixtures by a ruby laser and a flash-tube were monitored on-line by time-of-flight mass spectrometry. The distribution of stable gases from the coal is not greatly influenced by the addition of small quantities of powdered flame inhibitors. Preliminary studies of the reaction of elementary radicals with coal and coal/inhibitor mixtures are described. The different types of experiments are discussed with regard to possible modification and application to studies of flame inhibitor action. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 64-73. The Commercial Demand for Gold in the United States, by Roger C. Van Tassel and Constantine Michalopoulos. August 1973. 63 pp. Part I of this report analyzes the review and revision of the 1969 projection of the commercial demand for gold by end use in the United States with additional data for 1969-72.

The report presents the summary of the end use projection of gold use for 1978 for the assumed gold prices of \$52 per troy ounce and \$70 per troy ounce. Part II analyzes the commercial demand for gold in the rest of the world. The report also discusses the role of the price of gold and the existing projections for gold use in the rest of the world. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Juneau, Alaska, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 65-73. Microminer-Research Dust Generator, by W. D. Kaiser, W. C. Bruce, G. H. White, and H. C. Meacham. Feb. 21, 1973. 17 pp. 10 figs. A small-size continuous-mining machine was designed and constructed.

The machine will be used to investigate the effect of assorted cutting parameters on the formation of dust in coal mines. Results will be used in the design of new continuous-mining machines. Coal operators and equipment manufacturers have shown great interest in the preliminary reports of this work. This machine has a wide range of variable cutting parameters such as sump speed, vertical and lateral rates, cutting speed, and pick configuration. Instrumentation is provided to monitor angular velocity of the cutting wheel, sump, vertical and lateral rates, force required to sump, and the force re-

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quired to rotate the cutting wheel. A service manual accompanies the final report. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 66-73. Analysis of Williams Brothers Engineering Company Coal Slurry Pipeline Tests, by Joanne S. Gerg. Pittsburgh Mining and Safety Research Center. July 5, 1972. 38 pp. This report includes the data and analysis of data provided by the Williams Brothers Engineering Company resulting from hydraulic transportation tests using minus 1-inch coal in a 4-inch-diameter pipeline. The head loss data for coal slurries over a range of concentrations and velocities and the laboratory screen analysis were selected as areas for investigation in the data analysis performed. This information is useful for designing hydraulic transportation systems. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 67-73. Permissible Automatic Data Acquisition System, by Environmental Science Division, The Bendix Corporation. March 1973. 25 pp. 5 figs. The objective of this research was to develop a permissible data acquisition system for recording readings of pressure transducers, borehole deformation gages, and other instrumentation installed in coal mines to monitor rock behavior. The research was successful, and the device obtained enables the collection of large amounts of instrument data over a long period of time, using very little manpower. Basically, the system is a portable, battery-powered, 24-channel data acquisition system designed for safe unattended operation of up to 30 days' duration in explosive environments. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 68-73. EM Location System Prototype and Communication Station Modification, by A. J. Farstad, C. Fisher, R. F. Linfield, and J. W. Allen. July 1973. 107 pp. 44 figs. A prototype electromagnetic (EM) location system consisting of six miniature transmitters, six miniature receivers, and one multichannel receiver was developed by Westinghouse Georesearch Laboratory and is described in this report. The equipment was designed to operate in a deep coal mine of relatively high overburden conductivity. One mine having these characteristics is the Geneva Coal mine operated by the U.S. Steel Corp. near Dragerton, Utah. The equipment was tested there. The system consisted of six manpack transmitters and six manpack receivers covering the frequency band from 900 Hz to 2,900 Hz as well as a six-channel receiver designed for use in a helicopter. Tests showed that EM signals from lightweight ($\frac{3}{4}$ lb) transmitters could be detected both on the surface and from a helicopter through as much as 1,650 feet of relatively high conductivity (2×10^2 mhos/m) overburden. Furthermore, the resulting field strength profiles could be used to determine source location to within 150 feet of the actual surveyed location in the mine. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver,

Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 69-73. Alaska 1/250,000 Scale Quadrangle Map Overlays Showing Exploratory Oil and Gas Well Drilling Locations and Productive Oil- and Gasfield Locations, by Staff, Bureau of Mines. November 1973. 87 overlays. Included on open file are subject overlays for oil and gas well drilling and field locations of productive wells in Alaska, with an additional set of overlays showing areas of leasing interest. Thirty-three overlays of Alaskan quadrangles contain the wells drilled and the productive fields. Fifty-four overlays contain quadrangles of leasing interest. Sets were made for the Resource Planning Team of the joint Federal-State Land Use Planning Commission for Alaska. Available for reference at Bureau of Mines offices in Juneau and Anchorage, Alaska, and at the Office of Wilderness and River Basins, Washington, D.C.

OFR 70(1)-73. Evaluation of Mine Electrical Systems With Respect to Safety, Technology, Economics, and Legal Considerations, Volume 1. Text, Tables, and Analyses, by Robert Stefanko, Lloyd A. Morley, and Atmesh K. Sinha. July 18, 1973. 171 pp. 82 figs. Volume 1 of this study includes tabular results and analyses. Electrical parameters of underground coal mine power systems were measured. The aim of the original proposal was to develop instruments and techniques and then make measurements of suitable power parameters, ground-fault currents, and ground resistance beds. Thus, it was possible to develop a meaningful simulator that would permit investigating electrical systems and components on paper without costly trial-and-error procedures. In the third year, a cable splice testing program was added to the project. Evaluation of several mine electrical systems and components are presented. It is hoped that increased electrical knowledge resulting from this investigation will improve electrical safety and efficiency. The analysis is based on power-parameter and ground-fault studies of 18 continuous-miner sections using strip chart recorder and transducer circuitry. Cable splice test measuring techniques are also presented. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 70(2)-73. Evaluation of Mine Electrical Systems With Respect to Safety, Technology, Economics, and Legal Considerations, Volume 2. Appendixes, by Robert Stefanko, Lloyd A. Morley, and Atmesh K. Sinha. July 18, 1973. 269 pp. 62 figs. Volume 2 consists of 11 appendixes covering detailed information resulting from the study. In this research, electrical parameters of underground coal mine power systems were measured and summarized. Measurement equipment assemblies are described. A computer model of a mine power system is given. Trailing cable splice evaluation techniques that were developed are reported, together with test data on various splices. The 11 appendixes cover expected power parameters, power parameter dynamic curves, cable sample description, cable splice data, mine electrical system simulator user's handbook, mine electrical system simulator software, strip chart software, digital recorder analysis program, digital recorder analysis program job control, and data input parameters, glossary of digital

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recorder analysis, and digital recorder program output examples. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 71-73. The State-of-the-Art in Continuous Mining Machine Bit Technology, by Kenneth L. Whitehead and Robert D. Saltsman. June 1973. 211 pp. 67 figs. After many years of research, the occurrence of pneumoconiosis, black lung disease, among miners has been related to the mass of respirable coal dust to which mining personnel have been exposed. As a result of the restrictions imposed by Public Law 91-173 in 1969, much work has been done in determining methods of either eliminating or suppressing respirable dust. The purpose of this project was to determine the state-of-the-art in continuous-mining machine bit technology, particularly with regard to dust production. The scope of the survey included visits to bit manufacturers, mining companies, mining machine manufacturers, and consultants in order to determine what bits are the best available, why they are the best, and the level of acceptance of past and present bits by the mining industry. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 72-73. Analysis of Communication Systems in Coal Mines, by M. D. Aldridge, West Virginia University. May 1, 1973. 127 pp. 52 figs. This paper reports the results of a 2-year research effort aimed at improving communication systems used in coal mines. This work was conducted under a program, the original goal of which, not only involved the development of practical and effective electronic systems for operational communications, but also for monitoring, at a central location, remote instruments at key positions in a mine. About half way through the originally proposed 3-year effort, the program was redirected to phase out the communication effort at the end of 2 years and to concentrate the program's resources on the investigation of new monitoring system concepts developed by this research. The latter was carried to the point of providing sufficient evidence to aid in the comparison of certain new communication concepts. For the concepts chosen for this study, the work was stopped short of hardware development and field testing. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 73-73. Extinguishment of Rock-Covered Mine Fires, by Edward T. McHale. Sept. 30, 1973. 61 pp. 9 figs. This research demonstrated that water, because of its high heat extraction capability, was superior to other agents for extinguishing covered coal fires. The water must be delivered directly to the site of the burning, and the sparger technique proved to have limitations for this purpose. A single sparger tube can extinguish a swath of burning coal about 20 inches in width. Therefore, in a real fire situation one sparger tube would have to be inserted into a covered fire for every 20 inches of entry width. This restriction on the sparger method might be eliminated by the use of high-pressure water

jets. It has been demonstrated that jets of water that are delivered at pressures of about 4,000 psi can penetrate coal to a depth of several feet. Accordingly, further research to evaluate the feasibility of high-pressure spargers for quenching covered coal fires should be considered. This recommendation, however, must be considered in light of other practical conditions that exist in entries, such as unavailability of high-pressure water supply. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 74-73. Influence of Mine Fires on the Ventilation of Underground Mines, by Rudolf E. Greuer. July 6, 1973. 173 pp. 70 figs. A comprehensive report was prepared dealing with the influence of accidental fires in underground mines on the ventilation of underground mines. The primary objective of the study was to obtain and evaluate all available information (mostly from foreign sources) dealing with methods of prediction of disturbances in a ventilation system by a mine fire. Particular aspects considered are as follows: Properties of mine fires, temperatures of fumes behind the fire zone, forces developed by fumes, and qualitative and quantitative prediction of disturbances caused by fires. The compilation of results indicates that the interaction of ventilation flows and fires can be predicted with more accuracy than was previously assumed. The organized study and theoretical review contained in the report should be of great interest to mining engineers. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 1-74. Development of High Strength Titanium Diboride Composites for Non-Sparking Tool Applications, by L. Kaufman and R. L. Pober. Sept. 1, 1973. 30 pp. 15 figs. Fifteen boride composites were synthesized by hot pressing and evaluated by physical and incendivity testing as nonsparking tool materials. The incendivity tests, conducted by the Albany (Oreg.) Metallurgy Research Center of the Bureau of Mines, compared the boride composites with standard cobalt-bonded tungsten carbide material used for coal cutter bits. Two titanium diboride composites and two zirconium diboride composites out-performed cobalt-bonded tungsten carbide in wear resistance and reduced tendency to cause ignitions. However, three of these candidates exhibited undesirable chipping. The remaining candidates, a TiB_2 -(Ni,Cu) composite, did not chip, nor did it cause ignitions at levels where cobalt-bonded tungsten carbide tools caused ignitions in the incendivity tests. The Bureau has for many years sought to improve safety in coal mining by developing methods for reducing the number and frequency of ignitions during cutting operations. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 2-74. Survey Report of the U.S. Bureau of Mines Electromagnetic Noise Measurement Program, by J. W. Adams, H. E. Taggart, and A. D. Spaulding.

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Nov. 30, 1971. 32 pp. 1 fig. This report describes the state-of-the-art of electromagnetic noise and the additional noise measurements required relative to coal mine communications. It surveys the efforts of six contractors to the Bureau of Mines with regard to their electromagnetic noise-measurement program. What has been done, what is planned, and evaluations and recommendations are given for each contractor. The main observation is that at the time of this report there was insufficient knowledge of electromagnetic interference in mine environments to design a reliable communication system. A major effort of the report, which is described in appendix A, was to establish parameters to be measured, units to be used, and workable formats for data presentation. Some details concerning equipment, procedures, locations, and sample data are included in appendix B. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 3-74. Automated Breathing Metabolic Simulator (ABMS).

Final Report, by Federal Systems Division, International Business Machines Corporation. January 1973. 53 pp. 12 figs. Through a contract, the Bureau of Mines has funded the development of an Automated Breathing Metabolic Simulator (ABMS). The ABMS simulates man in all of the breathing and metabolic parameters for monitoring support and resuscitation equipment. For the first time, complete breathing and metabolic simulation are incorporated in the same device. Breathing rate, breathing depth, breath velocity contour, oxygen uptake, and carbon dioxide release are all variable over wide ranges, simulating conditions from sleep to hard work with respiratory exchange ratios covering the range of hypoventilation to hyperventilation. In addition, all of these parameters are remotely controlled to facilitate the use of the device in hostile test environments. The exhaled breath is also at body temperature and completely saturated. The simulation is faithful to the extent of having a variable functional residual capacity and an anatomical dead space equivalent to that of humans. The ABMS will be used as a stand-in for humans in test and validation of respiratory equipment, permitting more extensive and safer evaluation in hazardous environments where human testing must be limited. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 4-74. Mine Systems Analysis—Tertiary Channel Deposits. The Badger Hill Pit, San Juan Ridge, Nevada County, Calif.,

by Thys B. Johnson, William R. Sharp, and John N. Williams. 1973. 77 pp. 21 figs. The objectives of this study were (1) to determine potential alternative mining systems for some of the large tertiary channel gold-bearing gravel deposits, and (2) to identify areas of technology where further investigation would be merited because of its potential inclusion in a mining system for such deposits. The study involved the development of a mineralized block inventory, an economic block inventory, determination of optimum ultimate mining limits, and a preliminary economic mining system evaluation. Computer programs

were developed and utilized for each of the study phases stated. Sampling conducted at Badger Hill by the Bureau, together with confidential drill hole data provided by the San Juan Gold Co., formed the basic gold values and distribution information from which a deposit model was developed. The analysis showed that underground mining of the Six-Mile Deposit was uneconomical, but that potential for an economic mining operation existed when the gravel resources of the channel were considered together with the gold. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 5-74. Summary of Heavy Metals Studies at San Juan Ridge, Nevada County, Calif.,

by Russell R. McLellan. 1973. 87 pp. 18 figs. The Tertiary channel gravel deposits in northern California were selected for detailed investigation by the Federal Bureau of Mines as part of a national program to locate potential sources of gold that might be developed rapidly by large-scale mining operations. This report summarizes the individual investigations by five Bureau research centers representing mining and metallurgy subsystems for possible solutions to the problem areas that long have discouraged resumption of large-scale mining in the deposits, and gives conclusions and recommendations after 2 years of field work at the deposits on San Juan Ridge. The studies indicate that modern mining technology can cope with the environmental problems that closed the immense hydraulic mines in 1884. However, they also indicate that mining can be conducted with only marginal profits unless the price of gold remains substantially above \$70 per ounce or unless sufficient byproducts can be recovered and sold to place the average value per cubic yard of gravel into a positive commercial range. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 6-74. Drilling and Sampling Tertiary Gold-Bearing Gravels at Badger Hill, Nevada County, Calif.,

by Russell R. McLellan, Richard D. Berkenkotter, Richard C. Wilmot, and Robert L. Stahl. 1973. 80 pp. Under the Heavy Metals Program, the Bureau of Mines conducted investigations at the old Badger Hill placer mine in Nevada County, Calif., to collect data regarding drilling and sampling methods and deposit characteristics. A team of five Bureau research groups studied ways to develop new or improved placer mining technology in the Tertiary gold-bearing channel gravel of northern California. This report describes the techniques used and the results obtained in the sampling and drilling stage of deposit delineation studies that were conducted. Sampling included the collection and processing of 400 tons of large- and small-volume samples from drill holes, underground workings, surface pits, and blast hole rounds. A total of 355 samples averaging 2,296 pounds per sample provided reasonably accurate data for analysis of the gold distribution. These studies indicate that the bulk of the gold is within 40 feet of bedrock in stacked, lenticular zones of cemented gravel largely confirmed to the relatively narrow, meandering course of the deepest

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portion of the bedrock channel. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Spokane, Wash., and Denver, Colo., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 7-74. Applicability of Speech Bandwidth Compression Techniques in Mine Electromagnetic Communications, by C. H. Manney. Feb. 2, 1972. 21 pp. 3 figs. This report deals with the feasibility of the use of vocoders as an integral part of a mine electromagnetic voice communication system. Limitations imposed by the nature of the transmission path, background noise, and equipment are examined. Some properties of vocoders and apparent advantages of the use of vocoders in a mine communications are discussed. The conclusion is reached that the manmade noise level will ultimately determine the workability of such a system. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 8-74. Coal Mine Combustion Products: Identification and Analysis, by K. L. Paciorek, R. H. Kratzer, J. Kaufman, and J. H. Nakahara. August 1973. 158 pp. 48 figs. The toxic products formed during thermal oxidative degradation of neoprene and polyvinyl chloride compositions, urethane foams, and various untreated and treated woods were determined quantitatively on a gram-per-gram basis. Quiescent and dynamic decomposition conditions were employed. Analyses were performed using high-vacuum separations, gas chromatography, mass spectrometry, infrared spectroscopy, and wet chemical methods. The main toxic species found included CO, HCl, HCN, SO₂, anhydride, aniline, and furfural. Thermogravimetric analyses were performed on all the compositions, and the data were correlated to available formulating information and product formation. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 9-74. Potential Mineral Resources in Selected D.2 Lands, by Robert G. Bottge. Oct. 10, 1973. 55 pp. 19 figs. This report discusses the need for Alaska's minerals, the need for surface transportation corridors, and their relationship to planned D.2 withdrawals. On May 4, 1973, 31 tracts within the planned D.2 withdrawals were jointly recommended for multiple use including mining by the Geological Survey and the Bureau of Mines. Twenty-one of these tracts of land are analyzed, and known mineral deposits and metallogenic provinces are shown. The potential economic value of each tract, its impact upon the State and Nation, and the salient mineral and transportation data for it are summarized. In December 1971, the U.S. Congress passed the Alaska Native Claims Settlement Act. Section 17(d)(2) of that act directs the Secretary of the Interior to withdraw up to 80 million acres of unreserved public lands which the Secretary deems suitable for inclusion in national parks, forests, wildlife refuges, and wild and scenic river systems. This report shows why the 31 tracts mentioned should be left open to mining. Available for reference

at Bureau of Mines facilities in Juneau, Anchorage, and Fairbanks, Alaska, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 10-74. The Demand for and Supply of Manpower in the Bituminous Coal Industry for the Years 1985 and 2000, by the Institute for Research on Human Resources, Pennsylvania State University. September 1973. 420 pp. 23 figs. Concern for assuring adequate supplies of energy in the near and distant future has been accompanied by many studies that have examined one or more of the many interrelated facets that affect supply and demand patterns for energy. Among the finds of the past studies has been a recognition that the existence of adequate resources or reserves will not automatically guarantee sufficient supplies of energy. This study did not attempt to forecast the demand for coal in the target years. Instead, emphasis was placed on developing a methodology for forecasting manpower supply and demand given alternative levels of output of bituminous coal. Forecasts of coal output were provided by the Bureau of Mines. Forecasts were made for low, probable, and high levels of total product. However, the majority of the discussion in this summary concerns those forecasts pertaining to the probable level of total product. In addition to the aggregate manpower forecasts that were developed, the investigators also developed forecasts of demand for and supply of manpower for nine Eastern States and a selected grouping of Western States. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Morgantown, W. Va., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 11-74. Process Optimization Study of Non-Sparking Titanium Diboride Tool Materials, by L. Kaufman and R. L. Pober. Manlabs, Inc. Oct. 20, 1973. 15 pp. 3 figs. A range of processing conditions and compositions have been evaluated in order to optimize the properties of TiB₂-(Ni, Cu) composites for application as a nonsparking tool material for use in coal mining operations. Fifty billets containing from 70 to 95 weight-percent titanium diboride were hot pressed at 3,000 psi between 2,400° and 2,650° F. Samples which were cut from these billets were used to measure hardness, bend strength, and impact strength so that composition processing optimization could be effected. Eight compositions selected on this basis were evaluated by incindivity tests in order to choose the best composition. The best results were obtained for an 85-weight-percent TiB₂-12-weight-percent Cu-3-weight-percent Ni composite hot pressed at 2,650° F and 3,000 psi. This material appears to be the best choice for fabrication of coal cutter bits to be evaluated in field tests. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 12-74. Development of Minimum Luminance Requirements for Underground Coal Mining Tasks, by Lyman C. Hitchcock. Jan. 31, 1973. 275 pp. 24 figs. The objective of this program was to determine the minimum luminance requirements for underground coal mining work from the working face to the first transfer point. The measurements necessary to produce usable

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data involved two distinct phases, the first being in-mine measurements. The second phase of measurements were made in a full-scale simulated mine work space with full-scale machinery models. The threshold visibility luminances were revised upward to encompass a 99-percent probability of detecting a dynamic visual task of varying location and further upward to encompass 95 percent of a 55- to 65-year-old population. Extensive reflectance measurements were made of coal surfaces, roof shales, and floor materials. The results will be useful in designing future luminaries and illumination systems. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 13-47. Solution to Problems of Pollution Associated With Mining in Northern Idaho, by Dale R. Ralston, Bryson D. Trexler, Jr., Chien J. Wai, William T. Renison, and Francis E. Rickman, Jr. Dec. 1, 1973. 99 pp. 29 figs. This report (Contract No. H0122070) describes the results of a two-phase investigation to identify sources and causes of mine water pollution in northern Idaho. The first phase effort examined the occurrence and production of acid water at the Bunker Hill mine, utilizing a water-monitoring network that extended throughout the mine. The report shows that low pH water was formed in those mine areas containing lead-zinc ore rich in pyrite and that water movement in the mine was important both in the production of acid and also in transportation of heavy metals. The second phase evaluated water movement characteristics in an abandoned tailings pile and the resultant impact on the hydrologic environment. Initial data indicated (1) the existence of a ground-water mound under the pond and (2) the transfer of ions from the tailings pile to the surrounding ground-water system. The report is of special interest to the mining industry of the Coeur d'Alene district of Idaho and of general interest to persons concerned about pollution associated with mining. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Spokane, Wash., and Denver, Colo., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 14-74. Statistical Evaluation of Inductive Effects in Mine Cables, by West Virginia University. June 29, 1973. 235 pp. 130 figs. This report (Contract No. G0122088) provides an analysis of Bureau of Mines data on induced voltages and currents in portable trailing cables and their influence on ignition hazard. The effects of cable configuration and length are considered under worst-case electrical load conditions. The advantage to be gained by the installation of diode bridges is quantitatively described, and a guide that eliminates the need for some physical measurement is included. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Spokane, Wash., and Denver, Colo., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 15-74. Standardization of Controls for Underground Electric Face Equipment—Phase I, by Applied Science Associates, Inc., October 31, 1973. 105 pp. The

primary purpose of this final report (Contract No. H0230021) is to apply modern human engineering technology to reduce human error and accidents associated with the on-site operation of electric face equipment. The main body of the report, entitled Phase I Activities, provides an in-depth accounting of the study activities to date. Other major sections of the report are concerned with specific problems of Phase I and plans for Phase II activities. Appendixes to the report contain reference lists and complete data on recommended control requirements and the level of acceptance of these requirements. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 16-17. Thru-the-Earth Electromagnetics Workshop, ed. by Richard G. Geyer. Dec. 31, 1973. 217 pp. 105 figs. This report (Contract No. G0133023) includes papers on current research in thru-the-earth communications. The papers presented herein summarize a workshop sponsored by the Bureau of Mines at the Colorado School of Mines, which was concerned with the problem of how information may be conveyed by electromagnetic waves propagating through rock media without the benefit of lines and cables. Some of the limitations and scope of such schemes are identified. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 17(1)-74. Develop, Assemble and Install a Permissible Surveillance and Communication System in the Bureau of Mines Mining and Safety Research Center Coal Mine at Bruceton, Pa. Volume 1. System Description, by Mine Safety Appliances Company. May 31, 1973. 35 pp. 16 figs. The system installed at the Bureau of Mines Bruceton Research Center comprised an aboveground central computer control facility (or surface monitor station) and 10 mine monitor stations at selected locations within the mine. Each station provided local measurement and display of several environmental parameters that were judged critical to safety in mining operations. These included smoke, noise, carbon monoxide, methane, hydrogen, temperature, rate of temperature rise, and ventilation rate. The system was designed to demonstrate that continuous monitoring of these parameters could provide early recognition of a potentially dangerous condition so that corrective action could be taken before a disaster occurs. One of the primary objectives of this contract effort was to provide a highly productive tool for mine safety research. For this reason, the surface monitor station included not only parameter display and alarm systems but a very flexible and functional data handling and storage system. This is a report on Contract No. H0110845. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 17(2)-74. Develop, Assemble and Install a Permissible Surveillance and Communication System in the Bureau of Mines Mining and Safety Research Center Coal

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Mine at Bruceton, Pa. Volume 2. Circuits and Installation, by Mine Safety Appliances Company. May 31, 1973. 141 pp. 73 figs. This report (Contract No. H0110845) describes a computer-controlled communication and monitoring system for monitoring the environment in underground coal mines. Ten underground stations transmit alarm information and values of air velocity; methane, carbon monoxide, and hydrogen concentration; temperature and rate of changes of temperature; noise; and smoke. The central processor controls polling of underground stations and records data on magnetic tape. A lamp console displays the status of the system. A complete description of the sensors, electronics, power supplies, and communications channel is given in this report. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 18-74. Development of a Personal Dust Sampler, by C. Froger and P. Courbon. May 1973. 17 pp. 12 figs. This report (Contract No. H0122032) gives results of a laboratory study and development of a modified approach to personal respirable dust sampling. Three prototype units of each of two designs, cap lamp and self-powered versions, of a personal dust sampler were designed and constructed. The samplers are based upon the use of polyurethane foam filters rotating at high speed to provide the air-moving pump. The units were designed to be intrinsically safe for use at the mine face and will be tested underground to determine applicability for use in the operator sampling program. The units will also be evaluated for use in noncoal mines. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 19(1)-74. A Study of Underground Mine Heat Sources.
1. Survey of Underground Mine Heat Sources, by James L. Fenton, June 30, 1973. 131 pp. 21 figs. In this study (Contract No. G0122137), the sources of heat flow into a mine along with the various effects that this heat has on mine personnel were investigated. The object of this study was to compile all available published information pertaining to these underground heat sources and their effects into one report. This will provide the mining industry with an available, easy-to-use reference to aid in the determination of mine ventilation requirements as the mines are in the phases of original planning or being extended to depth. Areas of significant deficiencies in knowledge were disclosed during this overall appraisal. Recommendations on important basic research needs were outlined for future consideration by Federal or industrial sponsorship. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 19(2)-74. A Study of Underground Mine Heat Sources.
2. Evaluating Underground Heat Sources in Deep Mines, by Walter I. Enderlin. June 30, 1973. 134 pp. 18 figs. This thesis (report of Contract No. G0122137) sets forth a practical method for evaluating underground sources of heat in deep mines and provides an improved

information base. Seven topics for further research are recommended. The heat sources considered are wall-rock, ground water, adiabatic compression, equipment, service lines, blasting, metabolism, curing of cement, and oxidation of sulfides and timber. Seven deep metal mines with high production rates and high heat loads were visited to obtain data necessary to assess their thermal environments. Mines records were examined, wall-rock temperatures were measured, and a survey of the mine ventilating and mine drainage was performed. Also, the thermal conductivity of wet and dry specimens of the host rock was measured in the laboratory. Data analysis disclosed that rock heat and adiabatic compression account for about 60 percent of the mine heat load at depth. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 19(3)-74. A Study of Underground Mine Heat Sources.
3. Underground Mine Air-Cooling Practices, by Floyd C. Bossard and Koehler S. Stout. June 30, 1973. 73 pp. 16 figs. This report (Contract No. G0122137) summarizes current practices of cooling and dehumidifying mine air. The principal objectives of underground mine air cooling systems are as follows: (1) Extract heat and water vapor from mine air and provide for their removal from the mine via water pumped to the surface or discharged mine exhaust air; (2) provide acceptable artificial ambient conditions for efficient working mine development and production areas; and (3) recondition the used air, thus supplementing the limited mine ventilation balance. Current mine air cooling and dehumidifying practices are described. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 20-74. The Role of Mineral Industries in Six Southeastern States, by John E. Husted. November 1973. 125 pp. Alabama, Florida, Georgia, North Carolina, South Carolina, and Tennessee were surveyed concerning economic factors pertaining to mined products and mineral-related industries for the years 1967, 1971, and 1972, using the Standard Industrial Classification system (SIC) of the United States Bureau of the Budget for 1967. In general, mineral-related industries were considered to be those which utilized mineral products for manufacture or production of their commodity. The information sought included product values and amounts, either mined or produced from mined materials; ingredients used for production; of of state purchase and/or shipments of mineral materials; and employment for the SIC numbers in the survey which ranged from 1011 to 3399. Data tabulations were made by SIC numbers for each State. In turn, these data were used to assist with obtaining estimates of total product amounts and total product values. Total dollar values of mineral-related goods were compared with total values of goods for each State. Georgia ranked highest. This report is Bureau of Mines Contract No. S80122112. Available for reference at Bureau of Mines libraries at Field Operation Centers in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Juneau, Alaska; at

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Bureau of Mines State Liaison Offices in University, Ala., Tallahassee, Fla., Atlanta, Ga., Raleigh, N.C., Columbia, S.C., Nashville, Tenn.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 21-74. Exploratory Studies of Flame and Explosion Quenching: First Annual Technical Progress Report, June 30, 1972—June 30, 1973, by Thomas A. Milne, Jacob Beachey, and Frank T. Greene. Dec. 7, 1973. 61 pp. 34 figs. These studies (Contract No. H0122127) were aimed at the development of improved agents to suppress coal dust-air explosions. The approach employed was to sample both gaseous species and particles from uninhibited and inhibited flames, to obtain basic information about the mechanism of coal dust burning itself and the mode of action of dry-powder fire extinguishing agents. Attempts to stabilize flat, laminar, premixed coal dust-air flames, without any augmentation, are described, culminating in the successful stabilization of flat flames on both 6.3-cm- and 12.6-cm-diameter Meeker-type burners. The combination of a fluidized-bed coal dust feeder, a turbulent mixing region for the coal dust-air at the bottom of a short burner, a corrugated matrix burner, and vibration of the burner matrix, has produced a flame with sufficient stability to warrant direct interfacing with a molecular beam, mass spectrometer sampling system. Dry powder extinguishing agent behavior is being studied by directly sampling particles from various regions of a premixed, CH_4 -air conical flame. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 22-74. Development of Techniques and the Measurement of Relative Permeability and Capillary Pressure Relationships in Coal, by J. J. Taber, P. F. Fulton, M. K. Dabbous, and A. A. Reznik. Jan. 24, 1974. 80 pp. 30 figs. In this study (Contract No. G0122006), gas and water permeabilities of a large number of samples from the Pittsburgh and Pocahontas coals were measured at various overburden and mean flow pressures. A wide variation in the air and water permeabilities was obtained for each type of coal. Overburden pressure has the most significant effect on the single-phase permeability. Considerable hysteretic effect was observed for both air and water permeabilities. Gas permeabilities are affected to a lesser degree by mean flow pressures above atmospheric. However, at subatmospheric mean pressures, appreciable increase in permeability occurs for low permeability samples. Air and water relative permeabilities were also measured for numerous samples of Pittsburgh and Pocahontas coals. Tests were performed under steady-state conditions for both drainage and imbibition cycles. Results indicate that the flow of gas is greatly reduced during the latter process, whereas it is largely undiminished over a wide water-saturation range during draining. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Morgantown, W. Va., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 23-74. Emission Controls and Fuel Economy of Seven 1973 Vehicles, by B. H. Eccleston. February 1974. 12 pp. This report is a summary of emissions and

fuel economy attainable by simple disconnection of the exhaust gas recirculation system and other very minor ignition system modifications on seven 1973 automobiles. The vehicles are considered standard to heavy cars. The average fuel economy change on modification was an increase in miles per gallon of 9 percent with a range of 4 to 14 percent. The CO emissions decreased about 2 percent, the hydrocarbon emissions were up 30 percent, and the NO_x emissions up 96 percent. An Environmental Protection Agency study released in January 1974 gave similar results for 10 cars covering a much wider range of vehicle sizes. Available for reference at Bureau of Mines libraries in Bartlesville, Okla., Laramie, Wyo., Morgantown, W. Va., Pittsburgh, Pa., San Francisco, Calif., and Grand Forks, N. Dak., at the Intermountain Field Operation Center in Denver, Colo., at the Mineral Supply Field Office in Dallas, Tex., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 24-74. Ventilation Studies and Escape Plans for Underground Hardrock Mines, by C. J. Hall, Terry Morris, and Jan Patricio. October 1973. 234 pp. 51 figs. This report (Contract No. S0230037) was prepared by the University of Idaho for the Bureau of Mines to provide a survey and analysis of noncoal mine ventilation and emergency escape plans with recommendations for improving existing systems. The ventilation systems and emergency escape plans for 16 underground noncoal mines were determined, evaluated, and analyzed. Possible hazards related to the ventilation system were identified for each mine and means to overcome them were recommended. The report includes a summary, which briefly describes the ventilation system for each mine and discusses problems that are common to a number of them. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 25(1)-74. Improved Sensors and Fire Control Systems for Mining Equipment, by FMC Corporation, Advanced Products Division. December 1973. 252 pp. 83 figs. This report (Contract No. H0122053) concludes that trucks of capacity in excess of 50 tons represent the greatest potential for fire and that efforts to provide fire protection system against B class (flaming liquid) and C class (electrical) fires in trucks will have maximum impact in operator safety and equipment protection. It is of utmost importance to detect and extinguish B and C class fires in equipment before they can evolve into major conflagrations involving the entire unit of equipment and endangering the operator. Because of his remote position of 10 feet or more above the ground, the operator must be made aware of a fire as rapidly as possible so that he may take whatever action is required to either extinguish the fire or remove himself from the danger area. A fast-responding, reliable fire-sensing and extinguishing system must be provided. The system would be semiautomatic and provide for the immediate detection of a fire and instant warning to the driver that a fire exists, allowing him to take corrective action. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

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OFR 25(2)-74. Improved Sensors and Fire Control Systems for Mining Equipment, by FMC Corporation, Advanced Products Division. May 1973. 178 pp. 51 figs. Effective fire protection can be obtained with current technology for mining equipment at moderate cost under a system developed under Contract No. H0122053. This report presents the study conducted by the FMC Corp., highlighting those features found to be effective in warning truck operators in mines of the danger of a conflagration in their piece of equipment. The equipment was tested on site in a mine and results of the investigation are given. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Spokane, Wash., and Denver, Colo., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 26-74. Pilot Study of the Feasibility of Subsurface Injection of Industrial Liquid Wastes in West Virginia, by Robert Hidalgo, Mary Behling, and Richard Drabish. March 1974. 106 pp. 49 figs. Subsurface injection of industrial liquid wastes is a widely expanding waste-management practice. Increased environmental awareness and the resulting more stringent legislation regarding discharge of wastes into surface waters have served to spur the expansion of this practice. Also the economics of subsurface waste injection are often more favorable, at least in a short-term sense, than advanced secondary or tertiary surface-treatment facilities. Therefore, it seems likely that industrial interest in subsurface injection of liquid wastes will remain high, and that Government should eliminate as much of the uncertainty involved in the practice as it can. Much of the present uncertainty arises from less than complete knowledge and understanding of the total subsurface geology and hydrology in most areas and the lack of a method to quickly assess total data base in a given area within the time-frame required for decision-making in specific cases. This study (Contract No. G0122075) was undertaken as a first step in solving the problems. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Morgantown, W. Va., Bartlesville, Okla., Laramie, Wyo., Grand Forks, N. Dak., San Francisco, Calif., and Denver, Colo.; at the Dallas, Tex., Field Office; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 27-74. Mathematical Model for Predicting Migration Patterns of Aqueous Waste Solutions, by Gordon W. Thomas. August 1973. 63 pp. 1 fig. Industrial waste products, in aqueous solutions, are frequently injected into disposal wells. Where injection occurs over long periods of time, it is important to predict the migration patterns of the waste solutions, the reservoir pressures created, and the extent to which adsorption strips the waste solution of toxic materials. This report (Contract No. H0122118) treats the development and application of a mathematical model of the aqueous waste injection problem. The model is a generalized reservoir simulator. It can handle reservoirs of arbitrary heterogeneity and geometry penetrated by an arbitrary number of wells on any desired areal pattern. Options are provided to perform calculations using either two-dimensional cartesian or cylindrical coordinates. Available for reference at the Bureau of Mines libraries in Bartlesville, Okla., Laramie, Wyo., Morgantown, W. Va., and Pittsburgh, Pa., at the Intermountain Field Operation Center, Denver, Colo., and

the Dallas Mineral Supply Field Office, Dallas, Tex., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 28-74. Electromagnetic Location Experiments in a Deep Hardrock Mine, by A. J. Farstad. September 1973. 54 pp. 33 figs. The report (Contract No. H0242006) gives the results of experiments in a north-west Idaho mine evaluating the performance of an electromagnetic system for detecting and locating trapped miners. The results show that lightweight portable transmitters can be effectively used to provide uplink communications and location information in deep hardrock mines. Tests were performed in the Galena mine using long wire transmitting antennas as well as horizontal and vertical transmitting loops at depths from 3,000 feet to 4,300 feet. Surface measurements were made of magnetic field strengths, field strength patterns, and background noise. These measurements were compared with theoretical predictions for a homogeneous ground conductivity consistent with the geologic region. Results also show that horizontal wire configuration can serve as an effective alternative to the magnetic dipole antenna in rescue work. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 29(1)-74. Effects of Alteration and Joint Fillings on the Mechanical Behavior of Rocks. 1. Annual Report, by Howard J. Pincus and Robert A. Wipf. May 31, 1973. 206 pp. 77 figs. The purpose of this study (Contract No. G0122066) was to investigate the effects of fracture filling and associated alteration on the mechanical behavior of rocks. Results are presented for specimens from the Climax and Henderson mines in Colorado and from the San Manuel mine in Arizona. The description of the rocks includes color, texture, mineral composition, composition and fabric of fracture fillings, density, and porosity. Unconfined and triaxial compression tests were run on the Climax and San Manuel specimens. Sonic velocities were measured during the compression tests. Tentative conclusions were that some relation appears to exist between compressive strength and the following features for all specimens: Dynamic Young's modulus, sonic velocity, density, rock composition, and veinlets. Available for consultation at Bureau of Mines libraries in Pittsburgh, Pa., Morgantown, W. Va., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 29(2)-74. Effects of Alteration and Joint Fillings on the Mechanical Behavior of Rocks. 2. Final Report, by Howard J. Pincus and Robert A. Wipf. Jan. 31, 1974. 89 pp. 35 figs. In this final report (Contract No. G0122066) experimental results are presented for specimens from the Climax and Henderson mines in Colorado and from the San Manuel mine in Arizona. Conclusions are that some relation appears to exist between compressive strength and the following properties and features for all specimens: Dynamic Young's modulus, sonic velocity, density, rock composition, slope of velocity curve, composition and fabric of fracture fillings, veinlets, and apparent porosity. There appears to

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be some relation between compressive strength and Shore scleroscope hardness for the quartz monzonite (San Manuel). A relation appears to exist between texture and compressive strength and the extent of failure on fracture fillings for schists, gneiss, and fine-grained granite (Climax). The amount of swelling clays (montmorillonite, hydromicas, etc.) present in the rock and the relative number of fractures, in which they constitute a major portion of the fracture fillings, are related to the strength of the rocks. Possible tests for checking the amount of these clays present are presented including saturation dyes and X-rays. A useful index relating to rock strength, as revealed in this study, is the presence of swelling clays in detectable abundances. These clays can be detected in the field with a simple wetting and striking test; in the laboratory they can be detected by X-ray and dye methods. Available for consultation at Bureau of Mines libraries in Pittsburgh, Pa., Morgantown, W. Va., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 30-74. Seismic Miner Detection and Location System. Phase 1, Final Report, by J. C. Fowler. September 1973. 110 pp. 109 figs. The design and field testing of a seismic miner detection and location system (Contract No. H0133112-1) are described. This work was carried out over a period of 3 years. The first 2½ years were sponsored by Continental Oil Co., although the last period of tests was done as the first part of a 1-year contract with the Bureau of Mines. Laboratory and field experimentation in three different mines under simulated emergency conditions have led to three important results: (1) Taps on roof bolts with normally available objects can usually be detected up to horizontal distances of 1,000 ft, (2) the origin of the taps can be located by on-site processing with a small computer, and (3) some predetermination of the approximate location is necessary for a quick and successful rescue. This report also includes preliminary specifications and cost guidelines for construction of a transportable field system capable of matching the performance characteristics of the one used during the field tests. Available for consultation at Bureau of Mines libraries in Pittsburgh, Pa., Morgantown, W. Va., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 31-74. Cause and Prevention of Failure of Freshly Exposed Shale and Shale Materials in Mine Openings, by G. E. Bobeck and D. F. Clifton. June 1973. 116 pp. 30 figs. This research (Contract No. G0111809) was performed to determine the mechanism by which coal mine roof rocks interact with the mine atmosphere and weaken and, coupled with the mechanical stresses, ultimately fail. The scope of the study was limited to the effects of environmental factors on the deterioration of rocks. Samples were obtained from several coal mines in the Western States. The rocks forming the roofs of most of the mines visited were shales of varying composition. These shales were subjected to tests to determine how the rocks changed with time after exposure. In addition, the identity of the minerals present in the shales was determined by X-ray diffraction and thermal analyses as well as by optical microscopy. The results of

the survey show that there is little known on the exact causes of coal mine roof rock failure. For this reason, only those references that pertain directly to a specific topic are cited in the text; the remainder are in the bibliography. Available for consultation at Bureau of Mines libraries in Pittsburgh, Pa., Morgantown, W. Va., Twin Cities, Minn., Denver, Colo., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 32-74. Disposal and Uses of Oil Shale Ash, by Thomas D. Nevens, William J. Culbertson, Jr., and Robert Hollingshead. April 1970. 90 pp. 45 figs. This study was initiated to determine some of the properties of waste shale ash. General studies dealing with a variety of Piceance Creek shales retorted and burned for various times and temperatures were made. One objective of this approach was to define as nearly as possible the best conditions for processing shale ash before it is dumped in order to obtain a well-stabilized dump least subject to wind and water erosion and landslides. In the studies two approaches were followed: (1) physical strength studies of shale ash as a function of a number of variables and (2) chemical studies as a function of these variables in order to define the cementing components in the hydration products of shale ash. The variables studied included (a) composition of shale ash, (b) burning temperature, (c) burning time, (d) moisture content, (e) degree of compaction, (f) storage time, and (g) storage temperature. Available for consultation at Bureau of Mines libraries in Denver, Colo., and Salt Lake City, Utah, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 33-74. System Modification and Validation Testing of Fire Protection Systems for Mine Haulage Trucks. Final Report, by FMC Corporation. April 1974. 170 pp. 28 figs. The validation testing of the automatic fire protection system, developed under Contract No. HO122053, and of the system as modified under Contract No. HO232059 proved that effective fire protection can be obtained within current technology at an installed cost (per system) of about \$3,000 to \$5,000. Available for reference at Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., Morgantown, W. Va., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 34-74. A Guide to the Selection of Automatic Fire Protection Systems for Mine Haulage Equipment, by FMC Corporation. April 1974. 8 pp. 2 figs. This manual, compiled from information developed under Contracts Nos. HO122053 and HO232059, familiarizes mining equipment owners and mine safety personnel with fire hazards and their prevention on large mobile machinery. As mine haulage vehicles become larger, the danger to a driver during a fire emergency is increased by the greater height of the cab above ground. This manual presents selection criteria to guide in tailoring an automatic fire sensing and suppression system for large, mobile, open pit mining equipment and mining situations. The systems described have been designed with this "flexibility of use" in mind. Cost and maintenance factors were taken into account during the design phases of the automatic truck fire protection work. It is estimated that the in-

stalled cost of the systems described in this manual will be from \$3,000 to \$5,000 for production run systems. Maintenance requirements are minimal. Available for reference at Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., Morgantown, W. Va., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 35-74. Natural Gas Fields—Cook Inlet Basin, Alaska, by Donald P. Blasko. April 1974. 24 pp. 2 figs. Oil and gas production, and production potential, in the Cook Inlet Basin area of Alaska extends essentially from Kachemak Bay north to the mouth of the Susitna River. Sixteen dry natural gas fields have been discovered in that area, but only five fields are being actively produced. Total combined remaining reserves of all natural gas fields in the Cook Inlet Basin are estimated to be nearly 6.7 trillion cubic feet of gas. Included in this figure are the reserves of those fields that have not been developed for production, which total nearly 2 trillion cubic feet of gas. Dry natural gases in the Cook Inlet area consistently exhibit low sulfur content and high Btu characteristics, making the gas ideal as a fuel for power generation as well as domestic heating and cooking. All production is from Tertiary formations. Available for reference at the Alaska Field Operation Center offices in Juneau and Anchorage, Alaska, and in the office of the Assistant Director—Mineral Supply, and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 36-74. Analysis of Large-Scale Non-Coal Underground Mining Methods, by Dravo Corporation. January 1974. 605 pp. 120 figs. The results of this study, conducted under Contract No. SO122059, provide a comprehensive up-to-date summary of the large-scale non-coal mining industry. The report identifies problem areas requiring research, identifies potential innovations to improve technology, and provides a basis for anticipating future needs of the industry. It contains statistics on underground mining methods and includes information on the equipment and systems used and on costs and productivity. The report represents the views of nearly one-half of the large underground mine operators in the United States regarding the technology and research needs of their industry. Particular emphasis is placed on current practices and problems, needed technological improvements, existing or potential environmental conflicts, and possible modifications that will assist in meeting projected national mineral needs. The report describes current practices for various mining methods, including block caving, room and pillar mining, in situ mining, and variations of these methods. Available for reference at Bureau of Mines libraries at Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 37-74. The Development of Health and Safety Indices for the Evaluation of Underground Coal Mining Systems, by E. P. Pfeider and A. D. Krug. November 1973. 200 pp. 11 figs. The primary objectives of this study (Contract No. HO122028) were to (1) determine the relationships in underground coal mining systems that affect the health and safety of mine personnel,

(2) develop these relationships into quantitative health and safety indices, (3) develop a computer-based model for projecting and evaluating health and safety profiles for specific mining systems, and (4) establish the groundwork for a further study that would incorporate these data into an overall underground systems optimization procedure. A 3-year data bank was established containing employment, injury, geology, and mine characteristics information on 203 mines in Illinois, Kentucky, Pennsylvania, and West Virginia. Three types of indices were developed for use in evaluating health and safety aspects of underground coal mining systems. Available for reference at Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 38(1)-74. Survey of Electromagnetic and Seismic Noise Related to Mine Rescue Communications.

Volume I. Emergency and Operational Mine Communications, by Robert L. Lagace, Alfred G. Emslie, Martyn F. Roetter, Richard H. Spencer, and Consultants. Arthur D. Little, Inc. January 1974. 512 pp. 143 figs. Volume I of this report (Contract No. HO122026) deals with theoretical, experimental, and practical implementation aspects of the Federal Bureau of Mines programs related to present and planned, emergency and operational, mine communications and miner location systems for underground coal mines. Investigations, evaluations, experiments, and analyses for these programs were made; breadboard and prototype hardware was developed; and assistance was given in the formulation and presentation of technology transfer seminars on mine communications. The report provides preliminary performance predictions related to through-the-earth electromagnetic communications systems and results of investigations related to wire, guided-wireless, and wireless communications systems for communicating with roving vehicles and personnel underground. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 38(2)-74. Survey of Electromagnetic and Seismic Noise Related to Mine Rescue Communications.

Volume II. Seismic Detection and Location of Isolated Miners, by Robert L. Lagace, John J. Ginty, Martyn F. Roetter, Richard H. Spencer, and Consultants. Arthur D. Little, Inc. January 1974. 364 pp. 89 figs. Volume II of this report (Contract No. HO122026) presents the findings of a short intensive assessment performed during the fall of 1972. This assessment provided the Federal Bureau of Mines with independent technical judgments regarding the potentials and limitations of seismic methods and systems for (1) detecting the presence of isolated signaling coal miners, (2) locating such miners to within the confines of a 600- by 600-foot mine section, and (3) further locating these miners to within a 15-foot entry width. Experimental seismic data previously gathered by others during a series of mine field tests, and other relevant seismic data were fully utilized for the assessment reported in this volume. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgan-

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town, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 39-74. Development of a Mobile Shield for Underground Mining, by Urbdata Associates, Inc., Mine Research Division. Apr. 27, 1973. 146 pp. 35 figs. This report (Contract No. H0110688) describes the development of a prototype mobile shield to protect mine personnel from roof falls in the area within 25 feet of the working face. A discussion of the support requirements and mine environment parameters that dictate the physical dimensions and performance specifications of the shield is presented. Results obtained from limited testing of the prototype are presented, with emphasis on those features that worked satisfactorily and on suggested modifications for those portions of the model that performed below expectations. The report is of use to other investigators engaged in studying the present state-of-the-art of mobile shields. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 40-74. Helix Pressure Gauge To Indicate Roof Bolt Loads, by Virginia Polytechnic Institute and State University. Sept. 24, 1973. 58 pp. 25 figs. This report (Contract No. H0111556) presents the results of a study to design, construct, and test a low-cost pressure gage to be used to monitor the change in load on individual roof bolts. The purpose of the gage is to offer a convenient means of estimating the stability of roof fall areas based on the premise that the load on individual roof bolts changes prior to failure. The gage indicated loads between 3,000 and 15,000 pounds with a ± 10 percent error. The unit can be read on a bolt to within $\pm 1,000$ pounds load from a distance of 20 feet. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 41(1)-74. Trapped Miner Location and Communication System Development Program. Volume I. Development and Testing of an Electromagnetic Location System, by A. J. Farstad, C. Fisher, Jr., R. F. Linfield, R. O. Maes, and B. Lindeman. May 1973. 181 pp. 85 figs. This report (Contract No. H0220073) describes work done on electromagnetic direction finding systems between July of 1972 and April of 1973. Two design approaches were included in this effort: (1) A prototype pulse system was fabricated and subjected to limited testing, and (2) a continuous wave system was fabricated and tested at three operating mine sites. In late 1972, the pulse system effort was discontinued in favor of the continuous wave system approach. After modifications, the continuous wave system was subjected to limited testing, which was completed in May of 1973. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 41(2)-74. Trapped Miner Location and Communication System Development Program. Volume II. Detection and Location of Entrapped Miners by Seismic Means: Methods and Computer Programs, by Dr. S. J. Duda. May 1973. 64 pp. 28 figs. This report (Contract No. H0220073) presents the adaptation of procedures for detecting and locating seismic sources to the case of entrapped miners. During an emergency, the entrapped miner is likely to generate seismic signals by knocking against the walls of the shaft. With a seismic array station deployed near the disaster area, the seismic signals can be recorded. Two algorithms are presented for the location of the source from the arrival time of a seismic phase. The first algorithm produces one most probable location under the assumption of constant velocity of propagation of seismic waves in the medium. The second algorithm is similarly applicable, however, without any restriction on the seismic velocities in the medium between the source and the array. The first algorithm uses an analytic approach; the second one is based on a trial and error procedure. The second algorithm gives locations with arbitrarily high accuracies, depending only on the accuracy of arrival time measurements and on the compatibility of the true velocity distribution and the assumed velocity model. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 41(3)-74. Trapped Miner Location and Communication System Development Program. Volume III. Monitoring, Locating and Communication System for Normal Mine Operation and Post-Disaster Rescue Operations, by J. W. Allen and R. F. Linfield. May 1973. 89 pp. 23 figs. This report (Contract No. H0220073) describes the result of efforts to develop and test a prototype model of a quasi-hardened subsurface communication system. Conceptually, the system provides a one-way digital information link interface between multiple subsurface terminals and a single surface station. Two-way voice communication is also provided. The system is capable of both a direct through-the-earth mode of operation or alternate linking through existing mine telephone hardware circuits. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 41(4)-74. Trapped Miner Location and Communication System Development Program. Volume IV. Performance Test and Evaluation of a Full Wave Location Transmitter, by R. F. Linfield, A. J. Farstar, and C. Fisher, Jr. May 1973. 52 pp. 19 figs. This report (Contract No. H0220073) describes the development, laboratory testing, and intrinsic safety testing of a full-wave location transmitter. The primary objective was to obtain as rapidly as possible an electromagnetic transmitter and receiver system for use in locating trapped miners. Since the transmitter would be used in coal mines, intrinsic safety was an important consideration. Other factors considered in the design included size, weight, cost, operating life, and ease of deployment. A miner's lamp battery was

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to be used as the source of prime power. Two basic location systems, a continuous wave system and a pulse-type system, were designed, fabricated, and field tested. Subsequently, a new design concept, using four switching transistors to obtain full-wave drive to a resonated loop antenna, was developed. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 42(1)-74. Protection and Troubleshooting of Coal Mine Electrical Cables. 1. Shuttle Car Reel Test Unit, by FMC Corporation. October 1972. 102 pp. 49 figs. Severe whipping of shuttle car trailing cables occurs when the car stops suddenly or reverses direction. This causes cable damage and can seriously injure personnel near the cable. This report (Contract H0122011) describes work to develop a reel control system that will reduce or eliminate whipping. Results of engineering effort show that the following conditions are primarily responsible for the whipping problem: Poor quality hydraulic components, improper adjustment of the hydraulic system, and hydraulic circuit design inappropriate to the components selected. The reel test unit developed demonstrated two different types of hydraulic systems that do not cause whip. Either of the two systems will provide shuttle car reel operation (1) that is essentially whipfree and (2) with maximum cable forces much lower than those common with existing systems. Available for reference at the Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 42(2)-74. Protection and Troubleshooting of Coal Mine Electrical Cables. 2. Continuous Miner Cable Reel System Design, by FMC Corporation. December 1972. 99 pp. 34 figs. Electrical cables are frequently damaged while in use, especially on continuous miners, and because of their weight and damaged condition present a safety hazard to personnel required to handle them. This report (Contract No. H0122011) presents the results of a feasibility study on techniques to improve trailing cable support and handling of power cables, describes the design for a proposed cable handling device, and concludes with a recommendation for future action to construct a test rig to evaluate the cable reel system. Available for reference at the Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 42(3)-74. Protection and Troubleshooting of Coal Mine Electrical Cables. 3. Summary Report. Cable Fault Locator Instrument for Period August 1971 to November 1972, by FMC Corporation. Feb. 20, 1973. 133 pp. 34 figs. This report (Contract No. H0122011) covers the development of cable fault locator instruments that can be used to find faults in electrical cables in the face area of coal mines. Electrical trailing cable used to power coal mining machinery is frequently damaged while in use by the tensile strain or crushing effect of mining machines running over the cable. One of the repair

problems is finding the exact location of a short or open in the cable so that it may be spliced or repaired. This report describes the performance of several existing instruments as trailing cable fault locators and also describes construction details and performance records of several cable fault location instruments designed, built, and tested as part of this project. Available for reference at the Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 42(4)-74. Protection and Troubleshooting of Coal Mine Electrical Cables. 4. Final Report, by FMC Corporation. September 1973. 113 pp. 24 figs. This report (Contract No. H0122011) summarizes the work completed during the period August 1971 to September 1973. The objectives were to study the feasibility of improved cable handling methods and to design a cable handling device for a continuous miner, to design and construct a cable reel control system to significantly reduce cable whip, and to design and construct prototype cable fault locators. The continuous miner cable handling device developed is a separate, independently powered tender. Cable whip was eliminated or reduced by studying a relatively large payout torque. Fault locating devices were developed. The demonstrated performance of the fault locating devices led to a 1-year extension of the contract for fabrication of 12 sample kits for extensive testing in mines. Available for reference at the Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 43-74. Coal Mining Using High Pressure Water Jets, by Madan M. Singh, Thomas J. Labus, and Lawrence A. Finlayson. October 1973. 88 pp. 36 figs. The objective of this research (Contract No. H0111789) was to determine the engineering feasibility of high-pressure water-jet coal mining and the degree of dust and noise health hazard associated with this mining technique. A portable water-jet device suitable for field use was designed, fabricated, and tested. The results indicated that with a hydraulic jet operating at 50,000 and 100,000 psi, the amount of dust produced per ton of coal is less than with conventional miners. The noise levels produced are comparable with the noise levels of conventional miners and were not optimized. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., Morgantown, W. Va., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 44-74. Coal Cleaning Plant Noise and Its Control, by E. E. Ungar, G. E. Fax, W. N. Patterson, and H. L. Fox. May 1974. 99 pp. 18 figs. This report (Contract No. H0133027) presents criteria applicable to noise in coal cleaning plants and discusses generally applicable noise control principles and approaches. The operating characteristics and equipment of coal cleaning plants are described. Considerations entering in the selection and design of noise control means are delineated, and specific means for equipment noise reduction are

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described. The limited utility of acoustically absorptive materials in plant space is indicated, administrative means for reducing worker noise exposure are pointed out, and ear-protective devices are described briefly. The reduction of plant noise reaching nearby communities is discussed. Programs leading to quieter machines and coal cleaning plants are suggested. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., Spokane, Wash., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 45-74. Effect of Stress on Permeability of Coal, by W. H. Somerton, I. M. Söylemezoglu, and R. C. Dudley. April 1974. 56 pp. 23 figs. This report (Contract No. H0122027) discusses the effect of stress on the permeability of three bituminous coals to nitrogen and methane. Test stress conditions simulated stresses possible in underground environments to depths of 2,000 feet. The study found that the permeabilities of different samples of the same coal varied over a wide range, that permeabilities decreased by one or two orders of magnitude with increasing stress, and that the permeability of coal is very dependent on previous loading and unloading of the sample. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., Spokane, Wash., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 46-74. A Study of Roof Warning Signals and the Use of Personal Hearing Protection in Underground Coal Mines, by James H. Prout, Paul L. Michael, and Less W. Saperstein. Dec. 15, 1973. 238 pp. 76 figs. Roof warning signals were studied in 18 mines covering 5 coal seams. The results of this study (Contract No. G0133026) confirmed that roof talk must be interpreted for each individual mine after all other conditions are present that indicate danger of roof fall. Roof talk and machinery noise records obtained during this study were used for subjective tests of ear protectors in a simulated coal mine noise environment. Results of these tests showed that the use of personal ear protectors in high noise levels does not degrade a miner's ability to discriminate speech and roof talk. A training course was developed to encourage coal miners to protect their hearing by proper use of personal hearing protectors. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., Spokane, Wash., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 47-74. Study of Water-Mineral Interface With Internal Reflection Spectroscopy, by Salim Akhtar. Sept. 14, 1973. 31 pp. 13 figs. This report (Contract No. G0110303) gives the results of a study of the surface OH groups on oxide surfaces using internal reflection spectroscopy. MgO-H₂O interface was studied with internal reflection spectroscopy. Both ATR and transmission techniques were employed. The chemisorption of oleic acid, octylamine, and deriphat 151 on hematite was studied, and the amount of chemisorbed species on the surface was compared with the recovery in flotation of hematite using the chemisorbing species as collectors. From the internal reflection spectra, it was not possible to

determine whether the carboxyl groups of oleic acid are directly bonded to the surface metal ions or through the surface OH groups. A theoretical approach was developed whereby the chemisorption on different surface sites could be inferred from the measurements of the pH of zero electrophoretic mobility. Available for reference at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 48-74. Industrial Engineering Study of Hazards Associated With Surface Coal Mines. Final Report, by Theodore Barry and Associates. June 24, 1974. 270 pp. 169 figs. This report (Contract No. H0230004) identifies the type of mining accidents that occur in strip mines, auger mines, mechanical preparation plants, and at the surface of underground mines. The hazards present and the direct causes of the accidents were identified, and practical solutions were recommended to reduce their occurrence. Available for reference at the Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 49-74. Evaluation and Determination of Sensitivity and Electromagnetic Interactions of Commercial Blasting Caps, by R. H. Thompson. August 1973. 210 pp. 27 figs. In this study (Contract No. H0210068), six different types of blasting caps, mainly of the type used in coal mines, were evaluated to determine both their radio frequency and direct current characteristics. Two of the caps were of foreign manufacture. All of the American made caps had "no-fire" (0.1 pct firing probability with 95 pct confidence, as determined by the Bruceton test) levels above 0.04 watts. One of the caps of foreign manufacture had a "no-fire" level of 0.023 watts. A worst case analysis of blasting cap pickup of radio frequency power in coal mines was performed, and safe distance curves were generated. Available for reference at the Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 50-74. Air Curtain Respiratory Protection Device. Final Report, by T. G. Donnelly and W. J. Krisko. Sept. 28, 1973. 116 pp. 21 figs. This final report summarizes the prototype development and testing of an air curtain respiratory protective device under Contract No. H0122087. The air curtain respiratory protective device, as part of a miner's hat, provides protection for the underground mining machine operator against inhalation of dangerous amounts of respirable coal dust. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., Morgantown, W. Va., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 51-74. Penetration Characteristics of the 10 mm Nylon Cyclone, by Erick B. Sansone, William Bell, and Judith Buchino. Oct. 31, 1973. 92 pp. 33 figs. The objective of this work (Contract No. G0110124) was to determine the flow rate at which the 10-mm nylon cyclone samples coal dust in accordance with the Atomic Energy Commission (AEC) definition of respirable dust. Penetration of coal dust through the nylon cyclone was

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measured at flow rates of 1.8 and 2.0 liters per minute over a wide range of humidities. The penetration data was found to more closely match the AEC standard at a cyclone flow rate of 2.0 liters per minute rather than 1.8 liters per minute. Relative humidity was not found to have a significant effect on the results. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., Spokane, Wash., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 52-74. Fire Suppression of Mining Equipment, by R. H. Hiltz and F. Roehlich. Dec. 15, 1973. 161 pp. 14 figs. This program (Contract No. H0111386) studies the adequacy of existing regulations as they relate to the hazards of fires on mining machinery. The report includes conclusions and recommendations relative to specific sections of the Coal Mine Health and Safety Act of 1969. Also included in the report are a review of prior fire experience since 1952, a survey of machine and in-mine influences, a review of fire detection and suppression systems, the results of extinguishment testing of typical fires in mine machinery, and a special study of the flammabilities of electric cable. Available for reference at the Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., and Twin Cities, Minn., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 53-74. Water Through the Drum, 120 M Jeffrey HELMINER, by Steven C. Goddard and John C. O'Neil. Aug. 19, 1974. 126 pp. 21 figs. This research (Contract No. H0232060) compared the dust suppression of a 120 M Jeffrey continuous mining machine using (1) water through the drum (wet head) or (2) conventional sprays. This objective was accomplished by collecting respirable dust samples at various locations of an operating mine production section. Twenty-eight valid samples were collected; eight used the conventional spray system and twenty used the wet-head technique. Statistical analysis of the data indicates that the wet-head technique reduces dust by about 10 percent over the conventional water sprays on the continuous miner. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., Spokane, Wash., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 54-74. Effectiveness of Respirable Dust Control by Water Through the Drum on an 11 CM Joy Continuous Miner, by Gerald P. Scanlan, Felix du Breuil, and Robert D. Saltsman. May 1974. 115 pp. 13 figs. Control of the dust produced by continuous mining machines in coal mines is generally obtained by water sprays from fixed nozzles mounted on the frame of the machine in back of the cutting head. Mounting the nozzles on the rotating head of the machine closer to the coal cutting bits may improve the efficiency of dust suppression. In this study (Contract No. 0232061) to test the concept, respirable dust measurements were made during 39 regular production shifts in an underground mine using a Joy 11 CM continuous miner. The equipment used, difficulties encountered, and measurements obtained are described. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., Spokane, Wash., and Morgantown, W. Va., and at

the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 55-74. Rock Breakage Performance Characteristics of (1) Small Diameter Confined Explosive Column Charges, and (2) Water Jets, by Richard L. Ash and David A. Summers. Feb. 28, 1973. 101 pp. 38 figs. This report (Grant No. G0122117) was written in two sections and describes the results of experimental work (1) using ammonium nitrate-fuel oil (AN-FO) in explosive charge columns with diameters of 2 inches or less and (2) on rock breakage by water jets on oriented cores of Barre granite. The explosives research shows that AN-FO can be successfully detonated in holes as small as 1/2 inch in diameter. The water jet research indicates that three to four times more rock can be removed by using the most preferred orientation of the traversing jet in relation to microfissures in Barre granite compared with the volume of rock removed using the least preferred rock orientation. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 56-74. System Study of Coal Mine Communications, by Collins Radio Company. July 27, 1973. 30 pp. 3 figs. This research (Contract No. S0122076) involved a three-phase program to establish a data base, perform communication system analysis and optimization, and prepare equipment specifications to be included in this report. Communication system requirements and constraints were determined along with a survey of current and potential mine communication equipment. An investigation was completed concerning theoretical low frequency and very low frequency propagation characteristics, and ultra-high frequency propagation tests were conducted in a working coal mine. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 57-74. Characteristics of Attached Radon-222 Daughters Under Both Laboratory and Field Conditions With Particular Emphasis Upon Underground Uranium Mine Environments, by J. A. Cooper, P. O. Jackson, J. C. Langford, M. R. Peterson, and B. O. Stuart. May 14, 1974. 288 pp. 102 figs. The objective of this research (Contract No. H0220029) was to study the characteristics of radon daughter products attached to aerosols under laboratory and underground mine conditions. This objective was achieved through identification of typical aerosols and their chemical composition. The presence or absence of carcinogens other than alpha emitters was determined. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., Morgantown, W. Va., and Spokane, Wash., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 58-74. Development of a Portable Task Luminaire for Underground Coal Mines, by Ocean Energy Inc. Aug. 21, 1974. 236 pp. 43 figs. This report (Contract No. H0220055) covers (1) the development of a lightweight, battery-powered portable luminaire for use by miners and other underground personnel for close tasks in the mine and (2) the development of fluorescent

machine-mounted and portable area systems supplied by mine power. The report describes the design, development, and performance testing of the hardware required under the contract. Electrical and mechanical design drawings are included for all hardware and components. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Twin Cities, Minn., Spokane, Wash., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 59-74. Surface Mined Land in the Midwest: A Regional Perspective for Reclamation Planning, by Ralph P. Carter, James R. LaFevers, Edward J. Croke, Allen S. Kennedy, and Stanley D. Zellmer. June 1974. 680 pp. 96 figs. This report (Contract No. S01233127) is a review and field observation study of coal surface mining and reclamation problems, policies, and practices in the Midwest coal producing region. A wide variety of subjects is covered including problems associated with surface mining reclamation technology and costs, environmental assessments of surface mined land, reclamation planning and policy, and a review of State reclamation laws and enforcement procedures. Available for reference at the Bureau of Mines libraries in Denver, Colo., Pittsburgh, Pa., Spokane, Wash., Twin Cities, Minn., Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 60-74. Evaluation of Thermal Methods for Recovery of Viscous Oils in Missouri and Kansas, by M. D. Arnold and A. Herbert Harvey. June 1974. 110 pp. 10 figs. This report (Grant No. G0133100) presents an economic analysis of four hypothetical heavy oil deposits that were considered to be representative of those found in the Missouri-Kansas border area. Oil production obtainable by various thermal recovery methods was computed for each of the four cases. Development and production costs were estimated, and the oil prices that would yield specified discounted cash flow rates of return on investment were computed. It was concluded that the best deposits are probably economically recoverable at current new oil prices, provided there is no major adverse revision in tax regulations. Available for reference at the Bureau of Mines libraries in San Francisco, Calif., Bartlesville, Okla., Morgantown, W. Va., Laramie, Wyo., and Dallas, Tex., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 61-74. Research on the Transmission of Electromagnetic Signals Between Mine Workings and the Surface, by Richard G. Geyer, George V. Keller, and Takashi Ohya. Jan. 10, 1974. 124 pp. 48 figs. Field studies (Contract No. H0101691) of ambient electromagnetic noise and electrical transmission properties of coal mine overburdens in Colorado, Illinois, Pennsylvania, and West Virginia were conducted. Field tests of the transmission of low-frequency (20 Hz to 20,000 Hz) signals by vertical axis loops and horizontal wire antenna were made and compared with theoretical predictions. Implications of the field tests for the design of an electromagnetic system to locate trapped miners are discussed. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 62(1)-74. Analysis of Ore Handling Systems in Underground Metal Mines for Improved Safety and Efficiency. Phase I Report. Present Systems Study, by Theodore Barry and Associates. June 1974. 133 pp. 18 figs. This report (Contract No. H0230004) provides the results of an industrial engineering study that assessed the safety and efficiency of underground ore handling in U.S. metal mines. The specific objectives of the present systems study were to determine and evaluate the productivity of existing ore handling systems in a representative group of underground metal mines, to relate the available historical accident record statistics of these specific mines to the specific operations in the overall ore handling operations, and to highlight the potential areas of improvement for each mine on the basis of productivity and associated hazardous index for each operation. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 62(2)-74. Analysis of Ore Handling Systems in Underground Metal Mines for Improved Safety and Efficiency. Phase I Appendices. Present Systems Study, by Theodore Barry and Associates. June 1974. 145 pp. 46 figs. This report provides the results of an industrial engineering study that assessed the safety and efficiency of underground ore handling in U.S. metal mines. One of the primary findings of this study (Contract No. H0230004) was the improvement needed in controlling muck size in the ore handling stream. Oversize ore causes much additional labor, creates work stoppages, and is a principal cause of accidents in metal mines. The report includes data on block caving, back cut and fill, room and pillar, shrinkage stoping, and sublevel stoping methods. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 62(3)-74. Analysis of Ore Handling Systems in Underground Metal Mines for Improved Safety and Efficiency. Phase II and Final Report. System Improvements and Research Recommendations, by Theodore Barry and Associates. June 1974. 167 pp. 63 figs. This report (Contract No. H0230004) covers the results of an industrial engineering study that assessed the safety and efficiency of underground ore handling in U.S. metal mines. It appears from the study that the productivity of the slushing equipment itself cannot be substantially increased using the existing technology. The unsafe situations associated with slushers can be improved by better anchoring practices, by providing better work station layout that incorporates improved clearances and protected walkways over the ore pocket, by lighting the slusher drift, and by improved operator training. Improved technology needs to be applied to the movement of broken ore in the stopes. Slushers will continue to be used in the mining industry in certain special and unique situations outlined in the report. Available for reference at the Bureau of Mines libraries in Pittsburgh, Pa., Denver, Colo., Spokane, Wash., Twin Cities, Minn., and Morgantown, W. Va., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

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The following patents were granted to the Bureau of Mines during the period January 1, 1970, to December 31, 1974. These processes, which can be used by any U.S. citizen or organization without royalty payment upon authorization by the Department of the Interior, were developed by Bureau scientists. Application for the use of any of the patents should be made to the Office of the Solicitor, U.S. Department of the Interior, Washington, D.C. 20240.

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B 655		PB 198 124	IC 8448		PB 191 004
B 656		PB 231 971	IC 8452		PB 190 646
B 657		PB 205 406	IC 8453		PB 190 999
B 658		PB 206 624	IC 8454		PB 191 000
B 659		PB 212 504	IC 8456		PB 225 165
B 660		PB 212 555	IC 8460		PB 190 647
B 661		PB 221 754	IC 8462		PB 228 658
B 662		PB 218 142	IC 8463		PB 192 031
B 663		PB 220 470	IC 8464		PB 198 245
B 664		PB 221 756	IC 8465		PB 198 246
B 665		PB 237 709	IC 8466		PB 198 247
B 666		PB 233 210	IC 8468		PB 198 248

IC 8469	.....	PB 198 249	IC 8570	.....	PB 220 476
IC 8470	.....	PB 192 017	IC 8571	.....	PB 220 495
IC 8471	.....	PB 198 250	IC 8572	.....	PB 220 496
IC 8472	.....	PB 198 251	IC 8573	.....	PB 226 702
IC 8473	.....	PB 193 331	IC 8574	.....	PB 228 149
IC 8474	.....	PB 194 938	IC 8575	.....	PB 220 463
IC 8475	.....	PB 198 252	IC 8576	.....	PB 226 725
IC 8476	.....	PB 201 803	IC 8577	.....	PB 226 794
IC 8477	.....	PB 198 253	IC 8578	.....	PB 226 789
IC 8478	.....	PB 198 254	IC 8579	.....	PB 226 788
IC 8479	.....	PB 193 210	IC 8581	.....	PB 223 746
IC 8480	.....	PB 198 255	IC 8582	.....	PB 221 837
IC 8481	.....	PB 193 980	IC 8583	.....	PB 221 839
IC 8482	.....	PB 198 256	IC 8584	.....	PB 221 765
IC 8483	.....	PB 198 257	IC 8585	.....	PB 218 565
IC 8484	.....	PB 193 981	IC 8586	.....	PB 227 281
IC 8485	.....	PB 198 258	IC 8587	.....	PB 227 282
IC 8486	.....	PB 194 939	IC 8588	.....	PB 227 283
IC 8487	.....	PB 198 259	IC 8589	.....	PB 220 786
IC 8488	.....	PB 198 260	IC 8589-8590 set	.....	PB 270 785
IC 8490	.....	PB 196 723	IC 8590	.....	PB 220 787
IC 8492	.....	PB 196 693	IC 8591	.....	PB 220 743
IC 8493	.....	PB 196 694	IC 8592	.....	PB 227 189
IC 8498	.....	PB 199 073	IC 8593	.....	PB 227 192
IC 8501		PB 199 074	IC 8594		PB 222 085
IC 8502		PB 198 134	IC 8595		PB 227 476
IC 8503		PB 197 913	IC 8596		PB 224 650
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IC 8507		PB 236 093	IC 8599		PB 221 918
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IC 8514		PB 218 692	IC 8603		PB 221 841
IC 8516		PB 200 707	IC 8604		PB 222 610
IC 8519		PB 203 897	IC 8605		PB 222 539
IC 8520	.....	PB 203 898	IC 8606	.....	PB 225 077
IC 8521	.....	PB 203 675	IC 8607	.....	PB 225 977
IC 8523	.....	PB 203 400	IC 8608	.....	PB 221 899
IC 8524	.....	PB 206 137	IC 8609	.....	PB 225 131
IC 8525	.....	PB 204 138	IC 8610	.....	PB 231 863
IC 8526	.....	PB 204 139	IC 8611	.....	PB 228 109
IC 8527	.....	PB 205 646	IC 8612	.....	PB 224 399
IC 8528	.....	PB 206 150	IC 8613	.....	PB 224 474
IC 8529	.....	PB 205 663	IC 8614	.....	PB 228 099
IC 8530	.....	PB 206 626	IC 8615	.....	PB 228 665
IC 8531	.....	PB 208 101	IC 8616	.....	PB 227 100
IC 8532	.....	PB 207 372	IC 8617	.....	PB 228 688
IC 8533	.....	PB 206 627	IC 8618	.....	PB 231 107
IC 8534	.....	PB 209 546	IC 8619	.....	PB 230 777
IC 8535	.....	PB 208 769	IC 8620	.....	PB 232 296
IC 8536	.....	PB 206 241	IC 8621	.....	PB 226 250
IC 8537	.....	PB 210 225	IC 8622	.....	PB 233 215
IC 8538	.....	PB 209 547	IC 8623	.....	PB 231 101
IC 8539	.....	PB 217 520	IC 8624	.....	PB 231 285
IC 8540	.....	PB 210 184	IC 8625	.....	PB 231 276
IC 8541	.....	PB 210 966	IC 8626	.....	PB 233 208
IC 8542	.....	PB 210 254	IC 8627	.....	PB 233 989
IC 8543	.....	PB 211 826	IC 8628	.....	PB 237 814
IC 8544	.....	PB 211 100	IC 8629	.....	PB 231 050
IC 8545	.....	PB 210 608	IC 8630	.....	PB 231 286
IC 8546	.....	PB 210 166	IC 8631	.....	PB 233 216
IC 8547	.....	PB 212 556	IC 8632	.....	PB 228 160
IC 8548	.....	PB 210 991	IC 8633	.....	PB 233 975
IC 8549	.....	PB 211 249	IC 8634	.....	PB 231 153
IC 8550	.....	PB 212 507	IC 8635	.....	PB 231 135
IC 8551	.....	PB 211 456	IC 8636	.....	PB 233 954
IC 8552	.....	PB 212 505	IC 8637	.....	PB 233 990
IC 8553	.....	PB 211 943	IC 8639	.....	PB 234 671
IC 8554	.....	PB 212 482	IC 8640	.....	PB 233 404
IC 8555	.....	PB 211 896	IC 8641	.....	PB 233 209
IC 8556	.....	PB 211 886	IC 8642	.....	PB 233 955
IC 8557	.....	PB 214 117	IC 8643	.....	PB 233 997
IC 8558	.....	PB 211 903	IC 8644	.....	PB 234 695
IC 8559	.....	PB 212 697	IC 8645	.....	PB 236 172
IC 8560	.....	PB 212 823	IC 8646	.....	PB 237 717
IC 8561	.....	PB 214 127	IC 8647	.....	PB 236 581
IC 8562	.....	PB 212 698	IC 8648	.....	PB 234 683
IC 8563	.....	PB 214 236	IC 8649	.....	PB 237 036
IC 8564	.....	PB 214 644	IC 8651	.....	PB 234 682
IC 8565	.....	PB 214 753	IC 8652	.....	PB 237 843
IC 8566	.....	PB 226 724	IC 8653	.....	PB 238 465
IC 8567		PB 226 703	IC 8654		PB 236 591
IC 8568		PB 213 945	IC 8655		PB 237 815
IC 8569		PB 240 477	IC 8658		PB 238 125

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IC 8661	PB 237 706	OFR 30-73	PB 220 328	OFR 42-74, 2	PB 235 640	RI 7389	PB 191 498
MY 1968, v. I-II	PB 198 621	OFR 31-73	PB 220 408	OFR 42-74, 3	PB 235 641	RI 7390	PB 192 004
MY 1968, v. III	PB 198 622	OFR 34-73, 1	PB 220 546	OFR 42-74, 4	PB 235 642	RI 7391	PB 192 308
MY 1968, v. IV	PB 198 623	OFR 34-73, 2	PB 220 547	OFR 42-74, set	PB 235 658	RI 7392	PB 192 302
MY 1969, v. I-II	PB 198 819	OFR 34-73, set	PB 220 545	OFR 43-74	PB 235 616	RI 7393	PB 192 301
MY 1969, v. III	PB 206 668	OFR 35-73	PB 220 806	OFR 44-74	PB 235 852	RI 7394	PB 192 305
MY 1969, v. IV	PB 209 669	OFR 38-73	PB 221 000	OFR 45-74	PB 235 854	RI 7395	PB 192 300
MY 1970, v. I	PB 212 185	OFR 40-73	PB 221 278	OFR 46-74	PB 235 867	RI 7396	PB 192 303
MY 1970, v. II	PB 214 239	OFR 41-73	PB 221 309	OFR 47-74	PB 235 915	RI 7397	PB 192 417
MY 1970, v. III	PB 221 061	OFR 43-73	PB 221 352	OFR 48-74	PB 235 927	RI 7398	PB 192 418
MY 1971, v. I	PB 221 062	OFR 44-73	PB 221 880	OFR 49-74	PB 236 119	RI 7399	PB 193 208
MY 1971, v. II	PB 227 842	OFR 45-73	PB 222 137	OFR 50-74	PB 236 090	RI 7400	PB 192 304
MY 1971, v. III	PB 227 843	OFR 47-73	PB 222 413	OFR 51-74	PB 236 277	RI 7401	PB 192 419
MY 1972, v. I	PB 234 388	OFR 48-73	PB 222 755	OFR 52-74	PB 236 592	RI 7402	PB 192 297
Mon 9	PB 213 419	OFR 49-73	PB 222 491	OFR 53-74	PB 236 584	RI 7403	PB 193 206
OFR 2-70	PB 189 383	OFR 50-73	PB 222 490	OFR 54-74	PB 236 652	RI 7404	PB 192 299
OFR 4-70	PB 191 691	OFR 51-73	PB 222 831	OFR 55-74	PB 237 217	RI 7405	PB 192 209
OFR 5-70	PB 192 204	OFR 52-73	PB 223 238	OFR 56-74	PB 237 218	RI 7406	PB 193 326
OFR 6-70	PB 192 181	OFR 53-73	PB 222 898	OFR 57-74	PB 237 557	RI 7407	PB 193 327
OFR 7-70	PB 192 181	OFR 54-73	PB 222 872	OFR 58-74	PB 237 854	RI 7408	PB 193 207
OFR 7-70	PB 193 342	OFR 55-73	PB 222 850	OFR 59-74	PB 237 830	RI 7409	PB 193 328
OFR 8-70	PB 193 343	OFR 56-73	PB 223 597	OFR 60-74	PB 237 831	RI 7410	PB 193 982
OFR 9-70	PB 193 344	OFR 57-73	PB 223 775	OFR 61-74	PB 237 852	RI 7411	PB 193 329
OFR 10-70	PB 193 934	OFR 58-73	PB 223 743	OFR 62-74, set	PB 237 860	RI 7412	PB 194 003
OFR 11-70	PB 193 948	OFR 59-73, 1	PB 225 364	OFR 62-74, 1	PB 237 861	RI 7413	PB 193 983
OFR 12-70	PB 193 286	OFR 59-73, 2	PB 225 365	OFR 62-74, 2	PB 237 862	RI 7414	PB 193 984
OFR 13-70	PB 195 014	OFR 59-73, 3	PB 225 366	OFR 62-74, 3	PB 237 863	RI 7415	PB 193 985
OFR 2-71	PB 197 693	OFR 59-73, 4	PB 225 367	OP 9-72	PB 201 465	RI 7416	PB 193 986
OFR 3-71	PB 197 780	OFR 59-73, set	PB 225 363	OP 83-73	PB 222 106	RI 7417	PB 193 330
OFR 4-71	PB 197 739	OFR 60-73	PB 223 742	RI 5225	PB 191 796	RI 7418	PB 194 082
OFR 7-71, 1	PB 202 275	OFR 61-73, 1	PB 224 730	RI 5735	PB 192 542	RI 7419	PB 194 078
OFR 7-71, 2	PB 202 276	OFR 61-73, 2	PB 224 731	RI 6165	PB 190 318	RI 7420	PB 194 940
OFR 9-71	PB 204 077	OFR 62-73, 1	PB 224 256	RI 6307	PB 192 543	RI 7421	PB 194 941
OFR 10-71	PB 204 522	OFR 62-73, 2	PB 224 257	RI 6450	PB 190 316	RI 7422	PB 194 947
OFR 4-72, 1	PB 207 226	OFR 62-73, 3	PB 224 258	RI 6692	PB 215 257	RI 7423	PB 194 942
OFR 4-72, 2	PB 207 227	OFR 62-73, 4	PB 224 259	RI 6778	PB 221 017	RI 7424	PB 194 943
OFR 5-72	PB 207 362	OFR 62-73, 5	PB 224 260	RI 7021	PB 192 544	RI 7425	PB 194 944
OFR 6-72	PB 207 363	OFR 62-73, 6	PB 224 261	RI 7085	PB 207 834	RI 7426	PB 194 945
OFR 7-72	PB 207 512	OFR 62-73, 7	PB 224 262	RI 7133	PB 189 903	RI 7427	PB 194 946
OFR 9-72, 1	PB 208 266	OFR 62-73, 8	PB 224 263	RI 7291	PB 190 648	RI 7428	PB 196 676
OFR 9-72, 2	PB 208 267	OFR 62-73, set	PB 224 255	RI 7326	PB 189 538	RI 7429	PB 196 677
OFR 9-72, 3	PB 208 268	OFR 64-73	PB 224 789	RI 7327	PB 189 539	RI 7430	PB 196 678
OFR 10-72	PB 209 273	OFR 65-73	PB 225 181	RI 7328	PB 190 031	RI 7431	PB 196 679
OFR 11-72	PB 209 274	OFR 67-73	PB 225 353	RI 7329	PB 188 559	RI 7432	PB 196 680
OFR 12-72	PB 209 548	OFR 68-73	PB 226 660	RI 7330	PB 190 032	RI 7433	PB 196 682
OFR 13-72	PB 209 575	OFR 70-73, 1	PB 225 476	RI 7331	PB 190 033	RI 7434	PB 196 683
OFR 15-72	PB 209 949	OFR 70-73, 2	PB 225 477	RI 7332	PB 190 027	RI 7435	PB 196 684
OFR 16-72	PB 210 841	OFR 70-73, set	PB 225 475	RI 7333	PB 189 541	RI 7436	PB 196 685
OFR 17-72	PB 210 620	OFR 71-73	PB 225 633	RI 7334	PB 189 542	RI 7437	PB 196 686
OFR 18-72	PB 210 795	OFR 72-73	PB 225 862	RI 7335	PB 189 543	RI 7438	PB 196 687
OFR 19-72	PB 210 833	OFR 73-73	PB 225 831	RI 7336	PB 190 028	RI 7439	PB 196 594
OFR 20-72	PB 210 930	OFR 74-73	PB 225 834	RI 7337	PB 188 645	RI 7440	PB 196 595
OFR 21-72	PB 211 052	OFR 1-74	PB 226 479	RI 7338	PB 190 029	RI 7441	PB 196 596
OFR 22-72	PB 211 412	OFR 2-74	PB 226 773	RI 7339	PB 190 030	RI 7442	PB 196 597
OFR 23-72	PB 211 433	OFR 3-74	PB 226 687	RI 7340	PB 190 034	RI 7443	PB 196 598
OFR 24-72	PB 211 472	OFR 4-74	PB 226 723	RI 7341	PB 190 012	RI 7444	PB 196 599
OFR 25-72	PB 211 423	OFR 5-74	PB 226 694	RI 7342	PB 190 013	RI 7445	PB 196 600
OFR 26-72	PB 211 328	OFR 7-74	PB 226 781	RI 7343	PB 190 774	RI 7446	PB 196 601
OFR 27-72	PB 211 732	OFR 8-74	PB 226 944	RI 7344	PB 190 035	RI 7447	PB 196 602
OFR 28-72	PB 211 980	OFR 9-74	PB 227 018	RI 7345	PB 190 773	RI 7448	PB 196 603
OFR 29-72	PB 212 070	OFR 10-74	PB 228 215	RI 7346	PB 190 479	RI 7449	PB 196 604
OFR 31-72	PB 212 046	OFR 11-74	PB 229 485	RI 7347	PB 190 480	RI 7450	PB 196 605
OFR 32-72	PB 212 047	OFR 12-74	PB 230 477	RI 7348	PB 190 649	RI 7451	PB 196 606
OFR 33-72	PB 212 048	OFR 13-74	PB 230 965	RI 7349	PB 188 560	RI 7452	PB 196 607
OFR 34-72	PB 212 746	OFR 14-74	PB 230 972	RI 7350	PB 190 014	RI 7453	PB 196 608
OFR 35-72	PB 213 204	OFR 16-74	PB 231 154	RI 7351	PB 190 772	RI 7454	PB 196 609
OFR 36-72	PB 213 717	OFR 17-74, 1	PB 231 574	RI 7352	PB 190 771	RI 7455	PB 196 610
OFR 37-72	PB 213 833	OFR 17-74, 2	PB 231 575	RI 7353	PB 190 770	RI 7456	PB 196 611
OFR 38-72	PB 213 725	OFR 18-74	PB 231 682	RI 7354	PB 190 769	RI 7457	PB 196 612
OFR 39-72	PB 213 741	OFR 19-74, 1	PB 233 540	RI 7355	PB 190 650	RI 7458	PB 196 613
OFR 40-72	PB 214 277	OFR 19-74, 2	PB 233 541	RI 7356	PB 190 966	RI 7459	PB 196 614
OFR 1-73	PB 214 124	OFR 19-74, 3	PB 233 542	RI 7357	PB 190 967	RI 7460	PB 196 688
OFR 2-73, 1	PB 220 566	OFR 20-74	PB 231 758	RI 7358	PB 190 968	RI 7461	PB 196 689
OFR 2-73, 2	PB 220 567	OFR 21-74	PB 231 991	RI 7359	PB 190 969	RI 7462	PB 196 690
OFR 2-73, set	PB 220 565	OFR 22-74	PB 232 244	RI 7360	PB 190 970	RI 7463	PB 196 691
OFR 3-73	PB 214 535	OFR 24-74	PB 232 304	RI 7361	PB 190 971	RI 7464	PB 197 105
OFR 4-73	PB 215 349	OFR 25-74, 1	PB 232 405	RI 7362	PB 190 972	RI 7465	PB 196 692
OFR 5-73	PB 216 397	OFR 25-74, 2	PB 232 406	RI 7363	PB 190 973	RI 7466	PB 197 106
OFR 6-73	PB 215 150	OFR 26-74	PB 232 421	RI 7364	PB 190 974	RI 7467	PB 199 076
OFR 7-73	PB 214 938	OFR 27-74	PB 232 885	RI 7365	PB 190 651	RI 7468	PB 197 107
OFR 8-73	PB 215 164	OFR 28-74	PB 232 880	RI 7366	PB 190 975	RI 7469	PB 197 021
OFR 9-73	PB 215 165	OFR 29-74, 1	PB 223 181	RI 7367	PB 190 976	RI 7470	PB 197 022
OFR 10-73, 1	PB 215 142	OFR 29-74, 2	PB 233 182	RI 7368	PB 190 977	RI 7471	PB 197 023
OFR 10-73, 2	PB 215 143	OFR 30-74	PB 232 887	RI 7369	PB 190 978	RI 7472	PB 197 024
OFR 12-73	PB 217 500	OFR 31-74	PB 232 891	RI 7370	PB 190 979	RI 7473	PB 197 025
OFR 13-73	PB 218 060	OFR 32-74	PB 234 208	RI 7371	PB 191 947	RI 7474	PB 197 026
OFR 14-73	PB 218 688	OFR 33-74	PB 234 577	RI 7372	PB 190 980	RI 7475	PB 197 027
OFR 15-73	PB 218 463	OFR 34-74	PB 234 575	RI 7373	PB 191 001	RI 7476	PB 198 283
OFR 16-73	PB 217 502	OFR 35-74	PB 235 767	RI 7374	PB 191 002	RI 7477	PB 198 824
OFR 17-73	PB 218 658	OFR 36-74	PB 234 555	RI 7375	PB 192 002	RI 7478	PB 197 027
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OFR 25-73, 2	PB 219 616	OFR 41-74, 1	PB 235 605	RI 7382	PB 192 307	RI 7485	PB 198 289
OFR 26-73	PB 220 203	OFR 41-74, 2	PB 235 606	RI 7383	PB 192 298	RI 7486	PB 198 290
OFR 27-73	PB 220 141	OFR 41-74, 3	PB 235 607	RI 7384	PB 192 306	RI 7487	PB 200 043
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RI 7494	PB 198 826	RI 7597	PB 208 003	RI 7699	PB 214 291	RI 7801	PB 225 366
RI 7495	PB 198 827	RI 7598	PB 208 004	RI 7700	PB 214 237	RI 7802	PB 225 345
RI 7496	PB 198 828	RI 7599	PB 206 890	RI 7701	PB 214 271	RI 7803	PB 225 288
RI 7497	PB 199 040	RI 7600	PB 206 940	RI 7702	PB 214 309	RI 7804	PB 225 273
RI 7498	PB 199 041	RI 7601	PB 206 891	RI 7703	PB 214 221	RI 7805	PB 225 270
RI 7499	PB 199 042	RI 7602	PB 208 005	RI 7704	PB 215 813	RI 7806	PB 225 287
RI 7500	PB 199 043	RI 7603	PB 208 006	RI 7705	PB 214 676	RI 7807	PB 225 276
RI 7501	PB 199 044	RI 7604	PB 206 910	RI 7706	PB 215 814	RI 7808	PB 226 101
RI 7502	PB 199 045	RI 7605	PB 208 007	RI 7707	PB 214 054	RI 7809	PB 226 090
RI 7503	PB 199 046	RI 7606	PB 208 008	RI 7708	PB 214 642	RI 7810	PB 224 531
RI 7504	PB 199 047	RI 7607	PB 208 009	RI 7709	PB 215 815	RI 7811	PB 227 218
RI 7505	PB 200 044	RI 7608	PB 209 008	RI 7710	PB 214 763	RI 7812	AD 226 230
RI 7506	PB 199 039	RI 7609	PB 208 010	RI 7711	PB 214 761	RI 7813	PB 228 738
RI 7507	PB 200 045	RI 7610	PB 209 013	RI 7712	PB 214 629	RI 7814	PB 227 707
RI 7508	PB 200 046	RI 7611	PB 209 009	RI 7713	PB 213 947	RI 7815	PB 231 102
RI 7509	PB 200 047	RI 7612	PB 209 014	RI 7714	PB 214 680	RI 7816	PB 228 624
RI 7510	PB 200 048	RI 7613	PB 209 010	RI 7715	PB 215 816	RI 7817	PB 227 176
RI 7511	PB 200 049	RI 7614	PB 208 011	RI 7716	PB 214 786	RI 7818	PB 226 229
RI 7512	PB 200 066	RI 7615	PB 208 012	RI 7717	PB 214 314	RI 7819	PB 231 109
RI 7513	PB 200 697	RI 7616	PB 209 536	RI 7718	PB 218 428	RI 7820	PB 227 388
RI 7514	PB 199 048	RI 7617	PB 209 015	RI 7719	PB 214 780	RI 7821	PB 227 381
RI 7515	PB 199 049	RI 7618	PB 209 016	RI 7720	PB 214 762	RI 7822	PB 224 571
RI 7516	PB 200 698	RI 7619	PB 209 017	RI 7721	PB 215 817	RI 7823	PB 228 628
RI 7517	PB 200 699	RI 7620	PB 209 011	RI 7722	PB 214 783	RI 7824	PB 227 385
RI 7518	PB 200 701	RI 7621	PB 209 537	RI 7723	PB 218 697	RI 7825	PB 229 213
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RI 7522	PB 200 704	RI 7625	PB 209 539	RI 7727	PB 227 187	RI 7829	PB 231 179
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RI 7527	PB 200 706	RI 7630	PB 209 543	RI 7732	PB 221 627	RI 7834	PB 231 281
RI 7528	PB 200 710	RI 7631	PB 210 167	RI 7733	PB 227 175	RI 7835	PB 229 482
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RI 7530	PB 201 895	RI 7633	PB 210 949	RI 7735	PB 228 782	RI 7837	PB 227 097
RI 7531	PB 201 896	RI 7634	PB 210 220	RI 7736	PB 227 190	RI 7838	PB 231 984
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RI 7537	PB 203 651	RI 7640	PB 209 544	RI 7742	PB 220 586	RI 7844	PB 229 217
RI 7538	PB 203 652	RI 7641	PB 210 983	RI 7743	PB 221 526	RI 7845	PB 231 298
RI 7539	PB 201 894	RI 7642	PB 211 004	RI 7744	PB 221 512	RI 7846	PB 231 295
RI 7540	PB 203 653	RI 7643	PB 210 984	RI 7745	PB 220 632	RI 7847	PB 228 098
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ARTICLES IN OUTSIDE PUBLICATIONS

- OP 1-70. Predicted Air Entrainment by Subsonic, Free Round Jets**, by E. B. Cook and J. M. Singer. *J. Spacecraft and Rockets*, September 1969, v. 6, No. 9, pp. 1066-1070. With the ultimate objective of developing a method for predicting mixing spread of buoyant and momentum-controlled hydrogen plumes and of air pollutants exhausted into the open atmosphere, a method of calculation was developed based on theoretical and empirical analyses and the theoretical predictions were compared with experimental results. Experiments were conducted covering free jets of helium, argon, and methane discharging at relatively low velocities into ambient air. A semiempirical correction is made for the effect of buoyancy based on Froude numbers and entrainment data of Ricou and Spalding. The computed results also are compared with the Morton analyses, in which approximations and simplifications are applied to jet entrainment with small density gradients. A FORTRAN V computer program was written to facilitate computation. It is applicable to round freejets for $5 \leq h/d \leq 200$, $r/a \leq 56$, and $0 \leq M \leq 1.4$.
- OP 2-70. Stabilization of Mineral Wastes**, by K. C. Dean, R. Havens, and E. G. Valdez. *Ind. Water Eng.*, v. 6, No. 10, October 1969, pp. 30-33. This article discusses methods of stabilizing mineral wastes including stabilization with soil and slag, chemical stabilization, vegetative stabilization, and a combination of both chemicals and vegetative stabilization.
- OP 3-70. Realistic K Values of C₇ Hydrocarbons for Calculating Oil Vaporization During Gas Cycling at High Pressures**, by Alton B. Cook, C. J. Walker, and George B. Spencer. *J. Petrol. Technol.*, v. 21, No. 7, July 1969, pp. 901-916. A simple method for calculating vaporization is presented, along with laboratory data that indicate which conditions of pressure, temperature and type of oil are favorable for maximum vaporization.
- OP 4-70. Reduction-Induration Applied to Iron Ore Pellets**, by M. M. Fine and R. B. Schluter. *Min. Eng.*, v. 21, No. 10, October 1969, pp. 21-24. It was observed that unfired iron ore pellets indurated in a bed of anthracite or certain lignite chars frequently acquired exceptional crushing strength. A diagnosis of the phenomenon revealed that sulfur in the fuel was the probable cause. Accordingly, a research program was established to test this premise and to put it to practical use. This article discusses that research.
- OP 5-70. Identification of Alkylbenzo[b]thiophenes in a Wesson, Texas, Crude Oil Distillate Boiling 200 to 250° C**, by R. L. Hopkins, H. J. Coleman, C. J. Thompson, and H. T. Rall. *Anal. Chem.*, v. 41, No. 14, December 1969, pp. 2041-2046. By a combination of chemical, chromatographic, and spectroscopic methods, 22 benzo[b]thiophenes were identified in Wesson, Tex., crude oil. Five compounds comprise 82 percent by weight of the total benzothiophenes identified. A marked order of preference for the position of the alkyl substituents on the benzothiophene ring was noted: $2 > 3 > 7 \geq 4 > 6$. Although no alkyl substitution in the 5-position has been found such substitution could be present in small amounts.
- OP 6-70. Zone-Melting Chromatography of Organic Mixtures**, by H. Plancher, T. E. Cogswell, and D. R. Latham. Ch. 28 in *Purification of Inorganic and Organic Materials*, ed. by M. Zeif. Marcel Dekker, Inc., New York, 1969, pp. 285-290. The advantages of induction heating (internal heating, efficient mixing, and short zones) formerly available only with metals are now applicable to organic systems, making ZMC of organic materials feasible. The application of this separation technique to a mixture of polycondensed aromatic materials is described in this chapter.
- OP 7-70. East Canton Oilfield Waterflood Evaluation**, by L. A. Schrider, R. J. Watts, and J. A. Wasson. 6th Ann. Eastern Regional Meeting SME, AIME, Columbus, Ohio, Nov. 6-7, 1969, Preprint SME 2764, 8 pp; *J. Petrol. Tech.*, November 1970, v. 22, No. 11, pp. 1371-1378. This report presents results of a Bureau of Mines reservoir study of the Clinton sand, East Canton oilfield, Stark, Carroll, and Tuscarawas Counties, Ohio. Considered in the evaluation were the reservoir geometry, lithology, continuity of the rock properties, fluid saturations and fluid characteristics. The study indicates that a properly engineered waterflood may be feasible for secondary oil recovery. Waterflood forecasts that account for a wide range of reservoir conditions are included and can be used for preliminary waterflood performance estimates.
- OP 8-70. The Effect of Additives on Impregnated Diamond Bit Performance**, by A. A. Selim, C. W. Schultz, and K. C. Strebis. *Soc. Petrol. Eng. J.*, v. 9, No. 4, December 1969, pp. 425-433. The effect of some organic additives in diamond drilling of quartzite was investigated in the laboratory. The drill was designed to measure the rate of penetration, the thrust, and the torque and to record each as a function of the distance drilled. A statistical plan was followed throughout the investigation and an equation representing the bit performance was derived from the mathematical theory of reliability. The drilling torque was found to increase with the use of additives while the sliding coefficient of friction and the wear coefficient decreased. The energy per unit volume consumed was found to increase with the use of additives. A hypothesis explaining the effects achieved with the additives is given.
- OP 9-70. A Method of Determining In-Situ Stress in Anisotropic Rock**, by Robert M. Becker and Verne E. Hooker. *Trans. SME, AIME*, v. 244, December 1969, pp. 436-445. The evaluation of in situ rock stresses from measurements of the change in diameter of a borehole that is stress relieved by overcoring has become a common practice. Generally the stress evaluation has been based on isotropic relations whereas rock in varying degrees is anisotropic. A plane elasticity solution for a circular hole along one axis of an orthotropic medium has been adapted to evaluation of in situ stress. The necessary elastic parameters for this evaluation may conveniently be obtained from static tests on the overcore in conjunction with a consistent orthotropic thick-wall cylinder solution. The method and equations for the laboratory and field evaluations are summarized and illustrated.

