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(with Subject and Author Index)

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Compiled by Staff, Office of Public Information

U.S. Bureau of Mines (USBM)
Department of the Interior

INTRODUCTION

The U.S. Bureau of Mines (USBM) was established in the public interest to conclude inquiries and scientific and technologic investigations on 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 increaseee 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 U.S. Bureau of Mines to "disseminate information concerning these subjects in such manner as will best carry out the purposes of this Act."

In accordance with this directive, USBM 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-USBM publications. The number of these reports, the wide range of subjects they cover, and the variety of mediums in which they appear make this kind of list both necessary and valuable.

This edition describes reports and articles published during calendar years 1992 and 1993. It supplements the 50-year list of Bureau publications from July 1, 1910, to January 1, 1960[2]; and these 5-year lists of publications and articles: from January 1, 1965, to December 31, 1969[4], from January 1, 1970, to December 31, 1974[5], from January 1, 1975, to December 31, 1979[6], from January 1, 1980, to December 31, 1984[7], and from January 1, 1985, to December 31, 1989[8].

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The Government Printing Office (GPO) sells:

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ABANDONED MINE LAND REPORTS

These research studies are available from the AML program at Bureau headquarters.

AML 01-93. **Abatement of Acid Mine Drainage by Encapsulation of Acid-Producing Geologic Material**, by Huang, Xiao; Evangelou, V.P. Univ. of Kentucky, Agronomy Dept., 1992. 67 pp.

BULLETINS

These are usually final reports and are available from NTIS.

1993

B 695. An Overview of Research on Self-Contained Self-Rescuer Training, by Vaught, Charles; et al. 1993. 19 pp. 13 illus. In 1985, U.S. Bureau of Mines and University of Kentucky researchers began a series of studies relating to self-contained self-rescuer (SCSR) donning proficiency. During the next 5 years investigators examined a number of factors that have a bearing upon miners' ability to put on and use the apparatus in an emergency: the procedure being taught; availability and utilization of training models; opportunities to practice; hygiene; and on-the-job training. This report presents an overview of that research. It concludes that companies should adopt a hands-on training protocol that allows them to integrate SCSR donning practice into other workplace routines such as fire drills.

B 694. Rock Stress Determinations from Overcoring—An Overview, by Bickel, David L. 1993. 146 pp. 69 illus. This bulletin describes the U.S. Bureau of Mines three-component borehole deformation gage and the overcoring techniques used in rock stress determination. Thirty years of experience with the borehole gage have shown that it is an accurate instrument for measuring deformation of a borehole. The theoretical basis relating the deformation of a borehole to the in situ field stress is presented. Rock anisotropy, variation of topography on the stress field, and nonlinearity of the rock can be accounted for in calculating the in situ state of stress. Drilling equipment, accessories, and instrumentation necessary for the overcoring are presented, as well as the design, fabrication, operation, and calibration of the gage; site selection; and proper overcoring procedures. Biaxial and triaxial testing of the stress-relief core to determine the elastic properties of the rock are discussed. Data reduction, stress calculations, interpretation of results, and computer codes are included to provide a complete working knowledge for determining surface or underground in situ rock stress. A comparison of alternative methods for determining the absolute in situ field stress is also presented.

COMPUTER PRODUCTS

The following computer products are available from the National Technical Information Service. (See order form in this book.)

CP 01-92. Documentation for PCMINSIM: A DCFROR Template for Use with Lotus 1-2-3, by Sam J. Fraser. 1991. Includes software on diskette. A MINe SIMulator model is used by the Bureau of Mines to evaluate the economics of a mineral recovery operation. This document explains the computations performed in this discounted cash flow rate-of-return (DCFROR) procedure and the use of a LOTUS 1-2-3 (R) template version (PCMINSIM) of this model. A MINSIM evaluation combines reserve tonnage and grade estimates and the associated capital and operating costs with information about financial and tax conditions to simulate the DCFROR that can be expected over the life of the mine. Solution options include the Net Present Value (NPV) of the property, the average total production cost over the life of the operation, or the after-tax rate of return expected at an assumed selling price for the marketable product. Running PCMINSIM is simplified by 11 tiered menus that direct the user through the evaluation process. The main contribution of the PCMINSIM is the use of automated spreadsheet technology to illuminate the relationships inherent in a DCFROR evaluation, to expedite interactive sensitivity analysis, and to facilitate modifications to explore new applications of this property evaluation tool. NTIS No. PB 92-501014; price code DO2.

INFORMATION CIRCULARS

These periodic reports are available from NTIS and can be viewed in USBM libraries.

1992

IC 9302. **STRESsOUT—A Data Reduction Program for Inferring Stress State of Rock Having Isotropic Material Properties: A User's Manual**, by Mark K. Larson. 1992. 158 pp., 7 figs. Researchers at the U.S. Bureau of Mines have developed a FORTRAN computer program that can calculate stress states from overcoring measurements obtained from hollow inclusion cells, triaxial cells, strain gauges installed on the wall of a bored raise, doorstopper gauges, borehole deformation gauges, or a combination of any of these gauges. Such stress states are calculated with reference to global and principal coordinate systems. The background of the development of the program, its capabilities, and its special features, as well as the input required, are described in this report. Sample output is shown in an appendix. Difficulties associated with numerical calculations of principal stresses and directions are pointed out. Threshold values for detecting these problems are reported; these values may be changed by the user as desired. Several test problems were set up to verify the computer program and were successfully solved.

IC 9304. **Smoke, Carbon Monoxide, and Hydrogen Chloride Production From the Pyrolysis of Conveyor Belting and Brattice Cloth**, by Margaret R. Egan. 1992. 14 pp., 7 figs. In an underground mine fire, a toxic mixture of combustion product gases and particulate matter is transported by the ventilating system, endangering everyone downstream. To determine the magnitude of the problem that these toxic combustion products pose, the U.S. Bureau of Mines is investigating the combustion products of typical materials found in underground mines. The total toxicity of the combustion products depends upon the evolving gas species and particulate matter, the amount of material involved, and the ventilation rate. In a simulated mine environment, the products from smoldering polyvinyl chloride (PVC) brattice and conveyor belting were analyzed for gas concentrations and smoke characteristics. The primary toxic gases are hydrogen chloride (HCl) and carbon monoxide (CO). Smoldering conveyor belts are more detectable than smoldering PVC brattice cloths. These results, combined with previous analyses, are used to estimate relative toxicities, product levels, and detectability of smoldering mine combustibles.

IC 9305. **Analysis and Design Considerations for Superimposed Longwall Gate Roads**, by Gregory J. Chekan and Jeffrey M. Listak. 1992. 14 pp., 8 figs. The U.S. Bureau of Mines is investigating longwall panel layouts to maximize coal recovery and minimize interactive problems in multiple-seam operations. When coalbeds are longwall-mined in descending order, the transfer of stress from overlying gate roads is a major design constraint affecting pillar stability in the lower mine. The lower mine gate road pillars must be properly designed to withstand the additional load transfer if gate roads are superpositioned in successive seams. The Bureau's MULSIM/NL model, a boundary element computer program, was used to analyze load transfer mechanics for superpositioned gate road pillars. Analysis of Longwall Pillar Stability (ALPS), an empirically based design method for longwall gate road pillars, was used to calibrate model input parameters. ALPS provided a basis to verify model trends and to recommend limits for safe pillar design when superpositioning longwall gate roads. The attributes of the MULSIM/NL model and ALPS were combined to develop a modified method for estimating pillar stress for multiple-seam cases. The modified method uses a multiple-seam factor (MS) to estimate the stress on superpositioned lower mine gate road pillars. Numerical analysis shows that MS depends on the interburden thickness and pillar width.

IC 9306. **Motor Monitoring System for a Continuous Miner**, by John R. Thalimer, John J. McClelland, and Gerald T. Homce. 1992. 12 pp., 11 figs. The U.S. Bureau of Mines has investigated the early detection of insulation failure in squirrel cage induction motors for the past 4 years. Research was done using a sophisticated empirical data-modeling technique based on values calculated from a motor's voltage and current phasors. This technique produces two polynomial equations that calculate the insulation leakage current and power. These models were implemented in a prototype system that monitors six motors on a continuous miner for insulation leakage. These insulation leakage values are used to anticipate insulation failure. The system consists of a motor data system for each motor on the machine and a control computer located away from the miner. Each motor data system consists of an analog interface to the motor's voltages and currents, a single-board computer that reads digitized data and calculates voltage and current phasors, and a bus node that interfaces the single-board computer with the rest of the system by way of a serial bus system. Using this bus system, the control computer requests and receives phasor data from the motor data systems. From these data the control computer calculates and displays two deterioration values for each motor, for leakage current and power, using Bureau-developed models. These values are stored in a data base from which the user can display graphs of each motor's deterioration values over time.

IC 9307. **PREVAL: Prefeasibility Software Program for Evaluating Mineral Properties**, by R. Craig Smith. 1992. 35 pp. 23 figs. This report presents the software documentation for PREVAL, a prefeasibility mineral property evaluation program developed by the U.S. Bureau of Mines on a Lotus 1-2-3 spreadsheet. It is presented in a step-by-step "users manual" format.

IC 9308. **Applicability of Electrical Methods in Deep Detection and Monitoring of Conductive Lixiviants**, by Jay C. Hanson. 1992. 31 pp. 29 figs. Various electrical and electromagnetic (EM) geophysical techniques are currently being evaluated by the U.S. Bureau of Mines for their effectiveness in the detection and monitoring of electrically conductive (1 to 5 S/m) lixiviant (leach solution) to depths of 600 m, either above or below the water table. These techniques include magnetotellurics (MT), controlled-source audiofrequency magnetotellurics (CSAMT), resistivity and focused resistivity, ground-penetrating radar (GPR), frequency-domain electromagnetics (FEM), and time-domain electromagnetics (TEM). Of these techniques, TEM may be the most effective, but CSAMT and focused resistivity also hold promise. Geophysical computer modeling of the borehole TEM technique was conducted based on an idealized geoelectric section (layered earth) with characteristics based on the Santa Cruz porphyry copper deposit near Casa Grande, AZ. Layer resistivities and thicknesses were obtained from geophysical data and geologic logs available from the site. Modeling of borehole TEM both in preleach and during leach situations was

conducted. Simulating the TEM method using computer modeling proved to be encouraging since there were substantial differences between leached and nonleached responses. The modeling does not prove the effectiveness of TEM in the field, but does indicate that detection of deep lixiviant zones is theoretically possible.

IC 9309. Research Toward Direct Analysis of Quartz Dust on Filters Using FTIR Spectroscopy, by Donald P. Tuchman. 1992. 17 pp. 14 figs. The U.S. Bureau of Mines is investigating Fourier transform infrared (FTIR) spectroscopy for on-filter quartz analysis of respirable dust. A custom accessory is described for full-face examination of filters utilizing a large-diameter infrared (IR) beam. The accessory positions samples to match diameters with that of the diverging analytical beam. Sample absorbance is then measured. With nonuniform deposition of dust on collection filters being a major issue for such analyses, this approach is the most direct way to accomplish sample area averaging. The approach is unconventional since it utilizes large-beam geometries instead of the usually desired minimized beam dimensions. The issues and problems involved in the analysis of quartz on a filter matrix are discussed. Absorption bands chosen, light-scattering effects, curved baselines, random noise, interference fringes, and possible solutions to technical difficulties are the topics covered. The more significant findings include a 20-micron g detection limit for quartz when the custom accessory is used and minimal occurrence of light-scattering effects at low wavenumbers. The custom accessory performance was satisfactory and merits further work. With continued research, an on-filter method for quartz analysis of respirable dusts seems achievable.

IC 9310. The Availability of Primary Copper in Market Economy Countries: A Minerals Availability Appraisal, by K.E. Porter and G.R. Peterson. 1992. 32 pp. 4 figs. The U.S. Bureau of Mines has estimated the potential availability of copper from 204 mines and deposits in market economy countries (MEC's). The evaluated properties have demonstrated resources totaling 436.4 million metric tons of contained copper and account for 90 pct of the Bureau of Mines reserve base for copper in market economy countries. Total recoverable MEC copper resources are 340.8 million metric tons, 69 pct of which is from producing mines and 31 pct from nonproducing mines and deposits. Chile had the lowest estimated average total cost from producing mines of $0.48 per pound of recoverable copper at a 0-pct discounted cash-flow rate of return (DCFROR), with estimated average total costs ranging from $0.40 to $0.81 per pound. The estimated average total cost of production, per pound of copper, for producing mines in the United States amounts to $0.57 in January 1988 dollars at a 0-pct DCFROR, with estimated total costs ranging from $0.36 to $0.85 per pound. In both real and nominal terms, the United Stales has, on average, significantly lowered its copper production costs since 1981. Rationalization of the industry and significant increases in productivity have made a strong improvement in the competitiveness of the U.S. copper industry to the extent that the United States should no longer be considered as a marginal producer of copper.

IC 9311. In-Mine Evaluation of Smoke Detectors, by G.S. Morrow and C.D. Litton. 1992. 13 pp. 5 figs. This report presents the results of a U.S. Bureau of Mines evaluation of smoke detectors placed in conveyor belt entries of underground coal mines. The selected mines are located in six different Mine Safety and Health Administration (MSHA) districts, are operated by seven different companies, and use atmospheric monitoring systems from seven different manufacturers. Principal concerns are early detection and warning of fires, reliability of operation, frequency of maintenance, and adaptability of detectors to monitoring systems and the mining environment. The data contained in this report provide for some comparisons between smoke detectors and CO sensors, specifically in the areas of early detection of fires and susceptibility to nuisance alarms due to diesel exhaust contaminants. Finally, recommendations for performance standards, sensitivity tests, detector classification, and maintenance are presented.

IC 9312. Bismuth-Uses, Supply, and Technology, by Stephen M. Jasinski. 1992. 16 pp. 4 figs. The development and industry adaptation of advanced technologies have led to many important uses for bismuth and its compounds. Bismuth-base alloys are essential for manufacturing jet engine turbine blades, lenses, and various safety devices, such as fire-protection sprinklers. The addition of bismuth to iron, steel, and aluminum imparts properties to these metals that make them useful in diversified applications. Bismuth is also used widely in medicine, pigments, and electronics. The United States relies heavily upon imports from South America and Europe to meet its demand for bismuth, which is recovered chiefly as a byproduct of lead processing.

IC 9313. Roof Control of Stress-Relief Jointing Near Outcrops in Central Appalachian Drift Coal Mines, by Gary P. Sames and Noel N. Moebs. 1992. 11 pp. 11 figs. This report discusses some practical applications of a geotechnical investigation conducted by the U.S. Bureau of Mines that can help mine operators meet revised Federal regulations in their roof control plans. The investigation, designed to characterize roof conditions near the coalbed outcrop in drift coal mines in eastern Kentucky, revealed that weathered stress-relief joints near outcrop are crucial ground control factors in the region. The joints' origin and character were determined through underground mapping of many joints in coal mine roof and detailed observations and measurement of joint trends and physical characteristics in widely separated strip mine highwalls and roadcuts. This resulted in an understanding of stress-relief-joint patterns and the effect of various rock types on the intensity of weathering in the joints. That information is used in this report to show how stress-relief joints contribute to roof failure and how, through improved roof support and mine planning, safer roof support plans can be developed.

IC 9314. Three-Dimensional Graphics Simulator for Testing Mine Machine Computer-Controlled Algorithms—Phase 1 Development, by Dean H. Ambrose. 1992. 17 pp. 14 figs. Using three-dimensional (3-D) graphics computing to evaluate new technologies for computer-assisted mining systems illustrates how these visual techniques can redefine the way researchers look at raw scientific data. The U.S. Bureau of Mines is using 3-D graphics computing to obtain cheaply, easily, and quickly information about the operation and design of current and proposed mechanical coal and metal-nonmetal mining systems. Bureau engineers developed a graphics simulator for a continuous miner that enables a realistic test for experimental software that controls the functions of a machine. Some of the specific simulated

functions of the continuous miner are machine motion, appendage motion, machine position, and machine sensors. The simulator uses data files generated in the laboratory or mine using a computer-assisted mining machine. The data file contains information from a laser-based guidance system and a data acquisition system that records all control commands given to a computer-assisted mining machine. This report documents the first phase in developing the simulator and discusses simulator requirements, features of the initial simulator, and several examples of its application. During this endeavor, Bureau engineers discovered and appreciated the simulator's potential to assist their investigations of machine controls and navigation systems.

IC 9315. **Proceedings of the Workshop on Coal Pillar Mechanics and Design**, by compiled by Anthony T. Iannacchione, Christopher Mark, Richard Repsher, Robert J. Tuchman, and Caddie C. Jones. 1992. 302 pp. 271 figs. This publication contains papers prepared for the Workshop on Coal Pillar Mechanics and Design, Santa Fe, NM, June 7, 1992. The workshop was held in association with the 33rd U.S. Symposium on Rock Mechanics and was sponsored by the U.S. Bureau of Mines, the Mine Safety and Health Administration, CONSOL Inc., and Jim Walter Resources, Inc. The proceedings are divided into two broad topics: Coal Pillar Mechanics and the Design of Coal Pillars. The Mechanics Section focuses on recent insights into the behavior of coal pillars in situ as interpreted from field measurements, numerical models, and laboratory tests. Papers in the Design Section discuss practical aspects and field-proven techniques illustrated by the authors' own experiences. The authors of these papers are representatives of Government, industry, and academia from the United States, Canada, Australia, the United Kingdom, the Republic of South Africa, and India.

IC 9316. **The History and Future of Longwall Mining in the United States**, by Thomas M. Barczak. 1992. 26 pp., 53 figs. This U.S. Bureau of Mines report chronicles the historical development of longwall mining in the United States and speculates on future developments to the turn of the century. The involvement and contributions made by the Bureau during these developments are also discussed. Two major periods of history are analyzed: (1) from 1875 to 1950 when small advancing faces were operated manually, and (2) from 1950 to 1990 when mechanized extraction and powered roof supports provided a system to efficiently extract large coal panels. Five eras of technological development during the modern period are described and analyzed. These eras discuss the development of (1) mechanized extraction, (2) powered roof supports, (3) high-capacity roof supports, (4) shield supports, and (5) system automation. Current trends are analyzed in terms of longwall utilization, face production, support capacity, face widths, and new technological developments. From these analyses, the future of longwall mining to the year 2000 is speculated. It is concluded that longwall mining will continue to grow in importance during the next decade and that the next major technological milestone will be the realization of a fully automated longwall mining system.

IC 9317. **Crystalline Silica Overview: Occurrence and Analysis**, by Sarkis G. Ampian and Robert L. Virta. 1992. 27 pp. 13 figs. Crystalline silica (quartz, cristobalite, and tridymite) is regulated by the Mine Safety and Health Administration (MSHA) and Occupational Safety and Health Administration (OSHA) because of its potential for causing debilitating but nonmalignant lung diseases. In 1987, the International Agency for Research Against Cancer conducted a review of the health literature and concluded that crystalline silica was a probable human carcinogen. As a result of this finding, OSHA was required to regulate crystalline silica under its Hazard Communication Standard (HCS). The standard requires that all materials handled by OSHA-regulated facilities be labeled according to the requirements of HCS and that workers receive proper training on the handling of the material if the crystalline silica content equals or exceeds 0.1 weight percent (0.1%). MSHA currently is considering enacting its own HCS. This will be similar to OSHA's HCS. If the standard is enacted, most mineral producers will have to determine the respirable monitor filter and bulk crystalline silica contents of their ores and products so that workers and/or customers will know whether they are in compliance with the 0.1% HCS and/or the OSHA permissible exposure level (PEL) of 50 micro-g for an 8-hour workday for respirable crystalline silica as determined from monitor samples. Two major concerns with the HCS are the widespread occurrence of crystalline silica in nature and the suitability of current technology for routinely determining crystalline silica concentrations at the 0.1% HCS level. Most ores are extracted from silica-bearing deposits, and silica is a common constituent of rocks and soils. OSHA's HCS will have the greatest impact on the producers of crushed stone, diatomite, dimension stone, gravel, industrial sand, perlite, pumice, pyrophyllite, sand, and talc because these materials frequently are shipped directly from the mill to the customer. MSHA's HCS would affect nearly all mineral producers. Those producers that have crystalline silica present in concentrations near the 0.1% cutoff point will have the most difficulty with the analysis. Crystalline silica can be quantified at the 0.1% level by X-ray difractometry in simple systems containing one, two, and possibly three minerals if (1) none of the accessory minerals has X-ray diffraction reflections that coincide or overlap with those of crystalline silica and (2) the standard has a particle size distribution and crystallinity similar to those of the sample. In some instances, it may not be possible to determine the crystalline silica content of a sample with any degree of certainty using the recommended regulatory protocol. In all cases, it is recommended that a qualified mineralogist identify the minerals in a sample prior to any regulatory analysis. Additionally, the uncertainty as to whether some silica polymorphs should be classified as crystalline or noncrystalline and the suitability of metastable high-temperature standards, such as cristobalite and tridymite, for regulatory analysis at ambient temperatures should be addressed further. This overview is written both to highlight these problems and to serve as a guide for analysts, regulators, and industry personnel who are involved in the crystalline silica issue. It also covers some of the difficulties and/or shortcomings in quantifying crystalline silica, such as the ubiquitous mineral quartz, in the workplace.

IC 9318. **Analyses of Natural Gases, 1991**, by J.E. Hamak and B.D. Gage. 1992. 97 pp., 1 fig. This publication contains analyses and related source data for 266 natural gas samples from 20 States and 2 foreign countries. None of the analyses have been previously published in annual reports. All samples were obtained and analyzed as part of the U.S. Bureau of Mines investigations of the occurrences of

helium in natural gases of countries with free market economies. This survey has been conducted since 1917. The analyses published herein were made by mass spectrometer and chromatograph.

IC 9319. **Risk Profile of Cumulative Trauma Disorders of the Arm and Hand in the U.S. Mining Industry**, by S.D. Hudock and C.M. Keran. 1992. 5 pp., 2 figs. A review of all upper extremity cumulative trauma disorder (UECTD) injuries was conducted by the U.S. Bureau of Mines for 1985 through 1989. This review was performed by analyzing each injury, as reported by law and maintained on the U.S. Mine Safety and Health Administration's accident data base. This analysis found that incidence rates in mining were lower than in private sector industry, although the number of reported UECTD injuries increased sevenfold and their percentage of all mining injuries increased fivefold from 1985 through 1989. Metal-nonmetal mines accounted for 80 pct of UECTD injuries, while coal mines accounted for 20 pct. Nearly 63 pct of UECTD injuries were accounted for by only four occupations-mechanics, laborers, boney (crusher) operators, and mines not elsewhere classified (NEC)-with an incidence rate well above the private sector industry rate.

IC 9320. **Examination of Design and Operation Practices for Longwall Shields**, by Thomas M. Barczak. 1992. 14 pp., 24 figs. The success of longwall mining can largely be traced to the development of powered roof support systems. The most significant improvement in powered support design has been the shield support, which improved kinematic stability and promoted the application of longwall mining in difficult-to-control caving conditions where chock and frame supports were inadequate. The most obvious trend in shield design has been an increase in shield size and capacity. This U.S. Bureau of Mines report examines shield design and operation practices and their consequences for the utilization of high-capacity shield support systems. An optimization goal is to minimize support loading by selecting an active shield setting force that is compatible with strata behavior and shield loading characteristics. Shield stiffness is an important design parameter that is often overlooked. A consequence of increasing shield capacity by incorporating larger diameter leg cylinders is a proportional increase in shield stiffness. Setting forces have also increased in direct proportion to the increase in shield capacity. The increased stiffness and higher setting force cause the available capacity to be consumed more quickly, severely limiting the ability of high-capacity supports to last longer and provide reserve capacity for difficult mining conditions.

IC 9321. **MULSIM/NL Theoretical and Programmer's Manual**, by Zipf, Jr, R. Karl. 1992. 52 pp. 53 figs. MULSIM/NL (multiple seams, nonlinear) is a three-dimensional boundary-element method (BEM) program developed at the U.S. Bureau of Mines for stress and displacement analysis of coal mines and thin metalliferous veins. It can analyze one to four parallel seams that can have any orientation with respect to the Earth's surface. Three main new features distinguish MULSIM/NL from its predecessors: (1) nonlinear material models, (2) multiple mining steps, and (3) energy release and strain energy computations. MULSIM/NL has six material models for the in-seam material: (1) linear elastic for coal, (2) strain softening, (3) elastic plastic, (4) bilinear hardening, (5) strain hardening, and (6) linear elastic for gob. Detailed checks show that numerical stress and displacement calculations compare well to known analytic solutions for simple problems. The total energy release calculated by MULSIM/NL is comprised of three basic terms: (1) strain energy release from the mined-out material, (2) linear kinetic energy release due to change in gravitational potential over the mined-out area, and (3) nonlinear kinetic energy release due to nonlinear materials in the total backfill and gob area. The strain energy release term is modified to account for nonlinear stress-strain behavior in the unmined materials. Comparisons of these numerical energy release rate calculations with known analytic solutions show excellent agreement.

IC 9322. **MULSIM/NL Application and Practitioner's Manual**, by Zipf, Jr, R. Karl. 1992. 48 pp. 41 figs. MULSIM/NL (multiple seams, nonlinear) is a U.S. Bureau of Mines boundary-element-method (BEM) program for calculating stresses and displacements (i.e., convergence) in coal mines or thin, tabular metalliferous veins. This manual gives detailed operating instructions for MULSIM/NL and illustrates its use with several practical examples. Three main features distinguish MULSIM/NL from its predecessors: (1) nonlinear material models, (2) multiple mining steps, and (3) comprehensive energy release and strain energy computations.

IC 9323. **Rib Stability: Practical Considerations To Optimize Rib Design**, by W.C. Smith. 1992. 16 pp., 16 figs. The Bureau of Mines examined previous research on rib stability in an effort to develop a practical approach to understanding, characterizing, and controlling weak rib conditions in underground coal mines. Because success in stabilizing ribs depends on a basic knowledge of how weak ribs behave, the report reviews the mechanics of rib failure and the relationship of coal mine geology and pillar constraint to rib instability. Strategies for choosing an effective method of rib support are considered, and various rib support methods are discussed. Finally, the report documents techniques for monitoring ribs and use of models to assess rib stability; such monitoring and modeling can also help determine the most effective method for roof support.

IC 9324. **Diesels in Underground Mines: Measurement and Control of Particulate Emissions. Proceedings: Bureau of Mines Information and Technology Transfer Seminar, Minneapolis, MN, September 29-30, 1992**, by Staff, Twin Cities R. 1992. 132 pp. 80 figs. The goal of the U.S. Bureau of Mines diesel engine research program is to reduce exhaust emissions from diesel-powered equipment used in underground mines. This research has led to significant advances in aerosol measurement and to the development of more effective emission controls. This Information Circular contains reports of some of the presentations made at the Bureau's Information and Technology Transfer Seminar on Diesels in Underground Mines given in Minneapolis, MN, on September 29-30, 1992. The seminar emphasized the measurement and control of diesel particulate matter emissions. Topics covered include a discussion of the health issues associated with the use of diesel equipment underground, an overview of regulations, measurement techniques for diesel exhaust aerosol, levels of diesel exhaust pollutants found in mines, and modern emission controls. An appendix is included that contains a report describing the capabilities of the Bureau's diesel emissions research laboratory, two papers describing the effects of engine maintenance on emissions, a paper describing

the monitoring of carbon dioxide in mine air as an indicator of air quality, a glossary, and a list of abbreviations and acronyms.

IC 9325. **MULSIM/PC—A Personal Computer Based Structural Analysis Program For Mine Design in Deep Tabular Deposits**, by Donato, Douglas A. 1992. 56 pp. 6 figs. This Information Circular presents the MULSIM/PC system of numerical modeling computer programs developed by the U.S. Bureau of Mines. This system consists of four programs: PREMUL, the preprocessor or mesh generator; MULSIM/PC, the actual numerical modeling program (number cruncher); MUL3D, a three-dimensional postprocessor; and MUL2D, a two-dimensional postprocessor. These programs were specifically designed to operate on IBM-compatible (MS-DOS-based) personal computers for easy transfer of this technology to the mining industry and academia. MULSIM/PC uses a subvariation of the boundary-element method, namely, the displacement-discontinuity technique, for linear-elastic geomechanical analysis of mine plans in one or two parallel underground tabular deposits. Results calculated by this technique include stresses and displacements as they relate to changing mine geometries and materials. In addition to describing the MULSIM/PC program and its features, and providing a detailed example model, this report also documents the associated preprocessing and postprocessing programs that are part of the MULSIM/PC system. User's guides for all the programs are contained in the appendixes following the main report.

IC 9326. **Controlling Coal Mine Floor Heave: An Overview**, by Wuest, William J. 1992. 17 pp. 18 figs. This U.S. Bureau of Mines report presents an overview of ground control considerations associated with floor heave. Factors affecting heave, such as in situ stress, floor characteristics, and mine geometry, are described. Floor-displacement monitoring and data analysis methods are outlined. Finally, floor heave remediation is discussed. The remedial techniques are divided into four categories: mine maintenance, supplemental support, mine structure, and techniques for multiple-seam operations. Other subjects covered in the report include laboratory and in-place testing of floor rocks, U.S. and international case studies, effects of mine layout, determination of excess horizontal pressure, and types of heave failure. The emphasis of this report is on practical considerations; theoretical discussions are kept to a minimum.

IC 9327. **Manganese Availability—Market Economy Countries: 1980's Perspective**, by Coffman, Joseph. There are 14 operations that supply 97 pct of the Market Economy Country (MEC) manganese and contain nearly all of its resources. Six mines account for about 70 pct of the production and 85 pct of the resources; there are no known resources that are economically close to those that are currently being mined. Costs (January 1989 dollars) of producing manganese concentrates from the operations evaluated are estimated to range from $0.96 to $1.86 per long ton unit (ltu or 22.4 lb) of contained manganese. Total MEC demonstrated resources evaluated amount to about 1.2 billion tons of in situ ore containing 474 million tons of manganese. Identified resources amount to about 1.8 billion tons of in situ material.

IC 9328. **HEAPREC: A Methodology for Determining Cyanide Heap Leach Reclamation Performance Bonds**, by Denton, Jr., David K.; Iverson, Stephen R.; Gosling, Burton B. 1992. 79 pp. 32 figs. The U.S. Bureau of Mines report presents the documentation for HEAPREC, a methodology for calculating reclamation performance bonds for cyanide heap leach operations. HEAPREC is a template developed for use with Lotus 1-2-3 release 2.01 or newer software. The report is presented in step-by-step "user's manual" format. Appendixes contain detailed background and reference material on performance bonding, cyanide detoxification regulation, cyanide detoxification methods, general mine reclamation procedures, and an example bond calculation.

IC 9329. **Utilizing Mechanical Linear Transducers for the Determination of a Mining Machine's Position and Heading: Underground Testing**, by Jobes, Christopher C.; Lutz, Timothy J. 1992. 23 pp. 22 figs. Computer-assisted control of a mining machine can place the operator in a safe, remote location. A guidance system aids remote positioning of a mining machine by determining its position and heading. The mechanical position and heading system (MPHS) is one of several guidance systems being developed at the U.S. Bureau of Mines. The MPHS uses linear position transducers (LPT's) to provide navigation information during face maneuvers. This report presents an overview of the MPHS theory and implementation, including recent design modifications made for more successful underground testing. This report also presents the experimental setup and procedure for the underground test. The test showed that the MPHS provides reliable and accurate results and can, therefore, provide useful guidance information for face navigation.

IC 9330. **Analysis of Microcomputer Network For Computer-Assisted Mining Research**, by Fries, Edward F. 1992. 10 pp. 6 figs. The U.S. Bureau of Mines is conducting research that will lead to computer-assisted mining equipment. This research will facilitate improvements in safety by relocating workers from dangerous areas and will increase production by providing more accurate control with less downtime of equipment. A Bureau-developed microcomputer network enhances this research by permitting a group of diverse computers to interact with a mining machine as well as with each other over a common data link. The network is composed of specially integrated off-the-shelf hardware and industry-standard operating system and programming languages. Using the network, researchers can conduct various experiments with the mining machine using a diverse group of sensors, computers, and microcontrollers. This report gives a brief background on the Bureau's work in computer-assisted mining, followed by discussions on the network hardware and architecture and the network packets, and an analysis of network operation.

IC 9331. **Longwall Gate Road Roof Instability and Methods of Control in the Lower Kittanning Coalbed of Central Pennsylvania**, by Bauer, E.R.; Listak, J.M.; Krupa, E.D. 1992. 20 pp. 23 figs. This report presents the results of a cooperative study to investigate longwall development entry roof instability. In-mine mapping of geologic and deformational features was conducted to reveal the major ground control problems encountered during gate road development. In addition, mining-induced pillar load monitoring was used to indicate development loading on variously dimensioned gate road pillars and to determine if pillar yielding occurred.

IC 9332. Preventing Coal Mine Groundfall Accidents: How to Identify and Respond to Geologic Hazards and Prevent Unsafe Worker Behavior: Proceedings: Bureau of Mines Technology Transfer Seminar, by Staff, Bureau of Mines. 1992. 89 pp. 82 figs. A major emphasis of the U.S. Bureau of Mines is to perform research on the prevention of fatal accidents at mining operations. The leading cause of fatalities in the underground coal mining industry is groundfalls. This proceedings volume presents several new developments that are helping to prevent fatalities and reduce injuries by groundfalls. The papers focus on the problem from two different perspectives. About half of the papers present information and techniques that can be used to train and motivate miners to protect themselves from groundfalls. The other papers explain how to identify and respond to various geologic conditions that affect the stability of the mine roof. Of the 95 groundfall fatalities that occurred during 1986-90, 75 pct took place in Kentucky, West Virginia, and Virginia. The rate of groundfall fatalities was much higher at small mines. During 1986-90, the rate of groundfall fatalities at mines employing fewer than 20 people was 4.3 times higher than the rate for larger mines. Because so many groundfall fatalities are occurring at relatively small mines in the southern Appalachian coalfields, many of the papers focus specifically on the needs of this category of mine operations.

IC 9333. Viewing Transformation Algorithm To Generate Three-Dimensional Scenes, by Rider, James P. 1992. 36 pp. 20 figs. This report describes a viewing transformation algorithm that generates a perspective view of a three-dimensional scene. This tool may be used by researchers to improve mine safety by assessing the visual capabilities of a mobile equipment operator. A listing of the computer routines along with sample output is included in the report.

IC 9334. Strategies for Improving the Effectiveness of Human Resources, by Peters, Robert H.; Randolph, Robert F. 1992. 24 pp. 6 figs. This review summarizes what has been learned from the large volume of empirical studies on the effectiveness of eight types of interventions intended to increase organizational effectiveness via changes in the management of human resources. The interventions concern the following: recruitment, selection, training, objective feedback, goal setting, reward systems, participative management practices, and organization development. An analysis of the relationship between coal mine productivity and safety is also presented. This analysis generally supports the view that good safety performance and high productivity are NOT incompatible goals. In fact, safe mines also tend to be more productive and vice versa.

IC 9335. Blasting Hazards of Gold Mining in Sulfide-Bearing Ore Bodies, by Miron, Yael. 1992. 10 pp. 4 figs. Two recent unplanned detonations occurred during blasting operations in sulfide-bearing ores in a Nevada gold mine. Other premature detonations have also reportedly occurred at other Nevada, California, and Arizona operations within the past few years, with increasing frequency. Unplanned or premature detonations can be extremely hazardous to life and can cause extensive property damage. A miner was injured in one of these occurrences. This report, by the U.S. Bureau of Mines, intended to acquaint personnel involved in such mining activities with the basic causes for these accidents. These causes include the exothermic oxidation of pyrite (FeS_2) and formation of ferrous sulfate ($FeSO_4$), the exothermic and energetic reaction of the ferrous sulfate with ammonium nitrate-fuel oil (ANFO)-based explosives, and the associated elevated temperatures that can set off detonators and explosives in the boreholes. Recommendations for safe operation by the Mine Safety and Health Administration, the Bureau, and the mine involved with the recent incidents include monitoring temperatures in the blast holes, analyzing for sulfate and ferrous ions, and limiting the time between loading and firing in accordance with conditions in the blast holes. Other procedures for safe operations should fit specific conditions in the mines.

IC 9336. Launching Total Quality Management in the Bureau of Mines: A Case Study. Quality Improvement Report: October 1990 Through September 1992, by Walker, Julie N.; Harris, Sheri L. 1992. 94 pp. This U.S. Bureau of Mines report reviews the first 2 years of the agency's progress in implementing total quality management (TQM), which the agency refers to as Quality Improvement (QI). All employees have been trained in basic TQM concepts, a cadre of facilitators has been selected and trained, and 13 Bureauwide teams are addressing specific issues that were identified by Bureau employees nationwide as problem areas. Also in place are a Quality Council composed of the Bureau's top executives, a Quality Management Board, and eight QI Working Groups to provide a national QI infrastructure. There are also Quality Steering Groups at each Bureau location nationwide to address local concerns. In addition to the narrative text, the texts of salient memoranda and other documents are included as appendixes.

1993

IC 9296. Basic Geological and Analytical Properties of Selected Coal Seams for Coal Interface Detection, by Maksimovic, Slavoljub; Mowrey, Gary L. 58 pp., 23 figs. 1993. One important element of the U.S. Bureau of Mines computer-assisted mining research program is the development of a reliable coal interface detection (CID) system. Several candidate CID concepts currently being investigated by the Bureau include use of natural gamma radiation (NGR), vibration, passive infrared, video, and radar. To help establish which CID sensor technologies need to be developed for a given seam, the Bureau has collected geological and mining practices data from over 460 underground and surface mines in the United States. Also, over 500 coal and rock samples have been obtained for laboratory analyses of ash content, sulfur content, heating value, and NGR. The Bureau's findings indicate that the immediate roof strata in 81% of the underground mines and 93% of the surface mines are made up of shale, draw slate, or claystone. The immediate floor strata in 88% of both the underground and surface mines consist of fireclay, shale, draw slate, or claystone. The results of the NGR testing indicate that the NGR method appears to be a potentially useful CID tool, provided that the immediate roof and floor are both composed of a high percentage of shale-type material.

IC 9337. **Chromium Availability in Market Economy Countries and Network Flow Model Analysis of World Chromium Supply**, by Boyle, Edward H.; Shields, Deborah J.; Wagner, Lori A. 131 pp., 33 figs. 1993. This report analyzes the availability of chromium in the form of ferroalloy products (high-carbon and low-carbon ferrochromium and ferrochromium-silicon) and chromite products (metallurgical, chemical, refractory, and foundry sands) in market economy countries (MEC's). A total of 873.5 Mmt of in situ material, containing 202.5 Mmt of chromium, in 10 MEC countries was analyzed for availability as of the January 1989 study date. Extraction and beneficiation of this in situ material would result in 475.4 Mmt of marketable chromite products. As analyzed, 288.5 Mmt of these chromite products would be available for export or for internal chemical and refractory use and 186.9 Mmt would be smelted in-country to produce 74.3 Mmt of high-carbon ferrochromium, and 2.0 Mmt of ferrochromium-silicon, all available for export. A network flow model, which includes centrally planned economy countries (CPEC's), was also constructed to analyze world chromium supply and demand interactions for the period 1986 through 1994 and to address a hypothetical North American embargo on direct imports of all South African chromium products beginning in mid-1990. The model shows capacity constraints developing in the MEC high-carbon ferrochromium industry in 1987 and a possible subsequent overreaction by the industry in terms of new capacity additions. The results suggest that sufficient chromium is available to North America should an embargo on direct imports from South Africa be imposed by its governments. However, the effect on export revenues in South Africa is relatively small, and timely increases to world ferrochromium, chemical chromite, and foundry sand chromite capacities would be required.

IC 9338. **Availability of Platinum and Platinum-Group Metals**, by Fogg, Catherine T.; Cornellisson, Joseph L. 54 pp. 19 figs. 1993. The U.S. Bureau of Mines investigated the availability of platinum, palladium, and rhodium from 16 deposits in four market economy countries (MEC's). Major recoverable products include 164 Moz of platinum, 80 Moz of palladium, 13 Moz of rhodium, 24 Moz of ruthenium, 4 Moz of iridium, 2 Moz of osmium, and 10 Moz of gold. The 12 deposits in the Republic of South Africa are estimated to account for 96.7 pct of total recoverable platinum. The base-case scenario estimates the long-term cost of production, including recovery of capital, but provides no return on the investment or 0-pct discounted cash-flow rate of return (DCFROR). The total production costs in January 1990 U.S. dollars ranged from $325/oz to $1,288/oz of platinum compared to an average January 1990 price of $450/oz or less. Approximately 83 pct of total recoverable platinum was economic at a cost level of $450/oz or less. At the 15-pct DCFROR, only 26 pct of total recoverable platinum was economic. For platinum-group metals (PGM), attention has been focused on the ratios of the three primary metals: Platinum, palladium, and rhodium. Sensitivity analyses were performed to determine the impact long-term rhodium price increases could have on the total cost of production for platinum and palladium.

IC 9339. **Evaluation of a Nitric-Oxide-Compensated Carbon Monoxide Free Sensor**, by Litton, Charles D.; Conti, Ronald S.; Tabacchi, John G. 10 pp., 7 fig. 1993. This U.S. Bureau of Mines report describes the result of two large-scale tests conducted to evaluate a prototype nitric oxide (NO)-compensated carbon monoxide (CO) fire sensor, developed by Carnegie Mellon Research Institute (CMRI). In the tests, small coal fires were allowed to develop in the presence of diesel exhaust at relatively low ventilation airflows. These tests compared the response of the CMRI fire sensor with that of other fire sensors, including the Bureau's diesel-discriminating smoke detector. During the tests, CO, NO, and smoke levels were continuously monitored in order to determine the sensor alarm times and gas levels as the fire developed. The data indicated that the NO-compensated CO fire sensor was capable of suppressing the CO produced by a diesel engine and that the sensor responded reliably to the CO produced from the test fires. The tests also showed that the Bureau's diesel-discriminating smoke detector alarmed earlier than the prototype NO-compensated CO fire sensor.

IC 9341. **Instrumentation Procedures for Fully Grouted Rock Bolts**, by Johnston, Joanne L.; Cox, Dennis J. 10 pp., 11 figs. 1993. Researchers at the U.S. Bureau of Mines have developed a new tehnique for bonding strain gauges to rock bolts. These instrumental bolts are used to determine load at intervals along the length of the bolt so that reliable, consistent measurements for the design of support systems can be obtained. In this Information Circular, this technique is described in detail and should result in improved miner safety in underground mines.

IC 9342. **Helium Resources of the United States, 1991**, by Hamak, John E.; Gage, Brent D. 18 pp. 6 figs. April 16, 1993. The U.S. Bureau of Mines estimates the identified helium resources of the United States at 630 Bcf as of December 31, 1990. This includes 295 Bcf of demonstrated reserves, 87 Bcf of demonstrated marginal reserves, and 42 Bcf of demonstrated subeconomic resources. The identified resources include 161 Bcf of helium in inferred and marginal reserves and 45 Bcf in inferred subeconomic resources. The identified helium resources contained on Federal lands are approximately 170 Bcf, including 32 Bcf in underground storage in the Cliffside Gasfield near Amarillo, TX. In addition to the identified helium resources, undiscovered helium resources in the United States are estimated at a most likely volume of 103 Bcf, with a maximum volume of 259 Bcf and a minimum volume of 41 Bcf. Also reported are 43 Bcf of helium in nonconventional and low-helium-content natural gases. Current extraction of helium in the United States occurs mostly from natural gases produced from the Hugoton gas area in Kanas, Oklahoma, and Texas, and the Riley Ridge area in southwest Wyoming. Helium extracted from natural gas in the United States in 1990 was 2.5 Bcf. If current trends continue, some shortfalls in helium supply may occur in about 5 to 10 years.

IC 9344. **A Summary of Injury for Independent Contractor Employees in the Mining Industry From 1983 Through 1990**, by Rethl, L.L.; Barrett, E.A. 16 pp. 20 figs. April 2, 1993. The U.S. Bureau of Mines summarized injury data for independent contractor employees working at all locations of coal and metal-nonmetal mines from 1983 through 1990. During the eight years, the greatest contrast in degree of injury between independent contractor and operator employees was in fatalities. From 1983 through 1990, there were 132 independent contractor employee fatalities in the mining industry. In 1988, though, independent contractor employees accounted for nearly one-fourth of all mining fatalities. The

fatality incidence rates of independent contractors were consistently higher than those of operators during the eight years. For instance, in 1990, the contractors' rate was twice that of operator employees in coal mining and nearly five times that of operators in metal-nonmetal mining. Three other salient facts highlight the independent contractor employees' fatality injury data during these years. First, 82% of the independent contractor employee fatalities occurred at surface locations. Second, two job classifications (truck driver and equipment operator) represented 37% of the fatalities throughout the 8-year period. And finally, four accident classifications (powered haulage, slips and falls, machinery, and electrical) accounted for 71% of all independent contractor employee fatalities.

IC 9345. **Soil Factors Affecting Mycorrhizal Use in Surface Mine Reclamation**, by Norland, Michael R. 1993. 24 pp. 2 figs. Surface and subsurface stabilization of mining-related wastes through revegetation depends upon the physical, chemical, and biological condition of the waste following mining. Mining disturbances can significantly alter the physical, chemical, and biological characteristics of a site, reducing or eliminating mycorrhizal fungi from the soil. Mycorrhizae are economically and ecologically important because they can alleviate environmental stresses caused by lack of proper soil condition and because they are vital to stabilization of mining waste by increasing plant survival and biomass through increased nutrient and water uptake. This report discusses some of the ecological factors that may affect mycorrhizae-plant associations on mining-related wastes and provides general information on mycorrhizae inoculation technology.

IC 9347. **Surface Subsidence Over a Room-and-Pillar Mine in the Western United States**, by Magers, Jeff A. 1993. 15 pp. 15 figs. This report summarizes the results from the subsidence research study completed by the U.S. Bureau of Mines at the Roadside Mine, Powderhorn Coal Co., Palisade, Co. This research was conducted from February 1981 to August 1985, with additional data obtained during July 1991, to evaluate residual subsidence. The Bureau studied subsidence at three district room-and-pillar sections at separate locations over the mine and determined the maximum subsidence values and surface subsidence profiles for each mining section. Maximum subsidence of 3.0 ft occurred over the room-and-pillar sections, with overburden depths ranging from 50 to 600 ft. Surface tension cracks had occurred, and were still evident during the residual subsidence survey.

IC 9346. **NUMOD and NUSTA: Software for Interactive Acquisition and Analysis of Time Domain Reflectometry Measurements**, by Huang, Fei-Chiu; O'Connor, Kevin M.; Yurchak, David M. 1993. 42 pp. 39 illus. The principle of time domain reflectometry (TDR) is being used by the U.S. Bureau of Mines to monitor strata displacements induced by mining. The Northwestern University TDR Signature Analysis (NUTSA) Program was developed under contract with the Bureau to allow for visual comparison of three TDR waveforms quickly and easily. This program is interactive, and on-line help is available. The Northwestern University Remote Control TDR Data Acquisition System and Modification of Tektronix SP232 Host Application Program (NUMOD) was then developed to allow acquisition of TDR waveforms from a remote cable tester via modem. The NUMOD system utilizes commercially available software, while the NUTSA program is available from the Bureau. This report begins with a discussion of TDR principles followed by a description of the NUMOD system. An interactive example of signature analysis is then used to demonstrate features of the NUTSA program.

IC 9348. **A Prefeasibility Software Package for Evaluating Coal Properties Using Lotus 1-2-3, Release 2.2***, by Plis, Matthew N.; Rohrbacher, Timothy J.; Teeters, Dale D. 1993. 93 pp. 51 illus. This U.S. Bureau of Mines report presents the documentation for COALVAL, a coal property evaluation software developed on Lotus 1-2-3, version 2.2 spreadsheets. The software is compatible with version 3.1 as well, and may provisionally be run on the earlier 2.01 version. COALVAL is a menu-driven program that produces a prefeasibility-level cost analysis of mine-planned coal resources. The package contains cost models for each of five coal mining methods commonly employed in Appalachia: auger, contour strip, mountain top removal, continuous miner, and longwall. Other models, such as a dragline cost model, will be incorporated as the Bureau's Coal Recoverability Program matures. COALVAL allows mine operators, evaluators, consultants, and Government entities to input resource data and the various production, operating, and cost variables that pertain to their property. The program can evaluate up to 25 seams, each to be mined with up to five different methods, within a given area. Summary spreadsheets listing the cost per clean ton to mine the resources, f.o.b. the tipple, are produced for each property, seam, and mining method/seam combination.
*Does not imply USBM endorsement.

IC 9349. **World Copper Smelter Sulfur Balance—1988**, by Towle, Stewart W. 1993. 9 pp. 4 illus. In 1989, the U.S. Bureau of Mines initiated a contract to gather engineering, operating, and environmental cost data for 1988 for 30 major foreign primary copper smelters in market-economy countries. Data were collected for 29 of the designated smelters together with information on applicable environmental regulations. Materials balance data obtained were used with available data for the eight U.S. smelters to determine the approximate extent of copper smelter sulfur emission control in 1988. A broad characterization of the status of sulfur emission control regulation was made. The 37 U.S. and foreign smelters represented roughly 73.2 pct of world and 89.3 pct of market-economy primary copper production in 1988. The 29 non-U.S. smelters attained 55.3% control of their input sulfur in 1988. Combined with the 90.4 pct control of U.S. smelters, an aggregate 63.4 pct sulfur control existed. Roughly 1,951,100 mt of sulfur were emitted from the 37 market-economy smelters in 1988. Identifiable SO_2 control regulations covered 72.4 pct of the 29 foreign smelters, representing 66.5 pct of smelting capacity. Including U.S. smelters, 78.4 pct of the major market economy smelters were regulated, representing 73.1 pct of smelting capacity. Significant changes since 1988 that may increase sulfur emission control are noted.

IC 9350. **The Materials Flow of Cobalt in the United States**, by Shedd, Kim B. 1993. 26 pp. 13 illus. An initial evaluation of the flow of cobalt-containing materials in the United States was prepared. The following aspects of materials flow were included: cobalt released as a result of mining and processing other metals and minerals; scrap

generation and subsequent recycling or cobalt recovery; and cobalt losses resulting from the generation of wastes, dissipative uses, and disposal of used products. Where possible, estimates were made to quantify the amount of cobalt lost from the materials flow. More than 2,000 metric tons (mt) of cobalt are released annually from mining and mineral processing in the United States, including 480 mt of cobalt in coal produced in the United States. Metallurgical industries examined in this study have well-established recycling or cobalt recovery practices. The petroleum industry recycles spent catalysts, and some chemical catalysts are also recycled. Losses generated during cobalt chemical and powder processing were estimated at 50 mt to 80 mt of cobalt annually. Losses from alloy processing and the manufacture of parts and products were estimated to be 360 mt. These industrial losses are greatly outweighed by an estimated 2,780 mt of cobalt consumed in the United States each year to make products that will ultimately be disposed of.

IC 9351. **Roof Control Strategies for Underground Coal Mines**, by Smith, William C. 1993. 17 pp. 8 illus. Roof support, an important aspect of ground control, involves maintaining roof competency to ensure a safe and efficient mining environment. Wide variability in rock quality and stress distributions requires a systematic approach to roof support design that satisfies specific goals. The success of past roof support in reducing the incidence of roof falls has been primarily attributed to safer roof bolting practices. However, roof falls continue to be the number one occupational hazard in underground coal mines. This U.S. Bureau of Mines report presents a general overview of roof bolting and other roof support methods used in the United States. Characteristics of bad roof and associated roof failure theories are briefly presented as background to roof support. Methods of detecting and monitoring roof behavior and/or bolt performance provide essential feedback on roof support requirements. A discussion follows on roof bolt design that assimilates roof and support parameters into useful equations or nomographs to help decide what bolt types to use and how they should be installed under different roof conditions.

IC 9353. **Diesel-Discriminating Detector Response to Smoldering Fires**, by Egan, Margaret R. 1993. 9 pp. 3 illus. Reliable fire detection is essential for both safe evacuation and containment or extinguishment. In order to increase reliability by reducing the number of nuisance fire alarms in underground mines that use diesel-powered equipment, the U.S. Bureau of Mines has developed a diesel-discriminating fire detector (DDD). It was designed to discriminate between smoke produced by a fire and the smoke-laden exhaust of a diesel engine. Experiments were conducted by the Bureau to compare the smoke detection capabilities of the DDD with those of conventional fire detectors in response to smoldering coal and conveyor belting. A comparison was made among the alarm times of a carbon monoxide (CO) detector with an alarm threshold of 5 ppm, a smoke detector with an optical density alarm threshold of 0.044 m^{-1}, and the DDD with an alarm threshold of 0.025 V. The results show that the DDD will reliably detect developing coal and conveyor belt fires. The average time delay separating the DDD alarm from the first detector to alarm was 76 s for smoldering conveyor belt and 65 s for smoldering coal. The longest time delay between the response of the DDD and the first dector to alarm was approximately 120 s.

IC 9352. **Fires in Abandoned Coal Mines and Waste Banks**, by Kim, Ann G.; Chaiken, Robert F. 1993. 58 pp. 61 illus. Fires that occur in abandoned coal mines, waste banks, and in coal outcrops constitute a serious health, safety, and environmental hazard. Toxic fumes, the deterioration of air quality, and subsidence constitute the greatest hazards from these fires. Although fires on abandoned mine land (AML) occur in every coal-producing state, the severity of the problem varies. Methods to extinguish or control AML fires, including excavation, fire barriers, and sealing, are generally expensive and have a relatively low probability of success. This U.S. Bureau of Mines report includes information from a variety of sources, i.e., agencies of the Federal Government, State agencies, research reports, conference proceedings, product information, and technical literature. This information has been collated into a comprehensive discussion of AML fire problems. Data on past fire control projects and on the estimated extent of the current problem have been compiled. Factors affecting the occurrence, propagation, and extinguishment of AML fires are discussed. Conventional fire control methods are described, and their probable effectiveness is evaluated. Information on the hazards of AML fires and safety considerations is included. The status of current technology, recent improvements in fire control methods, and areas of current research are discussed.

IC 9354. **Field Evaluation of the Modular Azimuth and Positioning System (MAPS) for a Continuous Mining Machine**, by Sammarco, John J. 1993. 14 pp. 12 illus. This report details the testing and evaluation of a modular azimuth and positioning system (MAPS) to provide navigational information for a continuous mining machine. Vehicle navigation is part of the U.S. Bureau of Mines research program in computer-assisted mining, serving as a tool to increase mining health, safety, and productivity. The Bureau is investigating other navigation systems, but MAPS seems to have the most promise. MAPS was installed on a continuous mining machine. An operator used the machine to cut coal while researchers collected machine and MAPS data. A comparison of MAPS data for xy position and data obtained with an electronic transit showed an increasing error for MAPS. After 30 min of operation, the easting position error was –0.02 m, and the northing position error was 0.019 m; after 60 min of operation, the easting position error was –0.19 m, and the northing position error was –0.19 m, and the northing position error was –0.26 m. Modifications to MAPS software and to the operational procedure of the machine significantly reduced this error, by a factor of 3.7. Researchers continue to reduce these errors.

IC 9355. **Coal Reserves of the Matewan Quadrangle, Kentucky**, by Rohrbacher, Timothy J.; Teeters, Dale D.; Sullivan, Gerald L. 1993. 36 pp. 11 illus. This report presents a U.S. Bureau of Mines study that incorporates coal mining factors, coal recovery factors, and economic factors into the definition of an economically recoverable coal resource. The relationship between these factors to the Energy Information Administration's estimate of U.S. coal resources—the "Demonstrated Reserve Base" is discussed. The Matewan 7-1/2 minute quadrangle in eastern Kentucky was selected as the initial study area. Results indicate that, of the original 1,193 million tons of resource in the quadrangle, only 89 million tons (7.5 pct) are economically recoverable at a cost of $25 per ton or less. At the current production rate of 5.3 million tons per year, this represents only 16.8 years of remaining reserves.

INFORMATION CIRCULARS

IC 9356. Analyses of Natural Gases, 1992, by Hamak, J.E.; Sigler, Stella. 1993. 62 pp. 1 llus. This publication contains analyses and related source data for 162 natural gas samples from 15 States and 4 foreign countries. Of the total samples, 154 were collected during calendar year 1992; the remainder were collected earlier, but releases granting permission to publish were not received until 1992. None of the analyses have been previously published in annual reports. All samples were obtained and analyzed as part of U.S. Bureau of Mines investigations of the occurrences of helium in natural gases of countries with free-market economies. This survey has been conducted since 1917. The analyses published herein were made by mass spectrometer and chromatograph.

IC 9357. Using Light-Scattering Intensities to Discriminate Waterdrops from Coal Mine Dusts, by Vinson, Robert P. 1993. 14 pp. 15 illus. The U.S. Bureau of Mines evaluated a light-scattering technique for discriminating between spherical and nonspherical particles. This evaluation was a three-step procedure. The first step required collecting light-scattering data for a variety of particles. This was accomplished with a particle analyzer called the DAWN-A. The DAWN-A measured the scattered light intensities of individual particles at a forward scattering angle of 40 degrees. These DAWN-A measurements of individual particles are called scattering signatures by USBM researchers. The second step in this evaluation was to calculate a sphericity index number using the scattering signatures produced by the DAWN-A. The sphericity index number can range from 0 to 1. A calculated sphericity index of 1 would show that, based on the intensity of scattered light, the particle was a perfect sphere. The third and final step of this evaluation was the comparison of the calculated sphericity indices of the various particles. Comparing these indices made it possible to discriminate between the nearly spherical waterdrops and the nonspherical coal and rock dust particles.

IC 9358. A Microcomputer Network for Control of a Continuous Mining Machine, by Schiffbauer, William H. 1993. 27 pp. 13 illus. This report details a microcomputer-based control and monitoring network that was developed inhouse by the U.S. Bureau of Mines and installed on a continuous mining machine. The network consists of microcomputers connected via a single twisted-pair cable. Each microcomputer was developed to provide a particular function in the control process. Machine-mounted microcomputers, in conjunction with the appropriate sensors, provide closed-loop control of the machine, navigation, and environmental monitoring. Off-the-machine microcomputers provide remote control of the machine, sensor status, and a connection to the network so that external computers can access network data and control the continuous mining machine. Because of the network's generic structure, it can be installed on most mining machines.

IC 9359. State-of-the-Art Techniques for Backfilling Abandoned Mine Voids, by Walker, Jeffrey S. 1993. 17 pp. 14 illus. Abandoned underground mine openings are susceptible to collapse because of the mining methods used, the character of the overburden, and the typically large, wide entries with minimal roof support. The final effect of the collapse of the underground workings is surface subsidence. To reduce the probability of subsidence, methods to backfill the mine void with various types of materials have been developed. This U.S. Bureau of Mines report describes the available technologies for subsidence abatement and discusses their operation and application. The basis of these abatement methods is the replacement of the mined material with mine waste. Backfilling of mine voids is the most common method of stabilization used to abate subsidence and protect surface structures. Hydraulic flushing and grouting, using remote methods from single or multiple boreholes, are the most often-used methods for the placement of backfill material. Other subsidence abatement techniques are available and may be more appropriate under different conditions. These other techniques include pneumatic stowing, either by in-mine or remote methods, and various point support methods that do not completely fill the mine void and are used for the protection of small areas of the land surface and surface structures.