OUTSIDE PUBLICATIONS

OP 10-70. Apparatus for the Preparation of Sealed Samples for NMR, by William J. Lanum and F. R. McDonald. *Appl. Spectroscopy*, v. 23, No. 6, November-December, p. 618. An apparatus for storing measured volumes of sample and solvent and combining them under vacuum in NMR tubes prior to running NMR spectra is described.

OP 11-70. Solubilisation of Low Rank Coal With Carbon Monoxide and Water, by H. R. Appell, I. Wender, and R. D. Miller. *Chem. and Ind.*, No. 47, Nov. 22, 1969, p. 1703. A procedure for converting lignite, lignin, and carbohydrates into benzene-soluble oil, water, and gas in nearly 90-percent conversions using carbon monoxide and steam is described.

OP 12-70. Slag Compositions for Titanium Electroslag Melting and Effects of Selected Melting Parameters, by R. H. Nafziger. 2d Internat. Symp. on Electroslag Remelting Technology, Mellon Institute, Pittsburgh, Pa., Sept. 23-25, 1969, *Proc.*, Pt. 1, collated and ed. by G. K. Bhat, January 1970. Electroslag melting of reactive metals such as titanium requires considerable modification of concepts and techniques from those commonly used in steel melting. These differences begin with the required equipment. Since titanium reacts readily at high temperatures with gaseous impurities such as oxygen, nitrogen, and hydrogen, a protective atmosphere is essential. For this purpose a modified cold-mold vacuum arc melting furnace with a 4-inch (~ 10 cm) round crucible was used for melting titanium. In later melts this feature was eliminated and dry slag was charged into the furnace before initiation of melting. All of the heats reported herein are single melts of titanium sponge pressed at 30,000 psi ($\sim 2 \times 10^6$ kg/m²) into bars each $2 \times 2 \times 10$ inches ($\sim 5 \times 5 \times 25$ cm) which were subsequently butt-welded to form the consumable electrode.

OP 13-70. Effect of End Constraint on the Compressive Strength of Model Rock Pillars, by Clarence O. Babcock. *Trans. SME, AIME*, v. 244, December 1969, pp. 357-363. Model rock pillars with end constraint were stronger when a 3,000 psi prestress constraint was used than when constraint was produced during the loading cycle and were stronger than straight specimens.

OP 14-70. Flammability of Fabrics and Other Materials in Oxygen-Enriched Atmospheres: Ignition Temperatures and Flame Spread Rates, by J. M. Kuchta, A. L. Furno, and G. H. Martindell. *Fire Tech.*, v. 5, No. 3, August 1969, pp. 203-216. Part I of this two-part report deals with the effects of oxygen enrichment on ignition temperatures and flame spread rates of materials that might be found in hospital hyperbaric chambers.

OP 15-70. Flammability of Fabrics and Other Materials in Oxygen-Enriched Atmospheres: Minimum Ignition Energies, by E. L. Litchfield and T. A. Kubala. *Fire Tech.*, v. 5, No. 4, November 1969, pp. 341-345. In this, the final part of a two-part report, the electrical energy required to ignite certain solids in air and in oxygen both at 1 atmosphere and at hyperbaric pressures is examined.

OP 16-70. Vapor-Liquid Equilibria and Dielectric Constants for Helium-Carbon Dioxide System, by D. W. Burfield, H. P. Richardson, and R. A. Guereca. *AIChE J.*, v. 16, No. 1, January 1970, pp. 97-100. Phase equilibria data are presented for the helium-carbon dioxide system at 253°, 273°, and 293° K. and pressures to 139 atm. Equilibrium is established

under flow followed by nonflow conditions, and liquid and vapor samples are isolated without disturbing equilibrium. Liquid- and vapor-phase compositions are monitored with miniaturized capacitors, and compressibility factors are computed from resulting dielectric constants. The data are internally consistent and compare favorably with available literature values.

OP 17-70. Limestone in Mine Drainage Treatment, by Maurice Deul. *Min. Cong. J.*, v. 55, No. 11, November 1969, pp. 88-91. Limestone treatment is the lowest cost process for neutralizing acid mine water yet developed. This article concerns treating acid mine water to produce a final effluent which has a pH between 6 and 9 and has less than 7 ppm iron.

OP 18-70. Gold Recovery From Scrap Electronic Solders by Fused-Salt Electrolysis, by E. K. Kleespies, J. P. Bennetts, and T. A. Henrie. *J. Metals*, v. 22, No. 1, January 1970, pp. 42-44. A process was developed for recovering gold and refining Sn-Pb solders from scrap solder discarded by the electronics industry. Contaminated solder can be treated by electrorefining in a molten-chloride system, yielding refined solder at the cathode and a high concentration of gold and other metal impurities at the anode. Subsequent recovery of gold from the anode bullion is by conventional fire refining.

OP 19-70. Domestic Tar Sands and Potential Recovery Methods—A Review, by George B. Spencer, W. E. Eckard, and F. Sam Johnson. *Interstate Oil Compact Commission Bull.*, v. 11, No. 2, December 1969, pp. 5-12. This paper reviews and evaluates present knowledge of U.S. tar sands including physical properties, occurrence, reserves, and recovery methods.

OP 20-70. Nature of Odor Components in Diesel Exhaust, by J. W. Vogh. *J. Air Pollution Control Assoc.*, v. 19, No. 10, October 1969, pp. 773-777. A human panel performed odor assessments in studying raw and modified diesel exhaust and synthetic blends representing portions of diesel exhaust. Their assessments were used in determining odorant identity and quantitative contribution to exhaust odor. Low molecular weight aldehydes appear to contribute little to diesel odors. The sulfur and nitrogen oxides have been examined as odorants, but of these apparently only nitrogen dioxide is a potential odor contributor.

OP 21-70. The Microseismic Technique Applied to Slope Stability, by David W. Wisecarver, Robert H. Merrill, and Raymond M. Stateham. *Trans. SME, AIME*, v. 244, December 1969, pp. 378-385. The use of the microseismic technique to evaluate the stability of large open pit walls was investigated. Wide-band, wide range microseismic equipment appears suitable for open pit investigations.

OP 22-70. Explosive Sensitivity of N-Chlorodimethylamine, N,N-Dichloro-Methylamine and N,N-Dibromomethylamine, by J. C. Cooper and D. R. Forshey. *Explosivstoffe*, v. 6, June 1969, pp. 129-130. Determination of the sensitivity of N-chlorodimethylamine, N,N-dichloromethylamine, and N,N-dibromomethylamine to initiation by mechanical impact or to initiation of detonation by shock showed that the dihalo compounds appear to present a greater explosion hazard than N-chlorodimethylamine.

OP 23-70. Reaction Rate of Titanium and Titanium Alloys With Titanium Lower Chlorides, by E. K. Kleespies and T. A. Henrie. *In The Science Technology*

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and Application of Titanium, ed. by R. Jaffee and N. Promisel. Pergamon Press, New York, 1970, 179-188. A technique was devised for measuring the rate of chemical reaction between titanium or titanium alloys and molten-salt mixtures containing titanium lower chlorides. The kinetics of the reaction of titanium, titanium-oxygen alloy, and titanium-iron alloy in molten salts were determined to provide a basis for understanding the reactions occurring in the preparation of titanium by metal reduction or electrolytic processes. The rates of the heterogeneous reactions were measured as a function of titanium content of the molten salts and of the oxygen and iron content of the titanium alloys.

OP 24-70. Properties of Wrought Shapes Formed From Electroslag-Melted Titanium, by C. E. Armantrout, J. T. Dunham, and R. A. Beall. In *The Science Technology and Application of Titanium*, ed. by R. Jaffee and N. Promisel. Pergamon Press, New York, 1970, pp. 67-74. This paper presents mechanical properties obtained for wrought shapes formed from electroslag-melted ingots, and compares the properties with those obtained for like shapes from double vacuum-arc melted material. The preparation of ingots and the working of ingots to shapes are described.

OP 25-70. Laboratory Extraction of Copper From Chalcocite by Roasting Reduction, and Smelting, by M. M. Fine and R. B. Schluter. AIME Ann. Meeting, Denver, Colo., Feb. 15-19, 1970, AIME Preprint 70-B-12, 15 pp. This paper discusses a new route from chalcocite concentrate to copper metal which includes a 2-stage fluid-bed treatment (one oxidizing, the other reducing). The reduced product is smelted with lime to effect a high recovery of metallic copper.

OP 26-70. Chemical Thermodynamic Properties for 1-Alkanethiols, by H. L. Finke, J. P. McCullough, J. F. Messerly, G. B. Guthrie, and D. R. Douslin. J. Chem. Thermodynamics, v. 2, January 1970, pp. 27-41. The thermodynamic quantities ($G_s - H^\circ_0$)/T, ($H_s - H^\circ_0$)/T, $H_s - H^\circ_0$, S_s , and C_s were evaluated for the solid and liquid states of ethanethiol, 1-pentanethiol, 1-hexanethiol, 1-heptanethiol, and 1-decanethiol in the range 10° to 370° K.

OP 27-70. Trimethylamineborane and Triethylamineborane: Low-Temperature Thermodynamic Properties, by H. L. Finke, S. S. Todd, and J. F. Messerly. J. Chem. Thermodynamics, v. 2, January 1970, pp. 129-138. The low-temperature thermal properties of trimethylamineborane and triethylamineborane were determined by adiabatic calorimetry over the range 12° to 390° K and 12° to 310° K, respectively.

OP 28-70. Gas-Liquid Chromatographic Separation and Spectrometric Identification of Nitrogen Bases in Hydrocracked Shale Oil Naphtha, by Dennis Brown, D. B. Earnshaw, F. R. McDonald, and H. B. Jensen. Anal. Chem., v. 42, No. 2, February 1970, pp. 146-150. A tar-base concentrate from a hydrocracked shale oil naphtha was separated by gas-liquid partition chromatography using nonpolar and polar columns. Final cuts were analyzed by mass, infrared, and nuclear magnetic resonance spectrometry. Fifty individual compounds were identified and eight additional structures are proposed as possible components of the concentrate. Alkylpyridines comprised about 64 percent of the bases and alkylanilines about 33 percent; the rest of the bases were quinoline and small quantities of cycloalkanopyridines. Substitution patterns for both the alkylpyridines and alkyl-

anilines showed that α substitution was favored over β or γ , and γ was favored over β .

OP 29-70. Reduction Roasting of Steep Rock Iron-Bearing Materials, by Charles Prasky and Willard S. Swanson. Skillings' Min. Rev., v. 58, No. 44, Nov. 1, 1969, pp. cover, 12-15. This article describes the Bureau's reduction roasting studies of Steep Rock iron-bearing materials to obtain a direct shipping materials for blast furnace consumption.

OP 30-70. The Sandwich Sample Technique Applied to Quantitative Microprobe Analysis, by James D. Brown. In *Electron Probe Microanalysis*, ed. by A. J. Tousimis and L. Marton. Academic Press, New York, 1969, pp. 45-71. Equations are developed in this article to correct for fluorescence, fluorescence due to the continuum, and atomic number effect to provide a new approach to quantitative electron probe microanalysis.

OP 31-70. Hydrogen Sulfide Removal From Hot Producer Gas With Sintered Absorbents, by Forrest C. Shultz and John S. Berber. J. Air Pollution Control Assoc., v. 20, No. 2, February 1970, pp. 93-96. The Bureau of Mines prepared sintered mixtures of fly ash and either Fe_2O_3 or red mud which act as regenerable absorbents for removing H_2S from producer type gas in the 1,000 to 1,500° F temperature range.

OP 32-70. Analysis: Surface Mine Regulation, by David B. Brooks. Coal Mining and Processing, v. 7, No. 3, March 1970, pp. 38-51. The "cost" of surface coal mine regulation in Kentucky is investigated by measuring its impact on production, employment, and operating structure. Regression analysis indicates that this "cost" is higher in the mountainous east Kentucky field than in the level west Kentucky field; it is also higher for strip than for auger mining. Stricter regulation was also associated with increasing size and concentration of operation.

OP 33-70. Inerting and Extinguishment of Aerozine-50 With Water and/or CF_3Br , by D. S. Burgess, G. H. Martindill, J. N. Murphy, F. J. Perzak, J. M. Singer, and R. W. Van Dolah. J. Spacecraft and Rockets, v. 6, No. 11, November 1969, pp. 1259-1268. Two parts by weight of water per part of Aerozine-50 (A-50) will "inert" a spill of A-50 against ignition in air. In the case of a burning A-50 pool, the fuel evaporation rate is about 0.6 lb/min-ft² during most of the duration of burning, and a well-distributed spray of 1.2 lb water/min-ft² of liquid surface is sufficient for extinguishment. To inert an A-50 spill against hypergolic ignition with N_2O_4 , as much as 10 lb of water are required per lb of fuel, depending on the circumstances of mixing. In situations where use of large amounts of water may not be practical, CF_3Br (Halon 1301) can abate fire hazards; ~70 percent of CF_3Br in the atmosphere will inert a small spill at room temperature against ignition by spark or pilot flame. The same concentration would extinguish most secondary fires ignited by the hypergolic reaction of A-50 and N_2O_4 , but impractically high concentrations of CF_3Br would be required to extinguish an established A-50 pool fire or to inert the maximum vapor concentrations of A-50 possible in a closed chamber.

OP 34-70. The Calculation of Cathode Current Efficiency and Metal Loss in a Small Alumina Reduction Cell, by V. Anthony Cammarota, Jr., and David Schlain. J. Electrochem. Soc., v. 117, No. 2, February 1970, pp. 282-288. Experimental data from a small Hall

cell were used to show the relationship between the cathode current efficiency and the carbon monoxide-carbon dioxide content of the anodic gas. The equation, $CE = 0.45 (\text{percent CO}_2) + 47.6$ was developed and shown to give reliable estimates of aluminum production. In this equation, the volume-percent of carbon dioxide is corrected for the Boudouard reaction which varies in amount with anode type and operating conditions. A second and equally effective equation is, $CE = \text{Anode } CE - EL$, where Anode CE is based on the oxygen in the anodic gases and EL is metal efficiency loss resulting from solubility and vaporization. The minimum value of EL is the solubility of metal in the electrolyte, which in the small cell was estimated to be 0.12 percent. Calculations made with experimental and literature data show that under industrial conditions the Pearson and Waddington equation gives good estimates of cathode current efficiency, because the lower efficiency indicated by the excess carbon monoxide from the Boudouard reaction compensates for the EL factor.

OP 35-70. Measuring Electrodeposit Adhesion, by S. D. Cramer, V. A. Cammarota, Jr., and David Schlain. *Metal Finishing*, v. 68, March 1970, pp. 3-8. The Bureau of Mines developed a new test for measuring the adhesion of nickel electrodeposits on copper substrates. The proposed test involves brazing the free surface of the deposit to a steel rod with silver solder, machining this specimen to a desired shape, and then measuring the strength of the deposit-substrate bond by the application of a tensile load.

OP 36-70. Method for Controlling Instability of Liquid Saturation Computations, by C. Kenneth Eilerts and Eudora F. Sumner. *SPE J.*, v. 10, No. 1, March 1970, pp. 5-7. A method is described for controlling instability in finite difference computations of liquid saturation near the bore hole of a recovery well. Differences of pressure- and saturation-dependent variables are indexed offcenter, upstream and downstream alternately, to provide a stabilizing average. Employing this algorithm, it was found that size of the time step could be increased by a factor of 4 without loss of numerical stability.

OP 37-70. Sample Preparation and Electron Microprobe Examination of Lignite Ash Deposits, by Walter W. Fowkes, Thomas D. Wilhelm, and Wayne R. Kube. *Metallography*, v. 2, No. 2-3, September 1969, pp. 209-225. A suitable technique was developed for preparation of lignite ash deposits for electron microprobe examination. Prepared samples were analyzed for concentrations and distribution relationships of seven elements at four separate positions in the bulk deposit. Forty-two discrete groups of these elements were identified, each of which may represent more than one chemical compound.

OP 38-70. The Recovery of Elemental Sulfur From Base Metal Smelters, by D. R. George, L. Crocker, and J. B. Rosenbaum. *Min. Eng.*, v. 22, No. 1, January 1970, pp. 75-77. The Bureau of Mines developed a new system for recovering sulfur dioxide from smelter gases containing 0.3 to 2 percent SO_2 .

OP 39-70. The Enthalpies of Formation of Ethylenediamine, 1,2-Propanediamine, 1,2-Butanediamine, 2-Methyl-1,2-propanediamine, and Isobutyldiamine. The C—N and N—F Thermochemical Bond Energies, by William D. Good and Richard T. Moore. *J. Chem. and Eng. Data*, v. 15, No. 1, January 1970, pp. 150-154. The enthalpies of combustion of ethylenediamine, 1,2-propanediamine, 1,2-butanediamine, 2-methyl-1,2-propanediamine, and isobutyldiamine, as determined by oxygen-bomb com-

bustion calorimetry, were used to derive the following values, in kcal per mole, for the enthalpies of formation of the liquid, $\Delta H_f^\circ_{298.15}$, from graphite and gaseous hydrogen and nitrogen: ethylenediamine, -15.06 ± 0.13 ; 1,2-propanediamine, -23.38 ± 0.10 ; 1,2-butanediamine, -28.74 ± 0.19 ; 2-methyl-1,2-propanediamine, -32.00 ± 0.16 ; and isobutyldiamine, -31.68 ± 0.12 . These values were combined with enthalpies of vaporization derived from vapor pressure measurements to obtain values of the enthalpies of formation in the gaseous state. For these molecules, the C—N thermochemical bond energy was derived and compared to that in the simple alkyl amines. The N—H thermochemical bond energy in a 1,2-diamine was compared to the N—F thermochemical bond energy in a 1,2-bis(difluoroamino)-alkane.

OP 40-70. The Enthalpies of Combustion and Formation of 1,1-bis(Difluoroamino)heptane. The N—F Thermochemical Bond Energy, by William D. Good and Norris K. Smith. *J. Chem. and Eng. Data*, v. 15, No. 1, January 1970, pp. 147-150. The enthalpy of combustion of liquid 1,1-bis(difluoroamino)heptane was measured in a rotating-bomb calorimeter. The enthalpy of vaporization was estimated. The experimental enthalpy of combustion and the estimated enthalpy of vaporization were used to calculate the following values, in kcal per mole at 298.15° K, for this compound: standard enthalpy of formation of the liquid from graphite and gaseous hydrogen, fluorine, and nitrogen, -64.8 ; standard enthalpy of formation of the gas (estimated), -52.8 . The N—F thermochemical bond energy in 1,1-bis(difluoroamino)heptane was estimated to 67.3 kcal, about the same as the N—F thermochemical bond energy in NF_3 , N_2F_4 , and 1,2-bis(difluoroamino)-4-methylpentane, but several kilocalories less than the N—F thermochemical bond energy in perfluoropiperidine.

OP 41-70. Discussion of "General Motors Efforts in Junk Car Processing" by F. J. Uhlig, by Norwood B. Melcher. *Proc. Open Hearth Conf.*, v. 52, February 1970, pp. 88-90. The paper discussed describes the use of a ripper-shredder system for breaking up old automobile hulks and improvements that have been made in the removal of impurities. The discussion of the paper by N. B. Melcher compares Uhlig's results with other processes, discusses economics, and describes related research by the Bureau of Mines.

OP 42-70. Solid State Reversible Reactions of Square Planar d^8 Complexes With Sulfur Dioxide, by Eneo C. Moroni, R. A. Friedel, and Irving Wender. *J. Organometallic Chem.*, v. 21, 1970, pp. 23-27. Gaseous SO_2 reacts reversibly with solid square planar d^8 complexes. Addition of more than 1 mole of SO_2 per mole of complex is obtained. Evidence is presented that only 1 mole of SO_2 is attached directly to the central metal.

OP 43-70. A Comparison of Sublimation and Vaporization for Purification of Samarium Metal, by J. E. Murphy, E. Morrice, and M. M. Wong. *Proc. 8th Rare Earth Research Conf.*, v. 2, April 1970, pp. 532-544. Purification of samarium metal by sublimation and purification by vaporization from a low-melting metal flux are compared at the same temperature. Vaporization is more effective for removing impurities such as magnesium, calcium, and manganese. Recovery of samarium, however, is more rapid by sublimation because of its constant rate of distillation.

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- OP 44-70. Isolation Procedures for Kerogens and Associated Soluble Organic Materials**, by W. E. Robinson. In *Organic Geochemistry*. Springer-Verlag, Berlin and Heidelberg, Germany, 1969, pp. 181-195. Various methods used in the separation of kerogens and the associated bitumens are discussed. These techniques are used in the study of the structure of the insoluble kerogen and the soluble bitumen.
- OP 45-70. Infrared-Visible Window Composite for Ultrahigh Vacuum**, by Wallace W. Roepke. *Rev. of Sci. Instr.*, v. 41, No. 2, February 1970, pp. 243-244. This note describes a composite window design which will allow visual or photographic observation and permit ir irradiation of test materials simultaneously in an ultrahigh vacuum system. The uhv compatibility has been ascertained by irradiating the sealant materials with a CO₂ laser while monitoring desorbed species with a quadrupole mass spectrometer.
- OP 46-70. Total Sulfur**, by C. J. Thompson and C. S. Allbright. *Analytical Chemistry of Sulfur and Its Compounds*. Pt. 1, ed. by J. H. Karchmer. Wiley-Interscience, New York, v. 29, 1970, pp. 89-144. Methods are described for the determination of total sulfur in a variety of materials. Sampling, sample treatment, finished techniques, interfering substances, range and precision of the methods are discussed.
- OP 47-70. Composition and Properties of Vapors Over Molten Silver Chloride**, by A. Visnapuu and J. W. Jensen. *J. Less-Common Metals*, v. 20, February 1970, pp. 141-148. Mass spectrometer analyses of equilibrium vapors over molten AgCl between 772° and 1,014° K, indicate the existence of the vapor molecule Ag₃Cl₂ in addition to the monomer and trimer. The data predict the monomer concentration to increase with increasing temperature. "Second Law" heats of vaporization for the three vapor species are 41.4 ± 2.2 kcal mole⁻¹ for AgCl, 33.6 ± 3.2 kcal mole⁻¹ for Ag₃Cl₂, and 26.9 ± 2.7 kcal mole⁻¹ for Ag₅Cl₃. A value of -97.3 ± 7.1 kcal mole⁻¹ is derived for the heat of trimerization. A dissociation energy of 3.4 ± 0.4 eV (78.2 ± 9.2 kcal mole⁻¹) for the monomer vapor molecule and a dissociation energy of 0.7 eV (16.1 kcal mole⁻¹) for the molecular monomer ion is calculated from the appearance-potential data.
- OP 48-70. Separation of Neodymium, Samarium, and Gadolinium by Liquid-Liquid Chromatography**, by J. Oscar Winget and R. F. Lindstrom. *Proc. 8th Rare Earth Research Conf.*, v. 2, April 1970, pp. 788-801. Neodymium, samarium, and gadolinium were separated by a liquid-liquid chromatographic technique. Sulfuric acid was more effective than hydrochloric or nitric acid as an eluant with di(2-ethylhexyl) phosphoric acid (EHPA) as the stationary phase. Recovery of 45 percent of the neodymium as greater than 90 percent Nd₂O₃, 84 percent of the samarium as greater than 99 percent Sm₂O₃, and 50 percent of the gadolinium as greater than 99 percent Gd₂O₃ was achieved. The degree of separation and the time required for the separation can be varied by changing the concentration of the eluant and the number of stages in the system. A system comprising a primary amine organic extractant and an aqueous eluant containing diethylenetriaminepentaacetic acid (DTPA) was less effective for separating the rare earths.
- OP 49-70. Thermogalvanic Cells: Equations for Special States and Ionic Mobilities**, by P. B. Lorenz. *J. Electrochem. Soc.*, v. 117, No. 3, March 1970, pp. 314-318. Linear equations of irreversible thermodynamics are used to explore the characteristics of special states of the thermogalvanic cell and the behavior of individual ions.
- OP 50-70. International Offshore Leasing Practices**, by Alvin Kaufman. *J. Petrol. Technol.*, v. 22, March 1970, pp. 247-252. In formulating their leasing practices, some countries are interested in maximum government revenue, others in maintaining low prices, still others in the industrial spill-overs resulting from the development of a natural resource. As a consequence of these varied goals, the regulations differ greatly from country to country.
- OP 51-70. Limestone Resources, Washington County, Florida**, by L. E. Shirley and J. W. Sweeney. *Florida Department of Natural Resources, Bureau of Geology, Geol. Bull.* 50, 1969, pp. 101-161. Results of drilling, chemical analyses, and tests on several properties in the county indicate the presence of small to large quantities of limestone, suitable for a variety of purposes, including road construction and chemical uses. The deposits have sufficient length, width, and depth, as indicated from drilling exposures, to be attractive for further exploration. In the course of drilling, a clay deposit which may have potential for glazed brick and pottery was found and further exploration and tests on this property appear warranted.
- OP 52-70. Bigger Markets Mean More Preparation for Lignite and Subbituminous Coal**, by R. C. Ellman and J. W. Belter. *Min. Eng.*, v. 22, No. 3, March 1970, pp. 47-50. Present and future preparation of Western fuels is described and physical characteristics of these fuels discussed. Substantial improvements in quality can be achieved if processes being studied are commercially feasible and economically attractive.
- OP 53-70. Measuring Gaseous Emissions From an Aircraft Turbine Engine**, by J. O. Chase and R. W. Hurn. *National Air Transportation Meeting, Society of Automotive Engineers*, New York, April 20-23, 1970, SAE 700249, 8 pp. Aircraft turbine engines generate the same pollutants that are generated by automotive reciprocating engines, but problems of emission measurement differ greatly between the two types of engines. This is a discussion of experimental work done to define more clearly the character of the turbine emissions and to gain experience in sampling and measuring the emissions. An explicit objective was to evaluate the adequacy of available instrumentation and to reveal emission measurement problems unique to the turbine engine. Results of the study showed that concentrations of gas phase pollutants in the turbine exhausts ranged from about one to three orders of magnitude lower than average concentrations of the same materials in exhausts of late model (1960-69) autos. Instrumentation now available for measuring hydrocarbon, CO, and NO_x is expected to be adequate but will require appropriate adaptation for measurements at concentrations typical for turbine exhausts. As is the case in automotive application, a method fully suitable for oxygenated materials is not yet available.
- OP 54-70. Utilization and Stabilization of Solid Wastes**, by K. C. Dean, R. Havens, and E. G. Valdez.

Proc. 16th Ontario Industrial Waste Conf., Niagara Falls, Ontario, Canada, June 15-18, 1969, pp. 18-42. Solid mineral wastes from mines, mills, and smelters are potential or active contributors to air and water pollution and, together with accumulations of automobile scrap, detract from the beauty of our landscape. Bureau of Mines researchers are seeking means for utilizing or stabilizing mineral waste and for recycling or economic use of automobile scrap. Studies have been directed to (1) production of copper from dump leach solutions using shredded auto scrap as a cementation medium, (2) recovery of zinc from foundry dusts, (3) recovery of additional values from copper and uranium mill wastes, and (4) production of ceramic and construction materials from waste products. Stabilization studies employing physical, chemical, vegetative, and combination techniques also have been made. A 34-acre uranium waste accumulation has been stabilized using an elastomeric polymer and a calcium-magnesium lignin sulfonate as chemical stabilizers. Ten acres of copper mill tailings also have been effectively stabilized using a resinous adhesive compound in conjunction with selected vegetation in a combination chemical-vegetative method.

OP 55-70. Characterization of Carbonate Minerals in Oil Shales and Coals by Infrared Spectroscopy, by Patricia A. Estep, John J. Kovach, Arthur L. Hiser, and Clarence Karr, Jr. In *Spectrometry of Fuels*, ed. by R. A. Friedel. Plenum Press, New York, 1970, pp. 228-247. Experimental procedures and results are presented for the identification of a wide variety of individual carbonate minerals in oil shales and coals by infrared spectroscopy.

OP 56-70. Kinetic Evaluation of the Factor Used in the Saltzman Analysis of Oxides of Nitrogen, by Robert W. Freedman, B. A. Coulehan, and H. W. Lang. *Am. Indust. Hyg. Assoc. J.*, v. 31, January-February 1970, pp. 76-80. The Saltzman reaction, a modification of the Griess-Isovoy diazotization-coupling, is commonly used for analysis of oxides of nitrogen at air pollution levels. A factor is generally applied to the results to compensate for partial conversion to nonreactive nitrogen (V). A modification of the method used at the Bureau of Mines for the higher levels of oxides of nitrogen found in diesel exhaust yields quantitative results. An explanation for this is offered, based on rate studies of the gas-phase oxidation of nitric oxide to nitrogen dioxide.

OP 57-70. Explosive Detonation Tested in Hydraulically Fractured Gas Wells, by W. D. Howell and J. B. Hille. *J. Petrol Technol.*, v. 22, April 1970, pp. 403-408. In the tests described here, the well completed in open hole, which was extensively fractured vertically by hydraulic treatment, responded poorly to explosive fracture stimulation. Detonation through perforated casing, however, damaged only the joint of casing in the perforated interval, and improved flow capacity by 40 percent.

OP 58-70. Inverse Gas-Liquid Chromatographic Studies of Asphalt. Variations in Experimental Parameters, by F. A. Barbour, S. M. Dorrence, and J. C. Petersen. *Anal. Chem.*, v. 42, No. 6, May 1970, pp. 668-670. In this report, a study is made of variations in the experimental parameters in the IGLC technique, showing how these variations affect the retention behavior of the test compounds. The parameters considered are carrier-gas pressure and flow rate, column temperature, size of column packing, size of sample of test compound, possible column poisoning,

and presence of water in the test compounds. A revised method for calculating the interaction coefficient is presented.

OP 59-70. Public Policy and the Mineral Industry, by Alvin Kaufman. *Proc. Council of Economics*, AIME, Denver, Colo., Feb. 16-19, 1970, pp. 15-20. This brief discussion attempts to give a list of issues and concepts that have some involvement in public policy. The prime need is for policymakers as well as policy followers to see the mineral industry and its problems as they exist today.

OP 60-70. The Use of Disposable Hypodermic Syringes for Collection of Mine Atmosphere Samples, by Helen W. Lang and Robert W. Freedman. *Am. Indust. Hyg. Assoc. J.*, v. 30, September-October 1969, pp. 523-526. A variety of hypodermic syringes were tested for efficiency of sampling and storage of gases commonly encountered in mine atmospheres. Quantitative retention of fixed gases and methane was measured by gas chromatographic comparison with gas standards. The most suitable type of syringe was selected on the basis of efficiency and cost.

OP 61-70. Flame Propagation in Layered Methane-Air Systems, by Israel Liebman, John Corry, and Henry E. Perlee. *Combustion Sci. and Technol.*, v. 1, 1970, pp. 257-267. A study was made of flame propagation along methane-air roof layers using a laboratory-scale gallery, 8 feet long by 3 inches wide by 6 to 10 inches high. The effects of various environmental and gas layer factors on the speed of the propagating flame were determined and dimensional analysis techniques were used to develop a relationship between these factors and flame speed. The model was designed to study the early stages of flame propagation along a methane-air layer ignited at the closed end of a tunnel.

OP 62-70. Thermal Cracking of Low-Temperature Lignite Pitch, by Richard L. Rice, Delmar R. Fortney, and John S. Berber. *Ind. and Eng. Chem.*, v. 9, No. 1, March 1970, pp. 30-33. Low-temperature lignite pitch was thermally cracked in a 4-inch id reactor at 1,200° to 1,450° F. and pitch feed rates of 5.5, 7.0, and 9.5 pounds per hour to produce coke, oil, and gas. Temperature had a much greater influence on product yields than pitch feed rate. Highest coke yield (30 weight-percent) was obtained at minimum pitch feed rate and 1,450° F. Maximum oil yield (28 weight-percent) was obtained at the lowest feed rate and intermediate temperature (1,325° F.). Gas yield was highest (30 weight-percent) at the lowest feed rate and maximum temperature (1,450° F.).

OP 63-70. New Thermodynamic Equation for Testing Consistency of Liquid-Vapor Phase Equilibria Data, by Robert E. Barieau. *Ind. Eng. Chem. Fundamentals*, v. 9, No. 2, May 1970, pp. 298-299. The following new thermodynamic equation is derived

$$\sum_i v_i \left(\frac{d \ln f_i}{dP} \right)_T = \frac{V_T/n}{RT}$$

where v_i is the mole fraction of the i th component in the charge fed to an equilibrium cell, V_T is the total volume of the cell, n is the total number of moles in the cell, and f_i is the fugacity of the i th component, with liquid and vapor in equilibrium. This equation does not contain any of the thermodynamic properties of the liquid phase. It can be used to test an assumed equation of state for the

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ability to calculate consistent fugacities for the vapor phase. For a two-component system, the derivatives, $(d \ln f_i/dP)_T$, along the coexistence curve, can be determined from phase equilibrium data and used to calculate the molal volumes of the liquid and vapor phases.

OP 64-70. Recovery of Metallurgical Values From Industrial Wastes, by Paul G. Barnard, Andrew A. Cochran, and Lawrence C. George. Proc. 2d Mineral Waste Utilization Symp., jointly sponsored by the U.S. Bureau of Mines and IIT Research Institute, Chicago, Ill., Mar. 18-19, 1970, pp. 7-14. Various industrial problems encountered in research on materials recycling are described. Some were solved by simple methods that promised quick economic return. Lack of laboratory facilities is often a deterrent to industrial problem solving. A novel method is presented for recycling the components of scrap cemented carbides by soaking them in molten zinc and then extracting the zinc by vacuum distillation. Results of investigation of two processes for recovery of metals from electroplating wastes are discussed. One leads to the selective recovery of high-purity nickel sulfate and copper from a waste nitric acid rack-stripping solution by controlled-potential electrolysis and selective precipitation with pH control. In the other, organic-cyanide stripping waste is treated with the nitric acid stripping waste, precipitating nickel, copper, and cyanides. Subsequently, copper is recovered by electrolysis, and nickel sulfate solution is sufficiently purified to recycle in a plating bath.

OP 65-70. X-Ray Absorption and Emission, by William J. Campbell and John V. Gilfrich. Anal. Chem. Ann. Rev., v. 42, No. 5, April 1970, pp. 248R-268R. This 1969 review consists of a critical evaluation of new developments and tabular summaries of X-ray spectrography, energy dispersion X-ray analysis using radioactive isotopic sources, and electron probe microanalysis. A 546-item bibliography is included.

OP 66-70. Pyrolysis, Hydrogenation and Incineration of Municipal Refuse—A Progress Report, by Richard C. Corey. Proc. 2d Mineral Waste Utilization Symp., jointly sponsored by the U.S. Bureau of Mines and IIT Research Institute, Chicago, Ill., Mar. 18-19, 1970, pp. 299-312. Carbonization, hydrogenation, and incineration studies are being made on a solid municipal refuse that is highly cellulosic. Carbonization is being done batchwise at 500° C (932° F), 750° C (1,382° F) and 900° C (1,650° F), and the yields and composition of the product chars, tars, oils, and gases are being determined. Depending on the carbonization temperature, a ton of dry refuse would yield up to 18,000 cu ft of gas with 6 million Btu available, up to 230 lb of char with 1.8 million Btu available, and up to about 6 gal of tar and light oil. Hydrogenation of the same refuse is being effected with carbon monoxide and water batchwise at 4,000 psig and 380° C (716° F). Initial results indicate that a ton of dry refuse would yield about 2.4 barrels of oil that is largely paraffinic. Comparative hydrogenation studies are also being made with molecular hydrogen, with and without catalysts. Using tangential overfire air to produce a vortex flow pattern above the charge, a continuous flow of shredded refuse is being incinerated, aiming to obtain basic design data on the optimum air velocity and nozzle geometry for maximum combustion efficiency and particulate retention, and for minimum excess air.

OP 67-70. The Enthalpies of Combustion and Formation of the Isomeric Pentanes, by W. D. Good, J.

Chem. Thermodynamics, v. 2, 1970, pp. 237-244. The enthalpies of combustion of the three isomeric pentanes were measured by oxygen-bomb combustion calorimetry. The following values, based on the mass of carbon dioxide produced, are reported* for the standard enthalpy of combustion ΔH_c (298.15° K)/kcal mol⁻¹ of these compounds in the liquid state: *n*-pentane, $-(838.69 \pm 0.16)$; 2-methylbutane, $-(837.57 \pm 0.20)$; 2,2-dimethylpropane, $-(834.71 \pm 0.14)$. These results were compared with modern values obtained by flame calorimetry. Older experimental results were reviewed, and "best values" of the enthalpies of combustion were selected. These selected values were compared with the enthalpies of combustion predicted by modern correlative procedures.

OP 68-70. Foundry Iron Production From Automobile Scrap, by Warren M. Mahan. Proc. 2d Mineral Waste Utilization Symp., jointly sponsored by the U.S. Bureau of Mines and IIT Research Institute, Chicago, Ill., Mar. 18-19, 1970, pp. 67-68. Test work on the production of foundry iron using automobile scrap has been conducted by the Federal Bureau of Mines in an 18-inch 1-ton basic-lined cupola furnace using preheated air. A statistically designed experiment is being used to determine best operation for the cupola and to determine the effect of operating variables upon responses. Various forms of automobile scrap have been used, but emphasis has been on the use of the heavy-melting scrap by-product from the Bureau's rotary kiln test program.

OP 69-70. Chemical Thermodynamic Properties of the Pentadienes. Third Law Studies, by J. F. Messerly, S. S. Todd, and G. B. Guthrie. J. Chem. and Eng. Data, v. 15, No. 2, April 1970, pp. 227-232. The chemical thermodynamic properties of the seven pentadienes are determined from adiabatic calorimetric studies over the range 12° to 320° K. Properties measured include the heat capacities in the solid and liquid state, heats of fusion, melting points, and purities of the samples. The heats of vaporization at 298.15° K are calculated from vapor pressure data, and the entropies of all seven pentadienes in the ideal gas state at 298.15° K are determined. Free energies of formation and the logarithm of the equilibrium constants of formation at 298.15° K are calculated.

OP 70-70. New Developments in Use of Ferrous Scrap, by Charles Prasky. Proc. 2d Mineral Waste Utilization Symp., jointly sponsored by the U.S. Bureau of Mines and IIT Research Institute, Chicago, Ill., March 18-19, 1970, pp. 59-66. This paper describes recent progress at the Bureau of Mines Twin Cities Metallurgy Research Center on the development of roasting procedures emphasizing the consumption of solid waste materials in a rotary kiln system. One phase of the research concerns the use of ferrous scrap as a reductant for the conversion of lean nonmagnetic iron ores to the magnetic form. Additional reduction research shows that other solid waste materials, such as municipal refuse and sewage sludge are also effective for the conversion of the nonmagnetic iron ores. Another phase of the Center's research concerns the treatment of ferrous scrap such as automobile hulks without accompanying iron ore to yield coproducts of high-grade iron oxide and dense residual steel scrap of high purity. The novel use of solid waste as a reductant is of potential value to the iron mining industry, and the direct roasting of ferrous scrap provides an effective method for the scrap processor to handle automobile hulks.

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OP 71-70. A Decline Curve Pitfall Using Least-Squares Solution, by Leo A. Schrider and Richard E. Cerullo. *J. Petrol. Technol.*, v. 22, April 1970, pp. 441-442. In this letter to the JPT Forum, the writer points out the weighting produced by logarithmic transformation.

OP 72-70. A Progress Report on the Implementation of Public Law 89-577, by Henry P. Wheeler. *Proc. Nat. Safety Cong.*, v. 16, 1969, pp. 20-22. This paper discusses the standards promulgated pursuant to the enactment of Public Law 89-577, the enforcement of these standards, and the part that the Bureau of Mines will play in inspection of mines and enforcement of these standards in cooperation with the various States.

OP 73-70. Storage Stability of High Temperature Fuels. Part III. The Effect of Storage Upon Thermally Induced Deposition of Selected Fuel Components and Additives, by M. L. Whisman, John W. Goetzinger, and Cecil C. Ward. *Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, Ohio, Tech. Rpt. AFAPL-TR-68-32, Pt. III*, June 1970, 85 pages. The Bureau of Mines investigated the contribution of selected components and additives of high-temperature aircraft fuels to thermally induced deposits before and after 52 weeks of storage at 130° F. Of particular concern was the influence of fuel constituents on thermal stability quality of jet fuels during storage. A microfuel coker test apparatus was used to measure the thermal stability of test fuels and blends. The contribution of selected fuel components, labeled with carbon-14, to deposit-forming mechanisms was determined by radioactive-counting techniques. Twenty-eight blends of the five test fuels with carbon-14-labeled fuel additives or components reached the final stage of storage at 130° F and received final analyses for deposit forming tendency. These additives included an amine-type antioxidant, a metal deactivator, and a corrosion inhibitor. Also included in this study group were oleic acid and 1,5-hexadiene. All three additives showed a marked tendency to degrade and react during storage and thermal stress. Oleic acid was found to interact with cadmium present in aircraft fuel systems and produce deleterious effects upon the thermal stability quality of the fuel. Sixteen blends of the five test fuels with nonradioactive components were prepared as part of a special study. Six of these blends contained 1 percent of selected aromatic compounds, five blends contained an anti-icing additive, and five blends contained an organic sulfur compound. Results showed changes in thermal stability quality of many of the blends containing sulfur compounds. Four additional special studies were performed as preliminary investigations to continued research of jet fuel stability characteristics. Both were designed to improve procedures or develop new, improved procedures for thermal stability tests.

OP 74-70. Index to Names of Oil and Gas Fields in Oklahoma, 1968, by O. C. Blade. *Mid-Continent Oil & Gas Association, Kansas-Oklahoma Division*, May 1969, 313 pp. The names of about 3,700 oil and gas areas in Oklahoma are listed according to assignments made by the Oklahoma Nomenclature Committee of the Kansas-Oklahoma Division, Mid-Continent Oil & Gas Association. Included are 2,300 current names of oil and gas fields with description of location by county, township, range, and section; 1,400 discontinued names of areas that have been combined with other fields with brief statements of the disposition of such names; and the date when each field was named.

OP 75-70. Effect of Additives on Phase Diagrams: Normal Butane Added to Condensate-Natural Gas System, by Byron A. Baker and C. Kenneth Eilerts. *Producers Monthly*, v. 32, No. 12, December 1968, pp. 8-15. The effect on phase-boundary pressures of a related series of condensate mixtures of additions of normal butane was determined with a windowed PVT cell. The investigation was conducted at pressures up to 5,000 psia and at temperatures in the range of 70° to 310° F. Relationship of the critical state to changing compositions was evaluated. The fluids were a mixture of intermediate hydrocarbons and selected distillation cuts from a field condensate combined with mole fractions of natural gas in the range 0.800 to 0.933. The data were subjected to statistical analysis using a computing program that provided a polynomial for interpreting the results. The polynomial yields phase-boundary pressures, and independent variables are temperature, natural gas content, and mole fractions of normal butane additive. A method is described for approximating such a polynomial before measurements are complete using a mathematical model that requires more measurements than are available.

OP 76-70. Storage Stability of High Temperature Fuels. Part I. Micro Fuel Coker Tests of Fuel-Radiotracer Blends Before Storage, by M. L. Whisman and C. C. Ward. *Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, Ohio, Tech. Rpt. AFAPL-TR-68-32, Pt. I*, March 1968, 94 pp. This report describes investigation of the influence of fuel constituents during storage on thermal stability of high-temperature hydrocarbon jet fuels. This study was initiated utilizing a micro fuel coker test apparatus to measure the thermal stability of fuels and the contribution of selected fuel components, labeled with radiotracers, to deposit-forming reactions. Forty-one blends using 5 fuels and 9 radioactive fuel components were prepared, given initial tests and stored at 130° F. Aliquots of the 5 test fuels were depolarized by silica gel percolation, and test blends were prepared from these treated fuels for comparison with untreated blends. In a third series of tests, contaminants in the form of red iron oxide and water were added to fuel-radiotracer blends.

OP 77-70. Determination of the Optical Properties of Absorbing Uniaxial Crystals From Reflectance at Oblique Incidence, by M. Berman, H. R. Kerchner, and S. Ergun. *J. Optical Soc. of America*, v. 60, No. 5, May 1970, pp. 646-648. Equations are presented for determining the optical properties of an absorbing uniaxial crystal by measuring the reflectance from a basal plane as a function of the angle of incidence and the angle of polarization. The technique is applied to a pyrolytic graphite crystal to determine the optical properties at 632.8 nm. The results are calculated numerically by use of a combination of the Taylor-series and gradient methods. The best-fit values found for the optical constants of pyrolytic graphite at 632.8 nm are $n_o=2.55$, $n_e=1.78$, $\kappa_o=0.66$, and $\kappa_e=0.00$.

OP 78-70. The Effect of Air/Fuel Level in the MHD Generator on the Operation of an Open-Cycle MHD-Topped Power Plant, by H. F. Feldmann, W. H. Simons, and D. Bienstock. *Energy Conversion*, v. 10, No. 2, April 1970, pp. 89-91. Operating a magnetohydrodynamic (MHD) generator at below stoichiometric air/fuel ratios and injecting additional air downstream of the MHD generator has the advantage of increased power density and reduced air preheat temperature without loss of overall plant thermal efficiency.

OP 79-70. Kinetics of Recovering Sulfur From the Spent Seed in a Magnetohydrodynamic (MHD) Power Plant, by H. F. Feldmann, W. H. Simons, J. J. Gallagher, and D. Bienstock. *Environmental Sci. and Technol.*, v. 4, No.

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6, June 1970, pp. 496-502. A process which removes the sulfur as hydrogen sulfide from the seed-slag mixture in MHD power generation is described. A kinetic interpretation of the experimental data is presented.

OP 80-70. Coal-Like Substances From Low-Temperature Pyrolysis at Very Long Reaction Times, by R. A. Friedel, J. A. Queiser, and H. L. Retcofsky. *J. Phys. Chem.*, v. 74, No. 4, Feb. 19, 1970, pp. 908-912. The importance of long reaction times in the coalification process has been demonstrated in the laboratory. Samples of cellulose and pine sawdust in evacuated, sealed glass vials have been heated at 200° C for 2 years. Black coal-like chars were produced; conventional heating at 200° C for hours produces very little chemical change. The chars were characterized by infrared and electron spin resonance spectra and by ultimate analysis. The infrared spectra of the pine sawdust char and of a subbituminous coal are nearly identical, except for differing carbonyl absorption. The spectrum of the cellulose char is also similar to that of the subbituminous coal. The electron spin resonance (esr) results show that *g* values, lines widths, and spin concentrations are very similar for the two chars, and resemble closely the corresponding values for subbituminous coal. 200° C is considered a reasonable coalification temperature; a feasible depth of burial can provide such temperatures. The experimental coalification obtained in only 2 years supports the hypothesis that geologic time could produce all ranks of coal, from lignite to anthracite, at temperatures below 200° C.

OP 81-70. Chemical Composition of Progressive Pyridine Extracts From Coal, by R. A. Friedel, J. L. Shultz, and A. G. Sharkey, Jr. *Fuel*, v. 47, No. 5, 1968, pp. 403-407. Progressive extraction consists of partial extractions of a single coal sample carried out consecutively with fresh batches of a single solvent. Progressive extraction of coal with pyridine has shown, by mass spectral and other analyses, that different constituents predominate at different stages of the extraction. Alkylbenzenes and phenols are prominent in the first extract; polynuclear aromatics are mainly extracted later. The order of extraction is important in the mechanisms of extraction of coals. Quantitative infrared absorption shows higher amounts of CH bonds in the extracts than in the residues. Also, all of the spectral bands of the extracts are more intense and better defined than the bands of the residues.

OP 82-70. Iron Ore Flotation—1969, by D. W. Frommer. *J. Am. Oil Chem. Soc.*, v. 47, No. 6, June 1970, pp. 189-192. Current flotation practice in the iron ore industry is reviewed with special attention given to gains made since 1966. Known applications are described with estimates of tonnage treated, the degree of beneficiation achieved, and the quantity and types of reagents used. Apparent trends and prospects for new applications of flotation in the iron ore industry are discussed.

OP 83-70. Gasflood Improves Appalachian Recovery, by K.-H. Frohne. *Petrol Eng.*, v. 42, No. 7, July 1970, pp. 79, 82, 84. The Bureau of Mines has been investigating the susceptibility of Appalachian oil reservoirs to various improved recovery methods. One study showed that gasflooding of the Cooper Sand of the Fork Run pool in Pennsylvania would result in the economic recovery of 1,753,000 barrels or 21 percent of the 8,200,000 barrels of oil in place at the beginning of the flood.

OP 84-70. Spectrochemical Method for the Analysis of Miscellaneous Materials, by Robert C. Gabler, Jr., and Maurice J. Peterson. *Appl. Spectroscopy*, v. 24, No. 3, May-June 1970, pp. 354-358. A spectrochemical method was developed for the analysis of solid waste products and other miscellaneous inorganic materials. Copper oxide and graphite are employed as diluents, and excitation is

by means of a sustaining ac arc in a controlled atmosphere for the determination of minor and trace elements. A complementary procedure using spark excitation of a rotating pellet prepared from the same material as used for the arc methods provides for the determination of major constituent elements. Relative standard deviations are about ±10 percent and the accuracy is in the same range. The methods have been successfully applied to the analysis of iron and steel, aluminum, zinc, lead, and copper alloys, fly ash, fume deposits, and silicates.

OP 85-70. A Two-Circle Goniometer for Establishing Angular Coordinates on Spherical Specimens, by K. E. Hjelmstad. *J. Phys. E: Sci. Instr.*, v. 3, 1970, pp. 246-247. The two-circle goniometer described precisely marks an angular coordinate system of meridians and parallels on the surface of spherical rock specimens. Physical property data obtained with respect to this frame of reference then can be accurately transferred on to a Schmidt (equal area) net and contoured with isolines to give the symmetry and magnitude of anisotropy of the physical property.

OP 86-70. Coal Pyrolysis Using Laser Irradiation, by F. S. Karn, R. A. Friedel, and A. G. Sharkey, Jr. *Fuel*, v. 48, No. 3, 1969, pp. 297-304. Coal pyrolysis at coking temperatures yields gases that are high in methane but very low in acetylene. Coal irradiated with laser light can produce gases rich in acetylene. The acetylene-to-methane ratio was shown to be related directly to the light flux at the surface of the decomposing coal. Temperatures cannot be measured directly, owing to the small crater size and the short duration of the laser pulse, but were estimated from equilibrium data. Temperatures can be changed by varying the energy of the laser beam, the laser focus, and the type of laser (ruby, neodymium, carbon dioxide). As the light flux increased from 190 W cm⁻² to 375 kW cm⁻², the C₂H₂/CH₄ ratio increased from zero to 3.6 for Pittsburgh seam (hvab) coal. Based on the gas composition and using published equilibrium data, temperatures were estimated as 1,160° to 1,250° K. Product gases were studied as a function of coal rank, particle size, and maceral.

OP 87-70. Ultrasonic Solvation of Coal in Quinoline and Other Solvents (Letter to the Editor), by T. Kessler, R. A. Friedel, and A. G. Sharkey, Jr. *Fuel*, v. 47, No. 2, 1970, pp. 222-223. The purpose of this letter is to report the high yield of dissolved material obtained by the extraction of coal in quinoline using ultrasonic energy. Seventy-nine percent of Pittsburgh seam hvab coal was dissolved by irradiating a coal-solvent slurry at approximately 36° C for 24 hours.

OP 88-70. Composition of Pyridine Extracts From Reduced and Untreated Coals as Determined by High-Resolution Mass Spectrometry, by T. Kessler, R. Raymond, and A. G. Sharkey, Jr. *Fuel*, v. 48, No. 2, 1969, pp. 179-186. High-resolution mass spectrometric analyses of pyridine extracts from reduced and untreated coals support reasons advanced by Reggel and co-workers for the increased solubility of reduced coals. High-resolution data on the reduced coal show evidence for (1) an increase in the volatile oxygenated compounds that may result from splitting of ether linkages in the coal, (2) a substantial reduction of sulfur in the coal, (3) the formation of smaller and more soluble coal units or 'molecules', and (4) the formation of hydroaromatic compounds.

OP 89-70. Carbothermal Reduction of Siliceous Minerals in Vacuum, by S. E. Khalafalla and Larry A. Haas. *High Temperature Sci.*, v. 2, June 1970, pp. 95-109. Carbothermal reduction of various quartz- and silicate-graphite mixtures was studied in a batch reactor at a pressure of about 0.01 torr and a temperature of 1,400° C. The extent of reaction was determined by the quantity

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of carbon consumed in a 5-hour period. Maximum reactivity occurred with particles having diameters of about 0.2 mm. At this reactant size, the bed porosity was sufficient to permit escape of carbon monoxide from the reaction site while securing maximum interparticle contact. The maximum reactivity occurred with a quartz-graphite molar ratio of 1 or weight ratio of 5. Carbothermal reducibilities of some 20 silicate minerals were studied at a fixed mineral-to-graphite weight ratio of 5. The millimoles of carbon consumed or carbon monoxide formed in 5 hours increased systematically with the fraction of silicon dioxide in the silicate when the mineral remained in the solid state at the reaction temperature. Silicates that melted at the reaction temperature reduced less readily than those that remained in the solid state. Carbothermal reducibility as well as free energy considerations show that complex silicates behave like weakly associated aggregates of simpler oxide groups. Therefore, the energy to dissociate the complex silicates is small, and the bulk of the energy goes to winning the oxygen from the metal and breaking up the individual oxide groups. Hence the influence of structure on reducibility is insignificant and is easily overrun by the silicate chemical composition.

OP 90-70. Technical Consideration for Plowshare Applications to Oil Shale, by D. B. Lombard, B. G. Bray, and H. W. Sohns. Proc. Symp. on Engineering With Nuclear Explosives, Las Vegas, Nev., Jan. 14-16, 1970, v. 2, CONF-700101, May 1970, pp. 1343-1363. This paper describes a variety of technical problems which must be solved before the use of nuclear explosives for recovering shale oil from deep oil shale deposits will be commercially feasible.

OP 91-70. Oil Shale Research Related to Proposed Nuclear Projects, by H. C. Carpenter, H. W. Sohns, and G. U. Dinneen. Proc. Symp. on Engineering With Nuclear Explosives, Las Vegas, Nev., Jan. 14-16, 1970, v. 2, CONF-700101, May 1970, pp. 1364-1375. This paper discusses research relating to the use of nuclear explosives for processing oil shale, particularly resource evaluation and shale oil recovery engineering studies.

OP 92-70. Disaggregation of Sandstones by Ultrasonic Energy, by W. K. Overbey, Jr., and B. R. Henniger. J. Sedimentary Petrology, v. 40, No. 1, March 1970, pp. 465-472. A rapid method of disaggregating sandstones was investigated, with emphasis on reducing specimens to individual grains without destroying surficial or volumetric parameters. Specific quantities of samples were used to test three ultrasonic generators with focused horns utilizing varying degrees of acoustical intensity and frequencies for preset periods of time. Results indicate that (1) ultrasonic energy with acoustical power input between 55 and 100 watts per cm² and a frequency of 10 to 20 kilocycles per second can be successfully used to disaggregate friable to moderately cemented sandstones, (2) lower frequencies and higher intensities promote disaggregation and reduce the time required, and (3) rate of disaggregation is a function of the type of cementing materials involved, and may be controlled by the shape and volume of irradiation chamber and the pressure within the chamber.

OP 93-70. Hydrocarbon Production and Fracture Systems, by W. K. Overbey, Jr., and J. Pasini III. Proc. Spring Meeting, Eastern District Division of Production, API, Evansville, Ind., Apr. 15-17, 1970, Paper 826-41-B, 26 pp. The Morgantown Petroleum Research Laboratory, Bureau of Mines, Morgantown, W. Va., is investigating subsurface fracture systems in hydrocarbon reservoirs to better locate and space wells for more efficient hydrocarbon recovery and gas storage. The results of analyses of surface and subsurface data show a correlation between surface lineations and the subsurface frac-

ture patterns. The association of these fracture systems with various geologic processes and techniques for surface mapping of lineations is discussed. Fracture systems in many fields control the movement of fluids in hydrocarbon producing reservoirs. Remote-sensing techniques show promise in delineating these fracture systems. The importance of fractured reservoirs to future hydrocarbon production is emphasized.

OP 94-70. ¹³C and ¹H Nuclear Magnetic Shieldings and Electrical Effects of Ortho Substituents in Monosubstituted Pyridines, by H. L. Retcofsky and F. R. McDonald. Tetrahedron Letters, No. 21, 1968, pp. 2575-2578. Since magnetic shieldings of ¹³C and ¹H nuclei in the *para*-positions of monosubstituted benzenes have been found to correlate well with Hammett ρ_n constants, the Bureau of Mines undertook the measurement of the shielding of the corresponding atoms, i.e., those in the 5-positions, in 2-substituted pyridines to investigate the electrical effects of *ortho*-substituents in monosubstituted pyridines.

OP 95-70. Spectral Studies of a Carbon Disulfide Extract of Bituminous Coal, by H. L. Retcofsky and R. A. Friedel. Fuel, v. 47, No. 6, 1968, pp. 487-498. The structure of the carbon disulfide extract of vitrain-rich Pittsburgh coal (hvab-82.6 percent C) was studied by various spectral techniques. The carbon disulfide-soluble material, which represented approximately 4 percent of the original coal, was obtained by extracting the coal with pyridine followed by extraction of the pyridine-soluble material with carbon disulfide. Both the pyridine and the carbon disulfide extracts were studied by ultraviolet-visible and infrared spectrophotometry and by electron and proton magnetic resonance. The carbon-13 magnetic spectrum of the carbon disulfide extract was also obtained. This represents the first application of this relatively new spectral technique to a coal extract and permitted direct measure of the aromaticity. The mean structural unit in the carbon disulfide extract was found to consist of two to three polynuclear condensed aromatic rings, with 0.4 of the available aromatic edge carbons bearing alkyl, phenolic, and/or naphthenic groups.

OP 96-70. Carbon Black From Low-Temperature Lignite Pitch, by Richard L. Rice, Robert E. Lynch, and John S. Berber. Rubber World, v. 162, No. 2, May 1970, pp. 66-69. Low-temperature lignite tar pitch was found to be a suitable feedstock for producing carbon black by thermal decomposition in pilot plant combustion equipment. Yields ranged from 16.5 percent at 1,800° F to 37 percent at 2,500° F, and the product compared favorably with commercial-grade carbon black.

OP 97-90. Coal Science Today, by A. G. Sharkey, Jr. Research/Development, v. 20, No. 2, 1968, pp. 28-30. This paper summarizes the topics discussed at the 7th International Conference on Coal Science held in Prague, Czechoslovakia, June 10-14, 1968. Twenty countries were represented by 222 official participants. The topics of the five sessions of the conference were as follows: (1) Physical structure and properties of coal and coke, (2) chemical constitution of coal, (3) chemical properties and reactions of coal and coke, (4) pyrolysis and coking, and (5) gasification and combustion. The meeting provided much new information, not only to the scientist interested in coal chemistry but also to the technologist concerned with the processing of coal.

OP 98-70. Laser Irradiation of Oxidized Coals (Letter to the Editor), by A. G. Sharkey, Jr., A. F. Logar, and F. S. Karn. Fuel, v. 48, No. 1, January 1969, pp. 95-96. The purpose of this communication is to describe use of a low-power CO₂ gas laser to investigate the surface of mildly oxidized coals. While it is well established that water vapor, carbon dioxide vapor, and carbon monoxide are major products from the pyrolysis of oxi-

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dized coal, little is known about other gaseous products and, in particular, about gases derived from surface components. Irradiation with laser light provides a means of limiting vaporization and pyrolysis to surface materials.

OP 99-70. Thermal Instability of Hydroaromatics—Limitation on Quantitative Mass Spectrometric Analyses, by J. L. Shultz. *Spectroscopy Letters*, v. 1, No. 8 and 9, 1968, pp. 345-347. Discrepancies in the determination of anthracene in dihydroanthracene were revealed when mass spectrometric analyses were compared with ultraviolet spectrophotometric data. A limited investigation indicated that dehydrogenation of the hydroaromatic in the mass spectrometer inlet system can be minimized but not eliminated. A combination of both ultraviolet and mass spectrometric analyses will be necessary to determine the components present in samples containing hydroaromatic structures.

OP 100-70. Evaluation of Electrode Binder Pitch by Mass Spectrometry, by J. L. Shultz, R. A. Friedel, and A. G. Sharkey, Jr. *Fuel*, v. 49, No. 2, 1970, pp. 175-179. Mass spectrometric data for the ratio of unsubstituted to alkyl-substituted aromatics in electrode binder pitches of coke-oven origin correlate with the pitch quality index and an overall ranking of the pitches based on numerous tests. The importance of several structural parameters (based on mass spectrometric data) in determining the suitability of binder pitch was investigated. This method of judging electrode binder pitches could provide a rapid screening for quality, eliminating many of the physical tests and chemical analyses now used.

OP 101-70. High-Resolution Mass Spectrometric Investigation of Heteroatom Species in Coal-Carbonization Products, by J. L. Shultz, T. Kessler, R. A. Friedel, and A. G. Sharkey, Jr. *Proc. ASTM Committee E-14 Meeting on Mass Spectrometry and Allied Topics*, May 1968, pp. 359-361. This investigation of the high-resolution mass spectra of coal-tar pitch and a concentrate containing the heteroatom species has resulted in the detection of approximately twice the number of structural types previously reported in the literature. Application of the high-resolution mass spectrometric technique in detecting changes in the concentration or composition of organic structures in complex mixtures has also been demonstrated by the studies of weathered road tars and coke-oven pitches. The concentration of organic structures containing oxygen increases more rapidly than other classes of organic compounds in tars weathered on road surfaces. Data obtained for polynuclear aromatic ring systems in two coke-oven pitches indicate that the degree of condensation as well as the average molecular weight and average number of rings per structural unit could be a factor in determining reactivity of pitches. The ratio of peri-condensed to cata-condensed aromatic hydrocarbons was 50 percent higher for the low-reactivity pitch than for the average-stability pitch investigated.

OP 102-70. High-Resolution Mass Spectrometric Study of Weathered Road Tars, by Janet L. Shultz, A. G. Sharkey, Jr., and R. A. Friedel. *J. Appl. Chem.*, v. 20, April 1970, pp. 126-128. Fractions of road tars of coke-oven and vertical retort origin were examined by high-resolution mass spectrometry before and after exposure to road conditions. Molecular formulae and relative concentrations were determined for eleven series of peaks. A progressive increase in the proportion of components of high molecular weight (> mass 200) was indicated with exposure to road conditions. In the high-molecular-weight range, the heterocyclic structures containing oxygen showed larger increases than the polynuclear aromatic hydrocarbons.

OP 103-70. K Emission Band of Graphite (Letter to Editor), by P. L. Walker, Jr., and J. M. Thomas.

Carbon, v. 8, 1970, pp. 101-103. This letter to the editor compares the K emission spectra obtained by Sagawa and other scientists with that obtained by the Bureau of Mines using an electron probe X-ray microanalyzer.

OP 104-70. Fire-Assay Emission Spectrographic Method for Platinum, Palladium, Rhodium, and Gold, by A. B. Whitehead and H. H. Heady. *Appl. Spectroscopy*, v. 24, No. 2, March/April 1970, pp. 225-228. A method has been developed for the determination of microgram levels of Pt, Pd, Rh, and Au. A 10-mg Ag bead containing the precious metals, as extracted by fire assaying, is arced at 10 A dc in graphic electrodes in the presence of 10 mg of either Rh or Pt metal powder. The matrix elements, Ag and Pt, or Rh, serve as internal standards, and intensity ratios Pt/Rh or Rh/Pt, Pd/Rh, and Au/Ag are determined. Precision of the method is about ± 5 percent coefficient of variation for Pt and Rh, ± 15 percent for Pd, and ± 19 percent for Au. Limits of detection are below 1 μ g, giving analysis limits (for a 1-assay-ton sample) of about 1 to 30 parts per billion for these precious metals.

OP 105-70. Rapid Mounting of Particulate Samples for Use in Scanning Electron Microscopy, by R. J. Willard and K. E. Hjelmstadt. *Power Technol.*, v. 3, No. 5, 1969/70, pp. 311-313. Particulate samples can be mounted readily for use in a scanning electron microscope by first depositing particles on doubleback adhesive tape attached to a metal slug and then coating with conductive metal. Coal dust was used to illustrate this technique. Since particles are not embedded in the tape, particle size can be measured reliably and accurate shape characterization is feasible.

OP 106-70. Neutron-Induced Autoradiography of Lithium Silicate Glasses, by F. W. Wood and A. H. Roberson. *J. Materials Sci.*, v. 5, No. 5, May 1970, pp. 425-433. Immiscibilities between silica and lithium disilicate were investigated. Alpha particles ejected from ^6Li atoms by thermal neutrons were used to autoradiograph surfaces representing diffusion-zone cross sections. Etchant-enlarged alpha tracks in nitrocellulose disclosed the distribution of lithium. For autoradiography, procedural details were established, suitable operating conditions were selected, and the method was calibrated. For diffusion, adequate couples had to be prepared. Subsequent experiments indicated phase separations along an 885° C isotherm of the silica-lithium disilicate system. There was evidence of metastable compositions near 30, 25, 20, 16, 11, and 7 mole-percent of lithia in silica. These results have been given a very tentative interpretation: The first two compositions may correspond to metastable extensions of liquidus boundaries, projected through a eutectic point of the system. The third and sixth compositions are probably points on a liquid-liquid miscibility boundary, and the fourth and fifth compositions could be on an associated spinodal boundary.

OP 107-70. In Situ Recovery of Copper from Sulfide Ore Bodies Following Nuclear Fracturing, by Joe B. Rosenbaum and W. A. McKinney. *Proc. Symp. Engineering With Nuclear Explosives*, Las Vegas, Nev., CONF-700101, 1970, v. 2, pp. 877-887. This paper explores the concept of in-place leaching of nuclear fractured, deeply buried copper sulfide deposits. On the assumption that fracturing of rock and solution injection and collection would be feasible, an assessment is made of solution systems that might be employed for the different copper sulfide minerals in porphyry ore bodies. These include the conventional ferric sulfate-sulfuric acid systems and combinations of sulfide mineral oxidants and different acids.

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OP 108-70. Programmes for the Price Optimum Design of Heat Exchangers, by S. Katell and P. R. Jones. *British Chem. Eng.*, v. 15, No. 4, April 1970, pp. 491-494. Because heat exchangers are expensive items and often account for a high proportion of the total cost of a plant, the incentives to optimize their design are considerable. The computer programs described in this article are for the optimum design for four important situations: (1) no change in phase, pumping costs for both fluids significant; (2) no change in phase, shell side pumping costs significant; (3) no change in phase, tube side pumping costs significant; and (4) change in phase on shell side.

OP 109-70. New Uses for Ferrous Scrap, by Charles Prasky. *Proc. 9th Internat. Mineral Processing Cong.*, Prague, Czechoslovakia, June 1-6, 1970, pp. 391-400. This report describes recent progress at the Bureau of Mines Twin Cities Metallurgy Research Center on pilot plant development of roasting procedures for consuming ferrous scrap in a rotary kiln system. One phrase of the research involves roasting lean iron ores of the non-magnetic variety using a novel solid reagent, metallic iron in the form of ferrous scrap, as a means of reducing the ores to artificial magnetite. Another phase of the research concerns the treatment of ferrous scrap, such as discarded automobile hulks, in a rotary kiln without accompanying iron ore to yield coproducts of high-grade iron oxide and dense residual steel scrap of high purity. The former procedure is potentially of value to the iron mining industry and the latter process provides an effective method for the scrap processor to handle automobile hulks at industrial centers.

OP 110-70. Experiments in Processing Marine Nodules, by P. T. Brooks, K. C. Dean, and J. B. Rosenbaum. *Proc. 9th Internat. Mineral Processing Cong.*, Prague, Czechoslovakia, June 1-6, 1970, v. 1, pp. 329-333. Mineral nodules that occur on the oceans' floors represent a substantial potential resource of manganese, nickel, cobalt, and copper. Process development studies to devise methods for unlocking the complex assemblies of elements in the nodules were done at the Bureau of Mines Salt Lake City Metallurgy Research Center using two distinct types of marine nodules. A calcareous type of nodule occurring at a depth of nearly 1 kilometer off the southeast coast of the United States contained, in percent, 17 Mn, 0.6 Ni, 0.3 Co, and 0.1 Cu. A siliceous type of nodule obtained from 3 to 4 kilometers off the southwest coast of the United States contained, in percent, 25 Mn, 1 Ni, 0.5 Cu, and 0.1 Co.

OP 111-70. The Vanadium-Oxygen System: Phase Relations in the Vanadium-Rich Region Below 1200° C, by J. L. Henry, S. A. O'Hare, R. A. McCune, and M. P. Krug. *J. Less-Common Metals*, v. 21, 1970, pp. 115-135. Alloy specimens in the high-vanadium region of the vanadium-oxygen system were prepared by the reaction of high-purity vanadium foil and oxygen. The system was studied by X-ray and metallographic examination of quenched specimens, by differential thermal analysis, and by high-temperature X-ray. Solubility was determined as a function of temperature at equilibrium pressure. Equilibrium pressures were not measured. The solubility of oxygen in α -vanadium—1.1 wt pct at 250° C, 1.3 wt pct at 400° C, 2.8 wt pct at 1,000° C, and 3.5 wt pct at 1,200° C—was found to be higher than previously reported. Retention of the high-temperature structure of α -vanadium by quenching is dependent upon the oxygen content and the quench

rate. The α -phase cannot be retained above 2.1 wt pct oxygen even when water quenched from 1,000° C. A peritectoid transformation was found at about 510° C between 2.2 and 4.2 wt pct oxygen. The peritectoid phase, V_6O (s.s.), has a composition range at 400° C of 2.9 to 3.9 wt pct oxygen. A martensite structure results from water quenching α -vanadium alloys having oxygen contents from about 2.2 to 3 wt pct. The martensite transforms to the stable V_6O upon reheating to temperatures in the range 200°-250° C. β -vanadium has a composition range at 1,000° C from 4.3 to slightly over 10 wt pct oxygen.

OP 112-70. Effect of Coal Rank on Composition of Low-Temperature Tar From a Bench-Scale Fixed-Bed Carbonizer, by Joseph R. Comberlati, Clarence Karr, Jr., Edward E. Childers, Jesse O. Mapstone, Jr., and Patricia A. Estep. *J. Institute of Fuel*, v. 43, No. 5, May 1970, pp. 147-150. The effects of rank (lignite, subbituminous, hva bituminous, hvb bituminous, cannel) on the amounts of some 100 individual compounds in each 500° C tar and light oil obtained by external heating in a nitrogen atmosphere are described for seven different coals. There was some evidence that yields of tar acids and certain aromatic hydrocarbons, such as naphthalenes, declined with decrease in rank whereas yields of olefins increased. Cannel coals gave extra large yields of aliphatic hydrocarbons. Yield of products from hva bituminous coals from two different locations in the same seam were different. Isomeric distributions indicated a partial approach to thermodynamic equilibrium for products from all seven coals.

OP 113-70. Operating Characteristics of a High-Temperature Electrostatic Precipitator, by C. C. Shale and G. E. Fasching. *South African Min. and Eng. J.*, v. 80, No. 4011, Dec. 19, 1969, pp. 1368-1369, 1371, 1373, 1375, 1377, 1379, 1383, 1385, 1387. A semi-commercial, high-temperature electrostatic precipitator and adjunct equipment are described, and operating characteristics at 1,470° F and 80 psig are presented for both positive and negative polarity. Removal efficiency for negative corona was about 91 to 96 percent while that for positive corona was only about 75 to 77 percent. Results are compared with those from bench-scale investigations, and equipment limitations are discussed. Theoretical aspects of the precipitation process are related to the operating characteristics.

OP 114-70. Dynamic Properties of Rock and Composite Structural Materials, by T. E. Ricketts and W. Goldsmith. *Int. J. Rock Mech. Min. Sci.*, v. 7, May 1970, pp. 315-335. The response of several rocks and concrete-like mixtures to dynamic loading was studied by observing the stress waves produced by sphere impact onto ballistically-suspended Hopkinson bars. The metamorphosis of the disturbance served as the basis for the delineation of the macroscopic behavior mechanisms of the materials.

OP 115-70. New Developments and Applications of Ion-Exchange Techniques for the Mineral Industry, by D. R. George and J. B. Rosenbaum. *Proc. Conf. on Ion Exchange in the Process Industries*, Soc. Chem. Ind., Imperial College of Science and Technology, July 16-18, 1969, London, England, 1970, pp. 155-162. Essential features of various applications of ion-exchange processes in the mineral industry are reviewed. Included in this work has been the development of improved ion-exchange contactors and operating techniques; the use of ion exchangers, both solid and liquid, for removing sulfate and recovering sulfur and sodium carbonate from brines and sea water; production of sulfur and

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sodium carbonate from gypsum; production of barium chloride from barite; recovery of potassium from brines; and the application of liquid ion-exchange techniques for the recovery of zinc, copper and aluminum.

OP 116-70. Catalytic Dehydrogenation of Coal: Part 5. Effect of Air on Catalytic Dehydrogenation of Coal, by L. Reggel, I. Wender, and R. Raymond. *Fuel*, v. 49, 1970, pp. 287-288. Dehydrogenation of a Pittsburgh seam coking vitrinite is relatively insensitive to mild oxidation, but the yield of hydrogen is considerably reduced after oxidation at 150° C for 66 hours.

OP 117-70. Quaternary System U-C-O-N at 1700° C: Phase Relations in the Low-Nitrogen Region, by Jack L. Henry, Robert Blickensderfer, and Gerald G. Thompson. *J. Am. Ceram. Soc.*, v. 51, No. 11, November 1968, pp. 617-621. Phase relations in the system U-C-O-N at 1,700° C were established at nitrogen levels up to a 1:3 atomic ratio N:C by microstructural and X-ray analyses of sintered powder compacts. An isothermal phase diagram for the low-nitrogen region of the U-C-O-N system is proposed.

OP 118-70. The Quaternary System U-C-O-N at 1700° C, by Jack L. Henry and Robert Blickensderfer. *J. Am. Ceram. Soc.*, v. 52, No. 10, October 1969, pp. 534-539. The system U-C-O-N was examined at 1,700° C by microstructural and X-ray analyses of sintered powder compacts. Subliquidus phase relations, oxycarbonitride solid-solution lattice parameters, and equilibrium pressures of N₂ and CO were studied. Although the emphasis was on the solid-solution field in the uranium monocarbide-mononitride-monoxide region, phase fields in the uranium-rich region and the carbon-nitrogen-oxygen-rich region were examined. Nineteen fields were established experimentally, and their boundaries were located. Two other fields are postulated on the basis of phase rule and topological requirements. An isothermal phase diagram of the system is proposed.

OP 119-70. Storage Stability of High Temperature Fuels. Part II. The Effect of Storage Upon Thermally Induced Deposition of Labeled Fuel Components, by M. L. Whisman and C. C. Ward. *Air Force Aero Propulsion Laboratory, Wright-Patterson Air Force Base, Ohio, Tech. Rpt. AFAPL-TR-68-32, Pt. II*, March 1969, 116 pp. This investigation is concerned with the contribution of selected components and additives of high-temperature aircraft fuels to thermally induced deposits before and after 52 weeks storage at 130° F. Of particular concern is the influence of these fuel constituents on thermal-stability quality of these jet fuels during storage. The study utilizes a micro fuel coker test apparatus to measure the thermal-stability of test fuels and blends. The contribution of selected fuel components, labeled with carbon-14, to deposit-forming mechanisms is determined by radioactive counting techniques.

Twenty-three blends of a carbon-14 labeled component in a jet fuel matrix were added to the program, and 67 blends reached the 52-week interval of storage at 130° F. These blends were tested to determine the extent of radiotracer contribution to thermally induced deposits. The greatest extent of reaction of the labeled hydrocarbon fuel systems studied was observed in blends containing methyl- and ethyl-substituted indenenes. Other aromatic types also showed some contribution to the deposits.

Special studies with 2 jet fuel antioxidants were conducted to determine the extent of thermal and chemical degradation during storage and testing. Tests with an additive of the amine-type showed

substantial amounts of the antioxidant reaction and/or decomposition to form filterable deposits in the preheater section of the test apparatus.

OP 120-70. Progress on Techniques of Investigating and Controlling Rock Bursts, by Galen G. Waddell. *Trans. SME, AIME*, v. 247, June 1970, pp. 185-192. Rock-burst research conducted by the Bureau of Mines in cooperation with the mining companies of the Coeur d'Alene mining district, Idaho, in addition to progress made by others throughout the world, have led to a good understanding of the rock-burst problem. This paper describes conditions which have caused specific bursts, present capabilities of detecting stress buildup and bursts, control methods, and a suggested approach to analyzing any individual mine-burst problem.

OP 121-70. Caliper Location of Leached Zones in Colorado Shale, by Harold E. Thomas and John Ward Smith. *Log Analyst*, July-August 1970, v. 11, No. 4, pp. 12-16. Accurate estimation of oil yields in Green River Formation oil shale requires knowledge of the presence or absence of cavities (vugs) left after the natural removal of the mineral nahcolite (NaHCO₃). Conventional well logs have not provided a means for detecting the vugular porous zone. This paper describes a 3-arm caliper logging system, logging technique, and mathematical correction method used by the Bureau of Mines to locate and compensate for the vugular porosity. The caliper defines the zone by sensing a high frequency of minor diameter variations as small as 1/10 inch. Estimations of oil yields and oil shale reserves from density logs can be significantly improved when the vugular zone's thickness is known. A porosity-density correction method is presented.

OP 122-70. Structural Response of Rich Green River Oil Shales to Heat and Stress and Its Relationship to Induced Permeability, by Peter R. Tisot and Harold W. Sohns. *J. Chem. & Eng. Data*, v. 15, No. 3, July 1970, pp. 425-434. Structural response and/or deformation of three rich oil shales to heat and compressive stress was determined. Specimens consisted of small cores and of small columns of fragments from oil shales assaying 34.5, 45.5, and 63.5 gallons of oil per ton. Effect of structural deformation on induced permeability in the fragmented specimens was determined. Stress-strain-time-temperature relationships of these oil shales provided information regarding their yield temperature, yield stress, rate of compressive strain, and loss of mechanical strength as they were heated from ambient to sub-retorting temperatures—that is, below those required for rapid pyrolysis of the organic matter to produce oil. Structural response of some cores was also observed as they were heated in a stress-free environment. Results provide guidelines to assess and evaluate some problems that may be associated with recovery of shale oil by underground retorting methods.

OP 123-70. On the Optimization of Electric Furnace Smelting Processes, by V. R. Spironello. *Electric Furnace Proc.*, 1969, AIME, August 1970, v. 27, pp. 157-163. The application of experimental design and statistical methods to electric furnace smelting is the purpose of this paper, although the basic concepts can be used for any industrial process, such as steelmaking.

Statistical tools are presented in this paper which can be used to evaluate selected variables. Any combination of variables can be used to suit the interests of a particular operator, or operation, or both;

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and any number of variables can be investigated, depending upon the complexity of the process and the time available.

OP 124-70. How To Predict Oil-Field Performance, by R. V. Higgins and H. J. Litchenberg. *Oil and Gas J.*, Sept. 14, 1970, v. 68, pp. 88, 93-94. The results of applying the least squares principles to the solution of the constants of the Arps equation and then the use of these constants in the equation to predict the production decline are presented in this article. In a computer study of the applicability of the Arps equation to California oilfields, the equation was found to be applicable to less than half the fields. Other findings are also presented.

OP 125-70. Effects of Vanadium (V and IV), Molybdenum (VI), and Lead (II) on the Oxidation Kinetics of Steel Scrap, by S. E. Khalafalla and S. L. Payne. *J. Metals*, v. 22, No. 9, September 1970, pp. 2-7. Surface impregnation of steel strips with small amounts of the oxides of vanadium (V), molybdenum (VI), and lead (II) increased their rate of oxidation in carbon dioxide atmospheres. The introduction of the accelerator species was effected by pickling of the oxidizable charge for short periods in moderately concentrated aqueous solutions of the sodium salt of the oxyacids. By contrast to the pentavalent vanadium in the metavanadate, the tetravalent state in vanadyl sulfate did not accelerate oxidation. X-ray fluorescence examination of the pickled steel strips indicated the presence of small amounts of the accelerator on the surface layer. The degree of oxidation acceleration could be inversely correlated with the melting point of the promoter oxide. The results are explained on the basis of the hydrolytic decomposition of the pickling agent with subsequent slow interaction with the metal surface, coupled with the tendency of vanadate to form polyanions. The data not only serve to elucidate the mechanism by which catastrophic oxidation takes place, but also show that the promoter species need not be alloyed with the oxidizable metal; surface impregnation by minute amounts of the promoter can still produce catastrophic effects. The oxidation of steel can be more than doubled by this procedure.

OP 126-70. Oxidative Roasting of Covellite With Minimal Retardation From the $\text{CuO} \cdot \text{CuSO}_4$ Film, by S. E. Khalafalla and I. D. Shah. *Met. Trans.*, AIME, v. 1, August 1970, pp. 2151-2156. Copper (II) sulfide can be efficiently converted to the oxide at lower temperatures than normally required in aerobic roasting by a new method involving programmed environment roasting (PER). When heating was conducted in absence of oxygen up to about 650° C, and then nitrogen was replaced by air, the sulfide was easily converted to oxide without need for further increase in temperature. Traditional oxidative roasting of chalcocite required a temperature range of 800° to 850° C for conversion to tenorite. Unlike the situation with conventional roasting, CuSO_4 was not detected in the X-ray diffractogram of the product obtained with the PER method above 625° C. Also, the amount of $\text{CuO} \cdot \text{CuSO}_4$ significantly decreased as the halt temperature in the PER process increased from 600° to 700° C. Apparently the shell of copper oxysulfate is impervious to oxygen and/or sulfur dioxide and delays the formation of tenorite until the sulfate and oxysulfate are decomposed. If the oxysulfate stage were bypassed with an inert atmosphere, then, even if small amounts of this salt were formed upon introducing the oxidant, it would decompose at an appreciable rate and the impedance of its thin film to gaseous transport would be considerably diminished. By contrast, the accelerating effect of externally added iron on the oxidative

roasting of covellite was confined to the low temperature reactions and hence iron promoted the extent of sulfate formation. Iron did not, however, lower the thermal requirement for complete oxidation of CuS or Cu_2S because it had virtually no effect on the thermal decomposition of $\text{CuO} \cdot \text{CuSO}_4$.

OP 127-70. Oil Vaporization During Steamflooding, by F. Sam Johnson, C. J. Walker, and Abdo F. Bayazeed. Pres. at 45th Ann. Fall Meeting, SPE, AIME, Houston, Tex., Oct. 4-7, 1970, preprint SPE #2977, 9 pp. A procedure was developed by the Bureau of Mines for calculating the amount of oil vaporized or distilled in the steam zone during steamflooding of an oil reservoir. The results of this procedure are intended to be used with other techniques for calculating oil recovery during steamflooding. Two experiments were conducted in which steam was injected into an oil-saturated, sand-packed tube to investigate oil vaporization by steam. In these experiments, the amount of vaporization of oil by steam is directly related to the amount of steam contacting the immobile oil. Calculations presented in this report indicate that oil vaporization during steamflooding increases as the volatility of the oil and as the steam temperature increases, but decreases as the steam-injection rates increase. Recoveries calculated by this procedure are conservative when compared with other laboratory experiments which included the effects of gas drive and solvent extraction.

OP 128-70. Does Crushing Affect Pyrite's Magnetic Susceptibility? by William R. Huff and William T. Abel. *Coal Min. and Processing*, July 1970, 4 pp. In experiments at the Morgantown, W. Va., Coal Research Center of the Bureau of Mines, particle size reduction in three different types of mills did not increase the magnetic susceptibility of pyrite.

OP 129-70. Mining Research in the United States Bureau of Mines, by T. E. Howard, W. E. Lewis, and T. C. Atchison. *Proc. VI Internat. Min. Cong.*, Madrid, Spain, June 1970, pp. 1-13. The objectives, content, and organization of the mining research program of the Bureau of Mines are described with emphasis on some of the more fundamental aspects of the work. Some basic scientific studies now in progress related to the five primary elements of the mining system—(1) rock and earth disintegration, (2) ground control, (3) mine environment control, (4) materials handling, and (5) mineral deposit delineation—are discussed in terms of their contributions and potential contributions to the advancement of mining technology.

OP 130-70. Hot Hardness, Thermal Diffusivity, and Electrical Resistivity of Uranium Oxycarbides, by Jack L. Henry, Robert Blickensderfer, Danton Paulson, and J. Lambert Bates. *J. Am. Ceram. Soc.*, v. 53, No. 6, June 21, 1970, pp. 335-339. Several predominantly single-phase uranium oxycarbide compositions were examined to determine the effect of oxygen content on the hot hardness, thermal diffusivity, thermal conductivity, and electrical resistivity. Little difference was noted in hot hardness over the low-temperature range; however, increased oxygen content appears to reduce the hardness above 700° C. Thermal diffusivity and thermal conductivity are reduced by increased oxygen content. This decrease is most pronounced at lower temperatures, and the temperature dependence varies significantly with oxygen content. The thermal diffusivity of oxycarbides having small percentages of oxygen decreases with increasing temperature, whereas that of oxycarbides with greater oxygen content in-

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creases very slightly. The thermal conductivity data are in fair agreement with those reported for the monocarbide. Electrical resistivity is increased by increased oxygen content and shows a positive temperature dependence. The data indicate that electronic conductivity at 1,500° C accounts for approximately 85 percent of the total thermal conduction at the 2-atomic percent-oxygen level and approximately 95 percent of the total at the 16-atomic percent-oxygen level.

OP 131-70. The Enthalpies of Combustion and Formation of *n*-Propylcyclohexane and Six Methylcyclohexanes, by W. D. Good. *J. Chem. Thermodynamics*, v. 2, 1970, pp. 399-405. The enthalpies of combustion of *n*-propylcyclohexane and six isomeric methylcyclohexanes were determined by oxygen-bomb combustion calorimetry. Enthalpies of formation in the liquid state were derived and compared with those predicted by the Allen correlation procedure.

OP 132-70. Reactions of Fuels and Chemicals in Electrical Discharges, by Yuan C. Fu. *Chemical Industry, Japan*, 1970, v. 21, No. 8, pp. 97-100. The technique of electrical discharges in syntheses of organic and inorganic compounds, reaction of fossil fuels, and surface modifications of materials are discussed in this Japanese language article.

OP 133-70. X-Ray Scattering by Very Defective Lattices, by Sabri Ergun. *Phys. Rev. B*, v. 1, No. 8, April 1970, pp. 3371-3380. There is evidence to indicate that some diffusely scattering substances are essentially highly defective lattices rather than made up of small domains diffracting incoherently with respect to each other. Equations have been derived for the diffraction profiles from such lattices; they are of a Cauchy type. Highly defective lattices are characterizable by a mean defect-free distance rather than a domain size. Several criteria are presented for distinguishing defect-broadening from domain or particle-size broadening, and procedures are outlined for the separation of strain and defect broadenings.

OP 134-70. New Tetragonal Compounds Nb₃Si and Ta₃Si, by D. K. Deardorff, R. E. Siemens, P. A. Romans, and R. A. McCune. *J. Less-Common Metals*, v. 18, 1969, pp. 11-26. Small ingots of Nb-Si alloys were made from high-purity, solid form (not powder) Nb and Si by arc melting and suction casting into a copper mold. Samples from these ingots were tested for the presence of a superconducting transition temperature (*T_c*) and were found to be superconducting (with a *T_c* near 7.5° K) up to 37.5 atomic percent silicon. Metallographic and microprobe studies to determine the superconducting phase in the system led to the discovery of an unreported compound, Nb₃Si, and indicated that Nb₃Si does not exist. Further investigation showed that Ta₃Si also exists and that Ta₃Si does not, these alloys being similarly prepared from solid-form, high-purity Ta and Si. Nb₃Si and Ta₃Si were found to have isomorphous tetragonal structures with parameters *a₀*=10.21±0.01 Å, *c₀*=5.19±0.01 Å, and *a₀*=10.17±0.01 Å and *c₀*=5.16±0.01 Å, respectively. The Ta₃Si pattern was found to be nearly identical to one reported by Brewer for TaSi_{0.20±0.05}. Nb₃Si was determined to be essentially a line compound which melts peritectically at 1945°±20° C. It was found to be nonsuperconducting above 4.2° K. The superconducting phase was determined to be Nb solid solution, which was present as a Nb-Nb₃Si eutectic up to 37.5 atomic percent Si.

OP 135-70. The Hafnium-Iridium System, by M. I. Copeland and D. Goodrich. *J. Less-Common Metals*, v. 19, 1969, pp. 347-355. The Bureau of Mines has studied hafnium-iridium phase relations by metallography, thermal analysis, electron-beam microprobe, and X-ray diffraction. Four intermediate phases were identified.

OP 136-70. Boron and Boron Carbide Coatings by Vapor Deposition, by Andrew A. Cochran, James B. Stephenson, and James G. Donaldson. *J. Metals*, v. 22, No. 8, August 1970, pp. 37-42. The formation of boron and boron carbide coatings by vapor deposition was investigated. Optimum parameters were determined for the hydrogen reduction of boron trichloride and for the formation of boron carbide coatings on graphite.

OP 137-70. Ion Exchange Papers in X-Ray Spectroscopy, by W. J. Campbell, T. E. Green, and S. L. Law. *Am. Lab.*, June 1970, pp. 28-34. The use of thin disks of ion exchange resin-loaded paper to collect samples for X-ray spectrography is discussed.

OP 138-70. Balanced Filters for Silver K_α X-Rays, by Martin Berman and Sabri Ergun. *Rev. Sci. Instr.*, v. 41, June 1970, pp. 870-873. The use of rhodium, ruthenium, and technetium is proposed for balanced filters for silver K_α X-rays. Rhodium and ruthenium are used to isolate the K_{α1}, ruthenium and technetium for the K_{α2}, and rhodium and technetium are used for the K_α doublet. General criteria are given for optimizing the intensity in terms of the transmission of one of the filters at the line of interest. The transmission of filter A (lowest atomic number) for any of the filter pairs should be about 12 percent for silver K_α X-rays.

OP 139-70. Gasbuggy Reservoir Evaluation—1969 Report, by C. H. Atkinson, Don C. Ward, and R. F. Lemon. *Proc. Symp. Eng. With Nuclear Explosives*, Jan. 14-16, 1970, Las Vegas, Nev., American Nuclear Society and U. S. Atomic Energy Commission, v. 1, May 1970, pp. 722-731. An evaluation of extended production tests of the Project Gasbuggy chimney well indicates that postshot gas recovery in 20 years should be 900 million cubic feet, which would be an increase by a factor of at least 5 over estimated recovery from conventional field wells in the area.

OP 140-70. The Effects of Contaminants in Methane as a Proportional Tube Counting Gas, by F. E. Armstrong, W. D. Howell, and D. W. Whitlock. *Nuclear Applications & Technology*, v. 9, July 1970, pp. 107-111. An investigation has been made of the effects of helium, ethane, propane, nitrogen, and carbon dioxide as contaminants in methane used as the filling gas for a proportional counting tube. The concentration of contaminant was similar to that normally encountered in natural gas. It was found that the principal effect was that of change in gas multiplication factor and that compensation may be made by an appropriate change in applied bias voltage.

OP 141-70. Development of Electroslag Melting Technique for Titanium: Selected Properties of Fabricated Material, by C. E. Armantout and R. H. Nafziger. *Am. Foundrymen's Soc. Trans.*, v. 77, 1969, pp. 353-359. This paper reports two aspects in the development of electroslag-melting techniques for titanium (1) the selection and treatment of slag systems and the manner in which these affect ingot impurity contents and (2) evaluation of the microstructure, mechanical properties, and corrosion resistance of vacuum-arc melted and electroslag-melted material.

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OP 142-70. Proceedings of the 8th Rare Earth Research Conference, April 19-22, 1970, Reno, Nevada, ed. by Thomas A. Henrie and R. E. Lindstrom. Sponsored by the Bureau of Mines, U.S. Department of the Interior, and the Rare Earth Research Conference Committee, 2 vols, 1970, 827 pp. This publication contains preprints of the 93 papers scheduled for presentation at the Conference. Included are research papers and discussions on the latest developments in the field of rare earth and related metals. Research topics discussed are interdisciplinary and include the fields of physics, chemistry, ceramics, and metallurgy of the elements, their compounds, and alloys. A discussion of industrial processes and geochemistry is also included.

OP 143-70. Factors That Predict Fracture Orientation in a Gas Storage Reservoir, by C. A. Komar, W. K. Overbey, Jr., R. L. Rough, and W. G. Lambert. Pres. at 45th Annual Fall Meeting, SPE, AIME, Houston, Tex., Oct. 4-7, 1970, preprint SPE 2968, 6 pp. Exploratory research was conducted in a gas-storage reservoir in Hocking County, Ohio, to determine why hydraulically induced vertical fractures tend to follow a preferred direction. Surface measurements of joints, aerial photograph lineaments, and residual stress orientations were compared to directional property measurements on oriented surface and subsurface cores. These data were compared to hydraulically induced vertical fracture orientations obtained by impression packers and borehole photographs in the reservoir.

Observations showed that macroscopic and microscopic features of reservoir rocks can be correlated to the preferred orientation of hydraulically induced fractures. Considering that existing theory advocates tectonic stress as the controlling factor in vertical fracture orientation, it becomes apparent that both macroscopic and microscopic features are indicators of the direction of this maximum horizontal stress as well.

Using this information, the petroleum engineer can locate wells to be fractured in a pattern which will optimize reservoir performance whether for production or storage of natural gas.

OP 144-70. Geologic Properties That Affect Waterflooding in the Big Injun Sand of West Virginia, by Royal J. Watts and William K. Overbey, Jr. Pres. at 45th Annual Fall Meeting SPE, AIME, Houston, Tex., Oct. 4-7, 1970, preprint SPE 3084, 7 pp. This study was made to determine the petrography, mineralogy, porosity, and permeability of the sandstone, and their relationship to waterflooding in Big Injun reservoirs. Rotary cores, geophysical well logs, petrographic thin sections, and results of chemical analyses of sandstone samples from several Big Injun oil reservoirs were used to determine these parameters. The results show a great range of reservoir characteristics within the area of study.

OP 145-70. Light-Induced Chemiluminescence in Derivatives of Coal and Petroleum, by Raymond E. Markby, R. A. Friedel, Sidney Friedman, and Heinz W. Sternberg. Fuel, v. 49, 1970, pp. 242-248. Solutions of coal tar, coal asphaltene and alkylated coal as well as petroleum asphalts exhibit chemiluminescence when exposed to oxygen and light. This chemiluminescence is believed to be due to decomposition of endoperoxides formed by photo-oxidation of acene-type compounds present in products derived from coal and petroleum.

OP 146-70. Detection Limit for Gold by Radioisotopic X-Ray Analysis, by P. G. Burkhalter and H. E.

Marr, III, Internat. J. Appl. Radiation and Isotopes, v. 21, 1970, pp. 395-403. The use of a Ge(Li-drifted) semiconductor detector and gamma-ray excitation with radioisotopic sources provides an X-ray analytical method that is advantageous for the determination of high-Z elements in ores. The 122-keV gamma radiation of Co^{57} was found to be an optimum energy for exciting gold K-radiation. The detection limit for gold was determined to be 30 to 40 ppm using both synthetic standards and analyzed gold ores. With a source strength of 60 mCi, a 21-ppm detection limit is obtainable in 3-minute counting times. The sensitivity of the radioisotopic X-ray method for several other high-Z elements was also determined. Using Co^{57} for excitation, the detection limits for tungsten, lead, and uranium were 25, 40, and 60 ppm, respectively.

OP 147-70. Kroll Process Beryllium, by Thomas T. Campbell, R. E. Mussler, and F. E. Block. Metall. Trans., v. 1, October 1970, pp. 2881-2887. High-purity beryllium metal was prepared on a laboratory scale by Kroll process procedures in which sodium was used as a reductant. Crude beryllium chloride, purchased from commercial sources, was purified by vacuum sublimation and fused-salt scrubbing. Purified beryllium chloride was vaporized and reacted at a controlled rate with molten sodium at temperatures ranging from 650° to 750° C to form beryllium sponge. Excess metal reductant and by-product salt were removed from the sponge metal by vacuum distillation. Beryllium sponge metal was wet ball milled to -200 or -400 mesh powders. Beryllium powder metal, subsequently consolidated by isostatic pressing, was hot extruded and machined into tensile specimens for evaluation of mechanical properties. Evaluation indicates that the beryllium described in this study is of higher purity than comparable commercial grades of metal; also, it is more ductile but has somewhat lower strength. The overall process appears to have an excellent potential from an economic standpoint.

OP 148-70. Boron and Boron Carbide Coatings by Vapor Deposition, by Andrew A. Cochran and James B. Stephenson. Metall. Trans., v. 1 October 1970, pp. 2875-2880. The Bureau of Mines investigated the formation of boron and boron-carbide coatings by vapor-phase reactions. Optimum parameters were determined for hydrogen reduction of boron trichloride and for the formation of boron-carbide coatings on graphite by reaction with the depositing boron. At 1,300° C, about 85 percent of the boron was deposited. Tungsten substrates did not react with the boron deposit; other substrates reacted to various extents. The hydrogen reduction of boron tribromide was briefly investigated. Boron carbide was deposited at 1,300° C by adding methane to the boron trichloride-hydrogen feed gas. The chemical composition of the vapor-deposited boron carbide approximated B₄C. A method of etching B₄C was developed to study its microstructure. When boron was deposited on graphite at 1,500° C, very hard, uniform, strongly adherent coatings of B₄C were formed that might be useful in applications such as rocket nozzles and chemical reaction and processing vessels.

OP 149-70. Finding Profits in Oil-Well Waste Waters, by A. Gene Collins. Chem. Eng., v. 77, No. 20, Sept. 21, 1970, pp. 165-168. Full exploitation of petroleum-associated brines for their chemicals will benefit the oil producer, the national economy, and pollution abatement. Sound conservation should favor the recovery of valuable elements from these

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brines, and with proper planning, the recovery processes should aid in ultimate disposal.

OP 150-70. Elimination of the Compton Component of Diffusely Scattering Substances, by S. Ergun, W. Braun, and E. Fitzer. *Rev. Sci. Instrum.*, v. 41, No. 8, August 1970, pp. 1133-1135. Experimental elimination and determination of the Compton component in diffuse scattering have been made by using crystal monochromated Ag K α radiation and balanced Rh and Ru filters. The K absorption edge of Ru ($\lambda=0.5605$ Å) lies very close to the wavelength of Ag K α ($\lambda=0.5594$ Å) so that the intensity obtained using balanced Rh-Ru filters at scattering angles $2\theta>20^\circ$ is essentially the unmodified Ag K α scattering. A procedure is outlined for the elimination of the Compton component at lower angles and for conversion of arbitrary intensities into electron units.

OP 151-70. A System for Measuring the Velocity of Sound in Compressed Fluids and Its Application to Helium Between -175 and 150° C, by B. E. Gammon and D. R. Douslin. *Proc. 5th Symp. Thermophysical Properties*, sponsored by the Standing Committee on Thermophysical Properties, Heat Transfer Division, ASME, Newton, Mass., Sept. 30-Oct. 1-2, 1970, pp. 107-114. Describes the derived results and a system of measurement for the velocity of sound in helium at -175° to 150° C and 10 to 150 atm.

OP 152-70. Vibrational Spectra of Benzene Derivatives—VII 4-Fluoro- and 4-Bromobenzenethiol, 4-Chloro- and 4-Bromophenylmethylsulphide, by J. H. S. Green, D. J. Harrison, W. Kynaston, and D. W. Scott. *Spectrochim. Acta*, v. 26A, No. 7, July 1970, pp. 1515-1523. The infrared spectra ($5,000$ to 40 cm $^{-1}$) of 4-fluoro- and 4-bromobenzenethiol, 4-chloro- and 4-bromophenylmethylsulphide, and the Raman spectra of the first and third of them, have been measured.

OP 153-70. Converting Non-Permissible Equipment to Permissible Equipment, by Frank R. Lee, Jr. *Min. Cong. J.*, v. 56, No. 7, July 1970, pp. 69-71. Types of non-permissible equipment found in underground coal mines fall into five categories. This article details procedures and sources of assistance for converting electric motor-driven face equipment in each category to permissible status as called for in Bureau of Mines Schedule 2G.

OP 154-70. A High-Hot-Strength Vanadium-Base Alloy, by G. H. Keith and J. S. Winston. *Metals Eng. Quart.*, v. 10, No. 3, August 1970, p. 56. A vanadium-base alloy that had exceptionally high strength at temperatures up to $1,200^\circ$ C was developed. This alloy was composed of 20 percent Mo, 10 percent Ti, 0.1 percent C, 0.5 percent Si, and 0.5 percent Y and was capable of fabrication to sheet 1.0 to 1.5 mm in thickness by a combination of hot swaging and hot and warm rolling.

OP 155-70. Electrowinning Oxygen From Silicate Rocks, by D. G. Kesterke. *Proc. 7th Ann. Working Group on Extraterrestrial Resources*, June 17-18, 1969, Denver, Colo., 1970, NASA SP-229, pp. 139-144. One phase of NASA-sponsored research for the utilization of extraterrestrial resources is directed toward determining the feasibility of extracting oxygen by electrolysis of simulated lunar materials. The method is based on a modification of existing techniques for electrowinning metals from their oxides in fused-salt systems. In this article, results of preliminary

work leading to the electrowinning efforts are presented. The current research being conducted by the Bureau of Mines is outlined, and operating conditions under which oxygen was successfully electrowon from fluoride-silicate mixtures are described.

OP 156-70. The Factors That Influence the Design of Slope Walls in Rock, by R. H. Merrill. *Proc. VI Internat. Min. Cong.*, Madrid, Spain, June 1-5, 1970, I-C. 2, 11 pp. The factors that influence the design of slope walls in rock are listed, together with brief comments about the state of knowledge concerning each. Various slope design techniques are summarized. Some of the factors and a design technique have been investigated in a full-scale instrumented test of a slope wall around an open pit; in situ stresses and rock strength were low, and the displacements and strains in the wall rock changed as the slope was steepened. These measured changes were compared with computations based on elastic, continuum mechanics. The comparisons show good evidence that the pit wall reacted elastically to its change in slope.

OP 157-70. Clay, A Raw Material For Aluminum, by F. A. Peters. *Iron Age*, v. 206, No. 13, Sept. 24, 1970, reprint 1795, pp. 76-78. Three of the most attractive processes for producing alumina from clay are briefly described. Previously published Bureau of Mines estimated capital and operating costs for these processes—nitric acid, sulfurous acid-caustic purification, and hydrochloric acid-isopropyl ether extraction—are compared with costs for the Bayer process.

OP 158-70. Catalytic Dehydrogenation of Coal: Part 4. A Comparison of Exinite, Micrinite, and Fusinite With Vitrinite, by L. Reggel, I. Wender, and R. Raymond. *Fuel*, v. 49, pp. 281-286. Four macerals from an hvab coal have been dehydrogenated. Quantitative data are given for the different yields of hydrogen from exinite, micrinite, fusinite, and vitrinite.

OP 159-70. Phase Equilibria and X-Ray Diffraction Investigation of the System Cu-Fe-O, by S. C. Schaefer, G. L. Hundley, F. E. Block, R. A. McCune, and R. V. Mrazek. *Metall. Trans.*, v. 1, Sept. 1970, pp. 2557-2563. An equilibria investigation for the system Cu-Fe-O determined nine regions of stability which were investigated in the oxygen pressure range of 1×10^{-4} to 5×10^{-1} atm ($P_{\text{total}} = 1$ atm) and at temperatures of $1,173^\circ$ to $1,250^\circ$ K. Oxygen dissociation pressures were determined for three univariant, four bivariant, and two trivariant equilibria. X-ray examination of selected equilibrated samples established conclusively that (1) cuprous ferrite (delafossite) is a stoichiometric compound, (2) cupric ferrite is a solid solution, and (3) solubility of delafossite in cuprous oxide is negligible. A relationship of lattice parameters with compositional variations was determined for the solid solution. Tetragonal-to-cubic spinel crystal transformation of cupric ferrite solid solution occurs with a c/a ratio at or slightly greater than 1.028. A volume discontinuity accompanies the tetragonal-to-cubic spinel transformation, which is a first-order type of thermodynamic transition.

OP 160-70. Combustion of Coal in Fluidized Beds, by N. H. Coates, P. S. Lewis, and J. W. Eckerd. *Trans. SME, AIME*, v. 247, September 1970, pp. 208-210. The

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Bureau of Mines designed, constructed, and operated an 18-in-diam fluidized-bed combustor for highly caking coals to evaluate the method for possible application to power generation. In initial tests, combustion was carried on successfully, with carbon losses as low as 0.8 percent. Coal ash was not satisfactory as a bed material, but mullite proved to be acceptable. Overall heat-transfer coefficients from the bed ($-20 + 50$ mesh mullite) to a water-cooled tube were about 75 Btu per hr-sq ft-°F.

OP 161-70. Mica Process Development, by James S. Browning. *Trans. SME, AIME*, v. 247, September 1970, pp. 269-273. For the past several years, the Bureau of Mines has conducted laboratory and continuous process development work on the weathered mica pegmatites ores of Alabama, Georgia, and North Carolina to determine the feasibility of recovering commercial-grade mica concentrates by flotation. The research has resulted in the development of two processes for flotation of mica: (1) an acid-cationic method for recovery of coarse mica and (2) an alkaline-anionic-cationic method for recovery of fine mica. The research indicated that the two processes may be effectively utilized separately or in combination for flotation of mica from weathered pegmatite ores. This report summarizes the process development work, and demonstrates the feasibility of producing commercial-grade concentrates with a high recovery of the contained mica.

OP 162-70. Corrosion of Heat-Exchange Tubes in a Simulated Coal-Fired MHD System, by D. Bienstock, R. J. Demski, and R. C. Corey. *ASME Winter Ann. Meeting*, New York, Nov. 29-Dec. 3, 1970, Preprint 70-WA/CD-3, 8 pp. Corrosion results are reported in a seeded flue gas with Haynes 23, stainless, and carbon steels at wall temperatures of 800° to 1,500° F and gas temperatures of 1,800° to 2,500° F.

OP 163-70. Effect of the Intermediate Principal Stress on the Fracture of Brittle Rock, by B. T. Brady. *Rock Mechanics—Theory and Practice*. Proc. 11th Symp. on Rock Mechanics, Univ. of California at Berkeley, Berkeley, Calif., June 20-22, 1969, pp. 267-279. The primary conclusion of the study is that the effect of the intermediate principal stress on the fracture strength of brittle rock (when the failure initiation models are specified by equations given) is not large enough to warrant its consideration in engineering calculations involving the behavior of brittle rock under multiaxial stress conditions. This conclusion is justified without qualification when all the principal stresses are compressive.

OP 164-70. Recent Developments and Applications of the Microseismic Method in Deep Mines, by Wilson Blake and Fred Leighton. *Rock Mechanics—Theory and Practice*. Proc. 11th. Symp. on Rock Mechanics, Univ. of California at Berkeley, Berkeley, Calif., June 20-22, 1970, pp. 267-279. Broad-band microseismic monitoring provides much more quantitative information about the behavior of a rock structure than can be obtained by traditional microseismic monitoring. When used regularly by experienced personnel, it can become a valuable engineering tool in detecting, delineating, and estimating the stability of potential failure zones in rock structures.

In deep mines, the location of zones of inferred high stress can be pinpointed in space. All rock bursts recorded during this study had their foci in these inferred high stress zones, but not all of these zones experienced rock bursts. The destressing of a potential rock-burst zone, while not yet done in this study, should now be more effective since these zones can be precisely located. Attempts at destressing can be evaluated readily by monitor-

ing with this technique. The use of low-sensitivity pickups should make this technique useful in areas where there is a continuous background of small rock noises. Such noises would essentially be filtered out by pickup selection. For precise source locations in rock structures where stress changes may occur daily, seismic velocities must be determined daily.

OP 165-70. Processing of Superalloy Scrap, P. T. Brooks, G. M. Potter, and D. A. Martin. *J. Metals*, v. 22, No. 11, November 1970, pp. 25-29. Superalloy grinding waste contains substantial quantities of nickel, cobalt, molybdenum, and chromium and for lack of an economical domestic recovery process is being marketed abroad. A process was developed and demonstrated on a laboratory scale for treating this complex waste product to recover the more valuable metals. The recovery process includes scrap preparation, dissolution of metallics in chlorinated acid solution, carbon adsorption, successive solvent extraction separations, and selective chemical precipitations. Nearly 90 percent of the nickel, cobalt, and molybdenum were separately recovered as metallurgical-grade oxides. For a more detailed discussion of the subject see Bureau of Mines Report of Investigations 7316.

OP 166-70. Partial Decarboxylation of Coal Aromatic Acids by Transition Metal Complexes, by Sidney Friedman, Samuel R. Harris, and Irving Wender. *I&EC Prod. Res. and Development*, v. 9, No. 3, September 1970, pp. 347-350. In the presence of carbon monoxide and hydrogen, dicobalt octacarbonyl, $\text{Co}_2(\text{CO})_8$, catalyzes the selective decarboxylation of phthalic acid or anhydride and substituted phthalic acids or anhydrides to yield the corresponding benzoic acids. In the case of pyromellitic acid, the $\text{Co}_2(\text{CO})_8$ is consumed in the decarboxylation, becoming a reactant instead of a catalyst. By using derivatives of $\text{Co}_2(\text{CO})_8$ in which one or two carbonyl groups are replaced by trialkylphosphine ligands, it is possible to preserve the catalytic activity of the complex. Such a catalyst will selectively decarboxylate benzenepoly-carboxylic acids containing carboxyl groups as adjacent carbons to mixtures of isophthalic and terephthalic acids. By applying this reaction to a mixture of acids obtained by alkaline oxidation of coal, char, or other coal derivatives, it is possible to obtain a product rich in isophthalic and terephthalic acids.

OP 167-70. Predicting Performance of Waterfloods at Highest Constant Injection Rate, by R. V. Higgins. *J. Petrol. Tech.*, v. 22, October 1970, pp. 1246-1247. Data from a Higgins-Leighton method at constant pressure may be easily and quickly used to predict the highest constant rate of injection and other engineering data of economic value.

OP 168-70. Carbon Black Produced by the Pyrolysis of Coal, by Glenn E. Johnson, William A. Decker, Albert J. Forney, and Joseph H. Field. *I&EC Prod. Res. and Development*, v. 9, No. 3, September 1970, pp. 382-387. Carbon black equivalent to commercial grade has been produced by the pyrolysis of coal at 1,250° to 1,350° C at the Bureau of Mines, Pittsburgh, Pa. The maximum yield of black obtained from Pittsburgh seam coal (hvab rank) is about 20 percent by weight based on the raw coal fed. The work has been done on a bench-scale electrically heated unit with a maximum coal feed rate (70 percent—200 mesh) of 3 pounds per hour. Byproducts are a coal char which could be burned for power generation and byproduct gas (8 to 9 cubic feet per pound of coal) containing 80 percent hydrogen. The carbon black product has been evaluated in chemical and rubber compounding tests by industrial companies and found to be equivalent in quality to fine thermal (FT) grade of commercial blacks. A patent has been granted to the U.S.

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Government. Cost studies indicate that the carbon black could economically be produced from coal.

OP 169-70. NO_x Emissions at Low Excess-Air Levels in Pulverized-Coal Combustion, by C. R. McCann, J. J. Demeter, A. A. Orning, and D. Bienstock. ASME Winter Ann. Meeting, New York, Nov. 20-Dec. 3, 1970. Preprint 70-WA/APC-3, 7 pp. Nitrogen oxides decreased 70 per cent (from 575 to 175 ppm) as the excess air was lowered from 25 to 1.4 percent in burning a Pittsburgh-seam coal. At lower excess-air levels, carbon combustion efficiencies could be maintained at 99 percent by increasing the air preheat to 700° F.

OP 170-70. The Use of Natural Gas and Oxygen in the Stack and Tuyeres of an Experimental Blast Furnace, by N. B. Melcher, R. B. Schluter, T. L. Joseph, and R. J. Leary. Proc. 27th Ironmaking Conf., AIME, Apr. 1-3, 1968, Atlantic City, N.J., 1969, pp. 151-161; discussion, pp. 161-164. Hot reducing gases (principally H₂ and CO) were injected into the stack to augment normal iron reduction. Iron production increased 40 percent; coke rate diminished correspondingly. Natural gas and oxygen were injected through the tuyeres for comparison.

OP 171-70. Coke Savings and Higher Productivity Achieved With Ultra High Blast Temperatures in an Experimental Blast Furnace, by E. J. Ostrowski, R. B. Schluter, and N. B. Melcher. Proc. 27th Ironmaking Conf., AIME, Apr. 1-3, 1968, Atlantic City, N.J., 1969, pp. 171-174; discussion 174-175. Blast temperatures in the range 2,200° to 2,700° F resulted in a constant coefficient of coke rate improvement, but required an increasing coefficient of blast moisture addition to maintain the minimum rate of reducing gas input.

OP 172-70. Microhydrogenation—A Useful Tool in Sulfur Studies, by C. J. Thompson and H. T. Rall. Mechanisms of Reactions of Sulfur Compounds, v. 4, 1969, pp. 111-114. Describes development and application of a method of microhydrogenation for identification of sulfur compounds in petroleum and other natural products. Method permits structure characterizations that would be difficult or impossible by other procedures.

OP 173-70. Effect of Rock Fracturing on the Modulus, As Determined by Borehole Dilation Tests, by Louis A. Panek. Proc. 2d Internat. Cong., Internat. Soc. Rock Mechanics, Belgrade, Yugoslavia, Sept. 21-26, 1970, Paper 2-16, 5 pp. In situ dilation tests were made in small boreholes to determine the apparent modulus of rigidity of fractured rock, using the Bureau of Mines cylindrical pressure cell. A steady decrease of modulus occurred with decreasing fracture spacing. Application of the law of similitude leads to an interpretation of this result as a size effect. This interpretation seems capable of rationalizing the results of all types of static tests to determine rock modulus. A good estimate of the apparent modulus for any size of structure, such as a dam foundation or a tunnel, can be derived from a testing program that takes proper account of rock fracturing.

OP 174-70. Ethylene-Steam Reaction Induced by Ozonizer Discharge, by T. C. Ruppel, P. F. Mossbauer, M. F. Ferrer, and D. Bienstock. I&EC Prod. Res. and Development, v. 9, No. 3, September 1970, pp. 369-376. The effect of molar ratio, space velocity, temperature, and reactor power on the ethylene-steam reaction in a Siemens ozonizer discharge was determined.

OP 175-70. Carbon Reduction of Iron Oxide Waste Materials To Be Reactive Sponge Iron in a Fluidized-Bed Reactor, by Espiridon G. Valdez, Henry Dolezal, and Karl C. Dean. Chem. Eng. Progress Symp. Series, v. 66, No. 105, 1970, pp. 221-224. Iron pellets of large surface

areas were successfully produced from hematitic and magnetitic materials in a fluidized-bed reactor. Scaling up this process to commercial scale will be dependent upon improvement of the process so as to make it economically practicable. Research is underway to develop a more efficient externally heated reactor, lower the cost of forming the pellets, and design a continuous operation.

OP 176-70. Methods and Equipment for Measuring Subsidence, by Louis A. Panek. In Third Symposium on Salt, ed. by Jon L. Rau and Louis F. Dellwig, The Northern Ohio Geological Society, Cleveland, Ohio, 1970, pp. 321-338. This report describes measurement techniques and equipment that are appropriate for determining the horizontal and vertical components of displacement and strain, tilt and curvature. Particular attention is given to the principal characteristics and uses of monuments, extensometers, tapes, electronic distance-measuring instruments, theodolite, alignment telescope, spirit level, tilt meter, and borehole inclinometer probe.

OP 177-70. The Anisotropic Thermal Expansion of the Crystal Lattice of α Hafnium, by Marion P. Krug and B. E. Davis. J. Less-Common Metals, November 1970, v. 22, No. 3, pp. 363-366. The two lattice parameters of hafnium with 2.1 weight percent zirconium were determined from measurements on 2 single-crystal specimens at temperatures from 23° to 1,600° C. These data are believed to be the most accurate thus far obtained for material of this composition, and, since hafnium of higher purity (with respect to zirconium) is difficult to obtain, they may be the best approximation to the thermal-expansion data for pure hafnium.

OP 178-70. The Granular Micrinite Component of Coal, by J. T. McCartney. Fuel, January 1970, v. 49, No. 1, pp. 409-414. The nature of the granular micrinite component of coal and relevant evidence offered by other investigators are discussed. Electron micrographs are presented that clearly show rounded discrete particles in the size range 100-1,000 Å. Ambiguous evidence offered by various investigators concerning the reactivity of this component is also discussed.

OP 179-70. Recovery of Metallurgical Values From Industrial Wastes, by Paul G. Barnard, A. A. Cochran, and L. C. George. In Proc. New Directions in Solid Wastes Processing 1970 Institute, Framingham, Mass., May 12-13, 1970, pp. 81-94. The Bureau of Mines research programs include studies to develop technically feasible, economic methods for treating solid wastes and secondary raw materials for recovering and recycling valuable metals and minerals. Significant tonnages of useful metals can be recovered which are often richer in metal content than ores presently being processed. An additional potential benefit is the alleviation of the stream and ground-water pollution to which these waste materials contribute.

OP 180-70. Nonmagnetic Taconites, by D. W. Frommer. Min. Eng., v. 22, No. 11, November 1970, pp. 79-81. Experimental reclamation of water from the anionic silica flotation treatment of nonmagnetic taconites is described. Reuse of this reclaimed water in flotation was shown to be feasible.

OP 181-70. Loose Rock Can Be Detected by Infrared Devices, by Robert H. Merrill and Raymond M. Stateham. Min. Eng., November 1970, v. 22, No. 11, pp. 59-62. This article summarizes the use of

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infrared techniques to detect loose rock around underground mine openings. Research to date shows that when differences of about 0.5° C or more exist between the air and rock temperatures in underground openings the loose rock will have a different temperature than the solid rock. The results obtained in several mines are discussed.

OP 1-71. How to Predict the Penetration Rate of Percussive Drills, by William E. Bruce. *Min. Eng.*, v. 22, No. 11, November 1970, pp. 62-64. Penetration rates for the two drills were determined in nine rock types, and the physical properties of the same nine rocks were measured and tabulated. Then the penetration rates were plotted against the individual properties to determine the general relationships on which methods for predicting drilling rates could be based.

OP 2-71. Shale Oil Recovery by In-Situ Retorting—A Pilot Study, by E. L. Burwell, T. E. Sterner, and H. C. Carpenter. *J. Petrol. Technol.*, v. 22, No. 12, December 1970, pp. 1520-1524. Results of this in situ combustion experiment, conducted by the Bureau of Mines near Rock Springs, Wyo., to produce shale oil from oil shale, indicate that a combustion zone can be established in a fractured oil shale body by using air injection and a propane burner. During the 6-week period that combustion was maintained, 8,000 gallons of oil was produced.

OP 3-71. Thermodynamic Research Under API Project 62, by D. R. Douslin. *Proc. 35th Midyear Meeting, Div. Refining, API*, May 13, 1970, Houston, Tex., 1970, v. 50, pp. 189-211. Under the API RP 62 program, experimental and correlational studies have been carried out on 61 compounds in various research areas described in this report. Emphasis on the 46 alkanes was directed to effects of branching and the formulation of a new general correlation of their thermodynamic properties.

OP 4-71. The Effect of Fuel Composition, Equivalence Ratio, and Mixture Temperature on Exhaust Emissions, by R. D. Fleming and B. H. Eccleston. *Pres. at Automotive Engineering Congress, SAE*, Detroit, Mich., Jan. 11-15, 1971, Preprint 710012, 9 pp. A single-cylinder research engine was operated on pure hydrocarbons (HC) and simple mixtures of pure hydrocarbons to study the effect of fuel composition, equivalence ratio, and mixture temperature on exhaust emissions. Used as fuel components were the following hydrocarbons: *n*-pentane, 2-methyl-2-butane, isooctane, and *m*-xylene.

Total hydrocarbon emission in terms of moles of exhaust HC/mole of fuel input was lowered by increasing the amount of xylene in the fuel when operating on the fuel-rich side of stoichiometric; total hydrocarbon emission was higher for higher aromatic fuels when air-fuel ratios approached the lean misfire limit; the effect of mixture temperature on hydrocarbon emission was insignificant.

1-Methyl-3-ethylbenzene was observed as a synthesis product of combustion in the exhaust from fuels containing *m*-xylene. With increasing *m*-xylene concentration in the fuel, the yield of 1-methyl-3-ethylbenzene increases, reaches a maximum, and then decreases. The effect of equivalence ratio is to shift this maximum point toward lower aromatic fuels as the fuel-air mixture is leaned out.

OP 5-71. Processing Pelletized Cu Concentrate, by M. M. Fine and R. B. Schluter. *Min. Eng.*, v. 22, No. 11, November 1970, pp. 71-74. A new route from copper concentrate to metal includes 2-stage fluid-bed treatment; pelletized concentrate ((33 percent Cu, 7 percent S) is first desulfurized (to about 0.5 percent S) in an oxidizing atmosphere. In the second stage, the calcine is metallized by reduction with hydrogen. Thereafter, the reduced product plus 10 percent CaO is routed to a

smelting furnace to separate metallic copper from the gangue. Pelletizing the fine concentrate into minipellets prior to fluid-bed treatment permits shorter reaction time and decreases dusting.

OP 6-71. Nuclear Gages Applied to a Pressurized Gas Producer for Location of Coal Bed Level and Combustion Zone, by G. R. Friggens and A. W. Hall. *Advances in Instrumentation, Proc. 25th Ann. Conf. and Concurrent Symp.*, Philadelphia, Pa. Oct. 26-29, 1970, v. 25, pt. 4, Preprint 70-804, 3 pp. The Bureau of Mines is applying nuclear methods to monitor the coal bed level and combustion zone of a pilot-scale pressurized gas producer. Detection instruments measure the transmission of cobalt-60 gamma rays through the 56-inch-diameter by 16-foot-high vessel and provide personnel with continuous operating information, including coal bed height, occurrence of voids, location of combustion zone, and accumulation of excessive ash. Smoother, more efficient operation of the producer has resulted in improved gas production.

OP 7-71. Use of Selective Ion Exchange Paper in X-ray Spectrography and Neutron Activation: Application to the Determination of Gold, by Thomas E. Green, Stephen L. Law, and William J. Campbell. *Anal. Chem.*, v. 42, No. 14, December 1970, pp. 1749-1753. Ion exchange resin-loaded paper disks containing a highly selective ion exchange resin serve as an excellent medium for separating and collecting trace quantities of elements in an optimum form for X-ray spectrographic and neutron activation determination. A new collection procedure provides a simple means for preconcentrating the trace elements from large samples. A radioactive tracer added to the original sample is used as the collection monitor. Use of a cyclotron-produced radiotracer permits the application of this procedure to neutron activation determination. The determination of gold in the ppm range by X-ray spectrography and in the ppb range by neutron activation are given as examples.

OP 8-71. Streaming Potential, Surface Conductance, and Electroviscous Effect in a Porcelain Sample With Sub-Micron Size Pores, by Larry C. Headley. *Proc. West Virginia Acad. of Sci.*, 1969, v. 41, pp. 359-367. The flow and electrical properties of water of conductivity ranging from 0.1 ohm⁻¹-meter⁻¹ to about 10⁻⁴ ohm⁻¹-meter⁻¹ were studied in synthetic porcelain porous samples of average pore radius 0.42 microns. Streaming potential and surface conductance were measured by standard techniques. The electroviscous effect was measured by shorting out the streaming potential electrodes and observing the resultant change in flow rate. The experimental results are compared with curves calculated from theoretical expression by two different authors. The results indicate that neither theory completely explains the processes which occur. Several hypotheses are advanced to account for the discrepancies.

OP 9-71. A Controlled-Atmosphere Plasma Arc for Emission Spectrography of Nonmetal Elements, by Raymond J. Heemstra. *Appl. Spectroscopy*, November/December 1970, v. 24, No. 6, pp. 568-572. To estimate the weight percents of certain nonmetal elements in organic compounds found in petroleum reservoirs, the Bureau of Mines designed and constructed a controlled-atmosphere plasma arc which effectively excludes air from the plasma. Selected organic compounds that contained nonmetal elements were mixed with a solvent essentially free of those elements. The weight percents of the nonmetal elements were estimated from the produced diatomic spectral bands;

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results were reasonably accurate. Analytical working curves were prepared for nitrogen in the range from 15 to 450 μg for 100 mg samples using the analytical carbon-nitrogen band at 3,883 $\text{\AA}$ and the internal standard carbon-carbon band at 3,607 $\text{\AA}$. Curves also were prepared for hydrogen, sulfur, and oxygen that had limited sensitivity to detection. Another indicated application of this plasma arc is for characterization of high-boiling petroleum fractions in liquid chromatographic effluents. The rates at which diatomic species are produced and destroyed directly influence the intensity of each corresponding band spectrum.

OP 10-71. Air Pollutants From Internal Combustion Engines, by R. W. Hurn. Pres. at 9th Aerospace Sciences Meeting, AIAA, New York, Jan. 25-27, 1971, AIAA paper 71-122, 11 pp. This paper seeks to place the characteristics of internal combustion engines in proper perspective with regard to clean-air requirements. The basic engine and fuel factors that influence pollutants are discussed in the context of achieving low emissions; the penalty to performance, if any, is also discussed.

Advantages and disadvantages in the use of lead-free gasoline, natural gas, and propane are reviewed. Finally, the more prominent characteristics of the several types of internal combustion engines are summarized with respect to the potential each holds for development to meet clean-air requirements.

OP 11-71. The Kinetics and Equilibria of the Gold-Chlorine System, by A. Landsberg and C. L. Hoatson. *J. Less-Common Metals*, v. 22, 1970, pp. 327-339. The kinetics and vapor-solid equilibria of the gold-chlorine system have been studied between 70° and 800° C at chlorine pressures ranging from 76 to 760 torr. Four kinetic regions, differentiated by separate controlling mechanisms, were found. Kinetic factors were correlated with equilibria involving (1) the vapor pressure of Au_2Cl_6 , (2) chlorine and Au_2Cl_6 vapor in equilibrium with Au_2Cl_3 , (3) chlorine and Au_2Cl_6 vapor over gold, and (4) chlorine and Au_2Cl_6 vapor over gold.

OP 12-71. Hexafluorobenzene and 1,3-Difluorobenzene: Low-Temperature Calorimetric Studies and Chemical Thermodynamic Properties, by J. F. Messerly and H. L. Finke. *J. Chem. Thermodynamics*, v. 2, No. 6, November 1970, pp. 867-880. The chemical thermodynamic properties for the condensed phases of hexafluorobenzene and 1,3-difluorobenzene from 12 to 320 K were calculated from low-temperature calorimetric studies made by the Thermodynamics Research Group of the Bureau of Mines Bartlesville Petroleum Research Center.

OP 13-71. Characterization of Crude Oils by Gel Permeation Chromatography, by H. H. Oelert, D. R. Latham, and W. E. Haines. *Separation Science*, v. 5, No. 5, October 1970, pp. 657-668. The classical method of dividing crude oil into narrow molecular-weight cuts—distillation—is not practical in the high-boiling region. Thus, gel permeation chromatography was evaluated as a technique for characterizing the high-molecular-weight portion of crude oils. Crude oils, stripped to 180° C, were separated in a dual-column GPC system. The fractions obtained provided information concerning the amounts of material with molecular weights between 400 and 3,000. Gross estimates were made of the proportion of ring and nonring carbons in these fractions. The latter estimates were obtained by relating molecular

weights determined on the fractions to a calibration plot made up from data on model compounds.

OP 14-71. Tetrahydrofuran: Vibrational Assignment, Chemical Thermodynamic Properties, and Vapor Pressure, by D. W. Scott. *J. Chem. Thermodynamics*, v. 2, No. 6, November 1970, pp. 833-837. A vibrational assignment is proposed for tetrahydrofuran and used with available structural, energetic, and calorimetric data to compile a table of the chemical thermodynamic properties. Determinations of the vapor pressure also are reported.

OP 15-71. Separation and Characterization of High-Molecular-Weight Saturate Fractions by Gel Permeation Chromatography, by J. H. Weber and H. H. Oelert. *Separation Sci.*, v. 5 No. 5, October 1970, pp. 669-675. Gel permeation chromatography (GPC) was applied to the saturate portion of a 450° to 475° C cut of Wilmington crude oil. Selected fractions were analyzed by mass spectrometry, which demonstrated that a separation based on the number of rings was achieved. An early fraction contained 95.5 weight-percent no-, one-, and two-ring compounds; and a late fraction contained 95.9 weight-percent three-, four-, five-, and six-ring compounds. The relationship of the experimental results to those predicted from calibration curves relating carbon number to both distillation and GPC is discussed.

OP 16-71. Chromatographic Separation of the Nuclear Spin Isomers of Hydrogen and Deuterium Below 60° K, by A. Purer and R. L. Kaplan. *J. Chromatographic Sci.*, v. 9, January 1971, pp. 59-62. This investigation was undertaken to study the separation characteristics of helium, hydrogen, and deuterium on a specially prepared capillary column. Complete separation of helium, parahydrogen, orthohydrogen, para-deuterium, and orthodeuterium was achieved by using neon as a carrier gas with an 82-m by 0.28-mm, id, soft-glass capillary column with an etched internal surface. The operating temperature range of 29° to 60° K was obtained by using a helium refrigerator. The interaction of helium with the column's adsorptive surface was found to be small at these temperatures.

OP 17-71. Single-Strand Strainwire Technique: Extensions and Refinements, by J. R. Zelonka, R. J. Kline, and L. Wade. *Experimental Mech.*, v. 10, No. 12, December 1970, pp. 539-544. This paper is the first of three papers on a refined internal strainwire technique. Availability of sensitive data-acquisition equipment has made possible a detailed investigation that resulted in reductions in both gage length and excitation voltage with little reduction in the quality of the information.

The method of measuring internal strains by embedded lengths of strain-gage wire has been extended to the construction and evaluation of strain rosettes. Experimentally measured principal strains on an interior plane of a compressed square prism are compared for statistical and theoretical consistency.

OP 18-71. Coal and Coke, by S. Ergun, R. A. Friedel, J. T. McCartney, and I. Wender. In *Encyclopedia of Industrial Chemical Analysis*, Volume 10, Ed. by F. D. Snell and L. S. Ettre, Interscience Publishers, New York, 1970, pp. 209-262. This article covers methods of analysis of coal and coke, including sampling, functional group analysis, spectroscopy, petrography, determining optical constants, density, electron microscopy, X-ray diffraction, proximate analysis, ultimate analysis, calorific value, ash fusi-

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bility, behavior on heating, grindability, and special constituents. Also included is an extensive bibliography on analytical methods for coal and coke.

OP 19-71. Separation of Nickel and Cobalt by an Electrolytic Process, by T. A. Sullivan. Ch. in Progress in Separation and Purification, Volume 3, ed. by Edmond S. Perry and Carel J. Van Oss. John Wiley & Sons, Inc., New York, 1970, pp. 285-304. Electrolytic separation of nickel and cobalt from nickel products containing up to 5 percent cobalt was accomplished in a molten $KCl-LiCl-NiCl_2$ electrolyte.

OP 20-71. Fundamentals of Statistical Screening, by C. W. Schultz and R. B. Tippin. Trans. SME, AIME, v. 247, December 1970, pp. 314-316. It was shown that an acceptable sizing separation can be attained using a statistical screening concept. Mathematical models were fitted to the experimental data showing the nature of the screening technique.

OP 21-71. Activation Analysis of Gold-Bearing Scrap Solders, by D. E. Shanks, K. G. Broadhead, and H. H. Heady. Internat. J. App. Radiation and Isotopes, v. 21, 1970, pp. 671-676. Neutron activation analysis is used to meet the metallurgical research requirements for the rapid, non-destructive, analysis of Sn-Pb solders to which Al has been added to effect a phase separation of Au. The elements determined are Au, Sn, Pb, Al, and Sb.

OP 22-71. Reservoir Rock Characteristics of the Madison Limestone in the Williston Basin, by E. J. White and L. C. Marchant. Log Analyst, v. 11, No. 5, September-October 1970, pp. 17-25. In this paper, the porosity and water saturations as determined from logs are compared with the values obtained from core analyses for reservoirs in the Williston Basin. The material will be useful to a log interpreter with wells in a carbonate reservoir.

OP 23-71. How Bearing Plates Affect Roof Bolt Performance, by Richard Oitto, Anthony Zona, and Juel Stears. Coal Min. and Processing v. 7, No. 12, December 1970, pp. 49-57. Results from a laboratory investigation by the Safety Research Center of the Bureau of Mines on roof bolts show that the bearing plate can cause tension bleed-off in a roof bolt assembly.

OP 24-71. Radiosotopic X-Ray Analysis of Silver Ores Using Compton Scatter For Matrix Compensation, by P. G. Burkhalter. Anal. Chem., v. 43, No. 1, January 1971, pp. 10-17. Radiosotopic X-ray analysis with semiconductor detectors was evaluated for determining silver in ores. X-ray and scatter peak intensities were obtained using computer processing for curve fitting backgrounds under the Ag $K\alpha$ peaks and unfolding overlapping spectra. The discrete Compton and coherent scatter peaks obtainable with monoenergetic excitation were evaluated as internal standards for matrix compensation. The Ag $K\alpha$ -to-Compton ratio provides compensation for X-ray absorption and a single, linear calibration curve can be used for silver determination in both uniform and variable matrix ores. For a set of samples taken from a drill core, silver was determined to within ± 10 percent for concentrations above 3 oz/ton and the detection limit was 0.3 oz/ton (10 ppm). For

Variable matrix ores, silver can be determined within ± 20 percent.

OP 25-71. The Chlorination of Columbite in a Fluidized-Bed Reactor, by Richard S. Olsen and Frank E. Block. Chem. Eng. Symp. Series, v. 66, No. 105, 1970, pp. 225-228. A fluidized-bed reactor for the continuous chlorination of columbite with elemental chlorine is described. This process uses a bed of fluidized metallurgical coke both as the reactor medium and as the reductant required for the chlorination reaction. The effects of pertinent operating variables on the operation of the chlorinator are discussed.

OP 26-71. Apparatus and Procedure to Reduce Impurities in Helium to Less Than One Part Per Billion, by C. A. Seitz, W. M. Bodine, and C. L. Klingman. J. Chromatographic Sci., v. 9, January 1971, pp. 29-31. Certain scientific applications require helium of greater purity than that routinely available. This paper describes a laboratory-size apparatus which reduces impurities in helium to less than 1 part per billion. The unit employs easily available, low-cost liquid nitrogen as a refrigerant to cool activated charcoal for the cyclic adsorption of impurities. The essential differences between the new purifier and previous adsorption units are the use of highly purified helium to purge and repressure the charcoal during and after regeneration and regeneration of the adsorbent before neon emerges. The unit produces a few hundred cubic centimeters of highly purified helium per minute, the amount depending upon the helium pressure required and the chosen cycle time. Continuous safe operation is achieved with only periodic observation and requires about 20 liters of liquid nitrogen per day.

OP 27-71. Aspects of Water Reuse in Experimental Flotation of Nonmagnetic Taconites, by D. W. Frommer. Trans. SME, AIME, v. 247, December 1970, pp. 281-287. Experimental reclamation of water from the anionic silica flotation treatment of nonmagnetic taconites is described. Reuse of this reclaimed water in flotation was shown to be feasible.

OP 28-71. Method and Apparatus for Determining Helium Content of Gas Mixtures, by David E. Emerson and Richard L. Kaplan. Anal. Chem., v. 42, No. 14, December 1970, pp. 1746-1748. A method and apparatus are described for determining the helium content of gaseous mixtures. The work was done so that the Bureau of Mines could more accurately and economically analyze helium-containing natural gases, crude helium purchased from private industries, and helium in gases used in research. Activated coconut charcoal is utilized at liquid nitrogen temperature to adsorb components other than helium in the mixture. A transducer is then used to determine the helium pressure. Twenty or more analyses with a standard deviation of ± 0.04 percent can be made in an 8-hour day.

OP 29-71. Determination of Nitrogen in Vanadium Nitrides and Uranium Nitride (UN), by Dean H. Bollman and D. M. Mortimore. Anal. Chem., v. 43, No. 1, January 1971, pp. 154-155. The Kjeldahl distillation and titration procedures for vanadium nitrides and uranium nitride are given.

OP 30-71. Purification of Vanadium by Vacuum Melting, by W. E. Anable. J. Vacuum Sci. and Technol., v. 7, No. 6, November/December 1970, pp. S74-S80. The Bureau of Mines compared the purification of two commercially available vanadium

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samples by three vacuum melting techniques: consumable-electrode arc melting at the top of the mold (TOM); consumable-electrode arc melting in a conventional deep mold; and conventional electron-beam melting (EBF). The purity of samples melted at the TOM approached the purity of samples prepared in the EBF. In some instances, a further decrease in the oxygen and metallic impurity content resulted from remelting selected materials in the electron-beam furnace. Little or no purification resulted from melting vanadium in the conventional deep mold. Purification proceeded faster and more completely on melting vanadium with small additions of yttrium, carbon, or aluminum; aluminum was largely removed on double melting, but carbon and yttrium remained in the products. Metal or carbon additions tended to stabilize the arc and improve metal recovery from 85 percent to greater than 90 percent during a consumable-electrode arc melt.

OP 31-71. Are Oil- and Gas-Well Drilling, Production, and Associated Waste Disposal Practices Potential Pollutants of the Environment? by A. Gene Collins. ACS Preprints, v. 10, No. 2, September 1970, pp. 1-14. Poor drilling and well completion practices and improperly abandoned wells provide potential avenues for pollution. Prime pollutants were found to be brine, petroleum, drilling muds, well completion chemicals, drilling fluids, and production-associated chemicals.

OP 32-71. Rapid Determination of Nitrogen Oxides With Use of Phenoldisulfonic Acid, by Barbara A. Coulehan and Helen W. Lang. Environmental Sci. and Technol., v. 5, No. 2, February 1971, pp. 163-164. A rapid, quantitative batch procedure for analysis of atmospheric nitrogen oxide samples ($\text{NO} + \text{NO}_2$, commonly referred to as NO_x) from mines, tunnels, and raw or dilute diesel exhaust is described. This modification of the phenoldisulfonic acid nitration procedure eliminates the time-consuming evaporation step and two transfer steps of the original procedure. Samples are collected in evacuated bottles containing an absorbent solution and hydrogen peroxide to completely oxidize the gas-phase NO_x to nitric acid. After destruction of excess oxidant, an aliquot of the absorbed sample is added to the phenoldisulfonic acid reagent in a 25-ml volumetric flask which is used as the reaction vessel for subsequent nitration and neutralization. This modified method can double or triple the number of analyses per day by the original method.

OP 33-71. An Evaluation of the Fuel Factor Through Direct Measurement of Photochemical Reactivity of Emissions, by Basil Dimitriadis, B. H. Eccleston, and R. W. Hurn. J. Air Pollution Control Assoc., v. 20, No. 3, March 1970, pp. 150-160. Findings in research at the Bureau of Mines Bartlesville Petroleum Research Center show that photochemical reactivities of vehicular emissions are reliably measured in laboratory experiments in which smog manifestations are observed directly. The concept was applied to determine differences in characteristics of emissions from 20 passenger vehicles, each tested using 10 different fuels. Significant fuel differences were found and are discussed in the paper.

OP 34-71. A Procedure for Routine Use in Chromatographic Analysis of Automotive Hydrocarbon Emissions, by Basil Dimitriadis and Donald E. Seizinger. Environmental Sci. and Technol., v. 5, No. 3, March 1971, pp. 223-229. Procedures have been developed for routine analysis of automotive fuels and the unburned hydrocarbon of exhaust emissions. Specific

attention is given to the hydrocarbon components that are photochemically reactive. Problems encountered in all phases of the analytical method are identified, and procedures that constitute a reasonable compromise between accuracy and practicality are defined. A packed and an open tubular column were used to separate the hydrocarbon content of exhaust and gasoline-vapor samples into 165 component groups; analysis time is 30 minutes. Raw chromatographic data are rapidly processed using a high-speed electronic integrator and a computer technique for automatic interpretation of chromatographic spectra.

OP 35-71. Carbon Monoxide in Lower Atmosphere Reactions, by B. Dimitriadis and M. Whisman. Environmental Sci. and Technol., v. 5, No. 3, March 1971, pp. 219-222. To understand more fully pollution problems posed by carbon monoxide, an experimental study of CO reactions in the lower atmosphere was conducted. The study involved exposure of CO to lower atmospheric conditions simulated in the laboratory and measurement of rate of CO oxidation in CO_2 . To simplify analytical measurements, the CO reactant was mixed with C^{14} -labeled CO. Results suggested that the CO oxidation rate in the lower atmosphere is approximately 0.05 percent per hour of day- or night-time, resulting in a lifetime of 0.3 year; observed rates cannot be explained only by CO reactions with oxygen atoms and ozone; and the presence of CO at typical levels does not necessarily affect the process of photochemical smog formation.

OP 36-71. A Closer Look at Hydrometallurgy, by J. T. Dunham. Iron Age, v. 206, No. 22, Nov. 26, 1970, pp. 42-43. The methods for leaching copper ores are summarized.

OP 37-71. Anthracite Preparation—Past and Present, by James W. Eckerd and John D. Spencer. Pres. at AIME Ann. Meeting, Mar. 1-4, 1971, New York, N.Y., Preprint 71-F-57, 9 pp. This report traces the development of some of the most important processes used through the years for anthracite preparation and describes present coal-cleaning methods.

OP 38-71. Production and Utilization of Metallized Ore, by M. M. Fine. Skillings' Min. Rev., v. 60, No. 9, Feb. 27, 1971, pp. 1, 8-11. Within the last few years iron ore prereduction has emerged as a viable operation in many parts of the globe. Some processes which are commercial (or potentially so) are briefly reviewed, and the reasons for the apparent economic breakthrough of direct reduction are discussed. Present and projected uses of metallized ore indicate a market which could be supplied from Lake Superior resources. Upgrading these resources to meet the specifications for metallized material will be one of the future challenges facing the iron producing industry of this area.

OP 39-71. Nitroglycerin Tests Prove New Application, by W. D. Howell, J. L. Eakin, J. S. Miller, and C. J. Walker. World Oil, v. 171, No. 6, November 1970, pp. 96-98. Two field tests were performed in shallow gas wells to evaluate the stimulation achieved by the displacement and detonation of desensitized liquid in formation fractures.

OP 40-71. Supersensitive Light Meter for Electron Microscopy, by Charles W. Huggins and Norman A. Pace. Norelco Reporter, v. 17, No. 2, December 1970, pp. 22, 24. A supersensitive light meter for electron microscopy that has been in use for 3 years at the Bureau of Mines College Park Metallurgy Research Center is described.

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OP 41-71. Oxygen Dilution Requirements for Inerting Aircraft Fuel Tanks, by Joseph M. Kuchta. Rept. 2d Conf. on Fuel System Fire Safety, sponsored by Flight Standards Service, Department of Transportation, and Federal Aviation Administration, Washington, D.C., May 6-7, 1970, pp. 85-116. The effectiveness of various inerting agents to prevent ignition and flame propagation in hydrocarbon fuel-air systems is briefly reviewed. Data are presented on the variation of limits of flammability, minimum ignition energies, and minimum autoignition temperatures with oxidant or diluent concentration. For inerting aircraft fuel tanks containing Jet A or Jet B type fuels at 100° F, it is recommended that the oxygen concentration be maintained below 10 volume-percent with nitrogen as the inert and below 12.5 volume-percent with carbon dioxide as the inert. An expression for calculating the oxygen dilution requirements at various temperatures is also given in this paper.

OP 42-71. Recommendation of Flash Point Method for Evaluation of Flammability Hazard in the Transportation of Flammable Liquids, by J. M. Kuchta and D. Burgess. Prepared for the Department of Transportation. NTIS'CH-SAM-828. 1970. 18 pp. This report on research conducted by the Bureau of Mines for the Department of Transportation discusses the use of Tagliabue (Tag) closed cup method to determine flashpoints of flammable liquids for transportation hazard classification purposes. Report presents comparative data for Tag open cup and Tag closed cup flashpoints and for Tag closed cup values and those calculated from lower flammable limits. Repeatability and reproducibility of several types of testers are compared.

OP 43-71. Crash Fire Hazard Rating System for Controlled Flammability Fuels, by Joseph M. Kuchta, Aldo L. Furno, George H. Martindill, and Agnes C. Imhof. National Fire Protection Assoc., Aviation Bull. No. 365, August 1969, pp. 1-17; 1-1, 1-3. A method for rating the potential crash fire hazard of gelled and emulsified hydrocarbon fuels was developed at the request of the Federal Aviation Administration, since the use of thickened aircraft fuels may provide a significant reduction in the crash fire hazard. The rating system is designed primarily for screening candidate thickened fuels with respect to their overall flammability hazard under laboratory-scale conditions.

OP 44-71. A Comprehensive In-House Course in Technical Writing for Engineers and Scientists, by Bill Linville. Proc. 4th Ann. Tech. Writing Inst., Texas Tech University, Lubbock, Tex., Apr. 2-3, 1970, February 1971, pp. 4-19. An in-house training program in technical writing for engineers and scientists of the Bureau of Mines Bartlesville (Okla.) Petroleum Research Center is helping them to improve their writing. Simultaneous instruction in English composition and technical writing techniques provides a new approach to short-course teaching methods. The course has improved the quality of written communications by the enrollees and has helped in motivating them to increase their writing for publication. The course is described and outlined.

OP 45-71. Fuels Management in an Environmental Age, by G. Alex Mills. Environmental Sci. and Technol., v. 5, No. 1, January 1971, pp. 30-38. In selecting a fuel the effects of production, processing, and utilization of each fuel on the land, water, and air must be considered. This presents a complex situation, since all the principal energy sources—

coal, oil, gas, nuclear, and hydro—have differing environmental effects. The severity of the pollution tradeoffs must be evaluated and decisions made as to which fuel is likely to have the least harmful environmental impact. Two fuels management problems are particularly urgent. The first, automobile fuels, is undergoing rapid change and little can be done in the short term to replace gasoline as a fuel. The second, generation of electricity, does have much substitutability from competing energy sources. Both pose unique management problems that must be solved if the nation is to benefit from low-cost energy that is produced and used in a manner that does not further degrade the environment.

OP 46-71. Non-energy Uses for Fuels, by G. Alex Mills and John S. Tosh. Proc. North American Fuels Technol. Conf., Ottawa, Canada, May 31-June 3, 1970, pp. 9.1-9.14. The use of fossil fuels for nonenergy uses in the United States and Canada has grown rapidly and has reached 10 percent of consumption. Many factors have contributed to this growth—new products, new technology, and an affluent and expanding economy. Factors influencing future of chemicals production from fossil fuels are discussed.

OP 47-71. Method for Rock Property Determination in Ultrahigh Vacuum, by Egons R. Podnieks and Peter G. Chamberlain. Proc. 5th Space Simulation Conf., Sept. 14-16, 1970, Gaithersburg, Md., October 1970, pp. 209-223. A special ultrahigh vacuum system was designed for determining deformational and strength properties of simulated lunar rocks. The system provides a vacuum of 10^{-9} to 10^{-10} torr (10^{-7} to 10^{-9} N/m²) depending on the specimen size and rock type. The vacuum was measured by various types of gages and also by ion pump current measurements. The partial pressure measurements of the various gas components were obtained by a quadrupole residual gas analyzer. The vacuum chamber has two stainless steel bellows-type feed-throughs for loading and a spring mechanism to compensate for the atmospheric pressure effect on the rock specimen. The uniaxial load was applied to the specimen by a servocontrolled hydraulic testing machine. Specimens of tholeiitic basalt, dacite, and semiwelded tuff were used. Special procedures in specimen preparation and preconditioning were developed. During the pumpdown period, prolonged roughing and an initial bakeout produced significantly low final pressures in the chamber. Test data presented include a typical load-deformation curve from rock specimen in ultrahigh vacuum, outgassing characteristics during loading in terms of pressure variation, and changes in the composition of gases being released by the specimen.

OP 48-71. Diamonds Flunk Test on Lunar Hammer-Drill, by Robert L. Schmidt. Drilling, v. 32, No. 2, December 1970, pp. 34-35, 64. This article describes the testing program conducted at the Bureau of Mines Twin Cities Mining Research Center to determine the suitability of diamonds as cutting elements in a percussive bit. This unusual application was studied as part of the lunar-drill research program.

OP 49-71. Kerogen of the Green River Formation, by W. E. Robinson. Ch. 26 in Organic Geochemistry—Methods and Results, ed. by G. Eglinton and M. T. J. Murphy. Springer-Verlag, Berlin, 1969, pp. 619-637. The structure of Green River Formation kerogen was studied by various chemical and physical methods. The results showed that this kerogen is predominantly a saturated cyclic structure with a few aromatic and long-chain constituents.

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OP 50-71. Thermal Decomposition of CuS to Cu_2S , by I. D. Shah and S. E. Khalafalla. *Metall. Trans.*, v. 2, February 1971, pp. 605-606. The conversion of covellite to digenite in the temperature range 310° to 338°C does not follow the unreacted core model. The observed linear kinetic curves suggest that the rate-controlling step occurs at the outermost constant area interface between covellite and the reacting gases.

OP 51-71. Examples of Nuclear Applications Research, by R. F. Stewart. *Proc. Conf. on Utilization of Nuclear Technol. in Ind. Operations*, Charleston, W. Va., June 8-9, 1970, Ser. 71, No. 2-1, August 1970, pp. 5-9. Eleven examples of the type of research project conducted at the Morgantown Energy Research Center, Morgantown, W. Va., are given. Nuclear applications in the coal industry include neutron thermalization to continuously monitor the moisture content of coal, beta and gamma backscatter to measure the explosive nature of mine dust, and neutron-gamma reactions used as a sulfur meter in the process control of coal cleaning methods. Other applications include tagging coal for flow measurements and level and density gaging for coal processes.

OP 52-71. Effect of Reduced Pressure on Thermal-Expansion Behavior of Rocks and Its Significance to Thermal Fragmentation, by K. Thirumalai and S. G. Demou. *J. Appl. Phys.*, v. 41, No. 13, December 1970, pp. 5147-5151. Thermal expansion is a significant parameter for the creation of thermal stresses to fragment rocks by heat. A method for experimentally measuring rock response to induced thermal stresses from cyclic thermal expansion of the rock surface is developed using strain-gage technique. Rock fracture caused by internal thermal stresses during heating and cooling in atmosphere and vacuum environment is examined. The response of rock material to induced thermal stresses is shown to be independent of reduced environmental pressure down to 15^{-5} torr. The results of reduced environmental pressure on thermal expansion behavior of some simulated lunar rocks are presented. These results provide a new insight on the feasibility of fragmenting the rock with thermal energy in vacuum environment.

OP 53-71. Single-Strand Strainwire Technique: Heating and Reinforcing Effects, by L. Wade, J. R. Zelinka, and E. M. Krokosky. *Experimental Mech.*, v. 11, No. 2, February 1971, pp. 94-96. This paper, the second of three on a refined internal strainwire technique, examines the effect of internally embedded single-strand strainwires, both as reinforcing and as heating elements within a matrix material. To investigate possible reinforcing effects, two identical plates, one containing internal wires and the other without these wires, were examined. The photoelastic-fringe patterns (isochromatics) were photographed to determine if the presence of the wires causes an alteration of the isochromatic patterns. An investigation of the possible heating effects was accomplished in the same way, only, in this analysis, voltage was passed through the internal gages. To learn more about the heating characteristics of the wire-matrix system, the voltage in the gages was increased until the heating effect manifested itself. Using this technique, it was possible to determine the upper limit of applied voltage. The long-term effects of the applied voltage were also examined.

OP 54-71. Theory and Optimization of the Pulsed NMR Driven Equilibrium Technique (Letter to the Editor), by

William E. Wallace, Jr. *J. Chem. Phys.*, v. 54, No. 3, Feb. 1, 1971, pp. 1425-1427. This letter reports a Bloch equation analysis of the driven equilibrium Fourier transform (DEFT) pulse technique resulting in the optimization of the recycling time, for purposes of speeding signal averaging, for the general case of T_1 , spin-lattice, and T_2 , spin-spin, relaxation times not necessarily equal. Some other uses and modifications of the technique are suggested.

OP 55-71. Discussion of "Rapid, Automatic Particle Size Analysis in the Subsieve Range," by J. P. Olivier and G. K. Hickin, by C. B. Daellenbach. *Proc. 31st Ann. Mining Symp.*, Duluth, Minn., Jan. 12-14, 1970, p. 127. A technical discussion of a paper describing the development of an apparatus for X-ray determination of particulate size distribution in subsieve range using sedimentation sizing methods.

OP 56-71. Ground Support Builds on Firm Foundation, by Walter E. Lewis and Robert L. Marovelli. *Min. Eng.*, v. 23, No. 1, January 1971, pp. 73-77. This article discusses ground support systems that have been used successfully in the past and points out the areas in which research is either underway or is needed.

OP 57-71. The Kinetics and Equilibria of the Platinum-Chlorine System, by A. Landsberg and J. L. Schaller. *J. Less-Common Metals*, v. 23, 1971, pp. 195-202. The kinetics and vapor-solid equilibria of the platinum-chlorine system have been studied between 470° and 880°C at chlorine pressures of 152 to 760 torr. Three kinetic regions, differentiated by separate controlling mechanisms, were found. Correlations were made between the kinetic factors and equilibria involving (1) the vapor pressure of PtCl_2 , (2) chlorine and PtCl_2 vapor in equilibrium with platinum, and (3) chlorine and PtCl_3 vapor over platinum.

OP 58-71. Opportunities in the Production of Secondary Non-ferrous Metals, by Max J. Spendlove. *Pres. at Expert Group Meeting on Utilization of Non-Ferrous Scrap Metal in Developing Countries*, United Nations Industrial Development Organization, Vienna, Austria, ID/WG.46/3; abs. in *Utilization of Non-Ferrous Scrap Metal*, UN Pub. E.70.II.B.30, 1970, p. 71. Discarded durable metal goods comprise a substantial part of the raw materials currently processed by secondary smelters and are a growing metal resource in the United States. Documented data on the actual quantity of scrap materials processed annually show that these materials supply a large part of the total metals consumed. The record also shows that primary and secondary metal production rise and fall approximately in unison, and the fraction of metal supplied from scrap even seems to be increasing slightly more rapidly than primary metal production. Such data may be useful for estimating the profitable scale of operations in a developing country simply by comparing its level of industrialization with comparable reliable data published by other countries. The ratio of profitable secondary metal production for two countries should be approximately proportional to the ratio of their levels of industrialization. Such a comparison of data would simply indicate the total volume potential, but the economic potential could then be estimated in accordance with domestic capabilities and other assets. Accordingly, opportunities in the production of secondary metals would be found through several means such as judicious management, adopting only the most efficient technology, and possibly negotiating trade agreements.

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OP 59-71. Plant Tests of a Neutron Moisture Meter for Coal, by R. F. Stewart, A. W. Hall, and J. L. Konchesky. Min. Cong. J., v. 56, No. 11, November 1970, pp. 44-48. A neutron moisture meter developed by the Bureau of Mines continuously and automatically monitors the moisture content of coal. The electronically operated device was tested for 11 months without malfunction or recalibration.

OP 60-71. Electroslag-Melted Molybdenum, by E. D. Calvert, R. A. Beall, and H. Kato. J. Less-Common Metals, v. 23, March 1971, pp. 129-151. The preparation of molybdenum ingots by electroslag melting is discussed, ingot characteristics are described, and results of mechanical testing of wrought products are compared with those from similar material prepared from arc-cast molybdenum.

Thermochemical considerations limit the choice of slag materials to a few high-temperature oxides; of these, yttrium oxide was found to be best suited for use in molybdenum melting. The use of additives to the slag was found necessary to minimize the occurrence of excessive oxide films at ingot grain boundaries. Changes in ingot surface and structure were found to be responsive to changes in such melting variables as power input, electrode spacing, electrode polarity, and environmental pressure conditions. Pressure conditions, electrode polarity, and the slag additives carbon and yttrium, were found to influence the oxygen level and occurrence of extraneous oxide phases in the ingots.

Excellent surface conditions are normally associated with the electroslag ingots; as a direct result, much less waste in conditioning for fabrication was encountered than is normal for arc-cast ingots. Additional material results from the unusually low temperature at which the electroslag ingots can be fabricated. Sheet fabricated from the electroslag-melted ingots appears to have mechanical properties superior to those of sheet prepared from similar arc-cast ingots.

OP 61-71. Solubility of Barium and Strontium Sulfates in Strong Electrolyte Solutions, by James W. Davis and A. Gene Collins. ACS Preprints, v. 11, No. 1, March 1971, pp. 115-124. Knowledge of the solubilities of BaSO₄ and SrSO₄ in solutions containing NaCl, CaCl₂, MgCl₂, and NaHCO₃ is needed to solve geologic and petroleum production problems. Samples of the sulfates were tagged with S³⁵ and prepared by precipitation. The solubility was measured in various concentrations of the major solutes by use of liquid scintillation technique to detect the SO₄ in solution. The observed solubilities plotted against ionic strength of the solution are similar for strong electrolytes. They reach a maximum at levels determined by ionic attraction and association, and presence of complex ions. The sulfate solubility in synthetic brines (principally NaCl) confirms the ionic strength-sulfate solubility relationships.

OP 62-71. How To Plan Your Mine for Methane Control, by Maurice Deul. Proc. Ann. Meeting, Illinois Min. Inst., Springfield, Ill., Oct. 9-10, 1969, pp. 23-30. Methane is expected to become more of a problem in coal mines as deeper coals are exploited and as nongassy coals are worked out. Because deep gassy coals are difficult to mine, relief can best be found in planning and designing new mines for methane control. This starts with exploration where large diameter vertical boreholes can be developed for multiple use. These boreholes will provide large coal samples for physical property measurements and washability studies, and for draining methane from the coal before mining. They will also provide

escapeways for men, service entrances for power and water, and auxiliary ventilation conduits, especially for gob drainage. Mining machines, which produce a minimum of coal fines should be specified. These machines produce a lower rate of methane emission from the mined coal. Mines should be designed to yield the smallest possible perimeter to reduce the amount of methane entering the mine. Large blocks of coal should be isolated from virgin coal early in mine development to permit maximum controlled bleedoff of methane. The suggested approach requires no radical new techniques.

OP 63-71. Experiments in Briquet Production From Western Bituminous Coals and Chars, by James W. Eckerd, Robert E. McKeever, and John D. Spencer. Proc. 11th Biennial Conf., Inst. for Briquetting and Agglomeration, February 1971, pp. 115-124. The Bureau of Mines investigated several Western bituminous coals, chars, coke breeze, and combinations of these for their briquetting potential in bench-scale experiments. Calcined briquets made from Sunnyside high-volatile B coal had the highest compressive strength, 1,380 psi. These briquets were formed at 15,000 psi and 710° F and calcined at 1,750° F using a heating rate of 7° per minute. Strongest raw briquets made at comparable conditions had a compressive strength of about 2,100 psi and were formed from equal parts of Hiawatha high-volatile B and Coal Basin medium-volatile bituminous coals and from equal parts of Sunnyside and Coal Basin coals; however, the latter combination crumbled during calcination. Briquets made from Sunnyside char mixed with 24 percent coal-tar pitch binder, formed at 3,000 psi and 275° F, and calcined for 55 minutes at 1,750° (heating rate of 9.5° per minute) had ASTM coke stability factors (plus 1 inch) ranging from about 9 to 56 percent, but no plus 2-inch material remained after the test. The average compressive strength of the calcined briquets, which was 1,220 psi when calcined at a heating rate of 9.5° per minute, was increased to 1,340 psi when the heating rate was 5° per minute, and breakage was less marked. Neither calcination of the char at 1,650° before briquetting nor preheating of the briquets before calcination improved the strength or appearance of the product.

OP 64-71. Propane as an Engine Fuel for Clean Air Requirements, by R. D. Fleming, J. R. Allsup, and R. W. Hurn. Proc. LP-Gas Engine Fuel Symp. Detroit, Mich., October 21-22, 1970. National LP-Gas Association, Chicago, Ill., April 1971, pp. 61-79. This paper describes the objectives and experimental design of a program to study the characteristics of propane as a low emission fuel. Results of preliminary work are given to show how emissions (using propane) vary with ignition timing, air-fuel ratio, speed, and load. Comparable data relating air-fuel ratio and emissions are shown for gasoline and natural gas. The bulk of these data are from experiments with a single-cylinder engine and from one full-scale engine; tests with both were run using an engine dynamometer operated at steady-state modes only. However, the principal study will involve full-scale engines and vehicles as they typically are used, and this progress report includes results of one series of tests to show the influence of ignition-timing schedule on exhaust emissions from a light sedan fueled with propane and operated through simulated traffic cycles.

OP 65-71. Flow Through a Tailings Pond Embankment, by C. Dan Kealy and Roy E. Williams. Water Resources Research, v. 7, No. 1, February 1971, pp. 143-154. Mathematical models that solve

the LaPlace or Richards' equation numerically have been used in two ways: to locate the phreatic surface within a mine tailings pond embankment, and to define the subsurface flow system that transports water outward from the pond. Input data needed for the finite element model include the saturated hydraulic conductivity (permeability) distribution within, and beneath, the embankment; the fluid potential values at both upgradient and downgradient boundaries of the embankment; and the geometry and elevation of an approximately impermeable layer at some depth beneath the surface of the embankment.

This technique has been applied to a tailing disposal system in northern Washington. Laboratory tests were used to obtain permeability values from samples collected by the Shelby tube method. Pond boundaries were examined by drillholes and piezometers. Piezometers were also used to validate the configuration of the phreatic surface predicted by the model. Of particular importance to slope stability analysis is the fact that both the model and the check piezometers indicate that a significant portion of the phreatic surface within the embankment is concave upward. Experimentation with the finite element model revealed that the concave upward portion is a consequence of the upstream boundary in a tailings pond being a flow line and embankment permeability being lower near the upstream boundary; the upstream boundary of the flow region in an earth dam is normally an equipotential line.

OP 66-71. Predicting Waterflood Performance, by R. V. Higgins. *Oil and Gas J.*, v. 69, No. 10, Mar. 8, 1971, pp. 68-72. Waterflood performance at constant-injection or other preset rates may be quickly evaluated by a new procedure. The method makes use of the calculations from the Higgins-Leighton constant-pressure evaluation. And performance data so determined provide the basic information for an economic evaluation. The effects of relative permeability—which appreciably influences recovery oil—are accounted for. Also, the method includes the use of layers to determine the effect of vertical-permeability variations. From this and other information made available by the new method, the constant-rate injection pumps can be designed. The predicted performance at constant pressure can be used to obtain predicted performance history at constant-injection rate, during the entire life of the flood. Performances can also be predicted for stagewise changes in injection rates, or even for continuously changing rates.

OP 67-71. Q-Switched Laser-Induced Reactions of Thiacyclobutane and Thiacyclopentane With Oxygen, by F. P. Miknis and J. P. Biscar. *J. Phys. Chem.*, v. 75, No. 5, 1971, pp. 725-726. The results of some investigations of the chemical reactions occurring during laser-induced gas breakdown of sulfur compounds in the presence of oxygen are reported. Thiacyclobutane and thiacyclopentane were chosen because they are sulfur compounds found in shale oil, a possible source of fuel for future use. While the reactions occurring during gas breakdown are chemically interesting in themselves, they are important practically in the sense that the products formed during the combustion of fuels containing sulfur compounds present a serious air pollution problem. Since the mechanisms of the oxidation of sulfur compounds are not well understood, chemical reactions initiated by laser-induced gas breakdown

provide a technique for the study of reactions initiated at a high temperature.

OP 68-71. Cost Reductions in Ion Exchange Processing of Uranium Ores, by J. B. Rosenbaum and D. R. George. *Proc. Symp. Recovery of Uranium*, Aug. 17-21, 1970, São Paulo, Brazil, 1971, pp. 297-309. A countercurrent, multistage ion-exchange column, initially developed for recovering uranium from dilute mine waters, also proved effective for handling clear solutions and slime pulps prepared by leaching uranium ores. In pilot plant tests, clear solutions and slime pulps containing up to 8 percent solids were processed at the exceptionally high flow rate of 15 gallons per square foot per minute, with high recovery and efficient loading of resin. A single-stage ion-exchange column was developed for eluting uranium from resins under countercurrent flow conditions. Substantially complete elution can be achieved using only 2 to 4 volumes of solution per volume of resin. Because of simple design, low construction cost, high throughput rates, low maintenance, ease of automation, and reduced resin requirements, use of these new types of ion exchangers enables substantial reductions in the cost of processing uranium ores. A cost estimate for a uranium-ore processing mill, using these new types of ion-exchange columns in a resin-in-pulp system, shows that capital costs for such a plant would be about 27 percent lower than for a mill employing thickeners and solvent extraction or conventional ion exchange. In addition a significant reduction in direct operating cost can be expected for the simpler and more readily automated plant.

OP 69-71. A Valence Force Field for Furan and Pyrrole and Their Deuterium and Methyl Derivatives, by D. W. Scott. *J. Molecular Spectroscopy*, v. 37, No. 1, January 1971, pp. 77-91. A molecular vibrational analysis was carried out for furan and pyrrole and their deuterium and methyl derivatives to establish vibrational assignments for use in statistical thermodynamic calculations. To insure convergence in the least-squares adjustment of force constants, interaction constants were assumed transferable between the furan and pyrrole rings, and observed wavenumbers of the two compounds and their derivatives were used in a single adjustment.

OP 70-71. Detection and Control of Air Pollutants From Fuel Briquetting Plants, by Donald Strimbeck and James W. Eckerd. *Proc. 11th Biennial Conf., Inst. for Briquetting and Agglomeration*, February 1971, pp. 17-25. Dust is the major potential air pollutant from briquet plants. Other possible air pollutants—droplets, gases, and odors—are less likely to be major problems. An air pollution control program for a briquet plant would involve monitoring of dust emissions at the source, such as stack or unit operation sites. Emissions also should be determined for the surrounding area as well as within the plant boundary. Furthermore, terrain and climatological effects on air pollution should be evaluated. Simple, inexpensive instruments and methods available for dust-load measurement include the dust-fall bucket, high-volume sampler, tape sampler, stack sampling equipment, and Ringelmann smoke chart. Conventional equipment, such as scrubbers, cyclones, and bag filters, is available to control emissions from unit operations. Control of air pollution in briquet manufacture has the benefits of a clean plant, healthful working conditions, and good employee morale.

OP 71-71. Single-Strand Strainwire Technique: Comparison With Existing Methods and a Proposed Photostrain

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Technique, by L. Wade, E. M. Krokosky and J. R. Zel-onka. *Experimental Mech.*, v. 11, No. 3, March 1971, pp. 142-144. This paper is the third of three papers evaluating a refined internal strainwire technique. This final paper evaluates the technique by comparing it with two elastic solutions, with a photoelastic solution, and with a new proposed photostrain technique. The problem chosen as the basis of comparison was a plane-stress problem of a plate with a circular hole under uniform tension. The proposed technique is experimental in nature and combines parts of the results of a photoelastic solution with those yielded by a three-wire internal strain-gage-rosette analysis to completely fix the state of stress in the model.

The scientific techniques used to compare the three-wire strain technique and photostrain technique are as follows: two elastic solutions, one evaluated at a point and one arrived at by integrating the stress functions over a finite length; a finite-element solution; a photoelastic analysis using the shear-difference technique to separate the principal stresses; and a three-wire-rosette analysis. A comparison is made of the values of principal stresses yielded by these methods.

OP 72-71. Tunnel Relaxation Method for Determining the Initial and Long-Term Deformation Around an Underground Opening, by Galen G. Waddell, Thomas J. Crocker, and Eugene H. Skinner. *Proc. 12th Symp. on Rock Mechanics*, Rolla, Mo., Nov. 16-18, 1970, pp. 903-931. This paper describes a method of measuring initial and long-term deformations which occur in the medium surrounding mine accessways and discusses the importance of this type of measurement in assessing support-problem areas. Delineated are (1) description of the rock-deformation monitoring equipment, (2) results of two field tests which monitored rock deformation around 4-foot-diameter raise bores, and (3) a numerical-analysis (finite-element) technique to correlate theoretical with experimental results. Instrumentation developed provided the sensitivity and resolution needed to measure rock deformation around a full-scale raise bore during excavation. Results of the tests conducted at the Lucky Friday mine, Mullan, Idaho, show the relationships between (1) deformation versus time, and (2) deformation versus bit progress. Based on theoretical evaluation of the initial deformation, the medium appeared to behave elastically. Using an estimated field stress of 5,500 psi and Poisson's ratio of 0.20, the gross modulus of elasticity of the rock was calculated to range from 3.15 to 6.0×10^6 psi (with one outlier which was determined to be $>12 \times 10^6$ psi).

OP 73-71. A Computer Program for AA Data Processing, by Robert C. Gabler, Jr., Raymond E. Brown, and Jack G. Haymes. *Am. Laboratory*, February 1971, pp. 10-16. BASIC, a conversational language that is compatible with most time-sharing computer systems, was used to write a computer program for atomic absorption calculations. The program is faster and cheaper than manual methods of data reduction, and its use greatly reduces the possibility of clerical and arithmetical errors. Since it is used in the time-sharing mode, the program is under operator control at all times. The output can be used as a final analytical report.

OP 74-71. Multiple Thermal Analysis of Natural Materials, by John Ward Smith and Donald R. Johnson. *Am. Laboratory*, January 1971, pp. 8-14. As part of its oil-shale research, the Bureau of Mines developed thermal analysis equipment that provides

simultaneous differential thermal analysis, thermogravimetry, and evolved gas analysis of a single sample during programmed heating. The equipment is described to illustrate its features and applications. Although it was created and assembled expressly for solid-fuel studies, this apparatus also solved the problems associated with thermal analysis of other natural materials.

OP 75-71. Alkali Metals as Hydrogenation Catalysts for Aromatic Molecules, by Sidney Friedman, Marvin L. Kaufman, and Irving Wender. *J. Organic Chem.*, v. 36, No. 5, Mar. 12, 1971, pp. 694-697. Alkali metals are hydrogenation catalysts for aromatic compounds at high temperature and pressure. Sodium metal and potassium carbonate give results comparable to potassium metal.

OP 76-71. Construction and Testing of Junk Auto Incinerator, by C. J. Chindgren, K. C. Dean, and J. W. Sterner. *Scrap Age*, v. 28, No. 2, February 1971, pp. 188-200. A refractory-lined, garage-type automobile incinerator with a natural gas afterburner for air pollution control was cooperatively constructed and tested by the Bureau of Mines and the Wasatch Metal & Salvage Co. in Salt Lake City, Utah. The incinerator is capable of relatively smokeless burning of 32 to 60 cars per day, dependent on the degree to which the cars are stripped prior to incineration. Preliminary burning campaigns indicate the cost of incineration to be approximately \$2.75 per car. (The subject is discussed in detail in Bureau of Mines Technical Progress Reports 21 and 31.)

OP 77-71. Discussion of "New Thermodynamic Equation for Testing Consistency of Liquid-Vapor Equilibria Data", by Robert E. Barieau. *Ind. Eng. Chem. Fund.*, v. 10, No. 2, May 1971, pp. 326-327. The author responds to criticism of his article published in this journal in May 1970. For abstract of article discussed see Bureau of Mines OP 63-70.

OP 78-71. The Enthalpies of Combustion and Formation of n-Propylcyclopentane and Five Methylcyclopentanes, by W. D. Good. *J. Chem. Thermodynamics*, v. 3, 1971, pp. 97-103. Enthalpies of combustion of n-propylcyclopentane and five isomeric methylcyclopentanes were determined by oxygen-bomb combustion calorimetry. Enthalpies of formation in the liquid state were derived.

OP 79-71. Stabilizing Mineral Wastes, by Karl C. Dean and Richard Havens. *Eng. and Min. J.*, v. 172, No. 4, April 1971, pp. 99-103. Chemical, physical, and vegetative methods, and combinations thereof, are being tried, often successfully, on all sorts of mineral wastes that range from copper mill tailings to uranium waste piles.

OP 80-71. Sunlight Photooxidation of Isobutylene and Butene-1 With NO₂ in Low- and High-Oxygen Concentrations, by C. F. Ellis. *Atmospheric Environment*, v. 5, February 1971, pp. 83-88. Sunlight photooxidations at ppm levels of butene-1 and of isobutylene with NO₂ were made in air and in atmospheres with less than 200 ppm oxygen to observe differences in products with low- and high-oxygen concentrations.

OP 81-71. Reaction of Carbazole Derivatives With Anhydrous Ferric Chloride (Letter to the Editor), by D. M. Jewell and J. W. Bunger. *J. Heterocyclic Chem.*, v. 8, April 1971, pp. 333-335. The reaction of carbazole derivatives with anhydrous ferric chloride in organic solvents offers many interesting possibilities for analytical and synthetic studies with these hetero-

cyclics. Intensely colored, stable complexes readily result from these reactions. The results of preliminary studies in this area are presented in this letter.

OP 82-71. NaF-KF-K₂NbF₆ Fused Salt Temperature-Solubility Diagram, by Frank X. McCawley and James A. Barclay. *J. Am. Ceram. Society*, v. 54, No. 1, January 1971, pp. 11-12. Freezing and eutectic temperatures were determined for the NaF-KF-K₂NbF₆ ternary system and the NaF-K₂NbF₆, KF-K₂NbF₆, and NaF-KF binary systems. The compound KF-K₂NbF₆ freezes congruently at 770° C; eutectics occur at 708° and 724° C for high- and low-K₂NbF₆ mixtures, respectively. The NaF-K₂NbF₆ eutectic freezes at 658° C. The ternary system has two eutectics, a high-KF mixture and a high-K₂NbF₆ mixture, which occur at 663° and 652° C, respectively.

OP 83-71. A Thermodynamic Study of Infrared Spectroscopy of the Association of 2-Quinolone, Some Carboxylic Acids, and the Corresponding 2-Quinolone-Acid Mixed Dimers, by J. Claive Petersen. *J. Phys. Chem.*, v. 75, No. 8, 1971, pp. 1129-1135. Self-association of 2-quinolone in carbon tetrachloride was studied by infrared spectroscopy, using the absorption bands in the amide NH and carbonyl stretching regions. 2-Quinolone forms a cyclic dimer from which the enthalpy (ΔH° , kcal/mol), free energy (ΔG°_{298} , kcal/mol), and entropy (ΔS° , eu) of association are -8.69, -6.11, and -8.76, respectively. Dimer formation is via a carbonyl-hydrogen bond, although evidence exists for the formation of a small amount of dimer via a π -hydrogen bond. 2-Quinolone was also found to form cyclic mixed dimers with carboxylic acids. Mixed dimers of 2-quinolone with benzoic, cyclohexanecarboxylic, and 4-cyclohexylbutanoic acids gave ΔH° values of -12.2, -10.3, and -10.4; ΔG°_{298} values of -6.36, -5.94, and -5.78; and ΔS° values of -19.9, -14.8, and -15.6, respectively. Thermodynamic data on the acid dimers and spectral data on the different systems studied are also reported. The 2-quinolone-carboxylic acid interaction is of importance because of the simultaneous occurrence of quinolones and carboxylic acids in many biologically derived materials.

OP 84-71. Platinum Metals Electrodeposited From Molten Cyanides, by D. Schlain. *F. X. McCawley, G. R. Smith. Platinum Metals Rev.*, v. 15, No. 2, April 1971, pp. 58-59. Platinum metal objects have been prepared by electroplating or electroforming. Publications and patents on the methods are cited.

CP 85-71. Processing Refractory Carbonaceous Ores for Gold Recovery, by B. J. Scheiner, R. E. Lindstrom, and T. A. Henrie. *J. Metals*, v. 23, No. 3, March 1971, pp. 37-40. An electrooxidation process is described for extracting gold from carbonaceous ores. Gold extractions in excess of 90 percent were obtained by the electrooxidation technique. Parameters affecting gold extraction, such as temperature, salt concentration, and power requirements, are discussed.

OP 86-71. Head Loss in Spiral Solid-Liquid Flow in Pipes, by Chao-Lin Chiu and Joseph J. Seman. *Advances in Solid-Liquid Flow in Pipes*, ed. by I. Zandi. Pergamon Press, New York, 1971, pp. 227-235. A spiral flow is the resultant of primary and secondary flows; in a regular circular pipe, spiral flow does not exist. There are two methods of generating spiral currents in a closed conduit: (1) installing helical ribs inside regular circular pipes and (2) using non-circular pipes.

Characteristics of spiral solid-liquid flows gener-

ated by these two methods are studied and compared with those of regular circular pipes. The critical deposit velocity and the head loss at various flow velocities in each pipe are compared and analyzed.

The results show that there is a good possibility that square pipes may be used to replace the traditional pipes for the transport of solids.

OP 87-71. An Amplifier Controlled Adiabatic Calorimeter, by George J. Filatovs and Alfred E. Schwanke. *Rev. Sci. Instr.*, v. 42, No. 4, April 1971, pp. 447-450. An automatic adiabatic differential calorimeter has been constructed to record the release spectrum of stored energy of deformation of metals from -196 to 500° C. Cold-worked and annealed specimens contain internal heaters which are powered by amplifiers, the signal inputs to which are specimen-to-calorimeter wall differential thermocouples. Control circuits attempt to maintain conditions as adiabatic as possible, and the power difference to the specimen heaters necessary to do this is taken as the stored energy of deformation.

OP 88-71. History, Development, and Geology of Oil Fields in Hocking and Perry Counties, Ohio, by W. K. Overbey and B. R. Henniger. *Am. Assoc. Petrol. Geol. Bull.*, v. 55, No. 2, February 1971, pp. 183-203. Most exploratory and development drilling for oil and gas in Hocking and Perry Counties, Ohio, prior to the 1950s was based on completion results of the nearest well. Economically profitable wells have become increasingly more difficult to obtain, requiring more detailed geologic knowledge of the reservoir rock.

The Silurian Clinton sandstone reservoir has received most of the recent attention. The Clinton is divided into three units within this area—the Stray Clinton, First Clinton, and Second Clinton.

Clinton sandstones belong to a deltaic complex of Median age. Studies of mineralogy, texture, sedimentary structures, and geometry indicate a variety of possible terrestrial-transitional and marginal marine subenvironments.

Oil and gas accumulation is dependent on stratigraphic variation rather than structure. Apparent reservoir-controlling parameters important to exploration and secondary recovery are (1) interstitial clay content, (2) shale stringers and laminations, (3) degree of cementing, (4) grain size, (5) pore geometry, and (6) thickness.

The best producing oil wells are those which have been completed in thick, shale-free distributary channel deposits and delta-platform tidal channels. The best secondary-recovery method appears to be gas repressuring, although waterflooding may have limited application. The orientation of natural and induced fractures should be considered in setting up drilling operations for secondary- and primary-recovery operations.

OP 89-71. Effective Technology and Research for Scrap Metal Recycling—Introduction, by Carl Rampacek. In *Effective Technology for Recycling Metal*, Proceedings of Two Special Workshops, Part I—Effective Technology and Research for Scrap Metal Recycling, Conducted by Nat. Assoc. Secondary Material Industries, Inc., and U.S. Bureau of Mines. Washington, D.C., Jan. 7, 1971. Nat. Assoc. Secondary Material Industries, Inc., New York, 1971, p. 1. This brief talk opened the joint government industry workshop on nonferrous metals recycling.

OP 90-71. Secondary Metals—A Primary Concern of the Bureau of Mines, by T. A. Henrie. In *Effective Technology for Recycling Metal*, Proceedings of Two

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Special Workshops, Part I—Effective Technology and Research for Scrap Metal Recycling, Conducted by Nat. Assoc. Secondary Material Industries, Inc., and U.S. Bureau of Mines. Washington, D.C., Jan. 7, 1971. Nat. Assoc. Secondary Material Industries, Inc., New York, 1971, pp. 2-5. This talk briefly discusses the waste products and scrap generated by the mineral and metals industry and the consuming public as a growing metal resource. The objectives of Bureau of Mines research in materials recycling are reviewed. And, the need for speedy adaptation of innovative technology by the secondary industry is emphasized.

OP 91-71. Opportunities in Recycling Nonferrous Metals, by Max J. Spendlove. In Effective Technology for Recycling Metal, Proceedings of Two Special Workshops, Part I—Effective Technology and Research for Scrap Metal Recycling, Conducted by Nat. Assoc. Secondary Material Industries, Inc., and U.S. Bureau of Mines. Washington, D.C., Jan. 7, 1971. Nat. Assoc. Secondary Material Industries, Inc., New York, 1971, pp. 9-11. This talk briefly discusses the following general areas where real opportunities might occur: (1) departing from the conventional in areas such as sorting procedures, computer services, production of coproducts, and improvement of processes, equipment and devices; (2) products; (3) new raw materials; and (4) improved communication of the results of research.

OP 92-71. Identification of Nonferrous Scrap Metals, by A. W. Maynard. In Effective Technology for Recycling Metal, Proceedings of Two Special Workshops, Part I—Effective Technology and Research for Scrap Metal Recycling, Conducted by Nat. Assoc. Secondary Material Industries, Inc., and U.S. Bureau of Mines. Washington, D.C., Jan. 7, 1971. Nat. Assoc. Secondary Material Industries, Inc., New York, 1971, pp. 12-14. This talk briefly discusses Bureau of Mines Research to develop improved methods for the identification and sorting of nonferrous scrap, especially aluminum alloys and copper-base alloys. The objective is to develop methods which will require a minimum of training of personnel.

OP 93-71. New Techniques for Refining Nonferrous Scrap, by H. S. Caldwell, Jr. In Effective Technology for Recycling Metal, Proceedings of Two Special Workshops, Part I—Effective Technology and Research for Scrap Metal Recycling, Conducted by Nat. Assoc. Secondary Material Industries, Inc., and U.S. Bureau of Mines. Washington, D.C., Jan. 7, 1971. Nat. Assoc. Secondary Material Industries, Inc., New York, 1971, pp. 15-16. This talk briefly discusses the type of problems the Bureau is investigating, why they were selected for study, and some of the metallurgical techniques being applied to solve them. Refining zinc-base die-cast scrap using sal skimmings and vacuum distillation separation and recovery of metals from scrap are specifically discussed.

OP 94-71. Separation and Recovery of Nonferrous Metals From Incinerator Residues, by M. H. Stanczyk. In Effective Technology for Recycling Metal, Proceedings of Two Special Workshops, Part I—Effective Technology and Research for Scrap Metal Recycling, Conducted by Nat. Assoc. Secondary Material Industries, Inc., and U.S. Bureau of Mines. Washington, D.C., Jan. 7, 1971. Nat. Assoc. Secondary Material Industries, Inc., New York, 1971, pp. 17-19. The Bureau of Mines' continuous pilot plant for the recovery of metals and glass from incinerator residues is described and illustrated.

OP 95-71. Recycling Automotive Scrap, by Karl C. Dean. In Effective Technology for Recycling Metal, Proceedings of Two Special Workshops, Part I—Effective Technology and Research for Scrap Metal Recycling, Conducted by Nat. Assoc. Secondary Material Industries, Inc., and U.S. Bureau of Mines. Washington, D.C., Jan. 7, 1971. Nat. Assoc. Secondary Material Industries, Inc., New York, 1971, pp. 22-31. Bureau of Mines studies indicate that two methods offer promise for recycling the metal values in junked automobiles. For urban centers that discard at least 40,000 cars per year, the preferred method is shredding. For areas that do not discard enough cars to support a shred plant, a combination of incineration, hand-tool dismantling, and baling can be profitably used. The Bureau's extensive investigations of recycling automotive scrap are described.

OP 96-71. Recovery of Nonferrous and Precious Metals From Electrical and Electronic Scrap, by G. M. Potter. In Effective Technology for Recycling Metal, Proceedings of Two Special Workshops, Part I—Effective Technology and Research for Scrap Metal Recycling, Conducted by Nat. Assoc. Secondary Material Industries, Inc., and U.S. Bureau of Mines. Washington, D.C., Jan. 7, 1971. Nat. Assoc. Secondary Material Industries, Inc., New York, 1971, pp. 32-34. This talk briefly describes methods by which electrical and electronic scrap can be recycled to prevent pollution and to eliminate bulky scrap product from the environment. Physical beneficiation, leaching, smelting, and aluminum removal were highlighted.

OP 97-71. Reclaiming Values From Superalloy Scrap, by G. M. Potter. In Effective Technology for Recycling Metal, Proceedings of Two Special Workshops, Part I—Effective Technology and Research for Scrap Metal Recycling, Conducted by Nat. Assoc. Secondary Material Industries, Inc., and U.S. Bureau of Mines. Washington, D.C., Jan. 7, 1971. Nat. Assoc. Secondary Material Industries, Inc., New York, 1971, pp. 35-39. The Bureau of Mines studied the chemical recovery of nickel, cobalt, and molybdenum from superalloy scrap. Much of the scrap from the machining of nickel- and cobalt-base superalloys is best utilized by remelting. However, when the scrap is contaminated, consists of mixed grindings, or is of obsolete alloys, chemical processing can convert contained metals to marketable forms. Chemical processing on a laboratory-scale recovered nearly 90 percent of nickel, cobalt, and molybdenum as metallurgical-grade oxides.

OP 98-71. Electrolytic Refining of Scrap Aluminum Alloys, by T. A. Sullivan. In Effective Technology for Recycling Metal, Proceedings of Two Special Workshops, Part I—Effective Technology and Research for Scrap Metal Recycling, Conducted by Nat. Assoc. Secondary Material Industries, Inc., and U.S. Bureau of Mines. Washington, D.C., Jan. 7, 1971. Nat. Assoc. Secondary Material Industries, Inc., New York, 1971, pp. 40-41. This brief statement describes two electrolytic refining systems, that have been developed by the Bureau of Mines for the extraction of aluminum from scrap and the concentration of other metal values.

OP 99-71. Processing Titanium Scrap Chips, by T. A. Sullivan. In Effective Technology for Recycling Metal, Proceedings of Two Special Workshops, Part I—Effective Technology and Research for Scrap Metal Recycling, Conducted by Nat. Assoc. Secondary Material Industries, Inc., and U.S. Bureau of Mines. Washington, D.C., Jan. 7, 1971. Nat. Assoc. Secondary Material Industries, Inc., New

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York, 1971, pp. 44-45. The speaker briefly describes the current Bureau of Mines research on cleaning and regaining titanium from scrap materials. A flowsheet for the cleaning of titanium lathe turnings is presented.

OP 100-71. Recovery of Nonferrous Values from Industrial Wastes, by P. G. Barnard. In *Effective Technology for Recycling Metal*, Proceedings of Two Special Workshops, Part I—Effective Technology and Research for Scrap Metal Recycling, Conducted by Nat. Assoc. Secondary Material Industries, Inc., and U.S. Bureau of Mines. Washington, D.C., Jan. 7, 1971. Nat. Assoc. Secondary Material Industries, Inc., New York, 1971, pp. 46-47. This talk briefly describes the Bureau of Mines' current studies on the recycling and recovering of nonferrous wastes from diamond dust; mill tailings and foundry molding sands; electroplating wastes and rinse solutions; copper and brass smelter fumes and steel furnace dusts; scrap gold dental alloys; phosphatizing wastes; and sludges.

OP 101-71. Nonferrous Scrap—As Viewed by Mineral Supply Specialists, by S. P. Wimpfen. In *Effective Technology for Recycling Metal*, Proceedings of Two Special Workshops, Part I—Effective Technology and Research for Scrap Metal Recycling, Conducted by Nat. Assoc. Secondary Material Industries, Inc., and U.S. Bureau of Mines. Washington, D.C., Jan. 7, 1971. Nat. Assoc. Secondary Material Industries, Inc., New York, 1971, pp. 48-51. The speaker describes the efforts of Bureau of Mines' Mineral Supply specialists to provide the mineral and economic intelligence, basic data, and analysis necessary to understand present and future mineral supply situations. He highlights specific, recently published materials as well as forthcoming reports.

OP 102-71. Gel Permeation Chromatographic Separation of Petroleum Acids, by T. E. Cogswell, J. F. McKay, and D. R. Latham. *Anal. Chem.*, v. 43, No. 6, May 1971, pp. 645-648. Gel permeation chromatography (GPC) was used to separate the components of an acid concentrate. This concentrate was prepared from the 400° to 500° C distillate of Wilmington (Calif.) petroleum. The separation was made with a cross-linked polystyrene gel, using methylene chloride as a solvent; and the fractions obtained were characterized by infrared spectra and by molecular weight data. A carboxylic acid fraction obtained was essentially free of phenolic and nitrogen-containing compounds. Results indicate that molecular association of some compound types is responsible for the separation.