IC 9360. Design Practices for Multiple-Seam Longwall Mines, by Chekan, Gregory J.; Listak, Jeffrey M. 1993. 35 pp. 35 illus. The U.S. Bureau of Mines is investigating longwall panel and gate road layouts to increase coal recovery and reduce multiple-seam interactive problems. This report presents design practices for longwall mining multiple seams to provide mine planners and operators with practical guidelines for designing productive longwall mines. Key aspects of mine design that control longwall interactions are examined, including sequencing of seams, design of gate road pillars, and orientation of gate roads and longwall panels. Theories that describe stress transfer between multiple seams and the mechanics of interaction are addressed in relation to geology. Common longwall designs were further investigated using a boundary element model, MULSIM/NL. The model provided insight into relative stress transfer and distribution that occurs between longwall operations in multiple seams. Findings from the model show that a longwall panel should be mined from the gob to the solid coal of an overlying mine, because the stress concentrations are lower; the approach angle should be kept under 30 degrees; and when mining in descending order, superpositioning gate roads usually produces the worst stress condition. To prevent this, the overlying isolated gate roads should be positioned from the centerline toward the headgate side of the underlying panel.

IC 9361. Engineering Methods for the Design and Employment of Wood Cribs, by Barczak, Thomas M.; Gearhart, David F. 1993. 34 pp. 28 illus. Wood cribs are used extensively by the mining industry to stabilize mine openings. While the cost per crib is relatively low, their extensive use can result in annual mine costs of over $1 million. In an effort to improve the utilization of these supports and to reduce ground control hazards, the U.S. Bureau of Mines has developed engineering methods to assist mine operators in wood-crib design and employment. Design and employment criteria are established based on the strength, stiffness, and stability of the crib structure in relation to the load conditions imposed by the mine environment. Models have been developed based on full-scale tests in the USBM's Mine Roof Simulator that compute the capacity of wood cribs of various configurations and material constructions as a function of displacement of the crib structure due to roof-and-floor convergence. These models permit the comparison of the loading characteristics and costs of employment of different crib designs and, in conjunction with roof behavior models, provide a means to determine the optimum design and employment strategy.

IC 9362. **Overview of Mine Subsidence Insurance Programs in the United States**, by Ingram, David K. 1993. 12 pp. 9 illus. Research performed by the U.S. insurance industry has determined that mine subsidence is uninsurable. Consequently, the insurance industry has decided not to voluntarily offer mine subsidence insurance. The U.S. Department of the Interior has long been investigating the effects of mine subsidence; these investigations have resulted in Federal regulations and controls. This U.S. Bureau of Mines report generally describes mine subsidence, the development of mine subsidence insurance programs, and the eight current programs in the United States. The States that have these subsidence programs include Colorado, Illinois, Indiana, Kentucky, Ohio, Pennsylvania, West Virginia, and Wyoming. Major aspects of the programs include history, administrative and operational procedures, insurable structures, recognition of mine subsidence, major exclusions, claims, insurance premiums, and the economic health of each program. Addresses of agencies involved with mine subsidence insurance are also given. Information within this report can be useful for residential and commercial property owners and mine operators. States that are considering starting or already have an existing mine subsidence insurance program can also use this report as a model for initiating or modifying programs.

IC 9363. **Vibration Environment of Instrumentation for Scrapers and Loaders**, by Utt, Walter K.; Gagliardi, John C. 1993. 13 pp. 12 illus. The vibration levels of the heavy machines used in surface mining are much greater than those for vehicles used on highways. In order to assure the proper functioning of electronic equipment placed on the surface mining vehicles, the U.S. Bureau of Mines has conducted a program of field measurements to define their vibration environment. The information in this report is for a class of vehicle that has a blade for scraping and wheels with rubber tires. The statistical information derived from these measurements can be used as a basis for laboratory testing to qualify equipment for a surface mining vehicle of this class. The envelope that would encompass 99 pct of the vibrations encountered in normal operations is presented for each location on the vehicle. The five locations for which data were recorded are the floor of the cab, the engine, the frame, the drive train (gear, differential, and torque converter), and the axle. Tabulated data are provided for those who which to use a different probability level. The appropriate test profile for the laboratory testing can be determined from the information presented in this report.

IC 9364. **A Unix Workstation Monitoring System for Coal-Bump Research**, by Coughlin, J.P.; Wilson, P.E. 1993. 12 pp. 10 illus. The U.S. Bureau of Mines has developed a monitoring system that acquires and analyzes data for use in determining the conditions that may precede mountain bumps in coal mines. Based on a UNIX workstation linked to an array of geophones in a working longwall operation, the system captures complete waveforms of microseismic events and simultaneously obtains continuous samples of the voltage levels of each geophone. Event rates and locations are calculated and displayed in real time on the UNIX workstation, which is situated in an underground instrumentation room. These results also are transmitted from the workstation to a display computer near the longwall face. The system runs continuously and has the capability to acquire, analyze, display, and archive microseismic (transient) data and single point data, such as closure and pressure changes, simultaneously.

IC 9365. **Haulage-Related Accidents in Metal and Nonmetal Surface Mines**, by Kenney, Jean M. 1993. 6 pp. 1 illus. Frequencies of haulage-related accidents in metal and nonmetal surface mines for the years 1988 through 1990 were investigated and compared with those of non-haulage-related accidents. This study was part of the U.S. Bureau of Mines program to improve mining haulage safety. Data were obtained through the U.S. Bureau of Mines Accident Data Analysis (ADA) program. The chi-square test was used to compare frequencies of haulage-related and non-haulage-related accidents for each of the following variables: degree of injury, age, total number of years of mining experience, and shift time. Significance was determined for degree of injury between haulage-related and non-haulage-related accidents. The age of those injured did not vary significantly, but total years of mining experience were found to be significant. Shift time for the accident proved to vary significantly between haulage- and non-haulage-related accidents. Events causing injury for haulage-related accidents were tabulated, and the most frequent determinants of haulage-related accidents were identified. Accident descriptions for both fatalities and permanent disabilities were studied, and the primary causes of these accidents were identified. These findings suggest that haulage-related jobs are among the most dangerous when considering accidents experienced by all workers in the metal and nonmetal surface mining work force.

IC 9366. **Update on Ventilation for Longwall Mine Dust Control**, by Jankowski, Robert A.; Jayaraman, Natesa I.; Potts, J. Drew. 1993. 11 pp. 11 illus. The U.S. Bureau of Mines, in cooperation with the Mine Safety and Health Administration (MSHA) and the mining industry, has identified and demonstrated the effectiveness of several improved face ventilation techniques for longwall mining systems. These include the following: identifying improved techniques for measuring face ventilation parameters on longwall sections, installing curtains at the intake end of the longwall face to maximize usage of the primary airflow, identifying optimum face airflow rates for maximizing dilution effects, and coursing the primary face intake from tailgate to headgate to minimize outby airflow contamination. Application of these techniques throughout the mining industry should reduce the health hazard associated with excessive exposure to respirable coal mine dust.

IC 9367. **Cost-Benefit Analysis of Computer-Assisted Mining Through Production and Cost Modeling: An Update of IC-9281**, by Bhatt, Suresh K. 1993. 40 pp. 1 illus. A mathematically simulated modeling technique is used in this U.S. Bureau of Mines report to represent a hypothetical mining operation with existing mining technology and prevalent mining costs. Mining scenarios were prepared and evaluated for potential benefits and costs available through computer-assisted mining. Base criteria, parameters, and methodology are described.

IC 9368. **Coal Resource Recoverability: A Methodology**, by Rohrbacher, T.J.; Teeters, D.D.; Sullivan, G.L. 1993. 48 pp. 17 illus. This report presents a U.S. Bureau of Mines methodology developed to incorporate factors of coal production (mining and cleaning methods, recoveries,

economics, etc.) into the definition of recoverability of a coal resource. Project procedures and computer models that were developed to include mine and preparation plant production rates, recoveries, and costs are explained. The results of these procedures and models are reviewed and compared to the Energy Information Administration estimate of U.S. coal resources the "demonstrated reserve base." The Matewan quadrangle in eastern Kentucky was selected to demonstrate the methodology.

IC 9369. **The Availability of Primary Lead and Zinc in Market Economy Countries: A Minerals Availability Appraisal**, by DiFrancesco, Carl A.; Cornellisson, Joseph L.; Peterson, Gary R. 1993. 39 pp. 19 illus. The U.S. Bureau of Mines estimated the potential availability of lead and zinc from 205 mines and deposits in market economy countries (MEC's) by performing detailed geologic, engineering, and cost evaluations. These evaluated properties had demonstrated resources totaling 57 million metric tons (Mmt) of contained lead and accounted for approximately two-thirds of the Bureau's reserve base for lead in MEC's (almost 96 Mmt). These properties had contained (in situ contained metal) zinc resources totaling 160 Mmt and also accounted for almost two-thirds of the Bureau's reserve base for zinc in MEC's (259 Mmt). Total recoverable (contained metal, milled, smelted, and refined) MEC lead resources from evaluated mines and deposits were 48 Mmt; 27% was from primary lead mines and deposits, and the remaining 73% from primary zinc mines and deposits. Of the primary lead mines, the United States had the lowest estimated weighted-average total cost for producers at $0.25/lb recoverable lead at 0% discounted cash flow rate of return (DCFROR). Total recoverable MEC zinc resources evaluated were 131 Mmt, 98% of which was from primary zinc mines and deposits. The remainder was from primary lead mines and deposits. The estimated weighted average total cost of production for producing mines in the United States amounted to $0.49/lb zinc in January 1990 dollars at a 0% DCFROR.

IC 9370. **Geological Features That Contribute to Ground Control Problems in Underground Coal Mines**, by Shea-Albin, Valois R. 1993. 38 pp. 14 illus. Ground control problems are an important factor affecting safety, production, and efficiency in underground coal mines. A major portion of ground control problems encountered in underground coal mines can be attributed to geologic features in the strata surrounding the extracted coal seam. The U.S. Bureau of Mines has complied information from numerous sources on the geological features that contribute to ground control problems in underground coal mines. The compliation includes (1) sedimentary features such as paleochannels, crevasse splays, clastic dikes, mold-and-cast structures, concretions, and lithologic factors, and (2) structural features such as folds, fractures, joints, cleat, and faults. The compiled information will aid in identifying the features, predicting their occurrence in advance of mining, and controlling or minimizing roof failure when these features are encountered in an underground coal mine.

IC 9372. **Ground Control Safety Analysis of Extended Cut Mining**, by Bauer, Eric R.; Pappas, Deno M.; Listak, Jeffrey M. 1993. 24 pp. 9 illus. The ground control aspects of extended depth-of-cut mining are presented in this U.S. Bureau of Mines report. A trend analysis of extended cut approvals was performed. A comparative review of roof fall fatalities for extended and nonextended cut mining is included. Current ground control guidelines for extended cut approval are summarized. The problems and concerns of this extraction system are addressed, and typical extended cutting face operations are described.

MINERAL COMMODITY SUMMARIES

This annual is the earliest Government publication to furnish estimates of the previous year's nonfuel mineral industry data. Most of the estimates are based on 9 months' data. The publication includes information on the domestic industry structure, Government programs, tariffs, and 5-year salient statistics for a number of minerals and metals. Contact GPO for copies, or read them in USBM libraries.

1992

MCS 92. **Mineral Commodity Summaries 1992**, by Staff, U.S. Bureau of Mines. 204 pp. This report is the earliest Government publication to furnish estimates covering the 1991 nonfuel mineral industry data. Most of the estimates are based on 9 months' data. These data sheets contain information on the domestic industry structure, Government programs, tariffs, and 5-year salient statistics for 90 individual minerals and metals. A general review of significant events in 1991 helps interpret the individual commodity data.

MINERAL INDUSTRY SURVEYS

MIS. **Mineral Industry Surveys 1992, contain statistical and economic data on various mineral commodities. These reports are issued at regular intervals (monthly, quarterly, semiannually, annually). Most of the data contained in these reports appear in permanent form in the *Minerals Yearbook*. Single copies of Mineral Industry Surveys can be obtained from Publication Distribution Bureau of Mines, Cochrans Mill Road, P.O. Box 18070, Pittsburgh, PA 15236.**

Mineral Industry Surveys dealing with various mineral commodities will be forwarded regularly if application is made to Mailing Lists, MS 9800, U.S. Bureau of Mines, Washington, DC 20241.

Preliminary annual data are published as soon as possible after the close of each calendar year; these statistics are later printed in permanent form in the Minerals Yearbook. Preliminary annual area reports also contain data on mineral production by State; final State figures are published as Volume II of the Minerals Yearbook.

MINERAL INSTITUTE REPORTS

The Mineral Institutes Program operates under Public Law 98-409. It is designed to improve the quality of mineral engineering research and education through support for research in mining, metallurgical processing, and related mineral sciences. The U.S. Bureau of Mines supports this research through annual allotment grants, matched by non-Federal funds, to mineral institutes at 30 universities throughout the United States and by research grants to these institutions to address specific mining and processing problem areas.

The following reports describe research conducted under research grants. Individual copies may be available from NTIS or the organizations cited. Copies of these reports are NOT available from the U.S. Bureau of Mines.

1992

MIR 01-92. Historical Changes in Shoreline Position Along the Mississippi Sound Barrier Islands, by Mark R. Byrnes, Randolph A. McBride, Shea Penland, Matteson W. Hiland, and Karen A. Westphal. Paper in GCSSEPM Foundation Twelfth Annual Research Conference Program and Abstracts. 1991, pp 43-55. A computer-based shoreline mapping methodology, within the framework of a geographic information system, was used to compile and analyze changes in historical shoreline position and island area between 1847-49 and 1986 for the Mississippi Sound barrier island system. The data base consisted of three to four cartographic shorelines and one to two air-photo-interpreted shorelines. The dominant direction of movement for Dauphin, Petit Bois, Horn, and Ship Islands is to the west, whereas cross-shore change in shoreline position is the primary mechanism by which the beaches on Cat Island respond to incident processes. Average shoreline change for the study area was about −1.7 m/yr; however, Horn Island Illustrated no net shoreline change for the period of record, and the western halves of Petit Bois and Ship islands were net progradational. Although spatial variability in shoreline movement was common, associated land loss was relatively consistent, ranging from −1.6 to −2.5 ha/yr. The magnitude of lateral island migration is generally an order of magnitude greater than cross-shore movements. East of Dog Keys Pass, the islands are moving to the west by updrift erosion and downdrift accretion at rates exceeding 30 m/yr. The eastern end of Petit Bois Island illustrates the greatest lateral movement, averaging 89.9 m/yr between 1848 and 1986. Long-term changes recorded for the ends of Ship Island are significantly smaller, mainly due to dredging at the Biloxi navigation channel and distance from sand source, limiting the quantity of sand available for natural bypassing to the west. Short-term lateral migration trends illustrate a similar response at Horn Island Pass. Research was done under Grant G1195128-2201.

MIR 02-92. Prediction of Precious Metal Heap Leach Behavior by Use of Unsteady State Models, by D.G. Dixon, J.L. Hendrix, and J.H. Nelson. Paper in World Gold '91. SME and Australian Inst. Min. and Metall., 1991, pp 201-212. A model based on non-steady state has been developed for dissolution and diffusion in porous ore particles. Results from the particular model have been incorporated, as a rate term, into a global, heap-scale model based on a plug flow reactor at unsteady state. The global model can be used to consider leaching by aqueous-phase reagents in equilibrium with a gas-phase component, such as oxygen gas, as well as strictly aqueous-phase reagents, such as cyanide. The flexibility of the model even allows prediction of the outcomes of using reagent sideflow injection in large heaps. Data from column leaching tests are compared to the model, and their relationship is discussed. Research was done at the Mackay School of Mines, University of Nevada, under Grant G1175132.

MIR 03-92. AI Techniques for Adapting to the Dynamic Mining Environment, by P.J.A. Lever, A. Gordon, and R.H. King. Paper in Computer Applications in the Mineral Industry: Proceedings of the Second Canadian Conference, ed. by R. Poulin, R.C.T. Pakalnis, and A.L. Mular. CIM, v. 1, 1991, pp 230-242. The mine environment constantly changes. New equipment, different equipment operators, modified layouts, and variable geological conditions make monitoring and control systems difficult to apply without continual software maintenance. This paper reports on algorithms that were developed, encoded with Knowledge Craft Tools, and tested on underground coal mine machine data to adapt to the dynamic environment. The system receives data from sensors in near real time. The data are reduced and patterns in the data are recognized. Then the data are automatically checked to determine the present operating mode

by comparing a set of mode features. If the operating mode has changes from the previous shifts, the system automatically learns the new mode characteristics and uses that mode context for further data analysis. The AI based system can produce reports that are tailored to a manager's interest. It uses a difference-detection module to locate interesting differences from previous data and a diagnosis module that determines the reason for the difference. The concepts presented in this paper are applicable to a wide variety of mining scenarios, not just to underground coal mining. Research was done at the Colorado School of Mines under Grant G1175151.

MIR 04-92. Geomorphic History, Geologic Framework, and Hard Mineral Resources of the Petit Bois Pass Area, Mississippi-Alabama, by Randolph A. McBride, Mark R. Byrnes, Shea Penland, David L. Pope, and Jack L. Kindinger. GCSSEPM Foundation Twelfth Annual Research Conference Program and Abstracts. 1991, pp 116-126. Approximately 200 line-km of high-resolution seismic reflection data, 24 vibracores, historical maps, and aerial photography were used to delineate the geomorphic history, geologic framework, and potential hard mineral resources of the Petit Bois Pass area. Petit Bois Pass is a natural tidal inlet system located between Petit Bois and Dauphin Islands at the Mississippi-Alabama state line. Since its opening, the inlet has migrated to the west at rates exceeding 50 m/yr. However, the main channel of Petit Bois Pass has remained relatively stable since 1917, occupying an antecedent topographic depression cut into underlying pre-Holocene deposits. Pre-Holocene deposits form the eastern core of Dauphin Island, where they are subaerially exposed. The pre-Holocene surface dips to the west, providing a platform for the narrow, elongated Holocene spit of Dauphin Island. The pre-Holocene surface crops out on the shoreface at the western end of Dauphin Island 8 to 9 m below mean low water (MLW). Farther to the west, vibracores from the main inlet channel of eastern Petit Bois Pass contain only Holocene sediment, suggesting that the pre-Holocene surface is >11 m below MLW. West of the main tidal channel, the undulating pre-Holocene surface shallows in the central portion of the pass before dipping down to >11 m under Petit Bois Island. It appears that tidal channels associated with Petit Bois Pass occupy pre-Holocene fluvial channels cut by either the Pascagoula, Escatawpa, or Fowl Rivers during periods of lower sea level. In the study area, the primary hard mineral resource targets include Holocene tidal inlet channels, ebb-tidal deltas, and shoreface sand ridges, while abandoned pre-Holocene fluvial channels are considered secondary. Research was done under Grant G1115128-2201.

MIR 05-92. Origin, Evolution, and Distribution of Shoreface Sand Ridges, Atlantic Inner Shelf, U.S.A., by Randolph A. McBride and Thomas F. Moslow. Marine Geol., v. 97, 1991, pp 57-85. A computer mapping system was employed to document the location of 259 shoreface-attached and detached sand ridges in water <20 m deep and the temporal and spatial distribution of 309 historical and active tidal inlets along the U.S. Atlantic coast (Montauk Point, NY, to Miami Beach, FL). This database was compiled through the analysis of over 600 historical maps, 50 bathymetric charts, and other published data. A genetic relationship between the location of certain historical and active tidal inlets and shoreface-attached sand ridges is documented. It is inferred that ebb-tidal deltas provided the initial sand source for the development of many shoreface-attached sand ridges. Although shoreface-attached sand ridges appear to have several different modes of formation, a two-step process for the development of most shoreface-attached and detached sand ridges along U.S. Atlantic barrier island and cape coastlines is proposed: (1) sand is deposited as ebb-tidal deltas or river deltas along the lower shoreface and/or inner continental shelf prior to or during transgression, followed by (2) further transgression, which reworks the deltaic sand bodies into linear sand ridges at the base of the shoreface by shelf processes. The best-developed shoreface sand ridge fields along the U.S. Atlantic shelf lie adjacent to shorelines characterized by all of the following: (1) transgression, (2) mixed energy, wave-dominated barrier islands, and (3) laterally migrating tidal inlet systems. Tidal inlet systems are natural sediment sinks that capture sand carried by longshore sediment transport. Ebb-tidal delta deposits associated with these migrating tidal inlets provide the initial sand body for the development of shoreface-attached sand ridges. The oblique orientation and linear form of shoreface-attached sand ridges appear to be a function of shoreline transgression, lateral inlet migration, and wave reworking of ebb-tidal delta deposits concentrated along an ebb-tidal delta retreat path. Shelf processes act as modifying agents in the evolution of sand ridges during and after ebb-tidal delta deposition. In general, shoreface-attached sand ridges are poorly developed or absent along eroding headlands, spits, and barrier island shorelines characterized by naturally stabilized tidal inlets. These latter inlets and shoreline types are dominated or influenced by one or all of the following: (1) antecedent topography, (2) higher tidal ranges, (3) larger tidal prisms, (4) lower wave energies, or (5) finer grain sizes. The coupling of shoreline and shallow marine sedimentary processes during a transgression is critical to the origin, evolution, and distribution of shoreface sand ridges in the study area. Modern shoreface-attached sand ridges are also known to occur in different coastal and shelf settings where large amounts of sediment were supplied to the shoreface and inner shelf during, or immediately before, transgression. Commonly observed vertical and lateral interrelationships of Holocene shoreface-attached sand ridges and tidal inlets or distributary channels have important ramifications for the development of shelf sandstone facies models. In addition, the geometric relationship documented in this study provides predictive petroleum and hard mineral exploration models of the spatial and temporal distribution of shoreface and shelf sand ridges. Research was done under Grant G1195128-2201.

MIR 06-92. Intelligent Decision-Support System for Mine Managers, by D.R. Schricker, P.J.A. Lever, R.H. King, and R.E. Cameron. Min. Eng., Sept. 1990, pp 1096-1098. Mine managers rely on their experience, section foremen's daily reports, and occasional time studies to make important production, maintenance, and forecasting decisions. This information is often subjective and imprecise, consumes expensive engineers' time, is often biased, and is restricted to short time periods. Managers need better information. Furthermore, if a recently purchased machine is being evaluated, a large increase (>10 pct) in productivity may be obvious, but small increases are usually masked by other variables. In today's highly competitive markets, cumulative small changes are important, especially since managers have already exhausted most available, obvious avenues of improvement. A technique to separate these charges from effects of other variables and to quantify the target effect is necessary. Colorado School of Mines researchers are addressing this need by developing an intelligent decision support system.

It provides key production and maintenance information to support management decisions by recognizing patterns in mining machine sensor data and representing knowledge about mine management, operations, layout, and equipment. Research was done at the Colorado School of Mines under Grant G1125151.

MIR 07-92. Equivalent Elastic Moduli of Cable Bolted Finite Elements, by F. Duan and W.G. Pariseau. Paper in Computer Methods and Advances in Geomechanics, ed. by G. Beer, J.R. Booker, and J.P. Carter. Balkema, 1991, pp 1135-1140. This paper presents a new computational procedure for approximating the equivalent elastic moduli of cable-bolted finite elements. The new approach replaces a heterogeneous borehole assemblage of reinforcing steel cable, cement annulus, adjacent rock, and the steel-cement and cement-rock interfaces contained within a finite element by a homogeneous, anisotropic material that is equivalent, on average, to the original assemblage. The new procedure readily incorporates cable bolt reinforcement effects in three-dimensional finite element models of excavations in rock. An important practical advantage is that changes in the pattern of reinforcement can be made without the need to rebuild the mesh, an otherwise costly procedure in the engineering design of cable bolt support systems in rock. The stiffening effects of cable bolt reinforcement are small at practical bolt spacings. Research was done at the University of Utah under Grant G1175151.

MIR 08-92. Fluid Inclusion Constraints on the Uplift History of the Metamorphosed Massive Sulphide Deposits at Ducktown, Tennessee, by D.L. Hall, R.J. Bodnar, and J.R. Craig. J. Metamorphic Geol., v. 9, 1991, pp 551-565. Standard petrographic, microthermometric, and Raman spectroscopic analyses of fluid inclusions from the metamorphosed massive sulphide deposits at Ducktown, TN, indicate that fluids with a wide range of compositions in the C-O-H-N-S-salt system were involved in the syn- to post-metamorphic history of these deposits. Primary fluid inclusions from peak metamorphic clinopyroxene contain low-salinity, H_2O-CH_4 fluids and calcite, quartz, and pyrrhotite daughter crystals. Many of these inclusions exhibit morphologies resembling those produced in laboratory experiments in which confining pressures significantly exceed the internal pressures of the inclusions. Secondary inclusions in metamorphic quartz from veins, pods, and host matrix record a complex uplift history involving a variety of fluids in the C-O-H-N-salt system. Early fluids were generated by local devolatilization reactions, while later fluids were derived externally. Isochores calculated for secondary inclusions in addition to the chronology of trapping and morphological features of primary and secondary fluid inclusions suggest an uplift path that was concave toward the temperature axis over the pressure-temperature range of 6 to 3 kbar and 550 to 225 ° C. Immiscible H_2O-CH_4-N_2-NaCl fluids were trapped under lithostatic to hydrostatic pressure conditions at 3 to 0.5 kbar and 215-20° C. Entrapment occurred during Alleghanian thrusting, and the fluids may have been derived by tectonically driven expulsion of pore fluids and thermal maturation of organic material in lower-plate sedimentary rocks which are thought to underlie the deposits. Episodic fracturing and concomitant pressure decreases in upper-plate rocks, which host the ore bodies, would have allowed these fluids to move upward and become immiscible. Post-Alleghanian uplift appears to have been temperature-convex. Uplift rates of 0.10 to 0.05 mm year^{-1} from middle Ordovician to middle Silurian-late Devonian, and 0.07 to 0.12 mm year^{-1} from middle Silurian-late Devonian to late Permian, are suggested by our uplift path and available geochronological data. Research was done at Virginia Polytechnic Institute and State University under Grant G1164151.

MIR 09-92. Three-Dimensional Finite Element Modeling of a Cable-Bolted Cut and Fill Stope, by W.G. Pariseau and F. Duan. Paper in Proceedings of the Second Canadian Conference on Computer Applications in the Mineral Industry, ed. by R. Poulin, R.C.T. Pakalnis, and A.L. Mular. CIM, v. 2, 1991, pp 655-667. A mechanized cut-and-fill stope at the Homestake Mine in Lead, SD, was instrumented, modeled, and monitored over a 3-year period. Conventional and bird-cage cable bolts were installed in regularly spaced fans of seven to nine holes over two sections of the stope prior to mining. Visual observations suggested that the birdcage cable bolts provided more support than conventional bolts. Calibration of a finite element model with respect to rock mass elastic and strength properties required extensive computations. Implementation of a rational cable bolt model showed little difference in rock mass motion with cable bolt supports. Research was done at the University of Utah under Grant G1125151.

MIR 10-92. The Flash Reduction of Electric Arc Furnace Dusts, by Li Wu and Nickolas J. Themelis. JOM, Jan. 1992, pp. 35-39. The flash processing of electric arc furnace (EAF) dusts is a promising method for recovering zinc and producing nontoxic slags for direct disposal. To reduce the zinc content of the dust particles and maintain the iron content in oxide form, a certain range of temperature and oxygen potential must be provided, as dictated by thermodynamic requirements. Experiments were conducted with EAF dusts at three levels of zinc concentration in an electrically heated flash reactor. The results showed that the CO:CO_2 ratio in the process gas was the most important parameter. The effects of zinc content in dust and O_2 in inlet gas on zinc recovery were secondary. Toxicity leach tests showed that the resulting slag, even at low zinc recovery, can be disposed safely as landfill. Research was done at Columbia University under Grant G1175129-3621.

MIR 11-92. Photocatalytic Oxidation of Cyanide, by Jinrong Zhang, James L. Hendrix, and Milton E. Wadsworth. Paper in EPD Congress '91, ed. by D.R. Gaskell. TMS, 1991, pp. 665-675. Fresh cyanide solution was treated by near-UV light with the assistance of photocatalysts. Cyanide was oxidized mainly to cyanate. Photochemical behavior of the anatase and rutile forms of TiO_2 was compared. It is found that anatase has a much higher activity than that of rutile. Bubbling of oxygen in the reactor showed no appreciable increase in cyanide oxidation, implying that the reaction is surface controlling. A very interesting finding in this study is that a natural mineral, ilmenite, can replace chemical titanium dioxide as the photocatalyst. Ilmenite without any treatment did not catalyze the oxidation of cyanide. But, after being roasted at high temperature with oxygen, the oxidation was enhanced dramatically. The mechanisms of photooxidation of cyanide and the roasting of ilmenite are proposed. Research was done at the University of Nevada under Grant G1175132-3223.

MIR 12-92. A Statistical Model for Assessing the Risk of Subsidence Above Abandoned Mines, by J.A.