OP 103-71. The Waste-Plus-Waste Method for Recovering Metals from Electroplating Wastes, by Lawrence C. George, Andrew A. Cochran, and Roy F. Waters. *Tech. Proc. Am. Electroplaters' Soc. Waste Treatment Conf.*, Post Junior College, Waterbury, Conn., May 21-22, 1971, 23 pp; *AIChE Environmental Quality Conf.*, Washington, D.C., preprint EQC 48, June 7-9, 1971, 8 pp. Addition of various acid wastes to alkaline cyanide wastes was investigated as a means of disposing of both materials. At final solution pH values near 7, metals and cyanides in both wastes were precipitated almost completely. The filtrate from this step was relatively harmless; compared with the original wastes, and met potable water standards for free cyanide content. Small amounts of hydrogen cyanide (HCN) were produced by the reactions; the HCN was collected and neutralized. The metal cyanide precipitate contained significant amounts of silver, nickel, and copper, which were

separated and recovered by additional processing. The waste-plus-waste method is economically attractive because of the low cost of mixing two wastes and the high value of the recovered metals.

OP 104-71. Solid and Gaseous Fuels, by Elizabeth A. Hattman and Carmen Ortuglio. *Anal. Chem. Ann. Rev.*, v. 43, April 1971, pp. 345R-356R. This article is the twelfth of a series of reviews on methods of sampling, analyzing, and testing solid mineral and gaseous hydrocarbon fuels. It covers material published between Oct. 1, 1968, and Oct. 1, 1970.

OP 105-71. Evaporative Emissions—Which Volatility Factors Count?, by R. W. Hurn. In *Effect of Automotive Emission Requirements on Gasoline Characteristics*, American Society for Testing and Materials, 1971, Philadelphia, Pa., STP 487, pp. 3-12. Several volatility parameters have been investigated in an experimental study of volatility/emission relationships. These volatility indexes include Reid vapor pressure and several distillation properties. The experimental data show that the fuel tank losses are related characteristically to one parameter while carburetor losses appear to be related to a different parameter. The effect of volatility upon exhaust emissions was investigated in connection with the evaporative loss studies, and it appears that these emissions also are related directly or indirectly to the volatility characteristics of the gasoline. The experimental results are used to illustrate how the several losses are related to the respective volatility parameters.

OP 106-71. Fuel Technology Now Requires Uniform GLC Analytical Procedures, by R. W. Hurn. In *Effect of Automotive Emission Requirements on Gasoline Characteristics*, American Society for Testing and Materials, 1971, Philadelphia, Pa., STP 487, pp. 54-62. Experimental work within the broad spectrum of fuels technology calls for both accurate and uniform analytical methods for fuels and combustion products. Recent experience, has shown wide variation in analytical results obtained by different laboratories each possessing generally high competence for petroleum analysis. Analytical capability across laboratories would be improved through use of more nearly uniform methods so that laboratories doing air pollution research would be able to separate, identify, and quantify the many fuel components and products in a comparable manner. Moreover, to fully utilize the advantages of such uniform analyses, results must then be expressed in a systematic, standardized format. Improved accuracy in the analytical data is needed, but accuracy alone will not suffice and should be sought in conjunction with uniform procedures and identification format. The paper suggests a hydrocarbon identification and classification scheme to be used in reporting analyses that are obtained following uniform, standardized analytical procedures. The resulting information would be readily translatable from laboratory to laboratory.

OP 107-71. Factors That Predict Fracture Orientation in a Gas Storage Reservoir, by C. A. Komar, W. K. Overbey, Jr., R. L. Rough, and W. G. Lambert, *J. Petrol. Technol.*, v. 23, No. 5, May 1971, pp. 546-550. The data presented here indicate that surface joints and lineaments as revealed by aerial photographs are related to the maximum horizontal stress in a region and to the orientation of induced vertical wellbore fractures. This information could help engineers to make the optimum choice of wells

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for fracturing, thus enhancing reservoir performance.

OP 108-71. Nonmetal Elements and Compounds, by J. C. Morris, D. R. Latham, and W. E. Haines. *Anal. Chem. Ann. Rev.*, v. 43, No. 5, April 1971, pp. 187R-191R. This paper is a review of 2 years of research (1968-69) on nonmetal elements and compounds in petroleum.

OP 109-71. Problems in Analysis of Wide Boiling Range Materials Using a Gas Liquid Chromatography-Flame Ionization Detector System, by R. E. Poulson and H. B. Jensen. *J. Chromatographic Sci.*, v. 9, May 1971, pp. 300-306. The Bureau of Mines investigated the sources of error of a GLC-FID system in quantitative analysis of wide-boiling-range mixtures such as are encountered in simulated distillation of crude shale oil or petroleum. The sample-introduction system, column effects, and the FID itself were studied using normal alkanes as a diagnostic aid. The on-column inlet technique of sample introduction is compared with the flash-vaporization inlet technique. Column-adsorption effects and the use of tail-reducing materials are discussed. Problems with the FID relating to insulator and electrode contamination, electrode emissivity, sample capacity, and burner design are illustrated and discussed. Normal alkane FID response relative to *n*-heptane over the C₁-C₂₀ range is shown to be 1.00 ± 0.03 for a parallel-plate FID when operating normally.

OP 110-71. Trasformazione Dei Rifiuti Urbani in Olio Combustibile Con L'impiego Di Monossido Di Carbonio Ed Acqua (Conversion of Urban Refuse to Oil Using Carbon Monoxide and Water), by John S. Tosh. *Proc. 3d Internat. Public Services Exhibition*, Sept. 25-29, 1970, Padua, Italy, pp. 239-251. Urban refuse can be converted to oil by the action of carbon monoxide and water at elevated temperatures and pressures. The yield is 85 to 100 gallons of oil per ton of dry refuse. The oil is low in sulfur, and its heating value is high. It could be used as a low-sulfur powerplant feed.

OP 111-71. The Calculation of Fugacities From Volumetric and Phase Equilibrium Data by Means of the Gibbs-Duhem Equation, by Robert E. Barieau. *I&EC Fundamentals*, v. 10, No. 3, August 1971, pp. 428-433. Liquid and vapor fugacities, except for constants of integration, can be calculated directly, for two-component systems, from volumetric and phase equilibrium data by means of the Gibbs-Duhem equation. The constants of integration may be evaluated from the fugacities of the pure components if they exist in two-phase equilibrium at the temperature in question. Such calculations are illustrated using data on the helium-nitrogen system. Isobaric temperature derivatives of the resulting fugacity values are used in the isobaric form of the Gibbs-Duhem equation to calculate relative enthalpies of the coexisting liquid and vapor phases. These are combined with the ideal enthalpies of the mixtures to present enthalpies of the coexisting liquid and vapor phases.

OP 112-71. Use of Chelating Agents for Recovery of Copper From Carbonate and Silicate Ores, by D. J. Bauer and R. E. Lindstrom. *J. Metals*, v. 23, No. 5, May 1971, 3 pp. Essentially complete recovery of copper from an oxide ore was obtained in a leaching operation by the U.S. Bureau of Mines using ethylenediaminetetraacetic acid (EDTA) as a chelative leachant. The EDTA was most effective in the form of a trisodium salt. Copper can be recovered as metal from leach solutions by reducing agents such as hydrogen, HCHO, and CO.

An integrated technique using Na₂CaEDTA-NaHCO₃ solution as the copper leachant, with lime as the copper precipitant, was also studied.

OP 113-71. Vapor Pressure of Water From -2.5° to 20° C, by D. R. Douslin. *J. Chem. Thermodynamics*, v. 3, 1971, pp. 187-193. The vapor pressure of water is presented for the temperature range -2.5° to 20° C. A direct measurement of the triple-point pressure of water (612.1 ± 0.4) Nm⁻² or (4.591 ± 0.003) torr is included.

OP 114-71. Conversion of Municipal Refuse to Oil, by Herbert R. Appell, Irving Wender, and Ronald D. Miller. *Refuse and Recycle of Wastes*, Proc. 3d Ann. North Eastern Regional Antipollution Conf., July 21-23, 1970. University of Rhode Island, Kingston, R.I. 1971, pp. 225-231. An investigation of the mechanism of lignite liquefaction with CO and steam led to a procedure for converting cellulosic wastes and urban refuse to oil. Oil was formed at temperatures of 250° to 400° C and pressures of 1,500 to 5,000 psig.

OP 115-71. Elastic and Attenuation Symmetries of Simulated Lunar Rocks, by Thomas R. Bur and Kenneth E. Hjelmstad. *Icarus*, November 1970, v. 13, No. 3, pp. 414-423. Studies were made to determine the elastic and attenuation symmetry of 14 igneous and metamorphic rocks. The rocks were previously chosen by the Bureau of Mines to cover the range of rocks most likely to be representative of rocks on the lunar surface. The studies were made by means of quasilongitudinal pulse velocity and relative amplitude measurements on spherical specimens. The elastic symmetry was successfully determined for all 14 rocks, and the attenuation symmetry for 11 of the rocks. These rocks demonstrated a wide range of characteristics, for instance the densities ranged from 0.47 to 3.32 g/cm³. It was found that the variations in the elastic and attenuation properties can be closely approximated by the symmetry of the orthorhombic and transversely isotropic systems. The range of velocity anisotropy found is roughly the same as for single crystals. The elastic and attenuation symmetries agree for most of the rocks, within experimental error; a significant difference found in a few rocks suggests a separate major contributing cause (subfabric) of the variations in each of these properties. Rocks in which the elastic anisotropy is notably associated with fracture systems have lower than normal mean velocities.

OP 116-71. Oil Vaporization During Steamflooding, by F. Sam Johnson, C. J. Walker, and Abdo F. Bayazeed. *J. Petrol. Technol.*, v. 23, No. 6, June 1971, pp. 731-742. A procedure is presented for predicting the amount of oil vaporized, or distilled, in the steam zone during steamflooding. Calculations indicate that oil vaporization increases with increasing volatility of the oil and temperature of the steam, but decreases with increasing steam injection rates.

OP 117-71. Catalytic Dehydrogenation of Coal: Part 6. Yield of Hydrogen From Whole Coals, by L. Reggel, I. Wender, and R. Raymond. *Fuel*, v. 50, No. 2, April 1971, pp. 152-156. Eight whole coals have been catalytically dehydrogenated in this study. The results are compared with dehydrogenation of vitrinites from bituminous coals, and it is found that the yields of hydrogen gas are only slightly lower when the whole coals are used. In a commer-

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cial process, therefore, whole coals would be suitable for catalytic dehydrogenation without separation of macerals.

OP 118-71. Thermal Synthesis of Sodium Calcium Carbonate—A Potential Thermal Analysis Standard, by John Ward Smith, Donald R. Johnson, and William A. Robb. *Thermochim. Acta*, v. 3, 1971, pp. 305-312. Sodium calcium carbonate—an equimolar double salt ($\text{Na}_2\text{CO}_3 \cdot \text{CaCO}_3$) never before described—forms by a novel solid state reaction when intimately mixed Na_2CO_3 and CaCO_3 powders are heated. The thermal synthesis and properties of this compound are evaluated. Its use as a thermal analysis standard is suggested.

OP 119-71. Approaches to Utilization of Plastics From Urban Waste, by J. W. Jensen, J. L. Holman, and J. B. Stephenson. *Special Centennial Symp. "Technology for the Future to Control Industrial and Urban Wastes," Continuing Education Series, University of Missouri-Rolla, Feb. 8-9, 1971*, pp. 32-34. Very large quantities of discarded plastic articles are entering the municipal waste disposal facilities, posing new problems in waste processing and accounting for a substantial and growing loss of resources. Methods for utilizing these waste plastics are being sought at the Research Center of the Bureau of Mines in Rolla, Mo. A sample of such waste obtained through a community-wide collection program, was analyzed and tested; the results are presented in this article. The fabrication of useful secondary products is discussed as a possible outlet for waste thermoplastics, polyethylene and polypropylene, and the possibility of using waste halide polymers, in particular polyvinyl chloride, as chemical raw material is considered. A flow diagram for a sink-float separation process for waste plastics is presented.

OP 120-71. Cost Estimation and Power Requirements of Centrifugal Gas Compressors, by P. R. Jones and Sidney Katell. *Trans. Amer. Assoc. Cost Eng.* 15th Ann. Meeting and 1st Internat. Symp., Montreal, Canada, June 19-23, 1971, pp. 315-317. The Bureau of Mines has written a computer program for the preliminary estimation of costs and power requirements of centrifugal gas compressors for two types of operation (1) in which interstage cooling follows each stage, and (2) in which interstage cooling follows every third stage. Well-known relationships were used to estimate the number of stages, temperature, pressure, compression ratio, input CFM, head, and horsepower. The compression ratio was limited to that which would develop a maximum of 15,000 feet of head which was equivalent to a peripheral velocity of slightly less than 1,000 feet per second per stage. Costs were estimated from an equation relating total horsepower and cost.

OP 121-71. Absorption Enhancement by an Organo-Metallic in Aqueous Solution—Methyl Mercury in Dilute Acid, by Stephen L. Law. *Atomic Absorption Newsletter*, v. 10, No. 3, May-June 1971, pp. 75-76. It is important that the analyst using atomic absorption techniques be aware that an organo-metallic in an organic solvent may behave differently than expected. The purpose of this report is to extend this caution to include at least one organo-metallic in aqueous solution, methyl mercury in dilute acid. Although this may be a special case, because of the high volatility of methyl mercury, it is reported here to make other analysts aware that such effects

OP 122-71. Removal of Antimony From Lead—Two Per Cent Antimony Alloy, by E. B. Amey, Dominic Montagna, Donald A. Wilson, and Joseph M. Marchello. *Secondary Raw Materials*, v. 9, No. 5, May 1971, pp. 71-74. One of the programs being undertaken by the College Park Metallurgy Research Center of the Bureau of Mines involves developing new methods and improving existing methods for recycling secondary scrap and waste materials. A refining technique that received considerable attention in these studies is the use of high-melting-point intermetallic compounds to remove small amounts of undesirable impurities from base metal scrap. Once the compound has been formed, separation from the base metal can be achieved by decanting, skimming, or filtering. This article describes a technique for removing antimony from lead by forming an insoluble aluminum-antimony intermetallic compound.

OP 123-71. Mine Dust Characterization Using the Scanning Electron Microscope and Dust Samplers, by Philip B. DeNee. *Scanning Electron Microscopy (Part I). Proc. 4th Ann. Scanning Electron Microscope Symp.*, April 1971, pp. 209-216. The inhalation and retention in the lungs of respirable coal mine dust in the size range from $0.1 \mu\text{m}$ to $10 \mu\text{m}$ diameter is a serious hazard in coal mining. Information on the aerodynamic and agglomeration behavior of dust particles can be obtained through better knowledge of the physical and chemical characteristics of individual dust particles. Hence, size, shape, surface topography, and agglomeration characteristics of mine dusts were studied using the secondary and backscatter electron modes of the SEM. Experimental techniques for preparing the substrate for mounting the dust specimens are described. Elemental identification, which is important since it allows inferences to be made about the mineral species to which particles belong, was done by energy dispersive X-ray analysis.

The importance of collecting meaningful dust samples which can be analyzed in the SEM is discussed and illustrated through the use of four collecting devices: a thermal precipitator, a filter, a cascade impactor, and a midjet impinger.

OP 124-71. Catalytic Reduction of Sulfur Dioxide on Iron-Alumina Bifunctional Catalysts, by Sanaa E. Khalafalla, Edward F. Foerster, and Larry A. Haas. *I&EC Product Res. and Dev.*, v. 10, June 1971, pp. 133-137. Mixtures of alumina and iron powder provide efficient catalysts for the interaction of low concentrations of SO_2 with CO. The catalytic reaction rate at 500°C depended significantly on the iron content of the binary catalyst mixture. Mixtures containing 43 percent freshly reduced iron exhibited a sharp peak in the catalytic activity at 500°C when compared with other catalyst compositions. The normalized reaction rate per gram of iron, instead of per gram of total catalyst, still portrayed a sharp maximum when plotted against the weight fraction of iron in the catalyst. This fact, in addition to nonsynergistic effects observed with iron-silica mixtures, disqualifies interpretations based solely on the antisintering or supportive action of alumina on iron. The results are best explained on the basis of a dual reaction site mechanism with both iron and alumina augmenting their specific sites activity at their interparticle contacts.

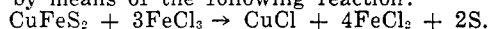
OP 125-71. Organic Reactions in Electrical Discharges, by Bernard D. Blaustein and Yuan C. Fu.

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Ch. 11 in *Physical Methods of Chemistry*, ed. by A. Weissberger and B. Rossiter. John Wiley & Sons, Inc., New York, v. 1, pt. 2B, 1971, pp. 91-207. A detailed review of organic reactions in electrical discharges is presented. Reactions of atomic hydrogen, oxygen, and nitrogen with organic compounds are also included.

OP 126-71. Georgia Minerals Serve the Nation and the World, by James D. Cooper. *Atlanta Econ. Rev.*, v. 21, No. 7, July 1971, pp. 30-32. Georgia's industrial mineral resource is of such magnitude that the State can become increasingly important as a minerals supplier in the decades ahead. The minerals with the greatest potential for impact outside the State are high-quality clays and kyanite, but others such as barite, dimension stone, and certain heavy minerals are increasingly significant. Intelligent planning and subsequent management can result in the working together of economical and ecological interests to ensure the development of the mineral resources of coastal Georgia.

OP 127-71. Recovery of Copper, Iron, and Sulfur From Chalcopyrite Concentrate Using a Ferric Chloride Leach, by F. P. Haver and M. M. Wong. *J. Metals*, v. 23, No. 2, February 1971, pp. 25-29. Smelting of copper concentrates results in the discharge of millions of tons SO_2 to the atmosphere each year. Because of increasing concern with air pollution, the Bureau of Mines has developed a hydrometallurgical procedure to obtain elemental sulfur from chalcopyrite by means of the following reaction:



Under optimum conditions, 99.9 percent of the copper and 73.7 percent of the iron was extracted in 2 hr from a typical mill concentrate containing approximately 75 percent CuFeS_2 and 15 percent FeS_2 . At the same time, 70.5 percent of the sulfur was oxidized to the elemental form. The leach was highly selective; gangue minerals, including pyrite, were not attacked, thus accounting for the relatively low recoveries of iron and sulfur.

OP 128-71. Oil Recovery Tests With Ultrasonically Formed Emulsions, by Charles A. Komar and Harold A. W. Moore. *Chem. Eng. Prog. Symp. Series*, v. 67, No. 109, 1971, pp. 117-123. The Bureau of Mines conducted oil displacement tests in the laboratory with three water-in-oil and five oil-in-water emulsions that were created with ultrasonic energy at a frequency of 20 kHz and acoustic intensity of approximately 100 w/sq. cm. Emulsions of either crude oil or kerosene, brine, and $\frac{1}{2}$ to 2 percent emulsifier were formed during 30 sec of acoustic irradiation.

Results indicate that ultrasonic energy induces greater and more uniform dispersion of one liquid in another in the presence of small amounts of chemical emulsifiers. When the emulsions were injected as a buffer slug before waterflooding, recovery of the oil-in-place was 8 to 22 percent greater than with conventional waterflooding in the test specimens, regardless of the continuous phase (oil or brine).

The emulsions do not appear to be applicable to the Appalachian area however, because the oilfields are too tight, the clays in the formation remove the emulsifier from the displacing fluid, and not enough additional oil is produced, compared with recovery with conventional waterflooding, to warrant the increased operating costs.

OP 129-71. Recovery of Metals and Phosphates From Waste Phosphate Sludge, by Roy F. Waters, Howard E. Powell, and Andrew A. Cochran. *Metal Fin-*

ishing, v. 69, No. 8, August 1971, pp. 39-42. Waste sludges from phosphate treatment of automobile and appliance components were processed in the laboratory to recover metal values and trisodium phosphate. After treatment of the sludge with NaOH, followed by hydrogen reduction and sintering, zinc and lead were recovered as fume; the sinter upon leaching was separated into a metallic residue, chiefly iron and nickel, and high-purity trisodium phosphate. The process offers an antipollution alternative in disposing of phosphate sludges in which there is an economic incentive to recycle the valuable materials.

OP 130-71. An Evaluation of a Porapak Q Column at Cryogenic Temperatures for the Separation of Helium-3, Neon, and Hydrogen in Helium-4, by G. W. Weems, C. A. Hoffman, and A. R. Howard. *J. Chromatographic Sci.*, v. 9, July 1971, pp. 444-446. An investigation was undertaken to evaluate a Porapak Q column for separating helium-3, neon, and hydrogen in helium-4. The column temperatures used for this study were 194° and 76° K. The results of this investigation were that helium-3, neon, and hydrogen are separated by using a 4.9 m by 0.47 cm id. column filled with 80/100-mesh Porapak Q using a helium-4 carrier gas. Using the separation characteristics of this column material, a chromatographic analytical method was devised.

OP 131-71. Ultrasound as an Aid in Drying Fine Coal, by John S. Wilson, Albert S. Moore, and Walter S. Bowie. *Chem. Eng. Prog. Symp. Series*, v. 67, No. 109, 1971, pp. 68-73. Ultrasonic energy was investigated by the Bureau of Mines as an aid in drying fine coal fluidized with air at 300° to 400° F. Sound at frequencies of 17, 20.2, 35.5, 65, and 93 kHz and amplitudes of about 135 db when applied in a 3-inch-diameter column aided water reduction from 10 to less than 1 percent by weight. Maximum increases in drying rates were achieved during the constant rate period, 46.9 percent when the sound was applied above the bed and 31.3 percent when it was applied below the bed.

OP 132-71. Cycloalkane Constituents of the Bitumen From Green River Shale, by D. E. Anders and W. E. Robinson. *Geochim. et Cosmochim. Acta*, v. 35, 1971, pp. 661-678. Fifty-two cyclic alkanes, isolated from the bitumen of Green River Shale, were analyzed by mass spectrometry. The molecular formula of each cycloalkane was determined and, where possible, structural assignments were proposed for the alkanes on the basis of principal fragment ions and similarities in spectra to products of known configuration.

Structural resemblance of these cycloalkanes to the hydrocarbon framework of biologically derived isoprenoid lipids was noted. Twenty-one cycloalkanes displayed fragmentation patterns similar to tetra-alkyl substituted cyclohexanes. These compounds probably had their origin in carotenoid pigments. Six additional cyclic hydrocarbons produced mass spectra resembling the spectra of alkyl substituted hexahydroindanes. A progenitor of these compounds may be the indane portion of vitamin D, formed from the irradiation of steroidal plant debris. Mass spectra of eight other cycloalkanes suggest a structural similarity to alkyl substituted gonanes (steranes) and were probably derived from plant steroids. Fifteen of the cyclic alkanes (six tricyclic and eleven pentacyclic) produce mass spectra similar to the hydrocarbon skeletons of pentacyclic triterpenoids and could have been derived from them.

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- OP 133-71. A Low Temperature Gradient Gas Bath Cryostat**, by Will E. DeVaney, Harold L. Rhodes, and Philip C. Tully. *Cryogenic Technol.*, July-August 1971, pp. 119-120. A windowed gas cryostat has been developed for studying systems requiring a near-zero vertical temperature gradient. Vaporized LN_2 is used as the refrigerant for temperatures from 95° K to near ambient. The vertical temperature gradient across a 15 cm beryllium-copper block was less than 0.05° K.
- OP 134-71. Current and Future Trends in Explosives and Blasting**, by Richard A. Dick. *Pit and Quarry*, v. 64, pt. 1, No. 1, July 1971, pp. 159-162, 174; pt. 2, No. 2, August 1971, pp. 165-107. This paper analyzes current trends in the explosives field and projects likely future trends. Consumption, product types, loading techniques, strength ratings, and explosives control are covered.
- OP 135-71. Calculation of the Intensity of Secondary Scattering of X-Rays by Non-Crystalline Materials**, by C. W. Duggins, Jr., and D. A. Park. *Acta Cryst.*, v. A27, pt. 3, May 1971, pp. 264-272. Equations that require numerical integration over only one variable were derived for calculating the intensity of secondary scattering of X-rays for noncrystalline samples of finite thickness. Both the reflection and transmission geometry cases were considered. Tables are given that allow the intensity ratio of secondary to primary scattering to be determined without making lengthy calculations. Modification of the normalization procedure when secondary scattering is important is discussed.
- OP 136-71. Some Observations on Near-Limit Flames**, by A. L. Furno, E. B. Cook, J. M. Kuchta, and D. S. Burgess. 13th Internat. Symp. on Combustion, Aug. 23-29, 1970, University of Utah, Salt Lake City, Utah, 1971, pp. 593-599. Lean mixtures of hydrogen-air and rich mixtures of *n*-butane-air were spark ignited within a 12-ft-diam sphere. At hydrogen concentrations below 8.0 percent, and at butane concentrations above 6.1 percent, the pressure rises were very small since little of the combustible mixture was consumed by upward flame propagation. With the onset of downward propagation at 8.5 percent hydrogen or 6.0 percent butane, combustion was complete. The limits of downward flame propagation are compared with available data on the detonable limits of gas mixtures when initiated by solid explosives. The interpretation follows Spalding's treatment of the optimum gas concentrations for spark ignition, using the concept of preferential diffusion.
- OP 137-71. Solubility of Nitrogen in Alpha Vanadium From 600° to 1,200° C**, by J. L. Henry, S. A. O'Hare, R. A. McCune, and M. P. Krug. *J. Less-Common Metals*, v. 25, September 1971, pp. 39-47. Alloy specimens in the vanadium-rich region of the vanadium-nitrogen system were prepared by the reaction of high-purity vanadium foil and nitrogen. Specimens were annealed, quenched, and examined by X-ray and metallographic techniques to determine the degree of nitrogen solubility in α vanadium. Solubility was determined as a function of temperature at equilibrium pressure. Equilibrium pressures were not measured. Nitrogen solubility is found to be 1.15 wt pct at 600° C, 1.65 wt pct at 800° C, 2.20 wt pct at 1000° C, and 2.95 wt pct at 1200° C. A sluggish transformation is observed between 500° and 600° C for alloys having nitrogen contents above 1 wt pct. It is likely that a peritectoid compound having a composition near V_{13}N is formed. The composition range of the hexagonal β phase could not be established accurately because of the small difference in lattice dimensions between the vanadium-saturated and nitrogen-saturated compound. The range is narrow, probably lying between $\text{VN}_{0.32}$ and $\text{VN}_{0.38}$ and does not appear to vary within the temperature range 300° to 1000° C.
- OP 138-71. An Ultra-High-Vacuum Chamber for High-Temperature X-Ray Diffractometry**, by M. P. Krug, R. A. McCune, and P. A. Romans. *J. Appl. Crystallography*, v. 4, pt. 2, April 1971, pp. 151-155. An attachment to a horizontal goniometer for X-ray powder diffraction at temperatures up to about 2,000° C in a vacuum in the 10^{-9} torr range is described. Specimen heating is by direct contact to a resistance strip heater with provision for electron beam heating. Temperature measurement is by thermocouple or optical pyrometer. High-temperature parameter measurements on vanadium are presented as one of the examples of the capability of the apparatus.
- OP 139-71. The Chlorination Kinetics of Tungsten, Molybdenum, and Their Alloys**, by A. Landsberg, C. L. Hoatson, and F. E. Block. *J. Electrochem. Soc.*, v. 118, No. 8, August 1971, pp. 1331-1336. The chlorination kinetics of tungsten, molybdenum, and three of their binary alloys have been studied as part of a Bureau of Mines effort to provide information of value when considering chlorine metallurgy processes. Tungsten and molybdenum were used for this initial investigation of alloys because they are chemically similar, form a complete range of solid solutions, and have been shown to chlorinate at temperatures sufficiently different so as to facilitate the determination of temperature dependency of reactivity by experiments based on the measurement of weight loss as the volatile chlorides are formed. Both the pure metals and alloys containing 22, 48, and 72 atomic percent (a/o) molybdenum were found to chlorinate between 400° and 775° C at rates of 10^{-7} to 10^{-5} mole per square centimeter per minute, with the reaction rate dependent upon the 0.6 power of chlorine pressure. Molybdenum exhibited the highest reactivity, tungsten was the least reactive, and the alloys showed intermediate reactivity with respect to temperature. Single crystals of the pure metals showed marked anisotropy upon chlorination. When chlorinated, the polycrystalline alloy specimens of 22 and 72 percent molybdenum tended to show the crystalline anisotropy exhibited by the major component, while the 48 percent molybdenum specimen developed no pattern similarity to the pure metals.
- OP 140-71. Electrorefining of Vanadium Prepared by Carbothermic Reduction of V_2O_5** , by K. P. V. Lei and T. A. Sullivan. *Metall. Trans.*, v. 2, August 1971, pp. 2312-2314. High-purity vanadium was prepared by molten-salt electrorefining of a crude vanadium feed material prepared by carbothermic reduction of vanadium pentoxide.
- OP 141-71. Determination of Proportions of Coal Components by Automated Microscopic Reflectance Scanning**, by J. T. McCartney, H. J. O'Donnell, and S. Ergun. *Fuel*, v. 50, August 1971, pp. 226-235. The Bureau of Mines has developed an automated reflectance scanning microscope system, primarily for determination of volume proportions, size distribution, and mode of association of the physical (petrographic) components of coals. The process, which is potentially more rapid and objective and less tedious than a visual microscopic procedure, involves

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magnetic tape recording of several million reflectance readings on micrometer sized areas of polished coal surface, and computer analysis and interpretation of some characteristics of the coal components. Results of petrographic analysis by automated reflectance scanning microscopy and conventional visual microscopy have been compared for four coals on the basis of a partially arbitrary interpretation of reflectance distributions. Such comparisons indicate fairly good agreement of results by the two methods for at least three of the coals, particularly in showing the considerably higher proportions of exinite and lower amounts of vitrinite in dull coal samples contrasted with bright coals. Despite the interpretation being arbitrary, the interest of other laboratories in such research, and possible advantages of greater objectivity and rapidity of analysis and correlation with coal utilization, encourage further study along these lines.

OP 142-71. Blast Vibration Studies at Shullsburg Mine, Wisconsin, by James J. Olson and Richard A. Dick. Canadian Min. J., v. 92, No. 7, July 1971, pp 49-53. The Bureau of Mines measured blast vibrations in the roof of a lead-zinc mine in Shullsburg, Wis., as part of a study to determine how blast factors such as explosive type, blast design, delays, charge weight per delay, rock type, and geologic structure affect maximum vibration amplitudes in different underground environments. Maximum vibration amplitudes were produced by the charge weight detonated with the zero delay caps. Peak particle velocities from the Shullsburg production blasts, scaled by the square root of the charge weight per delay, fell within the approximate bandwidth of velocity data obtained from many quarries in different rock types. This grouping of data indicated that scaling vibrations by some factor of the charge weight, perhaps the square root or cube root may, as found in the Bureau of Mines quarry blast studies, be an effective way to group and study vibration data from underground blasts.

OP 143-71. Discriminant Analysis as a Technique for Exploitation of Petroleum Reservoirs, by Leo A. Schrider and Jack Byrd, Jr. 46th Ann. Fall Meeting Soc. Petrol. Eng., AIME, New Orleans, La., Oct. 3-6, 1971, preprint SPE-3567, 1971, 10 pp. Discriminant analysis, a statistical technique, was used to classify oil wells into productivity groups based upon data obtained from geophysical well logs. A calibration run conducted in the northern area of the East Canton oilfield verified that valid forecasts can be obtained by the procedure. Of 20 wells studied, four appeared to have a greater potential than that indicated by actual production figures. A similar study of the southern area of the East Canton reservoir also proved discriminant analysis to be effective for predicting productivity, although different variables were significant than those for the north reservoir. Discriminant analysis was indicated to be adequate and potentially helpful in arriving at decisions concerning well completion.

OP 144-71. The Hot-Film Log—A Formation Evaluation Tool Designed for Shallow In-Situ Oil Shale Experiments, by Harold E. Thomas. 46th Ann. Fall Meeting Soc. Petrol. Eng., AIME, New Orleans, La., Oct. 3-6, 1971, preprint SPE-3501, 1971, 12 pp. The hot-film flow log was developed for evaluating shallow in situ fracturing and retorting (combustion) experiments in Green River oil shale. Two logging probes are described which employ a temperature-compensated conical, hot-film anemometer-type flow sensor. Wellbore fluid-flow profiles and fluid entry or exit points can be recorded while continuously lower-

ing or raising the probes in cased or uncased wellbores. Natural, hydraulic, and explosive fractures in oil shale have been evaluated by a combination of air injection, air production, and flow logging techniques. Fracture depths, types (horizontal or vertical), and flow characteristics within a single borehole or a system of boreholes can be interpreted from the logs. Gas flow profiles in in situ retorting experiments can be determined before ignition, during formation combustion, and after combustion termination. Limitations and potential applications are discussed.

OP 145-71. Effect of Overburden Pressure and Water Saturation on Gas Permeability of Tight Sandstone Cores, by Rex D. Thomas and Don C. Ward. 46th Ann. Fall Meeting Soc. Petrol. Eng., AIME, New Orleans, La., Oct. 3-6, 1971, preprint SPE-3634, Sept. 17, 1971, 8 pp. Permeability measurements were made on cores at simulated in-situ conditions for reservoirs amenable to nuclear fracturing. Results agree reasonably well with production test data.

OP 146-71. Properties of Silver Bromide Vapors, by A. Visnapuu and B. C. Marek. J. Less-Common Metals, v. 25, No. 1, September 1971, pp. 89-96. Knudsen cell mass spectrometric analysis of the vapors over molten AgBr between 711° and 963° K indicates the existence of three vapor molecules: AgBr, Ag₃Br₂, and Ag₃Br. "Second Law" heats of vaporization, ΔH_v , for the three vapor species are calculated to be 41.4 ± 1.1 kcal mole⁻¹, 33.6 ± 1.1 kcal mole⁻¹, and 29.2 ± 1.8 kcal mole⁻¹, respectively. The heat of trimerization is -95.0 ± 3.8 kcal mole⁻¹. Ionization potentials for AgBr, Ag-Br₂, and Ag₃Br₂ are 9.5 ± 0.3 eV, 10.0 ± 0.2 eV, and 9.8 ± 0.2 eV, respectively.

OP 148-71. Highlights of Some 50 Man-Years of Petroleum Sulfur Studies by the Bureau of Mines, by H. J. Coleman, R. L. Hopkins, and C. J. Thompson. Internat. J. Sulfur Chem. v. 6, pt. B, 1971, pp. 41-62. This paper summarizes a systematic 20-year study of the organic sulfur compounds of Wesson, Tex., crude oil and, to a lesser extent, of three other crude oils. This study has culminated in the identification of some 200 individual sulfur compounds. The Bureau of Mines has developed and applied separation and identification techniques which should be generally suitable for the characterization of sulfur compounds in any crude oil. This paper cites much of the early sulfur literature that covers individual sulfur compound identifications completed before this study and some 20 project papers that resulted from this work. The sulfur compounds in petroleum have long been of concern to the petroleum industry, and such compositional data should be of both theoretical and practical value.

OP 149-71. Iodine and Algae in Sedimentary Rocks Associated with Iodine-Rich Brines, by A. Gene Collins, J. H. Bennett, and O. K. Manuel. Geol. Soc. America Bull., v. 82, September 1971, pp. 2607-2610. Neutron activation analyses of iodine and uranium in Paleozoic sedimentary rocks from the northern Oklahoma platform of the Anadarko show 0.9 to 12.3 ppm I and 0.07 to 8.7 ppm U. The samples were taken from strata in Kingfisher County, Okla., where anomalously high concentrations of iodine were found in associated subsurface brines. Micropaleontological examinations reveal algal strands in the more iodine-rich rocks.

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OP 150-71. Exploitation of Minerals in Disposal Brines, by A. Gene Collins and Michael E. Croker. 46th Ann. Fall Meeting Soc. Petrol. Eng., AIME, New Orleans, La., Oct. 3-6, 1971, preprint SPE 3453, 8 pp. The practice of pooling disposal brines is gaining momentum in the petroleum industry, and large quantities of brines are processed by single disposal facilities. Through a survey of these facilities, the economic value of the minerals in some of these brines was determined. The results indicate that 6 of the 40 sampled brines contain concentrations of minerals and values comparable with those of a commercial brine. Twenty-nine brines contain concentrations of minerals more valuable than those found in seawater.

OP 151-71. Energy From Oil Shale: Environmental Research, by Glenn L. Cook. 46th Ann. Fall Meeting Soc. Petrol. Eng. AIME, New Orleans, La., Oct. 3-6, 1971, preprint SPE 3455, 1971, 5 pp. The development of the vast energy resources of the oil shales of the Green River Formation in Colorado, Utah, and Wyoming requires the application of satisfactory environmental controls. Expected waste materials from processing oil shale are the shales from which the organic materials have been removed, the water produced during retorting or mining, and the gases produced during retorting. Present status of environmental research on oil shales at the Laramie Energy Research Center is included.

OP 152-71. Can Chemical Stabilization Improve Ground Support?, by Lester J. Crow and Dennis J. Kelsh. Eng. and Min. J., v. 172, No. 8, August 1971, pp. 75-77. Marked improvement in strength and modulus of elasticity is possible through the impregnation of polymers in porous rock.

OP 153-71. Influence of Reduction and Thermal Shock on Nonmagnetic Taconite Grindability, by C. B. Daellenbach, R. A. Vik, and W. M. Mahan. Trans. Soc. Min. Eng., AIME, v. 250, September 1971, pp. 212-217. The influence of reduction roasting and thermal shock on the grindability of a refractory low-grade Michigan iron ore was examined in bench-scale tests. The quantitative effects of the various treatments were evaluated at three sieve levels, 48, 100, and 400 mesh, with ball-mill-grindability and work-index parameters as response indicators. Data from the testing program were statistically analyzed to isolate the effects of cooling rate, roasting temperature, mesh level, and ore chemical condition. All four variables were found to have an important influence on the grindability of the treated ore. Ore chemical condition and roasting temperature had the most pronounced effects.

OP 154-71. Some Mass Spectral and Analytical Aspects of Deuterium Labeling of Straight-Chain Olefins, by D. G. Earnshaw, F. G. Doolittle, and A. W. Decora. Organic Mass Spectrometry, v. 5, 1971, pp. 801-815. A calculation method has been developed to enhance the effect of deuterium labeling in the mass spectra of linear vicinal dideuterioalkanes (LVDA). Individual LVDA can be identified from these enhanced spectra. Single carbon-number mixtures of LVD nonanes and LVD decanes have been analyzed successfully using matrices derived from spectra of standards. In addition, enhanced mass spectra have been predicted for all of the LVD heptadecanes and LVD nonadecanes. Matrices have been constructed from the predicted spectra, and preliminary tests of these matrices have been conducted. All identifications and analytical results on the LVDA studied can be used to identify the precursor olefins.

OP 155-71. Laboratory Extraction of Copper From Chalcocite by Roasting, Reduction, and Smelting, by M. M. Fine and R. B. Schluter. SME J., v. 250, No. 3, September 1971, pp. 243-247. A process for winning copper from pelletized chalcocite concentrate without matte smelting and converting is under development at the Twin Cities Metallurgy Research Center of the Bureau of Mines. The new procedure includes a two-stage fluid-bed treatment in which the pelletized concentrate with 33 percent Cu and 7 percent S is first desulfurized to about 0.5 percent S in an oxidizing atmosphere, and then metallized by reduction with hydrogen. The reduced product is melted with flux to separate metallic copper from the gangue. The metal must be refined to remove residual sulfur and iron. The pelletizing of the fine concentrate into mini-pellets prior to fluid-bed treatment is an important feature of the process, because it permits shorter reaction time, decreases dusting, and facilitates subsequent processing.

OP 156-71. Gasification of Fossil Fuels in a Microwave Discharge in Argon, by Yuan C. Fu. Chem. and Ind. (London), No. 31, July 31, 1971, pp. 876-877. Different gasification characteristics of various fossil fuels in a microwave discharge in argon were investigated. The extent of gasification appears to be related to the carbon content of the solid.

OP 157-71. Gasification of Solid Fossil Fuels in a Microwave Discharge, by Yuan C. Fu, Bernard D. Blaustein, and Irving Wender. Chem. Eng. Prog. Symp. Ser., v. 67, No. 112, 1971, pp. 47-54. Gasification of solid fuels including lignite, high volatile A bituminous coal, oil shale, kerogen, gilsonite, and tar sands in a microwave discharge in argon yields hydrogen, carbon monoxide, and gaseous hydrocarbons. The extent of gasification appears to be related to the carbon content of the solid. High initial rate of production of various components of gases decrease rapidly with time in the early stages of reaction. In a carbon dioxide discharge, the product species present are oxidized to yield carbon monoxide; in a hydrogen discharge, the formation of hydrocarbons is enhanced.

OP 158-71. The Enthalpies of Combustion and Formation of Some Alkyl Cyclopropanes, by W. D. Good. J. Chem. Thermodynamics, v. 3, 1971, pp. 539-546. The enthalpies of combustion of six alkyl cyclopropanes were measured by oxygen-bomb combustion calorimetry. Values of the enthalpy of formation were derived.

OP 159-71. The Environmental Challenges of Alaskan Mineral Development, by Earl T. Hayes. UMR J., No. 2, June 1971, pp. 27-29. To meet the challenges of developing the Alaskan sources of mineral and fuel resources that are essential to all of us, we must conduct the research and planning necessary to see that the environment is not abused. There must be cooperation between Government and industry, between Federal and State Governments, between the doer and the dreamer, and between the engineer and the ecologist. The quality of what is done today will determine the quality of Alaska in the future—and the future is as near as tomorrow.

OP 160-71. Nuclear Magnetic Resonance Relaxation of Lithium Ions in Water Solutions in Porous Materials, by L. C. Headley, W. E. Wallace, Jr., and P. Waldstein. J. Magnetic Resonance, v. 5, No. 2, October 1971, pp. 168-173. Nuclear magnetic resonance (NMR) longitudinal relaxation times (T_1 's) of lithium nuclei were measured in porous porcelain media contain-

ing solutions of lithium chloride in water. For constant salt concentration, $1/T_1$ for ^7Li was found to be proportional to the specific surface area of the media. For constant specific surface area, T_1 (^7Li) decreased with increase in concentration within the range studied, while T_1 (^6Li) did not vary significantly with concentration. The results are discussed in terms of chemical exchange between bulk phase ions and ions in electrical double layers near the solid surface.

OP 161-71. High-Temperature Phase Relations in the System $\text{BaF}_2\text{-SrF}_2$, by Ralph H. Nafziger. *J. Am. Ceram. Soc.*, v. 54, No. 9, September 1971, p. 467. The alkaline-earth fluoride system $\text{BaF}_2\text{-SrF}_2$ was studied because the liquidus temperatures were thought to be sufficiently high to make compositions in this system useful as slags for electroslag melting of reactive metals such as Ti and Zr. Melting point temperatures were determined for BaF_2 and SrF_2 . The melting point of SrF_2 is approximately 200°C below that of Ti and 50°C above that of CaF_2 , which is the most commonly used slag for melting reactive metals. The high-temperature densities for all mixtures in the $\text{BaF}_2\text{-SrF}_2$ system are greater than that for CaF_2 , but less than that for molten Ti above its melting point. The heats of fusion for the pure components (3.0 and 4.26 kcal mole $^{-1}$ for BaF_2 and SrF_2 , respectively) are less than those for CaF_2 (6.78 kcal mole $^{-1}$).

OP 162-71. Molecular Interactions of Asphalt, by J. C. Petersen, R. V. Barbour, S. M. Dorrence, F. A. Barbour, and R. V. Helm. *Anal. Chem.*, v. 43, No. 11, September 1971, pp. 1491-1496. The tentative identification of 2-quinolones has been made in a Wilmington, Calif., asphalt. These compounds, which exist predominantly in the N-unsubstituted form, were concentrated in an asphaltic resin fraction and are largely responsible for the 1655 cm^{-1} infrared absorption band in the asphalt. A strong hydrogen-bonding association between the 2-quinolones and carboxylic acids in asphalt is reported. The association complexes between the 2-quinolones and the carboxylic acids in asphalt and between the model compounds 2-quinolone and cyclohexanecarboxylic acid were studied by infrared spectrometry using a silylation reaction in which the 2-quinolones and carboxylic acids reacted at different rates. The ability of two solvents, methylene chloride and tetrahydrofuran, to break up hydrogen-bonded molecular complexes is shown. The diagnostic value of these solvents in infrared spectrometry for identification of carbonyl functional group types has been demonstrated, and use of these solvents for molecular association studies in asphalts is reported.

OP 163-71. Possible Use of Magnetic Fields in Determining Pore Geometry of Porous Media, by C. I. Pierce, L. C. Headley, and W. K. Sawyer. *Soc. Petrol. Eng. J.*, v. 1, No. 3, September 1971, pp. 223-228. Simplified models consisting of single, circular channels and channels of different length and diameter in series and parallel combinations, are used in conjunction with the equations of Poiseuille and Hartmann to demonstrate the dependence of the rate of flow of mercury in the models on channel dimensions when the models are subjected to transverse magnetic fields.

Experimental tests conducted on mercury-saturated, glass-bead packs and a natural rock sample show that a magnetic field applied transversely to the direction of flow retards flow rate. The magnitude of the magnetic effect increased with increasing bead size and field intensity.

Results of this work suggest that magnetic fields have potential in the study of the internal geometry of flow channels in porous media.

OP 164-71. Corrosion of Heat-Exchange Tubes in a Simulated Coal-Fired MHD System, by R. Bienstock, R. J. Demski, and R. C. Corey. *Trans. ASME J. Eng. Power*, v. 93, No. 2, Ser. A, April 1971, pp. 249-256. An experimental unit was built to burn 125 lb of coal per hour at $4,000^\circ\text{F}$ in a cyclone burner with oxygen-enriched air preheated to $1,500^\circ\text{F}$ to ascertain the fireside corrosion problems that might be encountered in the coal-fired MHD generation of power. Haynes 25 was slightly attacked at $1,500^\circ\text{F}$ wall temperature, the stainless steels 310, 316, and 446 were resistant at $1,100^\circ\text{F}$, and carbon steel was attacked at 800°F .

OP 165-71. Environmental Aspects of MHD Power Generation, by D. Bienstock, R. J. Demski, and J. J. Demeter. *Proc. Intersociety Energy Conversion Eng. Conf.*, Boston, Mass., Aug. 3-6, 1971, SAE Paper 719157, 1971, pp. 1210-1217. With use of a non-sulfur potassium seed, obtained through regeneration of the spent seed, complete elimination of SO_2 emission is possible in MHD power generation. Two-stage combustion can be used to drastically lower NO_x emissions.

OP 166-71. Solubility of Barium and Strontium Sulfates in Strong Electrolyte Solutions, by James W. Davis and A. Gene Collins. *Environmental Sci. and Technol.*, v. 5, No. 10, October 1971, pp. 1039-1043. Knowledge of the solubilities of BaSO_4 and SrSO_4 in solutions containing NaCl , CaCl_2 , MgCl_2 , and NaHCO_3 is needed to solve geologic and petroleum production problems. Samples of the sulfates were tagged with sulfur-35 and prepared by precipitation. The solubility was measured in various concentrations of the major solutes by use of a liquid scintillation technique to detect the SO_4^{2-} in solution. The observed solubilities plotted against strength of the solution are similar for strong electrolytes. They reach a maximum at concentration levels beginning at an ionic strength of near 1. The sulfate solubility in synthetic brines (principally NaCl) confirms the ionic strength-sulfate solubility relationships.

OP 167-71. Use of C-14 in Studying Pollution of the Air by Petroleum Hydrocarbons, by B. Dimitriadis. *Isotopes and Radiation Technol.*, v. 9, No. 1, 1971, pp. 63-64. The interaction in hydrocarbon mixtures and the participation of CO in smog formation were studied using carbon-14 as a tracer.

OP 168-71. Aldehyde-Olefin Interaction in the Nitrogen Oxide-Sensitized Photooxidation of Aliphatic Olefins, by B. Dimitriadis and M. L. Whisman. *Chemical Reactions in Urban Atmospheres*, ed. by C. S. Tuesday. American Elsevier Pub. Co., Inc., New York, 1971, pp. 89-101. To predict photochemical smog potential of mixtures of hydrocarbon and hydrocarbon derivatives, it is necessary to establish whether component interactions affect behavior of individual components in the reaction system. This report covers work done at the Bureau of Mines, Bartlesville, Okla., Petroleum Research Center, for the purpose of investigating olefin-aldehyde interactions possibly occurring in NO_x -sensitized photooxidation of 1-butene-aldehyde mixtures.

First results showed that in such mixtures consumption of 1-butene is affected by the presence and nature of other hydrocarbons and/or aldehydes. Further investigation revealed that the effects of aldehydes on butene consumption could be explained

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in terms of effects on oxygen atom and ozone concentrations only during the later reaction stage following photooxidation of NO into NO₂. In the earlier stages, the aldehyde effects can be explained only if olefin-radical reactions occur in parallel with the olefin-oxygen atom reaction.

OP 169-71. Retorting Ungraded Oil Shale as Related to In Situ Processing, II, by L. Dockter, A. Long, and A. E. Harak. Preprints, Div. Fuel Chem., ACS., v. 15, No. 1, 1971, pp. 2-11. Results obtained from 17 experiments performed by the Bureau of Mines on Green River oil shales in a 10-ton batch retort are presented. The oil shales processed ranged in grade by Fischer assay from 20.4 to 48.0 gallons of oil per ton; air rates employed in retorting ranged to as high as 3.74 scfm per square foot of bed.

Multiple linear regression analysis was used to generate equations predicting the oil yield for given sets of retorting conditions. Using only controlled operating variables, an equation was developed that accounts for 83 percent of the variability in oil yield. Including ambient conditions in the regression improves the percentage to 93.

OP 170-71. Prediction of Isomeric Equilibria: A Better Calorimetric Basis, by D. R. Douslin. Proc. 36th Midyear Meeting, Div. Refining, API, San Francisco, Calif., May 10-14, 1971, pp. 361-375. The advantages of using internally consistent, comprehensive, experimental thermodynamic properties for calculating complex reaction equilibria are demonstrated for the systems *cis*-plus *trans*-hexahydroindan and the five isomeric aliphatic hexanes.

OP 171-71. Computing Movement of Injected Raw Helium in Bush Dome Reservoir, by C. Kenneth Eilerts and Eudora F. Sumner. 46th Ann. Fall Meeting Soc. Petrol. Eng., AIME, New Orleans, La., Oct. 3-6, 1971, preprint SPE 3435, 1971, 15 pp. The injection of conservation helium into the Bush Dome reservoir near Amarillo, Tex., began in January 1963. It is important that this purchased raw helium not mix with native gas unnecessarily and that the helium that accumulates in the formation be maintained in a position favorable for its efficient recovery. A program has been developed and used to compute the movement of injected gas under the influence of factors that are significant for 8 years of actual operations and 17 years of planned future operations.

OP 172-71. Emission Characteristics of Natural Gas as an Automotive Fuel, by R. D. Fleming and J. R. Allsup. Pres. at Nat. Combined Fuels and Lubricants, Powerplant and Truck Meetings, St. Louis, Mo., Oct. 26-29, 1971, SAE Paper 710833, October 1971, 7 pp. A study of natural gas as a low-pollution automotive fuel was conducted using a single-cylinder engine, a multicylinder engine, and six vehicles. Results showed that the light-load, lean-limit misfire region of natural gas begins at an air-fuel ratio between 140-150 percent of stoichiometric. Changes in ignition timing significantly influences emissions of nitrogen oxides and hydrocarbons but had little effect on carbon monoxide emission. Lower emissions can be achieved (by adjustment) with current design engines, but with heavy penalty to engine performance. Emissions from vehicles fueled with natural gas are virtually unaffected by temperature change within the range 20°-100° F. Natural gas exhaust is estimated to be 22-25 percent as reactive as gasoline exhaust.

OP 173-71. Solvent Stimulation of Viscous Crude-Oil Production, by G. L. Gates and W. H. Caraway. Soc. Petrol. Eng., AIME, 42d Ann. California Reg. Meeting, Nov. 4-5, 1971, SPE 3680, 1971, 11 pp. To improve both the rate and volume of production of viscous crude oils, the USBM made a study of solvents to stimulate production. Five laboratory methods were used to evaluate the effectiveness of several solvents in the stimulation of viscous oil production. These methods were (1) viscosity reduction, (2) gravity drainage production from sand columns, (3) displacement from capillary tubes, (4) effect of organic acids on crude oil viscosity and (5) hydrocarbon analysis. Solvents ranging from refinery cuts to chemical compounds were used with six California and one Kansas crude oils. Results indicated that small quantities of effective solvents greatly reduced the viscosity of viscous crude oils. The rate and volume of production of viscous crude oils by gravity drainage from laboratory sand columns were increased greatly by small quantities of effective solvents. It was also found that low molecular weight, aromatic hydrocarbon solvents effectively removed viscous crude oils from glass capillary tubes.

OP 174-71. Paleotopographic-Structural Controls on Thickness and Composition of Pittsburgh Coal in Southwestern Pennsylvania, by Bion H. Kent and Manuel Gomez. Pres. 84th Ann. Meeting Geol. Soc. America, Nov. 1-4, 1971, Washington, D.C.; abs. in Abstracts With Programs, Geol. Soc. America, v. 3, No. 7, October 1971, p. 622. Data on roof-rock type, coal-bed thickness, and the sulfur and ash content of the upper and the lower part of the main seam of Pittsburgh coal were obtained from about 550 cores taken in a 120-square-mile area that is now an underground mine in eastern Green County, Pa. The area of the study is in a northeast-trending zone on the east side of the Appalachian Plateau where amplitudes of folds change abruptly from 300 to 600 feet. To the northeast, in and near this zone, the Upper Freeport and the Lower Kittanning coalbeds also show evidence of paleotopographic-structural control.

OP 175-71. Methyl Mercury and Inorganic Mercury Collection by a Selective Chelating Resin, by Stephen L. Law. Science, v. 174, Oct. 15, 1971, pp. 285-287. A commercially available chelating resin selectively and quantitatively collects methyl mercuric and inorganic mercuric forms of mercury to the exclusion of all other metals studied, except the noble metals. Both forms of mercury can be collected from pH 1 to 9. Collected mercury is readily eluted with a slightly acid, 5 percent solution of thiourea, and the resin can be reused for many cycles. Selectively, pH effects, capacity, and elution characteristics of the resin are described. A resin-loaded paper composed of 50 percent resin and 50 percent cellulose shows properties similar to those of the loose resin.

OP 176-71. Combustion of Pulverized Char, by C. R. McCann, J. J. Demeter, A. A. Orning, and D. Bienstock. Nat. Meeting, Combustion Symp., Div. of Fuel Chem., ACS., v. 15, No. 2, September 1971, pp. 96-105. Chars with volatile contents of 5-15 percent required supplemental fuel, of 10-15 percent of the total enthalpy input, in combustion in a dry-bottom, horizontally fired, pulverized-coal furnace.

OP 177-71. Diesel Emissions as Related to Engine Variables and Fuel Characteristics, by W. F. Marshall and R. D. Fleming. Pres. at Nat. Combined Fuels and Lubricants, Powerplant and Truck Meetings,

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St. Louis, Mo., Oct. 26-29, 1971, SAE Paper 710036, October 1971, 7 pp. Experimental work was done to show how emissions could be minimized through adjustment of engine and fuel parameters. Adjustment for peak performance yielded lowest levels of all emissions except NO₂.

OP 178-71. Thermodynamic Relationships of the 2-Methylalkanes, C₅ to C₁₁, From 10 to 300 K, by J. F. Messerly, H. L. Finke, and D. R. Douslin. Preprints, Div. Petrol. Chem., ACS, v. 16, No. 1, February 1971, pp. A57-A61. Low-temperature thermal properties of 2-methylheptane and 2-methyldecane were measured from 11° to 370° K. Entropies at 298.15° K of the 2-methylalkanes, C₅ to C₁₁, were compared for liquid and ideal gas states.

OP 179-71. Progress in Coal Gasification, by G. Alex Mills. Proc. 3d Synthetic Pipeline Gas Symp., Rosemont, Ill., Nov. 17-18, 1970, pp. 59-78. At present the Bureau of Mines has the following active coal gasification projects: (1) The manufacture of high-Btu gas of pipeline quality in a fluidized bed with steam and oxygen or (2) by hydrogasification; (3) the production of low-Btu or producer gas in a fixed bed; and (4) production of hydrogen using a circulating solid heat carrier. The status of these projects is discussed in this report.

OP 180-71. A Study of Fly Ash Reactions and Deposit Formation in a Large Cyclone-Fired Generator, by A. A. Orning. Nat. Meeting, Combustion Symp., Div. of Fuel Chem., ACS, September 1971, v. 15, No. 2, pp. 150-157. Deposits from an industrial cyclone combustor were investigated. Color variations were attributed to ferric oxide content; alkali variations were related to ferric oxide and temperature.

OP 181-71. Engineering Properties of Mine Tailings, by Howard C. Pettibone and C. Dan Kealy. Soil Mechanics and Foundations Div., Am. Soc. Civil Eng., v. 97, No. SM 9, September 1971, pp. 1207-1225. The engineering properties of tailings from nine mines are summarized to demonstrate that these are good engineering materials. Presented are examples of their usage in the construction of a section of Interstate 90, near Kellogg, Idaho, and a theoretical design of a small earth dam.

OP 182-71. Stability of an Underground Room in Frozen Gravel, by Howard C. Pettibone and Galen G. Waddell. Proc. 9th Ann. Symp. Eng. Geology and Soils Engineering, Boise, Idaho, April 5-7, 1971, October 1971, pp. 3-30. Research was conducted by the Bureau of Mines to aid in estimating the economic and technological feasibility of mining gold from frozen gravel placers in Alaska. This presentation describes the progress of one of several projects conducted. As part of this study the Spokane Mining Research Center undertook to determine the conditions under which a 30- by 70-foot underground room would safely remain open without artificial supports. The evaluation was instrumented with closure points, thermocouples, recording thermometers, and hydraulic props.

OP 183-71. Pyrolysis of Municipal and Industrial Wastes, by W. S. Sanner and D. E. Wolfson. Proc. Special Centennial Symp., "Technology for the Future to Control Industrial and Urban Wastes", University of Missouri-Rolla, Mo., Continuing Education Series, Feb. 8-9, 1971, pp. 39-42. Satisfactory disposal of mounting quantities of municipal and industrial wastes is a problem of great national concern

from the standpoint of both environmental pollution and conservation of natural resources. Pyrolysis techniques used by the Bureau of Mines as a means of studying the carbonization characteristics of coal have been applied successfully to convert municipal and industrial wastes into usable or more manageable forms without adding to environmental pollution. By pyrolysis at elevated temperatures, refuse materials can be converted to potentially useful solids, liquids, and gases. The gas produced in the process is more than enough to supply the reaction energy.

OP 184-71. Kinetics and Mechanism of the Conversion of Covellite (CuS) to Digenite (Cu₁₁S₈), by I. D. Shah and S. E. Khalafalla. Metallurgical Trans., v. 2, September 1971, pp. 2637-2643. Rates of conversion of covellite (CuS) to digenite (Cu₁₁S₈) in N₂ and various partial pressures of O₂ have been studied in the temperature range 260° to 400° C. The reaction is first order with respect to O₂ concentration in N₂-O₂ mixtures at 1 atm. The experimental activation energy for the conversion of CuS to Cu₁₁S₈ is 23 ± 3 kcal. In a nitrogen atmosphere, the conversion proceeds at a slower rate but with the same activation energy and leads to the formation of elemental sulfur instead of SO₂. An externally added small amount of iron powder (0.6 percent) increased the rate of conversion but had no effect on the apparent activation energy. The rate-controlling reaction in the conversion mechanism is postulated to be Cu₁₁S₈ → 1.8 Cu⁺ + 1.8 e⁻ + S at the Cu₁₁S₈/gas interface. Reduction of CuS by copper(I) ions and electrons occurs by a rapid reaction, 0.8 Cu⁺ + 0.8 e⁻ + CuS → Cu₁₁S₈ at the CuS/Cu₁₁S₈ interface, which steadily contracts with time.

OP 185-71. BuMines Analysis Shows Characteristics of Prudhoe Bay Crude, by C. J. Thompson, H. J. Coleman, J. E. Dooley, and D. E. Hirsch. Oil & Gas J., v. 69, No. 43, Oct. 25, 1971, pp. 112-120. This paper presents compositional data on a sample of Prudhoe Bay, Alaska, crude oil and a description of the separation and identification methods used in the study.

OP 186-71. Determination of Pressure and Volume, by G. W. Thomson and D. R. Douslin. Physical Methods of Chemistry, ed. by A. Weissberger and B. W. Rossiter. John Wiley & Sons, Inc., New York, 4th ed., v. 1, 1971, pp. 23-104. This chapter presents a review at the undergraduate and graduate level of methods available for measuring the pressure and volume of the solid, liquid, or gaseous states of matter.

OP 187-71. Isolation and Analysis of Carbonyl Compounds as Oximes, by James W. Vogh. Anal. Chem., v. 43, No. 12, October 1971, pp. 1618-1623. Procedures were developed for collecting and isolating carbonyls from such complex mixtures as oximes, and for subsequent chromatographic analysis of the oxime mixture. The isolation procedure was based on the weak-acid properties of oximes, which permit separation from hydrocarbons and other neutral materials by extraction with pentane. Retention of oximes in the basic phase was improved by the addition of alcohols and by extraction at low temperatures. Chromatographic analysis of oximes was accomplished using an all-glass system. Oximes were decomposed to nitriles by hot metal surfaces but were stable in glass equipment that had been cleaned to remove heavy metal oxides. The most satisfactory chromatographic column had a glass tube filled with glass-bead support that was coated with a poly-

glycol liquid phase. In chromatograms, most aliphatic aldoximes showed double chromatographic peaks that were due to the *syn* and *anti* isomers. These were identified, and the isomer peak ratio was shown to be affected by steric interference. Phenols were recovered in the isolation procedure and could be analyzed in the same chromatographic system. Applications in diesel- and gasoline-engine exhaust are discussed.

OP 188-71. Reservoir and Production Characteristics of the Clinton Sand, East Canton Oilfield, by Royal J. Watts, Leo A. Schrider, and Jerry G. Craig. Eastern Reg. Meeting Soc. Petrol. Eng., AIME, Charleston, W. Va., Nov. 4-5, 1971, preprint SPE 3661, October 1971, 12 pp. Geophysical well logs, petrographic thin-section core analyses, and production- and pressure-decline curve analyses were used to characterize the geology and to estimate the reserves, recovery, and well life of the East Canton oilfield, northeastern Ohio. Clean sand sections of the Clinton were found to contain an average of 95 percent quartz and less than 4 percent clay. These sections correlated with the 80-percent-sand line determined by gamma ray logs and with core permeabilities averaging more than 0.1 millidarcy. Production was found to be more closely related to thickness of 80 percent sand than to any other reservoir characteristic. Economic life and output of the wells studied are predicted to be approximately 10 years and about 30,000 to 40,000 barrels per well. A primary recovery factor of 9 to 12 percent is indicated. Primary reserves of the 60,000-acre field are a minimum of 51 million barrels. Approximately 500 additional wells will have to be drilled to complete development of the field. With such a low primary oil-recovery factor, much oil will remain for secondary recovery possibilities.

OP 189-71. Liquid-Liquid Chromatographic Separation of Neodymium, Samarium, and Gadolinium, by J. O. Winget and R. E. Lindstrom. Separation Sci., v. 6, No. 4, August 1971, pp. 573-581. Neodymium, samarium, and gadolinium were separated by a liquid-liquid chromatographic technique. Sulfuric acid was more effective than hydrochloric or nitric acid as an eluent with di(2-ethylhexyl) phosphoric acid (EHPA) as the stationary phase. Recovery of 45 percent of the neodymium as >90 percent Nd_2O_3 , 84 percent of the samarium as >99 percent Sm_2O_3 , and 50 percent of the gadolinium as >99 percent Gd_2O_3 was achieved. The degree of separation and the time required for the separation can be varied by changing the concentration of the eluent and the number of stages in the system. A system comprising a primary amine organic extractant and an aqueous eluent containing diethylenetriaminepentaacetic acid (DTPA) was less effective for separating the rare earths.

OP 190-71. Continuous Rapid Carbonization of Powdered Coal by Entrainment-Response Surface Analysis of Data, by Robert J. Belt, John S. Wilson, and John J. S. Sebastian. Fuel (London), v. 50, October 1971, pp. 381-393. A study was made of rapid carbonization of coal in entrainment by composite factorial design of test-runs. From the data obtained through the operation of a 4-in-diameter flash carbonizer, the effects and interactions of the variables were determined and represented by three-dimensional models called response surfaces. These surfaces indicated the essential variables for each product yield or quality and showed the trend toward optimum values of these responses. Internal heating was shown to be superior to external heating from the standpoint of producing a uniformly devolatilized

char with higher throughput rates. Illustrating the method and the results obtained, the quality of the char, defined as the amount of volatile matter (VM) remaining in it, and the char yield for the internally and the externally heated carbonizer are shown as a function of the temperature, coal-feed rate, and composition of the entraining gas. Optimum char quality of 15 percent VM with the highest throughput rate, 750 g/h, was achieved by means of internal heating at 1,900° F, which resulted in a char yield of 1,075 lb/ton of coal carbonized.

OP 191-71. Low-Temperature Ashing of Lignite Using an Oxygen Plasma, by Philip G. Freeman and Walter W. Fowkes. Proc. North Dakota Acad. Sci., v. 24, 1971, pp. 119-124. Many processes utilizing lignite or other fossil fuels are concerned with the chemical and mineralogical composition of the ash. In an effort to better understand the original condition of the inorganic components in the fuel, a low-temperature oxidation unit was used to ash lignite. In this way temperature-sensitive structures are preserved. Carbonaceous material is oxidized with "active" oxygen generated in a microwave discharge under reduced pressure. The addition of a small quantity of nitrogen catalyzes the formation of active oxygen at temperatures below 60° C, as determined by a thermometer inserted in a well in the reactive chamber. The low-temperature ash was analyzed by X-ray diffraction and found to differ considerably from a corresponding high-temperature ash in that sodium occurred mainly as carbonate-sulfate in the latter and as nitrate in the former.

OP 192-71. The Enthalpies of Combustion and Formation of Indan and Seven Alkylindans, by W. D. Good. J. Chem. Thermodynamics, v. 3, No. 5, October 1971, pp. 711-717. The enthalpies of combustion of indan and seven alkylindans were determined by oxygen-bomb combustion calorimetry. Enthalpies of formation in the condensed state are derived.

OP 193-71. The Enthalpies of Combustion and Formation of Cyclopropylamine. The C—N Thermochemical Bond Energy, by W. D. Good and R. T. Moore. J. Chem. Thermodynamics, v. 3, No. 5, October 1971, pp. 701-705. The standard enthalpy of combustion of liquid cyclopropylamine, ΔH_c° (298.15 K), was found to be -532.20 ± 0.10 kcal/mol by oxygen-bomb combustion calorimetry. The standard enthalpy of formation, ΔH_f° (298.15 K), of the liquid is (10.95 ± 0.12) kcal/mol. The enthalpy of vaporization was derived from vapor pressure measurements, and the standard enthalpy of formation in the ideal gaseous state was calculated. The value of the thermochemical bond energy, $E(\text{C—N})$, was estimated.

OP 194-71. Effect of Lowering Tin Content of Secondary Red Brass, by L. W. Higley, E. R. Cole, H. Kenworthy, and J. L. Holman. Trans. Am. Foundrymen's Society, v. 79, 1971, pp. 157-160. Laboratory melts of the important secondary casting alloy, 85-5-5-5 (85 percent Cu, 5 percent Sn, 5 percent Pb, 5 percent Zn), one of the leaded red brasses, were made in which the tin content was reduced from 5 to 3 and 1 percent, with increased copper or zinc to offset the reduction in tin. The work was done as part of a Bureau of Mines program to promote more economic use of secondary nonferrous alloys since tin, nearly all of which is imported, accounts for nearly 20 percent of the raw materials cost of the 85-5-5-5 alloy. The mechanical properties and machinability characteristics of the resultant alloys were compared with minimum properties for leaded red brass as specified by ASTM and with typical

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properties for leaded red brass as published by the Brass and Bronze Ingot Institute. Results indicate that much of the primary tin added to achieve composition in leaded red brass could be eliminated without significantly affecting strength, ductility, or machinability.

OP 195-71. The Cost Engineer in Research & Development, by Sidney Katell. *CHEM TECH*, v. 1, No. 11, November 1971, pp. 648-649. Since cost is the ultimate, critical variable in any mission-oriented program, it is fair to ask when it should first be considered. The cost engineer's earliest roles are outlined in this publication.

OP 196-71. Production of Foundry Iron With Scrap and Prereduced Pellets, by N. B. Melcher and W. M. Mahan. *Proc. Internat. Conf. Sci. and Technol. of Iron and Steel. Sec. 1* (Trans. Iron and Steel Inst. Japan), v. 11, December 1971, pp. 109-111. The Bureau's Twin Cities Metallurgy Research Center operated its size "0" hot blast cupola to study the possibility of producing gray iron with scrap and prereduced pellets. Specification grade iron was produced using a charge of 50-percent prereduced pellets or with a 100-percent prereduced pellet charge. A 9-percent increase in coke rate was experienced under the latter conditions.

OP 197-71. Low-Temperature Thermal Properties of 2-Methylheptane and 2-Methyldecane: The Thermodynamic Properties of the 2-Methylalkanes, by J. F. Messerly and H. L. Finke. *J. Chem. Thermodynamics*, v. 3, No. 5, October 1971, pp. 675-687. Experimental measurements were made of the low-temperature thermal properties of 2-methylheptane and 2-methyldecane from 12° to 360° K and 12° to 390° K, respectively. From these measured values and data from the literature the following chemical thermodynamic properties were calculated at selected temperatures for the condensed phases of 2-methylbutane, 2-methylpentane, 2-methylhexane, 2-methylheptane, and 2-methyldecane: Gibbs energy function, enthalpy function, enthalpy, entropy, and heat capacity. The entropies of 2-methylheptane and 2-methyldecane in the ideal gas state at 298.15° K were calculated and methylene entropy increments obtained for the 2-methylalkanes, C₅ to C₁₁.

OP 198-71. Industrial Service Failures: Corrosion of Nickel in a Zirconia Chlorinator, by L. L. Oden, D. L. Paulson, and W. C. McBee. *Materials Protection and Performance*, v. 10, No. 11, November 1971, pp. 22-24. Zirconia, prepared by calcining high-purity zirconium sulfate, is chlorinated to produce zirconium tetrachloride, which is reduced to metal with calcium in the final steps of the modern extension of the Kroll process for preparing zirconium. The critical chlorination step is done in a fluidized bed reactor in the presence of carbon, and the reaction products plus unreacted chlorine and entrained solids are conducted to a separator where the unreacted solids are removed. The ducting and separator, which are constructed from 1/4-inch nickel sheet, are subjected to severely corrosive conditions, which result in embrittlement and reduction in cross section of the nickel ducts.

Corrosion testing of nickel in the temperature range 400° to 600° C in an atmosphere containing H₂, Cl₂, H₂O, CO, and CO₂ to simulate industrial conditions, produced specimens exhibiting uniform surface attack similar to the corrosion of nickel in pure chlorine. Since these observations were not consistent with the industrial service failures, a section of

corroded nickel sheet was obtained from an industrial zirconia chlorinator and investigated to determine the corrosion mechanism.

OP 199-71. The Regeneration of Alkalized Alumina, by M. D. Schlesinger and Eugene G. Illig. *Chem. Eng. Symp. Ser.*, v. 67, No. 115, 1971, pp. 46-51. Alkalized alumina can be used for the removal of sulfur dioxide from stack gases. Before the pellets are recycled to the sorption section, they must be regenerated with a reducing gas. Several practical alternatives for regeneration are possible, resulting in single- and multiple-stage mechanisms. Besides the reduction itself, consideration is given to side reactions that can have a deleterious effect on the ability of the sorbent to be reused, its ease of regeneration, and its physical properties.

Data were obtained from a bench-scale system designed to study the mechanism and kinetics of the reactions. Regeneration can be accomplished at 600° to 700° C with hydrogen, carbon monoxide, and their mixtures. When carbon monoxide is used, some of the sulfate is reduced to the sulfide and a second-stage reaction with carbon dioxide is needed to complete regeneration to the reactive oxide. Data from this and other research are being used for the design of a prototype sulfur dioxide-removal plant.

OP 200-71. Piperidine: Vibrational Assignment, Conformational Analysis, and Chemical Thermodynamic Properties, by D. W. Scott. *J. Chem. Thermodynamics*, v. 3, No. 5, October 1971, pp. 649-656. Interpretation of the molecular spectra of piperidine with the aid of a molecular vibrational analysis showed that the molecule exists mostly in the equatorial conformation in the vapor state and exclusively so in the crystalline state. An energy difference of about 0.6 kcal/mol between the axial and equatorial conformations was found consistent with calorimetric data. A table of the chemical thermodynamic properties has been compiled.

OP 201-71. Solubilization of an lvb Coal by Reductive Alkylation, by H. W. Sternberg, C. L. Delle Donne, P. Pantages, E. C. Moroni, and R. E. Markby. *Fuel* (London), v. 50, 1971, pp. 432-442. Pocahontas (lvb) coal, when treated with alkali metal in tetrahydrofuran in the presence of a small amount of naphthalene, is converted to a "coal anion." The coal anion is formed by transfer of negative charges from the alkali metal to the aromatic clusters in coal with naphthalene acting as an electron transfer agent. The coal anion, containing 12 charges per 100 carbon atoms, is readily alkylated by alkyl halides. The alkylated coals contain eight alkyl groups per 100 carbon atoms and are soluble in benzene at room temperature. Five of the alkyl groups are attached to carbon atoms and the remaining three to oxygen atoms. The molecular weight of the alkylated coals is in the same range (3,000-4,000) as that of petroleum asphaltenes. The solubility in benzene of alkylated coal and of petroleum asphaltenes is believed to be due to the presence of alkyl groups which prevent stacking of the aromatic clusters.

OP 1-72. X-Ray Intensity Measurements From Ores Using Semiconductor Detectors and Radioisotopic Excitation, by Philip G. Burkhalter. *Ch. in Applications of Low Energy X- and Gamma-Rays Symposia on Low Energy X- and Gamma Sources and Applications at Boston College, Brookline, Mass., June 1970.* Gordon and Breach, New York, v. 3, December

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1971, pp. 147-163. Recent experimental work at the Bureau of Mines has involved use of radioisotopic excitation combined with semiconductor detectors to determine the sensitivity for single-element X-ray analysis. Peak-to-background ratios have been measured for gold and silver and for other high-Z elements in ores. The ease of exciting the energetic K X-rays from high-Z elements with radioisotopes offer unique advantages for ore analysis. Sensitivities below 100 ppm for high-Z elements in ores are possible because of the good stability of radioisotopic excitation and detecting X-rays with semiconductor detectors. During the course of this experimentation, monoenergetic excitation with gamma-emitting or electron-capture radionuclides was found excellent for both single and multielement X-ray excitation in ores. Higher peak-to-background ratios were obtained compared with broad-energy excitation using bremsstrahlung sources. Equally important for analysis are the discrete scatter peaks obtained with monoenergetic excitation. The fluorescent X-ray intensity-to-Compton scatter ratio has been used to overcome changes in X-ray intensities because of absorption coefficient variations in the ore matrix. More recent work has shown the importance of separating the Compton and coherent scatter events to achieve compensation over wider matrix variations.

OP 2-72. A Recent Development in Slurry-Flow Research: Transport of Solids in Noncircular Pipes, by C. L. Chiu, J. J. Seman, and R. C. Wang. Ch. in Bulk Materials Handling, ed. by Minor C. Hawk, School of Engineering, University of Pittsburgh, Pittsburgh, Pa., v. I, December 1971, pp. 239-257. The results of an extensive investigation of the effect of pipe shape and orientation showed that, of the circular and noncircular pipes studied, a rectangular pipe with a wide side as a bottom was found to be most advantageous for transporting solids hydraulically.

OP 3-72. USBM Finds Many Routes to Stabilizing Mineral Wastes, by Karl C. Dean, Richard Havens, and Espiridion G. Valdez. Min. Eng., v. 23, No. 12, December 1971, pp. 61-63. This article is a summary of Bureau of Mines efforts toward stabilizing mineral wastes. Physical, chemical, vegetative, and combination methods are included as practical stabilization procedures.

OP 4-72. Exhaust Emissions From Small Utility, Internal Combustion Engines, by B. H. Eccleston and R. W. Hurn. SAS Paper No. 720197, January 1972, 9 pp. This report results from an exploratory experimental study designed to add information on the contribution to air pollution of exhaust emissions from small, utility engines, and to evaluate the procedures used to test small engines.

Gross measurements of hydrocarbon, carbon monoxide, and nitric oxide are reported for 29 4-cycle and seven 2-cycle engines; sizes of the engines ranged from 2 to 22 hp. Emission measurements were made on each engine for nine combinations of load and air-fuel adjustments; only one speed point—full governed—was covered in the tests. An overall average of the data indicate that, operated at full-load and optimum air-fuel ratio, the 4-cycle engines emitted about 8 g HC, 180 g CO, and 5 g NO₂ per horsepower-hour. Under comparable conditions, the 3 to 6 hp 2-cycle engines emitted an average of 140 g HC, 240 g CO, and 2 g NO₂ per horsepower-hour.

OP 5-72. Physical Properties of Bulk Materials, by D. E. Frisque and L. C. Marraccini. Ch. in Bulk

Materials Handling, ed. by Minor C. Hawk, School of Engineering, University of Pittsburgh, Pittsburgh, Pa., v. I, December 1971, pp. 364-380. Physical property measurements are defined, and the accepted laboratory procedures for measuring these properties are described. Examples of the use of these measured properties to the design of storing-reclaiming operations are given.

OP 6-72. Scanning Electron Microscopy of Metallurgical Cokes and Residues From Rapid Pyrolysis, by J. T. McCartney. Fuel (London), v. 50, 1971, pp. 457-460. A recent study of cokes by scanning electron microscopy described structures revealed by partial combustion of cokes from two coals of differing rank. Different structures have been observed in cokes formed in conventional slow carbonization (3° C/min, in the Bureau of Mines-American Gas Association carbonization apparatus) and in residues formed in very rapid heating of small coal particles (8,000° C/sec). The article includes photographs of the scanning electron micrographs of the cokes studied.

OP 7-72. State-of-the-Art of Bulk Materials Systems, by E. R. Palowitch, R. S. Fowkes, and C. A. Goode. Bulk Materials Handling, ed. by Minor C. Hawk, School of Engineering, University of Pittsburgh, Pittsburgh, Pa., v. I, December 1971, pp. 4-14. The state of the art of handling bulk materials is defined in terms of the following: the characteristics of the bulk material; the flow rates and routes through which the material must be handled; and the loading, transporting, transferring and storing/reclaiming unit operations. Emphasis is on systems for handling material resulting from mining operations.

OP 8-72. Effect of Preferred Orientation on the Damping Capacity of Magnesium Alloys, by Alfred E. Schwaneke and Robert W. Nash. Metall. Trans., v. 2, December 1971, pp. 3453-3457. The torsional vibration damping of Mg-4.5 Ce alloys has been correlated with the texture orientation resulting from the method of fabrication. Forged and forged-plus-swaged alloys at vibratory stress levels of 1,500 psi exhibit specific damping capacities, respectively, of 6 and 11 times that of an extruded alloy of similar composition. Pole figures show that the basal planes are oriented preferentially in the extruded alloys with a 20 degree tilt to the axis of the extrusion, while the basal planes are generally parallel to the rod axis for forged or forged-plus-swaged alloys. The correlations indicate that the major source of damping in these hexagonal magnesium alloys is stress-induced anelastic shear on the basal planes (probably by dislocation motion).

OP 9-72. Systems Study of Data Availability on Natural Gas, by Staff, Division of Fossil Fuels, Bureau of Mines. Air Pollution Control Offices, Environmental Protection Agency, June 1971, 106 pp. The Bureau of Mines, with financial support from the Air Pollution Control Office of the Environmental Protection Agency, could establish and proposes to initiate a natural gas data bank. A complete and efficient data bank program will be accomplished by using data sources which are credible, ongoing, provide a continuous data series, yield specialized information, and are sufficiently uniform for programming. There are apparent data deficiencies within existing data collection programs, but for the most part such data gaps may be reduced by modifying Bureau and other agency collection pro-

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cedures. As their collection procedures improve, other data sources will contribute to the bank. Available from the National Technical Information Service as PB 201 465.

OP 10-72. Effect of Moisture and Temperature on the Fracture Morphology of Dacite, by Robert J. Willard and Kenneth E. Hjelmstad. *Internat. J. Rock Mech. and Min. Sci.*, v. 8, No. 6, November 1971, pp. 529-539. A direct relation was found between point-load tensile strength and percentage of void fracture in a series of dacite disks. Dried disks yielded higher tensile strengths and more void fracturing than did water-saturated disks. The behavior of certain ceramic materials is compared with that of dacite to show similarities and to form a basis for understanding dacite behavior.

OP 11-72. Oil Availability by Sulfur Levels, prepared by the Bureau of Mines for the Environmental Protection Agency, Office of Air Programs. August 1971, 209 pp. This report presents information pertaining to the sulfur content of crude oil reserves, production, and selected refined products by geographical areas. Crude oil reserves (as of Dec. 31, 1969) and 1969 production were classified by sulfur content as were refinery receipts. Quantity and sulfur content of stocks and shipments of selected refinery products was determined; also tabulated was sulfur content of stocks held at bulk terminal-storage facilities. Domestic and foreign desulfurization operations were tabulated and technology discussed. Available from the National Technical Information Service as PB 202 281.

OP 12-72. Dry Separation of Pyrite From Coal, by W. T. Abel, M. Zulkoski, and G. J. Gauntlett. 162d Nat. Meeting ACS, Div. Fuel Chem., Washington, D. C., Sept. 13-17, 1971, Preprints v. 15, No. 2, 1971, 12 pp. A dry separation process for removing pyrite from fine coal utilizing centrifugal and electrostatic methods removed 35 to 55 percent of the total pyritic sulfur (amounting to 70 to 100 percent of available pyritic sulfur) in rejects of 10 to 15 percent. Both separation methods are benefited by restricting the particle-size range and by keeping the pyrite particles as large as possible. Removal efficiency is increased, therefore, by integrating the separation and grinding operations, as in stage grinding.

OP 13-72. Reclamation of Coal Mine Wastes and Strip Spoil With Fly Ash, by J. P. Capp and L. M. Adams. 162d Nat. Meetings ACS, Div. Fuel Chem., Washington, D. C., Sept. 13-17, 1971, Preprints v. 15, No. 2, 1971, 12 pp. Strip mine scars, coal refuse piles, and fly ash dumps are solid wastes resulting from the mining and combustion of coal. The total unreclaimed area resulting from these wastes is over 2 million acres. Disposition of these wastes is obviously a monumental problem. Large-scale field experiments in the reclamation of acid surface-mined coal lands and refuse piles with raw fly ash from bituminous-coal-fired powerplants were conducted at several sites in northern West Virginia. Plots were treated with varying tonnages of fly ash from area powerplants and were planted with a variety of grasses, legumes, trees, and shrubs. Greatest potential for growth and survival under harsh soil conditions was shown by Kentucky 31 fescue, rye and red top grasses, and by birdsfoot trefoil, a legume. Application of fly ash to the acid materials increased the pH to a range tolerable

to plant growth, improved the texture of the soil, increased the water-holding capacity of the resulting mixture, and added trace nutrients to the soil.

OP 14-72. Preparation of Alloys With High- and Low-Melting Point Components by Consumable-Electrode Arc Melting, by R. A. Beall, C. E. Armantrout, E. D. Calvert, and G. S. Root. *Proc. 3d Internat. Symp. on Electrosag and Other Special Melting Technology*, Pittsburgh, Pa., June 8-10, 1971. Sponsored by Am. Soc. for Metals, Pittsburgh Ch., and Mellon Inst. of Carnegie-Mellon Univ., pt. II, 1972, pp. 1-12. Consumable-electrode arc melting of "high-low" alloys can be facilitated by careful consideration of furnace atmosphere, electrode fabrication, and melting parameters. The use of reverse polarity is recommended as beneficial in particularly difficult cases.

OP 15-72. Measuring Gaseous Emissions from an Aircraft, by J. O. Chase and R. W. Hurn. *SAE Progress in Technology*, v. 14, Vehicle Emissions, pt. 3, 1971, pp. 839-845. Aircraft turbine engines generate the same pollutants that are generated by automotive reciprocating engines, but problems of emission measurement differ greatly between the two types of engines. This is a discussion of experimental work done to define more clearly the character of the turbine emissions and to gain experience in sampling and measuring the emissions. An explicit objective was to evaluate the adequacy of available instrumentation and to reveal emission measurement problems unique to the turbine engine.

OP 16-72. Reactivities of Exhaust Aldehydes, by Basil Dimitriadis and T. C. Wesson. *J. Air Pollution Control Assoc.*, v. 22, No. 1, January 1972, pp. 33-38. Experimental data on smog-forming reactivities of aldehydes were obtained in studies using a photoirradiation chamber. The aldehydes were studied both individually and in mixture typical of mixtures that appear in auto exhaust. Results showed reactivities of the aldehydes to differ greatly. As a group, the aldehydes in exhaust are judged to be as reactive as the olefin group. The aldehyde contribution to exhaust reactivity and methods for assessing such contribution are discussed.

OP 17-72. Pipeline Gas From Solid Wastes, by Herman F. Feldmann. *Chem. Eng. Prog.*, v. 67, No. 12, December 1971, pp. 51-52. This paper establishes the experimental and economic feasibility of converting solid wastes to pipeline gas by direct hydrogasification. Solid waste disposal costs are presented as a function of metropolitan population and pipeline gas price.

OP 18-72. Mercury Recovery by Electrooxidation, by T. A. Henrie and R. E. Lindstrom. Supplement volume to *Kirk-Othmer Encyclopedia of Chemical Technology*, ed. by A. Standen. John Wiley & Sons, Inc., New York, 2d ed., 1971, pp. 541-546. Electrolytic oxidation of cinnabar ores for mercury recovery was investigated. Oxidation was accomplished by the electrolysis of ore slurried with brine. Cinnabar was dissolved by oxidizing the insoluble sulfide to soluble mercuric salts. The mercury ion in a brine solution forms a stable tetrachloro complex. Subsequent mercury recovery from leach solutions was readily accomplished by precipitation on zinc.

OP 19-72. Evaporative Losses From Automobiles: Fuel and Fuel System Influences, by R. W. Hurn and B. H. Eccleston. *Proc. Conf. on Air Pollution Control*

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in Transport Engines, Solihull, England, Nov. 9-11, 1971. The Inst. Mech. Eng., Westminster, London, 1971, pp. 286-292. The principal influences bearing upon evaporative hydrocarbon losses from automobiles have been studied in experimental work at the Bartlesville Energy Research Center of the Bureau of Mines. Thirteen fuels and 31 vehicles were used in the study. Hydrocarbon losses, both exhaust and evaporative, were measured during tests that simulated typical city driving with the vehicles. Results show that fuel composition markedly affects both the amount and chemical character of the losses; the amount of loss is also dependent upon ambient temperature and factors related to the vehicle. The manner and degree in which the specific fuel and vehicle factors influence the losses are discussed.

OP 20-72. Comparison of Calculated with Experimental Imbibition Relative Permeability, by Carlton S. Land, SAE Journal, v. 79, No. 12, December 1971, pp. 419-425. The purpose of this report is to give the results of a laboratory study of imbibition relative permeability and to present a comparison of calculated relative permeability with relative permeability from laboratory measurements.

OP 21-72. The Refining and Petrochemical Industries of the United States From 1960 to 1970 (Stati Uniti d'America, "La raffinazione e la petrolchimica dal 1960 al 1970"), by C. M. McKinney. Ch. in Encyclopedia of Petroleum and Natural Gas (Enciclopedia del petrolio e del gas naturale), ed. by Carlo Colombo. Ente Nazionale Idrocarburi, Rome, Italy, v. 8, September 1971, pp. 945-956. Statistical information is presented on the capacity, types, and number of petroleum refineries and petrochemical plants in various areas of the United States during the decade 1960-69.

OP 22-72. Electroslag Melting of Zirconium and Selected Properties of Fabricated Material, by R. H. Nafziger and E. D. Calvert. Proc. 3d Internat. Symp. on Electroslag and Other Special Melting Technology, Pittsburgh, Pa., June 8-10, 1971. Sponsored by Am. Soc. for Metals, Pittsburgh Ch., and Mellon Inst. of Carnegie-Mellon Univ., pt. II, 1972, pp. 253-279. On the basis of this research, electroslag melting of zirconium should offer the same potential advantages and suffer the identical shortcomings that it does when used to melt titanium.

OP 23-72. Fluid-Bed Combustion: Suitability of Coals and Bed Materials, by Richard L. Rice and Neil H. Coates. Power Eng., v. 75, No. 12, December 1971, pp. 36-38. Tests made with eight coals and several bed materials indicate that although carbon utilization is acceptable when fluid-bed combustion is employed, the ash from some coals might be troublesome.

OP 24-72. Applications of Nuclear Quadrupole Resonance Spectrometry to Analytical Chemistry, by Harry D. Schultz. Appl. Spectroscopy, v. 25, No. 3, May-June 1971, pp. 293-303. Since Dehmelt observed the first pure quadrupole resonance signal in 1949, this technique has been developed to a high degree of sophistication for the investigation of bonding and structural features in compounds. Most of the early data were obtained on organic halides. More recently, NQR has been used to research inorganic bonding characteristics such as π and σ bonding in nitrogen compounds and transition metal complexes. The technique has also been extensively developed for mineral

logical research, including recent applications for quantitative analysis of specific minerals in natural ore deposits. The major developments in instrumentation that were made in an effort to solve these problems are discussed.

OP 25-72. 1-Aminopropane, 2-Aminopropane, and 2-Methyl-2-aminopropane: Vibrational Assignments, Conformational Analyses, and Chemical Thermodynamic Properties, by D. W. Scott. J. Chem. Thermodynamics, v. 3, No. 6, 1971, pp. 843-852. Molecular spectra of the three title compounds and of aminoethane, included for comparison, were interpreted by molecular vibrational analyses. Calorimetric entropy values for the three title compounds were used to obtain further understanding of the molecular energetics. Tables of the chemical thermodynamic properties are presented.

OP 26-72. Oxygenates in Exhaust from Simple Hydrocarbon Fuels, by Donald E. Seizinger and Basil Dimitriadis. J. Air Pollution Control Assoc., v. 22, No. 1, January 1972, pp. 47-51. The objective of this study was to identify and estimate the levels of oxygenated hydrocarbon derivatives in exhaust from simple hydrocarbon fuels. This information is expected ultimately to yield estimates of the relative levels of various classes of oxygenates in exhaust from full-boiling-range gasolines.

OP 27-72. Removal of Sulfur and Nitrogen Oxides From Stack Gases by Ammonia, by C. C. Shale, D. G. Simpson, and P. S. Lewis. Chem. Eng. Prog. Symp. Series, v. 67, No. 115, 1971, pp. 52-58. Complete removal of sulfur dioxide and partial removal of nitrogen dioxide impurities from a simulated stack gas mixture were effected in laboratory experiments by vapor-phase reaction with ammonia. A cyclic process utilizing ammonia involves recovery of the chemical reaction products by condensation and regeneration of the feeds by thermal decomposition and reaction of acidic constituents with zinc oxide. Ammonia is separated for recycle, and essentially pure sulfur dioxide is recovered as a byproduct. Ash particles not removed by mechanical separation are trapped in the condensate. A flow diagram for commercial application of this conceptual process is discussed.

OP 28-72. Separation Techniques as a Preliminary Step to the Determination of the Composition of Petroleum, by W. E. Haines and L. R. Snyder. Proc. 8th World Petroleum Cong., Moscow, U.S.S.R., v. 6, June 1971, pp. 223-230. High-boiling fractions of petroleum are complex because of the great structural diversity of the hydrocarbons and because of the large proportion of heteroatomic compounds. This increased complexity makes impractical the traditional isolate-and-identify approach to composition studies. First, defining the total composition in terms of individual compounds, even if possible, would be hopelessly unwieldy. Second, separated fractions will be complex because of the increasing difficulty of making discrete separations. These factors suggest that a system is needed for classifying the large variety of compositional parameters and that an increased proportion of the analytical information must come from an understanding of the separation itself.

A classification system is suggested, which starts with families such as hydrocarbons, thiophenes, and pyrroles and subdivides each family successively according to aromatic rings, cycloalkane rings, alkyl carbons, and individual compounds.

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An increased proportion of the analytical information can come from the separation itself by taking full advantage of modern separation science. Several separation procedures are examined, in terms of the classification system and modern separation science, with respect to their ability to provide useful separations. A preliminary separation scheme developed by American Petroleum Research Project 60 is discussed.

OP 29-72. *The Phenomenology of Explosions*, by Robert W. Van Dolah. Proc. Symp. on Inherent Hazards of Manufacturing and Storage in the Process Industry, Nov. 13-14, 1969, The Hague, Netherlands, 1971, Preprint, 22 pp.; disc., pp. 19-22. Explosions are generalized as the result of a rapid release of pressure without regard for the source of pressure; they may include a confined thermal explosion, a confined deflagration, a detonation, or simply pressurized gas. Each of these sources is examined in broad terms and some basic similarities of the physical processes are suggested.

OP 30-72. *Physicochemical Characteristics of United States Crude Oils (Stati Uniti d'America, "Caratteristiche fisico-chimiche dei grezzi")*, by C. C. Ward. Ch. in Encyclopedia of Petroleum and Natural Gas (Enciclopedia del petrolio e del gas naturale), ed. by Carlo Colombo. Ente Nazionale Idrocarburi, Rome, Italy, v. 8, September 1971, pp. 934-940. This article is a statistical study showing the physical and chemical characteristics of crude oils from 10 major producing areas of the United States.

OP 31-72. *The Outlook for Hydrocarbon Production From Domestic Oil Shale, Coal, and Tar Sands*, by J. Wade Watkins, G. A. Mills, and J. E. Phillips. Proc. Symp. on Current Status of Oil Recovery Research and Development, 71st Nat. Meeting, Am. Inst. Chem. Eng., Dallas, Tex., Feb. 20-23, 1972, Preprint, 25 pp. Among the latent domestic energy resources needed to meet further energy demands are gaseous and liquid fuels from oil shale, coal, and tar sands. Research and development on the production of fluids from oil shale and coal has reached demonstration-plant scale. Despite commercial-scale production of oil from the Athabasca tar sands in Canada, there is at present only a minimal effort in the United States. Available information indicates that there may be some commercial production from all three sources within the next decade.

OP 32-72. *BuMines Data Promise Help in Identifying Petroleum-Spill Sources*, by M. L. Whisman and F. O. Cotton. Oil and Gas J., v. 69, No. 52, Dec. 27, 1971, pp. 111-113. This report presents the vanadium and nickel contents of 186 foreign and domestic crude oils and other properties of potential value for pinpointing the source of oil spills.

OP 33-72. *Selected Properties of Beryllium-Base Alloys Consolidated by Vacuum-Arc Melting*, by C. E. Armantrout and C. O. Sims. J. Vacuum Sci. and Technol., v. 8, No. 6, November-December 1971, pp. VM23-VM28. A preliminary survey of beryllium-base alloys was conducted by melting and testing small button-shaped ingots. Hardness and impact resistance were compared with those of pure beryllium. Structures were examined by microprobe analysis and conventional metallographic techniques. Larger homogeneous ingots of alloys showing promise were then consolidated by consumable electrode arc melting of pressed electrodes of beryllium and the intermetallic compound NiAl. The ingots were formed

into rods of 1.7-cm (5/16-in) diameter at reductions of 9 to 1 by impact extrusion. Evaluation of the rods was by tensile tests, hardness measurements, and microprobe analysis. Tensile properties at room temperature ranged from about 51,000 to 55,000 psi; tensile modulus was $30-50 \times 10^6$ psi; elongation was about 1 percent at room temperature and 2 to 9 percent at 600° C.