Cervantes and Y.C. Kim. Ch. 39 in 23rd Application of Computers and Operations Research in the Mineral Industry, ed. by Y.C. Kim. SME, 1992, pp. 376-387. A statistical model for assessing the risk of ground subsidence in abandoned mine areas is presented. The model is based on the relationship that exists between the frequency and the location of subsidence events in a given area and the physical conditions of the ground. These conditions can be described by a series of geological, mining, and physical variables. The model suggests the existence of regions in the multidimensional space of variables that are associated with increases or decreases in the frequency of subsidence events. Regions associated with an increase in the frequency of subsidence events correspond to regions of higher risks, and vice versa. Risk assessment is based on the ability to express the limits of these high-and low-risk regions in the space of variables, and on the ability to express the degree of membership of blocks of land within any of these regions. The theoretical framework for the model is extracted from discriminant analysis. Risk is quantified by the probabilities of membership of blocks of land into any of these regions. Risk maps are produced by displaying membership probabilities in appropriate contouring levels. The model has been applied in two urban areas where subsidence of the ground has been active in the past. The two areas are Penn Hills, near Pittsburgh, and Scranton/Wilkes-Barre in northeastern Pennsylvania. In this paper, only the results for the Scranton/ Wilkes-Barre area are presented. In the Scranton/Wilkes-Barre area, geostatistical estimates of variables likely to affect the stability of the ground were made using samples from 53 drillholes. The estimates were made for 2,000- by 2,000-ft squared blocks of land covering the study area. Discriminate functions were computed from the estimated variables and used to establish regions for classifying blocks of land into one of these two populations: (1) blocks not likely to have a subsidence event, and (2) blocks likely to have one or more subsidence events. The same discriminate functions were used to compute membership probabilities for blocks of land to fall within any of these two populations. These probabilities were contoured to produce a risk map. The risk map produced compares well with the location of the subsidence events that have occurred to date in the area. Research was done at the University of Arizona under Grant G1125151.

MIR 13-92. Roof Support Selection Using Computer Simulation, by R. Fraher and C. Haycocks. Ch. 34 in 23rd Application of Computers and Operations Research in the Mineral Industry, ed, by Y.C. Kim, SME, 1992, pp. 338-342. The control of mine roof is of vital interest in underground coal mining, not only for reasons of safety, but also to avoid the high costs of cleanup, resupport, and production losses that can result from roof falls. The difficulty in determining roof stability minewide is due in large part to the broad variation of geologic and structural conditions that typically exist throughout a mining area. To ensure a stable roof over the entire mine, support systems must be selected to minimize the possibility of failure. The magnitude and cost of the support selected is a tradeoff against the cost of the number of falls that can still occur after it is installed. Because of the large number of variables involved in analyzing and optimizing roof stability versus support, a digital computer simulation was selected to find a cost-effective solution to roof support design. A total cost approach is used that includes the actual cost of the roof support as well as the cost of the roof fall in terms of resupport and loss of production. A Monte Carlo simulation program called ROCSIM (Roof Control Optimization Cost SIMulation) has been developed for determining the optimum roof control system and design layout for underground room-and-pillar mining. Research was done at the University of Arizona under Grant G1175151-5123.

MIR 14-92. Cost-Based Optimization for Roof Control, by Richard Fraher, Yingxin Zhou, and Chris Haycocks. Ch. in Use of Computers in the Coal Industry. Balkema, 1990, pp. 177-183. A Monte Carlo simulation model is presented for determining the optimum roof control system and design layout for underground room-and-pillar coal mines. Based on a database of roof falls, the program probabilistically simulates roof fall geometries and fall locations and determines the ultimate cost effectiveness of a support system. Lost production and subsequent cleanup Costs due to roof falls resulting from inadequate support are weighed against costs associated with increased support to determine an optimum balance. Details of the simulation process are also discussed. Research was done at Virginia Polytechnic Institute & State University under Grant G1175151-5123.

MIR 15-92. Probabilistic Techniques in Roof Failure Prediction, by R. Fraher, Y. Zhou, and C. Haycocks. Paper in Rock Mechanics Contributions and Challenges. Balkema, 1990, pp. 195-202. Based on this research the following conclusions can be made: (1) Roof rating systems offer realistic and readily usable techniques for ground failure prediction and evaluation, (2) probabilistic simulation methods are most suitable for roof control situations with a high degree of uncertainty and complex interactions, and (3) using the simulator program ROCSIM as a predictive tool enables the mine designer to optimize the choice of a ground control plan by allowing the advantages of a given plan to be seen in relationship to its true cost. Research was done at Virginia Polytechnic Institute & State University under Grant G1175151-5123.

MIR 16-92. Recent Developments in Reconnaissance Sampling Systems for Nearshore Applications, by Walter L. O'Niell and J. Robert Woolsey. Marine Min., v. 10, 1991, pp. 155-169. The Continental Shelf Division of the Marine Minerals Technology Center is proceeding with its drill systems technology program for the development of new sampling systems and the modification of existing sampling tools to meet the growing demand for more effective methods of reconnaissance exploration. Two existing drill systems, the remote placer drill and the percussion waterlift drill, have recently been modified to increase their effectiveness and versatility. The convertible drill system, a modified version of the remote placer drill, is operable in three different modes that will permit rapid reconnaissance sampling over a variety of sediment types: as a vibracore drill, as a vibralift drill, and as a remote placer drill. The percussion waterlife drill was originally used for land-based drilling operations for sampling placer mineral deposits and has been adapted for use in protected shallow-water environments. Both of these modified drill systems have been field tested, with additional modifications and testing scheduled for the near future. Research was done at the University of Mississippi under Grant G1195128.

MIR 17-92. Overview of Nuclear Techniques for Marine Mineral Survey and Environmental Assess-

ment, by Noakes, John E.; Harding, James L. Ch. 12 in CRC Handbook of Geophysical Exploration at Sea, 2nd ed., Hard Minerals. ed. by R.A. Geyer. CRC Press, 1992, pp. 311-321. The increase in offshore activities in the fields of survey, such as oceanographic, geological, hydrographic, and environmental, and the continuous rise of operation cost for such activities have resulted in the necessity of developing an array of instruments capable of efficient measurement of multiple parameters with a maximum of accuracy, reliability, and ease of operation. These conditions, combined with the socio-economic and geopolitical stresses associated with the declaration of the Exclusive Economic Zones (EEZ) by most of the maritime nations of the world, have resulted in the marine science community striving to develop survey tools that not only meet the above criteria, but that are also capable of rapid, real-time collection and interpretation of data. Research was done by the University of Mississippi under Grants G1185128, G1195128 and G1105128.

MIR 18-92. Computer Software for the Analysis of Sediment Geochemical Data in Marine Minerals Exploration, by Knoop, Peter A.; Owen, Robert. Marine Mining, v. 10, 1991, pp. 353-368. Recent advances in coring technology and in situ analytical instrumentation have made it possible to assemble large quantities of sediment geochemical data during scientific and mineral exploration cruises. The potential benefit of these improvements cannot be fully realized, however, unless the raw geochemical data can also be reduced and interpreted while the vessel is still at sea. This study involved the development and evaluation of personal computer software designed to meet this need. The software package Q_LM includes a modified Q-mode factor analysis program for use in isolating and quantifying significant geochemical end members that are present in a sedimentary mixture. The Q_LM package also includes a program for determining the relative amounts of any compositional end member present in the mixture; this program is designed to calculate solutions to overdetermined systems of inexact, linear equations using least-squares, linear programming, or Chebyshev (equal residuals) solution criteria. The Q_LM package was successfully tested by evaluating the performance of individual programs versus that of analogous programs run on a mainframe computer. The data sets used in the evaluation included sediment geochemical data from a placer exploration survey at Chagvan Bay, Alaska, and from ferromanganese nodules in the southeast Pacific Ocean. Research was done by the University of Michigan under Grant G1195128-2601.

1993

MIR 01-93. Evaluation and Application of a Portable Tailpipe Emissions Measurement Apparatus for Field Use, by Chan, L.M.; Carlson, D.H.; Johnson, J.H. Michigan Technological Univ. SAE International, v. SP-931, No. 921647, 1992, pp. 127-144.

MIR 02-93. Purification and Characterization of Monkey (Macacanemestrina) Tracheobronchial Mucin, by Devaraj, H.; et al. Pennsylvania State Univ. Archives of Biochemistry and Biophysics, v. 302, No. 11993, pp. 285-293.

MIR 03-93. Preliminary Analysis of Exploration Data from Pacific Deposits of Manganese Nodules, by Morgan, C.L.; et al. University of Hawaii. Marine Georesources and Geotechnology, v. 11, 1992, pp. 1-25.

MIR 04-93. New Perspectives on the Indeterminacy of Coalbed Methane Ownership, by Lewin, J.L.; Siriwardane, H.J.; Ameri, S. West Virginia Univ. 1993 International Coalbed Methane Symposium, 1993, pp. 205-215.

MIR 05-93. Experimental Setup for a Multiple-Fan Ventilation System, by Reddy, N.P.; Wang, Y.J. Transactions, J., SME, v. 292, 1992, pp. 1900-1904.

MIR 06-93. Characteristic Curves for Multiple-Fan Ventilation Systems, by Wang, Y.J.; Transactions, J., SME, v. 292, 1992, pp. 1829-1836.

MIR 07-93. Understanding Subsystem Characteristic Curves and Operating Points of Multiple-Fan Ventilation Systems, by Lin, S.; Wang, Y.J. Proceedings of the 6th U.S. Mine Ventilation Symposium (Littleton, CO). SME, 1993, pp. 232-236.

MIR 08-93. Fan Stall and Multiple Operating Points in Multiple-Fan Ventilation Systems, by Wang, Y.J.; Reddy, N.P. Mining Engineering, v. 44, No. 2, Feb. 1992, pp. 167-172.

MIR 09-93. Neural Networks for Processing Data from Multiple Redundant Sensors for Mine Systems Managment, Operation, Maintenance and Control, Sensor Fusion VI, by Gordon, A.; Chang, H.; King, R. The International Soc. for Optical Eng., SPIE, J., v. 2059, Sept. 1993, pp. 512-521.

MIR 10-93. Effects of Total Water Content on Dynamic Properties of Frozen Soils, by Fukunda, M.; Huang, S.L.; Soc. of Petroleum Eng, Inc., v. 22140, May 1991, pp. 621-629.

MIR 11-93. Evaluation of Coal Mine Spoil Pile Instability in the Interior Alaska, by Huang, S.L.; Speck, R.C.; Xu, M. Bull. of the Association of Engineering Geologists, v. XXIX, No. 1, 1992, pp. 1-9.

MIR 12-93. Characterization of Particle Shape, by Dumm, T.F.; Hogg, R.; Archives of Biochemistry and Biophysics, pp. 1-7.

MIR 13-93. Implementation of KBS for Mine Ventilation Planning and Design, by Ramani, R.V.; Prasad, K.V.K.; Ramani, R.V. Proceedings of 22nd International APCOM Symposium, v. 2, 1991, pp. 339-352.

MIR 14-93. The Kinetics and Shape Factors of Ultrafine Dry Grinding in a Laboratory Tumble Ball

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Mill, by Austin, L.G.; Yekeler, M.; Dumm, T.F. Part. Part. Syst. Charact., v. 7, 1990, pp. 242-247.

MIR 15-93. Characteristics of Dust Clouds at Longwall Faces, by Ramani, R.V.; Qin, J.; Jankowski, R.A. Mine Ventilation Society of South Africa, J., May 1991, pp. 69-79.

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MIR 19-93. Pollutant Levels in Underground Coal Mines Using Diesel Equipment, by Cantrell, B.K.; Rubow, K.L.; Watts, Jr., W.P. Preprint 91-35. SME, 1991, pp. 23-31.

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MIR 22-93. Development of a Bioassay for Pulmonary Cell Production of Fibrogenic Factors, by Reist, R.; et al.; Toxicology Methods, Raven Press, Ltd., v. I, No. 1, 1991, pp. 53-65.

MIR 23-93. One-Electron Reduction of Vanadium (V) by Flavoenzymes/NADPH, by Shi, X.; Dalal, N.S.; Archives of Biochemistry and Biophysics, v. 302, No. 1, 1993, pp. 300-303.

MIR 25-93. Generation of Free Radicals in Reactions of Ni (II)-Thiol Complexes with Molecular Oxygen and Model Lipid Hydroperoxides, by Shi, X.; Dalal, N.S.; Kasprzak, K.S. Inorganic Biochemistry, J., Elsevier Science Publishing Co., Inc., v. 15, 1993, pp. 211-225.

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MIR 27-93. Superoxide-Independent Reduction of Vanadate by Rat Liver Microsomes/NAD(P)H: Vanadate Reductase Activity, by Shi, X.; Dalal, N.S.; Archives of Biochemistry and Biophysics, v. 295, No. 1, 1992, pp. 70-75.

MIR 28-93. Deferoxamine Inhibition of Cr(V)-Mediated Radical Generation and Deoxyguanine Hydroxylation: ESR and HPLC Evidence, by Shi, X.; Sun, X.; Gannett, P.M. Archives of Biochemistry and Biophysics, v. 293, No. 2, 1992, pp. 281-286.

MIR 29-93. Inhibition of Proliferative Activity of Pulmonary Fibroblasts by Tetrandrine, by Reist, R.; Dey, R.; Durham, J.P. Toxicology and Applied Pharmacology, v. 122, 1993, pp. 70-76.

MIR 30-93. Development of a Bioassay for Pulmonary Cell Production of Fibrogenic Factors, by Reist, R.; et al., ; Toxicology Methods, v. 1, No. 1, 1991, pp. 53-65.

MIR 33-93. Computer Software for the Analysis of Sediment Geochemical Data in Marine Minerals Exploration, by Knoop, P.A.; Owens, R.M.; Marine Mining, v. 10, 1991, pp. 353-368.

MIR 34-93. The Use of Ion Flotation for Removing Trace Metals from Waste Water, by Doyle, F.M.; Fuerstenau, D.W.; Duyvesteyn, S. Proccedings, PMP '93, 1st Internat'l Conference on Processing Materials for Properties, 1993, pp. 1-4.

MINERAL ISSUES

This occasional publication is available from NTIS and at some libraries.

1992

MI. Toward a New Materials Paradigm, by Louis J. Sousa. 1992. 21 pp. 7 figs. During the last two decades, a number of major trends have converged on the materials sector of the economy to significantly and irreversibly alter its traditional structure and character. However, no alternative conceptual paradigm has yet been commonly accepted as a vehicle for coherently and adequately explaining the newly emerging materials economy. A new paradigm is needed to provide a more useful and appropriate framework for measuring the evolving materials economy and evaluating increasingly complex materials issues.

MINERAL LAND ASSESSMENT REPORTS

The following reports, part of a continuing series, are available for consultation from the U.S. Bureau of Mines, MLA Staff, Washington, DC, from Bureau libraries, and from the Natural Resources Library, U.S. Department of Interior, Washington, DC. Specific reports are also available at the field office indicated.

1992

MLA 03-92. Mineral Resource Investigation of the Black Warrior Study Area Adjacent to the Sawtooth Wilderness, Elmore County, Idaho, by Peter N. Gabby. 1992. 53 pp., 18 figs. Western Field Operations Center, Spokane, WA. In 1990, the U.S. Bureau of Mines conducted a mineral resource investigation of the 12,320-acre Black Warrior study area, one of several proposed additions to the Sawtooth Wilderness. No identified mineral resources were delineated. There were 123 lode and placer claims in or adjacent to the study area. There is a known hot spring adjacent to the study area, but presently no geothermal leases are pending. Lode mines in or adjacent to the Black Warrior study area have produced 4,022 tons of ore, from which 1,981 oz of gold and 811 oz of silver were recovered. None of the mines are currently active. During the field study 125 rock samples were taken. Significant gold assays and favorable geologic characteristics at seven properties indicate that gold occurrences and resources with byproduct metals may exist in the study area. Two other sites yielded anomalous gold assays; however, some favorable geologic characteristics are lacking. Presently, identified gold resources are being delineated by drilling programs in the nearby Atlanta and Rocky Bar mining districts. These districts have geologic characteristics similar to those of the Black Warrior area. During the field study 22 placer samples were taken. In most places where an anomalous concentration of gold was found, the stream channels are too narrow for operations other than recreational suction dredges. However, one area is estimated to contain over 2 million yd^3 of gold-bearing gravels.

MLA 04-92. Mineral Resource Investigation of the Smokies Study Area, Blaine, Camas, and Elmore Counties, Idaho, by Frank E. Federspiel, Michael C. Horn, H. Woody Campbell, and Thomas J. Peters. 1992. 244 pp., 10 figs. Western Field Operations Center, Spokane, WA. In 1989 and 1990, the U.S. Bureau of Mines conducted a mineral resource investigation of the 162,300-acre Smokies study area in south-central Idaho. The study area is underlain by granitic rocks of the Idaho batholith, a Tertiary-age granitic rock complex, Paleozoic-age sedimentary rocks, and Challis volcanics; gold-bearing alluvial deposits occur in the area. Mineralized structures are mainly gold- and silver-bearing quartz veins and shear zones cutting Idaho batholith granitic rocks; fissure fillings and replacement structures in Paleozoic sedimentary rocks contain silver and base metals. Total production from study area mines is approximately $3.5 million (historic value); most production was from the Sawtooth, Vienna, Little Smoky, and Skeleton Creek mining districts. Nine lode properties contain an estimated total of 375,000 tons of identified gold-silver resources averaging between 0.03 and 0.308 oz/ton gold, and from 0.3 to 20 oz/ton silver. Three placer properties have more than 8.1 million yd^3 of gravel with a maximum average of $1.00/yd at a gold price of $400/oz. Forty-eight other properties have a likelihood for resources. Approximately 1,500 lode and 100 placer claims have been located or relocated in the study area since 1872; 1,050 lode and 21 placer claims were current in February 1990. There are 69 patented lode and 8 patented placer claims in the area. Approximately 360 workings grouped into 62 properties were examined during the fieldwork for this study.

MLA 07-92. Mineral Resources of the Winegar Hole Study Area, Fremont County, Idaho, by Thomas J. Peters. 1992. 11 pp. 3 figs. Western Field Operations Center, Spokane, WA. The U.S. Bureau of Mines studied the 3,500-acre Winegar Hole study area, Idaho, a legislatively proposed (101st U.S. Congress) addition to the Winegar Hole Wilderness, WY; it adjoins the western boundary of the Wilderness at the Idaho-Wyoming border, about 15 miles east of Ashton, ID. The study was part of an Idaho Land Assessment Program to provide minerals information for land-use decisions and ensure domestic mineral supplies. The study area is an east-west elongated, wooded plateau south of Falls River. Although the area is covered with surficial glacial deposits, it is probably underlain by volcanic flows; light-colored and mafic flow rock were noted in sparse outcrops. No mines, prospects, mineralized areas, or mineral resources were found in the study area during a literature and field search. The only nearby prospects include geothermal and rock aggregate (volcanic cinder) sites and several placer claims. Although the Winegar Hole study area lies within a region of potential geothermal resources, no evidence of geothermal activity was observed. Rock in the area does not split into flat slabs that could be useful as dimension stone, and would require crushing to be used as aggregate. Alluvium (placer) samples contain less than $0.01 per cubic yard gold (at a $350 per oz price); alluvial deposits are too small to contain gold resources.

MLA 08-92. Mineral Resource Investigation of the Bear Creek-Poker Peak Study Area, Bonneville County, Idaho, by Richard L. Rains. 1992. 30 pp. 5 figs. Western Field Operations Center, Spokane, WA. The U.S. Bureau of Mines conducted a mineral investigation of the 95,850-acre Bear Creek and 18,600-acre Poker Peak roadless areas in the Caribou National Forest during 1991. Lying within the Western Overthrust Belt, the area is underlain by Paleozoic to Cenozoic sedimentary rocks, which have been complexly folded and thrust-faulted. Phosphate resources of at least 41 million tons have been delineated in the Known Phosphate Leasing Area within the study area. Phosphate leases in the study area are held by Western Cooperative Fertilizers Ltd. Travertine used for dimension stone is being mined from a 150-million-cubic-foot resource adjacent to and extending into the study area. Although two wells have been drilled in the area, all oil and gas leases in the study area expired in 1991. Placer gold has been intermittently mined from McCoy Creek since the 1860's, with 275 troy ounces of gold recovered from 66,000 cubic yards of gravel from within the study area. Placer gold resources examined by the Bureau of Mines averaged $0.33 per cubic yard of gravel at a gold price of $353 per troy ounce. The value is too low for the gold to be economically mined at large scale, but some may be recoverable by recreational-size suction

dredges in sections of McCoy Creek along the southern boundary of the study area. Twelve placer claims blanket the travertine deposit, and 30 placer claims are along McCoy Creek. There are no lode mining claims in the study area.

MLA 09-92. Mineral Resources of the Hanson Lakes Wilderness Study Area, Boise and Custer Counties, Idaho, by Thomas J. Peters and Peter N. Gabby. 1992. 114 pp. 27 figs. The U.S. Bureau of Mines studied the 63,985-acre Hanson Lakes study area, including the Ten-Mile East and part of the Ten-Mile West RARE II areas, plus additional acreage, all proposed at times for Wilderness designation. The study was part of an Idaho Land Assessment Program with the Idaho Geological Survey and the U.S. Geological Survey, to provide minerals information for land-use decisions and ensure domestic mineral supplies. The area is at the north end of the rugged Sawtooth Range and includes parts of the Sawtooth National Recreation Area, which is closed to mineral location. The Copper Mountain, Elk Mountain, and Observation Peak mineralized areas are in the study area, but only Copper Mountain is open to claim location. It is on the trans-Challis fault zone and contains Tertiary granite that is favorable for mineral deposits of gold, beryllium, columbium, REE (rare-earth elements), tin, molybdenum, copper, silver, and lead. Identified resources are 1.9 million tons of flake graphite at Elk Mountain, but much more graphite occurs in the vicinity. REE occurs in 18 black sand placer sites along the lower reaches of study area streams just outside the study area, on the Cape Horn Creek, Marsh Creek, and lower Valley Creek floodplains, and at one hydrothermal site near Observation Peak. Hydrothermal REE is commonly low in byproduct thorium, a radioactive disposal problem. Many advanced REE applications enhance the quality of life, and future uses in superconductivity may reduce energy consumption. Seventeen lode 1 geothermal, and 11 placer prospects were examined. Workings totaled about 20 adits, 1 shaft, several opencuts, and numerous small pits. Approximately 500 mining claims have been located or relocated in the study area, including a 200-claim block for disseminate molybdenum.

MLA 13-92. Mineral Resources of the West-Central Arizona and Southeastern California Detachment Terrane, by Kreidler, Terry J. 1992. 113 pp. 6 figs. In accordance with the Federal Land Policy and Management Act of 1976 (Public Law 94-579), and at the request of the Bureau of Land Management, the U.S. Bureau of Mines conducted mineral surveys, between 1979 and 1989, on 14 wilderness study areas (WSA's) in west-central Arizona and adjacent parts of southeastern California to appraise their mineral resources. Much attention has been focused on this region in recent years due to the discovery of several large-tonnage, low-grade gold deposits related to extensional tectonics (detachment faults). This report combines the Bureau data from the 14 WSA's and adds new data to present a regional study emphasizing the relationship of mineralization to detachment faulting.

MLA 14-92. Mineral Investigation of the Valle Vidal Unit, Carson National Forest, Colfax and Taos Counties New Mexico, by McDonnell, Jr, John R. 96 pp. 12 figs. Intermountain Field Operations Center, Denver, CO. The Valle Vidal Unit comprises 100,000 acres in Taos and Colfax Counties, New Mexico. During 1990-1991, the Bureau of Mines conducted a mineral investigation of the unit as authorized by an interagency Agreement (1987) intended to assist the Forest Service to incorporate mineral resource data in forest plans. The Bureau reviewed literature and records concerning mineral resources and mining activity, and performed a field examination of mines, prospects, and mineral occurrences in and near the Valle Vidal Unit.

MLA 15-92. Mineral Resources of the Kelly-Cayuse Study Area, Shoshone, Clearwater, and Idaho Counties, Idaho, Including Portions of Hoodoo, Moose Mountain, Bighorn-East Weitas, and Weir-Post Office Creek Roadless Areas, by Miller, Michael S. 117 pp. 20 figs. The Bureau of Mines conducted mineral investigations in the 464,000-acre Kelly-Cayuse study area of Idaho during 1990 and 1991. Approximately 1,100 mining claims have been located in or adjacent to the study area; about 460 are current and nine others patented. At least 1,1700 ounces of gold and 290 ounces of silver have been produced from placers in or adjacent to the study area. During the Bureau investigation of specific sites, 504 rock and alluvial samples were collected to delimit mineralization. Subeconomic lode resources of gold exist at the Driessel prospect. A new gold occurrence was found near Shale Mountain, at a mineralized area discovered by the Idaho Geological Survey. Small-scale suction dredging of placer gold is occurring; resources of placer gold that would be marginally economic for large-scale dredge mining occur along Moose Creek and North Fork Clearwater River. Other occurrences of gold, silver, copper, lead, zinc, garnet, titanium, rare-earth elements, silica, stone, limestone, and dolostone are not economic. Sand and gravel will be mined locally for road metal. Hot springs occur in the Weir-Post Office Creek Portion of the study area.

MLA 17-92. Mineral Resources of the Independence Range Special Study Area, Elko County, Nevada, by Schmauch, Steven W.; Gabby, Peter N.; Lipton, David A. 141 pp. 14 figs. Western Field Operations Center The U.S. Bureau of Mines conducted a mineral resource survey of approximately 232,000 acres in part of the Humboldt National Forest, Nevada, during 1989. About 75 pct of the study area was covered with mining claims. About 1,800 samples were collected and analyzed for 16 elements. Geologic structure, including thrust faults, is the most important factor in the localization of mineral deposits in the study area.

MINERAL PERSPECTIVES

This publication reports on the mineral resources, industries, and related infrastructure of foreign sources that are of major importance to our nation's mineral needs. Obtain copies from GPO.

1992

MP 01-92. The Mineral Economy of Mexico, by Martino, Orlando; Machamer, Jerome; Torres, Ivette. 1992. 150 pp. This Bureau of Mines report, a comprehensive view of the nonfuel and fuel mineral industries of Mexico, examines Mexico's significant role as a mineral supplier in the world economy and the vital position of the mineral industry within its domestic economy. Special focus is placed on the economic interdependency between Mexico and the United States with regard to mineral trade and investment. Also emphasized is Mexico's outstanding position in the Latin American region relative to mineral resources, production, and trade. This report describes the government structure, financial systems, mining and investment policies, and economic conditions within which the current mineral industry operates. Also described are Mexico's present mineral industry structure, mineral resource potential, and mineral production and trade over the past 25 years to provide historical perspective. The report concludes by underlining Mexico's large and diversified mineral potential as exploited by a modernized and efficient mineral industry in a developed infrastructure and with a skilled labor force. This assures that Mexico will continue as an important factor in the world mineral demand-supply situation well into the next century. The trilateral negotiations underway among the United States, Mexico, and Canada for the North American free trade agreement will open up new trade and investment opportunities in the mineral sector.

MP 02-92. International Strategic Minerals Inventory Summary Report: A Regional Assessment of Selected Mineral Commodities in Subequatorial Africa, by Coakley, George J.; Crockett, Richard N.; Hammerbeck, E.C.I. 1992. 44 pp. 4 figs. The major mineral resources of 19 countries of central and southern Africa are described in this summary report. A total of 27 categories of individual commodities, or groups of closely related commodities, are analyzed in detail. The size and diversity of the mineral endowment of the region owes much to various major geologic features that are rarely duplicated on a comparable scale elsewhere in the world. A simplified geologic map places these mineral resources within their broad geologic environments. A companion infrastructure map locates mines and deposits and highlights currently existing rail transport and export harbor capacities available to support the regional development of mineral resources. A summary listing of known mining and foreign investment legislation in each country is presented, as is a list of the mineral agencies of each country. The value of crude mineral production in the region is estimated to have been about $27 billion in current dollars in 1989. This represents a substantial proportion of a total gross domestic product (GDP) of about $136 billion. The region is of considerable importance as a substantial or principal supplier of several strategic minerals to the world market. Constraints related to geography, infrastructure, investment laws, lack of geologic and mining data, geopolitics, and labor exist in varying degrees in the 19 nations. These have limited full development of the region's mineral wealth in the past. As these constraints are overcome, the potential for further development of the mineral resources of subequatorial Africa from both known deposits and new discoveries may be considered to be very favorable.

MP 03-92. The Mineral Economy of Guinea, by Morgan, George A. 1992. 24 pp. 9 figs. Guinea's economy is dominated by bauxite, with minor production of diamonds and gold, which together account for about 90 pct of the country's foreign exchange earnings. Large resources of high-grade iron ore also exist, but their development remains uncertain owing to lack of infrastructure, cost, and regional difficulties. A review of mining policy is underway by the Government, which, coupled with a continuation of privatization schemes for Government services, may lead to increased exploration, development, and diversification of the mineral industry.

MINERALS YEARBOOKS

The Minerals Yearbook, published in three volumes, discusses the performance of the worldwide minerals industry and provides background information to help interpret developments during the year being reviewed. The complete volumes (and individual chapters) are sold by the Superintendent of Documents, part of the Government Printing Office (GPO). See order form in this book.

When GPO stocks are exhausted, the volume may be available from the National Technical Information Service, described in the front of this book.

Volume 1 of the Minerals Yearbook contains chapters on virtually all metallic and nonmetallic mineral commodities important to the U.S. economy. In addition, it contains a statistical summary chapter, a chapter on mining and quarrying trends, and a chapter discussing the statistical surveying methods used by the U.S. Bureau of Mines.

Volume II contains chapters on the mineral industry of each of the 50 States, the U.S. island possessions in the Pacific Ocean and the Caribbean Sea, Trust Territory of the Pacific Islands, and the Commonwealth of Puerto Rico. This volume also has a statistical summary.

Volume III contains the latest available mineral data on more than 150 foreign countries and discusses the importance of minerals to the economies of these nations. Beginning with the 1989 edition, Volume III appears in six separate parts: five area reports and one world overview.

1992

Vol III, 1989. **Mineral Industries of Africa**, by Staff, U.S. Bureau of Mines. 1992. 315 pp. GPO Stock No. 024-004-02221-3. $31.

Vol III, 1989. **Mineral Industries of Asia and the Pacific**, by Staff, U.S. Bureau of Mines. 1992. 383 pp. GPO Stock No. 024-004-02224-8. $26.

Vol III, 1989. **Mineral Industries of the Middle East**, by Staff, U.S. Bureau of Mines. 1992. 125 pp. GPO Stock No. 024-004-02223-0. $13.

Vol II, 1990. **Volume II. Area Reports: Domestic**, by Staff, U.S. Bureau of Mines. 1992. 52 ch. 541 pp. GPO Stock No. 024-004-02237-0. $38.

Vol III, 1990. **Mineral Industries of Africa**, by Staff, U.S. Bureau of Mines. 1992. 286 pp. GPO Stock No. 024-004-02234-5. $17.

Vol III, 1990. **Mineral Industries of Asia and the Pacific**, by Staff, U.S. Bureau of Mines. 1992. 365 pp. GPO Stock No. 024-004-02236-1. $21.

Vol III, 1990. **Mineral Industries of Europe and the U.S.S.R.**, by Staff, U.S. Bureau of Mines. 1992. 352 pp. GPO Stock No. 024-004-02233-7. $20.

Vol III, 1990. **Minerals Industries of Latin America**, by Staff, U.S. Bureau of Mines. 1992, 325 pp. GPO Stock No. 024-004-02231-1. $21.

Vol III, 1990. **Mineral Industries of the Middle East**, by Staff, U.S. Bureau of Mines. 1992. 106 pp. GPO Stock No. 0224-004-02235-3. $6.50.

1993

Vol I. 1990. **Volume I. Metals and Materials**, by Staff, Bureau of Mines. 1992, 83 ch. 1285 pp. This volume of the 1990 Minerals Yearbook, covering metals and minerals, contains 80 commodity or commodity group chapters with data on approximately 90 minerals that were obtained as a result of the mineral information gathering activities of the Bureau of Mines. In addition, this volume contains chapters on mining and quarrying trends and on statistical surveying methods used by the Bureau of Mines, plus a statistical summary. GPO Stock No. 024-004-02238-8. $51.

Vol III. 1989. **Minerals in the World Economy, 1989**, by Staff, Bureau of Mines. 1992. 52 pp.

Vol III. 1989. **Mineral Industries of Latin America and Canada, 1989**, by Staff, Bureau of Mines. 1992. 320 pp.

Vol III. 1990. **Mineral Industries of Africa, 1990**, by Staff, Bureau of Mines. 1992. 286 pp.

Vol III. 1990. **Mineral Industries of Latin America and Canada, 1990**, by Staff, Bureau of Mines. 1992. 1993. 325 pp.

Vol III. 1991. **Volume III. Mineral Industries of the Middle East, 1991**, by Staff, Bureau of Mines; 1993. 139 pp.

Vol III. 1991. **Volume III. Mineral Industries of Africa, 1991**, by Staff, Bureau of Mines; 1993. 352 pp.

Vol III. 1991. **Volume III. Minerals in the World Economy**, by Staff, Bureau of Mines; 1993. 49 pp.

MINERALS YEARBOOKS

Vol I. 1991. **Volume I. Metals and Materials 1991**, by staff. Bureau of Mines. 1993, 83 ch. 1754 pp. This volume of the 1991 Minerals Yearbook, covering metals and minerals, contains 80 commodity or commodity group chapters with data on approximately 90 minerals. Data were obtained as a result of the mineral information gathering activities of the Bureau of Mines. In addition, this volume contains chapters on mining and quarrying trends and on statistical surveying methods used by the Bureau of Mines, plus a statistical summary.

Vol III. 1991. **Volume III. Minerals Industries of Asia and Pacific 1991**, by staff. 1993. 404 pp.

Vol III. 1991. **Volume III. Minerals Industries of Latin America and Canada 1991**, by staff. 1993. 429 pp.

Vol II. 1991. **Volume II. Area Reports: Domestic**, by staff, USBM; 1993. 52 ch. 582 pp. This volume reviews the U.S. mineral industry by State and island possessions. It presents salient statistics on production, consumption and other pertinent data for each State and is prepared in cooperation with State geological surveys or related agencies.

PATENTS

These patents, which may be used by any U.S. citizen or organization without royalty payment upon authorization by the U.S. Department of the Interior, were developed by USBM scientists or under contracts with the U.S. Bureau of Mines. Please contact—

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1992

P 01-92. **Concave Drag Bit Cutter Device and Method.**, by Roger J. Morrell and David Larson, Jan. 7, 1992. U.S. Pat. 5,078,219

P 02-92. **Method for Locating Metallic Nitride Inclusions in Metallic Alloy Ingots.**, by Jack C. White, Davis E. Traut, Laurance L. Oden, and Roman A. Schmitt, May 5, 1992. U.S. Pat. 5,110,546

P 03-92. **Method for the Melting of Metals**, by Jack C. White and Davis E. Traut, May 19, 1992. U.S. Pat. 5,113,923

REPORTS OF INVESTIGATIONS

For copies of these publications contact NTIS, or read them in USBM libraries (field and headquarters).

1992

RI 9395. Accuracy and Precision of Microseismic Event Locations in Rock Burst Research Studies, by P.L. Swanson, L.H. Estey, F.M. Boler, and S. Billington. 1992. 40 pp., 25 figs. Stability analyses of fractured and faulted rock masses require delineation of the position, extent, and orientation of geologic discontinuities. The size of the smallest active discontinuity that may potentially be resolved using the spatial distribution of microseismic event locations is limited by the accuracy and precision of the location methods. At a hard-rock mine in Coeur D'Alene mining district of northern Idaho, two data sets consisting of calibration blast signals from a known source site and origin time and microseismic event signals were recorded using a stopewide accelerometer array. These seismic signals are used to quantify various sources of error in event location. Five factors influencing source location errors are examined in this U.S. Bureau of Mines study: (1) biases of the numerical source location techniques, (2) receiver array geometries, (3) uncertainties in receiver positions, (4) errors in picking arrival times, and (5) uncertainties in seismic velocity structure, including the effect of mine openings. In addition, synthetic data (accelerometer positions, travel-time picks, and wave velocity) are used to determine the effect of known systematic and random errors on source location calculations. It is shown that the commonly accepted association of minimum travel-time residuals with the best location solution does not necessarily hold true when there is a systematic error in seismic velocity. Recommendations are made for increasing the accuracy and precision of locations of microseismic events detected under similar field conditions.

RI 9396. Copper Exchange Capacity of Clays and Their Potential Effect on In Situ Copper Leaching, by J.S. Gomer, S.W. Yopps, S.P. Sandoval, and A.E. Clark. 1992. 11 pp. The U.S. Bureau of Mines conducted Cu exchange tests for six common clays under simulated in situ leaching conditions. Regression equations were obtained from the data expressing the Cu exchange capacity as a function of Cu concentration, pH, and temperature. Using these equations, an analysis was made of the impact each clay could have on overall Cu recovery. The results suggest that Ca and Na montmorillonite clays could have a major impact on Cu recovery and that attapulgite and illite clays could have a smaller, but still significant, impact. Kaolinite and ripidolite clays pose little threat to loss of Cu from in situ leaching solutions.

RI 9397. Production of Titanium Dioxide Pigment From Perovskite Concentrates, Acid Sulfation Method, by A.E. Petersen, M.B. Shirts, and J.P. Allen. With an Appendix on Economic and Technical Evaluation, by J.H. Schwier. 1992. 47 pp., 30 figs. To reduce U.S. dependence on imports of titanium, the U.S. Bureau of Mines has investigated the recovery of titanium from perovskite ($CaTiO_3$). Domestic perovskite deposits represent a significant, but untapped, titanium resource. An acid sulfation method was developed that will extract about 97 pct of the titanium and the columbium and 70 to 90 pct of the rare-earth byproducts from perovskite concentrates. A flowsheet for recovering titanium as pigment-grade titanium dioxide (TiO_2) is discussed. Test work performed in developing each unit operation is described. The first three unit operations have been demonstrated using laboratory-scale continuous methods of operation: acid sulfation of perovskite concentrates, leaching sulfation residue to dissolve metal values, and precipitation of titanium oxysulfate monohydrate ($TiOSO_4 \cdot H_2O$) from the resulting leach filtrate. Batch testing of other unit operations was performed: $TiOSO_4 \cdot H_2O$ redissolution and iron reduction, precipitation of TiO_2 by hydrolysis, and reged the complexes and precipitated the metals as insoluble carbonate salts. Ammonium carbamate leaching of other slags from several steelmaking plants produced lower manganese extractions, which suggests that the method cannot be applied satisfactorily to all steelmaking slags.

RI 9398. Predicting Materials' Ease of Combustion: Development of a Simple Test Method, by Maria I. De Rosa and Charles D. Litton. 1992. 9 pp., 5 figs. The U.S. Bureau of Mines conducted experiments for predicting materials' ease of combustion (smoldering onset, smoldering, flaming, and decomposition rates) by means of submicrometer smoke particle characteristics for the development of a simple test method. The experiments were carried out in an approximately 20-L furnace, with a 10-L/min airflow through the furnace for a 14-min duration, and set furnace temperatures of 150, 250, and 1,000° C. The variables studied as a function of time were the onset time of smoke particles, time and duration of maximum smoke particle generation, average concentration of smoke particles, and particles' average diameter, mass weight loss, and furnace temperatures. Results show that the onset time of smoke particles is predictive of materials' ease of smoldering, and the time of maximum smoke particle generation and its duration, coupled with mass weight loss, are predictive of materials' ease of smoldering and flaming (depending on the experimental temperatures), and decomposition rates.

RI 9399. Jet Fan Ventilation in Very Deep Cuts—A Preliminary Analysis, by Gerrit V.R. Goodman, Charles D. Taylor, and Edward D. Thimons. 1992. 12 pp., 11 figs. Future coal mining systems will be able to cut from crosscut to crosscut where advances could exceed 100 ft. However, limitations arise when ventilating such mining systems. In deep advance mining, there would be no workers at the face to advance ventilation tubing or curtain manually. Traditional methods also provide no means for maintaining face ventilation after the miner backs away from the face. U.S. Bureau of Mines research is studying means to provide effective ventilation at cut depths beyond the current limit of 40 ft. Several innovative ventilation schemes are currently being considered. One such method is the use of a jet fan to ventilate a deep cut. A jet fan is simply a freestanding fan using little or no ducting to direct the ventilation flow. Jet fan testing in a 90-ft entry revealed that higher exit velocities and greater penetration depth occurred when various configurations were used to confine and direct the air flow. Additional testing also indicated that 2,200 cfm of fresh air was delivered to the face 90 ft distant when a check curtain was used to limit entrainment around the fan. Without this curtain, this quantity dropped to only 1,000 cfm. This testing indicated that a jet fan was capable

of providing ventilation to a distant face area. It also highlighted potential problems, such as recirculation at the fan and reentrainment in the jet flow. Despite these potential problems, jet fans may be adequate for ventilating cuts exceeding 40 ft.

RI 9400. Recovery of Manganese From Steel Plant Slag by Carbamate Leaching, by Synthia N. McIntosh and Elizabeth G. Baglin. 1992, 10 pp. 9 figs. The U.S. Bureau of Mines investigated the feasibility of using ammonium carbamate ($NH_2CO_2NH_4$) leaching to recover manganese from steel plant slag. This investigation showed that treatment of the slag in hydrogen prior to leaching enhanced manganese extraction. Up to 80 pct of the manganese and 50 pct of the iron could be extracted from a silicon steel slag that had been pretreated in hydrogen at 700° C. Two 4-h leaching stages conducted at ambient temperature with a solution containing ammonia and carbon dioxide dissolved manganese and iron as their carbamate complexes. Heating the pregnant solution to 65 to 85° C decomposed the complexes and precipitated the metals as insoluble carbonate salts. Ammonium carbamate leaching of other slags from several steelmaking plants produced lower manganese extractions, which suggests that the method cannot be applied satisfactorily to all steelmaking slags.

RI 9401. Self-Contained Self-Rescuer Field Evaluation: Results From 1982-90, by Nicholas Kyriazi and John P. Shubilla. 1992. 18 pp. 9 figs. A joint effort by the U.S. Bureau of Mines and the U.S. Mine Safety and Health Administration (MSHA) was undertaken to determine how well self-contained self-rescuers (SCSR's), deployed in accordance with Federal regulations (30 CFR 75.1714), survived the underground environment with regard to both impact damage and aging. This report presents findings regarding laboratory-tested SCSR's from 1982 through 1990. The SCSR's were tested on human subjects and on a breathing and metabolic simulator. These results indicate that most of the apparatus, if they pass their inspection criteria, perform as expected except for units with manufacturing defects or design deficiencies. However, when the apparatus are carried in and out of the mine daily and stored at the working section, they may suffer abuse. Physical signs of abuse, unless extremely obvious, are frequently not detected by the miners or mine operators. This poses a potential danger to a user in an emergency. Recommendations include improved training in inspection procedures.

RI 9402. Materials of Construction for High-Salinity Geothermal Brines, by John P. Carter and Stephen D. Cramer. 1992. 8 pp. 3 figs. The U.S. Bureau of Mines conducted research to determine suitable construction materials for use in brine and steam environments produced from high-salinity geothermal brines. The high-temperature, high-salinity geothermal brines in the Salton Sea Known Geothermal Resources Area (KGRA) are a valuable source of energy and mineral values. The brine and steam produced from them are corrosive and cause early failure of many common materials of construction. Mass-loss and electrochemical corrosion measurements were conducted on over 60 metal alloys in brine and steam environments produced from geothermal well Magmamax No. 1, located at the Salton Sea KGRA, at temperatures from 180 to 215° C, and in synthetic Magmamax brine at 105 and 232° C. General corrosion, crevice and pitting corrosion, and stress corrosion were examined along with the effects of dissolved gases. The alloys with the most acceptable corrosion performance in high-temperature, high-salinity geothermal environments were the high-chromium ferritic stainless steels, the Inconels and Hastelloys, and the titanium alloys. Specific alloys that performed well in wellhead brine included Fe29Cr4Mo, E-Brite 26-1, stabilized Fe26Cr1Mo, 6X, Inconel 625, Hastelloy C-276, Hastelloy S, Hastelloy G, Ti50A, Ti0.2Pd, and TiCode 12.

RI 9403. Influence of Subjacent Gob on Longwell Development Mining in the Upper Kittanning Coalbed of South-Central Pennsylvania, by E.R. Bauer, G.J. Chekan, and G.P. Sames. 1992. 13 pp. 15 figs. The U.S. Bureau of Mines is investigating strata interactions associated with mining of multiple coalbeds to provide the mining industry with improved methods of planning and developing multiple coalbeds, conserving resources, and increasing the safety of underground coal mining. This study involves analytical predictions and underground observations of longwall development ground control problems at a south-central Pennsylvania coal mine affected by subsidence induced by multiple-seam mining. As predicted, strata interactions were found in upper mine areas mined over lower mine gob. Observations revealed roof deterioration accompanied by excessive water inflows in the first 170 ft after crossing the gob line as mining entered and exited the subsided area (over the lower mine gob). In contrast, superimposed mine areas and areas mined a substantial distance out over the gob showed no signs of interaction with previous lower seam mining, again as predicted.

RI 9404. Geotechnical Aspects of Roof and Pillar Stability in a Georgia Talc Mine, by Noel N. Moebs and Gary P. Sames. 1992. 29 pp. 32 figs. This report summarizes a U.S. Bureau of Mines study on the application of geotechnology to identify and minimize ground control hazards in talc mining operations in northwest Georgia. The major ground control hazard is pillar sloughing attributed to the steeply dipping orientation of a pronounced foliation in the talc ore body. The sloughing problem, which gradually reduces the effective support area of a pillar through attrition, can be minimized by appropriate artificial support, as determined by a rock classification system, and by a more uniform pillar design. A boundary element model confirmed the advantages of using a uniform pillar design to avoid excessive loads on portions of irregular pillars. Instrumentation to measure roof convergence and pillar loading was installed at selected locations in an active talc mine but failed to detect any significant changes, suggesting that the gneiss hanging wall constitutes a strong roof that probably can support large spans between pillars and permit high extraction ratios. This interpretation also is supported by a rock classification of the hanging wall gneiss.

RI 9405. Role of Oxygen Transfer in Acid Mine Drainage Treatment, by C.C. Hustwit, T.E. Ackman, and P.M. Erickson. 1992. 18pp. 4 figs. The U.S. Bureau of Mines formulated a new mathematical model to characterize iron oxidation. The new model is intended to replace the currently used model, recommended by the Environmental Protection Agency (EPA), for most acid mine drainage (AMD) treatment applications. The new model was evaluated in a series of five synthetic AMD treatment tests. The initial ferrous iron concentrations ranged from 800 to 2400 mg/L. In these tests, the Bureau model underpredicted the measured ferrous iron oxidation rates by a range of 3.24 to 8.03 pct. This

was considered to be in close agreement after consideration of experimental error. The model proposed by the EPA was also evaluated using the same test data. The EPA model undepredicted the oxidation rates by a range of 77 to 100 pct in four tests and overpredicted by 129 pct in one test. The model formulated by the Bureau expresses that the rate of iron oxidation is a function of a treatment system's oxygen transfer efficency and is independent of ferrous iron concentration when treated to near-neutral pH's. A new test method for evaluating oxygen transfer in flow-through reactors is also discribed.

RI 9406. Vapor-Phase Reactions To Prepare Titanium Nitride Powder, by G.J. Stevens. 1992. 21 pp. 16 figs. The U.S. Bureau of Mines conducted research on preparing submicrometer titanium nitride (TiN) powder as a substitute for tungsten carbide (WC) in cutting tools and wear-resistant parts. Earlier research on a small scale was expanded to include a larger reactor. The TiN powder was produced by contacting titanium tetrachloride ($TiCl_4$) with anhydrous ammonia (NH_3) in the presence of Mg at 1,100° C. The powder was collected in an electrostatic precipitator (ESP) filled with ultra-high-purity (UHP) Ar. All collected powder was thermal-vacuum-distilled to remove Mg and magnesium chloride ($MgCl_2$), leaving the purified TiN. Powder handling and purification procedures were conducted to assure low oxygen content in the powder product. Oxygen content in the distilled TiN powder product was as low as 0.40 wt pct. Nitrogen averaged near 22.0 wt pct with a high of 22.4 wt pct. The purified powder product had an average median particle diameter of 0.14 microns with a standard deviation of 0.09 microns.

RI 9407. Remote Fiber-Optic Methane Monitor, by T.H. Dubaniewicz, Jr., and J.E. Chilton. 1992. 8 pp. 10 figs. Fiber-optic technology is progressing rapidly, including the development of fiber-optic sensors for many applications. These sensors have the advantages of high sensitivity, light weight, small size, high bandwidth, and freedom from electromagnetic influences. The U.S. Bureau of Mines is investigating the use of fiber-optic technology to monitor mine atmospheres. This report describes a methane monitor based on differential absorption of infrared light. The monitor can detect methane concentrations as low as 0.2 vol pct as far away as 2 km via fiber-optic cable. The upper range is 100 vol pct methane. Since the system requires no electrical power within the mine, it is intrinsically safe.

RI 9408. Bending Fatigue Test 1 on a 2-Inch 6x25 Fiber Core Wire Rope, by W.W. McKewan, A.J. Miscoe, and J.R. Bartels. 1992. 11 pp. 17 figs. The U.S. Bureau of Mines has established a wire rope research laboratory to examine the factors that affect the life of wire rope. A 2-in-diam 6x25 fiber core rope was degraded on a bending fatigue machine. This was the first in a series of tests on rope of this construction and size. Baseline testing at the laboratory was reported in an earlier publication. Tensile and nondestructive tests were performed on samples of the rope to determine the relationship between rope deterioration and rope breaking strength. The tests indicated that as a wire rope nears the end of its useful life, deterioration and the consequent loss of rope strength increase at an accelerated rate.

RI 9409. Calculation of Vertical Stress Exerted by Topographic Features, by Valois R. Shea-Albin, Dennis R. Dolinar, and Douglas C. Peters. 1992. 33 pp. 15 figs. An accurate assessment of the vertical stress on a coal seam at depth is important for mine design. Vertical stress calculation techniques presently available either are not sufficiently accurate or cannot handle complex surface topography. Therefore, the U.S. Bureau of Mines developed a computerized method to calculate vertical stress exerted on surfaces at depth that includes the effect of topography. Two input data sets are required: a digital elevation model containing topographic elevations and a coal seam file defining coal seam elevations at depth. Boussinesq's equation then quantifies the vertical stress resulting from topography. The computerized method was tested on a coal seam overlain by a complex topography where a vertical stress map encompassing several square miles was produced. Results show that depth mitigates the effects of surface topography, while the coal seam topography has a direct effect on the vertical stress. In comparison to the computerized method, the direct stress method overestimates stress under hills and underestimates stress under valleys. The largest difference between the two methods occurs under the steepest topographic relief. A limitation of the computerized method is that stresses cannot be accurately determined near an outcrop.

RI 9410. Performance of Retimet Metal Foam Vents on Explosion-Proof Enclosures, by Lawrence W. Scott and Arthur J. Hudson. 1992. 9 pp. 13 figs. The performance of RETIMET metal foam as a flame arrester on explosion-proof enclosures was investigated by the U.S. Bureau of Mines both in laboratory tests and at the U.S. Mine Safety and Health Administration's (MSHA's) Approval and Certification Center, Triadelphia, WV. The objective of this research was to develop a permissible pressure vent for use on lightweight, vented, explosion-proof enclosures. In laboratory tests, four grades of RETIMET, a stainless steel foam material, were evaluated: 45 NC-7, 45 NC-13, 80 NC-7, and 80 NC-13. Explosive gas mixtures were prepared by a dynamic flow system. Ignition was by a low-voltage arc. Each grade of RETIMET metal foam successfully arrested the flame front in all methane-air tests. To evaluate RETIMET metal foam on large, commercial-size enclosures, a multicompartmented enclosure was designed and tested in MSHA's explosion gallery in Triadelphia, WV. Extensive explosion testing revealed that a minimum vent-area-to-enclosure-volume ratio of 11.33 in^2/ft^3 is required to keep internal pressure rises below 3 psig. The RETIMET metal foam functioned satisfactorily in all tests as evidenced by the absence of external ignitions.

RI 9411. BOMCRATR-A Curved Ray Tomographic Computer Program for Geophysical Applications, by D.R. Tweeton, M.J. Jackson, and K.S. Roessler. 1992. 39 pp. 18 figs. The U.S. Bureau of Mines has developed tomographic computer programs for geophysical applications and is distributing them as part of a Bureau plan to facilitate the transfer of technology to potential users. These programs were developed for predicting and monitoring the flow pattern of leach solution during in situ mining. The Bureau has also applied them to assessing high-wall blast damage and examining the integrity of mine-related geological structures. This report describes the curved ray program BOMCRATR (Bureau of Mines curved-ray tomographic reconstruction), tells how to run it, and gives examples with synthetic and field data. BOMCRATR provides optional mathematical constraints to counteract the nonuniqueness of tomographic reconstructions with crosshole data. These constraints include limiting the maximum and minimum velocities, fixing the velocity at any

point to any value, and establishing layers in which velocity does not vary with horizontal position. The user can test for nonuniqueness by varying the initial velocity pattern. The program can perform either curved or straight-ray analysis. Ray paths are calculated analytically in triangular pixels, which is faster than incremental numerical approximations.

RI 9412. Response of Underground Fire Sensors: An Evaluation, by Ronald S. Conti and Charles D. Litton. 1992. 13 pp., 16 figs. This U.S. Bureau of Mines report discusses the results of research conducted in the Bureau's experimental mine at Lake Lynn Laboratory on the response of fire sensors to simulated mine fires, which included (1) a slowly developing coal-conveyor belt fire, (2) a rapidly burning liquid fuel-belt fire, and (3) a liquid fuel-belt fire in the presence of diesel exhaust. During these tests, several mine fire sensors were evaluated with respect to sensor placement, spacing, and type. The data indicate that smoke sensors alarm several minutes before CO sensors do; and that, in the presence of diesel exhaust, a prototype diesel-discriminating smoke sensor can successfully function without being sensitive to the diesel contaminants. The vertical placement of sensors in the entry near the fire was also shown to be critical in terms of alarm times. Additional data showed that variations exist in response time and level of response for two brands of electrochemical CO sensor. Results also indicate that early detection of fires will improve the probability of miners' escape, because of reduced smoke concentrations during the incipient stages of the fire.

RI 9413. Effects of Horizontal Stress Related to Stream Valleys on the Stability of Coal Mine Openings, by G.M. Molinda, K.A. Heasley, D.C. Oyler, and J.R. Jones. 1992. 26 pp., 26 figs. The U.S. Bureau of Mines conducted an investigation to determine the nature and frequency of coal mine roof failure beneath valleys. A mechanism for this failure and suggestions for controlling this problem are presented. Hazardous roof conditions identified in some mines were positively correlated with mining activities beneath stream valleys. Mine maps with overlays of unstable roof and locations of stream valleys show that 52 pct of the instances of all unstable roof in the surveyed mines occurred directly beneath the bottom-most part of the valley. The survey also showed that broad, flat-bottomed valleys were more likely to be sites of hazardous roof than narrow-bottomed valleys. Evidence of valley stress relief was found beneath several valleys in the form of bedding plane faults and low-angle thrust faults. This type of failure, previously believed to be only a shallow phenomenon, was found at mining depths as great as 300 ft. In situ, horizontal stress measurements beneath a valley and the adjacent hillsides confirmed valley stress relief. Numerical analysis of 13 valleys overlying 1 mine property showed the effect of the valley excavation on horizontal and vertical stress.

RI 9414. Evaluation of Structures for Roof-Fall Areas, by Richard A. Allwes and C.P. Mangelsdorf. 1992. 31 pp., 35 figs. This U.S. Bureau of Mines report presents the results of structural analyses and full-scale physical tests conducted on a steel-set arch and tri-set. The purpose of the analyses and tests was to evaluate the suitability of these structures for use in roof-fall-prone areas. The arch canopy test and design procedures previously developed by the Bureau were utilized in this evaluation. Theoretical resistance functions were established for the steel-set arch and tri-set and were representative of the experimental behavior of the structures. The resistance functions were used to determine the energy absorption capacity of the structures and to predict their dynamic response to impact loading. The dynamic tests demonstrated that the arch canopy design procedure is appropriate for tri-sets and yields conservative designs for both steel-set arches and tri-sets. As a result of this work, it is recommended that these two structures may be considered for use in roof-fall-prone areas and for rehabilitation work, provided the arch canopy design procedure is utilized for each application and the principles underlying the design procedure are understood.

RI 9415. Cause of Floor Self-Heatings in an Underground Coal Mine, by Y. Miron, C.P. Lazzara, and A.C. Smith. 1992. 24 pp., 23 figs. This report presents a U.S. Bureau of Mines study to identify the causes of self-heating events beneath the floor of a deep underground mine. Mine samples from both heated and unheated areas were examined by various techniques, including visual, microscopic, thermal, chemical, and instrumental tests. The combined results led to the conclusion that pyrite (FeS_2) oxidation was the prime cause of the heatings. However, adiabatic oven tests of selected samples did not indicate the effect of the pyrite on the self-heating process, probably because of the experimental conditions. A fast, simple procedure to assess concentration of pyrite in the mine samples was developed, utilizing the reactivity of the sample with an aqueous solution of hydrogen peroxide (H_2O_2).

RI 9416. Influence of Electrode Material on Spark Ignition Probability, by Jeffrey Shawn Peterson. 1992. 19 pp., 21 figs. The testing procedures of the U.S. Mine Safety and Health Administration specify that intrinsic safety acceptance tests be conducted using a standard tungsten-cadmium electrode configuration in the breakflash apparatus. However, in realistic mining environments, other materials may be more likely sources of sparking. Information defining the probability of spark ignition between common materials such as aluminum, brass, copper, lead, tin, cold-rolled steel, and stainless steel is of more practical value in determining ignition hazards. The U.S. Bureau of Mines has completed an investigation of the influence of material on the ignition probability using the breakflash apparatus. By comparing ignition currents or ignition voltages corresponding to a probability of one ignition per thousand sparks to those found previously for cadmium, a margin of safety may be estimated for each material. This report presents the results of an investigation into the influence of disk electrode material on the probability of ignition.

RI 9417. Frictional Ignition of Natural Gas-Air Mixtures by Alternative Coal-Cutter Bit Shank Materials, by L. Garner McDonald. 1992. 14 pp., 11 figs. The U.S. Bureau of Mines tangentially impacted potential coal-cutter bit shank materials against sandstone to investigate the potential of the materials to ignite natural gas by a friction-generated hot streak. The shank material samples were mounted in a 24-in, 550-lb flywheel, which was rotated at surface speeds of 400 to 900 sfpm. The sandstone was advanced toward the rotating flywheel at feed rates of 1 mil per impact. The atmosphere mixture was 7 vol pct natural gas in air. Three grades of polycarbonate resin, an ultra-high-molecular weight polyethylene, and a zinc alloy (ZA27) were among the potential materials. None of these materials caused ignition of the

methane at any of the three test speeds (400, 600, and 900 sfpm), but the above materials do not have sufficient strength to hold a carbide tip during coal cutting. Of the materials having sufficient strength to hold a carbide tip, three nickel-based alloys proved less likely to cause a natural gas ignition than did iron-based alloys such as 4340 (a commonly used shank material for coal cutters).