OP 34-72. *Evaluation of an In-Situ Retorting Experiment in Green River Oil Shale*, by H. C. Carpenter, E. L. Burwell, and H. W. Sohns. J. Petrol. Technol., v. 24, January 1972, pp. 21-26. The purpose of this evaluation was to obtain information on the amount of oil shale that was affected by underground combustion, the amount of oil that was produced, the amount of oil that could be recovered, the areal extent, thickness, and depth of the combustion zone, and the preferential direction of travel of the zone.

The combustion experiment was conducted in a section of oil shale 20 ft thick located 68 to 88 ft beneath the surface of the ground. Two core holes were drilled before combustion was started, and 18 additional ones were drilled after the experiment was ended 6 weeks later. Areal extent of the zone investigated was approximately 10,000 sq ft. Approximately 30,200 gal of oil was produced, of which 8,000 gal was recovered aboveground.

OP 35-72. *Oil and Gas Wells—Potential Polluters of the Environment?* by A. Gene Collins. J. Water Pollution Control Federation, v. 43, No. 12, December 1971, pp. 2382-2393. Some of the chemicals that are used in the drilling, completion, and production in oil and gas well operations are noxious or poisonous. Poor drilling, completion, and abandonment practices can provide avenues for pollution. Results indicate that additional research is needed to determine what reactions occur in a salaquifer used for disposal, what valuable materials in petroleum-associated wastes can be recycled or recovered, and how petroleum-associated wastes can be permanently disposed.

OP 36-72. *Oil Shale—Recent Developments*, by Glenn L. Cook. Proc. North American Gasoline Tax Conf., Santa Barbara, Calif., Sept. 11, 1968, 42d Ann. Rept., Federation of Tax Administrators, Chicago, Ill., 1971, pp. 12-17. The possibilities for development of the oil-shale resources of Colorado, Wyoming, and Utah are discussed. Considered are the energy needs of the country and the effects of (1) current oil-shale technology and (2) the location of the oil shales and associated minerals on the development of the resource. The current status of private and government supported research is indicated.

OP 37-72. *Thiophenes*, by G. L. Cook, F. P. Miknis, J. C. Morris, and W. E. Haines. Ch. in Chemical Analysis: A Series of Monographs on Analytical Chemistry and Its Applications, ed. by Herschel Karchmer. John Wiley & Sons, Inc., New York, v. 29, pt. 2, 1972, pp. 433-490. The occurrence, toxicity, and uses of thiophenes are discussed in order to provide the setting within which analyses must be performed. Measured and calculated properties of thiophenes are given. Chemical and spectroscopic techniques for analysis of thiophenes are discussed and some applications of the techniques are indicated.

OP 38-72. *Some Mass Spectral and Analytical Aspects of Deuterium Labeling of Straight-Chain Olefins*, by D. G. Earnshaw, F. G. Doolittle, and A. W. Decora. Organic Mass Spectrometry, v. 5, 1971, pp.

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801-815. A calculation method has been developed to enhance the effect of deuterium labeling in the mass spectra of linear vicinal dideuterioalkanes (LVDA). Individual LVDA can be identified from these enhanced spectra. Single carbon-number mixtures of LVD nonanes and LVD decanes have been analyzed successfully using matrices derived from spectra of standards. In addition, enhanced mass spectra have been predicted for all of the LVD heptadecanes and LVD nonadecanes. Matrices have been constructed from the predicted spectra, and preliminary tests of these matrices have been conducted. All identifications and analytical results on the LVDA studied can be used to identify the precursor olefins.

OP 39-72. Enthalpies of Combustion of Nine Organic Nitrogen Compounds Related to Petroleum, by William D. Good. *J. Chem. and Eng. Data*, v. 17, No. 1, 1972, pp. 28-31. Enthalpies of combustion measured by precision oxygen-bomb combustion calorimetry are given for the following nine organic nitrogen compounds selected as key compounds present in or related to petroleum: 4-methylpyridine, piperidine, 2-methylpiperidine, 1-methylpyrrole, 2,5-dimethylpyrrole, indole, 2,3-dimethylindole, 9-methylcarbazole, and isoquinoline. Enthalpies of formation in the condensed phase were derived. Enthalpies of vaporization for five of the compounds were derived from vapor-pressure measurements, and enthalpies of formation in the gaseous state are given for these five compounds.

OP 40-72. Case History—Explosive Fracturing for Well Stimulation, by W. D. Howell and T. J. Clare. *Proc. Spring Meeting Mid-Continent District, Div. Production, API, Wichita, Kans.*, April 8-10, 1970, pp. 58-63. In cooperation with Sun Oil Company, the Bureau of Mines investigated the application of chemical explosive fracturing for stimulating natural gas recovery. Two tests conducted in the shallow Buzzard Sand formation in Osage County, Okla., demonstrated that desensitized nitroglycerin can be safely loaded, displaced, and detonated in hydraulically induced fractures both in open-hole intervals and through casing perforations.

OP 41-72. The Problem of Diesel Engine Exhaust in Underground Mines, by R. W. Hurn. *Proc. Conf. on the Underground Mining Environment*, Univ. of Missouri, Rolla, Mo., Oct. 27-29, 1971, pp. 241-250. The operation of diesel engines in underground areas requires careful attention to space ventilation in order that the concentration of toxic combustion products be held within acceptable limits. These ventilation requirements and the bases for calculating them are reviewed in the paper. A special hazard, the case of an engine rebreathing its own exhaust as a result of inadequate ventilation, is identified and described. This special case is shown to result in progressively accelerated carbon monoxide discharge with possibilities for very rapid development of extremely hazardous CO levels in the vicinity of an inadequately ventilated engine. Overall, the problem of maintaining safe atmospheres is lessened as the amounts of toxic pollutants from engines are reduced. Methods used to approach the minimal pollutant yield—and thereby minimal air poisoning hazard—are also discussed.

OP 42-72. Active Sites for Catalytic Reduction of SO₂ With CO on Alumina, by S. E. Khalafalla and L. A. Haas. *J. Catalysis*, v. 24, No. 1, January 1972, pp. 115-120. The method of catalyst perturbation

has been adapted to identify the active sites for catalytic reduction of SO₂ with CO. Hydroxyl groups associated with the Brønsted acid sites were the active groups in alumina.

OP 43-72. The Role of Metallic Component in the Iron-Alumina Bifunctional Catalyst for Reduction of SO₂ With CO, by S. E. Khalafalla and L. A. Haas. *J. Catalysis*, v. 24, No. 1, January 1972, pp. 121-129. The metal in iron-alumina bifunctional catalyst synergizes the catalytic reduction of SO₂ with CO. Mixed iron and aluminum oxides as present in red bauxite or Surinam red mud were effective in the recovery of sulfur from sulfurous waste gases.

OP 44-72. The Chlorination Kinetics of Zirconium Dioxide in the Presence of Carbon and Carbon Monoxide, by Arne Landsberg, C. L. Hoatson, and F. E. Block. *Metall. Trans.*, v. 3, No. 2, February 1972, pp. 517-523. Chlorination of zirconium dioxide, an important step in the commercial production of reactor grade zirconium metal, has been studied using carbon and carbon monoxide as reductants. Zirconium tetrachloride was produced when the oxide was reacted with chlorine alone above 1,000° C; by introducing carbon the reaction temperatures could be lowered 200° C, and when carbon monoxide was used the reaction temperatures necessary for similar rates were even lower. With carbon monoxide the chlorination of zirconium dioxide is described by two regions differentiated by temperature and the dependence of reaction rate upon chlorine and carbon monoxide pressures.

OP 45-72. Raman Spectra of Coals, by Leo E. Makovsky, Peter Waldstein, and William H. Edwards. *Nature Phys. Sci.*, v. 231, No. 24, June 14, 1971, pp. 154-155. Recently published Raman spectra of carbons suggest that it would be worth applying the Raman technique to the study of coal. This article reports Raman spectra of unpolished chips of coal and indicates some of the problems encountered as well as the sort of information that might be made available by this method.

OP 46-72. Electrowinning of Zirconium from Zirconium Tetrachloride, by G. M. Martinez and D. E. Couch. *Metall. Trans.*, v. 3, February 1972, pp. 571-574. The Bureau of Mines has produced ductile zirconium dendrites at 800° C in an electrolyte containing NaCl-NaF-ZrCl₄. The metal product, in the form of arc-melted buttons, has a hardness ranging from 130 to 170 Bhn and can be cold rolled into 15-ml-thick strips without intermediate annealing.

OP 47-72. Q-Switched Laser-Induced Reactions of Thiophene With Oxygen, by F. P. Miknis and J. P. Biscar. *High Temperature Sci.*, v. 3, No. 6, November 1971, pp. 478-480. Q-switched, laser-induced reactions of thiophene with oxygen were studied as a function of oxygen pressure in the range of 0 to 500 torr. The reaction products identified were CO₂, SO₂, H₂S, H₂O, C₂H₂, and COS. The product distribution varied with oxygen partial pressure. All products, except SO₂ reached maximum concentrations at 200 torr of O₂, whereas SO₂ reached a minimum at this pressure. No explanation for the behavior of SO₂ is given. A possible explanation for the small concentration of C₂H₂ detected in the reaction mixture was advanced from the standpoint of elemental plasma reactions.

OP 48-72. World Economics of Nickel, by Horace T. Reno. *Skills' Min. Rev.*, v. 61, No. 8,

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Feb. 19, 1972, pp. 10-13. This article reviews the nickel-producing industry of the world and the 1971 nickel supply-demand patterns. Short and long-term supply demands are forecast.

OP 49-72. Tetraethyllead. Vibrational Assignment and Chemical Thermodynamic Properties, by D. W. Scott. *J. Chem. Thermodynamics*, v. 4, No. 1, 1972, pp. 99-104. Vapor-state chemical thermodynamic properties were calculated for tetraethyllead. To that end, a molecular-vibrational analysis was used to estimate the unobserved C—Pb—C bending fundamentals, and a treatment of vapor-pressure data by currently available methods was used to estimate the enthalpy and entropy of vaporization.

OP 50-72. The Fuel and Energy Export Potential of the U.S.S.R. Through 1980, by V. V. Strishkov, George Markon, and Zane E. Murphy. *Combustion*, v. 48, No. 7, January 1972, pp. 6-18. The Soviet Union, by virtue of its importance as a major world power, as a large industrial state, and as a major energy producer and consumer, has been a subject of continued interest to specialists in the industrial and mining communities of the world. Despite a comparative wealth of literature on fuels and energy, however, there has been little reliable reporting on the future prospects or export potential of the energy industries. Of the mass of data reported by the Soviet Union on energy and fuels, the trade journals have adequately covered only the more general information.

If the average reader accepts some of this general reporting at face value, he may arrive at some misleading conclusions. For example, he may equate with standard Western reporting the Soviet data which include large quantities of lower rank fuels in gross coal production figures and estimates of refinery product yields. However, more accurate data are available in more obscure Soviet sources. This review is based solely on available Soviet reporting on energy and should provide the basis for an estimate of the probably future course of Soviet fuel and energy exports.

OP 51-72. Effect of Overburden Pressure and Water Solution on Gas Permeability of Tight Sandstone Cores, by Rex D. Thomas and Don C. Ward. *J. Petrol. Technol.*, v. 24, February 1972, pp. 120-124. Research conducted to determine the potential of nuclear explosions to stimulate gas production verifies that the gas permeability of tight sandstone cores is markedly decreased with increasing overburden pressure. Water saturation also reduces the gas permeability by a large amount. The relative permeability, however, does not change significantly with overburden pressure.

OP 52-72. Pressures and Consumable-Electrode Arcs, by F. W. Wood and E. D. Calvert. *J. Vacuum Sci. and Technol.*, v. 8, No. 6, November-December 1971, pp. VM5-VM12. An investigation of arc zone pressure during consumable-electrode vacuum-arc remelting (CEVAR) experiments has shown that pressure differences and gradients within furnaces are functions of pressure itself, electrode composition, and the degree of arc-zone confinement. There is evidence also that some previously puzzling contrasts in arc-furnace behavior may be explainable on the basis that two pressure dependent forms of electrical discharge operate with distinct potentials. The lower voltage form tends to become unstable at pressures < 0.5 torr and behaves best at pressures > 1 torr. The higher voltage form seems

to be most stable at pressures < 0.1 torr. For continuous operation and maximum versatility, a CEVAR furnace should be able to accommodate both discharge forms by providing for variability of vacuum conditions.

OP 53-72. An Evaluation of Dust Sampling Membrane Filters for Use in the Scanning Electron Microscope, by P. B. DeNee and R. L. Stein. *Powder Technol.*, v. 5, 1971-72, pp. 201-204. One of the established goals of the Bureau of Mines is the development of engineering procedures for the control of respirable dust and thereby the prevention of coal pneumoconiosis in the shortest possible time. This article evaluates the commonly used dust sampling membrane filters for use in the scanning electron microscope (SEM).

OP 54-72. Beneficiation of High-Clay Potash Ores by Flotation, by J. S. Browning and A. B. Johnson. *Trans. Soc. Min. Eng., AIME*, v. 252, March 1972, pp. 50-52. The Bureau of Mines has developed new and improved physical beneficiation techniques for economically recovering potash minerals from high-clay and low-grade ore from the Permian Basin of New Mexico. With the depletion of the high-grade ores a need for changes in industry's standard methods of recovery is a must. Technology may be improved in the beneficiation of the ore prior to mineral flotation and in brine clarification from the desliming phase to effect a reduction of losses of fine potash and brine in the disposal of the clay slimes. This report summarizes the results of these tests and demonstrates the feasibility of producing products that meet the requirements of the agriculture market, namely, 95 percent KCl equivalent to 60 percent K_2O with recoveries ranging between 80 and 90 percent.

OP 55-72. Inductoslag Melting of Titanium Scrap and Sponge, by P. G. Clites and R. A. Beall. *Light Metals 1972*, ed. by W. C. Rotsell. *Proc. AIME Ann. Meeting*, San Francisco, Calif., Feb. 20-24, 1972, pp. 325-351. This report describes inductoslag melting, an induction melting process which utilizes a split, water-cooled copper crucible and a cover of molten calcium fluoride slag. Equipment and techniques for melting ingots as large as 5 inches in diameter and 45 inches long are described. A comparative evaluation is made of ingots prepared from vacuum-distilled titanium sponge by vacuum arc melting and by inductoslag melting. The main advantage of inductoslag melting is that loose titanium sponge or scrap can be melted without fabricating a consumable electrode. While this process has some disadvantages compared to vacuum arc melting, sound ingots can be prepared by a single melt of clean titanium alloy scrap or vacuum-distilled titanium sponge. Ingots prepared by inductoslag melting have been forged and rolled to plate without machining the side walls.

OP 56-72. Recycling of Automotive Scrap, by Karl C. Dean, C. J. Chindgren, and E. G. Valdez. *Scrap Age*, v. 29, No. 2, February 1972, pp. 151, 155, 156, 158, 160, and 163. The potential for economic recycling of automobiles has been increased by recent research into the two principal automotive scrap handling procedures of (1) shredding with byproduct recovery from nonmagnetic rejects and (2) incineration, hand dismantling, and baling or shredding. Development of alternative procedures of sink-float and water classification for concentrating the nonferrous metal contents of the nonmagnetic reject

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products could benefit the economics of shredder operation. The use of cryogenics for separating brittle die cast from malleable aluminum and copper and for separating insulation from copper wire also appears promising for enhancing the recycling of shredded automotive materials. The economics of incineration operation are made more attractive by demonstrating the feasibility of burning mashed cars, thus increasing the capacity of the test incinerator from 50 to over 80 cars per day. An evaluation of alternate procedures for recovering the values in generators and starters shows mechanically assisted hand dismantling is preferable to salt sweating, ammoniacal leaching, or cryogenic techniques.

OP 57-72. Effects of Hydrocarbon and Nitrogen Oxides on Photochemical Smog Formation, by Basil Dimitriadis. *Environmental Sci. and Technol.*, v. 6, No. 3, March 1972, pp. 253-260. The role of hydrocarbon (HC) and nitrogen oxides (NO_x) in photochemical smog formation was investigated. Samples of automobile exhaust with varying HC and NO_x levels were irradiated in a smog chamber under conditions that resulted in levels of smog manifestations similar to those observed in the atmosphere. HC levels ranged from 0.3 to 5.0 ppm C, and NO_x levels ranged from 0.08 to 1.4 ppm. Photooxidation of nitric oxide (NO) and formations of oxidant, peroxyacetyl nitrate (PAN), formaldehyde (HCHO), and nitrogen dioxide (NO_2) were used as smog manifestations. Results showed that except for the NO_2 yield, all smog manifestations were intensified by increasing HC; NO_x inhibited the oxidant, PAN, and HCHO yields but promoted the rate of NO oxidation and the NO_2 yield. By use of these data, it was estimated that to achieve an air quality equivalent to the current California standards for oxidant and NO_2 , NO_x should be less than 0.33 ppm and HC less than $2.5 \times (\text{NO}_x)$.

OP 58-72. Hydrometallurgical Treatment of Sulfide Ores for Elimination of SO_2 Emissions by Smelters, by T. A. Henrie and R. F. Lindstrom. Ch. 9 in *Electrochemistry of Cleaner Environments*, ed. by J. O'M. Bockris. Plenum Press, New York, 1972, pp. 281-291. An electrooxidation process, which involves electrolysis of ore-brine slurry, was shown to result in favorable metal extraction from gold, silver, antimony, mercury, and molybdenum source materials.

OP 59-72. Analysis of Zinc Smelter Condensers by Color Microprobe Scanning, by John E. Kelley, Henry M. Harris, and Peter A. Romans. *Metallography*, v. 5, No. 1, February 1972, pp. 59-68. Two electron microprobe techniques were used to study factors that contribute to the failures of fireclay condensers in a horizontal zinc-reduction smelter. One method involved studying photographs of oscilloscope displays of X-ray intensity profiles of individual elements. This enabled determination of the elements present in the interface area between fireclay condensers and a hard adherent deposit which results from reaction with zinc vapors. The major elements were found, as well as their locations and extent of interaction with each other. Another electron microprobe technique, color composite scanning, was used to identify properly the locations of compounds resulting from reactions of elements at the fireclay-deposit interface. X-ray diffraction examination verified the electron microprobe findings. The major elements found in the interface area were aluminum, silicon, zinc, and chlorine. The majority of

the hard adherent coating was found to be zinc oxide and a zinc chloride compound with some metallic zinc.

OP 60-72. Positive Ion Species and Degree of Dissociation of SO_2 in dc Discharges of He- SO_2 Mixtures, by D. G. Kuehn and L. M. Chanin. *J. Appl. Phys.*, v. 43, No. 2, February 1972, pp. 339-344. Studies of the ionic and neutral gas components of dc glow discharges in He- SO_2 mixtures indicated that up to 80 percent of the SO_2 dissociated. The primary dissociation product was SO.

OP 61-72. Ignition and Incendivity of Laser Irradiated Single Micron-Size Magnesium Particles, by I. Liebman, J. Corry, and H. E. Perlee. *Combustion Sci. and Technol.*, v. 5, 1972, pp. 21-30. The ignition of single magnesium particles (28 to 120 micron diameter) suspended in cold oxidant atmospheres by means of an electrostatic levitation device, and the incendivity of these particles when suspended in a stoichiometric methane-air mixture, were investigated using pulsed laser radiation to heat the particles. High-speed Schlieren and direct photographic techniques were used in the study. The critical radiant power density required for particle ignition was found to increase with particle size. Approximately equal radiant power densities were required for ignition of identical particles suspended in air and pure oxygen, although an increase in radiant power density was necessary for particle ignition in a helium-20 percent oxygen mixture. Results indicate that particle ignition occurred in the magnesium vapor shroud following surface vaporization. The incendivity experiments indicate that the critical radiant power densities necessary for the particle to ignite methane-air mixtures increases with decreasing particle diameter. Incendivity depends on the amount and rate of energy released by the irradiated particle. The incendive mechanism is believed to constitute a three-stage process.

OP 62-72. Classification of Coals According to Degree of Coalification by Reflectance of the Vitrinite Component, by J. T. McCartney and M. Teichmüller. *Fuel*, v. 51, January 1972, pp. 64-68. The utility of reflectance of the vitrinite component of coals as a criterion of degree of coalification has been investigated. Present standard systems for classification of coals by rank are intended mainly as guides for utilization behavior, and there is a need for more widespread acceptance and usage of an objective rank criterion based more firmly on physical/chemical characteristics of a coal. The relations of reflectance of vitrinite to other commonly used or proposed rank parameters have been studied, using voluminous data supplied by United States and European laboratories. These relations were found to be excellent for high-rank bituminous coals, good for anthracitic coals, fair for low-rank bituminous coals, and rather poor for subbituminous coals, lignites, and brown coals. The data for the last category are least numerous, and work is continuing on their reflectance-rank characteristics, especially for the International Commission on Coal Petrology. The reflectance ranges established for present rank categories are listed and it is proposed that they be included in standard classification systems as supplementary criteria of rank.

OP 63-72. Production of Magnetic Superconcentrates by Cationic Flotation, by R. B. Tippin. *Trans. Soc. Min. Eng., AIME*, v. 252, March 1972, pp. 53-61. Laboratory and pilot plant studies showed that supergrade iron ore concentrates (containing less

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than 2 percent SiO_2) can be made from standard grade magnetic iron ore products by cationic silica flotation. Continuous tests were run using various flowsheet arrangements, whereby (1) super and standard grade products were made simultaneously or (2) only a superconcentrate was produced. After a caustic scrub and desliming pretreatment, the silica in a magnetic taconite concentrate was reduced to 1.8 percent SiO_2 by amine flotation. Approximately 75 percent of the iron was recovered in the single flotation stage, and by additional beneficiation 95 percent of the total iron was ultimately recovered.

OP 64-72. Choosing the Proper Borehole Size for Bench Blasting, by Richard A. Dick and James J. Olson. *Mining Eng.*, v. 24, No. 3, March 1972, pp. 41-45. Factors influencing the choice of borehole diameters are discussed, including geology, neighbors, operational factors, and type of blasting agent. The effect of borehole diameter on cost distribution is described.

OP 65-72. Alkaline-Earth-Fluoride- LaF_3 Systems With Implications for Electroslag Melting, by R. H. Nafziger and N. Riazance. *J. Am. Ceramic Soc.*, v. 55, No. 3, March 1972, pp. 130-134. Liquidus and solidus curves in the systems $\text{CaF}_2\text{-LaF}_3$, $\text{SrF}_2\text{-LaF}_3$, $\text{BaF}_2\text{-LaF}_3$, and $\text{MgF}_2\text{-LaF}_3$ under $\frac{1}{3}$ atmosphere helium pressure were determined by thermal analysis as an aid in the selection of suitable fluxes for electroslag melting of reactive metals. The systems $\text{CaF}_2\text{-LaF}_3$, $\text{SrF}_2\text{-LaF}_3$, and $\text{BaF}_2\text{-LaF}_3$ each contain (1) one eutectic, (2) no intermediate phases, and (3) two solid solutions whose lattice parameters vary linearly with composition. The liquidus curves in the systems $\text{SrF}_2\text{-LaF}_3$ and $\text{BaF}_2\text{-LaF}_3$ exhibit maxima. The system $\text{MgF}_2\text{-LaF}_3$ is of the simple eutectic type with no detectable terminal solid solutions. The smallest temperature interval observed between a fluoride-flux liquidus and the melting point of Ti occurs at the dystectic composition in the system $\text{SrF}_2\text{-LaF}_3$. Differences in density between metal and flux are more favorable in the system $\text{BaF}_2\text{-LaF}_3$ than in pure LaF_3 . These observations suggest potential advantages of using fluxes from the systems studied for electroslag melting of reactive metals.

OP 66-72. Rapid Excavation in Hard Rock: A State-of-the-Art Report, by William E. Bruce and Roger J. Morrell. *Proc., Deep Tunnels in Hard Rock—A Solution to Combined Sewer Overflow and Flooding Problems*. Environmental Protection Agency, 1970, pp. 187-219. This paper describes the evolution of present day tunnel-boring techniques. Emphasis is directed toward selected cases from the past decade which are discussed in some detail. The data presented has, in many cases, been generated by Bureau of Mines personnel during on-site studies of the particular job. Wherever feasible, samples of the rocks being bored were returned to the Twin Cities Mining Research Center for determination of the physical properties. This paper presents the significant problems and accomplishments for various actual operations. Wherever possible, it presents physical characteristics of the rock encountered to aid the reader in evaluating rock hardness.

OP 67-72. Effect of Temperature Variation on Internal Friction in Rocks, by F. N. Kissell. *J. Geophys. Res.*, v. 77, No. 8, Mar. 10, 1972, pp. 1420-1423. The effect of temperature changes ranging from -200° to $+600^\circ\text{C}$ on the internal friction of rocks was measured by Forster's method. Most, but not all, rocks showed what appeared to be a prominent loss peak near room

temperature. This peak was associated with the presence of tiny quantities of moisture in the rock. If the rock was heated sufficiently and allowed to cool, the peak was reduced or eliminated.

OP 68-72. Some Applications of Mine-Structure Analysis to Mine Safety Problems, by Louis A. Panek. *Proc. Conf. Underground Mining Environment*, Rolla, Mo., October 1971, Mar. 1, 1972, pp. 311-326. Current Bureau of Mines research projects on the ground control aspects of mine safety are interpreted as parts of a coherent program in which mine structure analysis provides the unifying concepts.

OP 69-72. The Importance of Temperature Approach in Heat Exchangers, by Yong Jai Yim, Paul Wellman, and Sidney Katell. *Chemtech*, v. 2, No. 3, March 1972, pp. 167-172. The optimization of a heat transfer system in the design of an energy intensive process, coal gasification, is exemplified in this article. Capital investment, steam production, cooling water requirements, and power consumption for three temperature approaches are discussed.

OP 70-72. Gasoline Via the Fischer-Tropsch Reaction Using the Hot-Gas Recycle System, by J. J. Elliott, W. P. Haynes, and A. J. Forney. 163d National Meeting ACS, Boston, Mass., Apr. 10-14, 1972, Preprints, v. 16, No. 1, pp. 44-50. A unique catalyst system of low-pressure drop sheet steel grids coated with a powdered magnetite catalyst was tested for the production of gasoline via the Fischer-Tropsch synthesis.

OP 71-72. Experience With Methanation Catalysts, by W. P. Haynes, J. J. Elliott, and A. J. Forney. 163d National Meeting ACS, Boston, Mass., Apr. 10-14, 1972, Preprints, v. 16, No. 2, pp. 47-63. Preparation and performance of various methanation catalysts and the performance of various types of methanation reactors are described. Scale of investigations range from laboratory to pilot plant.

OP 72-72. The Production of Methane by the Anaerobic Decomposition of Garbage and Waste Materials, by Glenn E. Johnson, L. M. Kunka, W. A. Decker, and A. J. Forney. 163d National Meeting ACS, Boston, Mass., Apr. 10-14, 1972, Preprints, v. 16, No. 4, pp. 70-78. Much of today's solid waste could be converted to methane by anaerobic digestion. Batch tests have been made with garbage, paper, wood, bovine wastes, grass, coal, and chars. Yields of methane of up to 4 cubic feet per pound of garbage have been obtained.

OP 73-72. Rapid Technique for Dissolution of Nitrides, by Dean H. Bollman. *Anal. Chem.*, v. 44, No. 4, April 1972, p. 887. Tin(II)-strong phosphoric acid reagent was found to be a remarkable medium for dissolving many transition metal nitrides without loss of nitrogen. Furthermore, the decomposition of the nitrides takes place within a few minutes. The reagent will work with TiN , ZrN , HfN , UN , AlN , and niobium oxynitride. Vanadium nitrides and boron nitride would not completely decompose. Because of lack of a sample, analysis of silicon nitride was not attempted.

OP 74-72. Oil Shale—An Impending Energy Source, by Glenn L. Cook. *Northern Plains Sec. Soc. Petrol. Eng., AIME, 4th Biennial Symp.*, Omaha, Neb., May 18-19, 1972, Preprint SPE 3861, 7 pp. The characteristics of the Green River oil-shale deposits are briefly reviewed. Recovery techniques for the energy potential are also reviewed. A prototype lease program of the Interior Department is described. The conclusion is reached that commercial development of oil shale in the next few years should be viewed optimistically.

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OP 75-72. An Evaluation of a Citrate Absorption Process for the Removal of SO₂ From Flue Gas, by Sidney Katell and William C. Morel. Session on Stack Gas—Tail Gas Desulfurization. Div. Ref., API, 37th Midyear Meeting, New York, May 9, 1972, Preprint 15-72, 13 pp. An economic evaluation for the citrate absorption system for the removal of sulfur dioxide from flue gas for a 1,000-megawatt powerplant utilizing a 3-percent-sulfur coal and a 4-percent-sulfur Kuwait residual oil indicates a capital investment of \$26,280,000 and \$25,380,000 for the coal and oil, respectively. Removal cost, after credit, is 1.126 and 1.094 mills per kilowatt hour for the coal and oil, respectively. The system was originally developed at the Salt Lake City Metallurgy Research Center for use in the copper industry.

OP 76-72. Computerized Discounted Cash Flow Analysis, by Paul Wellman and C. E. Jackson. Cost Eng., v. 17, No. 2, April 1972, pp. 4-11. Profitability of an industrial venture can be determined by any of several acceptable methods. One of the most widely used methods is the discounted cash flow rate of return. The program included performs the calculations with debt from 0 to 40 percent, and with interest rates of 6, 7, 8, and 9 percent on debt capital.

OP 77-72. Analytical Solution for the X-Ray Absorption Factor for Cylinders in Special Cases, by C. W. Dwiggins, Jr. Acta Cryst., v. A28, part 2, March 1972, p. 219. The equation for the absorption factor at Bragg angles of 0 and 90° is integrable, resulting in simple equations that are functions of well-known higher transcendental functions. Numerical results are easily obtained, and a comparison with those obtained using numerical integration is made.

OP 78-72. Calculations of the Intensity of Secondary Scattering of X-Rays by Noncrystalline Materials. II. Moving Sample Transmission Geometry, by C. W. Dwiggins, Jr. Acta Cryst., v. A28, part 2, March 1972, pp. 158-163. Equations that require numerical integration over only one variable were derived for calculating the intensity of secondary scattering of X-rays for noncrystalline samples in the case of a transmission geometry, in which the sample is rotated so that the incident and diffracted beams are always at equal angles with respect to a normal to the faces of the slab of sample. Tables are given that allow the intensity ratios of secondary-to-primary scattering to be determined without making lengthy calculations.

OP 79-72. Recycling of Steelmaking Dusts, by Paul G. Barnard, Aaron G. Starliper, Walde-mar M. Dressel, and Morris M. Fine. Proc. 3d Mineral Waste Utilization Symp. Sponsored by U.S. Bureau of Mines and IIT Research Institute, Chicago, Ill., Mar. 14-16, 1972, pp. 63-68. Methods are described for upgrading steel furnace dusts to produce high-iron pellets for recycling. These dusts contain impurities such as zinc, lead, and copper which reflect the character of the feed to the furnace and the operation of the furnaces. Treatment procedures described include (1) pelletization and reduction roasting to remove lead and zinc, (2) sulfation with sulfuric acid or SO₂ followed by leaching to remove copper and zinc and pelletization and reduction to remove lead and metallize the iron, (3) pelletization of mixtures of dusts containing carbon, zinc, and lead followed by roasting to eliminate said elements, and (4) pelletization and roasting of

mixtures of blast furnace dusts, basic oxygen furnace dusts, and mill scale.

OP 80-72. Copper-Zinc Removal From Scrap Iron Oxide by Pelletization-Chloridization, by C. B. Daelenbach and W. M. Mahan. Proc. 3d Mineral Waste Utilization Symp. Sponsored by U.S. Bureau of Mines and IIT Research Institute, Chicago, Ill., Mar. 14-16, 1972, pp. 113-120. Selective removal of metal contaminants from scrap iron oxide products was accomplished using a combined pelletization-chloridization process. Contaminants form volatile chloride compounds during the pellet-induration cycle. Pellet copper, zinc and lead levels, initially 0.43, 1.44 and 0.10 percent, were reduced to 0.08, 0.13 and 0.001 percent, respectively, while undergoing induration.

OP 81-72. Hydraulic Mining ... in the U.S.A., by J. N. Frank, D. E. Fogelson, and J. W. Chester. Proc. 1st Internat. Symp. on Jet Cutting Technology. Hydromechanics Research Assoc., Cranfield, Bedford, England, 1972, Paper E-4, pp. E4-45 through E4-60. This paper presents a brief review of the history of hydraulic mining in the United States and contains a review of Government, industry, institute, and university hydraulic research.

OP 82-72. Synthane—A Candidate for Success, by Philip A. Gallo. Gas World, Apr. 22, 1972, pp. 334-335. Several coal-to-gas processes are now being studied in the United States. For each of these processes there are potential advantages that justify the expenditure of manpower and funds. However, because of the design simplicity, the Synthane process is the likely candidate for commercial success.

OP 83-72. Industrial Demand for Sulfur and Alternative Inputs, by Olman Hee. Proc. Council of Economics, AIME, 1972, pp. 103-112. Historical time series show that industrial uses for sulfur exhibit diverse trends and significant fluctuations. A plausible reason for this behavior of industrial demand is the presence of alternative inputs used to replace sulfur. On the other hand, sulfur may replace existing inputs used by respective industries because of a more favorable relative price or because of its superior qualities. This study makes use of regression analysis to examine direct demand and cross-demand for sulfur and alternative inputs. The major industries that currently choose between sulfur and alternative inputs include the following: Chemicals, inorganic pigments, pulping processes, nonferrous ores leaching, and iron and steel pickling. Some of these industries show an increasing demand for sulfur while others show a declining demand. By examining and evaluating direct price elasticities and cross price elasticities, degree of substitution can be detected. Proper evaluation of the statistical results lends background support for action programs for the sulfur industry to promote uses where alternative inputs are at an economic disadvantage, and withdrawal from those uses where alternative inputs have a pronounced economic advantage.

OP 84-72. Resource Aspects of PVC in Urban Waste, by James B. Stephenson, James L. Holman, and James W. Jensen. Proc. 3d Mineral Waste Utili-

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zation Symp. Sponsored by U.S. Bureau of Mines and IIT Research Institute, Chicago, Ill., March 14-16, 1972, pp. 429-437. In conjunction with its research program on separation, recovery, and recycling of metal, mineral, and energy-based materials in urban refuse, the Bureau of Mines is developing means to reuse and recycle plastics discarded in raw municipal waste. Experimental work on plastic waste from a community collection has produced some guidelines for systematic methods of processing, including air classification, cleaning, and separation into types. The polyvinyl chloride (PVC) fraction—as well as the other plastic fractions—can be refabricated. Incineration is a practical means of disposal for those plastics that do not contain chlorine. Thermal decomposition of PVC has yielded four products: (1) Hydrochloric acid, (2) char, (3) liquid condensate, and (4) a combustible offgas. The hydrochloric acid can be utilized in chemical processing and the other three products could be used as fuel, with heat contents ranging from 12,000 to 20,000 Btu per pound.

OP 85-72. Accelerated Oxidation of Ferrous Materials in CO₂/CO Gas Mixtures, by S. E. Khalafalla and S. L. Payne. *Materials Sci. and Eng.*, v. 9, June 1972, pp. 313-321. Methods are devised to accelerate the slow oxidation of scrap steel by surface pretreatment in an aqueous solution or suspension of sodium vanadate, molybdate, plumbite, bismuthite, or antimonite.

OP 86-72. Pneumatic Transportation of Mine Run Coal Underground, by James L. Konchesky and Thomas J. George. *Min. Cong. J.*, v. 57, No. 12, December 1971, pp. 42-46. A practical, pneumatic system for moving coal from the mine face to surface might increase continuous miner operating time and also reduce the incidence of coal mining accidents. The U.S. Bureau of Mines is developing information in pilot-plant experiments that can be used to determine system feasibility.

OP 87-72. Steel Imports: A Case of Differential Market Penetration, by Richard J. Leary. *Proc. Council of Economics, AIME*, 1972, pp. 139-146. The growth of imported steel products in the U.S. market since 1957 is examined. A strong pattern of product-by-product market invasion is demonstrated. Domestic producers of products subjected to concentrated competition from imports are shown to have suffered much larger losses of market shares than the industry as an aggregate, and these differential losses of market occurred earlier in time. It is pointed out that the economic and social impacts of steel product imports are experienced at the plant level, where the loss of production occurs. Only aggregate statistics are available, however. Need exists for better input of economic information from plants and for a better understanding of how to relate plant and aggregate data to national statistics for policymaking. Better timing of action and more effective remedies should result.

OP 88-72. Blast Furnace Fuel Injection in the United States—State of the Art, by N. B. Melcher and W. M. Mahan. *Proc. Symp. on Blast Furnace Injection*. Illawarra Branch of The Australasian Institute of Mining & Metallurgy, Wollongong University College, Wollongong, Australia, May 1972,

pp. 2-1 through 2-8, 3-10. Successful use of fuel injection occurred at the Bureau of Mines' experimental blast furnace at Bruceton, Pa. in 1958-59. Commercial acceptance followed rapidly with two commercial furnaces practicing fuel injection in 1960 and 89 in 1965. Tables include total oxygen and fuels injected into U.S. blast furnaces and U.S. furnaces using fuel injection.

OP 89-72. High Temperature Laser-Induced Reactions Between Sulfur and Hydrocarbons, by F. P. Miknis and J. P. Biscar. *High Temperature Sci.*, v. 4, No. 1, January 1972, pp. 48-50. High-temperature, laser-induced chemical reactions between solid sulfur and hydrocarbon gases (ethane, ethylene, allene, propylene, and *n*-butane) are reported. The results suggest that a carbon atom insertion reaction is involved in the formation of the major product, CS₂. A possible mechanism for the reaction is proposed.

OP 90-72. Development of a Vortex Incinerator With Continuous Feed, by C. H. Schwartz, A. A. Orning, R. B. Snedden, J. J. Demeter, and D. Bienstock. *Proc. 1972 Nat. Incinerator Conf.*, June 4-7, 1972, pp. 145-154. Refuse incineration was studied in a pilot-scale vortex incinerator. Feed of secondary air to the center of the vortex eliminated a tarry particulate emission.

OP 91-72. Thermal Expansion Measurements of Simulated Lunar Rocks, by Russell E. Griffin and Sam G. Demou. *Proc. 3d Am. Inst. Phys. Conf., Symp. on Thermal Expansion*, Corning, N. Y., Oct. 27-29, 1971, 1972, pp. 302-311. Thermal expansion measurements were made on 14 kinds of rock over a temperature range of approximately -140° to 950° C. Chosen as likely to be representative of those to be found on the lunar surface, these rocks include a broad range of physical and chemical compositions from the large areas of volcanism in Oregon and northern California, and two nonvolcanic types. Analysis was performed on the expansion data that produced a direct plot of instantaneous coefficient of thermal expansion as a function of temperature. The data presented will add to the basic scientific and engineering knowledge needed to utilize extraterrestrial mineral resources for support of future space missions.

OP 92-72. Enthalpies of Combustion of 18 Organic Sulfur Compounds Related to Petroleum, by W. D. Good. *J. Chem. & Eng. Data*, v. 17, No. 2, April 1972, pp. 158-162. Enthalpies of combustion measured by rotating-bomb combustion calorimetry are given for 18 organic sulfur compounds including thiols, sulfides, thiophenes, and a disulfide selected for a comprehensive study of their thermodynamic properties. Values of the enthalpy of formation of the condensed phase are derived. Enthalpies of vaporization and enthalpies of formation in the gaseous state are derived for 15 of the compounds. Values of enthalpy of atomization are compared with values predicted by a correlation procedure.

OP 93-72. Sampling in Mines and/or in Explosive Atmospheres, by Murray Jacobson. *Air Sampling Instruments for Evaluation of Atmospheric Contaminants*. American Conference of Governmental Industrial Hygienists, 4th ed., 1972, pp. D-1 to D-2. Environmental sampling in areas where flammable materials are present necessitates the use of intrinsically safe or explosion-proof electrically operated devices. The designation of the classification of the hazard, the provisions for operation, and

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the agencies responsible for approving the equipment are described.

OP 94-72. Determination of Compound Types in Complex Mixtures Using Subtraction and Gas Chromatographic Readout, by R. E. Poulson, H. B. Jensen, J. J. Duvall, F. L. Harris, and J. R. Morandi. *Anal. Instr.*, v. 10, May 1972, pp. 193-201. A method for giving rapid, reliable, compound-type analyses on distillates from crude oils has been discussed and compared with a classical method for tar acids, tar bases, aromatics, olefins, and paraffins. The new method, using gas chromatographic readout before and after the subtraction of a compound type from a distillate with an internal standard, can be performed on very small samples or dilute solutions. In addition, the new method gives absolute values for saturates, olefins, and aromatics plus polars if polars are defined as those materials staying on silica gel with the aromatics when a nonpolar eluent is used. The determination of tar acids and tar bases has no effect on the saturate and olefin values, only on the aromatic value. Because the extractive determinations using gas chromatographic readout produce results having greater reliability and precision than older methods, the gas chromatographic readout method is useful for compound-type characterization work on polar materials. By comparison of results obtained using a variety of polar-subtractive reagents with those results available from nonaqueous titrimetry or other independent methods, new information on the chemical nature of polar materials can be obtained.

OP 95-72. Separation of High-Boiling Petroleum Distillates Using Gradient Elution Through Dual-Packed (Silica Gel-Alumina Gel) Adsorption Columns, by D. E. Hirsch, R. L. Hopkins, H. J. Coleman, F. O. Cotton, and C. J. Thompson. *Anal. Chem.*, v. 44, No. 6, May 1972, pp. 915-919. The Bureau of Mines has developed a chromatographic separation procedure using a single dual-packed adsorption column containing silica gel and alumina that will separate high-boiling petroleum distillates into four concentrates: saturates, monoaromatics, diaromatics, and polyaromatics-polar. Spectral, adsorption, and radio-tracer data indicate that the concentrates produced are predominantly as labeled. Subdividing the aromatics into major types greatly simplifies subsequent separation and characterization studies.

OP 96-72. Conductivity Cell Apparatus for Continuous Measurement of Sulfur Dioxide Concentrations Between 40 ppm and 1 Per Cent, by H. Richard Beard. *Anal. Chem.*, v. 44, No. 6, May 1972, p. 1104. Sulfur dioxide, at concentrations of 40 ppm to 1 percent in the off gas of an SO₂ removal system, must be monitored continuously in the presence of normal atmospheric gases and combustion products. An inexpensive and reliable conductivity cell using H₂O₂ as the absorbing reagent is used to measure SO₂ concentrations at less cost to the user than commercial instruments currently available. The instrument and systems for controlling the liquid and gas flows to obtain reproducible and reliable measurements of SO₂ concentrations are described.

OP 97-72. A Note on the Mineralization of Lignite, by W. W. Fowkes. *Fuel* (London), v. 51, No. 2, April 1972, pp. 165-166. The recently reported presence of [sodium] nitrate (and alkaline earth nitrates) in lignite and in the low-temperature ash produced by oxidizing lignite in a microwave-excited

plasma of atomic oxygen has elicited inquiries to the Bureau of Mines regarding such occurrence and the feasibility of recovering the nitrates. The nature of the mineral content of lignite has always been in some degree a concern of the Bureau, and more particularly in the past 8 years in relation to boiler-fouling problems. Even more recently, the mineralizing study has been extended to include coals of the Western United States other than lignites. A very extensive survey of mineral matter is an on-going Bureau project which contributes to studies of fouling characteristics and of beneficiation of the coal. This article presents the recent work being done on the mineralization of coal at the Bureau of Mines Laboratory in Grand Forks, N.Dak.

OP 98-72. Determination of Mercury in Low-Grade Ores, by H. G. Henry, K. R. Stever, W. L. Barry, and H. H. Heady. *Appl. Spectroscopy*, v. 26, No. 2, June 1972, pp. 288-293. Two new rapid and accurate methods are presented for determining mercury in low-grade ores and tailings: (1) A combustion-atomic absorption technique is described wherein a small sample of finely pulverized ore is heated to about 700° C, and the vaporized Hg is detected by atomic absorption. This method is suitable for determining Hg in the 0.1 to 5.0 lb/ton range, and the precision is about 5 percent coefficient of variation; (2) an X-ray fluorescence method is described wherein the unweighed, finely ground sample is merely packed into a holder, and the Hg line-to-background ratio is obtained. The problem of matrix effects is avoided by preparing standards to simulate the type of ore being analyzed. The method is suitable for determining Hg over a wide concentration range, with a lower limit of about 0.1 lb/ton. The precision, based on the analysis of a 2.0 lb/ton Hg ore, is about 5 percent coefficient of variation. These two techniques are compared to the commonly used Whitton and Bureau of Mines methods.

OP 99-72. Graphs Quickly Predict Waterflood Performance, by R. V. Higgins, D. W. Boley, and A. J. Leighton. In *Waterflood Handbook*. World Oil Eng. Handbooks, v. 3, 1969, pp. 9-16. This report deals with a shortcut graphical method for the quick determination of oil recovery versus cumulative water injected for a five-spot waterflood. Using only graph paper and a desk calculator, performance forecasts can be completed in about 30 minutes. Results are within an average of 2 percent of performance calculated by an electronic computer, a high degree of accuracy for a graphical method.

OP 100-72. Computer Prediction of Water Drive of Oil and Gas Mixtures Through Irregularly Bounded Porous Media—Three-Phase Flow, by R. V. Higgins and A. J. Leighton. *Trans. AIME*, v. 225, No. 225, 1962, pp. 1048-1054. The authors present a fast method for calculating thoroughly the performance of two-phase flow in reservoir rock with complex geometry. The accuracy of such a method is shown by comparison with laboratory performance of a five-spot pattern. In making the performance calculations, the octant of the five-spot pattern was divided into four channels. The computer time required for the calculation was 1 minute. This is roughly about ¼ minute per channel.

OP 101-72. Quick Determination of Pressures in Well Spacing Patterns, by R. V. Higgins and A. J. Leighton. *Pres. Rocky Mountain Reg. Meeting SPE of AIME*, Billings, Mont., June 5-7, 1968, and 39th Ann. Calif. Reg. Meeting SPE of AIME, Bakersfield, Calif., Nov. 7-8, 1968, Preprint SPE

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2125, 1968, 16 pp. A quick method to determine the pressure distribution between wells for various well patterns is presented. In the determinations the effect of well diameter may be included. Comparison of the results with potentiometric models presented in the literature showed excellent agreement. By the method presented, it would be easy to obtain quickly the pressure distribution in an entire reservoir.

OP 102-72. Reactions of Iron Sulfides in Simulated Stack Gases, by C. Karr, Jr., R. V. Rahfuss, and P. F. Langdon. *J. Appl. Chem. Biotechnol.*, v. 22, 1972, pp. 613-622. The rates of production and consumption of SO_2 by the reactions of O_2 , SO_2 , and mixtures of O_2 and SO_2 in simulated stack gases with fixed and fluidized beds of FeS prepared from pyrite were determined over the temperature range 800° to 950° C. The rates of production of SO_2 by reaction of Fe_2O_3 with FeS in different gas systems were also determined. The rate controlling factors were derived for each reaction.

OP 103-72. Environmental Effects on Rock Properties, by E. R. Podnieks, P. G. Chamberlain, and R. E. Thill. Ch. in *Proc. 10th Symp. on Rock Mech.*, University of Texas, Austin, Tex., March 1972, pp. 215-241. Although the effects of moisture or temperature on rock properties have been previously studied, their combined effect on rock properties is unknown. In this study, uniaxial compressive strength, Young's and stiffness moduli, and longitudinal wave velocity were determined and compared under controlled conditions of temperature, moisture, and pressure for eleven environments considered to be of particular interest in laboratory, in situ, and even in simulated lunar environments.

OP 104-72. Effectiveness of Commercial Antistatic Wall Coatings, by R. L. Stein and W. H. Ryback. *J. Colloid and Interface Sci.*, v. 38, No. 3, March 1972, pp. 634-635. Containers of Plexiglas, Lucite, polystyrene, and similar polymers have frequently been used as chambers for aerosol studies. These materials, because of their high surface resistivity and polarizability, have large areas of positive and negative surface charge, which exist in random distribution over the plastic surface. These charge islands create electric fields within the chamber which interact with charged particles in the aerosol, resulting in high rate of particle loss to the wall. A detailed study of this phenomenon was recently undertaken by the Dust Control Group of the Pittsburgh Mining and Safety Research Center as part of the Bureau of Mines' ongoing program of research to control respirable dust in underground coal mines. A report of this work is in preparation.

To examine the effect of this surface electrostatic charge on the wall loss rate, control experiments were conducted using a film of a hygroscopic conducting detergent on the wall. Various commercial antistatic detergents were available for this purpose since they are used industrially to retard dust accumulation. A study of several of these agents was conducted to determine their effectiveness in reducing electrostatic wall loss of aerosol to a polystyrene surface.

OP 105-72. Soviet Union, by V. V. Strishkov. *Mining Annual Review*. Mining J., London, 1972, pp. 420-430. The U.S.S.R. has maintained its position as the world's leading producer of iron, manganese and chromium ores, pig iron, crude steel, platinum-group metals, lead, potassium salts, and

cement. It occupies second place, following the United States, in world output of aluminum, copper, petroleum, natural gas, coal, and phosphate rock; it ranks after Canada in the production of zinc, nickel, silver, and asbestos; and it follows South Africa in gold production.

The expansion of the mineral industry continues to be achieved mainly through increased labor and capital rather than through advancing technology. The productivity of labor and equipment is below planned levels, and practically all sectors of the mineral industry maintain greater numbers of production personnel than called for by plan targets. During the present (1971-75) Five-Year Plan, however, efforts are being made to increase recoveries, and of the planned rise in production, about half is expected to come from improved productivity and technology, the balance from new investment.

Soviet mineral policy has continued to emphasize maximum self-sufficiency. It has become the most self-sufficient of the world's leading industrial nations in minerals and metals.

OP 106-72. Analysis of Slopes in a Discontinuous Rock Mass, by Fun-Den Wang. Ch. in *Proc. 10th Symp. Rock Mech.*, University of Texas, Austin, Tex., May 20-22, 1968; March 1972, pp. 599-620. An open pit rock structure usually contains geological planes of weakness. They are formed by joints, faults, bedding planes, fractures, and cleavages. Rock slope failures often occur in the form of sliding of rock blocks along a plane or several planes. Such a rock block has three-dimensional geometry, and consequently a vector method of analysis has been found useful in evaluating its stability. The present chapter presents the analysis of rock blocks formed by planes of weakness of arbitrary orientation, and of three-dimensional geometry.

A plane of weakness is represented by its dip and strike in vector form and is reduced to the form of a linear equation. The geometry of the rock block is defined by solving the linear equations. The geometric characteristics of a rock block are based on triangles and tetrahedrons. By this treatment, the three-dimensional geometry is simplified and the number of calculations of forces and moments is reduced. Methods of finding the geometric characteristics are presented, along with equations for calculating the resultant forces and moments and the factor of safety.

OP 107-72. Laboratory Apparatus for High Temperature Forging Under Vacuum or Inert Atmospheres, by Robert Blickensderfer. *Rev. Scientific Instruments*, v. 43, No. 6, June 1972, pp. 947-948. An apparatus was designed, constructed, and used to forge refractory metal specimens at temperatures up to $1,900^\circ$ C under a vacuum or an inert atmosphere. The electrical resistance heater with radiation shielding located inside the vacuum chamber allowed good temperature control. Simultaneously with the forging stroke, the specimen was automatically moved onto the anvil below the heating element, where it was immediately forged. The apparatus has the potential for operation at considerably higher temperatures and for multiple forging blows if required.

OP 108-72. Manganese, by G. N. Broderick and G. L. DeHuff. *Eng. and Min. J.*, v. 173, No. 3, March 1972, pp. 150-151. World oversupply of high-grade manganese ore continued through 1971, and more of the same is likely to be in store for 1972. U.S. imports increased from 1.7 million short tons in 1970 to approximately 2 million tons in 1971, but domestic consumption of ore was expected to be

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lower than the 2.364 million tons consumed in 1970. Manganese ore is mainly dependent on the steel industry for its markets. Its chief use is to counteract the undesirable effects of sulfur in the production of steel. Manganese ore, chiefly the dioxide, has important uses in manufacturing manganese chemicals, as an oxidizing agent, and as a depolarizing agent in dry-cell batteries. Other uses for manganese ore include the manufacture of synthetic manganese dioxide, ceramic colorants, and fertilizer additives. The price outlook, the industry in the United States, as well as foreign developments are delineated in the article.

OP 109-72. Asbestos, by R. A. Clifton. Eng. and Mining J., v. 173, No. 3, March 1972, pp. 147-148. The production of asbestos in the United States is estimated to have set a new record-high tonnage in 1971, the projected 132,000-ton production representing a 5-percent increase over that of 1970. Analysis of the world production over the last 20 years shows an average annual growth of a little over 2 percent. Projecting this rate to the year 2000 would call for a cumulative production of 163 million tons; or approximately half of the known reserves. An average growth rate of 6 percent (it is now about 5 percent) would exhaust the known reserves by the year 2000.

OP 110-72. Advance in Technology for Recycling Obsolete Cars, by K. C. Dean and C. J. Chindgren. Scrap Age, v. 29, No. 5, May 1972, pp. 55, 72-73, 83, and 85. Each year in the United States about 8 million cars are retired from operation, and in many localities the accumulation of discarded hulks is a major eyesore and land pollutant. Yet, of all the manufactured items used in daily life the automobile probably represents the greatest potential source of recyclable materials. The automotive industry in 1969 consumed the following percentages of important materials used in the United States: rubber 65, zinc 33, steel 20, nickel 11, aluminum 10, and copper 8. Clearing the environment of the vast accumulations of junked autos with simultaneous recovery of the automotive components for reuse has been the objective of the Bureau of Mines auto scrap research programs. This paper summarizes the pertinent techniques developed by the Bureau, working in conjunction with industry for processing scrap autos.

OP 111-72. Factors Affecting Methane Emission and Their Implications Regarding the Selection of Control Techniques, by Maurice Ducl and Fred N. Kissell. Proc. Conf. on the Underground Mining Environment, Oct. 27-29, 1971, Univ. of Missouri, Rolla, Mo., 1972, pp. 229-240.

The best thing that can be said of the methane problem is that most of the gas produced during the coalification stage is gone. Tens of thousands of cubic feet of methane are produced in those reactions that transform vegetation into a ton of coal, and on the average only a few hundred cubic feet of methane remain. Even this amount creates enormous problems. A ton of coal is approximately 25 cubic feet; this means about 10 cubic feet of gas for 1 cubic foot of coal. It has been said that mining of deep coal seams is like digging out a low-grade gas well. Coal adsorbs gas like a low-grade activated charcoal. Because of its basic graphitic structure it contains an extensive network of fine pores, called micropores. These micropores are extremely small; diameters have been estimated in the 5 to 10 Angstrom range. As a result, coal, like charcoal, has a large internal surface. One hundred square meters per gram is a typical figure for coal. Most of the gas in coal is

adsorbed on this internal surface under pressure. These pressures can range from just a few psi upwards. Gas pressures as high as 650 psi have been measured in U.S. coalbeds, and the Russians have seen over a thousand.

It has been known for a long time that the pressure, and consequently the amount of gas, correlates with the depth of the coalbed more than with anything else, and that shallow mines have less gas. Of course there are other factors: for instance, the coalbed around an older mine has been draining into the mine for some time and therefore is at lower pressure and contains less gas. Factors like this natural drainage are the subject of Bureau of Mines studies.

OP 112-72. Solid Fuel Resources and Utilization in North Dakota, by James L. Elder and Wayne R. Kube. Min. Record, Western Coal Ed., v. 83, No. 13, March 29, 1972, p. 7. In 1967 the coal and lignite resources of Wyoming, North Dakota, and Montana were estimated at 1,455 billion tons, which amounted to 45 percent of the weight of the solid fuel resources of the United States. Lignite in North Dakota constitutes about one-third of this reserve and would be more conservatively estimated at 350 billion tons. Lignite production in North Dakota in Fiscal Year 1971 amounted to 5.8 million tons, which is more than double the production in 1965. By 1976 it is conservatively estimated that production will exceed 10 million tons. Currently, most of the lignite has been used for electric power production.

OP 113-72. The Combustion of Pure and Composite Propellants. The Expansion and Application of Laminar Flame Theory to Heterogeneous Solid Propellants, by Martin Hertzberg. Oxidation and Combustion Rev. (The Netherlands), v. 5, 1971, pp. 1-81. The theory presented here is based upon the laminarized solutions to the energy and flow conservation equations. It differs from the previous theories in two significant respects. First, the philosophical viewpoint is different from that of the previous theories. We refrain from assuming that the rate is governed by an exponential pyrolysis function of the surface temperature. Instead, the regression rate is assumed to be a kind of "eigen value," namely, that value of the surface regression rate that is required to maintain the convective energy balance of the surface. It is that value of the rate whose magnitude determines a convective energy loss term, which, when combined with the subsurface conductive loss term, just balances the conductive gain term from the gas. The surface temperature is still a significant parameter; however it is no longer the most significant variable. In many respects, the viewpoint is a macroscopic analogue of the new microscopic theories of chemical kinetics: those that emphasize the energy and momentum balance as being the causative factors in determining the rates of elementary reactions. The "causative factor" in this theory, is no longer the temperature of the surface, but rather the rate of heat generation in the gas flame above the surface. This leads us to the second significant difference between this and previous theories. This theory is more realistic in recognizing the nature of this heating-rate problem, and in obtaining a practical solution to estimating its magnitude.

OP 114-72. Electrolytic Preparation of High-Purity Chromium, by K. P. V. Lei, J. N. Hiegel, and T. A. Sullivan. J. Less-Common Metals, v. 27, No. 3, June 1972, pp. 353-365. The preparation of high-

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purity chromium from commercial, aqueous electrolytic chromium has been investigated. Factors influencing the refining process, such as cell design, electrolyte components, chromium concentration in electrolytes, and cell operating parameters, have been studied. An improved molten-salt electrolytic refining process has been developed for the preparation of high-purity chromium with total impurity contents of less than 70 ppm, using a KCl-LiCl-CrCl_2 electrolyte at 520°C . High-purity chromium deposits ranging from 0.2 to 0.3 kg have been routinely prepared with initial cathode current densities of 40 to 210 A/ft^2 with average current efficiency of 96 percent. The chromium recovery in the process was 99 percent.

OP 115-72. *cis*- and *trans*-Hexahydroindan. Chemical Thermodynamic Properties and Isomerization Equilibrium, by H. L. Finke, J. P. McCullough, J. F. Messerly, A. Osborn, and D. R. Douslin. *J. Chem. Thermodynamics*, v. 4, No. 3, 1972, pp. 477-494. Calorimetrically determined values of the enthalpy and entropy of pure *cis*- and *trans*-hexahydroindan were used to calculate the thermodynamic properties and isomerization equilibrium mole fractions of the isomers in liquid and vapor phases. Experimental results are presented for heat capacities of the condensed phases from 12° to 390°K , enthalpies and entropies of fusion and solid-solid transitions, triple-point temperatures, sample purities, vapor pressures from 0.3 to 2025 Torr, and derived thermodynamic functions $[G_s(T) - H^\circ(0)]/T$, $[H_s(T) - H^\circ(0)]/T$, $[H_s(T) - H_s(0)]$, and $S_s(T)$ at selected temperatures in solid, liquid, and vapor phases. Calculated isomeric equilibrium mole fractions for the reaction: *trans*-hexahydroindan-*cis*-hexahydroindan, based on the calorimetric measurements, are compared with mole fractions observed in catalyzed reaction equilibrium studies.

OP 116-72. Thermodynamic Properties of Acrylonitrile, 1-Aminopropane, 2-Aminopropane, and 2-Methyl-2-Aminopropane, by H. L. Finke, J. F. Messerly, and S. S. Todd. *J. Chem. Thermodynamics*, v. 4, No. 3, 1972, pp. 359-374. Low-temperature calorimetric quantities were determined for acrylonitrile, 1-aminopropane, 2-aminopropane, and 2-methyl-2-aminopropane from 12°K to near their respective normal boiling temperatures. Values of molar heat capacity at saturation pressure of the condensed phases, transition and melting temperatures, and enthalpies of transition and fusion were measured by adiabatic calorimetry. From these data the thermodynamic quantities $-[G_s(T) - H^\circ(0)]/T$, $[H_s(T) - H^\circ(0)]/T$, $[H_s(T) - H_s(0)]$, S_s , and C_s were evaluated for the solid and liquid states. For acrylonitrile a revised vibrational assignment was made from Raman and infrared wavenumbers reported in the literature, and a table of thermodynamic functions for the ideal gas state from 0° to $1,000^\circ\text{K}$ was prepared. Values of the enthalpy, Gibbs energy, and logarithm of equilibrium constant of formation for acrylonitrile also were computed for the range 0° to $1,000^\circ\text{K}$.

OP 117-72. Propane as an Engine Fuel for Clean Air Requirements, by R. D. Fleming, J. R. Allsup, T. R. Franch, and D. E. Eccleston. *APCA J.*, v. 22, No. 6, June 1972, pp. 451-458. Air pollutants in exhaust gas produced from LP-gas (propane) were studied using both laboratory engines and vehicles. The objective of the study was both to evaluate propane as a low-pollution fuel and to provide information on adjustment of engine parameters

for advantageous use of propane as a low-pollution fuel. Variables in the study were air-fuel ratio (A/F), ignition timing schedule, and ambient temperature. Data comparable to that for propane relating A/F and ambient temperature to emissions are shown for natural gas and for gasoline. Results showed that engines using propane as compared with gasoline can operate over a wider range of A/F with minimum carbon monoxide and hydrocarbon emissions. Propane and natural gas emission levels were similar. No significant difference in nitrogen oxides was found for the three fuels. In simulated typical city driving using propane as a fuel, emissions were markedly reduced by retarding ignition timing with A/F increased to approach the lean misfire limit. However, serious power loss accompanied engine adjustment for minimum emissions.

In addition to favorable lean-limit characteristics, propane offers two other advantages as low-pollution fuel: (1) Mixture enrichment during starting and during warmup is avoided. In addition, carbon monoxide and hydrocarbon emissions with propane are unaffected by ambient temperature—in contrast to highly significant increases in emissions at low ambients with gasoline. (2) The photochemical reactivity of hydrocarbon emissions from propane, although higher than those from natural gas, are lower than the reactivity of hydrocarbon emissions from gasoline.

OP 118-72. Studies of the Solid and Gaseous Products From Laser Pyrolysis of Coal, by F. S. Karn, R. A. Friedel, and A. G. Sharkey, Jr. *Fuel (London)*, v. 51, No. 3, 1972, pp. 113-115. Laser pyrolysis of coal yields a variety of gaseous and solid products. Irradiation with high energy from a pulsed ruby laser produces (1) a gas having a high concentration of hydrogen and acetylene and (2) a solid having approximately the same elemental composition as the original coal. Low-energy irradiation with a continuous CO_2 laser produces (1) a complex mixture of hydrogen, carbon monoxide, and hydrocarbon gases and (2) a low-ash solid having a slightly lower C/H ratio than the parent coal. The solid has several interesting characteristics including a very low density and a high solubility in benzene. A high-resolution mass spectrum of this material revealed that it is a very complex mixture of organic molecules with many of the characteristics of coal. The solid has also been investigated by gel-permeation chromatography and catalytic dehydrogenation.

OP 119-72. Evaluation of Solid Mineral Wastes for Removal of Sulfur From Flue Gases, by D. H. McCrea, G. J. Cinquegrance, R. J. Leister, and A. J. Forney. *Proc. 3d Mineral Waste Utilization Symp.*, IIT Inst., Chicago, Ill., March 14-16, 1972, pp. 153-160. The Bureau of Mines has been investigating the use of solid mineral wastes for removing sulfur oxides from flue gases. A literature survey identified more than 20 materials that are available in large quantity, have thermodynamic potential of reacting with SO_2 , and can be supplied to the North Central United States for less than \$20 per ton. Reactivity of these materials toward SO_2 was determined experimentally over a temperature range of 130° to 700°C . In most cases, SO_2 was absorbed, but capacity and rate of absorption were low. However, two waste products, red mud and lead-zinc ore tailings, absorbed substantial quantities of SO_2 .

Lead-zinc ore tailings consist primarily of dolomitic carbonates. Their use was evaluated in differential kinetic experiments and by injection into a small pulverized coal-fired furnace. Results showed

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that injection of the tailings is probably less attractive than injection of limestone.

Red mud, the byproduct of bauxite refining, was also studied in differential kinetic experiments and by injection into the furnace. Results showed that, when the injection method is used, the short residence time prevents efficient SO_2 removal. Experiments demonstrated, however, that if a reactor is employed to increase residence time a high degree of SO_2 removal can be obtained at 550°C . The red mud can be thermally regenerated at 650°C . A conceptual regenerable process has been suggested.

OP 120-72. U.S. Bureau of Mines Progress in Mine Water Research, by E. A. Mihok and N. N. Moebs. 4th Symp. Coal Mine Drainage Research, Mellon Inst., Pittsburgh, Pa., April 26-27, 1972, pp. 33-40. This paper presents a brief summary of past and current work conducted by the U.S. Bureau of Mines dealing with the acid mine drainage problem.

OP 121-72. Separation and Identification of Minerals From Northern Great Plains Province Lignite, by L. E. Paulson, W. Beckering, and W. W. Fowkes. Fuel (London), v. 51, No. 3, 1972, pp. 224-227. Minerals were separated from nine lignite samples on the basis of specific gravity differences by float/sink of fine particles in carbon tetrachloride. Examination of the sink fractions showed the presence of nacrite, barite, pyrite, hematite, quartz, calcite, gypsum, and fragments of a mixture of α -quartz and nacrite. No separable minerals were found in which sodium was a major constituent.

OP 122-72. Surface Tension and Density of Liquid Lead, by Alfred E. Schwaneke and Wilbert L. Falke. J. Chem. and Eng. Data, v. 17, No. 3, July 1972, pp. 291-293. New measurements of the surface tension of 99.999 percent lead from 344° to 652°C with an improved maximum bubble pressure (MBP) system indicate that data reported in the literature many years ago are probably better than more recently reported measurements. Results show that the surface tension of liquid lead (γ) is given by $\gamma(\text{ergs/cm}^2) = 467.7 - 0.066 T (^\circ\text{C})$ with a standard deviation from regression of 2.1 ergs/cm^2 . Density of liquid lead was also obtained with the MBP system over the range from 384° to 551°C . The density of lead (ρ) is given by $\rho(\text{g/cm}^3) = 11.13 - 0.14 \times 10^{-2} T (^\circ\text{C})$ with a standard deviation from regression of 0.24 g/cm^3 . A table of experimental and calculated values is given with graphs for comparison with data reported in the literature.

OP 123-72. Development of a New High-Temperature Solder System, by A. E. Schwaneke, W. L. Falke, and O. K. Crosser. Welding J., v. 51, No. 7, July 1972, pp. 361-s-368-s. A new high-temperature soldering system has been developed for use on copper, copper alloys, and low-carbon steel. The method is applicable to automobile radiators and home appliances. The system uses a unique sacrificial metal coating method to promote spontaneous wetting and spreading of zinc and zinc alloy solders on metallic substrates. The 10^{-5} - to 10^{-6} -cm thick, electroplated or sputtered, sacrificial nickel coating is absorbed by the molten filler alloy during soldering and produces a direct solder-substrate metallic bond. Preliminary measurements on butt joints with copper members give tensile strengths over 32,000 psi at room temperature using 95 Zn-5Al alloy as solder. Spontaneous wetting, spreading, and capillary penetration are extremely rapid and produce joints as easily as 50-50 tin-lead solders. Recrystallization or annealing of the wrought copper joint members is negligible at

the soldering temperatures of 450° to 490°C and lower. A list of typical fluxes and solder alloys is included.

OP 124-72. Boron, by K. P. Wang. Eng. and Min. J., v. 173, No. 3, March 1972, pp. 146-147. Increased 1971 demand for boron minerals and compounds, particularly in the glass and enamel industries resulted in sustained high output. For some time all U.S. output had been in the form of sodium borates and boric acid. In mid-1971, however, production of calcium borate (colemanite) on a commercial scale was resumed. The United States is by far the largest world producer of boron minerals. About half of U.S. output is normally exported, divided nearly equally in terms of boron content between semifinished boron compounds and refined compounds, with only the latter reported in official trade returns. During 1971, recorded exports declined considerably as compared with the previous 2 years. The paper further delineates the expected production, trade, consumption, and price outlooks.

OP 125-72. Fluorspar, by H. B. Wood. Eng. and Min. J., v. 173, No. 3, March 1972, pp. 151-153. Forecasting the future for the fluorspar industry is similar to forecasting the future growth of the chemical, steel, and aluminum industries, because about 96 percent of the fluorspar is consumed by these industries. Certain phases of these basic industries are dependent on fluorspar, and no economical substitute has been found to replace it or its fluorine derivatives. It is expected that fluorspar demand for the next 10 years, or longer, will increase at least 4 percent per year.

OP 126-72. Thorium, by W. C. Woodmansee. Eng. and Min. J., v. 173, No. 3, March 1972, pp. 148-149. Primary thorium supply, provided by one domestic monazite producer and by imported monazite and thorium compounds, continued well in excess of industrial demand, which remained little changed for nonenergy uses. Growing demand of certain rare-earth elements in monazite contributed to the thorium oversupply. Significant developments took place in the role of thorium as a nuclear fuel.

OP 127-72. Fire Assay-Emission Spectrographic Determination of Iridium, Ruthenium, and Osmium, by K. G. Broadhead, B. C. Piper, and H. H. Heady. Appl. Spectroscopy, v. 26, No. 4, July-August, 1972, pp. 461-467. This paper describes a fire assay-spectrographic method for determining microgram levels of Ir, Ru, and Os in ores and concentrates. Radio-tracers are used to monitor the recovery of these metals in a 10 mg Pt bead during the normal fire assaying procedure.

OP 128-72. Mining Ergonomics, by James C. Church. Proc. 48th Ann. Safety Conf., Lake Superior Mines Safety Council, Duluth, Minn., May 25-26, 1972, pp. 28-33. This paper covered the following: (1) The background of ergonomics, including development and history and the available industrial technology; and (2) Mining ergonomics, including areas of utilization, applications (methods and constraints), and mineral industry benefits, with particular emphasis on the health and safety of miners and the productivity of mine operations.

OP 129-72. Depleted Uranium as a Catalyst for Hydrocracking Shale Oil, by P. L. Cottingham and L.

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K. Barker. Preprints, Div. Fuel Chem., ACS, v. 16, No. 2, 1972, pp. 24-46. This article describes the process by which low nitrogen and sulfur gasoline with an octane number of 89 has been made by reforming hydrogenated shale oil at 900° F and 200 psig.

OP 130-72. Recovery of Metals From Electroplating Wastes. by L. C. George and A. A. Cochran. Ch. in *Environmental Management: Science and Politics*, ed. by Morton Gorden and Marsha Gorden. Allyn and Bacon, Inc., Boston, 1972, pp. 175-178.

The treatment of concentrated acidic and alkaline-cyanide electroplating wastes by innovative methods to neutralize and precipitate the cyanides and recover the metal content are discussed. Large quantities of cyanides, plus significant tonnages of useful metals, such as silver, nickel, and copper, are customarily discarded and contribute to stream and ground water pollution. The addition of an acid waste to an alkaline-cyanide waste was investigated as a means of neutralizing both materials while alleviating pollution from these sources. At a final solution pH value near 6.5, metals and cyanides in both wastes were precipitated almost completely. The filtrate from this step was relatively harmless compared to the original waste and had a free cyanide content of less than the detection limit of 0.08 ppm. The metal cyanide precipitate contained significant amounts of copper and nickel, which were separated and recovered by additional processing. Valuable metals were also recovered from the acid waste by selective precipitation of the metal hydroxides and by a combination of selective precipitation and electrolysis.

OP 131-72. Making Copper Without Pollution, by F. P. Haver and M. M. Wong. *Min. Eng.*, v. 24, No. 6, June 1972, pp. 52-53. This article describes a process in which copper concentrate is roasted with lime to fix the sulfur as anhydrite. Metal values are then recovered by a dilute acid leach.

OP 132-72. Methane/Hydrogen Mixture as a Fuel for Spark-Ignition Engines, by R. W. Hurn. Proc. 2d Conf. on Natural Gas Research and Technology. Cosponsored by the American Gas Association and the Institute of Gas Technology, Atlanta, Ga., June 5-7, 1972, pp. 1-8. Experimental work was done using methane/hydrogen fuel in a single cylinder, variable compression ratio engine. Fuel economy and emissions were measured. The objective was to determine characteristics of the mixture as the fuel in a low-emission, high-efficiency engine. Results suggest that methane/hydrogen may enable engine operation under conditions that are simultaneously conducive to improved fuel economy and low emissions.

OP 133-72. Ion-Exchange, Coordination, and Adsorption Chromatographic Separation of Heavy-End Petroleum Distillates, by D. M. Jewell, J. H. Weber, J. W. Bunker, Henry Plancher, and D. R. Latham. *Anal. Chem.* v. 44, No. 8, July 1972, pp. 1391-1394. Information about the composition of heavy-end petroleum distillates is needed because of the increased use of this material as an energy source. The complexity of the heavy ends requires extensive separation to give fractions amenable to compositional studies. A separation scheme is described that separates heavy-end petroleum distillates into acid, base, neutral-nitrogen, saturate, and aromatic fractions. The analytical techniques used include anion- and cation-exchange chromatography,

coordination chromatography, and adsorption chromatography. The scheme has been applied to heavy-end distillates from a variety of crude oils having different compositional characteristics. Data from mass spectral analysis of the saturate and aromatic fractions are presented.

OP 134-72. The Separation of Acidic Compound Types Isolated From High-Boiling Petroleum Distillates, by J. F. McKay, D. M. Jewell, and D. R. Latham. *Separation Sci.*, v. 7, No. 4, 1972, pp. 361-370. Two methods for separating the acid compound types of high-boiling petroleum distillates have been investigated. The first method utilized ferric chloride and ion-exchange resins, and the second method used gel permeation chromatography. Each method was found to have merits, and the two methods can be used to complement each other. The major compound types of a Wilmington 400° to 500° C acid concentrate have been separated and identified using these methods. Data from the separation schemes will aid in the characterization of the acidic materials.

OP 135-72. Goals and Status of Bureau of Mines Coal Mine Health and Safety Research, by James J. Scott. *The New Sketch (India)*, Republic Day Spec. No., Jan. 26, 1972, pp. 103-110. This article is a presentation on coal mining health and safety research which was made to the National Safety Congress in Chicago, Ill., Oct. 25, 1971. The Federal Bureau of Mines research program to improve health and safety in the coal mines is comprehensive and deals with problems from a variety of approaches. The Congress and the American people have given the Bureau of Mines the task of improving safety in the coal mines. This is certainly not a simple task. The health and safety problems in U.S. coal mines have been there for decades and cannot be solved overnight. However, with the help of the academic and industrial communities and the coal industry, many of the urgent problems can be overcome within a relatively short time. New and improved mining systems can be developed that will provide U.S. miners with better working environments and greater safety protection.

OP 136-72. Coal Utilization Under Changing Energy Patterns and Social Restraints, by Zane E. Murphy and Eugene T. Sheridan. *The New Sketch (India)*, Republic Day Spec. No., Jan. 26, 1972, pp. 24-31. The continued rise in energy requirements has attracted a great deal of attention in the United States in recent years. It is only recently, however, that a new awareness of social problems and costs has directed attention to ways and means of reconciling social objectives and problems of supplying acceptable and adequate energy to the expanding economy. Unless one is willing to accept a considerably lower standard in his life style, the goals of both society and those of the individual should be directed toward greater and more efficient utilization of all available energy sources and the development of new fuel utilization patterns that will allow for an adequate energy supply while causing the least disturbance to the environment.

OP 137-72. Segregation of Alpha and Beta Stabilizers in Titanium, by F. W. Wood and P. A. Romans. *Mat. Sci. and Eng.*, v. 10, No. 3, September 1972, pp. 182-185. Metallic phase stabilization is a matter of thermodynamic balance involving the free energy state of metal. The thermodynamics of a particular system is commonly summarized in an equilibrium phase diagram. Many binary phase diagrams are available and it is sometimes possible to use

these as bases for conjecture about more complex systems. Miscible, binary combinations based on titanium tend to be of two types: alpha stabilizing or beta stabilizing. In the Ti-6Al-4V alloy, Al is the alpha stabilizer and it tends to reside selectively in beta-phase parts of the structure. Hence, certain features of structure containing hypernormal concentrations of Al or V sometimes are identified as aluminum-stabilized alpha segregation or vanadium-stabilized beta segregation. When unusual amounts of oxygen or nitrogen can be associated with an alpha-stabilized irregularity, it is commonly identified as interstitial-stabilized segregation, but valid questions exist about the role of the gaseous contaminants when their presence in unusual concentrations is neither detected nor suspected.

OP 138-72. Determination of Carbon Dioxide, Hydrogen Sulfide, Sulfur Dioxide, Ethane, and Propane Using a Carbon Molecular Sieve Column, by Dean H. Bollman and Donald M. Mortimore. *J. Chromatographic Sci.*, v. 10, August 1972, pp. 523-527. A 2-foot carbon molecular sieve column will separate CO₂, H₂S, SO₂, C₂H₆, and C₃H₈ from each other and from the gases H₂, O₂, N₂, CH₄, and CO. At 100° C the column is particularly helpful for determining CO₂ rapidly in the presence of the other gases listed. The method can be applied to analyzing offgases from furnaces and kilns.

OP 139-72. Modern Methods for Manufacturing Substitute Natural Gas From Various Fuel Stocks, by A. J. Forney. *Proc. 1972 Operation Section, Am. Gas Assoc. Distribution Conf.*, Atlanta, Ga., May 8-10, 1972, pp. D-60-D-63. This paper discusses the various feed stocks that could be used to make a supplemental natural gas. The most likely prospects, coal and naphtha processes, are described, using as examples the Synthane coal-to-gas process and the CRG naphtha-to-gas process. Other possible processes using feed stocks such as oil shale, shale oil, and wastes are discussed briefly.

OP 140-72. The Enthalpies of Combustion and Formation of *n*-Octane and 2,2,3,3-Tetramethylbutane, by W. D. Good. *J. Chem. Thermodynamics*, v. 4, No. 5, September 1972, pp. 709-714. Combustion calorimetry confirmed existing enthalpy-of-formation values for *n*-octane and 2,2,3,3-tetramethylbutane. Inability of correlation schemes to predict accurate enthalpy-of-formation values for such complex molecules as 2,2,3,3-tetramethylbutane was demonstrated.

OP 141-72. Progress in Suppressing the Noise of the Pneumatic Rock Drill, by James W. Jensen and Aarne Visnapuu. *Proc. Inter-Noise 72, 1972 Internat. Noise Control Eng. Conf. and Equipment Exposition*, Oct. 4, 1972, pp. 282-287. The pneumatic rock drill, a percussion tool basic to the mining industry, causes one of the worst noise hazards to which mine workers are exposed. Sound pressure levels range from 115 to 130 dB at the operator's position with unmodified drills. Three domains of noise emission must all be controlled or suppressed to achieve appreciable improvement. They are the air exhaust noise, the impact and resonance noise of the drilling machine, and the resonance noise of the steel drill rod. To be functionally acceptable, modifications to reduce the noise should not reduce drilling rate or efficiency, cause severe overheating of the machinery

or icing in the exhaust system, or be much less durable than the unmodified equipment. To have the operator's acceptance, there must be a minimum of added weight or bulk, and the modifications should not hamper operation or reduce the reliable performance of the drill. Modifications have been developed, with consideration for these requirements, that reduce the sound pressure level of a portable commercial drill to about 100 dB. A close-fitting case, consisting of a metallic skeleton filled with viscoelastic material and a hard, metallic cover, provides a high degree of suppression of mechanical noise and the necessary rigidity and durability. Expansion chambers incorporated in the case provide the essential exhaust muffling. Damping alloys have been substituted at strategic points in the drill. The drill steel resonance noise is reduced by a special damping treatment on the outside of the drill rod. The performance of this equipment, its evaluation according to the criteria set forth, and additional prospects for better noise suppression receive comment in this report.

OP 142-72. Brittle Fracture of Rock, by Leonard Obert. *Fracture, an Advanced Treatise, Volume VII, Fracture of Nonmetals and Composites*, ed. by Harold Liebowitz. Academic Press, Inc., New York, 1972, pp. 93-155. This chapter considers the mechanics of the fracture process in rock, with emphasis on the engineering viewpoint. The development of a consistent fracture mechanics for rock is complicated by several factors, such as the extreme constitutive variability of rock. These factors are discussed in some detail. Next, empirical procedures for determining limiting states of stress are reviewed. In these procedures, the state of stress in the specimen is either homogeneous or inhomogeneous. However, the limiting states of stress, as determined in homogeneous and inhomogeneous tests, are often in disagreement, and possible reasons for differences are discussed. The Coulomb-Navier, Mohr, and Griffith theories of fracture are reviewed, and the merits and defects of each considered. Processes by which initial and branch fractures extend and ultimately produce terminal failure are examined. The chapter is concluded with a summary in which the state of the art is evaluated. Areas in which information regarding the fracture mechanism in rock is deficient or inconsistent are indicated, and topics for future research are suggested.

OP 143-72. Sulfur-33 Magnetic Resonance Spectra of Selected Compounds, by H. L. Retcofsky and R. A. Friedel. *J. ACS*, v. 94, 1972, pp. 6579-6584. Sulfur-33, because of its low natural abundance, spin of 3/2, and large quadrupole moment, has been a much neglected nucleus in nmr as well as in other branches of spectroscopy. The use of high rf power levels incident upon the sample, large modulation amplitudes, and signal averaging, however, permits nmr spectra with reasonable signal/noise ratios to be obtained. The present ³³S nmr investigation was undertaken to explore the potential of the technique as a structure-determining tool. ³³S chemical shifts and spectral line widths are presented for 12 materials. The range of chemical shifts is nearly 600 ppm, whereas spectral line widths vary from ~0.2 to 16 G. The organic compounds investigated were carbon disulfide, dimethyl sulfoxide, ethyl disulfide, tetrahydrothiophene, thiophene, and three substituted thiophenes. The inorganic compounds examined included concentrated and dilute (10 N) sulfuric acid, aqueous sodium sulfide, and the sulfide anion in cubic zinc sulfide. The highest field resonances were observed for aqueous sodium sulfide and for S²⁻; the

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lowest field resonance was for 10 N sulfuric acid. The effects of high symmetry about sulfur and fast chemical exchange on ^{33}S spectral line widths are discussed and illustrated. The ^{33}S nmr results are compared with those of other nuclei in chemically similar compounds.

OP 144-72. Molten Titanium Can Explode in Water, by Floyd W. Wood. *Metal Prog.*, v. 102, No. 4, October 1972, p. 7. As with aluminum in water, titanium-water explosions are of three types: (1) moderately rapid expansion of steam; (2) violent release of steam that has built up a high pressure in confinement; and (3) chemical explosions involving exothermic reactions. In consumable-electrode vacuum-arc melting, as used for titanium, the most likely source of water is the cooling water outside of the copper crucible, and leakage of this water to contact molten titanium usually results from penetration of the crucible wall. At least one factor affecting the chance of penetration is the adequacy of arc-gap and arc-voltage control.

OP 145-72. Process for Converting Coal Into Gaseous and Liquid Fuels, by D. W. Gillmore. *Soc. Petrol. Eng. AIME, Preprint No. SPE 4158*. November 1972. 12 pp. The future of coal usage to alleviate the energy shortage depends on our ability to burn coal cleanly and to convert it to gaseous and liquid products. This paper discusses the state-of-the-art of coal conversion and reviews briefly by simplified flow sheets the major gasification and liquefaction processes. At present, technology has not advanced beyond pilot plant or demonstration stages; even the optimistic experts predict that commercial operations will not be realized before the 1980's. Hence, a large and concerted effort is needed now to implement the conversion of coal to gas and oil.

OP 146-72. Dechlorination of Ferric Chloride With Oxygen, by A. W. Henderson, T. T. Campbell, and F. E. Block. *Metall. Trans.*, v. 3, October 1972, pp. 2579-2583. Because of increasing ecological concern, the Bureau of Mines is investigating the use of chlorination technology in extractive metallurgy. A key problem is the fact that ferric chloride is commonly generated during processing of a wide variety of ores and minerals. This paper describes small, laboratory-scale studies designed to effect dechlorination of ferric chloride by oxygen in a fluidized bed reactor to produce a viable, nonpolluting iron oxide product and chlorine gas, which could be recycled in a chlorination process. These studies demonstrated that close to 100 percent conversions of ferric chloride to ferric oxide and chlorine can be effected by reaction with oxygen at temperatures ranging from 500° to 650° C. the offgas from the single-stage reactor contained up to 95 percent chlorine. The study also demonstrated that the presence of a small amount of NaCl in the reactor catalyzed the reaction between ferric chloride and oxygen and permitted high conversions at temperatures as low as 450° C.

OP 147-72. Le Probleme Des Gaz D'Enchappement Des Moteurs Diesel Dans Les Galeries Souterraines (Previously published in English as OP 41-72.), by R. W. Hurn. *Cashiers De Notes Documentaires*, 1972. No. 69. pp. 391-396. The operation of diesel engines in underground areas requires careful attention to space ventilation in order that the concentration of toxic combustion products be held within acceptable limits. These ventilation requirements and the bases for calculating them are reviewed in the paper.

OP 148-72. Kinetics of Carbothermal Reduction of Quartz Under Vacuum, by S. E. Khalafalla and L. A. Haas. *J. Am. Ceram. Soc.*, v. 55, No. 8, August, 1972. pp. 414-417. Kinetics of carbothermal reduction of quartz at reduced pressures is consistent with a model based on a transitory phase intermediate. An Austin-Rickett equation with an exponent close to 2 gives the best fit to the kinetic curve.

OP 149-72. Feasibility of Utilizing MHD for Powering High-Speed Land Vehicles, by J. J. Lacey, F. E. Spencer, J. J. Demeter, and D. Bienstock. *Proc. 7th Intersoc. Energy Conversion Eng. Conf.* September, 1972. pp. 1022-1027. A combined MHD and closed Brayton cycle for providing "on-board" low-pollution power for high-speed land vehicles was evaluated using hydrogen and hydrocarbon fuels and attaining thermodynamic efficiencies greater than 40 percent.

OP 150-72. Mass Spectrometry Study of Microwave Discharges in Hydrogen-Carbon Monoxide-Argon Mixtures, by R. G. Lett, W. A. Steiner, and Y. C. Fu. *J. Phys. Chem.*, v. 76, 1972. pp. 2941-2946. Microwave discharges in a flow system containing hydrogen-carbon monoxide-argon mixtures have been sampled by a time-of-flight mass spectrometer. Depending upon experimental conditions, from 5 to 30 percent of the carbon monoxide was converted to methane, acetylene, and carbon dioxide. The formation of the major gaseous products was studied as a function of reactant gas composition, pressure, microwave power, and flow rate. The consumption of carbon monoxide appears to be first order at short residence times. Ions were sampled from the discharges at pressures below 5 torr. The most abundant ions were H_3O^+ , HCO^+ , and primarily hydrocarbon ions in the C_2 , C_3 , and C_4 regions.

OP 151-72. A Miniature Straddle Packer, by J. C. Roegiers and V. W. Delloriano. *Proc. 27th Ann. Conf. and Exhibit Instrument Soc. of America*, v. 27, October 1972, pp. 610-1-610-4. Controlled crack propagation has been a goal for better understanding of the mechanism of rock failure. The development of servocontrolled testing machines have brightened the horizon of research. By controlling other parameters besides the usual increase of pressure, and feeding the signal back, one is actually able to follow the fracture step by step. However the amount of fluid present in a typical hydraulic fracturing test introduces a softening element into the high rigidity of the system. A miniature straddle packer of 1 inch diameter was developed to achieve the stated goals.

OP 152-72. Interfacial Compositions of Soldering Alloys on Copper and Brass, by A. E. Schwaneke, W. L. Falke, and W. C. Clinton. *Am. Soc. for Metals—Conf. on Copper*. Oct. 16-19, 1972. Cleveland, Ohio. pp. 1-12. In a study of factors affecting wetting in solder systems, tin, lead, and tin-lead alloys were allowed to spread as sessile drops on copper and brass substrates without fluxes in vacuum. X-ray microprobe analyses and optical micrographs show the alloying reactions, which not only occur at the interface but also throughout the bulk of the solder. For example, with tin on copper substitutes, copper diffuses upward into the molten tin, and two separate bands of Cu-Sn alloy are formed at the interface. The upper, a 67 Cu-33 Sn alloy, streams upward through the sessile drop to form columnal sections that end at the drop surface and are encased in a 47 Cu-53 Sn alloy. Ordinary 50

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Sn-50 Pb solder on copper exhibits up to five regions of definite but different compositions. Tin diffuses out of the solder forming Cu-Sn alloys that leave behind lead-rich areas. The zinc component in brass produces different results with solders. Various binary and ternary alloys are formed at the interface and throughout the solder. Other details of interfaces between tin, lead, or tin-lead solders spread on copper or brass are presented in the article.

OP 153-72. Keynote Address at BRANA Convention, by Max J. Spendlove. *Product Recycling*, v. 11, No. 3. 1972. pp. 3, 6. In giving the keynote address to the Bumper Recycling Association of North America (BRANA), Mr. Spendlove spoke of Bureau of Mines research into the problems of recycling raw materials and products recycling. He noted that pollution control is only one aspect of recycling. The talk emphasized the recycling of old or junk raw materials into valuable rebuilt products.

OP 154-72. Refining of Crude Shale Oil Produced by In Situ Retorting, by C. M. Frost. *Preprints*, Div. Fuel Chem., ACS, v. 16, No. 1. 1972. pp. 73-87. Catalytic reforming and catalytic cracking of hydrogenated in situ crude fractions produced gasolines with leaded research octane numbers of 90 and 99.2, respectively.

OP 155-72. Structural-Environmental Characteristics of Tailings Ponds, by C. D. Kealy, R. E. Williams, and Leland L. Mink. *Proc. AIME Meeting*, San Francisco, Calif. Feb. 21-23, 1972, October, 1972. pp. 173-189. Ground-water pollution in one portion of the Coeur d'Alene mining district results from leaching of old jig tailings that are intermixed with the upper part of a sand and gravel aquifer. High concentrations of zinc, lead, and cadmium occur in ground water and soil samples taken from the portion of the sand and gravel aquifer containing the old jig tailings. Analysis of water samples from a tailings pond located in this area indicates that the pond water is not the source of the heavy metal concentrations found in the down-gradient ground water. However, leakage from the pond and water from the pond's decant system combine with natural ground water to compound the problem by raising the water table into old jig tailings which cover the upper portion of the aquifer. The ground water which discharges from this aquifer causes a statistically significant decrease in the quality of the receiving stream water.

OP 156-72. Removing Methane From Coalbeds in Advance of Mining by Surface Vertical Boreholes, by Joseph Cervik and C. H. Elder. *Proc. Conf. on the Underground Mining Environment*, University of Missouri at Rolla, Oct. 27-29, 1971, pp. 209-228. Because of the need to mine deeper and more gaseous coalbeds at increasingly higher rates to meet the demand for coal, it is increasingly more difficult to provide a sufficient quantity of air to dilute the gas emitted at the working face to a safe concentration. An alternative to greater ventilating air volumes is degasification of the coalbed to lower methane emission rates. One technique for degasifying a coalbed is through the use of surface boreholes drilled from the surface into the coalbed in advance of underground mining. This paper summarizes experience in degasification by surface boreholes in three major coalbeds—the Pittsburgh, the Pocahon-

tas No. 3, and the Mary Lee—and presents data on the properties and characteristics of these coalbeds.

OP 157-72. Oil Shale—An Impending Energy Source, by Glenn L. Cook. *J. Petrol. Technol.*, November 1972, pp. 1325-1330. Recent political, technical, and economic developments lead to optimism for the commercial exploitation of oil shale as a source of energy. Although presently the production of oil by mining or aboveground retorting seems feasible, the production of oil by in situ techniques or of pipeline gas by either aboveground or underground gasification is less probable for a while.

OP 158-72. The Scientific Basis for Evaluation of the Methane Problem in New Mines, by Maurice Deul. *Proc. West Virginia Coal Mining Inst.*, October 1970, pp. 19-23. The design and development of new mines, especially in coalfields where there is little or no recent experience, is often hampered by lack of knowledge of potential methane control problems. Ventilation system layout, total air requirements, and rock dust supply are only a few of the factors directly dependent on methane emission, but ultimately the productivity of the mine may depend on the capability of mine management to control methane which may, in fact, overwhelm all other considerations. Even mines which have been in production for decades, using a conventional "cut-drill-load-shoot" mining system, may encounter severe methane control problems after converting to a continuous boring-type machine mining system. The reasons for this can be explained best if how methane is present in coalbeds is understood.

OP 159-72. Progress Report on SNG Technology, by A. J. Forney. *Pipeline Industry*, v. 37, No. 3, September 1972, pp. 27-29. The various fuels could be converted to a high Btu gas are coal, light petroleum fractions, oil shale and heavy oils resulting from development of an oil shale industry, and treating of garbage and bovine wastes. Recent events have shown the most promising and quickest routes are processes using light oil feedstocks. However, there is a definite limitation to the amount of this material available. In the long run, the other sources show more promise for a large share of the gas market.

OP 160-72. Mines, Dust Control, by Murray Jacobson. In *Encyclopedia of Occupational Health and Safety*, v. 2, Internat. Labour Office, Geneva, Switzerland, 1972, pp. 889-892. The production of dust in mining is associated with the extracting of coal or mineral from the solid seam. The methods of determining the dust hazard and preventive measures for control of dust are discussed. As there is no universally applicable dust standard, typical dust standards from a number of countries are presented.

OP 161-72. A Flow Chart Mine Cost Model, by Guy A. Johnson. *Trans. Am. Assoc. Cost Engineers*, 1972, pp. 81-85. Cost engineering, a basic part of most industry and government work, involves the problems of how to communicate the cost information developed and what analysis techniques were utilized. At the conclusion of a mineral economics study concerning the costs to mine and mill the vast, deep low-grade native copper deposits of Upper Michigan, a DCF flow chart mine cost model was developed to help solve these problems. The flow chart mine cost model is a straightforward, graphic definition of the elements required to develop the preliminary "capital required" and "operating

costs" estimates for a mine, while it depicts the interrelationships of these elements as they combine to form the total discounted cash flow cost picture.

OP 162-72. Fluorescence Spectrometry in the Characterization of High-Boiling Petroleum Distillates, by J. F. McKay and D. R. Latham. *Anal. Chem.* v. 44, No. 13, November 1972, pp. 2132-2137. Use of fluorescence spectrometry as a qualitative analytical technique in the characterization of high-boiling petroleum distillates is reported. Examples of fluorescence emission and fluorescence excitation spectra obtained from compound types in 400° to 500° C distillates are shown. Among the compound types identified were carbazoles, 11*H*-benzo[*a*]carbazoles, 7*H*-benzo[*c*]carbazoles, perylenes, coronenes, benzo[*ghi*]perylene, and chrysenes. Fluorescence and excitation peak maxima of 35 aromatic model compounds are reported. The separation scheme which produced samples suitable for fluorescence analysis involved the use of ion exchange chromatography, gel permeation chromatography, and thin-layer chromatography.

OP 163-72. Sulfur in Products vs. Crude Oil, by C. M. McKinney. *Hydrocarbon Processing*, October 1972, pp. 117-120. Distribution charts are presented for estimating the sulfur contents of distillates and residues if the sulfur content of the crude is known.

OP 164-72. Correlation of Fractional Monolayer Oxygen Determinations Obtained by Proton-Excited X-Ray and Auger Electron Spectroscopy Analysis of Fe Surfaces, by P. B. Needham, Jr., T. J. Driscoll, and N. G. Rao. *Appl. Phys. Letters*, v. 21, No. 10, Nov. 15, 1972, pp. 502-505. Oxygen *K α* X-rays excited by the impact of 120-keV protons have been used to determine absolute oxygen surface coverages ranging from 4.8×10^{14} to 5.2×10^{15} atoms/cm² on polycrystalline iron samples mounted in an Auger spectroscopy system. Amplitudes of the electron-beam-excited oxygen *KL₂L₂* Auger electron spectra obtained from the samples corresponded linearly with the coverages determined by the proton-excited X-rays (PEX). Estimates of the oxygen adatom coverages using the Auger results and the theoretical approach of Bishop and Riviere were found to agree within a factor of 2.15 ($\pm$ 0.22) with the PEX-determined coverages.