RI 9418. Canopy and Base Load Distribution on a Longwall Shield, by Thomas M. Barczak and David F. Gearhart. 1992. 23 pp., 31 figs. This U.S. Bureau of Mines report examines the roof and floor contact pressure provided by the interaction of a shield with the surrounding strata. Controlled forces were applied to an 800-ton two-leg shield in the Bureau-s mine roof simulator; the distribution of forces acting on the canopy and base of the shield were measured with 24 hydraulic pressure cells. Several influential factors that affect the load distribution were investigated: (1) the magnitude of loading (leg pressure); (2) the profile of the canopy, principally the upward-sloping tip; (3) the base-lifting device; (4) horizontal load acting on the shield; and (5) compliancy of the immediate roof and floor. It was concluded that the shield does not develop full canopy or base contact without deformation of the strata. Maximum contact pressures are developed at the rear of the canopy and on the toes of the base. Less than 10 pct of the available shield capacity is developed at the canopy tip despite the design intention to ensure tip contact. Horizontal loading reduced the toe pressure acting on the base by as much as 75 pct. The base-lifting device exaggerated the inherently high toe loading, increasing the contact pressure by more than 200 pct.

RI 9419. Gallium and Germanium Recovery From Domestic Sources, by D.D. Harbuck. 1992. 26 pp., 30 figs. To decrease reliance on foreign sources for the strategic and critical metals gallium and germanium, the U.S. Bureau of Mines identified and developed processing technology for two domestic sources of these metals: a Tennessee zinc residue and a Utah ore. Sulfuric acid (H_2SO_4) solutions were used to solubilize gallium and germanium in both sources. Statistically designed experiments showed that the most important parameter for high metal extraction from zinc residue was the H_2SO_4 concentration. At a concentration of 2.9*M* H_2SO_4, 95 pct of the gallium was extracted, and at a concentration of 0.6(Italics M) H_2SO_4, 73 pct of the germanium was extracted. Controlled H_2SO_4 concentration was also the key for metal extractions (97 pct Ga, 87 pct Ge) from the Utah ore. Such control was achieved using a two-stage countercurrent leach circuit. Testing showed that the insoluble germanium in both the residue and ore was tied up with silica. Several methods for overcoming this problem are given. To recover gallium and germanium from the leach solutions, the solvent extractants octylphenyl acid phosphate (OPAP) (for gallium) and LIX 63-OPAP (for germanium) were identified. These extractants were tested in separate, continuous, solvent-extraction circuits, yielding a gallium recovery of 94 pct and a germanium recovery of more than 90 pct.

RI 9420. Teleoperation of a Highwall Mining System, by August J. Kwitowski, Albert L. Brautigam, and Michael C. Leigh. 1992. 17 pp., 13 figs. The U.S. Bureau of Mines developed and tested a teleoperating system to control a new highwall mining system. A remote operator was provided out-of-sight sensory information and control of coal extraction and haulage equipment. Surface and production testing proved that the teleoperating system supplied the operator with sufficient sensory information to operate the mining system. Details on the teleoperating system provided in this report include (1) sensor selection, (2) a description of the electronic control system, (3) equipment selection and modifications, (4) the positive test results, and (5) recommendations for system improvements.

RI 9421. Mine Fire Diagnostics Applied to the Carbondale, PA, Mine Fire Site, by Ann G. Kim, Thomas R. Justin, and John F. Miller. 1992. 16 pp., 16 figs. The U.S. Bureau of Mines applied its mine fire diagnostic method to an abandoned anthracite mine fire site in Carbondale, Lackawanna County, PA. The technique to locate fires in abandoned coal mines and coal refuse piles includes the determination of hydrocarbon concentrations in mine gases, the imposition of an underground gas flow direction, and use of a surface mapping method to define heated and cold zones in underground coal strata. The heated zones at Carbondale were characterized by elevated methane concentrations. The results of 25 communication tests were analyzed to define 2 large (approximately 100 by 250 ft) and 5 small, isolated heated zones. An approximate correlation existed between the location of the heated zones and areas of anomalous snow melt. The correlation between the results of the diagnostic test and subsurface temperatures was not significant.

RI 9422. Apparatus For Measuring Diesel Tailpipe Emissions in Underground Mines, by Carlson, D.H.; Taubert, T.R.; Johnson, J.H. 1992. 14 pp. 12 figs. The U.S. Bureau of Mines and Michigan Technological University (MTU) are collaborating to develop an apparatus for measuring diesel tailpipe emissions in underground mines. A tailpipe emissions measurement apparatus (EMA) is described that dilutes diesel exhaust and measures the concentrations of diesel particulate matter (DMP), CO, CO_2, NO, and NO_2 at known dilution ratios. The EMA was evaluated by side-by-side comparison of its measurements with those by laboratory-grade instruments. Concentrations of CO and CO_2 measured by the EMA were usually within ≈14 pct of concentrations measured by laboratory-grade instruments for CO and ≈20 pct for CO_2. EMA-measured DPM concentrations were, on average, 29 pct lower than those measured by laboratory-grade instruments, with the differences being fairly consistent. The CO and CO_2 differences are related to the method of calculating the EMA's dilution ratio, and the difference in DPM concentrations is attributed to thermophoretic and/or condensation losses related to the EMA's unheated sample probe. Preliminary analysis of data obtained with a heated sampling probe and modifications in the sampling procedures have indicated reduced variability in DPM and in the calculated dilution ratios.

RI 9423. Hybrid Fiber-Optic Electrochemical Carbon Monoxide Monitor, by Chilton, J.E.; Carpenter, C.R. 1992. 13 pp. 21 figs. The U.S. Bureau of Mines has developed an intrinsically safe carbon monoxide (CO) monitoring system for mines by coupling a fiber-optic data telemetry (FODT) system with a prototype electrochemical CO monitor. The CO monitoring system can be used in a coal mine as one component of an early fire warning system. This system may be used in belt haulage entries when the entries are used for supplying ventilation air to working places. The FODT accepts a 0.1- to 1.1-V analog signal from the monitor and

converts it to pulses (0 to 5 V) at frequencies from 1.1 to 11 kHz that drive a light-emitting diode (LED). An electrically nonconducting fiber-optic cable carries the LED signal to a remote receiver. The receiver analyzes the incoming light signal and displays the measured CO concentration in parts per million. This report discusses the performance of the FODT system and characteristics of the CO monitor such as response times, linearity, and temperature and pressure effects.

RI 9424. Delineation of Fractures in Igneous Rock Masses Using Common Offset Radar Reflection, by Michael J. Friedel, James J. Jessop, and Richard E. Thill. 1992. 15 pp., 10 figs. As part of an investigation aimed at improving the health and safety and competitiveness of the mining industry, the U.S. Bureau of Mines evaluated the application of common offset radar profiling, using a 250-MHz ground-penetrating radar system, for the detection of fractures in igneous rock. A series of radar reflection surveys were conducted to detect and delineate the extent of fracturing at various granodiorite and gabbro quarries and outcrops located in Minnesota. The application of radar profiling for detecting joints, sheeting fractures, shear zones, and depth to water table was demonstrated to be feasible with minimal processing. Radar reflection interpretations were verified by visual inspection of the rock mass and field mapping of local structure. The radar reflection section provides a simple, rapid, and cost-effective means for mapping of shallow (less than 10 m) small-scale fractures (greater than 0.25 cm) in igneous rock masses (characteristic of velocities between 0.061 m/ns for gabbro and 0.125 m/ns for granodiorite). Depth or distance estimates to fractures are within 10 pct of the actual, and time-shift compensation is necessary only when topographic irregularities exceed 30 cm.

RI 9425. Relationship of Coal Seam Parameters and Airborne Respirable Dust at Longwalls, by Organiscak, J.A.; Page, S.J.; Jankowski, R.A. 1992. 18 pp. 16 figs. The U.S. Bureau of Mines investigated the relationship of bituminous coal seam parameters and the amount of airborne respirable dust generated at longwalls. Dust and coal samples were obtained from 20 longwalls operating in geographically representative coalfields throughout the United States. Statistical analyses of coal seam parameters and airborne respirable dust measurements indicate a likely causal relationship between seam type and respirable dust. Low-ash, high-volatile coal seams were associated with higher airborne respirable dust levels. A negative linear correlation (significant at the 95-pct confidence level) was observed between the seam's ash content and airborne respirable dust, explaining up to 18 pct ($R^2 = 0.18$) of headgate dust level variation and up to 15 pct of tailgate dust level variation. Volatile matter was found to have a positive linear correlation with tailgate dust level, explaining 16 pct of the variation. Further data examination indicated that these relationships with dust are most likely nonlinear, because of improved R^2 values over the linear correlations. However, a notable portion of longwall dust production is influenced by other operational parameters, so additional research under more controlled conditions is needed to determine the seam's causative functions.

RI 9426. Dust Considerations When Using Belt Entry Air To Ventilate Work Areas, by Potts, J. Drew; Jankowski, Robert A. 1992. 12 pp. 5 figs. In this U.S. Bureau of Mines study, four underground respirable dust surveys were conducted to determine factors affecting belt entry dust levels and how using belt air to ventilate work areas affected dust exposures. Belt entry dust levels on the surveyed longwall and continuous miner sections averaged 0.59 and 0.26 mg/m^3 respectively. The stageloader-crusher contributed an additional 0.5 to 0.9 mg/m^3 of dust to belt air, while the feeder-breaker contributed 0 to 0.2 mg/m^3 of dust. A 1,000-ft increase in belt entry length or a 200- to 500-st-per-shift increase in production resulted in roughly a 0.1-mg/m^3 increase in dust. Using the belt entry as an intake entry on the continuous miner section appeared to reduce dust levels by 0.1 to 0.3 mg/m^3 during cutting. Belt air was not used to ventilate the face on the longwall section.

RI 9427. Large-Scale Strata Response to Longwall Mining: A Case Study, by Kneisley, R.O.; Haramy, K.Y. 1992. 25 pp. 26 figs. This U.S. Bureau of Mines report summarizes a study of large-scale strata response to longwall mining at a western U.S. coal mine. This study utilized surface and subsurface measurements, geologic mapping, in situ stress measurements, and pressure cell readings to characterize strata behavior. Preliminary analysis of surface subsidence and time-domain reflectometry (TDR) was used to determine a suggested main roof caving sequence. Coal ejected from the face apparently resulted from brittle failures that occurred because of lack of significant yield zone development. The combination of a strong coal with pronounced directional behavior, low overburden pressures, a good caving roof, and a high-production environment that minimized time-dependent loading apparently reduced yielding of the longwall face. The panel 1 headgate-entry design appears adequate; however, the abutment pillar and adjacent panel tailgate rib are highly stressed and may contribute to problems during second panel mining. The small chain pillar yielded after passage of the face, but the pillar width may be near maximum since evidence of a stressed core exists.

RI 9428. High-Temperature Cyanide Leaching of Platinum-Group Metals From Automobile Catalysts—Process Development Unit, by Kuczynski, R.J.; Atkinson, G.B.; Walters, L.A. 1992. 11 pp. 5 figs. The U.S. Bureau of Mines operated a 2,000-g (4.4-lb) batch process development unit for recovering platinum-group metals (PGM) from automobile catalysts. Virgin monolith, used pellet, and used monolith catalyst samples were tested. Leaching twice with 1-pct sodium cyanide (NaCN) solution at 160° C for 1 h dissolved more than 95 pct of the PGM from virgin catalysts and more than 90 pct from used pellet catalysts. More than 85 pct of the PGM was dissolved from used monolith catalysts when a third autoclave step was added. Solid PGM concentrates containing more than 99.8 pct of the dissolved PGM and analyzing greater than 70 pct PGM were recovered by heating the pregnant leach solutions from virgin catalysts to 250° C and used catalyst to 275° C for 1 h. The solution after heating contained less than 0.2 ppm total cyanide. The virgin residues passed the EPA Extraction Procedure Toxicity Test (EP Tox Test), the EPA Toxicity Characteristic Leaching Procedure (TCLP), and the California Waste Extraction Test (WET) for all elements except Ba. Adding sodium sulfate (Na_2SO_4) to the virgin leach residues reduced the amount of Ba dissolved to an acceptable level. The used leach residues passed the EP Tox Test for all elements but failed the WET and TCLP for Pb.

REPORTS OF INVESTIGATIONS

RI 9429. Bending Fatigue Tests 2 and 3 on 2-inch 6x25 Fiber Core Wire Rope, by Bartels, J.R.; McKewan, W.M.; Misoce, A.J. 1992. 12 pp. 17 figs. The U.S. Bureau of Mines has established a wire rope research laboratory to examine the factors that affect the life of wire rope. Two 2-in-diameter 6X25 fiber core (FC) ropes were degraded on a bending fatigue machine. These were the second and third ropes in a series of tests on this construction and size rope. Tensile and nondestructive tests were performed on samples of the rope to determine the relationship between rope deterioration and rope breaking strength. The tests indicated that once a wire rope nears the end of its service life, both deterioration and the consequent loss of rope strength begin to increase at an accelerated rate.

RI 9430. Determining the Source of Longwall Gob Gas: Lower Kittanning Coalbed, Cambria County, PA, by Diamond, William P.; Ulery, James P.; Kravits, Stephen J. 1992. 15 pp. 9 figs. This report presents results of a cooperative research project between the U.S. Bureau of Mines and BethEnergy Mines, Inc. Four coreholes (two before mining and two after mining) were drilled at a longwall mine operating in the Lower Kittanning Coalbed to obtain coal and rock samples from overlying strata to determine their gas content at various times in the mining cycle. The results of those tests indicate that 91 pct of the gas removed from the overlying strata came from coalbeds. Material balance calculations were made to compare the volume of gas produced both from gob vent holes drilled on the panel and gas removed by the mine's ventilation system with the volume of gas removed from strata directly overlying the panel to a height of 275 ft. This analysis indicates that only 40 pct of the total gas produced from the panel actually came from the strata directly overlying the panel. The remaining volume of gas production probably migrated to the longwall gob from overlying and perhaps underlying, strata immediately adjacent to the panel and perhaps from greater distances downdip because of the establishment of a long-term pressure gradient in the study area.

RI 9431. Development and Testing of a Computer-Assisted Remote-Control System for the Compact Loader-Trammer, by Ruff, T.M. 1992. 10 pp. 14 figs. A prototype mucking machine designed to operate in narrow-vein stopes was developed under contract with the U.S. Bureau of Mines. The machine, called a compact loader-trammer, or minimucker, was designed to replace slusher muckers in narrow-vein underground mines. The minimucker is a six-wheel- drive, skid-steered, load-haul-dump (LHD) machine that loads muck at the front with a novel slide-bucket system and ejects it out the rear so that the machine does not have to be turned around. An automatic guidance system that used ultrasonic ranging sensors and a wall-following algorithm was installed. Additional tests in a simulated test stope showed that these changes improved the operation of the minimucker.

RI 9432. Rock Mechanics Investigations at the Lucky Friday Mine (In Three Parts): 1. Instrumentation of an Experimental Underhand Longwall Stope, by Williams, T.J.; Whyatt, J.K.; Poad, M.E. 1992. 26 pp. 26 figs. Researchers monitored rock mass response to mining of an experimental underhand longwall stope in Hecla Mining Co.'s Lucky Friday Mine, Mullan, ID. This stope design, the Lucky Friday underhand longwall (LFUL), was proposed as a means of controlling rock bursting while also allowing increased mechanization of mining operations. This study and mining experience suggest that underhand longwall mining could be considered a feasible mining method for rock-burst-prone ground.

RI 9433. Rock Mechanics Investigations at the Lucky Friday Mine (In Three Parts): 2. Evaluation of Underhand Backfill Practice for Rock Burst Control, by Whyatt, J.K.; Williams, T.J.; Board, M.P. 1992. 10 pp. 11 figs. The energy release rate (ERR) index was used to evaluate three underhand stope backfill parameters cement content, density, and placement gap to determine their influence on rock bursts. This index provides a relative measure of the likelihood of rock bursting for a given rock mass. There was no indication that increasing initial fill strength through increased cement content would affect the ERR.

RI 9434. Rock Mechanics Investigations at the Lucky Friday Mine (In Three Parts): 3. Calibration and Validation of a Stope-Scale, Finite-Element Model, by Pariseau, W.G.; Whyatt, J.K.; McMahon, T.J. 1992. 16 pp. 9 figs. The present study uses rock deformation measurements to validate and calibrate a geomechanical model of the experimental Lucky Friday underhand longwall (LFUL) stope on the 5,100-ft level of the Lucky Friday Mine, Mullan, ID. This model suggested that stress-related ground control problems would be encountered west of the stope where the vein makes a right-angle turn and then splits.

RI 9435. Transfer of Self-Contained Self-Rescuer Donning Skills Under Similar Conditions of Practice: The Draeger Oxy-SR60B and the CSE SR-100, by Brnich, M.J.; Vaught, C.; Wiehagen, W.J. 1992. 7 pp. 4 figs. The purpose of this U.S. Bureau of Mines study was to assess the ability of trainees to don an unfamiliar self-contained self-rescuer (SCSR) after having become familiar with how to put on a different type of apparatus. Prepractice instruction was the same for individuals learning to put on a device: a step-by-step, hands-on talk-through using the "3+3" method. Subjects were assigned to groups that had their initial donning instruction delivered on either the Draeger OXY-SR60B or the CSE SR-100. Trainees' performances were then evaluated using the other model. Donning trials were analyzed using a number of measures. It was found that SCSR design had a moderate influence upon how well the donning task transferred.

RI 9436. Casting P-900 Armorplate By the Expendable Pattern Casting Process, by Hansen, J.S.; Turner, P.C. 1992. 7 pp. 9 figs. The U.S. Bureau of Mines developed a system for casting unique, slotted steel armor by modifying the conventional expendable pattern casting (EPC) process that is normally used for making aluminum castings. Three innovations were added to the EPC process to make the successful adaptation: (1) Vacuum was applied to sand molds, (2) continuous narrow-necked feeding systems were used to permit the casting of thin walls, and (3) fixtures were designed to prevent pattern damage and to hold critical casting tolerances.

RI 9437. Machining Of Fe_3Al Intermetallics, by Woodyard, Jack R. 1992. 7 pp. 11 figs. Iron aluminides were studied as possible substitutes for stainless steels. In a Bureau investigation on the mechanical properties of Fe-28Al, the material's machining properties were

significantly improved at slow tool and feed speeds. This study shows that the alloy can be machined at higher speeds using high-speed steel end mills, and that water-soluable cutting oil is a suitable lubricant and coolant.

RI 9438. **Effectiveness of Iron-Based Fuel Additives for Diesel Soot Control**, by Zeller, H. William; Westphal, T.E. 1992. 26 pp. 28 figs. The U.S. Bureau of Mines evaluated the effects of two iron-based fuel additives on diesel particulate matter (DPM) emissions. This report is mainly about a ferrocene-based additive that reduced DPM between 4 and 45 pct, depending on engine operating conditions. The report concludes that the DPM reductions were caused by the catalytic oxidation properties of a ferric oxide coating that developed inside the engine's combustion chamber. The results suggest that the effectiveness of ferrocene was partially offset by increased sulfates because of the high-sulfur fuel used.

RI 9439. **A Summary of Current Bureau Research Into the Effects of Whole-Body Vibration and Shock On Operators of Underground Mobile Equipment**, by Love, Arnold C.; Unger, Richard L.; Bobick, Thomas G.; Fowkes, R.S. 1992. 15 pp. 5 figs. This report discusses research on the effects of whole-body vibration (WBV) and shock on underground mobile equipment operators. Vibration data were collected from shuttle cars and ramcars at several underground coal mines. The data were formatted so that they could be used to drive the Bureau's motion platform, and to compare them with ANSI S3-1979. Human subject testing in the Bureau's vibration research laboratory evaluated the effects of two different seat angles and of the presence or absence of vibration and of foam padding on heart rate, blood pressure, and subjective discomfort.

RI 9440. **Underground Test Results of a Laser-Based Tram Control System for a Continuous Miner**, by Anderson, Donna Lynne. 1992. 10 pp. 10 figs. This report documents the status of a laser-based underground guidance system for tracking and controlling the movements of underground mobile mining equipment. The first section of this report includes details of the laser sensors, communication network, and computer hardware. The next section includes experimental results, which show the system capable of accurately tracking and controlling the tram maneuvers of a continuous miner underground. The final section discusses conclusions and recommendations.

RI 9441. **Design of an Experimental Electric Arc Furnace**, by Hartman, Alan D.; Ochs, Thomas L. 1992. 9 pp. 8 figs. Instabilities in electric steelmaking furnace arcs cause electrical and acoustical noise, reduce operating efficiency, increase refractory erosion, and increase electrode usage. The U.S. Bureau of Mines is investigating methods to stabilize these arcs. To perform experiments to test new hypotheses, Bureau researchers designed and instrumented and advanced, experimental single-phase furnace. This report describes this furnace, which was equipped with high-speed data acquisition capabilities for electrical, temperature, pressure, and flow-rate measurements; automated atmosphere control; ballistic calorimetry; and view ports for high-speed cinematography.

RI 9442. **Dewatering of Alaska Placer Effluent Using PEO**, by Sharma, Sandeep K.; Scheiner, B.J.; Smelley, A.G. 1992. 10 pp. 7 figs. The U.S. Bureau of Mines has been investigating new techniques to improve the dewatering of mineral slurries, to recover water lost in the waste slurry, and to produce dewatered solids suitable for disposal. As part of this investigation, a study was undertaken to investigate the feasibility of dewatering Alaska placer effluent. Based on the laboratory tests, preliminary field tests were conducted on three placer mines in Alaska. In the second year of the project, a large-scale dewatering unit was set up at a mine located in the Livengood district. Feed to the dewatering unit generally ranged between 300 and 26,500 NTU and required PEO dosages of 0.02 to 0.14 lb per 1,000 gal to produce water from the screen underflow with turbidities of 20 to 50 NTU.

1993

RI 9443. **A General Design and Implementation Procedure for Sensor-Based Electrical Diagnostic Systems for Mining Machinery**, by Kohler, J.L.; Sottile, J. 25 pp., 11 figs. March 24, 1993. Component failures in the electrical control circuits of mining machines account for a large percentage of the total downtime of the machine. Once a failure has occurred it is always a tedious and usually a time-consuming task to locate the failed component. Moreover, the pressure to quickly locate the cause of a delay can lead to compromises in safety. Thus an onboard diagnostic system, essential for an automated machine, would be a very useful addition to existing machines. This report details U.S. Bureau of Mines development of a generic procedure for synthesizing diagnostic systems for electrical-control-circuit failures in mining machinery. A continuous mining machine is used as the testbed to illustrate the application of the developed methodology. Substantive differences among mining machine control circuits made it impossible to achieve a generic diagnostic system, but a generic approach for the synthesis of the diagnostic system was possible. As the research progressed, it became apparent that an algorithmic approach was better than an expert-system-based implementation. A prototype system was constructed and used to evaluate the diagnostic system. Prototype implementation issues are also examined.

RI 9446. **In Situ Stress Measurements Near the Ross Shaft Pillar, Homestake Mine, South Dakota**, by Johnson, J.C.; Pariseau, W.G.; Scott, D.F. 17 pp., 11 figs. 1993. In situ stresses are important input data for the design of safe, stable stope layouts and extraction sequences. However, it is commonly assumed that normal and shear stress gradients in a stress field are negligible and, consequently, that stresses are uniform throughout the region of analysis. To evaluate these assumptions and to provide input for an analysis of a shaft pillar mining plan, in situ stresses were measured at the Homestake Mine, Lead, SD. The results showed that normal stresses within the shaft pillar were less than, but comparable to, those estimated from finite-element modeling. Shear stresses were an order of magnitude less than normal stresses and varied considerably from site to site. Possible causes of this variability

include effects of scale, elastic moduli, ansotropy, and axial strain. Because of the variability, it is not possible to determine the magnitude of horizontal stress gradients.

RI 9447. Estimation of Shear Strength Using Fractals as a Measure of Rock Fracture Roughness, by McWilliams, P.C.; Kerkering, J.C.; Miller, S.M. 36 pp. 17 figs. March 18, 1993. Researchers at the Bureau of Mines investigated the use of close-range photogrammetry and subsequent stereo digitizing to obtain data from rock fracture roughness profiles. The photogrammetric process yielded results that were acceptable but somewhat inferior to those obtained by a mechanical profilometer. On the basis of this study, further pursuit of photogrammetry as a data collection method in mining is proposed. Fractal geometry was investigated as a means of measuring the roughness of rock fracture profiled. Four fractal algorithms were used: divider method, modified divider method, box method, and spectral method. A comparison of the methods gave ambiguous results. Brown's modified divider method provided the best means of obtaining the fractal dimension. Shear strength estimates were obtained using the parameters of the modified divider method and Myers' Z2 measure. Because of differences in results when comparing the different ways of obtaining the fractal dimension, future users of fractals in studies of rock fractures are advised to cross-check their results carefully.

RI 9448. Seismicity and Stress Changes Subsequent to Destress Blasting at the Galena Mine and Implications for Stress Control Strategies, by Boler, F.M.; Swanson, P.L. 21 pp., 19 figs. 1993. The U.S. Bureau of Mines conducts research at the Galena Mine, Wallace, ID, with the aim of mitigating the effects of rock bursting. Destress blasting is commonly used as a stress control technique at the mine. A digital seismic array and an array of borehole pressure cells (BPC's) had been installed near the site of a stope undergoing mining and periodic destressing. The instrumentation was being monitored at the time of a destress blast of the 46-99 stope. No significant seismic events occurred coincident with the destress. However, the destress was followed by a 2 1/2-week period of increased seismic activity, including two damaging events on February 7, 1990, at 034500 (hour, minute, and second) and 122020 Pacific standard time. BPC measurements indicated coseismic ground pressure changes on the order of 200 to 300 kPa associated with the damaging events. Fault plane solutions and dislocation models established that stress changes induced by the event at 034500 may have been significant in promoting the occurrence of the event at 122020. Theoretical investigations suggest that applying knowledge of the existing field, an understanding of rock burst mechanics, and fracture mechanics principles can improve destress effectiveness.

RI 9449. Magnetic Susceptibility of Minerals in High Magnetic Fields, by Dahlin, D.C.; Rule, A.R. 15 pp., 8 figs. 1993. The U.S. Bureau of Mines investigated the magnetic susceptibility of minerals as a function of magnetic field strength to determine how it might affect the potential for high-field magnetic separation as an alternative to other separation technologies. Single-mineral concentrates were prepared from specimens from the same deposit to compare magnetic susceptibilities of minerals that occur together and from specimens from different deposits to compare magntic susceptibilities of like minerals. A vibrating-sample magnetometer with a superconducting magnet capable of producing a magnetic field of 7.16 X 10^6 A/m (90 kOe) was used to measure the magnetic moment of the samples. The data were then converted to specific magnetic susceptibility data and plotted as a function of magnetic field strength. Cursory studies were also completed on the effects of iron content and oxidation roasts on magnetic susceptibility in high fields. The results showed that magnetic susceptibility is essentially constant in magnetic fields above those needed to saturate ferromagnetic constituents. Although magnetic susceptibility is influenced by iron content and by thermal treatment, the changes are not large enough to influence separations in fields above 1.59 X 10^6 A/m (20 kOe)

RI 9452. Characteristics of Ultrasonic Ranging Sensors in an Underground Environment, by Strickland, W.H.; King, R.H. 39 pp., 35 figs. April 9, 1993. Ultrasonic ranging sensors are inexpensive, have no moving parts, have no lenses to clean, are normally small and unobtrusive, and can measure distances through moderate amounts of dust, smoke, and humidity, so they are well suited to underground mines. In the work reported here, conducted by the U.S. Bureau of Mines, researchers tested ultrasonic ranging sensors for their ability to define rib line features for computer-aided navigation of underground mine mobile equipment. The investigation began with laboratory tests of field of view, angle of incidence, intersensor variation, and ranging accuracy of the individual rangers in a ring array produced by Denning Robotics of Wilmington, MA. The results showed that the sensors have good accuracy and low variability. Additional experiments at AMAX's Henderson Mine showed the sensors could accurately and reliably measure the distance to mine features, including convex and concave corners and rib intersections. The results showed that when used properly, the ranger data are accurate enough for reliable mine vehicle navigation. When used incorrectly, ultrasonic rangers do not provide the anticipated data. Therefore, this report explains the principles of ultrasonic range measurement, describes the ranger's strengths and weaknesses, and explains proper ranger use and data analysis.

RI 9453. Rare-Earth Occurrences in the Pea Ridge Tailings, by Vierrether, C.W.; Cornell, W.L. 10 pp., 10 figs. March 18, 1993. Tailings from the Pea Ridge iron mine contain significant amounts of apatite, which has rare-earth element values associated with it. In association with the recovery of rare-earth minerals as a secondary resource, the U.S. Bureau of Mines conducted an investigation on the recoverability of the rare-earth minerals from the tailings. The mill tailings were subjected to a phosphate flotation to separate the apatite from other constituents. More than 70-pct recovery of the rare-earth values was achieved. Based on mineralogical characterization and prior analysis of rare-earth-bearing breccia pipe material at Pea Ridge, it is proposed that processing this phosphate concentrate on a vanner table would yield up to a 95-pct recovery of the rare earths in the concentrate, with the apatite reporting to the tailings. Intensive ore microscopy studies of the original tailings to the flotation products led to the identification of monazite, xenotime, and rare-earth-enriched apatite as the major rare-earth-bearing minerals in the tailings.

RI 9454. Vibration Testing of Off-Road Vehicle Seats, by Gagliardi, John C.; Utt, Walter K. 25 pp., 24 figs. April 9, 1993. The U.S. Bureau of Mines, in cooperation with Carter Mining Co., conducted vibration tests of four off-

road vehicle seats. The purpose of the tests was to determine which seat provided the best vibration attenuation under laboratory conditions. Laboratory tests were constructed to simulate the mining vibration environment within the limitations of the test equipment. The acceleration test levels and corresponding response of the seats were low compared to ISO 2631's fatigue-decreased-profociency time limits. Two of the seats employed mechanical suspensions and two seats employed air suspensions. The seats were tested using a 22,241-N (5,000-IBF) electrodynamic shaker. Mechanical suspension seats were tested with various preload-to-mass ratios (PMR's) and cushion densities. Air suspension seats were tested with various air pressure levels and seat cushion densities. Air suspension seats provided good vibration attenuation if pressurized greater than 552 kPa (80 psi). Mechanical suspension seats' attenuation performance decreased if the PMR exceeded 9.8. Seat cushions of lower density provided less vibration damping.

RI 9456. **A Simple and Accurate Method for Calculating Viscosity of Gaseous Mixtures**, by Davidson, Thomas A., 12 pp., 4 figs. April 2, 1993. The Bureau of Mines Helium Field Operations has developed a simple and accurate method for calculating the viscosity of gas mixtures. Only the composition of the mixture and the molecular weights and viscosities of the pure components in the mixture are required. The momentum fraction is calculated from the composition. The fluidity is calculated as a quadratic function of the momentum fractions. The efficiency factor for transfer of momentum in collisions between bodies of different masses is derived and used with one empirical constant. The viscosity is the reciprocal of the fluidity. Results of the method are compared with 752 reported viscosities for 40 dilute binary systems at temperatures from −78 to 276.9 C. Using this method the average absolute deviation is 1.29%, the root-mean-square deviation is 1.99%, and the average deviation is −0.84%.

RI 9457. **Predicting Flow Characteristics of a Lixiviant in a Fractured Crystalline Rock Mass**, by Miller, Nadia C. 1993. 24 pp. 35 figs. In situ metals research to characterize the hydrology of a fractured crystalline rock mass in underground mine stopes is discussed. The objective of this study was to find the potential direction, velocity, and concentrations of a lixiviant plume, should leaching solvents (lixiviants) escape from a test stope. The study was conducted by the U.S. Bureau of Mines at the Colorado School of Mines Experimental Mine in Idaho Springs, CO. Since this was a method evaluation site, the lixiviant was simulated using water and acceptable tracers. The site is located in moderately fractured Precambrian migmatite-biotite gneisses of the Idaho Springs Formation. The data required for the characterization were obtained from geologic maps and reports, core logs, and air and water permeability tests. The acquired data were analyzed and applied to a computer model that calculated the characteristics of a lixiviant plume originating at the stope. A sensitivity analysis showed that dispersivity, ground water velocity, fracture porosity, and fracture spacing had notable effects on the concentration of the plume. Assuming a saturated rock mass, the lixiviant plume would disperse to undetectable levels in a very short time because of a high fracture density at the mine site.

RI 9459. **The Effect of Ventilation on the Water Spray Pattern of Automatic Sprinkler Heads**, by Smith, A.C.; Ryan, M.W.; Pro, R.W. 1993. 14 pp. 6 figs. The U.S. Bureau of Mines conducted a study to evaluate the effect of ventilation on the water spray patterns of automatic sprinkler heads. Experiments were performed in a rectangular tunnel with pendent, upright, pendent sidewall, and horizontal sidewall sprinkler heads at air velocities of 0, 150, 300, 500, and 800 ft/min. As the air velocities were increased, there were significant shifts in the total coverage areas, density distribution patterns, and the maximum coverage densities for all types of heads. The pendent and upright heads exhibited upstream shifts in total coverage in the direction of the airflow ranging from 4 to 6 ft, while the downstream coverage distances were extended up to 14 ft at the 800 ft/min airflow. The shift in upstream coverage distance for the sidewall heads ranged from 6 to 12 ft, while the downstream coverage was extended up to 22 ft at 800 ft/min. The results showed that airflow can have a significant effect on the coverage characteristics of automatic sprinkler heads and needs to be considered in the design of effective sprinkler fire suppression systems for ventilated areas.

RI 9460. **Innovative Method for Casting Steel Armorplate**, by Turner, Paul C.; Hansen, Jeffrey S. 1993. 9 pp. 6 figs. The U.S. Bureau of Mines, through an Interagency Agreement with the U.S. Tank-Automotive Command (TACOM), has successfully developed a steel expendable pattern casting process (EPC) for the manufacture of armorplate. The new armor is lighter and more ballistically effective than conventional rolled homogeneous armor (RHA), and costs less. An applique armor spinoff from the program was field-tested during the Gulf War. The applique armor withstood direct impacts from enemy munitions without failure.

RI 9461. **Biosorption of Metal Contaminants Using Immobilized Biomass: Field Studies**, by Jeffers, T.H.; Bennett, P.G.; Corwin, R.R. 1993. 10 pp. 3 figs. The U.S. Bureau of Mines has developed porous beads containing immobilized biological materials such as sphagnum peat moss for extracting metal contaminants from waste waters. The beads, designated as BIO-FIX beads, have removed toxic metals from over 100 waters in laboratory tests. These waters include acid mine drainage (AMD) water from mining sites, metallurgical and chemical industry waste water, and contaminated ground water. Following the laboratory studies, cooperative field tests were conducted to evaluate the metal adsorption properties of the beads in column and low-maintenance circuits, determine bead stability in varied climatic situations, and demonstrate the beads' potential as a viable waste water treatment technique. Field results indicated that BIO-FIX beads readily adsorbed cadmium, lead, and other toxic metals from dilute waters; effluents frequently met drinking water standards and other discharge criteria. The beads exhibited excellent handling characteristics in both column and low-maintenance circuits, and continued to extract metal ions after repeated loading-elution cycles. Based on laboratory and field data, cost evaluations for using BIO-FIX technology to treat two AMD waters were prepared. Operating costs for BIO-FIX treatment, which ranged from $1.40 to $2.30 per 1,000 gal of water treated, were comparable with chemical precipitation costs.

RI 9462. **A Method to Eliminate Explosion Hazards in Auger Highwall Mining**, by Volkwein, Jon C.; Ulery, James P. 1993. 14 pp. 8 figs. The U.S. Bureau of Mines investigated a method of using inert gas to prevent the formation of explosive gas mixtures in auger highwall mining of coal. A combination of gasoline and diesel engine exhaust

gases was introduced into auger drill hole using a short section of pipe located at the collar. Gas samples were taken and analyzed on-site with infrared detectors for oxygen, carbon dioxide, methane, and carbon monoxide. Evacuated bottle samples were also taken and analyzed by gas chromatography in the laboratory. These gas results were analyzed for explosibility. Coal samples from various depths were used to obtain the gas content of the coal using the modified direct method. Personal exposure to carbon monoxide was also monitored. The highest methane level observed was 9.55%. The levels of inert gas (carbon dioxide and nitrogen) were sufficiently high to prevent any ignition of the methane. Results showed that for all conditions during mining, gas concentrations were nonexplosive. The gas content of the coal was about 0.30 cm3/g. The maximum personal time-weighted average sample for carbon monoxide was 20 ppm. This system provides a safe, inexpensive, simple method for preventing explosions during auger mining.

RI 9458. Behavior of Simulated Longwall Gob Material, by Pappas, Deno M.; Mark, Christopher. 1993. 39 pp. 37 illus. This report presents results of a U.S. Bureau of Mines study of longwall gob material. The objective of this work was to determine material stiffness properties of the gob for use in numerical models of rock mass response to longwall mining. Photographs of actual mine gob were digitized to obtain approximate particle size gradations of gob material. The gradation curve was shifted down to a laboratory scale, and 20 uniaxial compression tests were conducted. Varying the maximum particle size was not found to affect the stress-strain behavior, but changing the gradation appeared to influence that behavior. The stress-strain relationship of the simulated gob material was nonlinear, the stress-secant-modulus relationship was approximately linear, and the stress-tangent-modulus relationship was approximately a second-order polynomial function. Equations were generated from these curves, providing numerical modelers with a means to estimate gob moduli based on the stress level. In addition, the experimental data were statistically evaluated using multiple regression analyses, producing a series of equations to predict the secant and tangent moduli from the given stress level, bulking factor, rock strength, and thickness-to-width shape ratio of the particles.

RI 9463. Thermal Modeling of Portable Power Cables, by Yenchek, Michael R.; Cole, Gregory P.; Edwards, John C. 1993. 19 pp. 15 illus. The U.S. Bureau of Mines investigated the performance of portable power cables under transient conditions. This research had a twofold purpose: (1) to define the thermal characteristics of electrically overloaded trailing cables, and (2) to conceptualize electrical protection for cables that allows maximum cable efficiency without diminishing electrical safety in underground mines. Several tasks were undertaken in support of these goals during the 3-year research effort. Overload tests ranging from 2 to 12 times rated ampacity were conducted in the Bureau's Mine Electrical Laboratory. Two thermal models of energized type G-GC trailing cables were constructed, one based on thermodynamic theory and the other using empirical data from previous Bureau load tests. The empirical model was then incorporated into an interactive computer program that can assist designers and approvers of mining machines in selecting the appropriate size trailing cable. This program can be the basis for a cable protection system that ensures that cables are not the source of fires, ignitions, burns, or explosions underground.

RI 9464. Selective Electrowinning of Silver and Gold from Cyanide Process Solutions, by Nehl, F.H.; Murphy, J.E.; Atkinson, G.B. 1993. 7 pp. The U.S. Bureau of Mines investigated the selective electrowinning of Ag and Au from cyanide solutions contaminated with Cu, with the goal of decreasing the amount of Cu codeposited. Decreasing Cu codeposited will reduce refinery costs. Direct current was applied to the cell in pulsed and square wave voltages at 0.070 A–h per 150 mL of solution. Times tested for each cycle ranged from 1 to 10,000 ms. Graphite, lead, and stainless steel were evaluated as electrode materials. Square wave electrowinning at 70 degrees C gave the best separation of Ag and Au from Cu. Applying 2.5 V during the duty cycle, 0.0 V the rest of the period, a duty cycle to 10 to 30 pct, and a period of 100 to 1,000 ms gave the following results: Ag concentrations decreased from 34 to 0.1 micro-g/mL, Au concentrations decreased from 54 to 0.2 micro-g/mL, and Cu concentrations remained almost constant at 560 micro-g/mL.

RI 9465. Hexagonal Phase Transformation in the Engineered Scavenger Compound Lithium Titanate, by Collins, W.K.; Riley, W.D.; Jong, B.W. 1993. 11 pp. 9 illus. Engineered scavenger compounds (ESC's) developed by the U.S. Bureau of Mines are a novel class of compounds that selectively can recover a desired element from a solid or molten alloy. Lithium titanate ($Li_2Ti_3O_7$ or $Li_2O–3TiO_2$) is used as an ESC to recover lithium (Li) from aluminum-lithium (Al-Li) alloys. X-ray diffraction measurements have shown that $Li_2Ti_3O_7$ undergoes a phase change during scavenging from an orthorhombic structure to a hexagonal structure. This change is due to the incorporation of lithium in the matrix of the material and the effect of temperature. Although both phases are metastable, the hexagonal phase that forms during the scavenging of lithium from Al-Li alloys appears to be the more stable phase. Recovering lithium from the ESC by electrodeposition does not cause the structure to revert to the orthorhombic phase. The orthorhombic and the hexagonal structures of $Li_2Ti_3O_7$ have similar scavenging capacities for lithium. This report proposes a new mechanism for the phase transformation.

RI 9466. Wire Rope Research: Analysis of Bending Fatigue in a 2-inch IWRC Wire Rope, by Miscoe, A.J.; McKewan, W.M. 1993. 14 pp. 17 illus. A unique machine for inducing bending fatigue in wire ropes was built at the U.S. Bureau of Mines' Pittsburgh Research Center. This machine can produce nine levels of degradation through repetitive cycling of long samples of wire ropes of the types used in the mining industry. This report provides an analysis of the results of the first wire rope to be fatigued on this machine. These results have indicated that as a wire rope accumulates bending cycles, its strength first decreases because of wear and then increases due to cold working of the wires. As the amount of cold working increases, more and more of the embrittled wires break and the strength of the rope decreases rapidly. In this test, application of several of the regulatory retirement criteria to various sections of the rope suggests that there may be some inconsistency among them.

RI 9467. Improved 6.8-L Furnace for Measuring the Autoignition Temperatures of Dust Clouds, by Conti, Ronald S.; Cashdollar, Kenneth L.; Thomas, Richard A. 1993. 26 pp. 23 illus. A new U.S. Bureau of Mines 6.8-L ignitability furnace was used to study the thermal

autoignitability of dust clouds. This furnace has a quartz window to allow observation of the early stages of the ignition process and to allow measurement of the dust explosion temperature. Thermal ignitability data were obtained for various carbonaceous and metal dust clouds, with particular emphasis on various ranks of coal dusts. One of the reasons for the construction of the new 6.8-L furnace was to evaluate the effect of chamber volume on the measured autoignition temperatures. Therefore, data from the 6.8-L furnace were compared with data measured earlier in a 1.2-L furnace. The conclusion is that the autoignition temperatures measured in the 6.8-L furnace were only slightly lower on average than those from the 1.2-L furnace. These data on the minimum autoignition temperatures of various materials will be useful in analyzing the thermal ignition hazards of dust clouds in the mining industry and other industries that manufacture, process, or use combustible dusts.

RI 9469. **Reducing Respirable Dust Concentrations at Mineral Processing Facilities Using Total Mill Ventilation Systems**, by Cecala, Andrew B.; Klinowski, George W.; Thimons, Edward D. 1993. 11 pp. 11 illus. The U.S. Bureau of Mines has designed and evaluated total mill ventilation systems at two different mineral processing operations. Both systems have proven very effective at reducing respirable dust levels throughout the mill in a cost-effective manner. A 25,500-cfm system installed at a clay processing mill provided approximately 10 air changes per hour. This system reduced respirable dust concentrations by approximately 40 pct throughout the mill building. The second evaluation was performed at a silica sand operation. Tests were performed with 50,000 and 100,000 cfm of ventilation to the mill building, corresponding to 17 and 34 air changes per hour. Average mill-wide respirable dust reductions were 36 and 64 pct, respectively. Not only did these systems reduce respirable dust concentrations and increase visibility throughout the mills, they were also easy to install and required minimal maintenance. A total mill ventilation system provides a general purging of the mill air; the system should be viewed as a supplemental technique to assist other dust control systems in operations.

RI 9468. **Neutralization of Acidic Discharges From Abandoned Underground Coal Mines by Alkaline Injection**, by Aljoe, William W.; Hawkins, Jay W.; 1993. 37 pp. 40 illus. The hydrologic characteristics of two abandoned underground coal mine sites, near Latrobe, PA, and Uniontown, PA, were investigated by the U.S. Bureau of Mines for possible implementation of alkaline injection into the mine pools as a means of abating their acid discharges. The Latrobe site was chosen for a one-time application of alkaline injection to achieve a partial, short-term neutralization of a limited portion of the mine pool. A quantity of alkaline reagent (sodium hydroxide) sufficient for a one-time neutralization of the water in this portion of the pool was added. Although nearly all of the neutralizing reagent had moved away from the injection wells within 6 weeks, no evidence of neutralization was noted at the mine discharge during the study period. This lack of neutralization probably occurred because the injection wells did not intercept a primary flow path through the mine. Criteria for successful application of alkaline injection at this or other sites include (1) positive identification of the primary flow paths through the mine pool and (2) addition of quantities of alkaline reagent sufficient to neutralize the entire volume of the pool along the primary flow path.

RI 9470. **Geologic Investigations Near an Underhand Cut-and-Fill Stope, Lucky Friday Mine, Mullan, ID**, by Scott, Douglas F. 1993. 21 pp. 16 illus. Researchers from the U.S. Bureau of Mines conducted, in an area of the Lucky Friday Mine, Mullan, ID, geologic investigations that included the 5300-107 demonstration stope using underhand longwall cut-and-fill mining. Structural analysis of the area suggested that argillite beds form planes of weakness between blocks of brittle quartzite, and energy may be released along these planes and at the junctures of fractures. Mapping argillite beds and fractures in the stope wall rock showed that the planes of these features diverged, and that their attitudes corresponded from one wall to the other. Seismic analysis showed that the number and location of events varied as each cut was mined, with about 39 pct of the total number of events occurring above the cut being mined, about 54 pct below, and 7 pct at the same elevation.

RI 9471. **Transverse-Mounted End-Cab Design for Low Coal Shuttle Cars**, by Mayton, Alan G. 1993. 19 pp. 2 illus. A prototype end-cab shuttle car (SC) design has been developed to improve protection and address ergonomic concerns of the SC operator in low coal mines. The new design features an end cab transversely mounted to the SC and equipped with a closed-circuit video system. The end cab was retrofitted to a low-coal SC and evaluated in surface trials at the U.S. Bureau of Mines. During surface trials, test operators evaluated the end-cab SC relative to visibility; cab features—space, seating, controls, and operator position; tramming—inby, outby, and turning corners; and dumping. Trials were conducted using 12 test subjects; 6 were experienced SC operators. Results of the trials were promising. Of the experienced operators, the only operator with low-coal experience gave the new design the highest rating. Four experienced operators rated the end-cab design "better" to "much better" than a standard center-driven, side-cab SC for visibility when tramming, protection from roof and rib hazards, and no change in seat position with direction of travel. This report discusses research to modify a used 21SC JOY SC, retrofit the SC with the Bureau-developed end-cab, and evaluate the retrofitted end-cab SC in surface trials.

RI 9472. **Hydrometallurgical Production of Copper from Flotation Concentrates**, by Cobble, J.R.; Jordan, C.E.; Rice, D.A. 1993. 14 pp. 11 illus. Dissolution of chalcopyrite with acidified ferric sulfate produces a sulfur layer on the unreacted chalcopyrite surface that interferes with further dissolution. The U.S. Bureau of Mines has developed a process to improve the leaching kinetics of these types of diffusion-controlled systems. The system features the Bureau-developed turbomill, an attrition grinder that scrubs the reaction product coating away from the unreacted mineral grains during leaching. The system can be operated continuously at any temperature up to the boiling point of the leaching agent. This method is a hydrometallurgical alternative to chalcopyrite smelter technology and eliminates sulfur dioxide emission problems with their associated costs. Batch testing at 90° C with the chalcopyrite-ferric sulfate system resulted in copper extraction exceeding 99 pct. At an optimal energy consumption of 1,520 kW–h/st, 95 pct of the copper was extracted. The pregnant liquor was clarified and tested for typical solvent-extraction recovery of the copper. Two-stage extraction and two-stage stripping recovered 96 pct of the copper in an electrolyte suitable for copper electrowinning.

RI 9473. Use of Oxygen-Enriched Gas for the Oxidation of Acid and Fluxed Taconite Pellets, by Haas, Larry A.; Nigro, John C.; Moe, Robert C. 1993. 22 pp. 24 illus. The U.S. Bureau of Mines, in cooperation with Cleveland-Cliffs, Inc. (Hibbing, MN), investigated ways of enhancing the quality (compressive strength, after-tumble, and reducibility) of domestic acid and fluxed magnetic pellets by modifying the oxygen content during the preheat and induration periods of the firing operation. Oxidation of magnetite was best accomplished when sufficient oxygen and time were available before the peak induration temperature was reached. The rate of magnetite oxidation increased directly with the gas oxygen content during the preheat period at 700° C and above. With 30 pct (or more) O_2 and a preheat rate 200° C/min, most of the magnetite was oxidized during the preheat period. With laboratory tube and mini-pot furnace tests, oxygen enrichment during the preheat period improved the pellet properties more in the simulated grate-kiln tests than in the simulated straight-grate tests. The longer induration period with the grate-kiln test resulted in more sintering of the residual magnetite and its reaction with the silicon compounds. When flux was present in the pellets, calcium silicates and calcium and magnesium ferrites were formed. More calcium ferrite was formed when the magnetite was oxidized early and less iron was present in the fayalitic calcium silicate slag.

RI 9474. Field Evaluation of Cable Bolt Supports, Homestake Mine, Lead, SD, by Goris, J.M.; Brady, T.M.; Martin, L.A. 1993. 28 pp. 36 illus. The U.S. Bureau of Mines, in a cooperative project with the University of Utah, Salt Lake City, UT, and Homestake Mining Co., Lead, SD, conducted in situ monitoring and numerical modeling of rock masses supported with cable bolts in two mechanized, cut-and-fill stopes and a shaft pillar at the Homestake Mine. Extensometers were used to measure rock displacement, while cable bolt strain gauges were installed to measure loads on both conventional and birdcage cable bolt supports. These instruments provided an assessment of rock mass behavior during mining as well as essential data for verifying results from computer analyses. The numerical modeling program FLAC was used to analyze cable patterns and supports. Results from the evaluation study indicated that cable bolt strain gauges and extensometers were effective instruments for monitoring the behavior of rock masses supported with cable bolts. Also, numerical modeling of the 45-48N stope using the FLAC code provided displacement values comparable to measurements from field extensometers.

RI 9475. Recent Progress in Discriminating Between Coal Cutting and Rock Cutting with Adaptive Signal Processing Technologies, by Pazuchanics, Michael J.; Mowrey, Gary L. 1993. 15 pp. 10 illus. This report documents the current status of the U.S. Bureau of Mines' ongoing investigation of the use of adaptive signal discrimination (ASD) systems to distinguish between cutting coal and cutting rock. Cutting-tool forces and vibrations were measured in the laboratory, using both conical bits and roller cutters in a linear-cutting apparatus for several materials samples and two cutting directions. A number of ASD systems consisting of one or more signal classifiers were trained and tested to study how data window size, type of signal feature, and combining (polling) of classifier results influence system performance. The results show that ASD system recognition rates can be improved by increasing data window size, removing air-cutting portions from the signal data, overlapping data windows, and combining (fusing) information at various levels of ASD system operation.

RI 9476. Facility for Melting Residues from Municipal Waste Combustion: Design Criteria and Description of Equipment, by Hartman, Alan D.; Oden, Laurance L.; White, Jack C. 1993. 10 pp. 11 illus. The U.S. Bureau of Mines, under a Memorandum of Agreement with the American Society of Mechanical Engineers (ASME), established design criteria for a facility to melt residues from municipal waste combustion. This facility, which is available to potential users on a cost-sharing basis, is also applicable to a variety of inorganic waste materials from smelting or melting operations. The design consists of a mechanical feed handling system, electric arc melting furnace, fume-offgas handling system, and thermal oxidizer for final offgas treatment. Screw conveyors and a bucket elevator deliver up to 2,000 lb/h of minus 1-in material to a three-phase electric arc melting furnace. This unique 800-kV–A furnace has a water-cooled shell and roof to minimize interaction of the melt with the refractory lining. The volume of the hearth below the slag taphole is approximately 1.2 st of steel. The furnace is sealed, allowing atmosphere control within the furnace and fume duct by nitrogen or inert gas injection. A jet-pulsed baghouse removes particulate from the offgas and serves as an acid gas scrubber. The clean offgas is heated to 1,800° F for 1 s in a propane-fired thermal oxidizer before being vented to the atmosphere.

RI 9477. Strength Characteristics and Air-Leakage Determinations for Alternative Mine Seal Designs, by Weiss, E.S.; Greninger, N.B.; Stephan, C.R. 1993. 21 pp. 17 illus. The U.S. Bureau of Mines and the U.S. Mine Safety and Health Administration (MSHA) are participating jointly in a research program to evaluate the strength characteristics and air-leakage resistance of various proposed seal designs for use in underground coal mines. The full-scale seals were constructed in the USBM's experimental mine at the Lake Lynn Laboratory, air-leakage tested, then subjected to pressure pulses of 20 psig or greater. In experiments prior to this study, seven seal designs using solid-concrete blocks were tested. Only the standard-type seal passed the explosion and air-leakage criteria. Tests also were performed on four seals constructed with low-density foam blocks. All four of these seals designs withstood the pressure pulse. In more recent studies, nine cementitious foam seal designs of varying thicknesses and densities were investigated. Six of the nine designs successfully survived the explosion overpressures. Six wood-block convergence seals also have been tested. The typical 3-ft-thick, wood-block seal design currently used in many coal mines did not maintain its integrity, in the absence of convergence forces, following the explosion test. Five modified wood-block seals successfully withstood the 20-psig pressure pulse. Based on these tests, three alternative seal construction materials, cementitious foam, low-density foam block, and wood, have been approved by MSHA for use in underground coal mines.

RI 9478. Evaluation of Catalyzed Diesel Particulate Filters Used in an Underground Metal Mine, by Baz-Dresch, John J.; Bickel, Kenneth L.; Watts, Jr, Winthrop F. 1993. 13 pp. 9 illus. Catalyzed diesel particulate filters (CDPF's) reduce the concentration of diesel particulate matter (DPM) and may reduce the emissions of carbon

monoxide (CO) and hydrocarbons (HC) in diesel exhaust. Asamera Minerals' Cannon Mine first installed CDPF's in 1987, and currently has 12 diesel powered vehicles equipped with these filters. The Cannon Mine and the U.S. Bureau of Mines collaborated to evaluate the durability and performance of a CDPF. One used at the mine was periodically evaluated in the USBM's diesel emissions laboratory after 839, 1,584, and 2,881 h of in-mine service. The objectives of this report are to present results from the USBM's evaluation of this CDPF, to describe the Cannon Mine's experience and cost analysis of using these filters and to make recommendations for their future use. CDPF's improve air quality at the Cannon Mine, but they frequently become plugged and are subject to excessive mechanical shocks and stress, shortening their useful life. Mine records indicate that CDPF's account for 0.8 to 4.9 pct of the vehicles' operating cost at the mine. Their life to date has ranged from 1,671 h to more than 5,992 h. Laboratory tests of the filter determined that DPM removal efficiency decreased and regeneration temperature increased over time.

RI 9479. **Effect of Ultralow Frequency Signaling on Blasting Array Current**, by Hjelmstad, Kenneth E.; Griffin, Russell E. 1993. 11 pp. 4 illus. The U.S. Bureau of Mines (USBM) has developed an electromagnetic (EM) fire warning alarm system for underground mines. The system generates a magnetic field for through-the-earth signal transmission to microreceivers carried by individual miners. EM fields can induce electric currents in metallic conductors; if an EM transmitting antenna and an electric blasting cap array are too close, the field could induce a current in the blasting array and cause an unintentional initiation of the electric detonators. The USBM conducted tests that define the safe and unsafe regions for using electric detonators near the transmitting antenna of the warning alarm system. The minimum safe distance between a transmitting antenna and a blasting array is the distance where the induced electrical current in the blasting array is 50 mA, which is the safe current level specified in Federal mine safety regulations. Tests indicate that at transmitting power levels of 100- and 1,000-W, separation distances of 9 and 21 m, respectively, were required. These distances are small compared with the dimensions of a mine. Thus, the tests indicate that, with proper placement of the transmitting antenna, the warning system can be used safely in the proximity of blasting arrays.

RI 9480. **Impact of Air Velocity on the Development and Detection of Small Coal Fires**, by Egan, Margaret R. 1993. 16 pp. 3 illus. The U.S. Bureau of Mines conducted experiments in the intermediate-scale fire tunnel to assess the influence of air velocity on gas production and smoke characteristics during smoldering and flaming combustion of Pittsburgh seam coal, and its impact on the detection of combustion products. On-line determinations of mass and number of smoke particles, light transmissions, and various gas concentrations were made. From these experimental values, generation rates, heat-release rates, production constants, particle sizes, obscuration rates, and optical densities were calculated. Ventilation has a direct effect on fire detection and development. The results indicate that, in general, increased air velocity lengthened the onset of smoke and flaming ignition, increased the fire intensity, but decreased the gas and smoke concentrations. Increased air velocity also lengthened the response times of all the fire sensors tested. Rapid and reliable detector response at this most crucial stage of fire development can increase the possibility that appropriate miner response (fire suppression tactics or evacuation) can be completed before toxic smoke spreads throughout the mine.

RI 9481. **Recycling of Neodymium Iron Boron Magnet Scrap**, by Lyman, J.W.; Palmer, G.R. 1993. 28 pp. 24 illus. The U.S. Bureau of Mines investigated methods of separating valuable rate-earth materials from Fe in neodymium iron boron (NdFeB) magnet scrap. A selective oxidation treatment of the scrap oxidized the rare-earth portion while leaving elemental Fe. Magnetic and leaching procedures were tried for separating the metallic Fe and rare-earth oxides, but the extremely fine grain size of the oxidized scrap prevented recovery by either technique. The best separation of rare earths from bulk NdFeB magnet scrap was obtained by dissolution with H_2SO_4 followed by precipitation of recyclable rare-earth salts. By precipitating neodymium-alkali sulfate double salts as an intermediate that can be converted to a variety of useful products, many materials-handling and economic disadvantages found with direct precipitation with fluoride or oxalate were avoided. Iron was removed from magnet leach solutions by precipitation as a jarosite, eliminating a major disposal problem. Research was also conducted with contaminated mixed $SmCo_5$ and NdFeB swarf. Using a flotation-leaching technique allows the $SmCo_5$ to concentrate in the froth, while the grinding-medium contaminant sinks and is removed as tailing. The NdFeB is dissolved by H_2SO_4 during the process.

RI 9455. **Blast Vibrations and Other Potential Causes of Damage in Homes Near a Large Surface Coal Mine in Indiana**, by Siskind, David E.; Crum, Steven C.; Plis, Matthew N. 1993. 62 pp. 27 illus. The U.S. Bureau of Mines studied seven homes near Evansville, IN that had various° of damage that the owners attributed to vibrations from surface coal mine blasting. Researchers monitored vibration and airblast impacts, crack behavior before and after blasts, and dynamic structural responses to blasting and other sources. Level-loop surveys were performed to quantify possible settlement and subsidence. These results were combined with State and coal company measurements to determine if recent vibration characteristics, airblast propagations, or structural responses were typical of results found in historical studies that produced criteria for safe blasting and regulatory limits. Researchers found that the blasting vibrations were occasionally of low frequency, down to 3 Hz, making them unusually noticeable. The low vibration amplitudes and lack of additional cracking and extensions during this study indicated that phenomena other than blasting were responsible for the structural damage observed in the study area. The nature of the damage, a soil evaluation, and information on soils from nearby southern Illinois suggest that expansive clays and/or highly erodible soils are primarily responsible for the foundation-related structural damage, with possible contribution from drainage and slope failure. Airblasts are likely responsible for homeowners' occasional and irregular high perceptibility of blasting.