OP 165-72. Steam Oxygen Gasification of Various U.S. Coals, by A. J. Forney, S. J. Gasior, R. F. Kenny, and W. P. Haynes. *Proc. 2d Internat. Conf. on Fluidized-Bed Combustion*, Oct. 4-7, 1970, Pub. AP109, pp. III-3-1-III-3-6. The Bruceton process for making a supplemental natural gas from coal consists of gasification, purification, and methanation steps. The advantages of the system are that caking coals can be used in the fluid-bed gasifier, and more than half of the methane can be made in the gasifier instead of in the methanator. Furthermore, the final product contains no sulfur and has a heating value exceeding 900 Btu/cu ft.

OP 1-73. Coal Mine Spoil and Refuse Bank Reclamation With Powerplant Fly Ash, by L. M. Adams, J. P. Capp, and D. W. Gillmore. *Compost Science, J. Waste Recycling*, v. 13, No. 6, 1972, pp. 20-26. Numerous coal mine refuse piles and strip spoil banks mar the countryside, contributing to stream and air pollution and land degradation. Experi-

mental reclamation of several such sites with fly ash from bituminous coal-fired powerplants was conducted in West Virginia and Pennsylvania. Conventional farm equipment was used at some of the sites; large earthmovers were required at others. The fly ash served as a neutralizing agent, diluent, and soil amendment, providing some nutrients that encouraged vegetation of the barren areas while disposing of significant quantities of the powerplant waste. Estimated cost of reclamation by this method is \$300 per acre of previously leveled area. This figure can vary considerably depending upon the topography of the site, distance from the source of fly ash, and quality of the fly ash.

OP 2-73. Catalytic Reforming of Hydrogenated Shale-Oil Naphtha, by Lawrence K. Barker and Philip L. Cottingham. *Preprints, Div. Fuel Chem, ACS*, v. 16, No. 1, 1972, pp. 97-111; *I&EC Product Res. and Development*, v. 11, No. 4, December 1972, pp. 399-404. Naphtha from hydrogenated crude shale oil was suitable for established reforming processes. Good quality no-lead gasoline with an octane number of 89 was made from the naphtha. The octane number and low nitrogen and sulfur content of gasoline from shale oil compared favorably with regular gasolines. Regular grade gasolines now using lead additives have octane ratings near 94. The reforming feed was twice treated with hydrogen. Over 90 percent of the nitrogen and sulfur compounds (which usually inactivate the catalysts used in present reforming processes) was removed from the shale oil during the first hydrogenation step with a cobalt-molybdate catalyst. The relatively "clean" naphtha was then hydrogenated in the presence of nickel-tungsten catalyst, lowering the nitrogen content to 7 ppm of the gasoline and lowering the sulfur content to less than 0.001 weight-percent. Preselected ranges of temperature and pressure within the commercial reforming ranges were chosen for investigation, with other possible variables held constant.

OP 3-73. On the Mechanism of Low-Velocity Detonation in Liquid Explosives, by Robert F. Chaiken. *Astronautica Acta*, v. 17, 1972, pp. 575-587. A theoretical description of low-velocity detonation (LVD) in liquid explosives has been developed, based upon a cavitation model of the phenomena. In this model, precursor waves cause cavitation of the liquid; the cavities are then shock-initiated by the advancing detonation front. The Chapman-Jouguet (C-J) condition of classical detonation theory has been extended to this case where precursor wave effects are important. In essence, it is shown that coupling of rate processes through a precursor wave limits the number of Hugoniot adiabat states that are accessible. Thus, the solution to the Rankine-Hugoniot equations for the steady-state detonation velocity involves a minimization of the velocity subject to the constraints imposed by the coupled rate processes.

For the case of LVD in liquid explosives, six rate processes are identified and treated analytically to yield an expression coupling the detonation pressure, extent of liquid cavitation, and wall shock attenuation rate. This expression, along with the applicable jump conditions for the cavitating liquid and an equation of state for the detonation products, yield a quantitative description of stable LVD. Calculated detonation velocities, pressures, and stability conditions are in very good agreement with the available experimental data for nitroglycerin, ethylene glycol dinitrate, and nitromethane.

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OP 4-73. Chemical Composition of Deep Formation Waters in Southwestern Louisiana, by Parke A. Dickey, A. Gene Collins, and Ivan Fajardo M. *Am. Assoc. Petrol. Geologists Bull.*, v. 56, No. 8, August 1972, pp. 1530-1533. Forty-one formation-water samples from gas fields near Lafayette in southwestern Louisiana were analyzed to determine whether there is any difference in chemical composition between waters in normally pressured and abnormally pressured geologic intervals. Indications are that the concentration of dissolved solids in the waters is related to the degree of compaction of the adjacent shale, and that most of the samples taken from high-pressure zones are less concentrated in dissolved solids than those taken from normally pressured zones.

OP 5-73. Infrared Structural Characterization of Single Grains From Two Apollo 15 Dusts, by P. A. Estep, J. J. Kovach, and C. Karr, Jr. *The Apollo 15 Lunar Samples*, ed. by J. W. Chamberlain and C. Watkins, Lunar Science Institute, Houston, Tex., October 1972, pp. 470-474. Single grains ($>150\mu$) of minerals, basalts, and glasses from two Apollo 15 dusts have been structurally characterized by infrared absorption spectroscopy. The two comprehensive dusts were obtained from geologically different terrains—sample 15301,83 from the Apennine Front on the northeast rim of Spur Crater (Station 7), and lying on a narrow ridge that may be a ray formed from the craters Aristillus or Autolycus; and sample 15601,72, from the Mare-Rille terrain, collected approximately 20 meters northeast of the rim of Hadley Rille (Station 9a), lying off the ridge. The infrared spectral data show that grains from each dust have distinctive structural features that characterize the site of collection and may help to interpret its geology. Structural features of grains from the Front dust were similar to those in grains that were previously isolated from Apollo 14 Fra Mauro highland samples, while those from the Rille dust were similar to those that were observed in grains from Apollo 11 and 12 mare basaltic samples. Differences between the two Apollo 15 samples as determined by single-grain infrared analyses may further serve to distinguish ray material from non-ray material. The dusts were dry-sieved and single grains isolated from only the +100 mesh fractions. The Front dust gave a smaller amount of +100 mesh (15.5 weight-percent) than the Rille dust (32.6 weight-percent), or any of the six other dusts that we previously studied from Apollo 11, 12, and 14 Missions (21.7 to 32.1 weight-percent). Infrared analyses for single grains from the dusts, as shown in table 1, were obtained by recently developed microsampling techniques. These made it possible to detect grain-to-grain structural variations in several different mineral classes within each dust sample, and to characterize the structures of some trace accessory minerals.

OP 6-73. Impending Mineral Supply Problems, by Stanley A. Feitler. *Communicator*, v. 3, No. 5, October 1972, pp. 5-6. Based on the trend of the 20-year period 1950-70, domestic primary mineral demand will exceed production by \$64 billion (1970 dollars) in the year 2000. Several options are open to avoid future balance-of-payments crises or reduced living standards. The options briefly discussed are recycle more mineral scrap, increase exports, increase the rate of growth of mineral production, and decrease the rate of growth of consumption.

OP 7-73. Effectiveness of Halogenated Agents Against Gaseous Explosions and Propellant Fires, by Joseph M. Kuchta and David Burgess. *Proc. Nat. Acad. Sci. Symp. on An Appraisal of Halogenated Fire Extinguishing Agents*, Apr. 11-12, 1972, pp. 257-277. This report summarizes Bureau of Mines studies on the effectiveness of halogenated agents as fire and explosion suppressants and on the limitations of a commercial Halon 1301 extinguisher for use as an ignition-quenching device. Halons containing bromine tend to be more effective than those without bromine in inerting hydrocarbon-air mixtures; the Halon 1301 requirement for inerting methane-air mixtures was greater than that previously published. Methane-air ignitions in the Bureau's Experimental Mine were quenched by a commercial Halon 1301 extinguisher only when the agent was applied before the fireball diameter exceeded some critical value (~ 18 inches). Dispersion experiments revealed that extinguishment failures in the mine tests were attributable to nonuniform agent distribution which resulted in the formation of voids with very low agent concentrations. A practicable concentration of Halon 1301 (for example, 10 percent) can inert a small spill of propellant such as Aerozine-50 at room temperature against ordinary ignition sources. However, impracticably high Halon concentrations would be required to extinguish an established Aerozine-50 pool fire or to inert the maximum vapor concentrations of this propellant possible in a closed chamber.

OP 8-73. Research and Development—Key to Advances for Rapid Excavation in Hard Rock, by James J. Olson and Thomas C. Atchison. *Proc. 1st North American Rapid Excavation and Tunneling Conf.*, AIME v. 2, ch. 78, 1972, pp. 1393-1441. The purposes of this paper are (1) to show the potential ability of technologic forecasting to meet future demands in rapid excavation through the acceleration of excavation rates by research and development in several related technologic fields, (2) to provide a brief review of the initial development of the ARPA (Advanced Research Projects Agency) Rock Mechanics and Rapid Excavation program, (3) to draw attention to the research projects completed or underway in the FY 1970-72 ARPA program and explain where information or program results can be obtained, (4) to summarize the progress and accomplishments of applied research contracts in the rock disintegration element of the ARPA program, and (5) to discuss the research directions planned for the remaining years of the program.

OP 9-73. Relaxation and the Behavior of Failed Rock, by S. Peng and E. R. Podnieks. *Internat. J. Rock Mechanics and Min. Sci.* v. 9, No. 6, November 1972, pp. 699-712. A servocontrolled hydraulic testing machine was used to conduct uniaxial compression tests which demonstrate the time-dependent behavior of a brittle porous rock such as tuff. The applied strain rate ranged from 10^{-2} to 10^{-7} /sec. The strength increased as applied strain rate was increased, and strength variation was confined to the range between elastic limit and ultimate stress. Load-deformation behavior for all test specimens was essentially the same for the load range below elastic limit regardless of applied strain rate. Stress relaxation curves were obtained by holding applied deformation constant as soon as a macrocrack initiation was observed in the specimen. From the behavior of stress relaxation, a theory of time-dependent rock strength was presented.

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OP 10-73. Study of Rock Behavior in Cyclic Loading, by Syd S. Peng, Egons R. Podnieks, and Patrick J. Cain. *Proc. 6th Conf. on Drilling and Rock Mechanics*, AIME, SPE 4249, 1973, pp. 181-186. Specimens of Salem Limestone were loaded cyclically at a frequency of two cycles per second in uniaxial cyclic compression, tension, and compression-tension. The maximum deformation with time for each cycle and the load-deformation hysteresis loops were recorded at predetermined intervals.

OP 11-73. Electrogasdynamics Application to Dust Monitoring, by Nelson S. Smith and George E. Fasching. *Proc. 2d Internat. Clean Air Congress*, Washington, D.C., Dec. 6-11, 1970, CP-19E, December 1971, pp. 432-436. Fly ash emissions from power-plant stacks are not as easily detected or measured as smoke or gaseous pollutants. To meet this need, the Bureau of Mines, U.S. Department of the Interior, is developing an instrument based on electrodynamic (EGD) principles to continuously measure and record the size distribution and mass flow rate of fly ash in stack gases. Such an instrument would have the advantage of continuous measurement over systems in which the fly ash is filtered, weighed, and analyzed on an intermittent basis. It would also have the advantage of size-determination capability of similar systems that can only determine the total mass flow rate. A study of EGD reveals that a gas stream carrying unipolar ions or charged particles can gain energy from or impart energy to the charged bodies. Although an obvious application of this interaction is that of power generation, other uses are possible, for example, dust precipitators. A precipitator based on the EGD principle is made up of three sections. The dust-laden gas stream first enters a high-velocity ionizing section where the dust particles take on a unipolar charge. The gas then passes through a dielectric diffusing section where the velocity is reduced to permit charged particle radial velocities of the same magnitude as the axial velocity. Finally, the stream enters a collecting section (metal) where the space charge of the particles causes them to move to the collector wall. Velocity of the gas is maintained low enough that reentrainment of the particles is minimal, and if the collector section is long enough more than 90 percent of the dust can be removed.

OP 12-73. Development and Potentials of Moiré Method of Strain Analysis for Rock Testing, by K. Thirumalai and R. L. Fischer. *Stability of Slopes*, *Proc., 13th Symp. Rock Mechanics*, ed. by E. J. Cording, American Society of Civil Engineers, 1972, pp. 727-751. Created by an optical interference of two closely spaced arrays of lines or grids, the moiré effect is a phenomenon offering a convenient means of detecting large field inplane displacements for strain analysis. This pioneering study carried out by the Bureau of Mines develops an experimental technique for using the moiré method in making remote full field strain distribution measurements for rock fragmentation study. The paper briefly explains the basic principles of the moiré method and its significance to measure strain distribution during rock testing.

OP 13-73. Diamond Drilling With Surfactants in Upper Michigan Conglomerates Using Surface-Set Bits, by Harold F. Unger, Byron S. Snowden, and William H. Engelmann. *Proc. 6th Conf. on Drilling and Rock Mechanics*, AIME, SPE 4236, 1973, pp. 71-77. A drilling study was carried out, testing two rotational speed levels, two diamond bit grade levels, and four flushing agents (including water as control).

The lower speed and higher thrust yielded faster penetration rates over those of the higher speed/lower thrust combination. Comparison of all low-speed/high-thrust groups of tests shows that the nonionic surfactant produced a 35-percent overall average increase over water, the anionic a 29-percent increase, and the cationic a 28-percent increase. These increases in penetration rates resulted in a 22- to 26-percent reduction in cost over flushing with water alone.

OP 14-73. Probe Drilling for Rapid Tunneling, by T. N. Williamson and R. L. Schmidt. *Proc. 1st North American Rapid Excavation and Tunneling Conf.*, AIME, v. 1, ch. 8, 1972, pp. 65-87. This paper describes one of several research projects funded by the Advanced Research Projects Agency to extend the technology of rapid underground excavation. This study and field research effort are to investigate alternative means to determine rock and geological conditions in advance of a tunnel boring machine (TBM). Approximately 1 year of a planned 3-year program has resulted in the definition of three candidate drill systems. Hardware has been assembled to field test these candidates and testing has begun.

OP 15-73. Dry Separation of Pyrite From Coal, by William T. Abel, Michael Zulkoski, and Galen J. Gauntlett. *I&EC Prod. Res. and Develop.*, v. 11, September 1972, pp. 342-347. A dry separation process for removing pyrite from fine coal by use of centrifugal and electrostatic methods removed 30-50 percent of the total pyritic sulfur (equivalent to 50-70 percent of the available pyritic sulfur). Both separation methods were benefited by restricting particle size range and keeping pyrite particles as large as possible. Removal efficiency, therefore, was increased by integrating the separation and grinding steps as in stage grinding. With stage grinding, nearly 90 percent of the available pyritic sulfur was removed from a Pittsburgh seam roof coal.

OP 16-73. New Packer Helps Control Methane in Coal Mines, by J. H. Cobbs and J. D. Hadden. *Coal Age*, v. 78, No. 1, January 1973, pp. 60-62. A new type of borehole packer has been developed and tested which has proved superior in performance to the conventional balloon-type packers and yet costs less than half that of the balloon types. The new packer, designed and manufactured by James H. Cobbs Engineering, works on a unique compression principle and thus cannot suffer a rupture of its sealing element. The simplicity of the new packer permits it to be easily disassembled in the field for maintenance. Moreover, its weight has been reduced to about half that of the balloon types. Interest in packers has grown because of the Bureau of Mines' search for improved methods for controlling the emission of methane in coal beds. One control technique would divert the methane from an active face area through the use of horizontal holes drilled in the coal bed. Another method employs water infusion to block the methane from entering the face area. In each case the methane emissions in the active face area are cut down, thus reducing the possibility of a methane ignition.

OP 17-73. Two-Dimensional Lattice Orientation and Three-Dimensional Crystallinity in Carbon Fibres, by Sabri Ergun. *Nature Phys. Sci.*, v. 238, No. 87, August 1972, pp. 137-139. It has been found that some carbon fibers prepared from polyacrylonitrile possess three-dimensional crystallinity of a graphite-

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like lattice, and that the two-dimensional graphite-like lattice has a preferred orientation with respect to the fiber axis in addition to being parallel to the fiber axis. The observed two-dimensional preferred orientation and other considerations indicate that fibers possess a three-dimensional lattice.

OP 18-73. Reaction of Coal With Nitrogen in a Microwave Discharge, by Y. C. Fu, B. D. Blau-stein, and A. G. Sharkey, Jr. *Fuel*, v. 51, No. 4, October 1972, pp. 308-311. In a microwave discharge in nitrogen, high-volatile bituminous coal produces gaseous products, namely hydrogen cyanide, acetylene, small amounts of cyanogen and low-molecular-weight hydrocarbon gases, and nitrogen-containing compounds, in addition to the usual hydrogen and carbon oxides. The reaction of coal in the nitrogen discharge occurs in two stages: interaction of active nitrogen with the coal molecule to cause rapid volatilization of gaseous products, and slow gasification of residual char by active nitrogen. Various factors influencing product type, yield, and distribution are examined. Under conditions where the gaseous products can be quickly quenched or removed, as by trapping at a very low temperature, more than 42 percent of carbon in the coal can be converted mainly to hydrogen cyanide and acetylene, which together constitute about 90 percent of the total products.

OP 19-73. Safety Design for Metal Tailings Dams, by Dan Kealy. *Min. Cong. J.*, v. 59, No. 1, January 1973, pp. 51-55. Mineral tailings can be used to build structurally safe tailings embankments. Recent technology has provided engineers with the "tools" needed to assess overall embankment stability. For example, one can predict the ultimate height to which the dam can be built and still remain safe. Complete control of surface and seepage water is the key requirement to building safe dams. In general, peripheral discharge building methods promote safe tailings ponds via good water control, and, in addition, aid in controlling environmentally detrimental water. Practical testing and instrumentation technology are available to monitor the safety of any embankment on a routine basis. Some thoughts relative to design requirements for final abandonment of the tailings pond are also presented.

OP 20-73. Delineation of Subsurface Fracture System in a Petroleum Reservoir: An Experiment, by C. A. Komar, L. Z. Shuck, W. K. Overbey, Jr., and T. O. Anderson. Pres. at 47th Ann. Fall Meeting, Soc. Petrol. Eng., AIME, San Antonio, Tex., Oct. 8-11, 1972, SPE Preprint 4048, 8 pp. Short-duration pressure-interference tests were conducted to delineate the natural and induced subsurface fracture system in a petroleum reservoir near Bradford, Pa. The test site is a 36-acre lease with 16 five-spots. Pressure sensors were put in 40 wells. Pressure responses were measured before, during, and after each well was pressured at 1,400 psig for 30 minutes and 10 hours and at 2,000 psig (surface pressure) for 15 minutes. Responses were obtained at 300 to 1,000 feet from the injection well and were automatically recorded at preselected intervals ranging from 30 seconds to 1 hour. Small increases in pressure during various injection tests indicated near wellbore communication and the location, extent, and orientation of joints and fractures. The multi-sensor array demonstrated that hydraulic pressurization can be useful in delineating subsurface fracture

systems in petroleum reservoirs and can help petroleum reservoirs and can help petroleum engineers establish patterns of injection and production wells to avoid premature waterfront breakthrough, thus increasing sweep efficiency and oil recovery from flooding operations.

OP 21-73. New Techniques for Rock Fracture Energy Measurements, by Warren W. Krech and Peter G. Chamberlain. Pres. at 47th Ann. Fall Meeting, Soc. Petrol. Eng., AIME, San Antonio, Tex., Oct. 8-11, 1972; SPE Preprint 4060, 6 pp. The use of closed-loop, servo-controlled test systems to obtain rock fracture energy measurements in uniaxial tension, torsion, and direct shear is described. Results of fracture energy tests performed on three rock types are presented. Analysis of the test results substantiates the usefulness of measuring fracture energy by the new test techniques. The advantage of these new tests, providing data potentially useful for input into analytical rock response calculations, far outweighs the advantage of the usual test methods—simplicity of test procedure. Fracture energy values for three rock types tested under a series of load configurations indicate that fracture energy requirements increase with confining stress level. The ratio of fracture energy required in uniaxial compression to that in uniaxial tension ranges from 140 for Berea Sandstone to 560 for Barre Granite.

OP 22-73. Solution Mining, by William A. McKinney. *Min. Eng.*, v. 25, February 1973, pp. 56-57. This article describes current technology and research programs involved with solution mining. Increased pressure to develop technology for the recovery of metals and minerals with minimum pollution of the environment resulted in many new developments in solution or chemical mining in 1972, particularly apparent in the number of new field applications of true solution mining or in situ leaching of copper ores.

OP 23-73. Plugging Abandoned Gas and Oil Wells, by Joseph Pasini III, G. E. Rennick, F. E. Armstrong, and J. R. Abrams. *Min. Cong. J.*, v. 58, No. 12, December 1972, pp. 37-42. The U.S. Bureau of Mines is investigating the plugging of low-productivity wells and the reopening and replugging of abandoned wells as a means of solving various problems these wells pose to coal mining operations. This has resulted in an effort to develop and demonstrate the safety and feasibility of an improved mandatory safety standard to regulate the maintenance or elimination of coal pillars around oil and gas wells.

OP 24-73. Carbon-13 Magnetic Resonance in Diamonds, Coals, and Graphite, by H. L. Retcofsky and R. A. Friedel. *J. Phys. Chem.*, v. 77, January 1973, pp. 68-71. Carbon-13 magnetic resonance (^{13}C NMR) spectra of gem-quality diamonds, powdered natural graphite, and four coals were obtained as part of a comprehensive spectral investigation of the structure of coal and other carbonaceous materials. The chemical shift in diamond was found to agree well with empirical predictions based on prior studies of pure aliphatic and alicyclic hydrocarbons. The spectrum of graphite reflects both a chemical shift anisotropy and the semiconductivity of the material. The results for the coals were compared with those

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for diamond and graphite and found to be best rationalized in terms of increasing carbon aromaticity with increasing coal rank leading finally to the formation of graphite-like structures.

OP 25-73. Note on the Communication "Characteristic ^{13}C NMR Chemical Shifts in Organic Materials" by Jensen and Petrakis, by H. L. Retcofsky and R. A. Friedel. *J. Magnetic Resonance*, v. 8, 1972, p. 398. Recently, Jensen and Petrakis published a potentially useful chemical shift-structure correlation chart for ^{13}C NMR. The chart, though reasonably comprehensive, neglects allenic type carbons. We feel that this is an unfortunate omission since (1) allenic carbons of the type $=\text{C}=$ give chemical shifts in the region generally attributed to carbonyl carbons, and (2)

$=\text{CH}_2$ and $=\text{CH}$ allenic carbon resonances appear in the same spectral region as do the triply bonded carbons in alkynes.

OP 26-73. Adsorption of Methane/Ethane Mixtures on Dry Coal at Elevated Pressure, by T. C. Ruppel, C. T. Grein, and D. Bienstock. *Fuel*, v. 51, October 1972, pp. 297-303. The binary adsorption characteristics of methane and ethane on dry coal to 40 atm pressure have been calculated from pure-component isotherms. In some coal seams, pressures exceeding 40 atm have been recorded and the methane sampled from the virgin coal often shows a few percent of ethane. The binary adsorption characteristics were calculated by employing the ideal adsorbed solution theory of Myers and Prausnitz, and experimentally-determined (Type I) pure gas isotherms at 0° , 30° , and 50° C. The coal used in this investigation was high-volatile A bituminous (hvab) from the Pennsylvania Pittsburgh seam. Gas nonideality was accounted for by replacing pressure with fugacity. Adsorption of methane on dry coal is purely physical; the isosteric heat of adsorption does not exceed 2.4 kcal/mol at 30° C on the above coal. Isobars on the resulting binary equilibrium diagram exhibited an unexpected phenomenon of intersecting each other which might be attributable to the above nonideality considerations. The region of a few percent of ethane, which is of practical importance from the viewpoint of coal seams, was expanded and reduced to an equation: $V(\text{CH}_4) = -21.52 + 7.18(VF) + 16.88(VF)^2 - 0.395(P) - 0.00661(P)^2 + 0.824(T) - 0.00030(T)^2 + 0.928(VF)(P) - 0.858(VF)(T)$. $V(\text{Total}) = 25.9 - 23.6(VF) + 0.655(P) - 0.00875(P)^2 - 0.795(T) + 0.743(VF)(T)$ where $V(\text{CH}_4)$ and $V(\text{Total}) = \text{cm}^3(\text{STP})\text{CH}_4$ and total gas respectively adsorbed per g dry coal; VF = volume fraction of methane as analyzed at 1 atm ($0.94 \leq VF \leq 1.0$); P = seam pressure, atm ($0 \leq P \leq 40$); T = seam temperature, $^\circ\text{C}$ ($-10 \leq T \leq 50$).

OP 27-73. Thermal Analysis in Earth Science: Experience and Expectations, by John Ward Smith. *Proc. 3d ICTA Davos*, v. 3, 1971, pp. 605-635. Thermal analysis in earth science is a relatively mature field with a huge background of experience. Throughout its development thermal analysis has been preoccupied with characterization of rocks and minerals, the primary use of thermal analysis in earth science. The clays, now largely a standardized part of ceramics studies, claimed a major part of the early work. Recently, however, development of thermal analysis in the area of earth science has slackened. The widespread routine use of thermal analysis in soil characterization, clay testing, and

raw material evaluation for several types of manufacturing insures that the field is still viable. Both the routine application and the decline in published developments, however, indicate that thermal analysis in earth science is a mature field whose basic information has largely been amassed. Development now requires (1) moving in new directions which can exploit this amassed knowledge, and (2) accepting problems of broader scope like the study of more complex materials. An example of such a material is oil shale of the Green River Formation. Scope of the oil-shale problem is outlined. This paper attempts to highlight patterns for development by surveying and evaluating some of the information already compiled, reviewing problems specific to applying thermal analysis to earth science, suggesting ways of meeting these problems, surveying new developments, and postulating directions that thermal analysis might move in earth science.

OP 28-73. Preparation of High-Purity Vanadium by Magnesium Reduction of Vanadium Dichloride, by T. T. Campbell, J. L. Schaller, and F. E. Block. *Metall. Trans.*, v. 4, January 1973, pp. 237-241. High-purity vanadium was made by magnesium reduction of vanadium dichloride. Procedures used included (1) the preparation of vanadium tetrachloride by chlorination of partially reduced vanadium oxide-carbon briquets, (2) rechlorination of crude vanadium tetrachloride containing oxychloride compounds, (3) thermal decomposition of vanadium tetrachloride to vanadium trichloride, (4) hydrogen reduction or thermal disproportionation of vanadium trichloride to vanadium dichloride, (5) magnesium reduction of vanadium dichloride to vanadium sponge, and (6) consolidation of vanadium sponge to metal by arc-melting. This work showed that higher yields of high-quality vanadium metal can be prepared by reduction of vanadium dichloride than can be prepared from trichloride. Metal of >99.8 pct purity was prepared by magnesium reduction of vanadium dichloride with reaction efficiencies approaching 98 pct. Only minor losses of vanadium are experienced because of the high efficiencies of the individual process steps and because of the potential for recycling process streams.

OP 29-73. Perspectives in Current Research for Control of Airborne Dust in Coal Mines, by W. G. Courtney. *Annals New York Acad. Sci.*, v. 200, Dec. 29, 1972, pp. 717-723. The Federal Coal Mine Health and Safety Act of 1969 specified that the maximum allowable concentration of airborne respirable dust in bituminous coal mines in the United States be 2 mg/m^3 by the final deadline of December 30, 1975. Although the actual operational deadline for imposition of the 2 mg/m^3 level is uncertain because the Interim Compliance Panel (ICP) can issue or refuse noncompliance permits that allow operation at an interim 3 mg/m^3 level, it is generally expected that the ICP will refuse noncompliance permits if the available dust control technology is deemed adequate and is not being fully used.

The 1969 Act also directed that the Departments of the Interior and Health, Education, and Welfare shall "develop new or improved means and methods of reducing the concentration of respirable dust in the mine atmospheres of active workings of the coal mines." Advanced technology would assist the mine operator in meeting the stringent dust limits imposed by the Act. The Federal Bureau of Mines was assigned the responsibility for designing and implementing a research and development program to

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provide the advanced technology for reducing coal mine respirable dust. This paper briefly describes the Bureau's program.

OP 30-73. Recent Advances in the Analysis of Respirable Coal Dust for Free Silica, Trace Elements, and Organic Constituents, by R. W. Freedman and A. G. Sharkey, Jr. *Annals New York Acad. Sci.* v. 200, Dec. 29, 1972, pp. 7-16. The occurrence of pneumoconiosis (black lung disease) in coal miners has prompted considerable study of the chemical agents that may be implicated. Miners who suffer from this malady undergo long-term accumulation of carbonaceous and other particles in the lungs. The classes of material chosen for study in this paper are free silica (crystalline or amorphous SiO_2), elements (mainly trace metals), and organic compounds. Background information in each area is briefly presented before the discussion of analytical advances.

OP 31-73. Nonferrous Metals in 1972, by R. A. Heindl, *Min. Cong. J.* v. 59, No. 2, February 1973, pp. 94-99. The Nonferrous Metals industry in 1972 was a microcosm of the economic world. There were no major strikes, demand increased, and prices increased. However, at the year's end the industry faced numerous problems.

OP 32-73. Electrolytic Preparation of Vanadium From Vanadium Carbide, by K. P. V. Lei, R. E. Campbell, and T. A. Sullivan. *J. Electrochem. Soc.*, v. 120, February 1973, pp. 211-215. The preparation of vanadium by molten-salt electrolysis of a commercial vanadium carbide (VC) containing 84 percent vanadium was investigated. An electrolytic process was developed for the extraction of vanadium from VC in an LiCl-NaCl-VC_2 electrolyte contained in a helium-atmosphere cell at 650°C. The effects of electrolyte composition, vanadium depletion of the VC, and cathode current densities on the process, as well as the effects on the quality of vanadium products, were determined. Vanadium of 99 percent purity was prepared with an 85 percent recovery of vanadium and a cathode current efficiency of 70 percent. The vanadium contained approximately 0.60 percent oxygen and had a 100 Rockwell B hardness. High-purity, ductile vanadium was prepared from the VC by electrorefining the extraction products in a separate cell or by combining the extraction and electrorefining processes in a single cell. In the combined process, the vanadium was first extracted from the VC and deposited on a cylindrical electrode; this vanadium was then electrorefined and deposited on a central cathode rod. Both methods yielded vanadium of 99.9 percent purity with 35-40 Rockwell B hardness. With limited tests in the combined process, 58 percent recovery of ductile vanadium from the VC was achieved.

OP 33-73. Sampling Techniques for Raman Spectroscopy of Minerals, by Leo E. Makovsky. *Appl. Spectroscopy*, v. 27, No. 1, January/February 1973, pp. 43-44. When using laser Raman spectroscopy to study heterogeneous mineral samples such as ores and rocks, it is frequently necessary to isolate small homogeneous particles embedded in the heterogeneous matrix without mechanically destroying the matrix. For this purpose a simple masking device was constructed which, if necessary, can be purged with inert gas during illumination.

OP 34-73. High-Temperature Thermal Analysis of the Systems $\text{LaF}_3\text{-YF}_3$, $\text{SrF}_2\text{-YF}_3$ and $\text{MgF}_2\text{-YF}_3$, by R. H. Nafziger, R. L. Lincoln, and N. Riazance. *J. Inorganic Nuclear Chem.*, v. 35, February 1973, pp. 421-426. Thermal analysis experiments have established high-temperature phase relations in three systems containing YF_3 having potential use as fluxes for electroslag melting of reactive metals. The $\text{LaF}_3\text{-YF}_3$ system is characterized by (1) a eutectic occurring at 81 wt percent YF_3 and approximately 400° C below the LaF_3 melting point, (2) a low-temperature hexagonal compound, (3) an extensive LaF_3 solid solution, and (4) limited YF_3 solid solution. A hexagonal compound with a range of composition, and whose X-ray lattice parameters increase with increasing SrF_2 content, is stable in equilibrium with liquid in the $\text{SrF}_2\text{-YF}_3$ system, resulting in the presence of two eutectics. A small liquidus-curve maximum occurs in the region where an extensive fluorite solid solution is the primary phase. No discernible solid solubility of SrF_2 in YF_3 was detected. The $\text{MgF}_2\text{-YF}_3$ system contains one eutectic with limited terminal solid solution and a possible low-temperature compound. Due primarily to higher liquidus temperatures, systems containing LaF_3 possess a wider range of suitable electroslag fluxes than do systems containing YF_3 . However, an optimum combination of high liquidus temperature and low electrical conductivity indicates that selected compositions containing relatively low YF_3 in these systems may provide useful fluxes. Compounds present in systems containing YF_3 would probably not find uses in the electroslag process because of their relatively low stability temperatures.

OP 35-73. Aerosol Deposition on a Charged Plastic Surface, by R. L. Stein and W. H. Ryback. *Annals New York Acad. Sci.*, v. 200, Dec. 29, 1972, pp. 737-746. Qualitative information regarding respirable coal dust electric charge distribution was inferred from the rate of concentration decrease in a plastic chamber.

OP 36-73. Mixed Potassium-Cesium Seeding in Open-Cycle MHD Power Generation, by P. D. Bergman and D. Bienstock. 13th Symp. Eng. Aspects of Magnetohydrodynamics, Stanford University, Palo Alto, Calif., Mar. 26-28, 1973, pp. V.5.1-V.5.6. The high price of pollucite ore, its limited availability, and the need to provide stack removal of SO_2 present formidable obstacles to the use of pure cesium as a seeding material in open-cycle MHD power generation. Cost estimates indicate that mixed potassium-cesium seeding is preferable to the use of either pure cesium or pure potassium. Cheaper electricity and higher open-cycle MHD operating efficiencies result from the use of mixed seed. Savings of \$3 million per year in power costs for a 1,000 MWe open-cycle MHD powerplant are envisioned if the mixed seeding technique is adopted.

A coal-burning combustion experiment employing a 15 mole-percent cesium carbonate-85 mole-percent potassium carbonate seed was conducted in the 89 has been made by reforming hydrogenated shale oil at 900°F and 200 psig. Bureau of Mines MHD pilot plant. The resulting mixed seed-fly ash residue was leached with hot water. It was established that cesium seed recovery is of no greater order of difficulty than that for potassium.

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- OP 37-73. Air Pollution Aspects of MHD Power Generation**, by D. Bienstock, P. D. Bergman, J. M. Henry, R. J. Demski, J. J. Demeter, and K. D. Plants. 13th Symp. Eng. Aspects of Magnetohydrodynamics, Stanford University, Palo Alto, Calif., Mar. 26-28, 1973, pp. VII.1-VII.1.10. Magnetohydrodynamics has very low air-pollution potential. In pilot plant tests in which a 2.2 wt-pct sulfur coal was burned in a cyclone furnace at 200 lbs/hr and 4,000° F (2,500° K) at a seed concentration of 1 g-mole K_2CO_3 /kg coal, 99.8 percent removal of SO_2 was obtained with only 5 ppm SO_2 in the gaseous effluent. Operating the combustor with 95 percent of stoichiometric oxygen and ambient air admitted at 2,000° F (1,370° K), NO_x emissions decreased to 150 ppm or 0.12 lb NO_2 /million Btu. This represents a 94 percent reduction from single-stage operation at 102 percent of stoichiometric oxygen. As the gas-cooling rate in the experimental unit is higher than projected for a commercial plant, it is expected that a commercial plant would experience even lower NO_x emissions. A mathematical model using the Zeldovich mechanism was adequate to follow the NO_x decomposition in the air-rich system; an extended Zeldovich was more appropriate in the fuel-rich regime. Experiments showed that at high slag-rejection rates of greater than 90 percent, recovery of the potassium seed by aqueous extraction was better than 99 percent. Cost estimates of a 1,000-MWe MHD-steam plant, in which the spent seed is recovered by aqueous extraction and then regenerated with reducing gases to remove the sulfur, showed an operating cost of the seed recovery-sulfur removal steps of 8 percent of the overall power costs of 10.3 mills/kwh. Seed make-up costs have a marginal impact even at potassium recoveries as low as 95 percent. The capital costs of SO_2 removal is \$10.4/kw, approximately one-fifth of that in conventional power plants.
- OP 38-73. Upgrading the Iron Content of Blast Furnace Dusts by Coke Flotation**, by Arthur F. Colombo. Ironmaking Proceedings, Metall. Soc. AIME, Chicago, Ill., v. 31, 1972, pp. 320-328. Blast furnace dusts from the Ford Motor Company's Steel Division Operation were separated into coke and iron oxide products by applying a fuel oil-frother flotation system.
- OP 39-73. Bureau of Mines Synthane Process: Research and Development on Converting Coal to Substitute Natural Gas**, by Richard C. Corey. Proc. Conf. Synthetic Fuels from Coal, Oklahoma State University, Stillwater, Okla., May 1, 1972. 35 pp. This article summarizes the national energy problem, the role of substitute natural gas (SNG) in meeting growing demands for non-polluting fuel, and describes the laboratory- and pilot-plant development of the Bureau of Mines Synthane process for converting coal to SNG.
- OP 40-73. Depleted Uranium as Catalyst for Hydrocracking Shale Oil**, by Philip L. Cottingham and Lawrence K. Barker. I&EC Prod. Res. and Develop., v. 12, No. 1, March 1973, pp. 41-47; Preprints, Div. Fuel Chem., ACS, v. 16, No. 2, 1972, pp. 24-46. This article describes the process by which low nitrogen and sulfur gasoline with an octane number of 89 has been made by reforming hydrogenated shale oil at 900° F and 200 psig.
- OP 41-73. Ignition of Methane by Frictional Sparks Between Metals and Rusty Steel**, by D. H. Desy, J. S. Risbeck, and L. A. Neumeier. Pres. at Ann. Meeting Soc. Min. Eng., AIME, Chicago, Ill., SME Preprint 73-F-29, Feb. 25-Mar. 1, 1973, 8 pp. This research was undertaken to establish the incendivity of aluminum alloys against rusty steel under frictional impact conditions at typical coal mine fan speeds, to determine any differences in incendivity among various aluminum alloys, and to investigate less incendive materials as substitutes for aluminum alloys. With a specially designed apparatus, three aluminum casting alloys and three constructional steels were tested for incendivity in frictional impact against rusted steel in flammable methane-air mixtures. Although varying in degree, all aluminum alloys investigated exhibited a high ignition probability under the test conditions; none of the steel specimens tested caused any ignitions under the same conditions.
- OP 42-73. Prerduced Pellets From Iron and Steelmaking Wastes**, by W. M. Dressel, P. G. Barnard, and M. M. Fine. Pres. at Ann. Meeting Soc. Min. Eng., AIME, Chicago, Ill., SME Preprint 73-B-82, Feb. 25-Mar. 1, 1973, 12 pp. Over 2 million tons of steel furnace dusts are produced each year in the United States. Recycling of these dusts rather than disposal would conserve mineral resources, reduce land requirements for disposal, and decrease pollution. In addition to the iron content, the dusts contain appreciable amounts of zinc and lead. Removal of lead and zinc with simultaneous reduction of iron oxide has been achieved by inert atmosphere roasting of carbon-containing pellets prepared from steel furnace wastes. High- and low-carbon wastes were blended to obtain mixtures with sufficient carbon to serve as a reductant during subsequent roasting. The mixtures were pelletized with the addition of bentonite and water, and the dried pellets were roasted in a stream of nitrogen at temperatures ranging from 900° to 1,150° C. Zinc and lead contents were reduced to the 0.1 percent level or less by roasting mixtures containing as little as 7 percent carbon for 1 hour at 1,100° C. Iron metallization increases with available carbon content; 50 percent metallization is achieved with 7 percent carbon, 85 percent metallization with 12.5 percent carbon, and over 95 percent metallization when the pelletized mixtures contained in excess of 20 percent carbon.
- OP 43-73. 3-Methylpentane and 3-Methylheptane. Low-Temperature Thermodynamic Properties**, by H. L. Finke and J. F. Messerley. J. Chem. Thermodynamics, v. 5, No. 2, 1973, pp. 247-257. Low-temperature thermal properties of 3-methylpentane and 3-methylheptane were measured by adiabatic calorimetry from 10° to 330° K and 10° to 380° K, respectively. The results were used to calculate the thermodynamic functions at selected temperatures for the solid and liquid phases.
- OP 44-73. Instrumentation and Techniques for Measuring Emissions**, by R. W. Hurn. Ch. in Engine Emissions: Pollutant Formation and Measurement, ed. by G. S. Springer and D. J. Patterson. Plenum Publishing Corp., New York, 1973, pp. 291-317. The chapter covers instrumentation and procedures for the measurement of objectionable air pollutants in auto exhaust. Instruments that are suitable for the application are described; proper use and operation are discussed.

OP 45-73. Coal Mine Explosions: Seasonal Trends, by Fred N. Kissell, Allan E. Nagel, and Michael G. Zabetakis. *Science*, v. 173, Mar. 2, 1973, pp. 891-892. An analysis of disaster reports on coal mine explosions indicates that gas explosions are randomly distributed throughout the year, whereas dust explosions (which may or may not be triggered by a gas explosion) occur with greater frequency during the dry fall and winter months. The lack of adequate moisture during cold weather tends to increase the rate and severity of the dust explosions.

OP 46-73. Rapid Excavation and the Role of Engineering Geology, by Leonard Obert. *Geological Factors in Rapid Excavation* (Engineering Geology Case History Number 9), ed. by H. J. Pincus, The Geological Society of America, Boulder, Colo., 1973, pp. 1-4. There is ample testimony that the demands for underground excavation will increase significantly in the future. Because of these increasing demands, there is a special incentive for improving all phases of underground excavation techniques. The author of this article addresses himself to the role of engineering geology and the engineering geologist in improving the underground excavation process.

OP 47-73. Some Geologic Structural Influences in Quarrying Limestone and Dolomite, by Joseph M. Pugliese. *Geological Factors in Rapid Excavation* (Engineering Geology Case History Number 9), ed. by H. J. Pincus, The Geological Society of America, Boulder, Colo., 1973, pp. 11-16. The objective was to determine to what extent geology, mainly structure, influenced blasting practices and results in limestone and dolomite quarries, and to ascertain how geologic features could be utilized to advantage in quarrying. The rock in the quarries visited was mined by bench blasting with long cylindrical charges in vertical boreholes. The gross geologic features observed to influence blasting are: Horizontal bedding without conspicuous jointing, horizontal bedding with conspicuous jointing, and folds, faults, unconformities, caves, and filled joints. As an ex-

ample of how geology affects blasting, horizontal bedding with conspicuous jointing provided a condition where ammonium nitrate-fuel oil, AN-FO, misfired. The following reasons for the misfire are possible: (1) When poured into the borehole, the AN-FO was lost into open joints and bedding; (2) water migrating along joint and bedding planes intersecting boreholes desensitized the AN-FO because the blasting agent was not loaded into a plastic sleeve; (3) the undetonated explosive column in the borehole was cut off by rock shifting along bedding and joint planes. This shifting is caused by rock stresses produced by earlier detonation of nearby charges. A first step in planning a blast design is to identify the geologic features such as those mentioned above. The quarry officials attempt to adjust blasting techniques to minimize detrimental geologic effects and maximize beneficial geologic effects.

OP 48-73. Equilibrium Electron Density of Coal-Combustion Mixtures—Computer Study and Comparison With Experiment, by F. E. Spencer, Jr., J. C. Hendrie, Jr., and D. Bienstock. 13th Symp. Eng. Aspects of Magnetohydrodynamics, Stanford University, Palo Alto, Calif., Mar. 26-28, 1973, pp. VII.4.1-VII.4.6. Computer electron densities and conductivities are reported for a typical seeded coal combustion mixture. Results are compared with those for a clean fuel gas produced from the same coal, from which the ash, sulfur, and chlorine have been excluded.

The radical OH appears to be the most important electron acceptor in clean systems. For direct coal firing however, one should consider the ions AlO_2^- , BO_2^- , Cl^- , PO_2^- , and SO_2^- , all of which have noticeable (order of 1 percent or more) effects on electron density.

OP 49-73. Deposition of Aerosol in a Plastic Chamber, by R. L. Stein, W. H. Ryback, and A. W. Sparks. *J. Colloid and Interface Sci.*, v. 42, February 1973, pp. 441-447. A study was made of the concentration decrease of aerosol in a polystyrene chamber. Losses to the walls of the plastic chamber owing to electrostatic attraction were as high as 75 percent in 20 min. Using a dry aerosol dispersion technique, the wall-loss rate constant β was nearly independent of concentration but decreased with time. A spray aerosol dispersal technique from ethanol gave lower values of β , which were either constant or slightly decreasing with time. These differences have been attributed to electrical mobility distributions produced by the dispersal techniques.

OP 50-73. Noise Control for the Pneumatic Rock Drill, by Aarne Visnapuu and James W. Jensen. Pres. at Ann. Meeting Soc. Min. Eng., AIME, Chicago, Ill., SME Preprint 73-AU-62, Feb. 25-Mar. 1, 1973, 17 pp. Unmodified pneumatic rock drills may have noise levels of 115 to 130 dB at the operator's position. Experimental modifications have been made to a standard drill to suppress the noise from the three main sources: the air exhaust noise, the noise radiated from the drill, and the resonance noise of the steel drill rods. A prototype model developed at the Bureau of Mines, Rolla Metallurgy Research Center, operates at a noise level below 100 dB. A close-fitting case and muffler unit, consisting of a metallic skeleton filled with viscoelastic absorber and having a durable cover, provided both muffling and noise absorption. Damping alloys were used at strategic points in the drill. Drill steel resonance noise was reduced by a constrained-layer treatment on the outside of the drill rod. The singular and combined effects of the treatments are presented in detail.

OP 51-73. Light Oils From Hydrocarbonization of Coal, by J. R. Comberati, J. O. Mapstone, Jr., L. R. Little, Jr., and C. Karr, Jr. *Proc. West Virginia Acad. Sci.* (1971), v. 43, 1973, pp. 127-136. Yields and characteristics of light oil in the gasoline boiling range were determined for six coals ranging in rank from low-volatile bituminous to lignite. The coals were hydrocarbonized at low temperature in a fixed-bed carbonizer, and the vapors produced were catalytically hydrorefined at hydrogen pressures of 300, 600, and 900 psig. Light oil produced in this manner was olefin free and rich in benzene, toluene, and xylene (BTX), and would be suitable for blending in the production of nonleaded gasoline. A maximum BTX yield of 76 lb was obtained from a ton of dry, ash-free high-volatile bituminous coal. Linear polynuclear aromatic compounds were found in the tar in sufficient amounts to make this a potential source of additional benzene, toluene, and xylene.

OP 52-73. Infrared and Raman Spectroscopic Studies of Structural Variations in Minerals From Apollo 11, 12, 14, and 15 Samples, by P. A. Estep, J. J. Kovach, P. Waldstein, and C. Karr, Jr. *Proc. 3d Lunar Sci. Conf.*, Houston, Tex., Jan. 10-13, 1972 (Supplement 3, *Geochimica et Cosmochimica Acta*), The M.I.T. Press, v. 3, 1972, pp. 3047-3067. Infrared and Raman vibrational spectroscopic data, yielding direct information on molecular structure, have been obtained

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for single grains ($> 150 \mu\text{m}$) of minerals, basalts, and glasses isolated from Apollo 11, 12, 14, and 15 rock and dust samples, and for grains in Apollo 14 polished butt samples. From the vibrational data, specific cation substitutions were determined for the predominant silicate minerals of plagioclase (An_{71} to An_{95}), pyroxene (Fs_6 to Fs_{53}), and olivine (Fa_{14} to Fa_{45}). Unique spectral variations for grains of K-feldspar, orthopyroxene, pyroxenoid, and ilmenite were observed to exceed the ranges of terrestrial samples, and these variations may be correlatable with formation histories. Alpha-quartz was isolated as pure single grains, in granitic grains composited with sanidine, and in unique grains that were intimately mixed with varying amounts of glass. Accessory minerals of chromite and ilvospinel were isolated as pure grains and structurally characterized from their distinctive infrared spectra. Fundamental vibrations of the SiO_4 tetrahedra in silicate minerals were used to classify bulk compositions in dust sieved fractions, basalt grains, and glass particles and to compare model characteristics for maria, highland, and rille samples. No hydrated minerals were found in any of the samples studied, indicating anhydrous formation conditions.

OP 53-73. Novel Wet-Digestion Procedure for Trace-Metal Analysis of Coal by Atomic Absorption, by A. M. Hartstein, R. W. Freedman, and D. W. Platner. *Anal. Chem.*, v. 45, No. 3, March 1973, pp. 611-614. Coal workers' pneumoconiosis, its causes and cure, is the subject of intensive studies by different laboratories throughout the world. This form of pneumoconiosis is believed to be caused by the inhalation and retention of respirable coal mine dust. Whether specific chemical compounds or synergistic effects of several compounds exacerbate the effects of the disease is not presently known. It is clear that before these questions may be answered a complete chemical analysis of coal dust must be made. This may then be compared with chemical analysis of coal dust found in the lungs of deceased coal workers. Discrepancies between these results may then indicate suspect chemical compounds. As part of an investigation to fully analyze respirable coal dust, trace elemental analysis by a novel wet-digestion procedure was developed.

OP 54-73. Matching Calculated With Actual Waterflood Performance With Estimation of Some Reservoir Properties, by R. V. Higgins and A. J. Leighton. *Soc. Petrol. Eng. AIME, Preprint SPE 4412*, May 15, 1973, 4 pp. The Higgins-Leighton mathematical model was tested by comparing the prediction of performance with observed performance in a mature waterflood in the Dominguez field in Southern California. Although accurate reservoir data were not available, the first match was a reasonably good first approximation. For example, the deviation between the calculated and actual recovery for the first 5 years averaged above 15 bbl/acre-ft. Study of the results of the first match indicated that it could be improved by using revised estimates for two variables, interstitial water saturation and permeability distribution. By trial and error with successive revision of these two variables, values were obtained which gave an excellent match. The deviation between the calculated and actual recovery averaged 4 bbl/acre-ft. The results showed that the reservoir contained more mobile water at the beginning of the flood than suspected by the operator and that a few high-permeability layers had produced the major part of the oil produced from the 155-ft section.

OP 55-73. Coal Ash Analysis With an Argon Plasma Emission Excitation Source, by Susanne S. Karacki. *Appl. Spect.*, v. 27, No. 1, January-February 1973, pp. 41-42. Knowledge of the composition of coal ash and related materials has become important today in the investigation of air and water pollution, coal miners' pneumoconiosis, and strip mine reclamation as well as in the traditional investigation of clinkering and slagging problems in industrial use. Simplified procedures are needed to analyze these materials. In 1962, a description of a rapid method for analyzing coal ash based on colorimetric, flame photometric, and chelatometric titration techniques was published. This procedure, although faster and more direct than classical wet chemical procedures, requires two dissolutions per sample plus numerous reagents and dilutions. A more desirable route to the analysis of coal ash would involve the preparation of a single solution that could be analyzed directly. The application of a lithium metaborate fusion has enabled coal ash samples to be completely analyzed with one dissolution.

OP 56-73. The Processing of Energy Dispersion X-Ray Data in a Timesharing Computer, by Harold E. Marr and William J. Campbell. *Advances in X-Ray Analysis*, v. 16, 1973, pp. 206-216. A time-sharing computer was used in conjunction with a semiconductor detector and radioisotopic sources to evaluate energy dispersion X-ray analysis for the rapid analysis of copper-base alloys. The time-sharing computer served two purposes: to aid in the development of the analytical method and to simulate the action of a dedicated computer that would eventually be used as part of an on-line analytical device. Some of the general capabilities of time-sharing computers are discussed in this paper with some emphasis on the differences between the computer requirements of energy dispersive X-ray methods and conventional X-ray spectroscopy. An annular source of americium 241 was used with a secondary fluorescer to excite 23 brass and bronze alloys. The 400-channel spectrum from a multichannel analyzer was recorded on paper tape. A telephone coupled teletype was used to transmit the X-ray spectrum to the central processing facility. Curve fitting and statistical analysis programs similar to those available from most commercial time-sharing computer operations were utilized as well as other programs written at the College Park Metallurgy Research laboratory for processing digitized spectra.

OP 57-73. Soviet Coal Productivity: Clarifying the Facts and Figures, by V. V. Strishkov, George Markon, and Zane E. Murphy. *Min. Eng.*, v. 25, No. 5, 1973, pp. 45-49. Although there is considerable literature on the Soviet coal industry, no single source provides an authoritative study of how the U.S.S.R. coal industry functions and how well it performs its job. Soviet reports are singularly lacking in the precise data in terms that are comprehensible to a westerner. This article attempts to summarize the U.S.S.R. coal data and to clarify some of the data on coal, labor, and productivity.

OP 58-73. Interpretation of Gas Chromatographic Spectra in Routine Analysis of Gasoline Exhaust Hydrocarbons, by B. Dimitriadis, C. J. Raible, C. A. Wilson, and S. L. Mayo. *Preprints, Div. Fuel Chem. ACS*, v. 16, No. 3, 1972, pp. 54-57. In studies of atmospheric pollution from automobile emissions a practical method is required to routinely analyze the emission samples for hydrocarbon components. The study undertaken to develop such a method and the results of that study are described in this report.

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- OP 59-73. Thermodynamic Properties of Compressed Gaseous Methane**, by Roland H. Harrison, Richard T. Moore, and Donald R. Douslin. *J. Chem. and Eng. Data*, v. 18, No. 2, April 1973, pp. 131-134. Real gas thermodynamic properties, $H - H^\circ$, $S - S^\circ$, and $G - G^\circ$, of methane were determined as functions of temperature (0° to 350° C) and molal density (0.75 to 12.5 mol dm⁻³) over a pressure range of 0 to 400 atm. These properties are recommended as standards for the development of equation-of-state relations, since the analytical and graphical correlating techniques produced results that reflect all the inherent accuracy of the basic data.
- OP 60-73. Density of Molten NaCl-TiCl₂-TiCl₃ Mixtures**, by David J. MacDonald, Paul R. Bremner, and Andrea E. Raddatz. *J. Chem. and Eng. Data*, v. 17, No. 2, April 1973, p. 187. Densities of nine molten salt mixtures containing ≤ 0.08 mole fraction TiCl₂ and ≤ 0.15 mole fraction TiCl₃ in NaCl were measured by the Archimedeian suspended-sinker method in the temperature range of 800° to 950° C. Measurement of the density of NaCl by the same method produced a result duplicating that of Van Artsdalen and Yaffe within 0.2 percent. The partial molar volumes of TiCl₂ and TiCl₃ calculated from the density data were 45.5 and 74.9 cm³/mol⁻¹, respectively, which suggests the presence of substantial proportions of TiCl₃⁻ and TiCl₄⁻ complexes.
- OP 61-73. High Strength Iron Oxide Pellets by Polymer Impregnation**, by John C. Nigro and Charles Prasky. *Proc., 12th Biennial Conf. Inst. For Briquetting and Agglomeration*, v. 12, August 1971, pp. 125-144. A laboratory research program was initiated to determine the technical feasibility of utilizing organic polymers as binding materials for iron oxide pellets. Predried magnetite and hematite pellets impregnated with low-viscosity vinyl liquid monomers and polymerized in situ by thermal-catalytic techniques yielded compressive strengths equivalent to those reported by high-temperature induration plants. One-half-inch-diameter magnetite pellets containing less than 5 wt-pct poly(methyl methacrylate) gave compressive strengths in excess of 500 lb after polymerization at 80° C (176° F) and annealing at 200° C (392° F). Somewhat lower pellet strengths were obtained with methyl methacrylate-styrene and styrene-acrylonitrile copolymers. Polymer impregnation of both heat-hardened and cement-bonded pellets resulted in exceptionally high compressive strengths. The compressive strength of partially oxidized magnetite pellets (500° C (932° F)) increased from about 100 lb to over 1,000 lb after impregnation with less than 5 wt-pct poly(methyl methacrylate). Similar strength increases were obtained after impregnation of green magnetite pellets containing from 2.5 to 5.0 pct portland cement binder.
- OP 62-73. Time-Dependent Aspects of Rock Behavior as Measured by a Servocontrolled Hydraulic Testing Machine**, by S. S. Peng. *Internat. J. Rock Mech., Min. Sci., and Geomech. Abs.*, v. 10, No. 3, May 1973, pp. 235-246. The closed-loop, servocontrolled hydraulic testing machine was used to study the mechanisms of rock failure. It was found that applied load relaxes appreciably as soon as macrocracks initiated at the specimen surfaces. The behaviors of load relaxation were obtained for Berea sandstone, Tennessee marble, and Arkose sandstone. Load relaxation was used to establish the residual strength and creep behavior of the fractured specimens of Tennessee marble and Arkose sandstone. The load relaxation was also used to explain the experimental result that the negative slopes of the postfailure curves of all four rock types increased with a decrease in the applied deformation rate. In addition, a fast response visicorder was used to record the rapid fracture of Charcoal granite and Berea sandstone. The result indicated that the testing machine was not able to follow the fracture processes owing to its slow response and the high crack propagation velocity.
- OP 63-73. Effect of Preheating Upon Metallization of Iron Ore Pellets**, R. B. Schluter and P. L. Ruzzi. *Skilling's Min. Rev.*, v. 61, No. 37, Sept. 9, 1972, pp. 1, 4-6. The Bureau of Mines processed three magnetite and two hematite concentrates through the unit operation of pelletizing, preheating in air, and reduction to metal, to determine the effects of preheating upon the properties of the metallized pellets.
- OP 64-73. Acoustical Methods for Monitoring Failure in Rock**, by Richard E. Thill. *New Horizons in Rock Mechanics, Part VI—Earthquake and Other Dynamic Phenomena. Proc. 14th Symp. Rock Mechanics*, ed. by H. R. Hardy, Jr., and R. Stefanko. *Am. Soc. Civil Eng.*, 1973, pp. 649-687. Monitoring elastic wave velocity variation and the acoustic emission in rock in the process of fracturing affords a method of assessing the structural quality of rock, detecting the onset and progress of fracturing, and providing information on the attitudes of fractures and the mode of failure. The technique used in the present investigation, referred to as BVM (biaxial velocity monitoring), monitors longitudinal (compressional) wave velocity in the directions of greatest σ_1 and least σ_3 principal stresses. Velocity data are concurrently obtained with stress-strain characteristics during unconfined and conventional triaxial compression tests to permit the interpretation of velocity variation in terms of the deformational and fracture characteristics of the rock. Such interpretations are also assisted by recording acoustic emission and pulse amplitude data, and by examining the structural damage in sections of the deformed cylindrical specimens treated with a dye penetrant. Experiments are conducted on granodiorite and marble specimens exhibiting contrasting modes of failure (brittle versus ductile) under uniaxial compression and at uniform lateral (triaxial) confinement of up to 69 MN/m² (≈ 10 ksi). The combined acoustic data are used to infer the stress level and deformation characteristics in rock under stress. Deformation conditions that can be recognized are (1) crack closure, (2) linear elasticity, (3) fracture initiation and development, (4) accelerated fracture development, and (5) gross failure and post peak behavior.
- Since it is imperative that convenient and feasible methods be developed to appraise rock properties and to predict rock behavior underground, the encouraging results of these investigations suggest that these combined acoustic monitoring techniques may be used profitably in solving rock mechanics or geophysical problems concerned with determining the structural integrity of mine, tunnel, or dam structures, with delineating the zone of fractures in blasting experiments, or with earthquake prediction.
- OP 65-73. Converting Coal Into Nonpolluting Fuel Oil**, by Paul M. Yavorsky, Sayeed Akhtar, and Sam Friedman. *Chem. Eng. Prog.*, v. 69, No. 3, March 1973, pp. 51-52. Features of the Bureau of Mines Synthoil process for producing nonpolluting fuel from coal and pilot data on the hydrolique-

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faction of a Kentucky coal (4.6 percent S, 17 percent ash) to a low-sulfur, low-ash oil are presented.

OP 66-73. Analysis of Some Aromatic Hydrocarbons in a Benzene-Soluble Bitumen From Green River Shale, by D. E. Anders, F. G. Doolittle, and W. E. Robinson. *Geochim. et Cosmochim. Acta*, v. 37, 1973, pp. 1213-1228. The hydrocarbons in an aromatic fraction from Green River oil-shale bitumen were studied by mass and infrared spectrometry, gas chromatography, and a dehydrogenation technique.

OP 67-73. An Exact Solution to the Radially End-Constrained Circular Cylinder Under Triaxial Loading, by B. T. Brady. *Internat. J. Rock Mech. and Min. Sci.*, v. 8, 1971, pp. 165-178. An exact theoretical solution is presented for the stresses and displacements in a radially end-constrained elastic cylindrical specimen deformed axially between cylindrical end-plates of different elastic properties from those of the specimen. The exact solution for the stresses and displacements is expressed by a Fourier series representation. The solution is exact in the sense that the stresses are expressed by series and became exact in the limit as more terms are used.

OP 68-73. Initiation of Failure in a Radially End-Constrained Circular Cylinder of Brittle Rock, by B. T. Brady. *Internat. J. Rock Mech. and Min. Sci.*, v. 8, 1971, pp. 371-387. Results are presented of a Bureau of Mines study of the effect on the fracture initiation stress of loading a cylindrical specimen of brittle rock between steel end-plates with a diameter either equal to or slightly larger than the specimen diameter. The effect on fracture initiation stress of interposing a low-modulus insert material between the specimen and end-plates is discussed. In this paper, fracture initiation stress is defined to be the stress required to initiate microcracking (void growth) in the rock specimen. The three-dimensional axisymmetric finite-element method of solution is used to calculate the stress distribution in the specimen when a constant displacement is applied over the surface of the end-plates. These results are then used to calculate the fracture initiation stresses.

OP 69-73. The Effect of Confining Pressure on the Elastic Stress Distribution in a Radially End-Constrained Circular Cylinder, by B. T. Brady. *Internat. J. Rock Mech. and Min. Sci.*, v. 8, 1971, pp. 153-164. Results of a three-dimensional axisymmetric finite element investigation of the effect of confining pressure on the stress distribution within an elastic cylindrical specimen loaded axially between rough end-plates of the same diameter as the specimen are presented. A constant displacement was applied to the end-plates to approximate the loading conditions which exist when a specimen is loaded axially in the laboratory.

OP 70-73. Oil and Gas Wells—Potential Polluters of the Environment? by A. Gene Collins. Ch. in *Fresh Water Pollution I: Bacteriological and Chemical Pollutants*. MSS Information Corp. New York, v. 1, 1973, pp. 66-76. An investigation was made of several possible ways that activities associated with the production of oil and gas can contribute to the pollution of the environment. The study indicated that possible polluters include the following: drilling fluids, drilling muds, well treatment chemicals, corrosion inhibitors, friction reduction additives, crude oil, natural gases, oilfield brines,

abandoned disposal ponds, and inadequate subsurface disposal wells. It was recommended that the mineral wealth should be extracted from oilfield brines to help pay disposal costs and conserve valuable natural resources.

OP 71-73. Analysis of Tunnel Support Structure With Consideration of Support/Rock Interaction, by J. D. Dixon. *Soc. Min. Eng., Trans. AIME*, v. 250, December 1971, pp. 304-309. Procedures are given for calculating stresses in underground tunnel supports which accounts both for the structural behavior of the support and that of the adjacent rock mass. Stresses in the support are caused by service loads and rock reactions. Service loads are due to rock pressures, hydrostatic and hydraulic pressures, self-weight of the support, or other utilitarian-type loads. Rock reactions, equal and opposite those in the support, are due to the deformational interaction that results as service loads deform the tunnel support against the adjacent rock mass. The procedures developed for solving this problem are an application of matrix structural analysis. The principles involved in this method allow for the consideration of the deformable characteristics of most tunnel support systems and an iterative solution procedure is applied to determine the areas of support-rock interaction. Numerical results of example problems are given.

OP 72-73. First-Arrival Seismic Holograms, by G. L. Fitzpatrick. *Acoustical Holography*, ed. by Glen Wade. *Proc. 4th Internat. Symp. on Acoustical Holography*, Santa Barbara, Calif., Apr. 10-12, 1972, Plenum Publishing Corp., New York, v. 4, 1972, pp. 381-400. Under certain conditions, phase-only impulse seismic holograms of underground objects may be made by using only the source-object-detector travel times to calculate the relative phases of the arriving signals. This circumstance eliminates the necessity of recording and processing entire signals and, in principle, allows one to make seismic holograms by resorting to simple and rapid timing circuitry, rather than the comparatively complex apparatus needed to record and digitize entire signals. By eliminating such noise contributions as shear and surface waves the technique of first-arrival seismic holography also results in a large improvement in the signal-to-noise ratio of the recorded fringe data. A comparison of first-arrival seismic holograms made with actual field data and holograms made with entire signals from the same field data shows that the first-arrival holograms (and their reconstructions) are superior to those made with the full seismic records.

OP 73-73. Magneto-Gravimetric Separation of Nonmagnetic Solids, by S. E. Khalafalla and G. W. Reimers. *Trans. AIME*, v. 254, June 1973, pp. 193-198. A colloidal solution of a ferrimagnetic material, such as magnetite, in a liquid that is immiscible with and lighter than water is projected for use in selective separation of particles according to their density spectrum. Magnetic levitation forces can be created as an antigravity field when the fluid is properly placed in an inhomogeneous magnetic field. When the gradient of the magnetic field is directed downwards, the levitation force in the fluid will be in an upward direction to float sinking nonmagnetic bodies by counterbalancing their density mismatch with the magnetic fluid. Several nonmagnetic objects with densities ranging from 2.50 to 11.35 g cm⁻³ were made to float or submerge at will in a 0.96-g cm⁻³ density fluid placed in vertical magnetic field gradients ranging from 0.1 to 1 kilo-

oersted cm^{-1} . The magnetic levitation force in dyne cm^{-2} was found to vary linearly as a function of the object-fluid density mismatch with a slope equal to one g, the acceleration due to gravity.

OP 74-73. Polyaromatic Hydrocarbons in High-Boiling Petroleum Distillates, by J. F. McKay and D. R. Latham. *Anal. Chem.*, v. 45, No. 7, June 1973, pp. 1050-1055. The identification of seven polyaromatic ring systems in petroleum is reported. The ring systems are 1,12,2,3-dibenzoperylene; 1, 12-o-phenyleneperylene, pyreno-[1.3:10'.2']pyrene; 2,3, 10,11-dibenzoperylene; 1, 2, 4, 5-dibenzopyrene, benzo[e]pyrene, and benzo[g]chrysene. These polyaromatic hydrocarbons were isolated by a separation scheme involving ion exchange chromatography, gel permeation chromatography, and thin-layer chromatography and were identified by fluorescence spectroscopy. Gel permeation chromatography separated pericondensed aromatic ring systems from cata-condensed ring systems and the other components of an acid concentrate.

OP 75-73. Recovery of Copper From Crushed and Sized Porphyry Mine Wastes, by W. A. McKinney, L. G. Evans, and W. W. Simpson. *Soc. Min. Eng. AIME*, Feb. 15-19, 1970, Preprint No. 70-B-102, 11 pp. In conventional dump leaching of porphyry mine strip wastes, many years are required to extract up to 20 percent of the copper from the contained sulfide minerals. Furthermore, none of the molybdenum, gold, or silver in the strip wastes is recovered by current leaching practices. Because mineralization occurs predominately along fracture planes, breaking of the rock during mining operations liberates and concentrates some of the metal values in the fines.

Research shows that upgraded fines can be screened from mine wastes and froth floated for early recovery of copper, molybdenum, gold, and silver. For example, screening a dump sample assaying 0.35 percent copper as chalcopyrite removed about 20 percent of the copper as minus- $\frac{1}{4}$ -inch material that analyzed 0.6 percent copper. About 35 percent of the molybdenum and 20 percent of the gold and silver also reported in the fines. Crushing the mine dump sample to minus-3 inch before screening increased the distribution of copper and molybdenum in the minus- $\frac{1}{4}$ -inch screen fraction to 28 and 50 percent, respectively. Similar results were obtained by screening fines from two other large samples of mine waste dump materials.

Flotation studies established that the enriched minus- $\frac{1}{4}$ -inch fines from the three dump samples could be effectively concentrated. Comparative testing revealed that the combination of froth flotation of fines and acid-ferric sulfate leaching of the coarser fraction enabled doubling the recovery of copper over direct leaching of the samples. In addition, significant amounts of molybdenum, gold, and silver were recovered by flotation.

OP 76-73. Leaching Tests on Chino "J" Dump Core Samples, by W. A. McKinney, L. G. Evans, and W. W. Simpson. *Soc. Min. Eng. AIME*, Feb. 15-19, 1970, Preprint No. 70-AG-77, 5 pp. The U.S. Bureau of Mines, Kennecott Copper Corp., and New Mexico Institute of Mining and Technology are cooperating on a research project to improve extraction of copper from previously leached waste dumps that are in part compacted and impervious to leach solutions. The field work is being done at the "J" leach dump, Chino Mines Division, Kennecott

Copper Corp., Santa Rita, N. Mex. The laboratory percolation leaching tests were made at the Bureau of Mines Salt Lake City Metallurgy Research Center on drill core samples from the "J" dump to determine how much copper might be leached if permeability could be restored by explosive heaving or other means.

The core samples from nine drill holes on "J" dump contained from 0.06 to 0.14 percent copper. Copper extractions ranging from 15 to 38 percent were obtained in 75 days by percolation leaching of minus-1-inch material with dilute sulfuric acid. The tests results indicate that about 27 percent of the copper remaining in the "J" dump could be extracted under ideal leaching conditions.

OP 77-73. Dissolution of Copper Sulfide Minerals From Fractured Ore Bodies, by Joe B. Rosenbaum and W. A. McKinney. *Soc. Min. Eng. AIME*, Oct. 21-23, 1970, Preprint No. 70-AS-329, pp. 1-15. Leaching now yields about 15 percent of the Nation's annual new copper production. About 220,000 tons of copper was made in 1969 by heap and vat leaching of ore, dump leaching of waste, and in-place leaching of caved underground workings. Although in-place leaching was practiced as long ago as the 15th century, it is little used and contributes only a few percent of the total leach copper production. Current technology in this area is exemplified by practice at the Miami, Ariz., mine of the Miami Copper Co. Despite its limited use, the concept of extracting copper by in-place leaching without physically mining and transporting the ore continues to present intriguing cost saving possibilities. Unfortunately, the bulk of the copper in deep ore deposits occurs as sulfide minerals that are not easily dissolved. On the assumption that fracturing of rock and solution injection and collection would be feasible, an assessment is made of solution systems that might be employed for the different copper sulfide minerals in porphyry ore bodies. These include the conventional ferric sulfate-sulfuric acid systems and combinations of sulfide mineral oxidants and different acids.

OP 78-73. A Countercurrent Column for Fluid-Bed Ion Exchange of Uranium Ore Slurries, by Joe B. Rosenbaum and J. R. Ross. *Ch. in Proc. Internat. Symp. on Hydrometallurgy*, AIME, Feb. 26-Mar. 1, 1973, pp. 535-551. Bureau of Mines research has resulted in the development of fluid-bed ion-exchange columns for recovering uranium from slime pulps. In pilot plant tests, slime slurries containing up to 6 percent solids were processed at flow rates of 10 gallons per square foot per minute with high uranium recoveries and efficient resin loadings. Uranium was effectively eluted in a laboratory fluid-bed elution column at eluate-to-resin ratios of less than 5:1 and eluate flow rates of 3 gallons per square foot per minute. Construction costs of mills using these improved ion exchange techniques are estimated to be 25 percent less than for mills using solvent extraction of clear solutions. For mills having a capacity of 2,000 to 2,500 tons of ore per day, the saving would be in the range of \$2.5 million. In addition, a saving of about \$0.80 per ton of ore in total operating costs is indicated.

OP 79-73. Seismic Refraction Modeling by Computer, by James H. Scott. *Geophys.*, v. 38, No. 2, April 1973, pp. 271-284. A computer program has been developed by the Bureau of Mines for designing a two-dimensional, layered earth model as an aid in interpreting seismic refraction field measure-

ments. The program requires input data consisting of shotpoint and geophone locations, refraction travel times, and identification of the refraction layer associated with each travel time. In the program, a first approximation model is generated by a computer adaptation of the delay-time method, followed by a series of improved approximations that are made by use of a ray-tracing procedure. The final result of the program is a model designed to minimize the discrepancy between field-measured travel times and computed travel times of rays traced through the model. Test applications indicate that the accuracy of interpretation is improved, and that time and effort of the professional interpreter are greatly reduced by use of the computer technique.

OP 80-73. Wiederverwertung von Siedlungsabfällen in den USA (Utilization of Urban Refuse in the USA), by Max J. Spendlove. UMSCHAU in Wissenschaft und Technik (Germany), Heft 12, June 1973, pp. 364-369. Urban refuse is the only renewable resource that is capable of supplying a significant part of the growing U.S. demand for minerals and energy. Viable processes in the United States and other highly industrialized countries follow a typical pattern of transferring valuable constituents from host materials of natural origin to consumer goods and energy materials. Most of these valuable constituents, not totally consumed, are thus concentrated in two places: in the large reservoir of goods in use and in the discarded goods and daily urban wastes of the total society. The most valuable component of the urban wastes and similar discarded materials is commonly known as municipal refuse. It contains huge quantities of recoverable minerals and organic materials of great total value. The ultimate practice of recovering and recycling such values will not only increase domestic supplies of needed minerals and energy raw materials, but it will also offer a solution to many waste disposal problems of current critical importance. The municipal resource known in the Federal Bureau of Mines as "urban ore" is, by comparison with its natural counterpart, rich in grade, has a variety of values, and is relatively simple to process. These materials, formerly considered to be a great liability, appear destined to become a great national asset. A number of recovery processes have been developed and tested through the pilot plant scale, and some are scheduled for full-scale demonstrations in the immediate future. These events indicate a strong trend toward optimum recovery of values from wastes wherever possible. The practice will undoubtedly become commonplace within the decade.

OP 81-73. A Study on a New Concept of Thermal Hard Rock Crushing, by K. Thirumalai and J. B. Cheung. New Horizons in Rock Mechanics, Part V—Rock Breakage Techniques, Proc. 14th Symp. on Rock Mechanics, ed. by H. R. Handy, Jr., and R. Stefanko. American Society of Civil Engineers, New York, 1973, pp. 527-554. A new concept of thermal crushing of hard rocks is examined in this study. The theoretical methods developed to analyze thermal stresses and fragmentation induced by partial and complete surface heating of rock blocks are correlated with experimental results. A three-dimensional state of tensile stresses induced in the rock specimen interior during surface heating initiates fragmentation, quartzite) as well as poor spalling (Dresser basalt). Thermal crushing of both good spalling (Sioux Quartzite) as well as poor spalling (Dresser basalt) rock types was achieved in laboratory tests. The size distribution of thermally crushed fragments was

controlled by varying the thermal shock conditions. Crushed fragment size decreased with increasing intensity of surface heating. The specific energy requirement for laboratory thermal crushing of Sioux quartzite test blocks using multiple heat sources was within 12 kw-hr/ton and produced a fragment size distribution of about 0.2 cm to about 6.0 cm. The study shows that the process of thermal crushing is feasible and can be applied for size reduction of hard rocks.

OP 82-73. Changing Regional Supply of Coal Resulting From Environmental Controls, by Robert D. Thomson and Paul H. Mutschler. Proc. Council of Economics, AIME, February 1973, pp. 164-179. The bituminous coal industry, its markets, and its production sites have changed over the past decade. An examination of the supply and demand situations, future potential coal energy supply areas in terms of total resources and sulfur content, and the effects environmental controls may have on the future demand-supply relationship for coal revealed that coal markets in the East will continue to decline, production from the Western coal-producing region will increase at an accelerated rate, and Western producers will expand existing coal markets and develop new ones, principally in the midwest. Over the long run, all coal-producing regions should grow. This will be a consequence of (1) an economical stack gas system being developed, permitting the use of coals of higher than 1 percent sulfur, and (2) the desire for domestic sources of fuel rather than foreign sources.

OP 83-73. A Cubical Test Cell for Multiaxial Testing of Materials, by Richard Henry Atkinson. University of Colorado. July 1972. 206 pp. 78 figs. This report describes the design, fabrication, and testing of a new type of multiaxial testing device for geologic materials. The new testing device reduces the effects of boundary conditions in determining the physical properties or constitutive relations for elastic anisotropic material, and the development of a procedure to obtain anisotropic shear compliance values are contained in chapter 2. A literature survey and discussion of past work in multiaxial testing of geologic materials are found in chapter 3. In chapter 4 a detailed look is taken at the boundary conditions associated with the cubical test. Based on conclusions reached in chapter 4, a new type of multiaxial test device was designed and built as described in chapter 5. In chapter 6 results of experimental studies to determine the effectiveness of this new device are presented. Chapter 7 contains the results of the application of the new device to the determination of the constitutive relations of an actual material. Chapter 8 gives the summary and conclusions and makes recommendations.

OP 84-73. Process for Recycling Cemented-Carbide Scrap, by P. G. Barnard, A. G. Starliper, and H. Kenworthy. Trans. Soc. Manufacturing Eng., v. 1, 1972, pp. 1-3. The Rolla Metallurgy Research Center has developed a new method for recycling cemented-carbide scrap. This method involves the alloying of zinc with cobalt binder. The zinc is then distilled from the carbide scrap leaving a porous mass of carbides and cobalt which can be totally reground and recycled. The Bureau of Mines' process can be used to recover costly components in the scrap that are presently being discarded. Since the annual sales of cemented-carbides are approximately \$250 million, a great economic potential exists for augmenting conservation of resources by recycling of the cemented-carbide scrap.

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- OP 85-73. Destressing Test at the Galena Mine, Wallace, Idaho,** by Wilson Blake. Soc. Min. Eng., Trans. AIME., v. 252, September 1972, pp. 294-299. As a part of a USBM-ASARCO cooperative rock-burst research program, a burst-prone stope pillar at the Galena mine was successfully destressed. Destressing was accomplished by blasting a single line of long holes in the footwall of the vein. As a result of destressing, the pillar was fractured and softened; hence it yielded, releasing a large amount of stored elastic strain energy nonviolently. In addition, the high stress in the pillar was shifted out around the stope walls and in the sandfill. Both broad-band microseismic monitoring and seismic velocity surveys were used to evaluate the destressing test. The mechanics of destressing were determined by finite element computer model studies of destressing. Results of the field destressing test agreed remarkably well with the predicted results from the computer model.
- OP 86-73. Smelting of Military Electronic Scrap,** by Raymond O. Dannenberg and George M. Potter. Proc. 2d Symp. Mineral Waste Utilization, Chicago, Ill., Mar. 18-19, 1970, pp. 113-117. Potential processes for the recovery of precious metals and copper from diverse types of complex electronic scrap were investigated. Leaching-type processes were not successful, and attempts to physically separate the various gangue metals and plastics from more valuable components were also unsuccessful. The most promising approach was a smelting process, followed by electrolytic treatment to separate precious metal from copper. Recovery of precious metals from the anode sludge may follow conventional procedures. An alternative to the above process is incorporation of the scrap with the concentrate fed to an industrial copper reverberatory or converter furnace, possibly preceded by direct melting to form an assayable bullion and dross.
- OP 87-73. Research on Processing Systems for Automotive Materials,** by Karl C. Dean, C. J. Chindgren, and J. W. Sterner. Proc. 2d Symp. Mineral Waste Utilization, Chicago, Ill., Mar. 18-19, 1970, pp. 79-85. Time and motion studies were completed for hand dismantling a total of 15 incinerated and unburned junk cars representative of the more popular models during a 10-year period. Based on data derived from this study, a cost evaluation was made for processing 48 cars per 8-hour day via smokeless incinerating, hand dismantling, and baling to prepare marketable steel, cast iron, and nonferrous metal products. The evaluation indicated that an investment of \$345,000 in such a plant would enable a return on investment of about 19 percent. As unburned cars cannot be profitably dismantled and open field burning is rapidly becoming illegal, a complementary study was made that led to the design and construction of a low-cost smokeless incinerator. Initial testing of this unit has established that it can effectively burn the combustibles in cars with minimal air pollution at reasonable cost. Research also has been started with the goal of devising methods for recovering marketable nonferrous metals from the nonmagnetic rejects of shredder-type plants. An air elutriation technique has proved effective for separating the metallics from the low-density nonmetallics. Future work will comprise separating and recovering the several nonferrous metals as salable products.
- OP 88-73. Reclamation of Mineral Milling Wastes,** by K. C. Dean and R. Havens. Proc. 3d Symp. Mineral Waste Utilization, Chicago, Ill., Mar. 14-16, 1972, pp. 139-142. Legislation pending in Congress will provide the Government with authority to regulate adverse environmental effects resulting from mineral production. To assist in the reduction of environmental degradation resulting from milling operations, the Bureau of Mines has developed, and successfully demonstrated, chemical, vegetative, and combined chemical-vegetative procedures for stabilizing milling wastes under varying environmental conditions. Costs of achieving reclamation using these stabilization procedures are compared with those of other physical and vegetative approaches. The Bureau's chemical-vegetative procedure for establishing vegetation directly on fine-sized wastes compares favorably with other stabilization processes that have been used.
- OP 89-73. Stabilization of Mineral Wastes From Processing Plants,** by Karl C. Dean and Richard Havens. Proc. 2d Symp. Mineral Waste Utilization, Chicago, Ill. Mar. 18-19, 1970, pp. 205-213. Fine-sized mineral wastes from flotation milling and chemical plants are potential or active contributors to air and water pollution. Researchers at the Salt Lake City Metallurgy Research Center, Bureau of Mines, are developing practical methods for stabilizing such wastes. Chemical, vegetative, and combination stabilizing methods have been studied and evaluated by laboratory testing on diverse kinds of fine-sized mineral wastes, and field tests have been made using the more promising techniques. Chemical treatment methods were applied to 34 acres of uranium leach plant residues in an arid area and to a 19-acre area of vanadium leach plant residue. A combination chemical-vegetative method was used to stabilize 10 acres of copper flotation mill tailings in Nevada, and similar procedures were recently applied on mill wastes in Colorado, Idaho, Michigan, and Missouri.
- OP 90-73. Problems in Determining the Noble Metals in Ores,** by E. V. Elliott and K. R. Stever. Atomic Absorption Newsletter, v. 12, No. 3, May-June 1973, pp. 60-62. Disagreement between our laboratory and two commercial laboratories over the analyses of ores alleged to contain platinum and gold has led to a study of atomic absorption methods used by the outside laboratories. In their procedures, the sample is digested in acid, filtered, and analyzed by atomic absorption. The Bureau of Mines has made tests on known samples, duplicating outside laboratory procedures as closely as possible, and from results of continuum lamp studies has identified the sources of error as scattering and/or broad band molecular absorption. Errors due to wrong assumptions as to solubility of the noble metals were also demonstrated.
- OP 91-73. Structure of Graphite,** by Sabri Ergun. Nature—Phys. Sci., v. 241, No. 107, January 1973, pp. 65-67. This note presents observed and calculated geometric structure factors of some (*hk*0) reflections of pyrolytic graphite.
- OP 92-73. Thermal Decomposition of Dawsonite,** by Charles W. Huggins and Thomas E. Green. Am. Mineral., v. 58, May-June 1973, pp. 548-550. X-ray diffraction, infrared spectroscopy, and thermal methods of analysis were used to resolve conflicting statements in the literature on the thermal decomposition of dawsonite [$\text{NaAl}(\text{OH})_2\text{CO}_3$]. By 350°C the dawsonite structure collapses and water equivalent to the hydroxyl group and a large portion of the carbonate CO_3 are lost. This decomposition product then gradually loses the remainder

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of the CO₂ and remains amorphous until crystalline NaAlO₂ is formed at approximately 670°C.

OP 93-73. Renovation of Wastes by Mine Tailings Ponds, by Leland L. Mink, Roy E. Williams, Alfred T. Wallace, and Lewis McNay. *Min. Eng.*, v. 25, No. 7, July 1973, pp. 81-88. Seven tailings pond systems in the Coeur d'Alene mining district, Idaho, were studied to identify the discharge of heavy metal ions into regional water resources. Two major categories of tailings ponds were studied: ponds receiving only concentrator effluents and ponds receiving wastes from concentrators, processing plant and smelters, and acid mine drainage. Analytical results indicate that tailings ponds using peripheral discharge and constructed in a series were effective in reducing suspended solids, pH, and dissolved metal ions. Tailings ponds receiving several types of industrial wastes were not satisfactorily removing deleterious metals from their pond discharges. Peripheral discharge of milling wastes also encourages tailings pond stability.

OP 94-73. Designing the Hendrix No. 22 Shortwall, by E. R. Palowitch and T. J. Brisky. *Min. Cong. J.*, v. 59, No. 6, June 1973, pp. 16-22. This article describes the factors considered in the design of the mining system and equipment requirements for the Bureau of Mines-Beth-Elkhorn Corp.'s shortwall face in the Hendrix No. 22 mine, Deane, Ky.

OP 95-73. Transfer Function for a Continuous Mechanical Froth Flotation Cell With a Distributed Rate Constant (Technical Note), by Leon Y. Sadler III and E. K. Landis. *Trans. Soc. Min. Eng., AIME*, v. 254, June 1973, pp. 131-133. The mathematical description in the form of a transfer function of the continuous or flow-cell under unsteady-state conditions with a distributed flotation rate constant has not been presented in the literature. This note presents the development of an equation for this transfer function. The type of analysis used here has promise for adaptation to other physical descriptions of the continuous cell such as the "two-phase" model and for incomplete mixing.

OP 96-73. Solid Waste Resource, by Max J. Spendlove. *Proc. Conf. Solid Waste*, Worcester Polytechnic Institute, January 9-11, 1973, ed. by T. C. Crusberg, F. C. Lutz, and A. J. Silva. Worcester Polytechnic Institute, July 1973, pp. 245-268. This paper discusses the values that may be retrieved from solid wastes in the United States, with particular attention to the metal and nonmetal values that may be retrieved from burned and unburned urban refuse. The Bureau of Mines incinerator residue process can recover products worth about \$6 from each ton of refuse at a total cost of \$4 per ton. The raw refuse process is less advanced, but shows considerable promise. Synthetic oil with practically no sulfur content has been produced from organic components of raw municipal refuse.

OP 97-73. Carbon Monoxide: Chemical Aspects, by Irving Wender and Charles Zahn. *Encyclopedia of Chemistry*, ed. by C. A. Hampe and G. G. Hawley. Van Nostrand Reinhold, New York, 3d ed., 1973, pp. 197-201. The topics discussed are (1) preparation of carbon monoxide in the laboratory and in industry mainly by converting petroleum fractions into synthesis gas, a mixture rich in carbon monoxide and hydrogen; (2) recovery of pure carbon monoxide from synthesis gas by low-temperature separation or selective adsorption; (3) detection of

carbon monoxide; (4) physical properties of carbon monoxide, including thermodynamic values; (5) chemical properties of carbon monoxide; and (6) uses of carbon monoxide.

OP 98-73. Collection of Airborne Dust by Water Sprays, by Lung Cheng. *I&EC Process Design & Development*, v. 12, July 1973, pp. 221-225. A general theoretical equation was developed for the collection efficiency of airborne dust particles by spray drops. The model assumes an inertial impaction collection mechanism and is based upon mean interdrop length and mean interparticle area. Particular attention was given to the optimum drop size for collection with open and also confined sprays from a high-pressure nozzle. This general model was specifically adapted to the collection of dust particles in a horizontal tunnel by a solid-cone water spray by including the effects of duct size and spray configuration. The theoretical collection efficiencies agreed reasonably well with experimental data. The present results can be used to select a specific spray nozzle that will provide optimum collection efficiency for airborne dust based upon the available water flow rate and line pressure.

OP 99-73. Corrosion of Commercial Alloys in a Chlorine-Sulfur Atmosphere at High Temperatures, by P. E. Sanker and L. L. Oden. *Materials Protection and Performance*, v. 12, No. 6, June 1973, pp. 24-27. The corrosion rates of nickel and selected nickel-, cobalt-, and iron-base commercial alloys in chlorine containing minor amounts of sulfur were measured at temperatures from 350° to 650° C. The alloys tested were Inconel 600, Inconel 601, IN-793 (exp), Incoloy 800; Hastelloy N, Hastelloy C-276, Hastelloy G, Haynes 25, Multimet; Durichlor 51; ASTM Nickel 200, and AISI 310, 316, 309, 304, 347, 430, and 410.

OP 100-73. Advances in Technology for Recycling Obsolete Cars, by K. C. Dean and C. J. Chindgren. *Proc. 3d Mineral Waste Utilization Symp.*, Chicago, Ill., Mar. 14-16, 1972, pp. 213-221. Shredding, smokeless incineration, and hand dismantling methods for recycling automotive scrap are rapidly making inroads into the accumulations of obsolete cars across the country. This paper summarizes Bureau of Mines' developments in the smokeless incineration of scrapped automobiles and in the design and operation of equipment for the recovery of nonferrous metals from shredded automotive non-magnetic rejects by air and water classification methods. Results of experimental work on the recovery of copper and iron values in generators and starters by hand dismantling and leaching methods and on separation of copper wire from insulation by cryogenic techniques are also reported.

OP 101-73. Recovery of Values From Shredded Urban Refuse, by Karl C. Dean, C. J. Chindgren, and LeRoy Peterson. *Proc. 3d Mineral Waste Utilization Symp.*, Chicago, Ill., Mar. 14-16, 1972, pp. 295-304. Air and water classification systems have been developed by the Bureau of Mines for separation and recovery of metallic, glass, and combustible fractions from shredded urban refuse. Samples from two different types of shredders and three different urban locations were separated by air classification, magnetic separation, screening, and water elutriation to recover potentially useful products. More than 92 percent of the metals were recovered in a clean iron product contaminated only by adhering coatings or entrapped materials, and 97 percent of the combustibles were recovered in a

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97-percent combustible product. Cleaning of the preliminary 97-percent combustible fraction from one sample produced a 100-percent combustible product containing 98 percent paper. Retreatment of the noncombustible fraction produced a relatively clean glass product.

OP 102-73. Reclamation of Mineral Milling Wastes, by Karl C. Dean and Richard Havens. Pres. at AIME Annual Meeting, San Francisco, Calif. Feb. 20-24, 1972, Preprint 72-B-82, 8 pp. To assist in the reduction of environmental degradation resulting from milling operations, the Bureau of Mines has developed, and successfully demonstrated, chemical, vegetative, and combined chemical-vegetative procedures for stabilizing milling wastes under varying environmental conditions. Costs of achieving reclamation using these stabilization procedures are compared with those of other physical and vegetative approaches. The Bureau's chemical-vegetative procedure for establishing vegetation directly on fine-sized wastes compares favorably with other stabilization processes that have been used.

OP 103-73. An Economic Evaluation of Pipeline Gas From Coal, by Sidney Katell. Gas, v. 48, No. 8, August 1972, pp. 32-34. An economic evaluation was made of a plant designed to produce 250 million standard cubic feet per day of high-Btu gas using Pittsburgh seam coal. A fluidized gasification system followed by shift conversion, purification, and single-stage tube wall methanation was used to produce 927-Btu gas. The total capital investment is estimated to be \$194,606,200, or 78 cents per daily scf of gas production capacity.

OP 104-73. The Pumpable Rock Bolt: A New Roof Control Concept, by J. Habberstad, C. Waide, and R. Simpson. Eng. and Min. J., v. 174, No. 8, August 1973, pp. 76-79. A new pumpable fully grouted polymer roof bolt that achieves several advantages over grouted steel and conventional expansion shell bolts is being developed by the Bureau of Mines' Spokane Mining Research Center.

OP 105-73. Gravity Flow of Powder in a Lunar Environment: Part 1. Testing of Simulated Lunar-Basalt Powder for Gravity Flow, by D. E. Nicholson. Proc. POWTECH '71: Internat. Powder Technology and Bulk Granular Solids Conf., Powder Technol. Pub. Ser. 1, pp. 163-182. This paper investigates the mechanical behavior of fine soils in a lunar environment in engineering gravity-flow bins.

OP 106-73. Catalytic Dehydrogenation of Coal: Part 7. The Effect of Some Catalyst Variables, by Leslie Reggel, Irving Wender, and Raphael Raymond. Fuel, v. 53, No. 3, July 1973, pp. 162-163. When vitrinite is catalytically dehydrogenated in the presence of phenanthridine as vehicle, the yield of hydrogen is not greatly influenced by the catalyst support or the concentration of metal on the support. The metal used has a large effect, palladium giving the highest yield of hydrogen.

OP 107-73. Electronic Scrap Reclamation, by E. L. Sinton and T. A. Sullivan. J. Metals, v. 25, No. 8, June 1973, pp. 31-34. The Bureau of Mines research described in this report was conducted to develop technology for recovery and recycling of metal values from obsolete electronic equipment. Aluminum of 99-percent purity can be recovered from this equipment, plus copper, lead, tin, silver, and gold. A molten salt electrorefining process was used to extract aluminum from sweated electronic scrap and, at the same time, to concentrate

other metal values into a product that could be treated by commercial smelting and refining methods to recover other valuable metals.

OP 108-73. Mining Equipment Controls Standardization, by James C. Church. Proc. 46th Ann. Meeting AIME and University of Minnesota 34th Ann. Min. Symp., Univ. Minn., Jan. 15-17, 1973, Duluth, Minn., 1973, pp. 102-111. This paper presents the results of the Bureau's Health and Safety contract H0220033 "Standardization of Front-End Loader Controls," by The Bendix Research Corporation. It describes the mining safety benefits which can be realized through the standardization of mining equipment controls.

OP 109-73. Degasification of Coalbeds: A Commercial Source of Pipeline Gas, by Maurice Deul, H. H. Fields, and C. H. Elder. Pres. Ill. Inst. Technol. Symp., Clean Fuels From Coal. Inst. Gas Technol., Chicago, Ill., Sept. 10-14, 1973, 9 pp. A byproduct of intensive research conducted by the Bureau of Mines on degasification of coalbeds for improved mine safety is evidence that commercial quantities of pipeline quality natural gas can be produced. Coalbed degasification by draining gas from the coalbed before it is mined can be accomplished by drilling vertical holes into coalbeds with subsequent stimulation by hydrofracturing. By drilling horizontal holes into virgin coalbed areas from small specially designed boreholes, drainage holes from large ventilation shafts can be sunk to the coalbed in advance of mining. It is estimated that the minable coalbeds of the conterminous United States that are less than 3,000 feet deep may contain 260 trillion cubic feet of natural gas. The pertinent coalbed properties are discussed and results of a novel drilling method are presented.

OP 110-73. Pressure, Volume, Temperature Relations of Ethane, by D. R. Douslin and R. H. Harrison. J. Chem. Thermodynamics, v. 5, July 1973, pp. 491-512. A comprehensive study of pressure-volume-temperature relations for ethane includes new experimental vapor pressures to the critical, orthobaric densities for the coexistence envelope, critical constants, virial coefficients, and compression factors in the compressed fluid to 400 atm and 623 K.

OP 111-73. Analysis of the Structure of a Glassy Carbon Using the Fourier Transform Technique, by Sabri Ergun and Richard R. Schehl. Carbon, v. 11, 1973, pp. 127-138. The structure of a heat-treated (~3000° C) glassy carbon produced from a polymer of furfural alcohol has been studied by the Fourier inversion of scattering intensities obtained using AgK α_1 radiation. Using Cauchy's distribution, novel theoretical expressions have been developed for the Fourier transforms that take into account the effects of distortion and defects in the lattice in addition to termination effects. The cosine transform of the (002) reflections showed that stacking of layers is extensive but faulty, mean spacing between faults being ~21 Å. The mean interlayer spacing was found to be 3.42 ± 0.03 Å, the value of 0.03 Å representing the semi-quartile range of the mean interlayer spacing. A detailed analysis of the Fourier transforms of the (*h**k*) reflections revealed that the sample studied is made up of distorted hexagonal rings. The distortion is severe enough to make it very difficult, if not to prohibit, precise definition of the two-dimensional lattice. Three different lattices (two involving quinoidal rings) have been found to explain the observed transforms equally well. The transform yielded a mean defect-free distance in

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the layers of ~ 86 Å. Compared to 37 Å indicated by the line-width of the (11) reflections, it is clear that distortion effects outweigh the defect or layer size effects in the observed profile of the (11) reflections. In the absence of equations for intensity profiles of random layered lattices that take into account the distortion effects, the Fourier transform procedure outlined in this study constitutes the only method that permits an authentic structural analysis.

OP 112-73. Two-Dimensional Lattice Orientation and Three-Dimensional Crystallinity in Carbon Fibers, by Sabri Ergun. *Nature, Phys. Sci.*, v. 238, No. 87, 1972, pp. 137-139. Most carbons give rise to diffraction peaks closely corresponding to the (*hk*0) and (00*l*) reflexions of graphite. The (*hk*0) reflexions are produced by the two-dimensional lattice of the layers and the (00*l*) reflexions by the presence of stratiform domains. If the normals of the stratiform domains in a sample were completely random the sample would be isotropic. Some carbons are anisotropic, and the anisotropy is explained by a preferred orientation of domain normals. In carbon fibres the normals tend to be perpendicular to the fibre axis; the layers tend to be parallel to the fibre axis but the fibres are radially isotropic. It appears that fibres possess a two-dimensional preferred orientation and that the presence of a preferred lattice orientation is obscured by radial and longitudinal deformation of layers.

OP 113-73. Hydraulic Fragmentation Research in the U.S.A., by Jacob N. Frank. *Proc. 46th Ann. Meeting AIME and University of Minnesota 34th Ann. Min. Symp.*, Univ. Minn., Jan. 15-17, 1973, Duluth, Minn., 1973, pp. 129-142. Modern hydraulic mining in the United States was started in 1949 by the American Gilsonite Company at Bonanza, Utah. Extensive research is now being carried out throughout the United States on the disintegration of rock and coal by water jet cutting. Universities, institutes, and Government agencies are engaged in programs of hydraulic fragmentation research and mining. The Bureau of Mines has conducted research in hydraulic fragmentation and mining since 1958, chiefly to determine if coal could be mined economically by jets at pressures up to 5,000 psi. In 1966 this work was extended to laboratory studies on the cuttability of concrete and native copper ores by water jets at pressures up to 80,000 psi. Field studies have also been conducted on the frozen gravels of Alaska and the cemented gravels of California. At present, the Bureau has both in-house and contract programs directed at determining the feasibility of hydraulic mining of coal and metal and nonmetal ores, the feasibility of using water jets for hard rock tunneling, and the environmental impact associated with hydraulic fragmentation.

OP 114-73. Hydrodenitrification of Crude Shale Oil, by C. M. Frost and H. B. Jensen. *Preprints, Div. Petrol. Chem., ACS*, v. 18, No. 1, February 1973, pp. 119-128. Hydrodenitrification tests on crude shale oil showed that, at 740° F and 2,000 psig, the denitrification rate constants for indoles will exceed those for quinolines.

OP 115-73. Kinetic Evidence of a Reactive Intermediate in Reduction of SO₂ With CO, by L. A. Haas and S. E. Khalafalla. *J. Catalysis*, v. 29, No. 2, May 1973, pp. 264-269. The synergic increase of the SO₂ reduction with CO in the presence of both Fe and alumina in the catalyst was explained by

the formation of an intermediate SCO on the Fe sites and its reaction with SO₂ on an Al₂O₃ site.

OP 116-73. Analysis of Pressure Interference Tests Using Computer Graphics, by R. D. Haynes and W. K. Sawyer. *Pres. 48th Ann. Fall Meeting, Soc. Petrol. Eng., AIME, Las Vegas, Nev.*, Sept. 30-Oct. 3, 1973, SPE Preprint 4570, 8 pp. Computer graphics were used to analyze dynamic pressure responses from short-term interference tests that were conducted in an attempt to outline the natural and induced fracture systems in a petroleum reservoir. By use of a time-programmable data acquisition system, pressure responses from 40 wells arranged in 16 regular 5-spots were monitored during 74 water injection tests that resulted in over 120,000 individual pressure readings. To aid in the interpretation of the complex field behavior, the data were transferred to computer cards. Software was then developed using cathode ray tubes (CRT), drum plotter, and on-line printers to reduce and evaluate the data. Pressure-time plots were generated for each well in a test. From these plots, tests that indicated evidence of existing fracture systems were selected for more detailed analysis. Of the selected tests, sequenced delta pressure contour maps were used to show the dynamic behavior of the field due to the interference test. Graphic three-dimensional perspective views of the changing field pressures were also used in the interpretation of the reservoir behavior. Results of two specific tests are shown.

OP 117-73. Nuclear Magnetic Resonance Relaxation of ²³Na in Porous Media Containing NaCl Solution, by L. C. Headley. *J. Appl. Physics*, v. 44, No. 7, July 1973, pp. 3118-3121. Nuclear magnetic resonance (NMR) longitudinal and transverse relaxation rates repetitive pulse steady-state magnetizations were measured in porous media containing solutions of NaCl in water. Longitudinal rates show a linear relationship with sample specific surface area, but transverse rates show more complicated behavior. These results are discussed in terms of diffusion and adsorption in the media. Experimental results for steady-state magnetizations achieved by repetitive pulsing are compared with theoretical calculations presented here. Theoretical expressions are also presented for use in optimizing fast repetitive pulse experiments.

OP 118-73. Use of a Damping Alloy Rotation Chuck in Development of a Quiet Rock Drill (Abstract), by James W. Jensen and Aarne Visnapuu. *J. Acoustical Soc. America*, v. 54, No. 1, July 1973, pp. 278. The modification of a percussion drill, of the type used in mining, to reduce the noise to permissible levels requires drastic reduction of exhaust noise, drill-steel resonance noise, and machine noise from the drill mechanism. Efficiency and utility of the portable tool must be retained in the quiet version. The impact of the piston on the drill steel generates excessive airborne and structure-borne noise, and containment and suppression of this noise at or near its source is vital. A rotation chuck machined from manganese-copper damping alloy, when substituted for the standard steel chuck, enclosing the impact area within the drill, very effectively suppressed the shock noise from the impacting surfaces. Test-stand data show that greater noise reduction was achieved by this method than was obtained by some external covers when the steel chuck was in use. Technical problems and implications of using these alloys are discussed.

OP 119-73. Sorption of Methane in Moist Coal, by James I. Joubert, Clifford T. Grein, and Daniel

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Bienstock. Fuel, v. 52, July 1973, pp. 181-185. The natural oxygen content of a given coal and the bed moisture content play a major role in determining the methane capacity of the coal. Moisture present in excess of a certain critical value has no effect on methane sorption.

OP 120-73. Mining Instrumentation Goes Automatic by J. R. McVey and T. O. Meyer. Min. Eng. AIME, v. 25, No. 8, August 1973, pp. 39-41. The Bureau of Mines has designed and environmentally packaged a 10-channel automatic data acquisition system for use with underground strain gage applications and associated instruments. Accuracies of 0.01 percent and resolution of 1 microvolt have been obtained in underground tests.

OP 121-73. Les vibrations dues aux tirs et leurs effets sur les constructions (Blasting Vibrations and Their Effects on Structures), by Henry R. Nicholls, Charles F. Johnson, and Wilbur I. Duvall. Explosifs, No. 1, January-March 1973, pp. 4-33. This report presents the results of the Bureau of Mines 10-year program to study the problem of air blast and ground vibrations generated by blasting. The program included an extensive field study of ground vibrations; a consideration of air blast effects; an evaluation of instrumentation to measure vibrations; establishment of damage criteria for residential structures; determination of blasting parameters which grossly affected vibrations; empirical safe blasting limits; and the problem of human response. While values of 2.0 in/sec particle velocity and 0.5 psi air blast overpressure are recommended as safe blasting limits not to be exceeded to preclude damage to residential structures, lower limits are suggested to minimize complaints. Millisecond-delay blasting is shown to reduce vibration levels as compared to instantaneous blasting, and electric cap delay blasts offer a slight reduction in vibration levels as compared to Primacord delay blasts. Vibration levels of different blasts may be compared at common scaled distances, where scaled distance is the distance divided by the square root of the maximum charge weight per delay. Geology, rock type, and direction affect vibration level within limits. Empirically, a safe blasting limit based on a scaled distance of 50 ft/lb^{1/2} may be used without instrumentation. However, a knowledge of the particle velocity propagation characteristics of a blasting site determined from instrumental blasts at that site are recommended to insure that the safe blasting limit of 2.0 in/sec is not exceeded.

OP 122-73. Simulation of a Finite-Capacity Vertical Fracture in a Gas Reservoir, by W. K. Sawyer, C. D. Locke, and W. K. Overbey, Jr. Pres. 48th Ann. Fall Meeting, Soc. Petrol. Eng., AIME, Las Vegas, Nev., Sept. 30-Oct. 3, 1973; SPE Preprint 4593, 11 pp. One- and two-dimensional gas reservoir simulators were combined in such a manner that pressure distributions, both in an induced vertical fracture and in the surrounding formation, could be determined as a function of time for any specified well production rate. Basic assumptions regarding the fracture were as follows: (1) The fracture completely penetrates the formation, (2) all flow into the wellbore enters via the fracture, and (3) flow in the fracture is described by Darcy's law. The combination model developed provides the only known means of simulating a vertical fracture of given characteristics in a gas reservoir under transient conditions. Thus, the technique developed would be useful in locating wells in a storage field in that the effects of both fracture length and conductivity could be considered prior to drilling and fracturing operations.

OP 123-73. Some Comparisons of Simultaneous Stack Gas Particulate Determinations Using the ASME and EPA Methods, by S. J. Selle and G. H. Gronhqvist. J. Eng. for Power, Trans. ASME, July 1973, pp. 145-149. Simultaneous determinations of particulate concentrations were made by the ASME and EPA methods on flue gas from a test furnace burning about 75 lb/hr of low-sulfur North Dakota lignite.

OP 124-73. A Method for Calculating m/e 's of Peaks From Time-of-Flight Mass Spectra, by F. G. Doolittle and D. G. Earnshaw. Appl. Spectroscopy, v. 26, No. 3, 1972, pp. 403-404. This study has shown that m/e 's can be determined to the nearest unit mass from TOF spectra by using a single equation in conjunction with a calibration curve. The calibration curves are unique for individual analog scanners, are stable within 0.3 amu over a 3-week time span, and are independent of scan rate within 0.3 amu even when the scan rate is varied by a factor of 4. The authors feel that a 25-cm record for 200 mass units is minimal, and any shorter record would introduce significant measuring errors. Where the analyst has been using an internal standard he can now make a single run on the marker compound and construct a calibration curve to be used over a period of time.

OP 125-73. Exhaust Emissions From Small, Utility, Internal Combustion Engines, by B. H. Eccleston and R. W. Hurn. SAE Trans., v. 81, 1973, pp. 741-749. This material reports findings of an explanatory experimental study designed to add information on the contribution to air pollution of exhaust emissions from small, utility engines, and to evaluate the procedures used to test small engines. Gross measurements of hydrocarbon, carbon monoxide, and nitric oxide are reported for 29 4-cycle and 7 2-cycle engines; sizes of the engines ranged 2 to 22 hp. Emission measurements were made on each engine for nine combinations of load and air-fuel adjustments; only one speed point—full governed—was covered in the tests. Test procedures are described. An overall average of the data indicate that, operated at full-load and optimum air-fuel ratio, the 4-cycle engines emitted amount 8 grams HC, 180 grams CO, and 5 grams NO₂ per horsepower-hour. Under comparable conditions, the 3 to 6 hp 2-cycle engines emitted an average of 140 grams HC, 240 grams CO, and 2 grams NO₂ per horsepower-hour.

OP 126-73. Mineral Resources, by C. D. Edgerton. Resource and Land Information, South Dade County, Florida. Geol. Survey Inv. I-850. Washington, D.C., 1973, pp. 16-17. This article reviews the economic aspects, quarrying methods, and environmental implications of the limestone industry in South Dade County, Fla. Limestone, the most significant mineral commodity in the area, is found at or near land surface throughout the entire area, and is used as base material for roads and airport runways, as construction aggregate, and in the manufacture of cement.

OP 127-73. An Equation of State for Medium-Density High-Temperature Conditions, by D. R. Forshey, W. G. Courtney, and J. B. Greenshields. J. Phys. Chem., v. 77, No. 1, 1973, pp. 82-87. An equation of state for medium high-temperature conditions has been developed based upon an Abel-type co-volume model. The formation of discrete clusters was examined using statistical thermodynamics but was found to be unimportant to the equation of state for most conditions considered here. Theoretical PV isotherms using this simple model agreed to within

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several percent with experimental *PV* isotherms for Ar, N₂, and CO₂ for densities between 0.001 and 1.5 g/cm³ for temperatures about 100 K greater than the critical temperature. For these conditions the ideal gas, van der Waals, and Beattie-Bridgman models agreed only to within about 25 percent. Agreement for H₂O was less satisfactory and comparable with that obtained with the other models.

OP 128-73. Nitride Inclusions in Titanium Ingots: A Study of Possible Sources in the Production of Magnesium-Reduced Sponge, by Jack L. Henry, S. D. Hill, J. L. Schaller, and T. T. Campbell. *Met. Trans.*, v. 4, No. 8, August 1973, pp. 1859-1864. An experimental program is being conducted to investigate possible sources of nitride defects in the production of magnesium-reduced titanium sponge and to determine if such defects are capable of surviving consumable-electrode arc melting. Pilot plant experiments have shown that both air-burned and nitrified sponge pieces lose their color and texture when seeded into the process during both the reduction cycle and the distillation cycle. Such defect pieces act as nuclei for sponge growth during the reduction and are often found partially or completely clad by newly formed sponge. Simulated air leaks during both reduction and distillation cycles and the incorporation of air-contaminated magnesium have been studied. The resulting sponge has a very uneven distribution of nitrogen. Some regions show nitrogen concentration as high as 12 percent and contain ϵ -Ti₂N or Δ -TiN, or both. Alpha-stabilized inclusions have been found in ingots produced from sponge made from dross-contaminated magnesium and from sponge contaminated by air during vacuum distillation. Although the nitride in the sponge is in the form of a fine powder, powder pockets, or soft friable lumps, it is capable of surviving single and in some cases, double arc melting. A theory of the mechanism of survival of these defects is proposed.

OP 129-73. Gaylussite: Thermal Properties by Simultaneous Thermal Analysis, by Donald R. Johnson and William A. Robb. *Am. Mineralogist*, v. 58, July-August 1973, pp. 778-784. Simultaneous thermal analysis apparatus was used to determine the thermal properties of gaylussite over a temperature range from ambient to 1,000° C at 10° per minute in several carefully controlled atmospheres. In a dry atmosphere, dehydration occurs in a single step, but in the presence of water, dehydration occurs in two steps. Dehydration converts gaylussite to double carbonate, Na₂Ca(CO₃)₂, which generate the thermal effects above 250° C. From 250° to 500° C thermal analysis indicates one major crystal change and two crystal inversions in the double carbonate. Above 500° C the thermal properties of the double carbonate are controlled by the presence or absence of CO₂ in the atmosphere surrounding the sample. In a CO₂ atmosphere Na₂Ca(CO₃)₂ first melts, then decomposes to form Na₂CO₃ and CaO. In a CO₂-free atmosphere the double carbonate decomposes to form Na₂CO₃ and CaO. Melting is again detected by thermal analysis; however, the material that melts is Na₂CO₃ formed from decomposition of the double carbonate.

OP 130-73. An Exercise in Mine Costing Communications, by Guy A. Johnson. *Proc. Council of Economics, AIME Ann. Meeting*, Chicago, Ill., Feb. 25-Mar. 1, 1973, AIME, 1973, pp. 105-112. Cost engineering, a basic part of most industry and government work, involves the problems of communicating the cost information developed and the analysis techniques utilized. A discontinued cash flow

(DCF) chart-mine cost model has been developed to help solve these problems. Because the model is based on mine and mill equipment costs, manning tables, and standard discounted cash flow analysis, it is applicable to open pit or underground mining projects, large or small, of almost any commodity. In short, the flow chart-mine cost communications model is a straightforward, graphic definition of the elements required to develop the preliminary "capital required" and "operating costs" estimates for a mine, while it depicts the interrelationships of these elements as they combine to form the total total DCF cost picture.

OP 131-73. Limiting Factors on Steady-State Thermal Reactor Performance, by Robert H. Kadlec, Everett A. Sondreal, Donald J. Patterson, and Marshall W. Graves, Jr. *Internat. Automotive Eng. Conf.*, Detroit, Mich., Jan. 8-12, 1973, SAE Preprint 730202, January 1973, 15 pp. A comprehensive analytical and experimental study of thermal reactors has been made. The findings have been incorporated into a computer model capable of simulating reactor performance both during warmup and steady-state operation. This paper treats the warmed-up case. Arbitrary reactor configurations may be explored in regard to the steady-state extent of oxidation of hydrocarbons (HC), CO, and H₂ with perfect or imperfect mixing and the detrimental effects of heat losses. This experimental and analytical program focused on the Chevrolet 350-in³ engine-Du Pont model V reactor combination. Experimental and calculated results are presented and compared where possible. Analytical models for the DuPont reactor were developed, each of which treated the exhaust ports, core, and annulus differently. An experimental technique was developed that permits an assessment of the completeness of mixing between exhaust and injected air within a thermal reactor and is expected to be useful as a design aid. In addition to oxidation results for CO, H₂, and HC as a whole, measurements were made to determine any changes in NO, aldehydes and olefin, paraffin, and aromatic class proportion affected by the thermal reactor.

OP 132-73. Gas From Coal as an Automotive Fuel, by J. R. Allsup. SAE, Paper No. 730802, 1973, 8 pp. The Bureau of Mines studied the characteristics of simulated coal gas as an automotive fuel in a multicylinder engine in a standard and high compression ratio engine configuration. While using simulated coal gas fuel, increasing the engine compression ratio improved the fuel economy and vehicle performance but increased hydrocarbon emissions by 40 percent. An oxidizing catalyst used with the simulated coal gas fuel resulted in elimination of all but trace amounts of carbon monoxide and reactive hydrocarbons in the exhaust. Spark gap geometry and firing voltage were varied and, within the range tested, had little effect on vehicle performance and emissions using simulated coal gas fuel.

OP 133-73. Factors Controlling Fracture Orientation in Sandstone, by C. A. Komar and K.-H. Frohne. *Pres. 48th Ann. Fall Meeting Soc. Petrol. Eng., AIME*, Las Vegas, Nev., Sept. 30-Oct. 3, 1973, SPE Preprint 4567, 8 pp. Laboratory-scaled hydraulic fracture tests were conducted on directionally oriented sandstone material, along with measurements of directional rock properties such as tensile strength, permeability, sonic velocity, and dynamic elastic constants. In these tests, fracture orientation was determined as a function of various

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combinations of stress, rock saturation, rate of borehole pressurization, and direction of minimum tensile strength relative to minimum horizontal compressive stress. The objective of the experiment was to investigate whether horizontal stresses always controlled the orientation of induced vertical hydraulic fractures, or if, under conditions of small differences in stress and/or slow borehole pressurization rates, the induced fracture direction was influenced by directional properties of the rock matrix. This study shows that the expected influence of horizontal earth stress on the orientation of an induced hydraulic fracture becomes negligible whenever the magnitude of the difference between the compressive stresses is 200 psi or less. When this occurs, fracture orientation is controlled by the directional properties of the rock—primarily permeability and tensile strength.

OP 134-73. Resin-Loaded Papers for Methyl Mercury & Inorganic Mercury Determination, by Stephen L. Law. *Am. Lab.*, v. 5, July 1973, pp. 91-97. The quantitative determination of mercury at parts per billion levels in the environment has become increasingly imperative as research continues to document the toxic effects of trace levels of mercury, especially when converted to an organic form. In order to obtain reliable analyses for low mercury levels, the capabilities of essentially all applicable analytical instrumentation have had to be extended by the use of chemical separating and concentrating procedures. An effective and yet simple concentrating technique for trace metals involves the use of resin-loaded papers. These papers consist of approximately 50 percent cellulose and 50 percent powdered ion-exchange or chelating resin material. A resin-loaded paper may be used as a very short ion-exchange column (the thickness of construction paper) where a solution is filtered several times through the paper to obtain quantitative collection of the elements of interest; or the paper may be simply suspended in a solution, relying on diffusion of the collectable ions to the resin-loaded paper. In either case, the trace elements of interest are concentrated from a large volume into a volume more amenable to instrumental determination. Of equal importance, the desired elements are separated from the bulk matrix, thereby reducing interference problems. Both of these accomplishments result in increased analytical sensitivity. In the case of mercury, the added capability of distinguishing between organic and inorganic forms makes the use of resin-loaded papers highly inviting.

OP 135-73. Reactor Studies for Exhaust Oxidation Rates, by H. A. Lord, E. A. Sondreal, R. H. Kadlec, and D. J. Patterson. *Internat. Automotive Eng. Cong.*, Detroit, Mich., Jan. 8-12, 1973, SAE Preprint 730203, January 1973, 12 pp. A laboratory test reactor has been used to determine the rates of oxidation of carbon monoxide (CO), hydrocarbons (HCs) as a class, and hydrogen (H₂). The feed was supplied from the exhaust of a single-cylinder engine, with additions of H₂ and CO in some runs. The test reactor was designed to be well mixed, and this was verified experimentally for mixing on macroscopic and microscopic scales. Wall effects were found to be unimportant. Kinetic data from 157 runs were correlated with global reaction rate expressions containing Arrhenius temperature dependence and power law concentration dependence. CO oxidation was found to be approximately 1/4 order in CO with an activation energy of 28,200 cal/g-mole. HC oxidation was found to be approximately 1/4 order in HC and 1/2 order in each of

O₂, CO, and NO with an activation energy of 29,800 cal/g-mole. H₂ oxidation rates were not well correlated, but a zero-order rate with an activation energy of 52,000 cal/g-mole is reasonable. Simulations of the test reactor were compared with experimental data with excellent agreement. These simulations demonstrate that higher orders for these reactions, reported in the literature, may be attributable to mixing limitations in those experiments.

OP 136-73. Warmup Limitations on Thermal Reactor Oxidation, by Donald J. Patterson, Robert H. Kadlec, and Everett A. Sondreal. *Internat. Automotive Eng. Cong.*, Detroit, Mich., Jan. 8-12, 1973, SAE Preprint 730201, January 1973, 14 pp. Warmup of the Du Pont model V reactor during unchoked engine operation with air injection has been characterized by a nonreactive period, followed by a transition to an ignited condition. The early period is quenched by heat loss. The transition is gradual for hydrocarbons, but more abrupt for carbon monoxide. Model building for the warmup period is directed to the objective of developing a rapid computer simulation to predict light-off times and temperature histories for various reactor designs and operating conditions. Reactor gas temperature and chemical conversions are calculated as solutions for an ideal backmix reactor. Heat balances maintain a record of all reactor metal temperatures for the given configuration. Heat transfer by radiation, convection, and conduction is considered. The presence of a hot spot in the reactor has a strong effect on time to light-off. In addition to lowering the time, such an ignition source shows a great sensitivity to combustible concentration. The relative amounts of CO, H₂, and hydrocarbons are also important, since there is a sequential transition to high conversion. Initial reactor temperature and exhaust temperature are also important variables. Variables of reactor design, such as insulation thickness, materials of construction, internal configuration, and reactor size, also affect warmup. A brief exploration of these parameters has been made.

OP 137-73. Field Testing of Liner Backpacking System, by Howard C. Pettibone. *Proc. 11th Ann. Symp. Eng. Geol. & Soils Eng.*, Idaho Dept. Highways, Pocatello, Idaho, Apr. 4-6, 1973, September 1973, pp. 203/216. One of Spokane Mining Research Center's projects is the development of engineering criteria for designing flexible liner backpacking systems for underground support. Until 3 years ago, the system advantages were all theory backed by small-scale lab experiments. Then a model tunnel liner was installed in a Coeur d'Alene mine—48 feet of steel pipe, 3 feet in diameter. The test pipe has four different thicknesses, and each section is instrumented with soil pressure cells, stop closure devices, and pipe deformation points. Instrumentation has been monitored for over 2 years. This field study has produced valuable time deflection data under the field loading conditions encountered.

OP 138-73. Substructure Improves Properties of Lead Alloys, by M. M. Tilman and L. A. Neumeier. *Met. Trans.*, v. 4, August 1973, pp. 1997-1999. Substructure in a Pb-1.4 Cd-1.6 Sb alloy increases creep resistance at 700 psi by a factor of 3.6×10^4 and increases tensile strength by approximately 21 percent without serious loss of ductility. In PB-1 Sb alloy, substructure increases 700 psi creep resistance by a factor of 45 and tensile strength by approximately 9 percent, again without significant loss of ductility. Polygonized substructure was devel-

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oped in Pb-1.4 Cd-1.6 Sb sheet, which had been previously rolled to 1/16-inch at 125° C, by one or more cycles of rolling at room temperature to 4 percent reduction in a single pass, annealing at 200° C for 4 hours, and air cooling. In the Pb-1 Sb alloy, polygonized substructure was developed by initial rolling at room temperature, annealing at 220° C and then rolling in one pass to 5 percent reduction at 175° C and air cooling.

OP 139-73. Suppression and Collection of Respirable Coal Dust Using Water and Steam, by T. F. Tomb, L. Cheng, and R. L. Stein. *Ann. New York Acad. Sci.*, v. 200, Dec. 29, 1972, pp. 724-736. From laboratory experiments, an empirical relationship relating water spray droplet concentration, size, and velocity to the suppression of respirable coal dust was determined. Also, the effect of steam in suppressing respirable coal dust was determined.

OP 140-73. Liner Backpacking System Theory, by Robert C. Bates and Sidiq M. Dar. *Proc. 11th Ann. Symp. Eng. Geol. & Soils Eng. Idaho Dept. of Highways, Pocatello, Idaho*, April 4-6, 1973. September 1973, pp. 185-201. A set of theoretical equations, assuming linearly elastic materials, has been developed that describes the stresses and displacements everywhere in a line-backpacking support system. It is assumed that the field stresses are applied to the system after the liner has been placed, and that the pressures due to the instability of the rock opening itself are not considered. Theoretical work is applicable to any number of concentric layers of material, thereby enabling one to handle underground situations where backpacking can be placed between liner and rock. Graphs showing the benefits and limitations of backpacking are given along with an example showing the effects of an ultrasoft layer of material surrounding the liner. These equations, where applied to existing field data, show good agreement with measured values, and they have also guided the design of field liner installations.

OP 141-73. A New Concept in Information Exchange for Petroleum Chemists, by John S. Ball. Preprints, ACS Div. Petrol. Chem., v. 17, No. 4, September 1972, pp. H40-H51. The preprints of the Division of Petroleum Chemistry of the American Chemical Society, through cooperative efforts of the members, provides speedy, inexpensive, and reliable dissemination of technology.

OP 142-73. Petroleum Division Preprints, by John S. Ball. *Chemtech*, v. 3, No. 8, August 1973, pp. 491, 506. This article describes the planning and compiling of information that is published by the Petroleum Division of the American Chemical Society in their preprints.

OP 143-73. Magnetohydrodynamics—Low Air Pollution Power Generation, by D. Bienstock, P. D. Bergman, J. M. Henry, R. J. Demski, J. J. Demeter, and K. D. Plants. *Pres. ASME Ann. Winter Meeting*, Nov. 11-15, 1973, Detroit, Mich., Preprint No. 73-WA/Ener-3, 1973, 12 pp. Magnetohydrodynamics has very low air pollution potential. In pilot plant tests in which a 2.2 wt.-pct sulfur coal was burned in a cyclone furnace at 200 lb/hr and 4000° F at a seed concentration of 1 g-mole K₂CO₃/kg coal, 99.8 pct removal of SO₂ was obtained with only 5 ppm SO₂ in the gaseous effluent. Operating the combustor with 95 pct of stoichiometric oxygen and ambient air admitted at 2000° F.

NO₂ emissions decreased to 150 ppm or 0.12 lb NO₂/million Btu. This represents a 94 pct reduction from single-stage operation at 102 pct of stoichiometric oxygen. As the gas-cooling rate in the experimental unit is higher than projected for a commercial plant, it is expected that a commercial plant would experience even lower NO_x emissions. A mathematical model using the Zeldovich mechanism was adequate to follow the NO_x decomposition in the air-rich system; an extended Zeldovich was more appropriate in the fuel-rich regime. Experiments showed that at high slag-rejection rates of greater than 90 pct recovery of the potassium seed by aqueous extraction was better than 99 pct. Cost estimates of a 1,000-MWe MHD-steam plant, in which the spent seed is recovered by aqueous extraction and then regenerated with reducing gases to remove the sulfur, showed an operating cost of the seed recovery-sulfur removal steps of 9 pct of the overall power costs of 9.1 mills/kW-hr.

OP 144-73. An Experimental Determination of the True Uniaxial Stress-Strain Behavior of Brittle Rock, by B. T. Brady, W. I. Duvall, and F. G. Horino. *Rock Mech.*, v. 5, 1973, pp. 107-120. Results are presented of an experimental study of the behavior of six rock types deformed under uniaxial compression into their respective postfailure regions. Based on the observation that a rock sample in a postfailure state can be considered to be composed of broken and unbroken rock and assuming that the reduction in load-bearing capability of rock in the postfailure region is due to a reduction of the effective cross-sectional area of the specimen resulting from the growth of large cracks within the rock sample, the authors show that there is a maximum true stress that the unfractured solid rock can sustain without inelastic deformation. This stress is constant and is defined to be the true failure strength of the rock. The value of this stress is calculated by dividing the force on the rock sample at any point along the postfailure curve by the true load-bearing cross-sectional area of the rock sample at that point. Theoretical and experimental techniques are developed which allow an estimate of the true load-bearing area of the rock sample at any point along the postfailure curve of the sample. For the rock types used in the study, which were deformed to preselected positions along their respective postfailure curves and with the assumption that the fractured rock carried none of the applied load, the two techniques of measuring the effective load-bearing area give results which are equivalent.

OP 145-73. Artesian Aquifer, New Fork Tongue of the Wasatch Formation, Northern Green River Basin, by George F. Dana and John Ward Smith. *Wyo. Geol. Assoc. Guidebook (25th Field Conf.)*, 1973, pp. 201-206. An artesian aquifer is found in the New Fork Tongue of the Wasatch Formation in the northern Green River Basin. Overlying the aquifer is the Wilkins Peak Member of the Green River Formation which contains potentially developable oil shales. The aquifer contains substantial amounts of water available for possible use in an oil-shale industry. Flow rates as high as 500 gallons per minute are presently being produced from abandoned oil test wells. The water, containing sodium carbonate and sodium bicarbonate as the principle dissolved solids, is not classed as potable owing to excessive amounts of fluoride and total dissolved solids. Recharge for the aquifer is found to the north where the New Fork Tongue becomes arkosic. The area of known artesian production is about 500 square miles. An additional 700 square miles may contain artesian water from the same source.

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- OP 146-73. Black Trona Water, Green River Basin**, by George F. Dana and John Ward Smith. Wyo. Geol. Assoc. Guidebook (25th Field Conf.), 1973, pp. 153-156. Black water has been found in 18 boreholes drilled since 1949 in an area around Farson and Eden in the northern Green River Basin. The black water is produced from unusually porous and permeable oil shales of variable richness in the Wilkins Peak Member of the Green River Formation. The black water color is caused by organic acids dissolved in a sodium carbonate solution. Because of minimal information, the explanation for the occurrence of the porosity, permeability, and the presence of black water in a usually impermeable shale is difficult and requires further study. However, in our opinion, the black water is original lake water incorporated in the sediments in a low place in the lake bed during recessions of the lake. Further deposition created closed aquifers which, when penetrated by drilling, produce artesian water due to overburden pressure rather than to the more common mechanisms of gas pressure or hydrodynamic drives. Since 1949, attempts have been made to produce the water for economic exploitation, but no economic use has yet been made of it.
- OP 147-73. Vegetative Stabilization of Mill Mineral Wastes**, by K. C. Dean, R. Havens, K. T. Harper, and J. B. Rosenbaum. Proc. Symp. on Ecology and Revegetation of Drastically Disturbed Sites, Pa. State Univ., University Park, Pa., Aug. 5, 1969, Paper VI-1, 1973, 18 pp; Ecology and Reclamation of Devastated Land, Gordon and Breach Science Pub., Ltd., London (1973), pp. 119-135. Mine, mill, and smelter wastes as barren piles on the landscape are considered pollutants. The fine minerals in such wastes that become airborne may cause air and water pollution. The Bureau of Mines is investigating methods of mitigating such pollution by devising means for stabilizing mineral industry wastes. Physical, chemical, vegetative, and combination methods of stabilizing fine wastes have been developed. Since vegetation offers the advantages of renewability and improved appearance, major research emphasis has been directed toward developing vegetative and combined chemical-vegetative stabilization procedures. A resinous adhesive compound used in conjunction with selected vegetation appears exceptionally effective for achieving stabilization of many mill tailings. Treatment of a 10-acre plot of typical copper mill tailings by the combination method effectively stabilized the fine sands against wind erosion.
- OP 148-73. Further Studies of the Combustion of Pulverized Char and Low-Volatile Coal**, by J. J. Demeter, C. R. McCann, D. Bienstock. Pres. ASME Ann. Winter Meeting, Detroit, Mich., Nov. 11-15, 1973, Preprint No. 73-WA/Fu2, 1973, 5 pp. Pulverized char was fired in a dry-bottom, front-wall-fired furnace, capable of burning about 500 lb of the material per hour. Earlier experiments with chars injected at ambient temperatures into this furnace had indicated that increasing amounts of supplementary fuel (natural gas) were required to maintain good combustion as the volatile matter of the char decreased with standardized conditions of burning rate, excess air, and primary air to fuel ratio. In the present investigation, the char-primary air mixture was preheated to eliminate the need for a dual fuel system. Effects of operating parameters such as secondary air preheat and fuel particle size were studied. A low-volatile (5-percent) char was burned successfully without supplemental fuel at a char preheat temperature of 450°-500° F and a secondary air temperature of 600° F. A char preheat temperature of 550° F was required to obtain stable combustion without auxiliary fuel when the secondary air temperature was lowered to 500° F. Low-volatile (18-percent) Pocahontas coal could be burned in the experimental combustor without either auxiliary fuel or preheat of the coal, thus giving an indication of the order of difficulty in burning low-volatile char.
- OP 149-73. Clean Fluid Fuels From Coal and Wastes**, by A. J. Forney and W. P. Haynes. Trans. ASME, v. 95, No. 3, July 1973, pp. 142-144. The economy of the United States is based on energy. Energy is the universal raw material which is essential for man's requirements for food, clothing, and shelter. Recently it has become evident that we are straining our available energy resources to the limit and must change our energy consumption and production patterns. The demands for more energy have been intensified by the demands for clean energy; that is, energy that will have a minimum impact on the environment. Pollution abatement regulations and the difficulty of removing sulfur oxides from the flue gases of coal-burning plants have compounded the problem. The shortage of natural gas has crystallized plans for making substitute gas from LPG and naphthas and some of these plans will be realized by 1973. Recent funding of projects concerned with coal conversion processes is the result of this energy shortage. This paper is a review of recent developments in the research on the conversion of coals and wastes to more usable clean fuels, namely, gas and oil.
- OP 150-73. Catalytic Thermal Decomposition of Carbonyl Sulfide and Its Reaction With Sulfur Dioxide**, by L. A. Haas and S. E. Khalafalla. J. Catalysis, v. 30, No. 3, September 1973, pp. 451-459. The thermal decomposition of carbonyl sulfide (SCO) was studied in an integral reactor with various catalysts. An apparent activation energy of 28.7 kcal/mole was measured for SCO decomposition without a catalyst. In presence of a contact catalyst such as alumina or silica, the apparent activation energy was lowered to 5.6 kcal/mole. At temperatures below 635° C, the main decomposition products of SCO were CO₂ and CS₂. At higher temperatures, the main products were CO and S. With pure ch-alumina, the decomposition of SCO at 550° C was 35 percent, but when a stoichiometric quantity of SO₂ was added to SCO, about 90 percent of the SCO and SO₂ were converted at a much lower temperature (about 400° C). The degree of interaction of SCO and SO₂ was greater with pure ch-alumina than when transition metals were present.
- OP 151-73. Les Vibrations dues aux tirs et leurs effets sur les constructions (Blasting Vibrations and Their Effects on Structures)**, by Henry R. Nichols, Charles F. Johnson, and Wilbur I. Duvall. Explosifs, No. 2, April-June 1973, pp. 45-92. This report, the second part of this French translation of Bureau of Mines Bulletin 656, presents the results of the Bureau's 10-year program to study the problem of air blast and ground vibrations generated by blasting. The program included an extensive field study of ground vibrations; a consideration of air blast effects; an evaluation of instrumentation to measure vibrations; establishment of damage criteria for residential structures; determination of blasting parameters which grossly affected vibrations; empirical safe blasting limits; and the problem of human response. While values of 2.0-in/sec particle velocity and 0.5-psi air blast overpressure are recommended as safe blasting limits not to be exceeded to preclude damage to residential structures, lower limits are suggested to minimize complaints. Millisecond-delay blasting is

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shown to reduce vibration levels as compared to instantaneous blasting, and electric cap delay blasts offer a slight reduction in vibration levels as compared to Primacord delay blasts. Vibration levels of different blasts may be compared at common scaled distances, where scaled distance is the distance divided by the square root of the maximum charge weight per delay. Geology, rock type, and direction affect vibration level within limits. Empirically, a safe blasting limit based on a scaled distance of 50 ft/lb^{1/2} may be used without instrumentation. However, a knowledge of the particle velocity propagation characteristics of a blasting site determined from instrumental blasts at that site are recommended to insure that the safe blasting limit of 2.0 in/sec is not exceeded. The first part of this translation appeared as OP 121-73 in the September issue of New Publications—Bureau of Mines.

OP 152-73. Deposition of Aerosols on a Charged Polystyrene Surface, by Richard L. Stein. *Am. Ind. Hygiene Assoc. J.*, v. 33, No. 12, December 1972, pp. 775-783. A study was made of the decrease in the concentration of coal and fluorescent pigment aerosols in a polystyrene chamber. Losses to the walls of the plastic chamber were as high as 85 percent for coal (75 percent for fluorescent pigment) in a 20-minute period. Wall loss rates decreased with increasing humidity. These losses were shown to be due to the electrostatic attraction between the charged aerosol and the natural charge on the plastic surface. Difference in the wall loss rate constant, β , was attributed to the variation of mobility distribution between the coal and fluorescent pigment aerosols. Areas of positive and negative charges on the plastic surface were mapped. Preliminary investigation of the electrostatic charge on coal particles has indicated that the median charge is about 40 to 200 elementary electronic charges.

OP 153-73. Analyzing Heavy Ends of Crude, by C. J. Thompson, J. E. Dooley, D. E. Hirsch, and C. C. Ward. *Hydrocarbon Processing*, v. 52, No. 9, September 1973, pp. 123-130. To obtain compositional information on both hydrocarbon and non-hydrocarbon components of crude oil and to develop suitable analytical methods applicable to any crude oil, the Bureau of Mines, through American Petroleum Institute Research Project 60 (API RP 60), is studying in some detail the higher boiling fractions of five crude oils of different chemical composition and geological origin. To effectively process and use the heavy ends of petroleum it is necessary to develop suitable separation and characterization procedures not currently available. A systematic procedure developed by the Bureau of Mines uses techniques such as isothermal and molecular distillation, chemical treatment, silica-alumina gel chromatography, gel permeation chromatography and spectrometry. Using these techniques, the Bureau reports herein a detailed separation and characterization of 370° to 535° C distillate from Gach Saran, Iran, crude oil. Such a systematic procedure, applicable to any crude oil, should be of value in selecting feedstocks and optimizing petroleum processing operations.

OP 154-73. Electroslog Remelting of Type 316 Stainless Steel, by W. E. Anable, R. H. Nafziger, and D. C. Robinson. *J. Metals*, 31st Electric Furnace Conf. Issue, v. 25, November 1973, pp. 55-61. The Bureau of Mines, in cooperation with the United States Atomic Energy Commission, electroslog remelted two groups of type 316 stainless steel ingots for ultimate conversion to tubing for tests associated

with the liquid metal fast-breeder reactor. The reduction in imperfections achieved suggests electroslog remelting as a promising alternative to vacuum arc or vacuum induction melting.

OP 155-73. Fast Analytical Procedure for the Separation and Determination of the Polythionates Found in Wackenroder's Solution by High Speed Liquid Chromatography, by J. N. Chapman and H. R. Beard. *Anal. Chem.*, v. 45, November 1973, pp. 2268-2270. Since the 1920's, there has been interest in determining polythionates in solution. The reaction of H₂S with SO₂ in solution yields Wackenroder's solution, which contains S₂O₃²⁻, S₃O₆²⁻, and S₅O₆²⁻, but no other polythionates or S₂O₆²⁻. Many methods have been developed for determining polythionates contained in this mixture, but there is no satisfactory way of separating and quantifying them that is not lengthy and time consuming. Because the time involved in these separations is long, the stability of the polythionates from the beginning to the end of analysis is in doubt. The method described in this paper will separate and quantify the above named polythionates in 15 minutes. The method depends on the adsorption and elution from activated carbon by high-speed liquid chromatography. The factors governing the separation are described.

OP 156-73. The Effects of Physical Properties on the Design of Conveyor Systems, by R. W. Christensen, R. W. Heins, and K. K. Wu. *Proc. 4th and 5th Annual Seminars on Bulk Materials Handling*, December 1971 and December 1972, ed. by M. C. Hawk. Univ. Pittsburgh, Pittsburgh, Pa., v. 2, No. 1, October 1973, pp. 19-34. Discussed is the application of statistical experimental design to analyzing belt conveying of bulk materials. Tests are presently being made to determine the influence of such material properties as particle shape, particle size distribution, angle of internal friction, angle of repose, angle of surcharge, and moisture content on the way these materials are transported by a conveyor belt.

OP 157-73. Compositional Studies of a High-Boiling 370°-535° C Distillate From Prudhoe Bay, Alaska, Crude Oil, by H. J. Coleman, J. E. Dooley, D. E. Hirsch, and C. J. Thompson. *Anal. Chem.*, v. 45, No. 9, August 1973, pp. 1724-1737. Separation and characterization methods applicable to high-boiling petroleum fractions are described. Using these methods, extensive compositional data were obtained on a sample of Prudhoe Bay, Alaska, crude oil.

OP 158-73. Solid Fuels and Heat Generation, by Richard C. Corey. *Sec. in Chemical Engineers' Handbook*, 5th ed., McGraw-Hill Book Co., Inc., New York, November 1973, pp. 9-14-9-23. This section discusses the origin, classification, and composition of coals; the physical properties of coal, coke, and other solid fuels; combustion stoichiometry; and the kinds and characteristics of equipment used for burning coal.

OP 159-73. Corrosion of Solders in Automobile Coolant Systems, by W. L. Falke, A. E. Schwaneke, and A. Y. Lee. *Welding J.*, v. 52, October 1973, pp. 460-s-465-s. Corrosion experiments were conducted on three high-lead and two zinc-base solders in commercial antifreeze coolant solutions, in a rust inhibitor solution, and in corrosive water. The experiments were made to compare the corrosion resistance of presently used soldering systems with that of new systems that can be used for assembling automotive radiators. The high-lead solders, 70Pb-30Sn, 95Pb-5Sn, and 95Pb-3.8Sn-1.2Ag, are similar to those used to make automobile radiators. The zinc-base

solders (95Zn-5Al and 89Zn-7Al-4Cu) were developed for possible use in automobile radiators. Glassware corrosion tests were conducted on each of the soldering alloys for periods of 336 hours at temperatures of 165° and 200° F. A limited number of in-service tests were performed by introducing the sample bundles into the cooling system of two automobiles for 10,000-mile tests. Results are presented as the corrosion weight loss in milligrams for each specimen of (1) bulk solder, (2) solder coated copper, and (3) solder coated brass. Corrosion resistance of the soldering alloys and of the solder-coated copper and brass proved to be more dependent on coolant solution type and temperature than on solder alloy composition, whether high-lead or zinc-base type solders. Increased corrosion occurred for both soldering systems in corrosive water; however, the amount of increase was much greater for the zinc-base system. With the exception of the zinc-base bulk solders, the rust inhibitor solution offered little protection to the solder systems tested.

OP 160-73. The Synthane Process—Research Results and Prototype Plant Design, by A. J. Forney and J. P. McGee. Proc. 4th Synthetic Pipeline Gas Symp., Chicago, Ill., Oct. 30-31, 1972, pp. 51-71. The paper discusses the development of the Synthane Process at the Bureau of Mines laboratories at Bruceton, Pa., the research on a Synthane gasifier done at the Hydrocarbon Research, Inc., plant in Trenton, N. J., and the Lummus design of the 75-tpd prototype plant to be constructed at Bruceton, Pa. Because of the importance of environmental problems, the pollution aspects of the Synthane Process and solutions are also discussed.

OP 161-73. The Enthalpies of Combustion and Formation of 1,8-Dimethylnaphthalene, 2,3-Dimethylnaphthalene, 2,6-Dimethylnaphthalene, and 2,7-Dimethylnaphthalene, by W. D. Good. J. Chem. Thermodynamics, v. 5, No. 5, 1973, pp. 715-720. The enthalpies of combustion of 1,8-dimethylnaphthalene, 2,3-dimethylnaphthalene, 2,6-dimethylnaphthalene, and 2,7-dimethylnaphthalene were measured by precision oxygen-bomb calorimetry. Enthalpies of formation in the crystalline state were derived.

OP 162-73. The Enthalpies of Combustion and Formation of n-Butylbenzene, the Diethylbenzenes, the Methyl-n-propylbenzenes, and the Methyl-isopropylbenzenes, by W. D. Good. J. Chem. Thermodynamics, v. 5, No. 5, 1973, pp. 707-714. The enthalpies of combustion of n-butylbenzene and nine of its isomers were determined by precision oxygen-bomb calorimetry. Enthalpies of formation in the liquid state were derived.

OP 163-73. Nonmetal Elements and Compounds, by W. E. Haines and D. R. Latham. Anal. Chem., v. 45, No. 6, 1973, pp. 198R-203R. This paper is a biennial review summarizing research on nonmetal elements in petroleum for 1970 and 1971.

OP 164-73. The Theory of Free Ambient Fires. The Convectively Mixed Combustion of Fuel Reservoirs, by M. Hertzberg. Combustion and Flame, v. 21, 1973, pp. 195-209. The theory of fuel-reservoir fires (that is, pool flames) is extended and amplified into a quantitative formulation that includes all the significant physical processes—mass diffusion, heat conduction, convective mixing, convective heat transport, and radiative heat transport. The conservation equations across the Gibbsian surfaces of the pool flame are solved, in finite-difference form, under idealized but nevertheless realistic conditions. This semiempirical solution, which quantifies the consensus of

views of many previous researchers, is surprisingly simple considering the number of processes involved and their complexity. The predictions are compared with the data for three fuels (gasoline, liquid hydrogen, and methanol), and the comparison gives reasonable agreement. This steady-state theory idealizes the complexities of turbulent, eddy mixing in terms of a single, average mixing radius, whose magnitude is inferred from the observed flame structures. The radiative transport process from the hot flame volume to the pool reservoir is idealized as a planar surface-to-surface transfer function. The observed flame thickness is used to calculate both the emissivity of the upper "flame surface" and its average height above the pool. The theory presented is only a beginning in handling the major problem, that is, the feedback loop between the combustion source function and the flow mixing of vaporizing fuel with entrained air. Combustion and buoyancy forces are the sources of flow, but it is the flow mixing field itself that controls the strength of these forces.

OP 165-73. Physical and Chemical Properties of Respirable Coal Dust From Two United States Mines, by M. Corn, F. Stein, Y. Hammad, S. Manekshaw, R. W. Freedman, and A. M. Hartstein. Am. Ind. Hygiene Assoc. J., July 1973, pp. 279-285. This investigation was aimed at establishing procedures for obtaining data relative to the physical and chemical characterization of respirable coal mine dust for utilization in epidemiological studies of incidence of coal workers' pneumoconiosis in different U.S. mines.

OP 166-73. Unusual Concepts for Coal Mine Haulage, by W. K. Kleysteuber and A. J. Miscoe. Proc. 4th and 5th Annual Seminars on Bulk Materials Handling, December 1971 and December 1972, ed. by M. C. Hawk. Univ. Pittsburgh, Pittsburgh, Pa., v. 2, No. 1, October 1973, pp. 132-142. Some of the unusual concepts for coal mine haulage now under investigation are described. The article discusses the advantages, disadvantages, and study plans of the following: Hydraulic and pneumatic transport; a sidetrail and sidewheel system; a heavy media hoist; a peristaltic conveyor and an undulatory conveyor; an air-cushioned belt conveyor propelled by linear induction motors; an adaptation of the Archimedes' screw; and possible application of the Rolamite device for conveying.

OP 167-73. Concentration Profiles for Radical Species in a Methane-Oxygen-Argon Flame, by C. P. Lazara, J. C. Biordi, and J. F. Papp. Combustion and Flame, v. 21, 1973, pp. 371-382. Concentration profiles through the reaction zone of a low-pressure, slightly lean methane-oxygen-argon flame have been measured, in situ, for the following unstable species: Oxygen atoms, hydrogen atoms, hydroxyl radicals, methyl radicals, and formyl radicals. The conditions of measurement, means of identification, and method for estimating the concentrations of the radicals are described. The observed maximum mole fractions are 2.3×10^{-2} for H, 1.1×10^{-2} for OH, and 0.8×10^{-2} for O, the maxima occurring in the recombination zone for these species. The maximum values are in excess of equilibrium concentration by factors of $\sim 10^{-10^3}$. Methyl and formyl radicals have maximum mole fractions in the reaction zone of 2.2×10^{-3} and 6×10^{-5} , respectively. Equilibrium constants, calculated from the appropriate measured species concentrations for the fastest reactions of the $H_2 = CO = O_2$ flame, which is the last stage of this hydrocarbon flame, suggests that these reactions are essentially balanced in this part of the flame.

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- OP 168-73. Risques dus à la réaspiration des gaz d'échappement par les moteurs en espace confiné (Hazard From Engines Rebreathing Exhaust in Confined Space)**, by W. F. Marshall and R. W. Hurn. Cahiers de Notes Documentaires, Institut National de Recherche et de Sécurité, No. 73, 1973, pp. 471-481. The Bureau of Mines conducted a series of experiments to determine the influence of exhaust rebreathing on emissions from various gasoline and diesel engines. Tests were conducted that simulated operation of engines in nonventilated spaces as well as in spaces with partially restricted ventilation. Results of these tests showed that exhaust rebreathing can have a marked effect on exhaust emissions and thus on the composition of the air in the working space. For the case of restricted ventilation, unacceptably high (greater than 50 ppm) levels of CO in the air of the working space resulted from exhaust rebreathing rates as low as 8 percent exhaust in the engine's intake. Operation in a nonventilated space resulted in highly critical CO levels (fatal in a few minutes) at times corresponding to 1 to 3 pounds of fuel consumed per 1,000 cubic feet of space. Tests involving spaces of various sizes showed that volume of the air space per se is not important—the primary variable is fuel consumed per unit volume of air space. This paper is a translation of Bureau of Mines Report of Investigations 7757.
- OP 169-73. Synthetic Argentojarosite: Physical Properties and Thermal Behavior**, by A. May, J. J. Sjöberg, and E. G. Baglin. Am. Mineralogist, v. 58, September-October 1973, pp. 936-941. Artificial argentojarosite, $\text{Ag}_2\text{Fe}_6(\text{OH})_{12}(\text{SO}_4)_4$, prepared in connection with Bureau of Mines research on refractory silver ores, has been synthesized in considerably greater quantities than in previous studies. As a result, a detailed study of its thermal decomposition, optical properties, and physical properties was possible by a combination of chemical analyses, differential thermal analyses, X-ray diffraction, and optical techniques. Cell dimensions are $a = 7.347 (\pm 0.010)$, $c = 16.580 (\pm 0.053)$; refractive indices are $n_x = 1.789-1.790$, $n_z = 1.889-1.890$. Twenty-nine observed X-ray diffraction reflections including reflection indices, relative intensities, and observed and calculated d -spacings are listed.
- OP 170-73. Current Bureau of Mines Research on Junk Car and Related Ferrous Scrap**, by C. B. Kenahan. Secondary Raw Mater., v. 11, January 1973, pp. 48-51. This paper describes the Bureau of Mines research program on junk cars and other ferrous scrap. Included are the topics of scrap melting, junk car incineration, and ferrous scrap refining research.
- OP 1-74. Methods and Costs for Stabilizing Tailings Ponds**, by Karl C. Dean and Richard Havens. Min. Cong. J., December 1973, pp. 41-46. About 1.7 billion tons of mineral wastes are discarded annually in the United States. The total accumulated mineral solid wastes amounted to about 25 billion tons. These mineral waste piles currently cover more than 2 million acres. They are second only to agricultural wastes in quantity and represent nearly 40 percent of the total solid wastes produced in the United States. A part of the mineral discard is fine-size material requiring some sort of stabilization if air and water pollution are to be minimized. On active mill tailing ponds, air pollution is controlled by keeping the surfaces of the ponds wet either by tailings discharge or by sprinkling. On inactive ponds, a more permanent solution is required, usually that of physical, chemical, or vegetative stabilization. Other physical methods of stabilization evaluated include (1) the use of bark covering and (2) the harrowing of straw into the top few inches of tailings.
- OP 2-74. Research Finds Methane Can Ignite by Frictional Sparks Between Aluminum Alloys and Rusty Steel**, by D. H. Desy, J. S. Risbeck, and L. A. Neumeier. Coal Age, v. 78, No. 12, November 1973, pp. 65-68. The Bureau of Mines has conducted research on the ignition of methane by sparks caused by frictional impact of aluminum alloys on rusty steel at typical coal mine fan speeds. The objectives were to establish the incendency of aluminum alloys under these conditions, to investigate differences between aluminum alloys, and to evaluate substitute materials for the aluminum-steel combination. With a specially designed apparatus, three commercial aluminum casting alloys and a series of experimental aluminum alloys were tested for incendency in frictional impact against rusted steel in flammable methane-air mixtures. All aluminum alloys tested produced some ignitions. In a series of experimental alloys, the harder alloys and those containing silicon tended to be more incensive than the others. Constructional steel, stainless steel, brass, and plastic did not cause ignition of methane-air mixtures in frictional impact against rusty steel. Some ignitions occurred with constructional steel at high speed in more flammable gas mixtures. It is suggested that other constructional materials than the aluminum-steel combination would minimize or eliminate this hazard.
- OP 3-74. Penetration of Sodium Chloride Aerosol Through Respirator Filters**, by B. I. Ferber, F. J. Brenenborg, and A. Rhode. Am. Ind. Hygiene Assoc. J., December 1972, pp. 971-996. A method has been previously described for using a sodium chloride (NaCl) aerosol to measure penetration through respirator filters. The detector used at that time was not sensitive enough to determine the penetration of high-efficiency filters designed for protection against highly toxic particulates and radionuclides. In the present method, an ultrasonic nebulizer is still used to produce a NaCl mist. The NaCl concentration has been reduced to 10 $\mu\text{g/liter}$, and the particle size has been decreased to 0.53 μm , mass median diameter. Respirator filters were exposed to this aerosol at airflows of 16 and 42.5 liter/min. The flame photometric detector in this study could determine filter penetration in the range of 0.0005 to 51.6 percent. This is suitable for measuring the penetration of high-efficiency filters.
- OP 4-74. New Developments (II-B). 3. Partial Oxidation and Other Methods**, by A. J. Forney and J. H. Field. Ch. in Ammonia I (Fertilizer Science and Technology Series), ed. by A. Slack and G. James. V. 2, Marcel Dekker, Inc., New York, 1973, pp. 347-353. The general low cost and widespread use of natural gas and naphtha have discouraged research and development on coal gasification in most of the countries that have large coal reserves. An exception is the United States, where extensive research was begun in the 1960's—mainly under sponsorship of the Bureau of Mines Office of Coal Research—to develop a pipeline gas as a substitute for natural gas. Other work has been aimed at making synthesis gas or hydrogen for use as an intermediate in making liquid fuels from coal. Either type is suitable for making ammonia synthesis gas if the process can be adjusted to give the gas composition required. This chapter describes efforts of the Bureau of Mines toward these ends.

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OP 5-74. Service Lives of Respirator Cartridges Versus Several Classes of Organic Vapors, by R. W. Freedman, B. I. Ferber, and A. M. Hartstein. *Am. Ind. Hygiene Assoc. J.*, February 1973, pp. 55-60. The effective service life of chemical respirator cartridges varies with the organic vapor absorbed on the charcoal. Life versus various compounds was determined by exposing chemical cartridges to vapors, some of which were of fairly high toxicity. An apparatus was assembled to produce dynamic mixtures containing 1,000-ppm concentrations of organic vapors. The effluent was continuously monitored to determine cartridge service life using hydrogen flame ionization detection. Service life depends on the compound to which the cartridge is exposed. Breakthrough patterns for several compound classes may serve as a rough guide for untested compounds within a homologous series.

OP 6-74. Automatic Data Acquisition, by Thomas J. George. *Chem. Eng.*, Dec. 10, 1973, pp. 123-128. This paper describes how data acquisition equipment can record scientific data in a form suitable for later analysis by computer. The paper emphasizes the importance of installing workable data-acquisition systems rather than choosing more sophisticated equipment that will require a good deal of money and time to make them efficient. This article points out that attention to data-acquisition requirements before a project is begun is vital to effective, economic, scientific research.

OP 7-74. Air and Power Requirements for the Vacuum Transport of Crushed Coal in Horizontal Pipelines, by J. L. Konchesky, T. J. George, and J. G. Craig. *Pneumotransport 2*, 2d Internat. Conf. on the Pneumatic Transport of Solids in Pipes, BHRA Fluid Engineering, Cranfield, Bedford, England, Sept. 5-7, 1973, pp. B4-45-B4-55. Experiments in the vacuum transport of crushed coal through horizontal pipelines produced data for empirical equations and graphs that give minimum air and power requirements for combinations of coal rates, specific gravities, pipe diameters, and lengths. Highest coal throughput rate achieved in these experiments was 18 tons per hour of coal (1.4 specific gravity) through 200 feet of 6-inch-diameter pipe followed by three shorter runs connected by bends of different radii. About 800 cubic feet per minute of air was required to keep the coal moving in full suspension through the pipeline. Based on extrapolations of the equations, 155 tons per hour of 4- by 0-inch coal (1.4 specific gravity) can be pulled through 200 feet of straight 12-inch-diameter pipe by 5,500 cubic feet per minute of air requiring 150 theoretical horsepower. For 500 feet of pipeline, the haulage rate would be 70 tons per hour requiring 5,100 cubic feet per minute of air and 145 horsepower. Moisture content and size of the coal were not significant variables. Moistures should be considered, however, in the design of pick-up and acceleration sections where adhesion to the walls is more probable. Maximum coal size cannot exceed one-third the diameter of the pipe.

OP 8-74. Hard Rock Tunneling—Potentials for Automation and Improved Safety Through Sensor Development, by J. J. Olson. *Proc. Res. Workshop on Sensors for Automation*, Apr. 9-12, 1973. The Charles Stark Draper Laboratories, November 1973, pp. 102-148. Public pressure is mounting against disasters in tunneling projects. Many recommendations for elimination of these disasters involve removing or protecting man from hazardous conditions in underground operations through automation of the excavation process.

Although these recommendations for automation would help prevent loss of life in tunnel mishaps, much development is needed before man can be removed from tunneling and mining activities conducted underground. The goal of the Workshop on Sensors of Automation sponsored by the National Science Foundation and held at Lexington, Mass., April 10-12, 1973, was to identify research and development in sensors needed to improve productivity and enhance the overall quality of life in the United States. The workshop presentations emphasized four operational areas: industry, medicine, distribution, and hazardous environments. As part of the information presented in the hazardous environments session, this paper identifies emerging technologies for rapid, hard-rock excavation which will require automation and associated sensor development before these technologies can find practical application in tunneling and mining.

OP 9-74. Stability of an Underground Room in Frozen Gravel, by Howard C. Pettibone. *Proc. 2d Internat. Conf. on Permafrost*, Yakutsk, Russia, July 16-28, 1973. *Nat. Acad. Sci.*, Washington, D.C., December 1973, pp. 699-706. A 9.14- by 21.3- by 2.4-m-high room in frozen gravel near Fairbanks, Alaska, was heavily instrumented, then monitored for over 3 years. The room was stable and no artificial supports were needed at -5° C or colder.

OP 10-74. Mineral Resources and Water Requirements for New Mexico Minerals Industries, by Earl F. Sorensen, Ronald B. Stotelmeyer, and Don H. Baker, Jr. *N. Mex. BuMines and Min. Res. Circ.* 138, 1973, 26 pp. The circular outlines New Mexico mineral production, location of mineral resources, and estimated water requirements to the year 2020. Water requirements are estimated for metallic, non-metallic, and fossil fuel production.

OP 11-74. Velocity Anisotropy in Dry and Saturated Rock Spheres and Its Relation to Rock Fabric, by Richard E. Thill, Thomas R. Bur, and Robert C. Steckley. *Internat. J. Rock Mech., Min. Sci., and Geomech. Abs.*, v. 10, No. 16, November 1973, pp. 535-557. The effects of water saturation on compressional wave velocity, V_p , and elastic property anisotropy are investigated omnidirectionally in dry- and water-saturated spheres of Barre Granite and Tennessee marble by the ultrasonic pulse method. The technique of determining V_p in dry and saturated rock spheres is shown to provide information about (1) the presence of microcracks and their effect on the elastic constants, (2) the anisotropy in elastic as well as other physical properties, and (3) the dominant structural cause of anisotropy. The mean V_p in saturated rock moreover is useful for predicting the velocity in rock at shallow depths below the water table. The velocity difference method for detecting microcracks and their preferred orientation might be used to assess the effectiveness of certain fragmentation techniques and, moreover, may have widespread application in rock mechanics research because of the great effects microcracks can have on the elastic strength and other properties of rock.

OP 12-74. Discussion of "Absolute Stress Measurements at the Rangely Anticline, Northwestern Colorado," by R. V. de la Cruz and C. B. Raleigh, by J. R. Aggson. *Internat. J. Rock Mech. Min. Sci. & Geomech. Abstracts*, v. 10, No. 9, 1973, pp. 749-750. The authors of "Absolute Stress Measurements at the Rangely Anticline, Northwestern Colorado," have presented the results of comparative tests of five different methods of measuring the absolute state of stress in

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rocks in situ. The authors conclude that the Bureau of Mines' three-component borehole deformation gage is the most suitable method of measuring the state of stress in rock. Several statements presented in the paper are clarified in this technical discussion.

OP 13-74. Explosives and Borehole Loading, by Richard

A. Dick. Subsection 11.7 in SME Mining Engineering Handbook, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 1, 1973, pp. 11-78-11-99. The present state-of-the-art of explosives development and borehole loading techniques are described. Characteristics of explosive reactions are covered, and the physical and detonating properties of specific explosives are compared. A brief description of each commercial explosive type is included. Commonly used detonators and primers are described. General price trends for various categories of explosive products are shown as well as key factors in the choice of explosive. Common methods of loading both small- and large-diameter boreholes with cartridge, bagged, and bulk products are covered. Controlled blasting techniques (line drilling, presplitting, smooth blasting, and cushion blasting) are described, including recommended spacings. The reader is directed to key sources of available safety literature. The paper is concluded with 38 references considered useful to persons involved in commercial blasting operations.

OP 14-74. Chemical Fragmentation, by William H. Engelmann. Subsection 11.9 in SME Mining

Engineering Handbook, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 1, 1973, pp. 11-112-11-118. Chemical additives can be used to improve the performance of standard drilling methods. The term chemical fragmentation is defined as the breakage, fracture, or comminution of rock or mineral materials by mechanical forces, aided by the presence of chemical solutions. The latter are usually in the form of the aqueous pulp of a ball-mill grinding circuit, or the flushing and cooling fluids pumped down the hollow drill stem to the drill bit. Grinding and drilling are, therefore, the two most important processes benefiting by chemicals in solutions. Although these processes are the chief ones discussed, other chemically induced changes in rock toughness, as determined by special laboratory tests, are also noted.

OP 15-74. Glass Wool and Other Ceramic Products From Waste Glass, by Alan H. Goode, M. E.

Tyrrell, and I. L. Feld. Proc. Symp. on Utilization of Waste Glass in Secondary Products, Jan. 24-25, 1973, Albuquerque, N. Mex. Technology Application Center—Institute for Social Research and Development, University of New Mexico, 1973, pp. 237-249. A process for making commercial-quality glass wool from the glass fraction of municipal incinerator residues was developed by the Bureau of Mines. This research was a part of the Bureau's program to recover usable materials from reclaimed urban waste. Molten glass was fiberized into glass wool on a laboratory scale by impinging a jet of compressed air on a stream of the molten glass. Melt compositions were varied by adding dolomite and alumina to obtain molten glass with the handling characteristics required for producing final wool products of the desired composition and physical characteristics. When no charge is made for the waste glass and a credit

of \$70 per ton is allowed for the wool product, a 10 percent rate of return on investment after taxes is possible. If a charge of \$5 per ton is placed on the waste glass, a selling price of about \$72 per ton would be necessary to obtain a 10 percent rate of return.

OP 16-74. Fragmentation Principles, by Warren W.

Krech. Subsection 11.1 in SME Mining Engineering Handbook, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 1, 1973, pp. 11-2-11-3. This article covers the fundamental principles of fragmentation in rocks. Energy must be supplied by direct or indirect means to fragment that rock. The amount is dependent upon the properties of the rock and the type of loading system. The strength of rock is influenced by the environmental conditions imposed on the rock, such as confining pressure, pore fluid pressure, temperature, and rate of load application.

OP 17-74. Chromatographic Techniques Used in the Characterization of High-Boiling Petroleum Distillates,

by D. R. Latham and W. E. Haines. Preprints, ACS, Div. Petrol. Chem., v. 18, No. 3, August 1973, pp. 567-571. Several chromatographic techniques were combined into a scheme to separate high-boiling distillates into analytically significant fractions, amenable to further characterization. These techniques are discussed, and compositional information obtained from the application of the techniques is reported.

OP 18-74. Drilling Machines, Surface, by Roger G. Mor-

rell and Harold F. Unger. Subsection 11.4 in SME Mining Engineering Handbook, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 1, 1973, pp. 11-24-11-56. This article on surface drilling machines thoroughly describes rotary and percussive (both downhill and surface-mounted) drilling techniques. The discussion is limited to primary blasthole drilling as practiced in open pit, quarry, and stripping operations. Although primary blastholes usually are drilled vertically, angle holes are also common, and most blasthole drill rigs, therefore, have angle drilling capability. A few rigs are designed to drill horizontal holes for overburden removal, but these are limited in number. Most blasthole drill rigs use either rotary, percussive, or rotary-percussive drilling methods, with jet piercers used to a limited extent. Since all blasthole drills are designed for high production, they feature fast drilling, rapid tramming, quick setup, automatic drill steel handling, and rapid hoisting and lowering speeds.

OP 19-74. Cutting Machines and Cutting, by Parviz F.

Rad. Subsection 11.2 in SME Mining Engineering Handbook, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 1, 1973, pp. 11-3-11-5. The techniques of preblast cutting in soft minerals is described in this article. The first step in conventional coal mining is cutting. Cutting also is done in mining certain other stratified minerals. Cutting to produce an opening called a kerf is desirable because it provides one additional free surface for the coal to break to. Further, undercutting or overcutting relieves the coal seam from the stress acting on it due to overburden pressure. A cut seam

will require less explosive to blast, and the coal will be coarser than from an undisturbed seam. Further, less dust and methane are produced in blasting a cut seam.

OP 20-74. Dynamic Response of the Continuous Mechanical Froth Flotation Cell, by Leon Y. Sadler III. *Trans. Soc. Min. Eng., AIME*, v. 254, No. 4, December 1973, pp. 336-343. Three new transfer functions relating the time response of the amount of floatable mineral in the underflow to time-dependent changes in the amount of floatable mineral in the feed to the cell are presented. Using experimental stimulus-response data obtained from the flotation of minus 200- plus 325-mesh glass spheres in a rotor-stator-type cell, the new transfer functions are compared with the only transfer function to be presently found in the literature by nonlinear least-squares fitting in the frequency domain. The new mathematical model based on the amount of available bubble surface area and its rate of introduction is quite promising. The transfer function that allows for a distributed first-order flotation rate constant also gives good results. Simultaneous sodium chloride tracer and glass bead stimulus-response tests show that the mixing conditions in the cell were nearly ideal. It is felt that the new transfer functions presented offer excellent alternatives for use in the design of automatic process control equipment for the continuous mechanical froth flotation cell.

OP 21-74. Adsorption of Hexane on Attrition-Milled Silica, by Leon Y. Sadler III and William J. Hatcher, Jr. *AICHE J.*, v. 20, January 1974, pp. 174-175. The effectiveness of attrition milling in producing high-specific-surface materials that would be effective adsorbents is described. Silica was selected as the test material, and adsorption of *n*-hexane on the attrition-ground material was compared with adsorption on two commercial silica adsorbents. Attrition milling offers a new approach to the manufacture of high-surface-area solids for use as adsorbents and has the potential of providing high-surface-area materials that have not been available previously. Certain substances that cannot be chemically precipitated to form high-specific-area materials can be milled to a size that achieves the desired surface.

OP 22-74. Ground and Air Vibrations From Blasting, by David E. Siskind. Subsection 11.8 in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 1, 1973, pp. 11-99-11-112. This review describes the problems of ground vibrations and noise produced by surface and underground blasting. Emphasis is placed on seismic and airblast damage to structures, and the generation and propagation of seismic energy produced by mining, quarry, and excavation blasting. Ground motion and airblast damage criteria from Bureau of Mines Bulletin 656 are discussed in addition to instrumentation and methods for minimizing airblast annoyance complaints. Recommended is a maximum safe ground vibration level of 2 in/sec for residential structures of normal seismic damage risk, and an airblast caution threshold of 0.5 psi overpressure for properly mounted, strainless glass panels.

OP 23-74. Size Reduction of Ceramic Powders by Attrition Milling, by D. A. Stanley, L. Y. Sadler III, and D. R. Brooks. *Particle Reduction 1973*, Proc. 1st

Internat. Conf. in Particle Technol., IIT Research Institute, Chicago, Ill., Aug. 21-24, 1973, pp. 279-285. Attrition milling was developed by the Bureau of Mines in the early 1960's as an outgrowth of an earlier developed attrition scrubber. This type of milling is characterized by intense agitation of a grinding medium slurry in a baffled vessel by a radial-flow, concentrically mounted impeller. Attrition mills are being used commercially for producing paper-grade clays and paint pigments. Research studies are being conducted by the Bureau of Mines to extend the use of attrition milling to the preparation of submicrometer-size oxide powders suitable for the fabrication of ceramic articles. A number of the variables that influence rates of size reduction are discussed in which fluorspar, silica, calcite, dolomite, zirconia, and barium ferrite powders were milled. The effect of using spherical quartz, alumina, and zirconia milling media on contamination are described. Performance of conventional mills are compared, with the attrition type illustrating the greater efficiency of the latter.

OP 24-74. Principles of Drilling, by Sathit Tandanand. Subsection 11.3 in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 1, 1973, pp. 11-5-11-24. The principles of drilling are concerned with the energetics of rock penetration through use of mechanical energy, the functional responses, and the interrelationships between the drill system and rocks. The subjects discussed include strength characteristics of rock, mechanics of penetration, major factors influencing penetration rate, engineering properties related to drillability, and drillability determination.

OP 25-74. Thermal Drilling of Blastholes, by K. Thirumalai. Subsection 11.5 in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 1, 1973, pp. 11-56-11-60. This section on thermal drilling and chambering (jet piercing) of blastholes describes high-energy heating as a proven though relatively new method of preparing blastholes. Novel high-energy heat sources with the potential for drilling and disintegrating rocks are laser and infrared heaters, electron beams, plasma heaters, electrical heaters, and supersonic oxygen-fuel oil or compressed air-fuel oil burners. Supersonic "rocket" burners using oxygen and light petroleum-based fuel oil reactants have found wide acceptance for blasthole drilling, especially in some hard taconite formations.

OP 26-74. Drilling Machines, Underground, by Harold F. Unger. Subsection 11.6 in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 1, 1973, pp. 11-60-11-78. This description of underground drilling methods covers percussive, rotary, and rotary-percussive techniques. Topics specifically treated are types of drills, power sources, drill rods, types of bits, circulation or flushing systems, operating and performance specifications, and unit costs.

OP 27-74. Ecology of Some Mined Areas in North Dakota, by M. K. Wali and P. G. Freeman. *North Dakota Geol. Survey, Educational Ser. 5*, Grand Forks, N. Dak., 1973, pp. 25-47. The species composition and diversity and soil physical and chemical

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properties of some unmined areas have been compared with spoil banks that have been revegetated naturally over a period of time. The entire study has been located in such a way that the spoil materials represent a series along a time gradient. Emphasis has been laid on abundance of species in relation to water retention properties and macro- and micro-nutrient content of the soils. This study provides an insight into the regional ecological processes in operation that will have a bearing on the present as well as future revegetation and reclamation efforts.

OP 28-74. Reactions Catalyzed by $\text{Co}_2(\text{CO})_8$. Selective Deuterium Incorporation Into Some Polycyclic Hydrocarbons, by Thomas A. Weil, Sidney Friedman, and Irving Wender. *J. Organic Chem.*, v. 39, No. 1, Jan. 11, 1974, pp. 48-50. In the presence of D_2 (or D_2O), $\text{Co}_2(\text{CO})_8$ catalyzes the conversion of anthracene, anthraquinone, and 9,10-dihydroanthracene to 9,9,10,10-tetradeutero-9,10-dihydroanthracene. The tetradeutero compound acts as a deuterium source for hydroformylation reaction.

OP 29-74. Molecular Interactions of Asphalt: An Infrared Study of the Hydrogen-Bonding Basicity of Asphalt, by R. V. Barbour and J. C. Petersen. *Anal. Chem.*, v. 46, No. 2, February 1974, pp. 273-277. The hydrogen-bonding basicity of asphalts, oxidized asphalts, and asphalt fractions has been investigated by infrared techniques using phenol as the hydrogen-bonding acid. Evidence has been obtained that asphalts exhibit strong hydrogen-bonding basicity. Infrared frequency shift data give enthalpies of formation in the range 6 to 8 kcal/mole for the asphalt-phenol hydrogen bond in CCl_4 solution. The phenol interaction data suggest a hydrogen-bonding base concentration of at least 2 mmoles per gram of asphalt. Air oxidation of asphalts at elevated temperatures increased the measured hydrogen-bonding basicity of the asphalt and suggests the formation of new hydrogen-bonding bases. Sulfur-containing molecules are suggested as important to the hydrogen-bonding basicity of asphalts, and the oxidation of the sulfur in these molecules could account for some of the increased basicity on air oxidation. Data from the methylation of an asphalt and its fractions with diazomethane suggest the occurrence of molecular aggregation via hydrogen bonding.

OP 30-74. Design and Operation of an Automobile and Railroad Car Incinerator, by J. H. Bilbrey, Jr., K. C. Dean, and J. W. Sterner. *Met. Soc., AIME*, February 1974, TMS Preprint A74-88, 6 pp. A low-cost, smokeless automobile incinerator capable of burning up to 80 flattened automobiles in an 8-hour operating day was designed by the Bureau of Mines and has been operated during the past 4 years. Based upon the successful operation of this prototype, a modified incinerator capable of burning both railroad cars and automobiles was designed and constructed by a major scrap processor in conjunction with the Bureau of Mines. Research on the operation of this incinerator has been conducted during the past year, burning flattened and unflattened automobiles and stock, box, and work railroad cars. Although many maintenance problems were encountered from materials of construction, operation of the incinerator was successful. Smokeless incineration of railroad cars as well as automobiles was found possible in 23 of 25 tests made in the late stages of operation. Smoke emission in the other two burns was of less than 2-minute duration in each case. The average time for burning a batch of 20 unflattened automobiles was about 35 minutes, and

the railroad cars ranged from 60 to 75 minutes each for complete burnout.

OP 31-74. Coal Technology, by Richard C. Corey. Ch. in *Riegels Handbook of Industrial Chemistry*. Van Nostrand Reinhold Co., New York, 7th ed., 1974, pp. 23-61. This chapter discusses coal reserves, production, and consumption; origin and classification of coal; mining, cleaning, and composition; coal utilization, including combustion, gasification, and liquefaction; and nonfuel uses of coal.

OP 32-74. A Fragmentation Experiment for In Situ Extraction, by Dennis V. D'Andrea, Richard A. Dick, Robert C. Steckley, and William C. Larson. *Proc. Solution Min. Symp.*, ed. by F. F. Aplan, W. A. McKinney, and A. D. Pernicelli. 103d AIME Ann. Meeting, Dallas, Tex., Feb. 25-27, 1974, American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, 1974, pp. 148-161. A fragmentation experiment was performed in cooperation with Duval Corp. in a porphyry-copper-molybdenum deposit near the Sierrita pit south of Tucson, Ariz. A 10-hole test blast was detonated to establish relationships between blasthole spacing and the resulting fragmentation. Blastholes were 9 in in diameter and 110 ft deep. The 10 blastholes contained a total of 17,400 lb of aluminized slurry blasting agent in 50-ft columns with 60 ft of stemming. Blasthole spacings of 25, 20, and 15 ft were tested. Diamond drill core examination was the primary method used to determine the condition of the rock before and after blasting. Topographic surveys were used to measure the rock swell produced by the blast and a fragment size distribution was obtained for the rubble material on the surface. The rubble zone at the surface was ideal for in situ leaching. Fragmentation to depths of 110 ft was excellent from the 15- to 20-ft blasthole spacing patterns. Good breakage was also produced by the 25-ft pattern, although the effects of the blast were not as obvious. In situ leaching tests were not conducted. However, based on size consideration only, all three blasting patterns produced adequate breakage for successful leaching.

OP 33-74. Recovery of Aluminum From Shredded Municipal and Automotive Waste, by K. C. Dean, E. G. Valdez, and J. H. Bilbrey, Jr. *Met. Soc., AIME*, February 1974, TMS Preprint A74-91, 14 pp. The nonmagnetic rejects from shredding a typical automobile of the 1954-64 decade contain approximately 76 pounds of aluminum per ton. Urban refuse compositions vary greatly. Of two samples examined, one contained 4 pounds of aluminum per ton, and the other, 25. Methods have been developed for recovering aluminum from both sources. The nonferrous metals in the nonmagnetic rejects from a shredded automobile can be concentrated into a 98- to 99-percent nonferrous metal product by a combination of air and water classification plus magnetic separation. Aluminum can then be separated from the other nonferrous metals by a sink-float process. A metallic nonferrous concentrate can be recovered from shredded urban refuse by combinations of air and water classification and magnetic separation. The aluminum can then be separately recovered by hand sorting or sink-float.

OP 34-74. Recovery of Corrosion-Resisting Zinc From Junked Automobiles, by K. C. Dean, E. G. Valdez, and J. W. Sterner. *SAE Preprint 740032*, February 1974, 5 pp. Zinc galvanized coatings, zinc-rich primer coatings, and zinc die-cast are used in automobiles to combat corrosion. Most of the zinc in

an automobile is present as die-cast that is rejected with other nonmagnetic components when the iron is magnetically separated from the shredded automobile, or melts away from the iron if the automobile is incinerated before being compacted into bundles. Such zinc is readily recovered and recycled. If bundled automobiles are melted in iron foundries without prior die-cast removal by melting or hand-stripping, the flue dusts produced contain as much as 35 percent zinc. A double distillation procedure has been developed to produce a Prime Western zinc product from such enriched dusts.

OP 35-74. Effect of Carbon Monoxide in Quenching Magnesium Vapor in the Carbothermic Process, by V. E. Edlund and K. B. Higbie. *Met. Soc., AIME*, February 1974, TMS Preprint A74-92, 19 pp. Magnesium vapor produced by carbothermic reduction of magnesia must be quenched to prevent back reaction with carbon monoxide. Laboratory research by the Bureau of Mines has shown how the quenching efficiency varies with carbon monoxide content when using natural gas, hydrogen, or nitrogen for quenching. Typically, the efficiency is about 87 percent with no carbon monoxide, drops irregularly to 75 percent at 15 percent carbon monoxide, and then decreases less rapidly to 50 percent at 100 percent carbon monoxide. Estimated costs are presented to show how quenching at higher ranges of carbon monoxide content might affect the capital and operating costs of the carbothermic process.

OP 36-74. Leaching Coarse Native Copper Ore With Dilute Ammonium Carbonate Solution, by R. D. Groves, T. H. Jeffers, and G. M. Potter. *Proc. Solution Min. Symp.*, ed by F. F. Aplan, W. A. McKinney, and A. D. Pernicelli. 103d AIME Ann. Meeting, Dallas, Tex., Feb. 25-27, 1974, American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, 1974, pp. 381-389. Experiments on ammonium carbonate leaching of native copper ores crushed to 1-inch size showed that in 30 days 55 percent of the copper was extracted from 0.7 percent copper conglomerate-type ore, and 85 percent was extracted from 2.1 percent copper amygdaloid-type ore. Cupric ions were not necessary to initiate leaching, and dilute solution containing only 2.2 grams per liter NH_3 and 1.9 grams CO_3^{--} was a suitable solvent. Copper was recovered from the leach liquor by solvent extraction and electrolysis of the strip solution. Cyclic testing of the leach-solvent extraction-electrolytic procedure is in progress on a 6-ton charge of minus 12-inch conglomerate-type ore assaying 2.2 percent copper. Oxygen is metered to the closed leach vessel as required by the leaching reaction. Initial copper dissolution was much slower than from minus 1-inch ore, but the leaching rate then markedly improved.

OP 37-74. Probabilistic Simulation of Underground Production Systems, by Bruce D. Hanson and A. Aly Selim. *Ann. Meeting Soc. Min. Eng., AIME*, Dallas, Tex., Feb. 23-28, 1974, SME Preprint 74-AR-32, 20 pp. A computer model capable of simulating the basic production system in a variety of underground mining methods has been developed at the Twin Cities Mining Research Center. This Bureau of Mines paper describes the simulation of the basic production system at the working face, which includes drilling, blasting, mucking, and roof bolting. In addition to the description of the model, examples of simulation experiments that were performed on a room-and-pillar mine system are given. Use of the model to determine methods for improving the efficiency of the system is discussed.

OP 38-74. Mine Ventilation Principles, by E. J. Harris, R. W. Dalzell, and J. W. Stevenson. Subsection 16.2 in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 1, 1973, pp. 16-5-16-33. Techniques of airflow quantity determination in underground mines are presented for low, moderate, and high air-velocity conditions. Use of chemical smoke, rotating vane anemometers, and pitot tubes for air velocity measurements are described, and appropriate calculations are provided. The fundamental principles of airflow through underground passageways and those factors governing such flow are discussed, and the common pressure loss equation for mine ventilation calculations, $H = RQ^2$, is developed. In addition, the advantages of utilizing multiple passageways connected in parallel for underground airflow distribution are reviewed, methods of calculating the resistance of parallel flow circuits are presented, and the mine resistance curve is illustrated. Mechanical ventilation of mines by fans is described and the use of fan characteristic curves, in conjunction with the mine resistance curve to predict fan performance, is discussed and illustrated. Fan operation individually, in series with another fan, in parallel with another fan, and in series/parallel combinations are discussed and illustrated by fan characteristics, mine resistance curves. A graphic technique for determining fan performance when operated in series/parallel combination with another fan is illustrated and discussed.

OP 39-74. Reversed Carr-Purcell Train for Measurement of NMR Relaxation Times by Approach to Driven Equilibrium, by L. C. Headley, W. E. Wallace, Jr., and P. Waldstein. *J. Appl. Phys.*, v. 44, No. 12, December 1973, pp. 5624-5625. An experimentally simple nuclear magnetic resonance pulse technique is described for measurement of longitudinal and transverse relaxation times. The sequence consists of a Carr-Purcell train with π and $\pi/2$ pulses interchanged. The technique offers time savings over traditional methods in cases where relaxation times are long. Experiment times may be halved in some cases. Results obtained with this technique compare well with results obtained using traditional techniques.

OP 40-74. Ventilation of Pillared Areas by Bleeder Entries, Bleeder Systems, or Equivalent Means, by John D. Kalasky and Stephen Krickovic. *Trans. Soc. Min. Eng., AIME*, December 1973, v. 254, pp. 284-291. Adequate ventilation in coal mines depends upon good face control, as well as upon a well-designed and properly controlled overall ventilation system. The fundamentals of effective bleeding for provision of good ventilation and control and removal of methane are described. The various mine pillaring systems for which it is both easy and difficult to provide effective bleeder systems are detailed. Bleeders in conjunction with longwall mining are also discussed.

OP 41-74. A Gas Chromatographic Method for Analyzing Mixtures of Hydrocarbon and Inorganic Gases, by A. G. Kim and L. J. Douglas. *J. Chromatographic Sci.*, December 1973, v. 11, pp. 615-617. Gas samples containing oxygen, nitrogen, hydrogen, helium, carbon dioxide, methane, and trace amounts of C_2 to C_5 hydrocarbons are analyzed by a gas chromatographic method that utilizes both thermal conductivity and flame ionization detectors. Porapak and molecular sieve columns are used with argon as the carrier gas. A column selector valve makes it

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possible to perform a complete analysis either on one 1-ml sample in 40 minutes, or on two 1-ml samples in 20 minutes. Samples are introduced either by on-column injection or through a gas sampling valve. By varying operational parameters, the speed, sensitivity, and accuracy of analysis may be modified.

OP 42-74. Recovery of Copper From Crushed and Sized Porphyry Mine Waste, by W. A. McKinney, L. G. Evans, and W. W. Simpson. *Trans. Soc. Min. Eng., AIME*, December 1973, SME Tech. Note, v. 254, pp. 295-296. Research demonstrated that significantly improved recoveries of copper, molybdenum, gold, and silver were obtained from copper-bearing open pit strip waste by crushing and sizing techniques followed by flotation of an enriched fine fraction and leaching of the remaining coarse material. More copper was recovered from chalcocopyrite-bearing mine waste by flotation of fines than could be obtained by percolation leaching for 1 year. Copper recoveries were doubled by combining percolation leaching of the coarse fractions with flotation of the fines. The research also demonstrated that flotation of fines recovered substantial amounts of molybdenum and some gold and silver, all of which would be lost in conventional dump leaching.

OP 43-74. Design and Testing of a Pilot Plant for SO₂ Removal From Smelter Gas, by W. A. McKinney, W. I. Nissen, and J. B. Rosenbaum. *Met. Soc., AIME*, February 1974, TMS Preprint A74-85, 13 pp. Design considerations are presented for a pilot plant employing the Bureau of Mines citrate process to remove sulfur dioxide from smelter stack gas. The plant was constructed by the Bureau and is being operated jointly by the Bureau and the Bunker Hill Co. at the lead smelter in Kellogg, Idaho, to assess the feasibility of the citrate process for sulfur dioxide emission control. Nominal capacity of the Kellogg pilot plant is 1,000 scfm of 0.5 percent SO₂ gas yielding about 1/3 ton sulfur per day. Sulfur dioxide is absorbed from cooled and cleaned smelter gas in a 2.5-foot-diameter by 30-foot-high packed tower using about 10 gpm of a countercurrent flowing citric acid-sodium citrate-sodium thiosulfate solution. The absorbed SO₂ is reacted in three 100-gallon stirred closed vessels with added H₂S, thus precipitating elemental sulfur and regenerating the citrate solution for recycle. Sulfur is removed from the slurry by oil flotation, melted in a heat exchanger, and then separated from the occluded citrate solution and oil in a settler at 35 psi and 135° C.

OP 44-74. Solid Hydrocarbons, by F. Leo Misaqi. Subsection 4.5.7E in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, 1973, v. 1, pp. 4-38-4-39. Oil shales, representing the most important deposits of solid hydrocarbon (kerogen or pyrobitumen), are defined, and their classification on the basis of components and origin is described. Geological conditions of oil shale formation and its thickness in various economic deposits of the world are summarized. Prospecting guides in searching for oil shales are given. A brief mention of other solid hydrocarbons (mineral tar, asphalts, asphaltites, metamorphic hydrocarbons) is made.

OP 45-74. Special Exploration Techniques—Coal and Petroliiferous Solids, by Leo Misaqi. Subsec-

tion 5.2.5E in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, 1973, v. 1, pp. 5-50-5-53. Geological conditions of economic coal deposits are described, and their distribution by formation age and continents is given. Detailed prospecting, surface and subsurface examinations, and development of prospects for coal formations are defined and explained. Exploration methods for horizontal, folded, and faulted coal deposits are given, and practical guidelines for spacing of openings in coalfields are cited.

OP 46-74. Selecting a Mining Method—Rock Mechanics, Other Factors, by R. G. K. Morrison and Paul L. Russell. Section 9 in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, 1973, v. 1, pp. 9-29-22. After a mineral deposit has been discovered, delineated, and evaluated, a mining method must be selected that is physically, economically, and environmentally adaptable to recovering the mineral from the deposit. Factors that affect this selection are listed as are the types of recognized mineral deposits; most surface and underground mining methods are related to these parameters from the rock mechanics design concept.

OP 47-74. Effect of Dolomitic Lime on Magnetic Taconite Pellets, by John C. Nigro, Robert K. Zahl, and Charles Prasky. *Trans. Soc. Min. Eng., AIME*, December 1973, v. 254, pp. 328-336. The subject matter encompasses bench-scale and pilot plant research at the Bureau of Mines Twin Cities Metallurgy Research on "fluxed" iron oxide pellets. The paper deals specifically with the use of dolomitic lime as the basic additive in preparation of "fluxed" magnetite taconite pellets. Parameters affecting the physical competence of the high magnesia "fluxed" pellets in high-temperature oxidizing and reducing atmospheres are discussed.

OP 48-74. Roof/Rock Bolting, by Louis A. Panek and John A. McCormick. Subsection 13.10 in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, 1973, v. 1, pp. 13-125-13-134. A part of the major section "Roof and Ground Control," this article provides a concise summary of the principles, materials, and procedures used to stabilize ground around excavations in rock by installing bolts in holes specially drilled for them. The function of the bolts is to bind together a discontinuous rock mass through a fraction effect, a suspension effect, or a combination of the two. The presentation covers the characteristics of bolts and anchors, recommended practices for installing bolts and testing installed bolts, and the design of systematic bolting patterns.

OP 49-74. The Behavior of Salem Limestone in Cyclic Loading, by S. S. Peng, E. R. Podnieks, and P. J. Cain. *Soc. Petrol. Eng. J.*, February 1974, v. 14, No. 1, pp. 19-24. Specimens of Salem limestone were loaded cyclicly at a frequency of 2 cycles/sec in uniaxial cyclic compression, tension, and compression-tension. The number of cycles to failure, maximum deformation for each cycle, and load-deformation hysteresis loops were recorded. The fatigue life and fatigue limit values under cyclic

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compressive loading are comparable with those under cyclic tensile loading, whereas under cyclic compressive-tensile loading, the fatigue life and fatigue limit values are considerably lower.

OP 50-74. Heap Leaching Practice at the Carlin Gold Mining Co., Carlin, Nev., by Ramon Pizarro, J. D. McBeth, and G. M. Potter. *Proc. Solution Min. Symp.*, ed. by F. F. Aplan, W. A. McKinney, and A. D. Pernichele. 103d AIME Ann. Meeting, Dallas, Tex., Feb. 25-27, 1974, American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, 1974, pp. 253-267. Heap leaching is used by the Carlin Gold Mining Co., Carlin, Nev., to supplement conventional processing of gold ore by agitation leaching and countercurrent decantation. Selected open pit ore containing about 0.07 ounce gold per ton is crushed to $\frac{3}{4}$ inch, dumped by truck on an asphalt pad, and leached by sprinkling with dilute cyanide solution for 7 days. The heap is then drained and removed by front-end loader to tailings disposal. About 70 percent of the gold is dissolved. Leach solution from the heap joins the pregnant solution from countercurrent decantation for gold recovery by zinc precipitation. Labor, equipment, and reagent requirements for heap leaching are presented.

OP 51-74. A Computer Model Study of Methane Migration in Coalbeds, by H. S. Price, R. G. McCulloch, J. C. Edwards, and F. N. Kissell. *Can. Min. and Met. Bull.*, September 1973, 10 pp. The methane emission from deep coalbeds that are actively mined is a serious problem facing the mining industry today. Pinpointing the source of methane and predicting the emission of this gas from these coalbeds is necessary if preventive techniques are to be effectively used to control methane emission. In general, because most coalbeds have water associated with them, the system to be studied may be either single-phase (methane gas) or two-phase (methane and water). Because coal mine geometry is complex and the fluids have variable properties as functions of pressure and methane concentration, the differential equations describing the flow of methane and water are not amenable to analytic solution but must be solved numerically using high-speed computers. This paper presents the development of such a complex mathematical model along with some preliminary applications of the model to methane emission from one- and two-dimensional coalbeds with and without water present.

OP 52-74. Concentration, by Carl Rampacek. Subsection 27.7 in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, 1973, v. 2, pp. 27-56-27-69. As a general rule, except for some nonmetallic minerals and fossil fuels that are mined and used without further processing, most raw ores must be subjected to some form of concentration—physical beneficiation or chemical and pyrometallurgical treatment methods—to produce marketable-quality metal or mineral products. One or more concentrating steps usually are required. The choice of processes is dictated chiefly by the types of minerals present and the complexity of their association in the ore. Some of the processes most commonly used and their fields of applicability are identified, and references for more detailed study are given.

OP 53-74. Nuclear-Device Mining Systems, by Paul L. Russell. Subsection 21.10 in *SME Min-*

ing Engineering Handbook, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, 1973, v. 2, pp. 21-96-21-106. The ability to package a vast amount of energy in a very small container, together with the demonstrated ability of nuclear explosives to fracture and break large volumes of rock efficiently and at costs below those of conventional explosives, makes the use of nuclear explosives in underground mining systems potentially attractive. Nuclear explosives are described, available cost data is presented, and a number of potential applications are discussed. No actual tests have been conducted in mining as of 1974.

OP 54-74. Dolomite for Determining Atmosphere Control in Thermal Analysis, by John Ward Smith, Donald R. Johnson, and Max Müller-Vonmoos. *Thermochim. Acta*, 1974, v. 8, pp. 45-56. Dolomite's thermal decomposition is used to test the qualities of atmosphere control in thermal analysis. Atmosphere self-generation effects can be readily detected by thermogravimetry or differential thermal analysis.

OP 55-74. Diffusion of Methane Through Coal, by Edward D. Thimons and Fred N. Kissell. *Fuel*, v. 52, October 1973, pp. 274-280. Both methane and helium flow through solid coal by Knudsen diffusion, even at relatively high pressures. Knudsen permeabilities were determined for samples of Pittsburgh, Pocahontas No. 3, and Oklahoma Hartshorne coals. The average permeability for dry methane was 1.3×10^{-6} cm²/sec for Pittsburgh coal, 20×10^{-6} for Pocahontas No. 3 coal, and 13.8×10^{-6} for Oklahoma Hartshorne coal. A molecular-sieve effect exists for methane in all three coals examined and is very strong in Pittsburgh coal. If the methane is saturated with water vapor, the permeability decreases by a factor of 3 to 25, depending on the coal. The Knudsen permeability of solid coal disks seems to bear no relation to coalbed permeability. Lag-time measurements indicate systems of both larger and finer pores and the presence of blind pores. This effect is again more pronounced in the Pittsburgh coal.

OP 56-74. In Situ Gasification and Liquefaction Mining Systems, by Chi-shing Wang, John P. Capp, Malcolm T. Wane, and Stefan H. Boshkov. Subsection 21.9 in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 2, 1973, pp. 21-78-21-96. This section deals with the current state-of-the-art in the underground gasification of coal and the underground retorting of oil shale. It gives a brief account of the chemical and pyrolytic reaction mechanisms of both processes and introduces a variety of in situ gasification and retorting methods that have been developed in the United States and many other countries.

OP 57-74. The Mn₂(CO)₁₀ Catalyzed Hydrogenation and Hydroformylation of Olefins, by Thomas A. Weil, Sol Metlin, and Irving Wender. *J. Organometallic Chem.*, v. 49, 1973, pp. 227-232. Mn₂(CO)₁₀ catalyzes the homogeneous hydrogenation of 1- and 2-octene. In the presence of carbon monoxide and hydrogen at temperatures up to 235° C, it is also a homogeneous hydroformylation catalyst. Cyclohexene yields the expected product, cyclohexylmethanol, at 235° C, but at 200° C the major product is cyclohexylmethyl formate.

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OP 58-74. Formation of Airborne-Respirable Dust at Belt Conveyor Transfer Points, by Lung Cheng. *Am. Ind. Hygiene Assoc. J.*, v. 34, No. 12, December 1973, pp. 540-546. A laboratory study of the formation of respirable dust by the dropping of broken bituminous coal from a belt conveyor is described. It was found that about 10 percent of the respirable dust adhering to the broken coal becomes airborne owing to dislodgement upon impact. The specific formation of airborne dust is correlated empirically with the volume fraction of the falling coal, which is determined by the belt speed, the thickness of the coal layer on the belt surface, the material density, the bulk density, the angle of repose, the size of the broken coal, and the height of fall. Results are interpreted in terms of the shock dislodgement of dust particles adhering to the broken coal and the dispersion of the dislodged particles by the surge of air from the space gaps in the impacting pieces.

OP 59-74. Boron and Boron Carbide by Vapor Deposition, by J. G. Donaldson, J. B. Stephenson, and A. A. Cochran. *Electro-deposition and Surface Treatment*, Elsevier Sequoia S.A. (Lausanne, Switzerland), v. 2, 1973/74, pp. 149-163. Boron trichloride can be reduced by hydrogen at 1,300° C with a recovery of approximately 85 pct as elemental boron. The optimum H₂ to BCl₃ molar ratio was 30 under the test conditions used. No reaction between tungsten substrates and the boron deposits could be detected. Other substrate materials tested, in order of increasing reactivity with the depositing boron, were fused silica, mullite, graphite, titanium, and nickel. Alumina reacted extensively with the chloride gases to form aluminum chloride. BBr₃ can be reduced by hydrogen at slightly lower temperatures than can BCl₃, but this advantage is probably outweighed by the lower boron content, lower volatility, and higher cost of BBr₃. When stoichiometric amounts of BCl₃ and CH₄ were reacted with an excess of H₂ at 1300° C deposits were obtained. An excess of CH₄ in the reaction mixture resulted in the codeposition of B₄C and free carbon. B₄C deposits contained 74.7 to 76.0 pct boron, compared with 78.3 pct for pure B₄C. The specific gravity of the B₄C was 2.32, which is 90 pct or more of the theoretical value. The Knoop microhardness of one B₄C deposit on a mullite substrate was 3,472. A method of etching B₄C was developed and used. Etching revealed that the B₄C deposits had a columnar microstructure with the columns perpendicular to the substrate. When BCl₃ was reduced with H₂ at 1,500° C with a graphite substrate, the depositing boron reacted with the graphite to produce uniform, strongly adherent coatings of B₄C on graphite. The Knoop microhardness of two of these B₄C coatings was 3,065 and 3,195, which corresponds to a Mohs hardness of approximately 9. Graphite coated with B₄C has many physical and chemical properties that would be desirable in rocket nozzle applications.

OP 60-74. Probabilistic Simulation of a Longwall Mine System in Hard Rock, by Bruce D. Hanson and A. Aly Selim. *Proc. 12th Symp. Applications of Computers and Mathematics in the Minerals Industry*, ed. by T. B. Johnson and D. W. Gentry. Colorado School of Mines, Golden, Colo., Apr. 8-12, 1974, v. 2, 1974, pp. G-63-G-94. A computer model capable of simulating the basic production unit in a variety of underground mine systems has been developed at the Bureau of Mines Twin Cities Mining Research Center. This paper describes the application of this

model to analyze the economic feasibility of using a longwall mine system for thin, flat-lying deposits in hard rock. The proposed system, which utilizes a mechanical mining machine, offers greater recovery as well as safer mining conditions in comparison to the current room-and-pillar system.

OP 61-74. A Performance and Cost Model for Underground Drilling and Blasting, by Guy A. Johnson. *Proc. 12th Symp. on the Applications of Computers and Mathematics in the Minerals Industry*, ed. by T. B. Johnson and D. W. Gentry, Colorado School of Mines, Golden, Colo., Apr. 8-12, 1974, v. 2, 1974, pp. G-95-G-152. A performance and cost model that describes percussive drilling and blasting has been developed for underground stoping and drifting situations. It predicts performance and costs from such inputs as mine design variables, machine parameters, and physical rock properties. Output of the model is in terms of footage drilled, tons broken, and costs per ton and per foot of advance. The drill-blast model was tested at a mine site using mine production data. Output from the model duplicated the mine's results for the various situations tested. The performance and cost model utilizes recent rock mechanics research work of the Bureau of Mines and others. It combines mathematical models of percussive drilling and underground blasting with the essential element of cost. The model can be used to analyze alternative drill-blast designs, equipment mixes, and manpower allocations and the effects of rock hardness.

OP 62-74. Contact Angle of Zinc on Some Ceramic Materials and Metals, by John E. Kelley and Henry M. Harris. *J. Testing and Mat.* v. 2, No. 1, January 1974, pp. 40-43. Measurements were made of the contact angle of molten zinc drops on 15 ceramic materials and 4 metals in high-purity helium and carbon monoxide atmospheres. Zinc of 99.9999-percent purity did not wet the oxide materials, glass-type coatings, or graphite; all contact angles were greater than 90 degrees at 500° to 700° C in helium and 500° to 800° C in carbon monoxide. Materials tested that were most resistant to wetting by zinc were ZnO sinter, glazed fireclay, graphite, and mullite.

OP 63-74. The System CaF₂-CaO-Al₂O₃ Under One-Third Atmosphere of Helium, by Ralph H. Nafziger. *High Temperature Sci.*, v. 5, No. 6, December 1973, pp. 414-422. A least three eutectics, one peritectic, and one ternary compound (11 CaO·7 Al₂O₃·CaF₂) characterize the metallurgically important system CaF₂-CaO-Al₂O₃ under one-third atmosphere helium. Primary phases of common fluxes used in the electroslag remelting process include CaF₂, 11 CaO·7 Al₂O₃·CaF₂ (probably in solid solution with 12 CaO·7 Al₂O₃), CaO, and CaO·Al₂O₃. Nearly all of these fluxes crystallize to the three eutectics whose compositions (weight-percent) and temperatures were determined as (1) 43 CaF₂-40 CaO-17 Al₂O₃, 1,193° ± 5° C; (2) 51 CaF₂-19 CaO-30 Al₂O₃, 1,352° ± 7° C; and (3) 69 CaF₂-6 CaO-25 Al₂O₃, 1,377° ± 4° C. Small postulated phase fields of 3 CaO·Al₂O₃ and CaO·Al₂O₃ are due to reactions with CaF₂. A two-liquid region and a stable compound (3 CaO·3 Al₂O₃·CaF₂) were not detected, in contrast to sealed capsule experiments described in the literature. The system in air would probably show slight modifications from the present results owing to phase hydrolysis.

OP 64-74. Survey of Trace Metals in Distillate Fuels, by C. C. Ward. *ASTM, Special Tech. Pub.*

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531, 1973, pp. 133-138. The amounts of trace metals in distillate fuels are receiving increased attention, especially those of metals that cause corrosion of gas turbine blades. Published information on the level of trace metals in distillate fuels is scarce, so members of Section D02.E on Burner, Diesel, and Gas Turbine Fuels Oils of ASTM Committee D-2 on Petroleum Products and Lubricants agreed to pool information available in individual laboratories. Twelve laboratories furnished data on 408 samples of kerosines, diesel fuels, burner fuels, aviation turbine fuels, and gas turbine fuels. Data on trace metals content included that of sodium, potassium, vanadium, calcium, lead, magnesium, and copper. Some laboratories did not report data on all metals. This survey to pool information available on the amounts of trace metals in random samples of distillate fuels does not lend itself to statistical treatment of the data. However, it does show that the level of trace metals in currently produced distillate fuels is much lower than the amounts presently allowed in ASTM Specification for Gas Turbine Oils (D 2880-71).

OP 65-74. Fracture Surface Mapping With the Scanning Electron Microscope and Its Application to Failure Analysis, by R. J. Willard and G. R. Vandenbos. *Scanning Electron Microscopy/1974*, Part IV, ed. by O. Johari and I. Corvin, Proc. Part IV—Failure Analysis and the Scanning Electron Microscope, IIT Research Institute, Chicago, Ill., Apr. 10-11, 1974, pp. 987-994. The capabilities of the scanning electron microscope offer a simple direct method for systematically mapping microtopographic features on fracture surfaces that can provide clues about the origins, kinds, and movement directions of fractures in laboratory test samples from a variety of deformed and/or fragmented materials. The method is particularly suitable for fractographic analysis of compositionally and structurally complex materials such as rocks, in which a fracture may have multiple origins and a surface topography without obvious visible features indicative of movement directions. The technique is illustrated by mapping fracture surfaces in blocks of bituminous coal broken under low velocity impact. Movement maps reveal that coal tends to fracture along natural planes of weakness, that the planes exhibit river features indicative of brittle fracture in tension, and that the fractures propagate from impacted area into and through the coal along the planes of weakness.

OP 66-74. Mechanical Roof Pulling Technique for Evaluating the Effectiveness of Roof Bolting Systems, by Chi-shing Wang. *Proc. AIME Ann. Meeting*, Dallas, Tex., Feb. 23-28, 1974, SME Preprint No. 74-AM-71, February 1974, 21 pp. The Federal Bureau of Mines has been developing the mechanical roof pulling technique as a method for evaluating the effectiveness and the comparative advantages and disadvantages of various roof bolting systems, based on the characteristic responses of bolted mine roofs to a prescribed external loading system. Preliminary experiments were conducted in the Bureau's Safety Research Coal Mine using a 12-foot- and a 16-foot-span test rig. The experiments have proved the capability of the test rigs and suggested the viability of the test method. This paper summarizes the test concept and the experimental results.

OP 67-74. Underground Haulage Pipelines, by James T. Clancey and Claude A. Goode. Subsection 14.5 in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of

Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, 1973, v. 1, pp. 14-27-14-34. The state-of-the-art of fluidic transportation systems, as applied to underground mining, is reviewed. The theory and formulations of fluid flow is developed for such systems, and the elements of alternative equipment selection are given. Several hydraulic systems specifically designed for hoisting are discussed.

OP 68-74. Stress Analysis of Hollow Cylindrical Inclusions, by Sidiq M. Dar and Robert C. Bates. *J. Geotech. Eng. Div., Proc. Am. Soc. Civil Eng.*, v. 100, No. GT2, Proc. Paper 10364, February 1974, pp. 123-138. Using elastic approach, the theoretical derivations predict stresses and deformations in any type of cylindrical liners buried underground as well as in the surrounding media.

OP 69-74. Use of Polymers for Stabilizing Mineral Wastes, by Karl C. Dean and George M. Potter. *Ch. in Recycling and Disposal of Solid Wastes—Industrial, Agricultural, Domestic*, ed. by T. F. Yen. Ann Arbor Science Publishers, Inc., Ann Arbor, Mich., 1974, pp. 251-260. Both chemical and chemical-vegetative methods have proven successful in preventing wind and water erosion from mill tailings accumulations. Elastomeric polymers are among the preferred materials for strictly chemical stabilization. Other allied uses of polymers that have been developed include applications to reagent stockpiles for improved storage, treatment of fine materials for transportation in open conveyances, and strengthening of soft, porous rocks by impregnation. Some polymeric chemicals are also beneficial in a combined chemical-vegetative stabilization procedure, but resinous compounds thus far are preferred for such use.

OP 70-74. Federal Coal Mine Health and Safety Act of 1969, by Edward D. Doney. Subsection 3.16.2 in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 1, 1973, pp. 3-42-3-51. The article is a synopsis of Public Law 91-173 (Federal Coal Mine Health and Safety Act of 1969). It contains the purpose of the act, a description of the titles under which it is administered, specific provisions of the act under each title, and other general requirements of the act with respect to the industry and the regulating agency including discussions of the interrelationships between the various phases of mining and applicable health and safety objectives.

OP 71-74. Effect of Additives Upon the Gasification of Coal in the Synthane Gasifier, by Albert J. Forney, W. P. Haynes, S. J. Gasior, and R. F. Kenny. *Pres. at 167th Nat. Meeting ACS, Div. of Fuel Chem.*, Los Angeles, Calif., Apr. 1-5, 1974, Preprints, v. 19, No. 1, 1974, pp. 111-122. Additives such as limestone, hydrated lime, and quicklime all have a positive effect on the gasification rate of coal. Limestone, in addition, raises the sintering temperatures and may lower the sulphur contained in the char from the gasifier.

OP 72-74. The Enthalpies of Formation of Ethylcyclobutane, Methylcyclobutane, and 1,1-Dimethylcyclopropane, by W. D. Good, R. T. Moore, A. G. Osborn, and D. R. Douslin. *J. Chem. Thermodynamics*, v. 6, March 1974, pp. 303-310. The enthalpies

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of combustion of ethylcyclobutane, methylenecyclobutane, and 1,1-dimethylcyclopropane were measured by oxygen-bomb combustion calorimetry. The following values are reported for the standard enthalpy of combustion ΔH_c° (298.15 K)/kcal_{th} mol⁻¹ of these compounds in the liquid state: ethylcyclobutane, $-(960.11 \pm 0.16)$; methylenecyclobutane, $-(765.95 \pm 0.12)$; 1,1-dimethylcyclopropane, $-(803.86 \pm 0.17)$. The enthalpy of vaporization of methylenecyclobutane was derived from vapor pressure measurements, and enthalpies of vaporization of ethylcyclobutane and 1,1-dimethylcyclopropane were estimated. Values of the enthalpy of formation in the liquid and gaseous states were derived for all three compounds. Ring-strain energy was estimated. Some regularities and irregularities in the accepted values of enthalpies of combustion of the alkylcyclopropanes and alkylcyclobutanes indicate an error in a previous determination of the enthalpy of formation of methylenecyclobutane.

OP 73-74. Catalysis of Coal Gasification at Elevated Pressure, by W. P. Haynes, S. J. Gasior, and A. J. Forney. Pres. at 165th Nat. Meeting of ACS, Div. of Fuel Chem., Dallas, Tex., Apr. 8-12, 1973, Preprints, v. 18, No. 2, 1973, pp. 1-28; Adv. in Chem. Ser. 131, Coal Gasification, ACS, 1974, pp. 179-202. The work on catalysis reviewed thus far does not include gasification at elevated pressures nor the use of volatile coals. The bench-scale work now reported compares the catalytic activity of various additives in the gasification of volatile coals with steam under pressure and studies other process parameters of interest such as gasification temperature, type of contact with the catalyst, degree of gasification, and repeated use of a catalyst. Results of pilot plant gasification tests using additives are also reported.

OP 74-74. Trace Components of Aviation Turbine Fuels and Exhausts, by R. W. Hurn, J. W. Vogh, F. W. Cox, and D. E. Seizinger. Proc. 2d Conf. on Climatic Impact Assessment Program, November 1972, Dept. of Transportation Rept. No. DOT-TSC-OST-73-4, 1973, pp. 194-198. The objective of this work is to provide information on the amounts of nonhydrocarbon materials that may be present in aviation turbine fuels. A secondary objective is to determine the degree and manner in which trace components of the fuel can be associated with turbine emissions. Analysis of aviation turbine fuel samples gathered from four international airports is also presented.

OP 75-74. Semimicro Procedure for the Determination of Hydrocarbon Types in Shale-Oil Distillates, by Larry P. Jackson, Charles S. Allbright, and Howard B. Jensen. Anal. Chem., v. 46, No. 4, April 1974, pp. 604-607. Saturated hydrocarbons and olefins were determined as groups in shale-oil distillates by acid absorption and hydroboration. The content of aromatics was obtained by difference.

OP 76-74. Recycling and Disposal of Waste Plastics, by James W. Jensen, James L. Holman, and James B. Stephenson. Ch. in Recycling and Disposal of Solid Wastes—Industrial, Agricultural, Domestic, ed. by T. F. Yen. Ann Arbor Science Publishers Inc., Ann Arbor, Mich., 1974, pp. 219-249. A processing system for waste plastics was developed at the Rolla Metallurgy Research Center, Rolla, Mo. A community collection campaign netted an 800-pound sample of waste plastics for analysis and experimental treatment, and samples of wirestripping wastes were also studied. Separations by air classifier, hydraulic classifier, and other liquid-media

methods are described. Thermal dissociation of polyvinyl chloride to recycle HCl and char is discussed. Fabrication experiments showed several possible product areas in which recycled plastics could be utilized. A hydraulic separator was developed capable of processing up to 50 pounds per hour of mixed plastics and based on standard methods used in mineral processing industries. Pure fractions of polyethylene, polystyrene, and polyvinyl chloride were readily extracted from the mixed wastes with this laboratory separator.

OP 77-74. Resin-Loaded Papers—A Versatile Medium for Sampling and Standardization, by Stephen L. Law and William J. Campbell. In Advances in X-Ray Analysis, Plenum Publishing Corp., v. 17, May 1974, pp. 279-292. Resin-loaded papers composed of approximately 50 percent cellulose and 50 percent ion-exchange or chelating resin provide an ideal matrix for many X-ray spectrographic analyses. Standards are prepared by multiple filtration of solutions of known composition through the paper to achieve quantitative collection or by the use of a radio-tracer as a monitor for nonquantitative collection. Solutions prepared from unknown samples are processed in the same manner as the standards. Advantages of the resin-loaded papers are as follows: Reduction of interelement effects because standards and unknowns are present in a similar low X-ray absorbing matrix; physical parameters such as metallurgical history, grain size, and surface preparation are eliminated; and sampling errors are significantly reduced and sensitivity greatly increased by concentrating trace elements separated from large samples. Application of these papers to a variety of metallurgical, geological, and water samples will be summarized. The possible use of resin-loaded papers as standards for air pollution monitoring will be examined.

OP 78-74. Kinetics and Mechanism of the Accelerated Oxidation of Low Carbon Scrap Steels, by S. E. Khalafalla and S. L. Payne. Oxidation of Metals, v. 7, No. 3, December 1973, pp. 201-218. Mixed parabolic law determines the oxidation of steels treated with oxidation promoters. The observed kinetics are best explained with the Zener diffusion model, which assumes that the activation energy for diffusion is spent in deforming the crystal lattice elastically in the vicinity of the saddle point.

OP 79-74. Sampling and Standards in a Recycled World, by H. E. Marr III, W. J. Campbell, and D. L. Neylan. In Advances in X-Ray Analysis, Plenum Publishing Corp., v. 17, May 1974, pp. 247-257. A number of procedures for fluorescent X-ray analysis have been introduced to accommodate the samples that are produced from research on the recovery of values from secondary metal sources. For some applications, standards are conveniently available such as those that can be purchased from the National Bureau of Standards. For other applications, secondary standards must be prepared and analyzed by independent methods. The sample preparation procedures vary considerably. For monitoring process efficiency, sample preparation is often kept at a minimum such as simply pouring loose powders into disposable cups. For the most accurate analyses, sample preparation requires casting the alloys and finishing the surfaces. Matrix correction procedures are employed where concentrations of major constituents vary over wide ranges.

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OP 80-74. Book Review of "Thermodynamics of Rock-Forming Crystalline Solutions" by S. K. Saxena, by Ralph Nafziger. *Am. Mineral.*, v. 59, Nos. 3-4, March-April 1974, p. 389. The reviewer concludes that this book will be of considerable use and recommends it to the geoscientists currently engaged in thermodynamic determinations. The book presents a useful consolidation of widely scattered concepts and examples for calculating the thermodynamic properties of crystalline silicate solutions.

OP 81-74. Crack Propagation and Fracture of Rock Specimen Loaded in Compression, by S. S. Peng and C. A. Ortiz. *Proc. Internat. Conf. on Dynamic Crack Propagation*, Lehigh Univ., Bethlehem, Pa., July 10-12, 1972, 1973, pp. 113-129. The stress distribution within a prismatic specimen loaded uniaxially was determined by the three-dimensional finite element method. The stresses are nonuniform and vary from point to point. Prismatic specimens of Tennessee marble were loaded uniaxially. Pictures of the two adjacent side surfaces were taken simultaneously at various deformation levels. Crack patterns in these pictures were then traced in the transparency and compared for crack growth study. Grain boundary cracks were identified as Griffith cracks. A model consisting of a crack subjected to the combination of modes 1 and 2 of basic crack surface displacement was developed. Quantitatively, the model was found applicable for describing the fracture processes of Tennessee marble specimens.

OP 82-74. Nuovo sistema di brasatura ad alta temperatura (A New High-Temperature Solder System), by A. E. Schwaneke, W. L. Falke, and O. K. Crosser. *Ingegneria Meccanica*, v. 22-L.700, No. 12, p. 11 (Abstract only—in Italian). A new high-temperature soldering system has been developed for use on copper, copper alloys, and low carbon steel. The method is applicable to automobile radiators and home appliances. The system uses a unique sacrificial coating method to promote spontaneous wetting and spreading of zinc and zinc alloy solders on metallic substrates. The 10⁻⁵-to-10⁻⁶-cm-thick, electroplated or sputtered, sacrificial nickel coating is absorbed by the molten filler alloy during soldering and produces a direct solder-substrate metallic bond. Preliminary measurements on butt joints with copper members give tensile strengths over 32,000 psi at room temperature using 95 Zn-5Al alloy as solder. Spontaneous wetting, spreading, and capillary penetration are extremely rapid and produce joints as easily as 50-50 tin-lead solders. Recrystallization or annealing of the wrought copper joint members is negligible at the soldering temperatures of 450° to 490° C and lower. A list of typical fluxes and solder alloys is included.

OP 83-74. Methane Flame Extinguishment With Layered Halon or Carbon Dioxide, by A. Strasser, I. Liebman, and J. M. Kuchta. *Fire Technol.*, v. 10, No. 1, February 1974, pp. 25-34. In quenching tests of downward propagation in stoichiometric methane-air mixtures based on flammability limits and flame speed data, Halon 1301 was about five times more effective, on a volumetric basis, than carbon dioxide as an extinguishant.

OP 84-74. Mine Costs and Control, by Sheldon P. Wimpfen. Section 31 in *SME Mining Engineering Handbook*, ed. by A. B. Cummins and I. A. Given. Society of Mining Engineers of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, v. 2, 1973, pp. 31-2—31-50. Guideline data for capital plant.

cost and for operating costs of mining and milling are presented in detail for representative operations. Included are detailed cost data for labor, supervision, supplies, and others as well as productivity data for typical operations. Typical cost sheets and report forms used by the mining industry are presented as guides to the new operators.

OP 85-74. Geochemistry of Oil-Field Water Applied to Exploration, by A. Gene Collins. *Oil and Gas J.*, v. 72, No. 21, May 27, 1974, pp. 90-94. The Bureau of Mines conducted a geochemical study of the Smackover Formation to determine what geochemical relationships are useful in exploration for and production of oil and gas. Samples of oil, gas, brine, and rock were collected and analyzed. It was concluded that oil and gas detection indicators include the following: Dissolved gases in the water, a pressure gradient <0.65 psi per foot of depth, hydrostatic or near-hydrostatic water, Cl-Ca type of water, S₁S₂A₂ class of water, SO₄×100/Cl<in Cl-Ca type of water, negative redox potential, temperature 69° to 149° C, positive indication of a source rock, organic acid salts dissolved in water, and iodide and bromide concentrations of 1 mg/l and 300 mg/l, respectively, in the water.

OP 86-74. Saline Groundwaters Produced With Oil and Gas, by A. Gene Collins. *Environmental Protection Technol. Series*, No. EPA-660/2-74-010, April, 1974, 68 pp. More than 60,000 saline water analyses were collected by the Federal Bureau of Mines for entry into automatic data processing system. Screening of the data eliminated 30,000 analyses; 20,000 were entered into STORET, the data processing system formulated by the Environmental Protection Agency; and 10,000 additional analyses could be entered with additional funding. The water analyses are used in studies related to identifying the source of a brine, classifying groundwater for use in geochemistry, plotting local and regional salinity maps, determining sources of pollution of freshwater and land by brines, and using saline water for desalination to produce freshwater and valuable minerals. Examples of each of these studies are given in this report.

OP 87-74. Radial Distribution Analysis for Sorting, by Robert M. Doerr. *Trans. Soc. Min. Eng., AIME*, v. 225, No. 1, March 1974, pp. 4-9. A method was developed for determining points representative of the relationship between fragment size, grade, and potential recovery from a selected heterogeneous solid such as an ore. These points, when combined with economic data and the mean grade of the solid, are useful in establishing the range of fragment size at which separation (as for preconcentration of an ore by techniques such as sorting) may be effective. If the fragments are too large, in many cases adequately rich parts will not have been liberated; if too small, separation economics may be adversely affected, particularly in serial sorting operations. The method involves the use of a microscope to find data on the spatial relationships of the target phase in polished sections of a sample of the solid. A computer is used to select appropriate "base" particles of the target phase, to establish the size-versus-grade relationship in a radial distribution analysis, and to find the potential recovery in beneficiations aimed at a selected concentrated grade.

OP 88-74. Matching Calculated With Actual Waterflood Performance by Estimating Some Reservoir Properties, by R. V. Higgins and A. J. Leighton. *J.*

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Petrol. Technol., v. 26, May 1974, pp. 501-506. The Higgins-Leighton mathematical model was tested by comparing predicted with observed performance in a mature southern California waterflood for which accurate reservoir data were not available. By using successively revised estimates for interstitial water and permeability distribution, an excellent history match was achieved.

OP 89-74. Geothermal Energy and the Environment, by William L. Miller. Proc. Symp. on Geothermal Energy and Colorado, Colorado Geol. Survey Bull. 35, Colorado Department of Natural Resources, No. 35, May 1974, pp. 61-70. A comprehensive discussion of the environmental implications of developing geothermal energy resources is presented. Discussed are land uses, subsidence, seismic activity, blowouts, noise pollution, noxious gases, mineral salts, and fish and wildlife.

OP 90-74. The Kinetics of Thin Oxide Film Formation on Iron Using Proton-Impact-Excited X-Ray Analysis, by P. B. Needham, Jr., H. W. Leavenworth, Jr., and T. J. Driscoll. J. Electrochem. Soc., v. 120, No. 6, June 1973, pp. 778-783; discussion, No. 12, December 1973, pp. 1791-1792. Studies of the oxidation of high-purity iron samples at 224°, 285°, and 350° C have been conducted in an oxygen partial pressure of 4×10^{-6} torr for exposure times ranging from 25 to 2,000 sec. The oxide films were measured and quantitatively analyzed for trace carbon impurities using proton-impact-excited characteristic X-rays. Analytical surface sensitivities to the equivalent of 10^{-3} monatomic layers have allowed direct studies of ultrathin (<50 Å) oxide film kinetics. A two-stage logarithmic oxidation rate law was observed at all temperatures with the transition from the first to second stage occurring at oxide thicknesses of 25, 36, and 52 Å at 224°, 285°, and 350° C, respectively. This observation is discussed in term of Uhlig's theory for logarithmic oxidation. Quantitative measurements of carbon impurities on the iron surfaces show that an increase in the preoxidation surface coverage from 0.1 to 1.0 monolayer results in a significant suppression of the oxidation process. In a discussion in a later issue of the journal, the authors respond to B. Chattopadhyay's use of their results to support his theory of metallic oxidation. The authors point out two errors in Chattopadhyay's theory that appear to invalidate his conclusions concerning the relative effects of surface state charge and space charge on the electrical potentials across growing iron oxide layers.

OP 91-74. Vapor-Pressure Relations for 15 Hydrocarbons, by Ann G. Osborn and Donald R. Douslin. J. Chem. Eng. Data, v. 19, No. 2, April 1974, pp. 114-117. Experimental values of vapor pressure for 15 hydrocarbons are measured in the low-pressure range 0.1 to 25 mm Hg by means of the inclined-piston deadweight gage and in the range 71 to 2,025 mm Hg by means of comparative ebulliometers. Correlations of the present results with selected literature values are given in terms of Cox equations.

OP 92-74. Correlation of the Chemical Thermodynamic Properties of Alkane Hydrocarbons, by D. W. Scott. J. Chem. Phys., v. 60, No. 8, Apr. 15, 1974, pp. 3144-3165. An internally consistent correlation was made of the extant experimental data on the entropy, heat capacity, enthalpy of formation, and isomerization equilibria of alkane hydrocarbons. Of the data selected as reliable, all 41 values of entropy, 98 out of 100 values of heat capacity, 52 out of 54 values of enthalpy

of formation, and all 15 values of enthalpy of isomerization from equilibrium data were fitted within the assigned experimental uncertainty. Working formulas, tables, and equations are given whereby thermodynamic properties for selected temperatures between 200 and 1500 K can be calculated for any alkane hydrocarbon with a tractably small number of molecular conformations (say $\leq 3^4=81$). Compounds with more conformations can be included by use of appropriate substitution methods. Values so obtained for the entropy, heat capacity, and enthalpy of formation at 298.15 K are tabulated for all alkanes C₃ through C₁₀. Variance-covariance matrices from least squares adjustment of constants provide estimates of the reliability of calculated property values. Gaps are noted in the data base that should be filled to permit improved correlations in the future.

OP 93-74. Superconcentration of Commercial Magnetic Taconite Concentrates by Cationic Flotation, by David L. Veith. Skillings' Min. Rev., v. 63, No. 23, June 1974, pp. 1, 6-9, and 23. Research employing caustic scrubbing and cationic silica flotation on samples representing 41 MMtons/year of commercial magnetic concentrates resulted in superconcentrates containing < 2 percent SiO₂.

OP 94-74. Manganese in the Ecosystem, by Gilbert L. DeHuff, Jr. Ch. in Manganese. National Research Council, Committee on Medical and Biologic Effects of Environmental Pollutants, 1973, pp. 3-50. Manganese is widely distributed in constantly changing complex natural relations involving physical, chemical, and biologic activity. It is used primarily in the production of iron and steel, and its emission to the atmosphere is principally the result of this use, either directly or indirectly. Much of the published emission data is old and must be used with caution and with due consideration given to various qualifying factors, including location, atmospheric conditions, degree of control, and method of sampling and analysis. Manganese pollution of the atmosphere is currently a local problem, for the most part an in-plant rather than an ambient-air problem. For the 12-year period ending in 1965, average U.S. urban ambient-air concentration was approximately 0.10 µg/m³. Maximum concentrations exceeded 10 µg/m³ but appear to have been of that order of magnitude. Manganese pollution of water does not appear to be a serious matter, except under very unusual local conditions. There are few reports of manganese contamination of soils.

OP 95-74. The Flammability Limits of Lean Fuel-Air Mixtures —Thermochemical and Kinetic Criteria for Explosion Hazards, by David Burgess and Martin Hertzberg. Pres. 20th Ann. Meeting, Anal. Instr. Symp., ISA, Pittsburgh, Pa., May 12-15, 1974, Reprint No. AID 74414, pp. 61-69. The present state of knowledge of the flammability limits of lean fuel-air mixtures is reviewed concisely in terms of the experimental methods used, the effect of apparatus size, accuracy of data, methods of data presentation, and the sensitivity of the limits to initial temperature and pressure. The heat of combustion per mole of gas mixture at the lean limit is a reliable thermochemical criterion for the flammability of organic fuels with comparable reactivities. The limit calorific value for the heavy paraffins is 11.5 ± 0.1 kcal/mole. However, kinetic effects strongly influence this value. Highly reactive fuels (hydrogen, acetylene) require lower energy contents, whereas less reactive fuels (ammonia) require higher values. Hydrogen-starved fuels (carbon monoxide, cyanogen) show marked

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anomalies and are sensitive to impurities that can provide H-atom chain carriers. These kinetic effects are reflected in the experimentally measurable burning velocity of the fuel. This parameter is a key ingredient in the theory of flammable limits, which is briefly sketched. Five competing processes dissipate power from the combustion wave and quench it at some characteristic limit velocity. The prevalent consensus is that the limits are controlled by natural convection is clearly demonstrated, and the complex interplay of kinetics and thermochemistry follows logically therefrom.

OP 96-74. The Outlook for Mercury in the United States, by V. Anthony Cammarota, Jr. *Proc. 1st Internat. Mercury Cong., Univ. Barcelona, Barcelona, Spain, May 6-10, 1974, v. 1, May 1974, pp. 93-98.* The past several years have witnessed perhaps the most turbulent times in the long history of mercury. The Environmental Protection Agency listed mercury as a hazardous pollutant. To prevent mercury contamination of waterways and aquatic life, some consumers curtailed or eliminated the use of mercury. The price in 1972 touched the lowest level in 22 years, with the result that the producing industry in the United States barely survives. This paper evaluates the outlook for mercury in the United States in the face of consumer disinterest, environmental control, and changing technology.

OP 97-74. Transient Thermal Stresses in Rectangular Prism, by John B. Cheung, Kuppusamy Thirumalai, and Ta-Shen Chen. *J. Eng. Mech. Div., Am. Soc. Civil Eng., v. 100, No. EM2, April 1974, pp. 463-467.* Fracture and fragmentation of brittle materials by heating are well-known but poorly understood phenomena. The process of thermal fragmentation, though not desirable in high temperature applications of ceramics, is used to break rocks and minerals. Fragmentation of corners of brittle materials by thermal stress concentrations induced during surface heating is a commonly known phenomenon. This study was carried out to help understand the initial stress concentrations and resulting fragmentation during surface heating of brittle prism solids. The present study deals with an infinitely long rectangular prism heated on its surface by a constant flux. The prism body is considered to be linearly elastic, homogeneous, and isotropic. To simplify the analysis, a plane strain assumption is used. Experiments were carried out on quartzite rock prisms subjected to a sudden uniform heating to correlate the theoretical predictions.

OP 98-74. Effects of Primer Type and Borehole Diameter on AN-FO Detonation Velocities, by Joseph L. Condon and James J. Snodgrass. *Min. Cong. J., v. 60, No. 6, June 1974, pp. 46-47, 50-52.* Approximately 75 percent (or 2 billion pounds per year) of all explosives and blasting agents used in the United States is ammonium nitrate-fuel oil (AN-FO). Strip mining accounts for about 50 percent of the total AN-FO consumption, and construction, metal mining, and quarrying account for about 50 percent. The Federal Bureau of Mines, to help resolve some of the confusion about proper AN-FO utilization, initiated an investigation to vary pertinent parameters that are under the control of the mine operator and to determine their effects on detonation velocity of AN-FO. This paper reports on those investigations.

OP 99-74. Oil Shale and the Energy Crisis, by Gerald U. Dinneen and Glenn L. Cook. *Technol. Rev., v. 76, No. 3, January 1974, pp. 26-33.* Oil shale is a potential source of fuels to help meet the

energy crisis. This paper discusses the location, size, and characteristics of the resource; current and developing technology for producing and utilizing shale oil; and recent political and economic developments.

OP 100-74. Thermoviscoelastic Properties of Rock at Elevated Temperatures, by R. L. Fischer and J. B. Cheung. *High Temperatures-High Pressures (Great Britain), v. 5, 1973, pp. 463-469.* Rocks exhibit elastic behavior at room temperature and viscoelastic behavior at elevated temperatures. It is important to understand the latter for application in the thermal fragmentation of rocks. Test results are presented on the short-time thermoviscoelastic behavior of Charcoal granite and Dresser basalt at elevated temperatures. Optical means have been used to measure creep compliance of Dresser basalt and Charcoal granite rock specimens. Within the temperature range of 850° to 1,000° C the temperature-time-shift theory has been found to be applicable.

OP 101-74. Bed Level Determination With Time Domain Reflectometry, by Walter Fuchs and Paul M. Yavorsky. *Chem. Eng., v. 81, No. 13, June 1974, pp. 145-148.* Most commercially available monitor systems for bed levels in chemical reactors or in storage bins have the drawback that their calibration is based on specific properties, which are often very difficult if not impossible to determine, of the bed and bed material. This report describes a method for a continuous monitoring of the levels of any kind of bed (liquid or granular, moving, fluid or fixed bed) utilizing the technique of time domain reflectometry. The transit time of an electromagnetic pulse, which travels downward along an electrode inside the vessel and is partially reflected by the surface of the bed, is measured. The principal novel feature of this method is the use of the propagation velocity of an electrical signal in a gas as the basis of measurement, making the calibration very reliable and stable. An additional advantage is the simplicity of the necessary probe system in the interior of the reactor vessel or container.

OP 102-74. Retorting Indexes for Oil-Shale Pyrolyses From Ethylene-Ethane Ratios of Product Gases, by I. A. Jacobson, Jr., A. W. Decora, and G. L. Cook. *Preprints, Div. Fuel Chem., ACS, v. 19, No. 2, 1974, pp. 183-191.* A number called retorting index is developed from the relationship of reciprocal temperature versus $\log[(\text{ethylene})/(\text{ethane})]$. The retorting index has the units of temperature. Its magnitude depends on both temperature and residence time for the reactants in the heated zone in oil shale retorting.

OP 103-74. Effect of Low Concentrations of Silica, Alumina, Lime, and Lithia on the Magnetic Roasting of Hematite, by S. E. Khalafalla, G. W. Reimers, and M. J. Baird. *Met. Trans., v. 5, May 1974, pp. 1013-1018.* The conversion of hematite to magnetite was investigated in a mixture of H_2 , H_2O , and N_2 . In the temperature range of 500° to 700° C, the magnetic roast reaction gives a sigmoidal kinetic curve with a finite induction time. The induction time decreases with rise in temperature and increases in the presence of alkali and alkaline earth oxides. The magnetic roast reaction was also studied in the presence of low concentrations of silica (quartz structure) and alumina (5.0 and 4.3 wt-pct, respectively, which correspond to 8.4×10^{-4} g atom of Si or Al per gram of mixture). The addition of SiO_2 to hematite decreases the induction time. At temperatures below

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550° C, alumina increases the induction time; at higher temperatures, it has about the same effect as silica. For pellets containing SiO₂, a maximum in the relative decrease in induction time, Δ , was observed at 578° C; for pellets containing Al₂O₃, there was a steady increase in Δ with increasing temperature. Because the $\alpha \rightleftharpoons \beta$ quartz transition occurs at 575° C, the enhanced surface activity at 578° C in the presence of quartz is attributed to the Hedvall effect of solid-state chemistry. The induction period of the magnetic roast reaction was exceptionally prolonged in the presence of lithia. Mixing of hematite with silica, alumina, and lithia (8.4 $\times$ 10⁻⁴ g atom, respectively, per gram of mixture) was found to eliminate the beneficial effect of quartz by inhibiting its $\alpha \rightleftharpoons \beta$ transformation.

OP 104-74. Pulsed NMR Examination of Oil Shales—Estimation of Potential Oil Yields, by F. P. Miknis, A. W. Decora, and G. L. Cook. Preprints, Div. Fuel Chem., ACS, v. 19, No. 2, 1974, pp. 86-91. A rapid method for assaying oil shales based on pulsed nuclear magnetic resonance techniques is discussed. Linear correlations were obtained between NMR measurements and Fischer assay oil yields for 440 samples.

OP 105-74. Innovations in Gold Metallurgy, by G. M. Potter and H. B. Salisbury. Secondary Raw Mater., March 1974, pp. 24-30. Low-cost methods of cyanidation have been developed for gold ore deposits too small, too low grade, or unsuited chemically or physically for treatment by conventional procedures. Applicability of heap leaching has been demonstrated to suitably porous and permeable ores, both in the laboratory and on a commercial scale, for recovering 60 to 95 percent of the gold from crushed or mine-run ore containing 0.06 to 0.6 ounce gold per ton. An expanded-bed, multiple-compartment, activated-carbon column developed by the Bureau of Mines is in use to recover the gold from recycling leach solutions. Recent engineering advances in handling pulp and carbon have made the carbon-in-pulp process more attractive for cyanidation of ores requiring fine grinding. Gold is removed from solution and the carbon is loaded by counter-current flow of carbon and leach pulp through a series of about four stirred contactors with a vibrating screen in each stage to separate the pulp and carbon. Loaded carbon is stripped of gold by hot caustic cyanide solution and reactivated by heating to 60° C before recycle to the gold absorption step, and gold is removed from the cycling strip solution by electrowinning.

OP 106-74. Characteristics of Synthetic Crude From Crude Shale Oil Produced by In Situ Combustion Retorting, by R. E. Poulson, C. M. Frost, and H. B. Jensen. Preprints, Div. Fuel Chem., ACS, v. 19, No. 2, 1974, pp. 175-182. The oil was found to be approximately 20 percent aromatic, 6 percent olefinic, and 72 percent paraffinic (including naphthnic) hydrocarbons. The 2 percent polar materials present were 55 percent pyrrole- and 45 percent pyridine-type nitrogen compounds.

OP 107-74. A Comparison of Shale Gas Oil Denitrification Reactions Over Co-Mo and Ni-W Catalysts, by H. F. Silver, N. H. Wang, H. B. Jensen, and R. E. Poulson. Preprints, Div. Fuel Chem., ACS, v. 19, No. 2, 1974, pp. 147-155. Relative to total nitrogen removal, rates of conversion of quinoline-, indole-, amide-type nitrogen in a shale-oil heavy gas oil hydrogenated using three different catalysts were measured.

OP 108-74. Overview of the Role of Geologic Investigation and Rock Property Determination in Fragmentation Field Testing, by R. C. Steckley, E. R. Podnieks, P. G. Chamberlain, and J. M. Pugliese. ASTM Special Tech. Pub. 554, 1974, pp. 100-115. This paper presents an overview of a systematic approach for the evaluation of the geology and rock properties of field sites used for fragmentation tests. Comprehensive flow diagrams illustrate the steps involved in selecting sites for field tests and in evaluating the results of field rock fragmentation tests. These steps consist of regional test site selection, field site selection, geologic and fabric investigations, pre-test rock property determinations, fragmentation tests, post-test geologic and fabric investigations, and post-test rock property determinations. A systematic approach, such as this one, is necessary if major rock excavation problems are to be solved.

OP 109-74. Impact of Gasoline Prices on the Demand for Minerals for the Manufacture of Automobiles, by Phillip N. Yasnowsky and Donald S. Colby. Proc. Ann. Meeting, Council of Econ. AIME, Dallas, Tex., Feb. 23-28, 1974, pp. 61-74. The increase in world crude oil prices and the shortage of petroleum in the United States have caused increases in the price of gasoline. These prices are likely to continue to rise in the future. The motoring public might be expected to react to such higher gasoline prices by curtailing driving, using public transportation more intensively, or buying smaller automobiles. Whichever the reaction, there will be impacts on the mineral industries. This paper looks at the potential impact resulting from a change to smaller size automobiles and a reduction in mileage.

OP 110-74. High-Sulfur Coal for Generating Electricity, by James T. Dunham, Carl Rampacek, and T. A. Henrie. Science, v. 184, Apr. 19, 1974, pp. 346-351. Continued use of petroleum and natural gas by the electric utility market at the present rate will aggravate the serious supply problems for these fuels. Programs underway to augment our oil and gas supplies and to diversify our energy base will have little impact for many years. In the meantime, fossil fuel-fired powerplants must supply a large part of our electrical power demands, and only coal is available in the United States in sufficient quantity to provide this energy. Pollution regulations restricting sulfur oxide emissions from powerplants have been one of the major deterrents to the use of the high-rank, high-sulfur coals of the Midwest and East. The cost of flue gas desulfurization will be high, ranging from 1.2 to 3.2 mill/kW-hr. The average cost increase to consumers is expected to be about 3 to 6 percent and in some instances as much as 15 percent. However, the added burden may not be as high as that of dependence on foreign oil, both in terms of price and reliability of supply. Combustion of high-sulfur coal followed by stack gas cleanup appears to be the cheapest alternative for meeting our electricity needs in the next few decades.

OP 111-74. Advanced Fragmentation Techniques, by David E. Fogelson. Advances in Rock Mech., Proc. 3d Cong. Internat. Soc. Rock Mech., v. 1, pt. B, 1974, pp. 1645-1663. Research on advanced fragmentation techniques is expanding to provide alternative fragmentation systems to overcome the disadvantages of conventional methods and to improve excavation rates. This paper reviews the state-of-the-art of the thermal, hydraulic, and chemical techniques and includes a description of an experimental tunnel excavated by projectile impact.

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- OP 112-74. Production of Synthetic Crude From Crude Shale Oil Produced by In Situ Combustion Retorting**, by C. M. Frost, R. E. Poulson, and H. B. Jensen. Preprints, Div. Fuel Chem., ACS, v. 19, No. 2, 1974, pp. 156-168. A premium synthetic crude oil was produced by catalytic hydrogenation of an in situ crude shale oil after selection of a suitable catalyst. The processes are described.
- OP 113-74. Vacuum Evaporation of Salt From Titanium Sponge**, by S. D. Hill and R. V. Mrazek. *Met Trans.*, v. 5, January 1974, pp. 53-58. The rate of salt removal from titanium sponge was determined using a thermogravimetric technique. Both magnesium- and sodium-reduced titanium sponge were used in the investigation. Measurements were made of the rate of salt removal by vacuum evaporation for a range of temperature, bulk density, and sponge surface areas. Removal of magnesium chloride was characterized by the presence of a long period of surface evaporation, or constant-rate drying, during which the major portion of the salt was evaporated. Sodium-reduced sponge showed no such constant-rate period.
- OP 114-74. Implication of Emission Controls for Fuel Economy**, by R. W. Hurn. *The Petroleum/Petrochemical Industry and the Ecological Challenge*, AIChE Symp. Ser., v. 69, No. 135, 1973, pp. 21-22. The paper calls attention to the alternatives that exist for controlling automobile emissions and provides information from which to better understand the impact that each of the several control options may have on fuel economy and on the energy resource. The paper deals specifically and exclusively with the costs of emission controls in terms of the energy requirement; dollar costs are not examined.
- OP 115-74. Potential Effects of Direct Reduction on Mineral Requirements**, by R. J. Leary and G. M. Larwood. *Proc. 34th Ann. Min. Symp.*, sponsored by Minnesota Sec., AIME, and Min. Resources Res. Center, Univ. of Minnesota, Jan. 15-17, 1973, Duluth, Minn., 1973, pp. 76-84; *Skilling's Min. Rev.*, v. 62, No. 28, July 14, 1973, pp. 1, 6-7, 10-12; No. 29, July 21, 1973, pp. 1, 6-9. Trends in consumption of minerals in iron and steel production were identified, and average and best practices were compared. The potential effects of direct-reduced material upon mineral supply needs were estimated for substitution in (1) blast furnace burdens and (2) electric-arc steelmaking charges. Collateral factors are analyzed, and principal metallurgical, industrial, and environmental consequences are discussed. Implications for the iron ore industry of the Great Lakes region are mentioned.
- OP 116-74. Measurements of the Strength of Grain Boundaries in Rock**, by George A. Savanick and Donald I. Johnson. *Internat. J. Rock Mech. Min. Sci. and Geomech. Abs.*, v. 11, No. 5, May 1974, pp. 173-180. A method has been developed for evaluating the strength of adhesion between materials at grain boundaries in rock. This method involves selectively extracting a small (4.5-mm-diam., 1.7-mm-thick disk), two-phase sample from a rock and determining the tensile strength of the boundary between the minerals by pulling normal to the grain boundary. This technique has been successfully applied to the study of quartz-feldspar interfaces separated from graphic granite and the Rockville granite and to the study of pebble-matrix interface selectively extracted from the Calumet conglomerate. Indirect tensile tests of these grain boundaries have also been performed, and their results have been compared with those of the direct pull tests. Examination of bicrystals broken at their grain boundary reveals that the bonds responsible for this adhesion operate over only a portion of the interfacial area. The significance of this work is that it demonstrates that strength tests can be conducted on small areas, for example, grain boundaries in rocks. This permits a determination of small-scale zones of strength or weakness, which may be related to the overall strength of the rock.
- OP 117-74. Energy in East Europe Through 1980**, by V. V. Strishkov, G. Markon, and Z. E. Murphy. *Trans. ASME, J. Eng. for Power*, v. 96, ser. A, No. 3, July 1974, pp. 292-306. This paper presents the results of a factual and comprehensive study of the potential of the energy industry in East Europe and its long-range objectives. The report cites the development of past and future interaction between domestic sources of energy. It also discusses the dependence of East European communist countries on foreign sources of fuels and power.
- OP 118-74. Thermal Expansion Behavior of Intact and Thermally Fractured Mine Rocks**, by K. Thirumalai and S. G. Demou. *Thermal Expansion—1973*, *Proc. Am. Inst. Phys.*, No. 17, 1974, pp. 60-71. Rock is a complex brittle solid consisting of heterogeneous aggregates of polycrystalline minerals that are characteristically anisotropic. An estimation of rock damage induced by cyclic temperature changes is important for planning utilization of underground space for storing energy. A method of predicting the damage induced by temperature variations from the thermal dilation characteristics of intact and fractured mine rocks was formulated and tested in this study. A dilatometer system capable of controlled heating and cooling rates was designed and used for the measurements. Test results of the thermal dilation characteristics of granite rock types for heating up to and cooling from 400° C at different rates up to 50° C/min indicate that predominant damage takes place during initial exposure of intact rock to temperature cycling. The damage induced in granitic rocks reaches a steady state after three successive thermal cycles.
- OP 119-74. Equilibrium Composition of Simulated Coal Combustion Products: Relationship to Fireside Corrosion and Ash Fouling**, by J. S. Wilson and M. W. Redifer. *Trans. ASME, J. Eng. for Power*, v. 96, ser. A, No. 2, April 1974, pp. 145-152. A computer solution of chemical equilibrium composition is presented for high-temperature combustion reactions related to fireside corrosion and ash fouling. A simple calculation system, which models the injection of a sodium-potassium mixture through a flame, is solved for equilibrium compositions of temperatures from 1,500° to 3,000° F at oxygen levels in the gas stream ranging from 0.1 to 17 percent and 1 atmosphere pressure. At equilibrium, principally alkali sulfates and hydroxides are produced in the model of a combustion product atmosphere resembling that in a coal-fired boiler. A total of 42 reactions involving 40 chemical species were treated in the reactant mixture, and compositions for the entire system are included.
- OP 120-74. Platinum-Vanadium and Nickel Baths for Inert Gas Fusion Oxygen Determination**, by Dean H. Bollman. *Anal. Chem.*, v. 46, No. 9, August 1974, pp. 1191-1194. Low and inconsistent results were encountered with an unalloyed platinum bath

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when analyzing thoriated and zirconiated tungsten for oxygen content by inert gas fusion. Data are given to show that vanadium additions to platinum baths made the recovery of oxygen easier from both of these tungsten-base alloys and also from titanium and FS-85 niobium alloys. Data are given to show that a nickel bath and wrap was superior to platinum for determining oxygen in zirconium and beryllium. In addition, a nickel bath and wrap works well for titanium and tungsten but not for FS-85 niobium alloy. The importance of carbon solubility in the melt and the role of tin are discussed.

OP 121-74. Castability of Titanium and Seven Titanium Alloys, by E. D. Calvert, H. Kato, and R. A. Beall. *Proc. 4th Internat. Conf. Vacuum Met., Iron and Steel Inst. of Japan, Sec. 8*, 1974, pp. 310-314. Casting experiments were conducted to determine the effects of alloying on the castability of titanium. Commercially pure titanium and seven alloys were examined. All of the alloys were found to be castable; however, minor changes in fluidity and mold filling characteristics can be effected by alloy composition. Data indicate that both silicon and molybdenum tend to decrease the flowability of titanium, probably because they tend to drastically expand the freezing range. Manganese was demonstrated to have a degrading influence on castability, because of the rapid extraction of heat from the melt due to vaporization of manganese. This is probably true for all high-vapor-pressure elements. On the other hand, aluminum tends to raise the heat of fusion of titanium and as a consequence improves flowability.

OP 122-74. Development of Technology for In Situ Oil Shale Processes, by Harry C. Carpenter and Harold W. Sohns. *Colo. School Mines Quart.*, v. 69, No. 2, April 1974, pp. 143-169. This report of research supporting the development of in situ retorting of oil shale includes the effects of gas velocity and oxygen concentration on oil yields, retorting advance rate, and oil quality. The effects of overburden pressure and system pressure are also considered.

OP 123-74. Air Injection and Hot-Film Flow Logging for Evaluation of Roof Cracks in White Pine Mine, by Samuel S. M. Chan, Harold E. Thomas, and Nicholas Bada. *Trans. Soc. Min. Eng., AIME*, June 1974, pp. 131-137. The Bureau Of Mines has developed a technique for locating and evaluating bedding plane cracks in mine roof by an air-injection and hot-film flow logging process. It is ultrasensitive to cracks and is especially useful for detecting the early stage of crack development. The required equipment is inexpensive and simple to operate.

OP 124-74. Conversion of Manure to Oil by Catalytic Hydrotreating, by Yuan C. Fu, Eugene G. Illig, and Sol J. Metlin. *Environmental Sci. & Technol.*, v. 8, No. 8, August 1974, pp. 737-740. Bovine manure is hydrogenated and liquefied by hydrogen or synthesis gas at 330° to 425° C and 2,000 to 3,000 psi in the presence of a recycle manure oil and a CoMo catalyst.

OP 125-74. The Use of Nitride Intermediates in the Preparation of Metals. A Study of the Reduction of Nb₂O₅ With NH₃, by R. A. Guidotti and D. G. Kesterke. *Met. Trans.*, v. 4, May 1973, pp. 1233-1237. Nb₂O₅ reacts with NH₃ in a range of 600° to 1,300° C to form three types of reaction products: at temperatures below 800° C, the δ -oxynitride phase (13.0 to 13.6 pct N, 3 to 5 pct O)

is formed; between 800° and 850° C, NbO₂ formation occurs; the formation of hexagonal NbN phase (13.2 pct N) is favored at higher temperatures. The most rapid and complete reaction occurred at 1,200° C using either molybdenum or alumina reactors resulting in products with oxygen levels of ≤ 0.1 pct. With a two-step reduction in the Al₂O₃ system, the reaction time was shortened from 50 to 4 hours.

OP 126-74. Effect of Moisture on the Methane Capacity of American Coals, by James I. Joubert, Clifford T. Grein, and Daniel Bienstock. *Fuel*, v. 53, No. 3, July 1974, pp. 186-191. An investigation of methane sorption in bituminous coals ranging from low-volatile to high-volatile B has been carried out. Equilibrium sorption isotherms for dry and moist coal were measured at 30° C and at pressures up to 60 atm. The natural oxygen content of a coal plays a major role in determining its methane capacity. Capacities of high-oxygen coals undergo a much greater reduction when saturated with moisture than do low-oxygen coals. Measurements of adsorbed-water saturation capacities clearly suggest that only adsorbed water affects the equilibrium capacity of a coal for methane; water present in excess of the adsorbed water has no effect on methane sorption. Excellent agreement has been found between the methane sorption data reported here and field measurements of methane emission from coal samples obtained during borehole drillings.

OP 127-74. Effect of Coal Breakage on Methane Emission, by Fred N. Kissell and Maurice Deul. *Trans. Soc. Min. Eng., AIME*, v. 256, June 1974, pp. 182-184. When coal is broken during mining, some of the methane trapped in the coal is released. Some recent investigations by the Bureau of Mines have shown that this methane released by breakage is only a small proportion of the total methane emission into the working section.

OP 128-74. Micellar-Polymer Flooding Planned for Shallow Sands of El Dorado Field, by Bill Linville. *Am. Oil and Gas Reporter*, v. 17, No. 4, July 1974, pp. 6-7. On June 28, 1974, the Bureau of Mines announced a cooperative contract with Cities Service Oil Co. for a field demonstration of tertiary oil recovery from the El Dorado, Kans., oilfield by micellar-polymer flooding. The purpose of the test is to determine the technical and economic feasibility of tertiary oil recovery using methods of micellar-polymer flooding. Two distinct micellar-polymer combinations will be tested. Tests should be completed by early 1978. Results will be published by the Bureau of Mines.

OP 129-74. Combustion Control of Pollutants From Multi-Burner Coal-Fired Systems, by C. McCann, J. Demeter, R. Snedden, and D. Bienstock. *EPA Technol. Ser.*, No. EPA-650/2-74-038, May 1974, 42 pp. Staged combustion resulted in a 50-pct reduction in NO_x emissions. A decrease in excess air lowered NO_x emissions further but decreased carbon conversion efficiency.

OP 130-74. Generalized Rayleigh Wave Propagation in Anisotropic Rock, by T. E. Ricketts. *Internat. J. Rock Mech. Min. Sci. and Geomech. Abs.*, v. 11, No. 6, June 1974, pp. 251-259. The surface waves in an anisotropic semi-infinite solid are examined analytically for the case of transverse isotropy. Closed-form expressions for group velocity (rate of energy propagation) of surface waves are presented when the elastic symmetry axis lies in the free surface plane of the half-space. These relations

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are evaluated for transversely isotropic Yule Marble and compared with experimental results obtained previously using transient point loading on a large Yule Marble block used to model a semi-infinite medium. The analysis and experiments assume that the direction of the axis of elastic symmetry does not vary in the media.

OP 131-74. Adsorption of Methane on Dry Coal at Elevated Pressure, by Thomas C. Ruppel, Clifford T. Grein, and Daniel Bienstock. *Fuel*, v. 53, No. 3, July 1974, pp. 152-162. Methane equilibrium adsorption isotherms were determined for several U.S. coal seams—Illinois No. 6 (Herrin seam), Oklahoma Hartshorne, Pennsylvania Pittsburgh, and Virginia Pocahontas No. 3 seams—using a volumetric method and an equation of state for methane. The amount of methane adsorbed on crushed and dried coal was measured as a function of pressure. Isotherms were measured at 30° C for the Illinois coal and at 0°, 30°, and 50° C for the others. Most measurements were made to 150 atm pressure, but a few were made to 240 atm.

OP 132-74. Solubilization of Coals by Reductive Alkylation, by Heinz W. Sternberg and Charles L. Delle Donne. *Fuel*, v. 53, No. 3, July 1974, pp. 172-175. Bituminous and subbituminous coals can be converted to benzene-soluble products by reductive alkylation; anthracite could not. Anthracite anion could not be alkylated.

OP 133-74. How We Reduced Our Plant's Energy Consumption by More Than 25 Percent, by Jerry A. Tipton and Warren F. Foster. *Proc. Western Plant Eng. Conf., Am. Inst. of Plant Eng., Anaheim, Calif., June 18-20, 1974*, pp. 1-1-2 to 1-14-2. A comprehensive energy conservation program was initiated in 1970 at the Bureau of Mines Bartlesville Energy Research Center, Bartlesville, Okla., to reduce operational costs. The primary thrust of this program included remodeling one laboratory building, optimizing control settings of main generators and absorption refrigeration units, adjusting fresh air makeup in building heating and air conditioning systems, adding ceiling insulation in several buildings, and reemphasizing routine window and door maintenance. The operational schedule of many cooling and heating units was altered to take advantage of the decreased load during nonworking hours, and changes were made in lighting and electrical equipment operation. The overall reduction of energy use was more than anticipated, and costs of operation, even with inflated fuel prices, show a net decrease. Because of the variation of weather conditions, changes in laboratory functions, and other intangibles, specific results of each measure implemented are estimated. However, accurate values of the total energy savings were documented and are described graphically.

OP 134-74. Statistical Analysis of Axial Data, by J. R. Alldredge, M. A. Mahtab, and L. A. Panek. *J. Geol.*, v. 82, No. 4, July 1974, pp. 519-524. A method is presented for estimating the confidence region for the mean of a set of axes that are non-circularly distributed about the mean axis. The data (plotted on the upper hemisphere) are projected, through Lambert's equal-area projection, onto the plane that is tangent to the estimated mean. An elliptical confidence region is constructed around the projected mean using bivariate normal theory. The confidence region is then projected back to the sphere. The method is applied to the analysis of a set of joint orientations.

C? 135-74. Coal Combustion Aspects of MHD Power Generation, by D. Bienstock, J. J. Lacey, P. D. Bergman, R. J. Demski, and J. M. Henry. *Proc. 1st U.S.-U.S.S.R. Colloquium in MHD Power Generation*, Feb. 25, 1974, 13 pp. The article is a review of the Bureau of Mines program utilizing coal as a fuel in the magnetohydrodynamic (MHD) generation of electrical power.

OP 136-74. Use of Cryogenics in Scrap Processing, by J. H. Bilbrey, Jr. *Proc. 4th Miner. Waste Utilization Symp., Chicago, Ill., May 7-8, 1974*, pp. 424-430. The need to meet strict pollution control regulations is providing an incentive to search for new, low-pollution scrap processing methods, and the availability of large volumes of liquid nitrogen at relatively low prices makes cryogenic processing more competitive with other processing methods on an economic basis. The Bureau of Mines has been conducting research on the use of cryogenic methods for reclaiming copper from scrap wire and in separating mixtures of nonferrous metals recovered from nonmagnetic residues from automobile shredders. Some preliminary work has also been done on cryogenic processing of automobile tires and scrap plastics.

OP 137-74. Rate Coefficient for $H + CH_4 \rightarrow H_2 + CH_3$ in the Temperature Range 1300-1700° K, by Joan C. Biordi, John F. Papp, and Charles P. Lazzara. *J. Chem. Phys.*, v. 61, No. 2, July 15, 1974, pp. 741-742. The rate coefficient for the title reaction has been determined from complete (that is, including atomic and radical species) microstructure studies of nearly stoichiometric methane-oxygen-argon flames burning at 0.04 atm.

OP 138-74. Nomogram for Relating Particle and Particle Cloud Parameters, by Lung Cheng. *J. Air Pollution Control Assoc.*, v. 24, No. 7, July 1974, pp. 680-681. Although most aerosol clouds are composed of polydisperse particles, a nomogram based upon monodisperse spherical particles has been found useful for providing a convenient conversion of dust concentration units.

OP 139-74. Analyzing Heavy Ends of Crude. *Wilmington, Calif.*, by J. E. Dooley, D. E. Hirsch, and C. J. Thompson. *Hydrocarbon Processing*, v. 53, No. 7, July 1974, pp. 141-146. This article discusses the characterization of the 370° to 535° C distillate from Wilmington, Calif., crude oil.

OP 140-74. Coal's Increasing Role in the Fossil Fuel Industry, by William E. Eckard. *Pres. at 49th Ann. Fall Meeting, Soc. Petrol. Eng., AIME, Houston, Tex., Oct. 6-9, 1974*, SPE Preprint 5093, 6 pp. The United States has about 20 percent of the world's coal resources, enough to last several centuries even at an expanded rate of consumption. Projected expansion of coal consumption for energy and fuels production will require the solution of several major problems, including those related to mining methods, mine health and safety, economics, and coal process technology.

OP 141-74. Recovery of Metals and Other Materials From Chromium Etching and Electrochemical Machining Wastes, by L. C. George and A. A. Cochran. *Proc. 4th Miner. Waste Utilization Symp., Chicago, Ill., May 7-8, 1974*, pp. 346-353. Bench-scale research on the development of practical processes for the recovery of metals and other values from a wide variety of industrial wastes is described. New treatment methods were successfully applied to two types

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of waste. Spent chromium solutions that were used to etch and brighten brass parts were treated by simple processes to recover separate chromium oxide, copper, and zinc products. Other materials investigated were electrochemical machining wastes, which normally are exceptionally slow in filtering. This characteristic was ameliorated by evaporating the wastes to dryness and diluting back to the original volume with hot water, which increased the filtration rate by factors ranging from 20 to 121. Filtration produced electrolyte solutions for recycling and mixtures of metal hydroxides. A typical hydroxide mixture was reduced with hydrogen to produce an alloy containing more than 60 pct nickel.

OP 142-74. Method for Recovery of Zinc and Lead From Electric Furnace Steelmaking Dusts, by L. W. Higley and H. H. Fukubayashi. *Proc. 4th Miner. Waste Utilization Symp.*, Chicago, Ill., May 7-8, 1974, pp. 295-302. About 1 to 2 pct of the charge to the electric steel furnace finds its way up the stack and is collected as particulate matter. The dust is rich in zinc, but there is no economic technology to recover this zinc and recycle the iron residue. Disposal is a problem because the dust easily becomes airborne. The Bureau of Mines conducted laboratory research to develop a pyrometallurgical process for the recovery of zinc and lead from electric furnace steelmaking dust (25 pct Zn, 2.5 pct Pb). Tests on both powdered and pelletized flue dust were made in a quartz tube, electrically heated in the temperature range 1,050° to 1,150° C. The dust was mixed with carbon and heated in an oxygen-free atmosphere. Ninety-nine pct of the zinc could be recovered, as a Prime Western grade, with only a single roast reduction treatment. By pre-roasting the dust in air, 90 pct of the lead was recovered as PbO, and 98 pct of the zinc was subsequently removed by roast-reduction. The offgas, carbon monoxide, was burned. Further study indicated that this method could be successfully applied to other zinc-bearing dusts and slags. The process has been scaled up successfully to 25-lb batches and seems to be adaptable to continuous operation.

OP 143-74. Effect of Certain Process Variables on Vapor Deposited Tungsten, by F. W. Hoertel. *Electrodeposition and Surface Treatment*, Elsevier Sequoia S.A., Lausanne, Switzerland, v. 2, 1973/74, pp. 327-341. The effects of certain process variables on the grain size, grain type, and microhardness of vapor-deposited tungsten were established, and the near-optimum parameters and the efficacy of the vapor deposition process were determined. No significant change in the grain size or microstructure resulted from ultrasonic vibration of the substrate during deposition, from variations in the hydrogen (H_2) to tungsten hexafluoride (WF_6) ratio, or from small increases in reaction chamber pressure. Near-optimum conditions were continuous deposition at atmospheric pressure, a deposition rate of 2 mils thickness per square inch of substrate area per hour, a temperature of 550° C, and a hydrogen to WF_6 ratio of 4:1. The addition, individually, of about 2 vol-pct of butane, 24 vol-pct of carbon dioxide, or 4 vol-pct of propane to the hydrogen and WF_6 mixture produced deposits with the finest grain size for each gas. A corresponding increase in microhardness accompanied the decrease in grain size. The addition of these gases did not alter the columnar microstructure found in vapor-deposited tungsten.

OP 144-74. Rhenium and Rhenium-Tungsten Deposition by Thermochemical Reduction of the Hexafluorides—A Preliminary Study, by F. W. Hoertel and J. G. Donaldson. *Electrodeposition and Surface Treatment*, Elsevier Sequoia S.A., Lausanne, Switzerland, v. 2, 1973/74, pp. 343-353. Consolidated rhenium deposits of high purity can be obtained by the hydrogen reduction of ReF_6 from the vapor phase, although some rhenium always deposits as a loose, black powder. The temperature of the reaction zone and the volume ratio of H_2 to ReF_6 significantly influence the amount of massive rhenium deposited. The near-optimum parameters are a temperature of 250° C and a volume ratio of H_2 to ReF_6 of 25 to 1. Operating at these gas ratios and temperature, with the equipment described, the best results were obtained with the deposition chamber at atmospheric pressure; both increasing pressure (to 790 millimeters of mercury) and decreasing pressure (to 600 millimeters of mercury) yielded excessive quantities of powdered rhenium. All tests at other than atmospheric pressure were made at the near-optimum parameters.

OP 145-74. Fuels and Emissions—Update and Outlook, 1974, by R. W. Hurn and T. W. Chamberlain. *Pres. at Nat. Combined Farm, Construction, and Ind. Machinery and Powerplant Meetings*, SAE, Milwaukee, Wis., Sept. 9-12, 1974, SAE Preprint 740694, 15 pp. A change has been observed in the amount and chemical makeup of automotive emissions since the late 1960's. In general, the trend toward decreased levels of the several categories of emissions is well known, but changes in the chemical character of the hydrocarbon component are less well known. The nature of these changes and implications for air pollution effects are discussed. Also, with supplies of motor fuel from petroleum sources in increasing jeopardy, there is growing interest in the character of emissions to be expected in using alternative fuels. The more viable options for alternative fuels are identified, and emission characteristics of these fuels are described.

OP 146-74. Tertiary Oil Recovery is Target of BuMines Project, by Bill Linville. *Am. Oil & Gas Reporter*, v. 17, No. 1, April 1974, pp. 46-47. The Bureau of Mines energy research center in Bartlesville, Okla., has begun a field demonstration of a micellar slug treatment for tertiary oil recovery from the Bartlesville sand in Delaware-Childers field. The site of the demonstration is about 8 miles northeast of Nowata, Okla. The micellar slug will be followed by a polymer-thickened water for mobility control. The field investigation will provide information for industry to follow in attempts to recover larger percentages of proved oil reserves.

OP 147-74. Low-Temperature Thermal Studies on Six Organo-Sulfur Compounds, by J. F. Messerly, H. L. Finke, and S. S. Todd. *J. Chem. Thermodynamics*, v. 6, No. 7, July 1974, pp. 635-657. Low-temperature calorimetric studies were made on pure samples of 3-methyl-1-butanethiol (12 to 370 K), 3-methyl-2-butanethiol (12 to 370 K), 2-methylthiacyclopentane (12 to 370 K), 3-methylthiacyclopentane (12 to 336 K), cyclopentyl-1-thiaethane (12 to 370 K), and phenyl-1-thiaethane (12 to 320 K). From the previous measurements the following thermodynamic functions at selected temperatures were calculated for the condensed phases:— $\{G_s(T) - H(0)\}/T$, $\{H_s(T) - H(0)\}$, $S_s(T)$, and C_s . By use of accurate vapor pressures from this laboratory, $S^\circ(g, 298.15\text{ K})$ was obtained for each compound. From previously published values of ΔH_f° for all six com-

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pounds and the measured value of S° (g, 298.15 K), ΔG° , and $\log_{10} K_r^\circ$ were calculated.

OP 148-74. Rock Breakage Research for Rapid Hard Rock Tunneling, by James J. Olson and Thomas C. Atchison. Proc. Symp. Rock Mech. and Tunneling Problems, Regional Engineering College, Kurukshetra (Haryana), India, Dec. 16-21, 1973, pp. 131-139. This paper describes the accomplishments in rock breakage resulting from the Rock Mechanics and Rapid Excavation Program. Funds for the program were authorized by the Advanced Research Projects Agency of the Department of Defense, and the program was managed by the Bureau of Mines, U.S. Department of the Interior.

OP 149-74. An Underground Coal Gasification Experiment, Hanna, Wyoming, by Leo A. Schrider, James W. Jennings, Charles F. Brandenburg, and Dennis F. Fischer. Pres. at 49th Ann. Fall Meeting, Soc. Petrol. Eng., AIME, Houston, Tex., Oct. 6-9, 1974, SPE Preprint 4993, 25 pp. Background information on the Bureau of Mines underground coal gasification experiment at Hanna, Wyo., is given, and results of material balance calculations are discussed. The test results indicate that gas volumes and gas heating values have fluctuated over a wide range depending on operating conditions.

OP 150-74. Progress in Stabilizing Mineral Wastes, by M. B. Shirts, W. R. McDonald, M. W. Glantz, and G. M. Potter. Proc. 4th Miner. Waste Utilization Symp., Chicago, Ill., May 7-8, 1974, pp. 269-273. Since 1965, the Bureau of Mines has pioneered the use of chemicals alone or in conjunction with vegetation as a means of stabilizing fine mineral wastes. This paper updates available information on continuing long-term field tests on selected uranium and copper mill tailings. Current research tests to improve plant growth on excessively acid tailings by use of leaching or neutralizing are discussed as well as the use of Indian ricegrass, a native grass, in stabilizing tailings.

OP 151-74. Feasibility of In Situ Retorting of Green River Oil Shale, Utilizing Nuclear Explosives for Fracturing, by H. W. Sohns. Proc. 3d Internat. Atomic Energy Agency-Peaceful Nuclear Explosive Panel, Vienna, Austria, Nov. 26-30, 1972 (pub. as Peaceful Nuclear Explosions III), pp. 99-121. Although hydraulic fracturing and chemical high explosives may be used to fracture shallow and thin beds, nuclear explosives may be required for adequate fracturing of the Green River oil shale in the center of the Piceance Basin of Colorado, where there are deposits as thick as 2,000 feet under as much as 1,000 feet of overburden. Experiments have been conducted at the Bureau of Mines Laramie Energy Research Center in batch-type retorts accommodating particle-size ranges expected to be present in a nuclear-explosive created chimney. Results of these tests have been somewhat encouraging and indicate that the creation of adequate permeability through carefully designed and controlled fracturing techniques is a critical factor.

OP 152-74. Production of Submicron Silicon Carbide Powders by Attrition Milling, by D. A. Stanley, L. Y. Sadler III, D. R. Brooks, and M. A. Schwartz. Proc. 2d Internat. Conf., Symp. Electrochem. Soc., Electrothermics and Met. Div., Boston, Mass., Oct. 7-11, 1973 (pub. as Fine Particles—Second International Conference), pp. 331-336. An attrition milling process developed by the Bureau of Mines

has been employed to produce submicrometer oxide and carbide powders. Lower energy requirements and improved properties are anticipated in forming these powders into sintered ceramic bodies. This paper describes SiC milling studies employing coarse rounded SiC and coarse Ottawa sand grinding media. Particle size less than 1 micrometer were achieved in approximately $\frac{1}{4}$ hour, and particle sizes about 0.1 micrometer were achieved in 2 hours of milling. The average rate of surface area generation in this powder for the first 3 hours of milling is 8 square meters per gram per hour for both silicon carbide and Ottawa sand media.

OP 153-74. Analyzing Heavy Ends of Crude. Recluse, Wyo., by C. J. Thompson, J. E. Dooley, J. W. Vogh, and D. E. Hirsch. Hydrocarbon Processing, v. 53, No. 8, August 1974, pp. 93-98. Compositional data on Recluse, Wyo., crude oil, one of the most paraffinic crude oils, is given. These data are useful in optimizing petroleum processing methods for improved utilization of petroleum.

OP 154-74. The Economics of Coal Conversion Systems, by Paul Wellman and Sidney Katell. Pres. at 49th Ann. Fall Meeting, Soc. Petrol. Eng., AIME, Houston, Tex., Oct. 6-9, 1974, SPE Preprint 5097, 15 pp. Cost studies of several systems being considered for converting coal to either liquid or gaseous fuels have been completed. Data are presented for two of the most promising systems developed by the Federal Bureau of Mines—the Synthane and the Synthoil processes.

OP 155-74. Geochemistry of Oilfield Waters, by A. Gene Collins. V. 1 in Developments in Petroleum Science, Elsevier Publishing Co., New York, 1974, 430 pp. This book was prepared in recognition of the importance of subsurface oilfield waters as they are related to the origin, migration, and maturation of oil and gas, and thus to the exploration and production of oil and gas as well as to the protection of the environment. The 16 chapters of this book cover such topics as sampling, analysis, interpretation of analysis, significance of constituents, origin, classification, effects upon the origin of oil, silicate solubilities, and environmental impact.

OP 156-74. Oil Shale, by G. L. Cook. Ch. in McGraw-Hill Yearbook Sci. and Technol., McGraw-Hill Book Co., Inc., New York, 1974, pp. 320-322. The possibilities for development of the oil shale resources of Colorado, Wyoming, and Utah are discussed in terms of resources, technology, and incentives.

OP 157-74. Homogeneous Nucleation of Water Vapor, by W. G. Courtney, D. R. Forshey, and J. B. Greenshields. J. Colloid and Interface Sci., v. 48, No. 3, September 1974, pp. 508-511. The popular molecular model for cluster thermodynamics is shown to involve almost insurmountable problems owing to its extreme sensitivity to the interactions between the molecules in a cluster.

OP 158-74. Development of Oil Shale in the Green River Formation. Report of the Committee on Environment and Public Planning, by Hollis Dole, Tom Beard, John Bredehoeft, G. U. Dinneen, John Donnell, John Rold, Paul Russell, Stanley Schumm, and Ellis Sedgely. The Geologist, v. 9, No. 4, July 1974, pp. 1-8. In the last two decades, U.S. petroleum demand has increased at a rate greater than that of

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domestic production. A domestic energy source that is under serious consideration to augment present supply is oil shale. The Green River Formation in Colorado, Utah, and Wyoming represents a potential resource containing about 2 trillion barrels of oil in shale that averages 15 gallons per ton or more than 400 billion barrels in 30-gallon-per-ton shale. This report considers the technological and environmental aspects of developing this resource for use by the people of the United States.

OP 159-74. Analyzing Heavy Ends of Crude. Swan Hills, Alberta, Canada, by J. E. Dooley, C. J. Thompson, D. E. Hirsch, and C. C. Ward. *Hydrocarbon Processing*, v. 53, No. 4, 1974, pp. 93-100. This article discusses the characterization of the 370° to 535° C distillate from Swan Hills, Alberta, Canada, crude oil.

OP 160-74. Atomic Absorption Determination of Rhenium in Ores and Concentrates, by E. V. Elliott, K. R. Stever, and H. H. Heady. *Atomic Absorption Newsletter*, v. 13, No. 5, September-October 1974, pp. 113-117. The Federal Bureau of Mines has developed an accurate, sensitive, and reasonably rapid method for the determination of rhenium in ores, concentrates, and tailings. The sample is solubilized by a novel fusion procedure or by a simple digestion technique. Rhenium in the resulting solution is extracted with a commercial quaternary amine in methyl isobutyl ketone, and the organic phase is aspirated directly into a nitrous oxide-acetylene flame. An accuracy of about 1 percent is achieved, based on the analysis of an NBS standard sample. The detection limit for a 5-gram sample is about 1 part per million.

OP 161-74. NMR Relaxation of ^7Li and ^1H in Appalachian Petroleum Reservoir Rocks Containing LiCl Solution, by L. C. Headley. *Nature Phys. Sci.*, v. 242, No. 119, Apr. 9, 1973, pp. 87-88. Proton nuclear magnetic resonance (NMR) longitudinal relaxation in reservoir rock containing water is recognized as an indicator of rock permeability within a given reservoir. Cylindrical sandstone core samples, 1 inch long by 0.75 inch in diameter, from several different Appalachian area reservoirs, were cleaned, dried, and saturated with a 14 M solution of LiCl in distilled water. In this study, it appeared that ^7Li relaxation was a better predictor of surface area/pore volume ratio (and thus of permeability) than ^1H relaxation.

OP 162-74. Coal Mine Noise Standard. Enforcement Under the Provision of the Federal Coal Mine Health and Safety Act, by Joseph A. Lamonica. *Am. Ind. Hygiene Assoc. J.*, November 1972, pp. 761-765. Various aspects of implementing the noise standards in the coal mining industry are discussed. These aspects include a history of the noise regulations, training of mining industry and Bureau of Mines enforcement personnel, requirements of the industry and the Bureau, and the treatment of violations. Those areas that are particularly troublesome and the research they have generated are presented.

OP 163-74. Catalytic Methanation, by G. Alex Mills and Fred W. Steffgen. *Catalysis Rev.*, v. 8, No. 2, 1973, pp. 159-210. This article reviews the catalytic methanation of carbon monoxide and, to a lesser degree, carbon dioxide. Methanation to remove traces of carbon oxide from oxygen-rich gases, such as those used in ammonia plants, has been con-

sidered as well as methanation to produce a methane-rich gas, such as SNG (substitute natural gas). Special catalytic problems related to methanation to produce a methane-rich gas are discussed in an additional section on equipment and heat-removal techniques.

OP 164-74. Rapid Excavation Research—Elements of a New Excavation Technology, by James J. Olson. Ch. 100 in *Proc. 1974 Rapid Excavation and Tunneling Conf.*, AIME, San Francisco, Calif., June 24-27, 1974, ed. by H. C. Pattison and E. D'Appolonia, v. 2, 1974, pp. 1503-1535. This paper reviews some of the significant research accomplishments obtained under a 3-year, \$66 million research program in rock mechanics and rapid excavation sponsored by the Defense Department Advanced Research Projects Agency (ARPA) and managed by the Bureau of Mines. In addition to the rock mechanics research, five major phases of excavation—systems analysis, geologic prediction, rock disintegration, ground support, and materials handling—were represented by the projects funded under the ARPA program.

OP 165-74. Oxidative Thermal Degradation of Selected Polymeric Compositions, by K. L. Paciorek, R. H. Kratzer, J. Kaufman, and A. M. Hartstein. *Am. Ind. Hygiene Assoc. J.*, March 1974, pp. 175-180. Tests were performed on (1) polyvinyl chloride-containing materials, (2) neoprene compositions, (3) polyurethane foams, and (4) miscellaneous materials (including jute and fiberglass) using a stagnation burner arrangement. In the case of the chlorinated materials, significant quantities of hydrogen chloride were detected; its rate of evolution is strongly temperature dependent. Once glow occurred, carbon monoxide became the predominant toxic species formed. Urethane foams produced CFCl_3 and CO , together with some HCl and chlorinated hydrocarbons. Jute compositions liberated methyl chloride as well as other products. A composition of resin reinforced with glass fibers ignited spontaneously at 487° C and produced significant quantities of carbon monoxide.

OP 166-74. Critical Ceramic Raw Materials, by Murray A. Schwartz. *Proc. Conf. Emerging Priorities in Ceramic Eng. and Sci.*, Alfred Univ., Alfred, N.Y., Nov. 4-6, 1974 (pub. as *Ceramic Engineering and Science: Emerging Priorities*, by Plenum Press, New York), pp. 105-122. Factors influencing availability of ceramic raw materials are discussed, including unprecedented industrial growth, depletion of high-grade minerals, increased competition from other industries and countries, costly environmental restrictions, inadequate transportation facilities, labor shortages, energy shortages and costs, and adverse international situations.

OP 167-74. Bureau of Mines Research on Vibrations From Underground Blasting, by James J. Snodgrass and David E. Siskind. Ch. 102 in *Proc. 1974 Rapid Excavation and Tunneling Conf.*, AIME, San Francisco, Calif., June 24-27, 1974, ed. by H. C. Pattison and E. D'Appolonia, v. 2, 1974, pp. 1561-1577. The Bureau of Mines investigated the effects of vibrations from underground blasting in four rock types to define blast parameters that affect vibration amplitudes and to establish means of predicting expected vibration levels. A summary of the work is presented, and the results of further analysis of the data are discussed.

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OP 168-74. Oil Shale: Its Role in Solving the Energy Problem, by Harold W. Sohns. Proc. Symp., The Energy Problem: What Can Be Done, Texas Tech Univ., Lubbock, Tex., Feb. 20, 1974, pp. 18-24. This paper discussed the occurrence and characteristics of oil shale, the principles and present development of methods for obtaining oil from it, and the environmental impact and prospects of an oil shale industry.

OP 169-74. Development and Economics of Treating a Brass Foundry Waste, by G. V. Sullivan and E. G. Davis. Proc. 3d Internat. Pollution Eng. Cong., Chicago, Ill., Sept. 9-11, 1974 (pub. as Pollution Engineering Techniques), pp. 59-65. Results of Bureau of Mines studies show that mineral processing techniques can be used to recover both brass and sand from brass foundry wastes. Both recovered products are suitable for recycling. In this instance, about 90 percent of the waste was recovered for recycle. An evaluation of the process showed favorable economics. A cooperating foundry is currently introducing a recovery unit.

OP 170-74. Single Fracture and Fragmentation of Brittle Solids Subjected to Thermal Shock, by K. Thirumalai. Indian J. Technol., v. 11, No. 10, October 1973, pp. 419-427. A new technique of inducing crushing of rocks and related brittle solids by a single fracture process using thermal shock principles has been developed by the Bureau of Mines in cooperation with the U.S. Army Advanced Material Concepts Agency. Thermal crushing of brittle solids is feasible by thermal shock techniques. Fragmentation is initiated by tensile thermal stress concentrations of material defects within the interior of the solid. The magnitude and distribution of thermal stresses and, therefore, the crushed product sizes can be controlled by varying the heating conditions. Increasing the thermal shock intensity reduces the size of the crushed fragments and the energy required for fragmentation.

OP 171-74. Nahcolite and Dawsonite Resources in the Green River Formation, Piceance Creek Basin, Colorado, by Thomas N. Beard, Donald B. Tait, and John Ward Smith. Paper in Energy Resources of the Piceance Creek Basin, Colorado, Rocky Mountain Association of Geologists—1974 Guidebook, 1974, pp. 101-110. Resources of nahcolite and dawsonite in oil shale of Colorado's Green River Formation are evaluated. Total resources of 29 billion tons of nahcolite and 19 billion tons of dawsonite are present.

OP 172-74. Rock Fragmentation by High Frequency Fatigue, by Patrick J. Cain, Syd. S. Peng, and Egons R. Podnieks. Proc. Adv. Rock Mech., 3d Cong. Internat. Soc. Rock Mech., v. 2, pt. A, 1974, pp. 367-372. The fatigue failure characteristics under high-frequency (10 kHz) cyclic loading were determined for Tennessee marble, Charcoal granite, and Sioux Quartzite. The fatigue strength for each rock type shows a correlation with the static strength. The analysis of the damping and internal heat generation indicated that nearly all of the power input was accounted for as a change in enthalpy. The thermal strain was calculated and found to range up to 30 pct of the dynamic strain amplitude. The specific energy required for failure was determined and possible applications are discussed.

OP 173-74. Vapor Deposition of Cobalt-Tungsten Alloys, by J. G. Donaldson. Electrodeposition and Surface Treatment, Elsevier Sequoia S.A., Lausanne, Switzerland, v. 2, 1973/74, pp. 419-434. Cobalt-tungsten binary deposits were formed in laboratory experiments by hydrogen reduction of the anhydrous mixed vapors of cobaltous chloride and tungsten hexachloride. The materials were sublimed in separately heated zones of a reaction tube and were transported in a stream of purified helium into the deposition section of the tube where the chloride gases were reduced to metal by a countercurrent flow of hydrogen. Heat-treating of the near stoichiometric binary metallic deposits converted nearly all to the intermetallic compound Co₂W; however, small quantities of both cobalt and tungsten remained. Mechanical tests showed that the tensile strength of heat-treated 75 pct cobalt-25 pct tungsten deposits was twice as high as that of similarly treated deposits of cobalt.

OP 174-74. Vapor Deposition of Molybdenum-Tungsten Alloys, by J. G. Donaldson and H. Kenworthy. Electrodeposition and Surface Treatment, Elsevier Sequoia S.A., Lausanne, Switzerland, v. 2, 1973/74, pp. 435-446. Binary alloys of molybdenum and tungsten were prepared by the Bureau of Mines in laboratory-scale experiments by hydrogen reduction of their vaporized hexafluorides. Near-optimum deposition parameters were determined, and the nature of the deposited alloys was investigated. Dense, homogeneous alloys were codeposited between 650° and 750° C with a reduction efficiency of more than 75 pct. The alloy composition was uniform when the hydrogen ratio in the gas feed mixture did not exceed three times the stoichiometric requirement. Regulating the proportions of the metal hexafluorides in the gas feed provided a large degree of control over the composition of the deposit. Hardness of the deposits varied directly with the proportion of excess hydrogen in the gas feed and with the weight-percent of tungsten in the alloy. Hardness was not affected by deposition temperature over the range of 650° to 750° C for specimens of similar composition. Extreme brittleness and unsuitable physical shapes of the alloys prevented tensile strength measurements.

OP 175-74. Fragmentation of Native Copper Ores With Hydraulic Jets, by J. N. Frank and P. D. Lohn. Proc. 2d Internat. Symp. Jet Cutting Technol., Apr. 2-4, 1974, St. John's College, Cambridge, England, Paper H3, 1974, pp. H3-29—H3-38. Results from an experimental program to examine mining of native copper ore with high pressure, continuous fluid jets are given. Variables that will influence the cutting rate and energy consumption of the mining process are considered. The variation of cutting depth and specific energy with both jet traverse speed and jet pressure is shown. Estimates are made of the reduction in energy consumption by adding mechanical cutting assistance to the excavation system.

OP 176-74. Bureau of Mines Research on the Recovery and Reuse of Post-Consumer Scrap, by Robert S. Kaplan. AFS Trans., October 1974, pp. 487-494. The Bureau of Mines has a continuing research program aimed at developing technology that can increase the supply and utility of ferrous scrap. This research has resulted in the development of processes for separating incinerated urban refuse into its component parts and for burning junk auto-

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mobiles smokelessly. In addition, methods have been devised for removing copper from high-carbon iron and for detinning incinerated cans, thereby increasing the utility of contaminated scrap. Other research has shown that impurities such as copper and tin can be tolerated in cast steels and gray irons, provided that the tin content does not exceed 0.08 pct.

OP 177-74. The Energy Balance Theory and Rock Fracture Energy Measurements for Uniaxial Tension, by Warren W. Krech. *Proc. Adv. Rock Mech.*, 3d Cong. Internat. Soc. Rock Mech., v. 2, pt. A, 1974, pp. 167-173. A new application of the basic Griffith theory of rupture of brittle solids, based on direct measurement of fracture energy requirements, is presented. The energy balance hypothesis is demonstrated by direct experiment, and non-recoverable energy used in fracturing rock is directly measured. Ten rock types were tested in uniaxial tension under closed-loop control. Observation of test results and measurements of fracture energy are presented.

OP 178-74. Separating Copper From Scrap by Preferential Melting. Laboratory and Economic Evaluation, by Vance G. Leak, M. M. Fine, and Henry Dolezal. *Proc. 4th Miner. Waste Utilization Symp.*, Chicago, Ill., May 7-8, 1974, v. 4, pp. 409-416. A technique for recovering copper and steel from metallic scrap based on preferential melting in molten salt baths at 1,150° to 1,250° C is described.

OP 179-74. New Device Collects Coal-Mine Float Dust To Measure Explosive Hazards, by H. G. Lucas and J. W. Martin. *Coal Age*, v. 79, No. 10, October 1974, p. 147. A roller-type device was developed by the Bureau of Mines that promises to effectively sample coal mine float dust. Float dust is the air-entrainable layer of fine coal that settles on the rock dust substrate in coal mine airways. Evaluating the potential hazard of float dust requires accurate sampling of this thin—approximately 1/64 inch—layer of coal dust, which is equivalent to 0.03 ounce of float dust per cubic foot of entryway. The prototype sampler is constructed from 40-mesh stainless steel screen formed into a cylinder 6 1/4 inches long by 3 1/2 inches in diameter. Seventeen 6-inch-long by 1/4-inch-wide flights are soldered inside the screen with about 1/8 inch of open screen between the flights. A dust-collection tray is suspended from the central axle of the cylinder so that the open side of the tray always remains upright. In laboratory tests, the rolling screen sampler made minimal impression in the dust surface and, therefore, removed a representative layer of re-entrainable solids. Extensive areas could also be rapidly covered by the sampler, thus increasing the recovery of sample material typical of the surface.

OP 180-74. Mineral Profile of Oil Shales in Colorado Core Hole No. 1, Piceance Creek Basin, Colorado, by William A. Robb and John Ward Smith. Paper in *Energy Resources of the Piceance Creek Basin, Colorado, Rocky Mountain Association of Geologists—1974 Guidebook*, 1974, pp. 91-100. Relative amounts of eight minerals were plotted with oil yield to obtain a mineral profile of Colorado's Green River Formation. Positive relationships between organic matter and silicate minerals were demonstrated statistically.

OP 181-74. Geochemistry of Oil-Shale Genesis in Colorado's Piceance Creek Basin, by John Ward Smith. Paper in *Energy Resources of the Piceance*

Creek Basin, Colorado, Rocky Mountain Association of Geologists—1974 Guidebook, 1974, pp. 71-80. A geochemical genesis pattern for oil shales in Colorado's Green River Formation is postulated to explain seven major observed characteristics of the deposit.

OP 182-74. Reaction of Sodium With Dibenzothiophene. A Method for Desulfurization of Residue, by Heinz W. Sternberg, Charles L. Delle Donne, Raymond E. Markby, and Sidney Friedman. *I&EC Process Des. and Develop.*, v. 13, No. 4, October 1974, pp. 433-436. Treatment of a petroleum residuum containing 1.65 pct S with excess metallic sodium (3.1 mole of Na/mole of S) in the presence of hydrogen at 350° C decreases the sulfur content to 0.3 to 0.4 pct. To lower the sulfur content below 0.1 pct requires 6 moles of Na/mole of S. Parallel experiments with dibenzothiophene dissolved in decahydronaphthalene resulted in >99 pct removal of sulfur to form primarily diphenyl. The rate of desulfurization is inversely proportional to hydrogen pressure and proceeds even in its absence. In the absence of hydrogen, however, char formation is favored.

OP 183-74. Soviet Coal Through 1980, by V. V. Strishkov, George Markon, and Zane E. Murphy. *Min. Cong. J.*, v. 60, No. 10, October 1974, pp. 40-52. Soviet industrial expansion depends on coal as a source of power and raw materials for the metallurgical and chemical industries. A knowledge of the coal resources and the outlook for production of the U.S.S.R. therefore is essential for a critical evaluation of Soviet industrial potential. Although there is considerable literature on the Soviet coal industry, no single source provides an authoritative study of how the industry functions and how well it performs its job. This article is based on a review of sources published by the U.S.S.R.

OP 184-74. Sulfur Utilization in Pollution Abatement, by T. A. Sullivan and W. C. McBee. *Proc. 4th Miner. Waste Utilization Symp.*, Chicago, Ill., May 7-8, 1974, v. 4, pp. 409-416. The development of methods to use sulfur in preventing air and water pollution from mineral processing wastes was initiated as part of the Federal Bureau of Mines sulfur utilization program. Sulfur-based materials have been developed to form protective crusts or coatings on dry mill waste tailings to prevent dusting and water erosion. The use of sulfur in impervious materials to contain acid leach liquors and prevent ground water pollution by waste liquors is described.

OP 185-74. Water Jet Cutting and Excavation of Hard Rocks by Thermohydraulic Method, by K. Thirumalai. *Proc. 2d Internat. Symp. Jet Cutting Technol.*, Apr. 2-4, 1974, St. John's College, Cambridge, England, Paper H6, 1974, pp. H6-63-H6-75. The Bureau of Mines has developed and tested a thermohydraulic method for hard rock kerfing and excavation. Heating induces structural weakness and subsurface damage in rocks and assists fragmentation by water jet impingement. Laboratory and field test results show that this novel combination method overcomes cuttability limitations of the thermal energy process in hard rocks.

OP 186-74. Combined Thermal Energy Processes for Hard Rock Fragmentation, by K. Thirumalai and John B. Cheung. *Proc. Adv. Rock Mech.*, 3d Cong. Internat. Soc. Rock Mech., v. 2, pt. B, 1974, pp.

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1460-1467. This paper discusses the principles and effectiveness of combination methods for breaking rocks using thermal energy to initiate subsurface fractures and rock weakening. The application potentials of combination processes are examined with examples of a thermohydraulic method for primary breaking and thermomechanical method for secondary breaking of hard rocks. Based on theoretical predictions of water jet cutting of thermally weakened rocks, a thermohydraulic combination process for hard rock kerfing is advanced.

OP 187-74. **Abating Noise: Achievements at Nominal Cost (A Case Study)**, by J. A. Tipton and J. M. Beaudry. Proc. 24th Nat. Plant Eng. and Maintenance Conf., Chicago, Ill., Mar. 12-15, 1973 (pub. as Techniques of Plant Engineering and Maintenance), v. 24, session 32, pp. 1-4. This case study describes a noise problem in an engine test facility at the Bureau of Mines Bartlesville Energy Research Center, Bartlesville, Okla., and the techniques used for noise abatement. A marked reduction in noise levels was achieved at very low cost, and the result was greatly improved working conditions for employees, which produced higher morale, less fatigue, and better research data.

OP 188-74. **Stratigraphic Framework of Green River Formation Oil Shales in the Piceance Creek Basin, Colorado**, by Laurence G. Trudell, Thomas N. Beard, and John Ward Smith. Paper in Energy Resources of the Piceance Creek Basin, Colorado, Rocky Mountain Association of Geologists—1974 Guidebook, 1974, pp. 65-70. Features of a time-stratigraphic framework for evaluating vertical and geographic variations of oil shales are summarized. Distribution of the minerals nahcolite, dawsonite, and halite is discussed.

OP 189-74. **A Study of Damage to a Residential Structure From Blast Vibrations**, by John F. Wiss and Harry R. Nicholls. American Society of Civil Engineers, 1974, 73 pp. A primary objective of this test project was to study, under carefully controlled conditions, the effects of earthborne blast vibrations upon a residential structure. Another objective was to compare the propagation characteristics of earthborne blast vibrations, when the explosive was detonated in soil, with the extensive information already available in blasts in bedrock. The dynamic strain recordings in the interior walls confirmed that ground peak particle velocity is the best criterion of potential damage to residential structures.

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ABBREVIATIONS

B Bulletin.
FNB Florida Department of Natural Resources.
GS Geological Survey.
HB Handbook.
IC Information Circular.
IG Instruction Guide.
MY* Minerals Yearbook.

OFR Open File Report.
OP Outside Publication.
P Patent
PPS Petroleum Products Survey.
RI Report of Investigations.
SP Special Publication.
TPR Technical Progress Report.

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