RI 9482. **Calculation of Promotion Energies and Atomic Sizes for Atoms with Two Valence "S" Electrons: Supplement to Engel-Brewer Theory for Alloy Design**, by Woodyard, Jack R. 1993. 7 pp. 4 illus. Bonding angles, promotion energies, and relative atomic sizes can be estimated through the solution of a set of algebraic equations generated from simple atomic models, and quantum mechanical

parameters such as bond strength can be estimated from simple, hydrogenic forms-wave functions. The precepts of the Engel-Brewer Theory are melded with the Crystal Approximation Model to produce atomic-structure models making these predictions. The two-valence-electron case is presented in this report. For the candidate atoms Be, Mg, Ca, Sr, and Ba the calculated promotion energies agreed within a few percent of their experimental values. These atomic parameters determine the possible crystal structure of the candidate atoms when alloyed. This is part of the effort at the U.S. Bureau of Mines to develop methods for alloy design in response to requirements for new high-performance alloys that conserve critical or rare materials.

RI 9483. Vibration Environmental Testing for Large Haulage Trucks, by Gagliardi, John C.; Utt, Walter K. 1993. 12 pp. 2 illus. The size and complexity of modern surface haulage trucks has resulted in an increased reliance upon sensors and electronic-based instrumentation for safe and efficient operation. Design engineers need accurate information about the equipment vibration environment to efficiently and effectively build components for installation on mobile mining equipment capable of withstanding the mine environment. Examples of such components include backup alarms, communication equipment, microprocessor controllers, and a wide variety of sensors. Unfortunately, this information is not available to the majority of both original equipment and aftermarket equipment manufacturers. To address this problem, the U.S. Bureau of Mines performed field vibration measurements on a variety of surface mining haulage trucks. The vibration measurements were then analyzed and test specifications were developed in the form of envelopes. In conjunction with test specifications, recommendations to aid manufacturers in implementing a vibration environment test program have been included with an illustrative example.

RI 9485. An Instrumented Pneumatic Backfilling System, by Dyni, Robert C. 1993. 14 pp. 22 illus. The use of techniques and equipment designed to pneumatically place backfill into an underground mine opening through boreholes for subsidence abatement has historically met with limited success, largely due to the inability to directly monitor the placement of the backfill in the opening. The success of a backfilling project cannot be guaranteed if it is not known whether the underground opening has been completely filled with backfill material. To overcome the inability to directly monitor backfill placement, the U.S. Bureau of Mines developed a pneumatic backfilling system that allows for direct viewing of the backfill as it is placed in an underground mine opening. This system utilizes a recently developed pneumatic nozzle coupled with an instrumentation package that allows for real-time observations and measurements of backfill placed in an underground opening through a borehole. The nozzle utilizes a high-velocity airstream to redirect backfill falling through a pipe in the borehole and directly in front of the nozzle; the airstream redirects and propels the backfill horizontally into the mine opening at over 100 ft/s. The instrumentation package, mounted directly to the nozzle, contains a video camera, high-intensity lamps, laser-rangefinder, electronic compass, and water sensor.

RI 9487. A Data Acquisition and Analysis System for Nondestructive Testing of Wire Rope, by Ruff, Todd M. 1993. 7 pp. 8 illus. Current methods of inspecting wire rope for broken wires or excessive wear include visual inspection, physical measurements of rope diameter, and electromagnetic nondestructive testing (NDT). Visual inspection and physical measurement are the least comprehensive methods. Electromagnetic NDT enables a more thorough assessment of the condition of a wire rope, but the repeatability, accuracy, and objectivity of this method can be improved. One means of achieving this goal is to use a computer to analyze the test data and determine the condition of the wire rope, including the presence of broken wires and corrosion, and the amount of wear. An off-the-shelf data acquisition and analysis system was tested in a U.S. Bureau of Mines laboratory using a continuous loop of wire rope containing fabricated flaws. The test rope was run through a commercially available NDT instrument. The output of the instrument, normally connected to a paper strip chart recorder, was digitized and analyzed with a personal computer. These initial tests were successful in showing that the use of a computer can improve current methods of NDT waveform collection and analysis.

RI 9488. Chemically Induced Strength Changes in Sandstone, by Stroud, William P.; Dolinar, Dennis R. 1993. 12 pp. 7 illus. Chemical alteration of the compressive strength of sandstone has been investigated by the U.S. Bureau of Mines (USBM). Successful development of this technology would offer an attractive alternative to the methods now used for stress control in mines. Sandstone cores were stressed to failure under uniaxial compression at two different strain rates. Specimens saturated with either distilled or tap water showed an average 14% reduction in stress at failure compared with those dried in vacuum. Samples saturated with dilute solutions of aluminum chloride, hydrochloric acid, and polyethylene oxide showed no statistically significant difference in failure stress compared with those saturated with water. By contrast, compressive strength of the cores was increased some 7% by saturation with the nonpolar solvent carbon tetrachloride. No correlation was found between zeta potential and compressive strength.

RI 9489. Room-and-Pillar Mining in Bump-Prone Conditions and Thin Pillar Mining as a Bump Mitigation Technique, by Mucho, Thomas P.; Barton, Timothy M.; Compton, Craig S. 1993. 18 pp. 20 illus. Retreat or pillar recovery mining redistributes the overburden weight onto the adjacent coal pillars in a room-and-pillar section. The additional stress and the resultant energy stored in the remaining pillars can become so great that pillars may bump or violently fail. An investigation at the Gary No. 2 Mine was conducted to examine the effectiveness of the thin pillar mining method for mitigating bump occurrences. Field observations were made and instruments were installed to monitor pillar behavior during extraction. Stress monitor instruments and roof-to-floor-convergence stations were installed in pillars and entries and crosscuts, respectively. Results indicated that high pillar stress concentrations occurred in these bump-prone geologic conditions. The thin pillar mechanism, the creation and progressive outby movement of an expanded yield zone, was also monitored through the instruments. The expanded yield zone, a result of using thin pillars in a highly stressed pillar line area, mitigates bump risk.

SPECIAL PUBLICATIONS

When Government Printing Office or USBM stocks are exhausted, these reports may be available from the National Technical Information Service, as described elsewhere in this book. As of late 1993, most Special Publications are available only through the Government Printing Office sales program.

1992

SP 01-92. Availability of Federally Owned Minerals for Exploration and Development in Western States: Idaho, 1988, by Paul C. Hyndman, James Ridenour, W. Dean Crandell, and Clayton M. Rumsey. 1992. 56 pp. 12 figs. The U.S. Bureau of Mines inventoried Federal mineral lands in Idaho and classified them in detail, section by section, according to their availability for mineral exploration and development as affected by legal restrictions and agencies' management practices. The Bureau also identified known mineral deposit areas (KMDA's) and areas conducive to oil, gas, and geothermal resources. This information is shown on maps (developed in part by geographic information system, technology) that spatially compare the availability for mineral entry of Federal land with these KMDA's to demonstrate the extent and severity of restrictions on mineral entry. Idaho contains 53.1 million acres, 35.7 million (67 pct) of which is Federal mineral land. About 7 million acres of this land is within KMDA's that host medium- to high-value locatable mineral deposits; 36 pct of this land is available, 27 pct is slightly to moderately restricted, and 37 pct is severely restricted or unavailable. For the leasable minerals, about 1.8 million acres are within KMDA's that host medium- to high-value phosphate deposits, about 5.4 million acres are favorable for oil and gas resources, and 3.9 million acres for geothermal resources. The percentages of land availability are 30, 45, and 25 pct for the phosphate acreage, 38, 34, and 28 pct for the oil and gas acreage, and 43, 30, and 27 pct for the geothermal acreage.

SP 02-92. Minerals in 1992, by Staff, Office of Public Information. 1992. 70 pp. This publication, intended for general audiences, profiles 34 minerals that have been identified as highly important to the economy or defense of the United States and reviews such topics as minerals and the environment and recycling.

SP 03-92. Advancing the Industry, by Proceedings of the First National Minerals Policy Forum, 1992. 94 pp. In November 1991, the U.S. Department of the Interior and the Bureau of Mines sponsored a 1-day forum to begin developing an overall minerals policy for the Department of the Interior. These proceedings contain the views expressed by leaders of industry and Government on mineral policy issues on that occasion.

SP 04-92. Research 92, by Staff, Bureau of Mines, 1992. 175 pp. This edition of the Bureau of Mines' annual report of its information and research activities highlights such topics as assessing and improving the ability to escape mine fires, recycling of residues for mineral recovery, biotechnology, and Federal lands and minerals. It also provides an overview of the Bureau's accomplishments by program area during the past year and lists recent publications and patents that have resulted from Bureau investigations.

SP 05-92. Crystalline Silica Primer, by Staff, Branch of Industrial Minerals, . 1992. 49 pp. 14 figs. Following studies in the 1980'a that suggested that crystalline silica is a carcinogen the substance has been regulated under the Occupational Safety and Health Administration's Hazard Communication Standard (HCS). Because crystalline silica is an extremely common mineral and the HCS will affect many mineral commodities, it is important that there be as clear an understanding as possible of what is and what is not crystalline silica, where it is found and used, and how it is qualitatively and quantitatively identified. This primer is an attempt to accomplish this in as nontechnical a manner as possible.

SP 06-92. Of Rock and Ice. An Explorer's Guide to the Geology of Prince William Sound, Alaska, by Kurtak, Joseph. 1992. 27 pp. Geared to those intending to explore Alaska's Prince William Sound by kayak, but of general interest to those familiar with the area, this pamphlet explains its rock formations, its history of glaciation, and other aspects of its geologic story. The U.S. Forest Service participated in the publication of the pamphlet.

1993

SP 01-93. A Cost Comparison of Selected Coal Mines from Australia, Canada, Colombia, South Africa, and the United States, by International Staff, U.S. Bureau of Mines; Aug. 1993. 65 pp. Free from USBM.

SP 02-93. Directory of Mineral-Related Organizations, by Carrico, Linda; USBM. Nov. 1993, 122 pp.

SP 03-93. Recycled Metals in the United States: A Sustainable Resource, by Staff, USBM Division of Mineral Commodities; Oct. 1993. 76 pp.

SP 04-93. Metal Prices in the United States Through 1991, by USBM Branch of Metals, Branch of Industrial Minerals. 1993. 201 pp.

STATE MINERAL SUMMARIES

State Mineral Summaries **were launched in 1989 to give State data comparable to those in the** ***Mineral Commodity Summaries.*** **Copies of the current issue may be available GPO, or they can be found in USBM libraries.**

1992

SMS 92. **State Mineral Summaries 1992**, by Staff, Bureau of Mines. 153 pp. This report provides estimated data and summaries of mineral activities for each State for 1992. Most of the estimates are based on 9 months' data. The summaries were prepared in cooperation with State geological surveys or related agencies.

ARTICLES IN OUTSIDE PUBLICATIONS

The following are articles by U.S. Bureau of Mines personnel in non-Bureau publications. This list is not meant to be comprehensive, and may include some non-USBM coauthors. Copies of these articles are NOT available from the U.S. Bureau of Mines; please contact the journal or publisher listed here.

1992

OP 01-92. Automation To Control Silica Dust During the Pallett Loading Process, by A.B. Cecala and A. Covelli. Min. Eng., v. 43, No. 12, Dec. 1991, pp 1440-1443. Two recent U.S. Bureau of Mines studies evaluated workers' dust exposures in automated pallet loading processes. The first study involved a Bureau-designed dust control system using a push-pull ventilation technique. The unit was shown to reduce workers' dust exposures by 76 pct during pallet loading at a ground silica operation. A hydraulic lift table was used to automate the bag stacking process. This kept the loading height constant throughout the entire pallet loading cycle. The second study evaluated different commercial, automated-pallet loading systems. These systems automatically stack the bags onto pallets, shrink wrap the pallets, and deliver the pallets to a fork lift pickup location. Results from a ground silica evaluation site indicated respirable dust samples taken were below the Threshold Limit Value as established by the Mine Safety and Health Administration.

OP 02-92. Rinsing of Spent Precious Metal Ores for Heap Leach Decommissioning, by P.G. Comba and S.L. McGill. Ch. 31 in Environmental Management for the 1990's, ed. by D.J. Lootens, W.M. Greenslade, and J.M. Barker. SME, 1991, pp 225-231. Many gold-producing States are requiring rinsing of spent heaps to render the leached ore compatible with the environment and are placing restrictions on effluent pH, cyanide, and metals concentrations. Parameters that may affect efficient rinsing of heaps have been investigated by the U.S. Bureau of Mines in laboratory column studies. Rinse profiles for cyanide, metals, and pH as a function of the volume of water passed through the spent ore are presented. Fresh water rinsing of spent ore in columns showed that rinsing of cyanide was not affected by the rinse solution application rate. Interrupted rinsing with a rest period between applications reduced the volume of water required to meet effluent cyanide concentrations. Chemical oxidation of the effluent with recycle of the rinse solutions reduced effluent cyanide concentrations and the volume of waste solution generated. Water rinsing was not successful in reducing the alkalinity of the cement agglomerated ore. A dilute acid solution had to be applied after cyanide removal to reduce effluent pH levels to specified limits.

OP 03-92. Mining's Future—Meeting the Environmental Challenge, by Randall E. Connolly and C. Dan Kealy. Paper in Proceedings of the First International Conference on Environmental Issues and Waste Management in Energy and Minerals Production, ed. by T.M. Yegulap and K. Kim. Battelle, 1991, pp 273-293. Today, it would be irresponsible to proceed with mine development without substantial knowledge of the mine's probable environmental impacts and costs. The creation of new mining Superfund sites is not acceptable. Mine planning from cradle to grave is absolutely necessary in today's world; furthermore, it is good economics. There are many complex issues involving the use of the Nation's resources. What is needed is a technique for assessing the implications of any corrective action. What solves one problem may in fact create new ones that may be even more serious and difficult for us to handle. Well-monitored field demonstrations must be conducted to complement data base development before major changes in disposal strategies are implemented. The economics of resource recovery, during both mining and processing, will become evident in the next decade. Metal contaminants, unlike many organic contaminants, have always been present in essentially the same amounts. We can neither create nor destroy them as we can organic contaminants. Alternate materials still require mined resources. Presently mandated control strategies create areas of high concentrations of metal contaminants that could lead to environmental catastrophes or become the future targets for mining. Research is showing that the environmental regulations must allow waste management strategies to be formulated around the specific attributes of each mine site. The adversarial roles of industry and environmental regulatory agencies must be reduced, and difficult issues must be mediated by independent technical and scientific agencies, such as universities and the U.S. Bureau of Mines. Industry and Government must establish a partnership to achieve environmental quality. Three concepts should guide how we manage mining wastes. First, waste management will dominate the industry's priorities and economics as costs, including liabilities, approach costs of the traditional mining cycle. Second, it is not appropriate to attempt long-term, permanent containment of mine waste contaminants. Third, we must manage our waste with the understanding that today's waste will be tomorrow's resource.

OP 04-92. Issues Relevant to Biomechanical Analysis of Loading on the Lumbar Spine in Stooped Lifting, by S. Gallagher. Paper in XIII International Congress on Biomechanics Book of Abstracts. Dept. of Human Movement Studies, Univ. of Western Australia, 1991, pp 224-225. Stooped lifting is prevalent in occupational settings. Of untrained workers, up to 90 pct will opt to use a stooped lift compared to other lifting strategies. As a result, accurate biomechanical modelling of lumbar mechanics in stooped lifting is of utmost concern in the field of occupational biomechanics. Epidemiological data clearly implicate stooping with an increased incidence of low back pain. However, use of lumbar compression as a design parameter tends to suggest increased load-handling capabilities when using this technique compared to the alternatives. This U.S. Bureau of Mines paper evaluates use of lumbar compression in analysis of stooped lifting and suggests the need to explore other biomechanical factors that may explain why this technique leads to increased risk of low back pain.

OP 05-92. Torque Production and Low Back Forces in Standing and Kneeling Back Exertions, by S. Gallagher. Paper in XIII International Congress on Biomechanics Book of Abstracts. Dept. of Human Movement Studies, Univ. of Western Australia, 1991, pp 222-223. In certain workplaces, workers are required to perform heavy lifting tasks in a kneeling posture (e.g., underground miners,

aircraft baggage handlers). While a great deal of information has been gathered on standing back strength capabilities, little is known about how the kneeling posture affects back strength or the load experienced by the lumbar spine. This U.S. Bureau of Mines study examined peak isokinetic torque production and used an electromyogram-driven low-back model to predict compression and shear forces on the lumbar spine during dynamic maximum voluntary contractions (MVC's) in standing and kneeling postures.

OP 06-92. Ergonomics in Mining: Ergonomic Intervention Strategies, by Christopher A. Hamrick. Appl. Occup. Environ. Hyg., v. 7, No. 1, Jan. 1992, pp 14-16. Occupationally related musculoskeletal injuries pose a significant problem to the mining industry, and ergonomics can help to reduce the costs associated with these injuries. Mines can institute committees to solve ergonomic problems. These committees should include representatives from management, the labor force, the medical department, and an occupational safety and health specialist. Various analysis techniques, such as job safety analysis, task analyses, material handling flowcharts, and preliminary hazards analysis, can be used to identify ergonomic problems in and around a mine. Once hazards have been identified, then solutions can be formulated and implemented. The preferred strategy is to redesign the job by eliminating the hazard, removing the worker from exposure, or mechanizing the task. If these strategies are not feasible, then the job should be designed so that it can be performed within the workers' capabilities. After any ergonomic solution is implemented, a follow-up analysis should be performed to ensure the effectiveness of the change and to guard against the introduction of any new ergonomic or safety hazards. Physical fitness programs and training can be used to supplement job redesign. By effectively instituting sound ergonomic implementation strategies, the costs associated with musculoskeletal disorders can be reduced.

OP 07-92. Spinal Forces During Asymmetric Lifting in Four Postures, by C.A. Hamrick. Paper in XIII International Congress on Biomechanics Book of Abstracts. Dept. of Human Movement Studies, Univ. of Western Australia, 1991, pp 226-228. The height of an underground coal mine is generally determined by the thickness of the mineral seam. Since workers must often perform heavy lifts in restricted postures, traditional recommendations for lifting in unrestricted postures may not be applicable to the underground mining environment. For example, the NIOSH lifting guidelines do not encompass restricted postures or asymmetric lifts. Previous U.S. Bureau of Mines studies have used an electromyogram-driven model to examine spinal forces in kneeling postures and stooping postures under a 1/2-m-high ceiling. The purpose of this work is to examine the biomechanical effects of additional postures, restricted and unrestricted, during asymmetric lifting. See also OP 8-92.

OP 08-92. Spinal Forces During Symmetric Lifting in Four Postures, by C.A. Hamrick. Paper in XIII International Congress on Biomechanics Book of Abstracts. Dept. of Human Movement Studies, Univ. of Western Australia, 1991, pp 228-230. The height of an underground coal mine is generally determined by the thickness of the mineral seam. In many cases, the seam is less than 1.2 m in height. Workers in coal mines are often required to lift heavy materials in severely restricted postures. Two common postures used for lifting are stooping or kneeling on two knees. Demands on the supporting structures of the spinal column are likely to differ considerably in these postures compared to unrestricted lifting situations. Thus, traditional recommendations for lifting in unrestricted postures may not be applicable to the underground mining environment. A recent electromyogram-driven model has been developed that is sensitive to changes in muscular recruitment and thus should be useful in analysing work performed in restricted postures. Previous U.S. Bureau of Mines studies have used this model to examine spinal forces in kneeling and stooping postures under a 1.2-m-high ceiling for both symmetric and asymmetric lifts. These studies found that compression was greatest in kneeling, and shear forces were greatest while stooped. The present study examines stooping under a higher roof and standing, in addition to the postures examined in the previous studies. See also OP 7-92.

OP 09-92. A Review of Existing Cyanide Destruction Practices, by Sandra L. McGill and Paul G. Comba. Paper in Proceedings of the Nevada Wildlife/Mining Workshop. NV Min. Assoc., 1990, pp 172-185. Cyanide is a well-known leaching agent for the extraction of gold and silver from ores; however, it can be harmful to the environment if not managed properly. In particular, wastes associated with cyanide leaching operations may contain cyanide concentrations that are toxic to wildlife. A number of methods are available for the destruction of cyanide present in mineral-processing wastes. This U.S. Bureau of Mines paper reviews the current practices for cyanide degradation, along with the fundamental reactions, operating parameters, advantages, and disadvantages.

OP 10-92. Surface and Corrosion Study of Laser-Processed Zirconium Alloys, by J. Rawers, W. Reitz, S. Bullard, and E.K. Roub. Corrosion, v. 47, No. 10, Oct. 1991, pp 769-777. Reactor-grade zirconium (Zircaloy-2) was laser-glazed and laser-alloyed with nickel (Ni) or chromium (Cr) powders in this U.S. Bureau of Mines study. Laser alloying produced a surface that was macroscopically, chemically homogeneous. However, at the microscopic level the melt zone was a mixture of microcrystalline pure zirconium (Zr) and extremely fine grain, or possibly amorphous, solid solution regions of Zr and alloying elements. Corrosion tests (potentiodynamic and long-term immersion) were conducted in 10 pct $FeCl_3$ solution. The potentiodynamic tests showed i and E_{corr} were a strong function of surface conditioning, altered by grit-blasting, laser processing, acid cleaning, and heat treating. Significant improvement was achieved in corrosion resistance by laser glazing and laser alloying.

OP 11-92. Biosorption of Metal Contaminants From Acidic Mine Waters, by P.G. Bennett, C.R. Ferguson, and T.H. Jeffers. Paper in Process Mineralogy XI: Characterization of Metallurgical and Recyclable Products, ed. by D.M. Hausen, W. Petruk, R.D. Hagni, and A. Vassiliou. TMS, 1991, pp 213-222. The U.S. Bureau of Mines' Salt Lake City Research Center has developed porous polymeric beads containing immobilized nonliving biological materials for extracting metal contaminants from wastewaters. Immobilized biological materials include peat moss, algae, biological polymers, and other materials that demonstrate high affinities for heavy metals. The beads, designated as BIO-FIX beads, have distinct advantages over traditional methods of utilizing biological materials in that they have excellent handling characteristics and can be used in conventional processing

equipment or low-maintenance systems. Toxic metals such as copper, cadmium, zinc, lead, and mercury are among the many heavy metals effectively removed from mine wastewaters using BIO-FIX beads. Continuous cyclic testing indicated that the beads continued to produce treated effluents which met National Drinking Water Standards after 175 loading-elution cycles. Adsorbed metals were removed from the beads using dilute mineral acids. In many cases, the extracted metals were further concentrated to enable processors to reclaim the metals, thus minimizing the generation of a hazardous sludge. Tests indicated that use of the beads in a low-maintenance system was particularly effective for treating remote acid mine drainage waters and small toxic seeps from hard-rock mining districts.

OP 12-92. **Recent Developments in Underground Metal Mining**, by Ernest L. Corp. Paper in MinTech '91: The Annual Review of International Mining Technology and Development, ed. by T.L. Carr. Sterling Pub. Int., 1991, pp 12-15. The goals of the metal mining research program at the U.S. Bureau of Mines are to increase productivity, improve safety, and prevent and remediate mining-related damage. Achieving these goals requires a systems approach to the entire life cycle of mining, beginning with conceptual design of a mine and ending with a final closure and reclamation plan. Some recent achievements in this program include advances in mine design technology; better ground control techniques, including the use of flexible tendons (cable bolts); increased production through automation and improved drilling technology; and alternative forms of mining, such as in situ leaching. Cooperative research and cost sharing with the mining industry are helping to transfer the new technology developed during the pursuit of these goals.

OP 13-92. **Biosorption of Metal Contaminants From Acidic Mine Waters**, by Richard R. Corwin and Tom H. Jeffers. Paper in Conference Proceedings for Association of Abandoned Mine Land Programs, 13th Annual Conference. MO Dep. Nat. Resour., 1991, pp 184-193. Content of this paper is similar to that of OP 11-92.

OP 14-92. **How Smoke Hinders Escape From Coal Mines**, by F.N. Kissell and C.D. Litton. Min. Eng., v. 44, No. 1, Jan. 1992, pp 79-83. This U.S. Bureau of Mines study predicts the level of smoke that miners might meet while trying to escape a coal mine fire and describes how smoke would impede their safe escape. For this study, the authors assumed that miners exit through an escapeway adjacent to the burning entry and that some air would leak from the burning entry to the escapeway. The following conclusions were made: (1) A very low amount of air leakage to the escapeway can produce a critical level of visual obscurity from smoke, showing that intake airways may be as susceptible to smoke visibility problems as return airways, (2) this critical level of smoke obscurity is reached much before a critical level of carbon monoxide is reached, and (3) small fires can cause a severe sensory irritation that further limits vision; thus, reliable eye protection is very important. These results show that methods to guide miners through dense smoke will contribute greatly to saving lives during mine fires.

OP 15-92. **Finite Element Analysis of a Laser-Processed Fracture Specimen**, by George Laird II and James C. Rawers. Int. J. Fracture, v. 53, 1992, pp 91-99. The U.S. Bureau of Mines used finite element analysis to simulate the static failure of an AISI 4140, three-point bend, Charpy specimen. Nonlinear finite element models (FEM) were constructed to represent standard Charpy, fatigue-precracked Charpy, and laser-processed Charpy specimens. For the laser-processed Charpy FEM, a strain-based failure criterion was used to simulate crack propagation through the 0.5-mm-thick laser-processed zone. For comparison, a 0.5-mm-long crack was used in the fatigue-precracked FEM and similarly loaded. Results showed that the numerically calculated load for crack initiation through this zone compared favorably to that reported in earlier experiments. Furthermore, after the crack had propagated through the laser-processed zone within the FEM, comparison of plastic strain contours for this model and those for a fatigue-precracked model showed that similar patterns exist around the crack tip. These results indicate that laser processing and fatigue precracking should provide a similar basis for fracture toughness measurements.

OP 16-92. **Case Study of the Influence of Longwall Panel Size on Methane Gas Emissions**, by Frank E. McCall and Fred Garcia. Abstract in Eastern Section Meeting Program. Am. Assoc. Petrol. Geol., 1991, p. 38. The mining of increasingly larger longwall panels has become one of the coal industry's primary means of increasing the productivity of its mining operations. Along with the positive productivity aspects of increasing panel size is an expected undesirable increase in gas emissions. A study to document the increase in gas emissions resulting from increasing panel size was conducted by the U.S. Bureau of Mines in the Pocahontas No. 3 coal bed, Virginia, where two contiguous longwall panels were investigated. The first panel was 630 ft wide, and the second panel was 700 ft wide. Gas emissions into the mine's ventilation system and gas produced from the gob gas vent holes were monitored during the mining of the two longwall panels. Gas emission data revealed that the second panel produced 69 pct more total methane gas than the first panel. However, the second panel was only 13 pct greater in area. Coal and rock core samples were obtained for gas content determination from a hole drilled before mining near the center of the first panel. The gas content data were used to calculate the volume of gas contained in the overburden and underburden strata for comparison to the volume of gas produced during the mining of the two longwall panels. Various geometric shapes were considered for the calculation of the gas volume contained in the strata. The calculations indicated that there must be some lateral migration of methane gas into the region affected by mining.

OP 17-92. **Treating Tailings for Disposal by Agglomeration**, by D.L. Pool. Paper in Proceedings of the Second International Conference on the Abatement of Acidic Drainage. Centre de Recherches Minerales, Quebec, Canada, v. 2, 1991, pp 499-515. Mill tailings are commonly disposed by deposition in a tailings pond which dries into a body of fine particles. Old tailings ponds can be a source of dust pollution because the fine particles are easily scoured from the surface by the wind. Weathering of the minerals in the fine tailings may be rapid. If sulfidic components are present, incident precipitation may mobilize the contained metals in the acidic effluent. Disposal of tailings as backfill in mines will prevent dusting, but oxidation and subsequent metal mobilization may still occur. A means of alleviating these problems is to chemically and physically stabilize the tailings by agglomeration, which consists of

tumbling the tailings with a binder and moisture to form agglomerates. The use of a chemically basic binder such as portland cement will neutralize acid generated during oxidation. If the proper binder is used, the bonds in the agglomerates will be strong and permanent. Properly agglomerated material is physically and chemically stable and easy to handle. This U.S. Bureau of Mines paper presents data obtained by agglomerating sulfide flotation mill tailings with three concentrations of a binder. Chemical stability of agglomerates was quantified by acid consumption data. Agglomerate physical stability was characterized by wetting tests and resistance to point loading.

OP 18-92. Structure, Nucleation, Growth and Morphology of Secondary Carbides in High Chromium and Cr-Ni White Cast Irons, by G.L.F. Powell and G. Laird II. J. Mater. Sci., v. 27, 1992, pp 29-35. Heat-treated high-chromium and Cr-Ni white cast irons are widely used by the mining and mineral industries for impact and abrasion resistance. With certain heat treatments, Fe-Cr carbides are precipitated within the chromium- and carbon-rich austenitic matrix, thereby destabilizing the austenite which transforms substantially to martensite on subsequent cooling. In this U.S. Bureau of Mines study, the crystal structures of these carbides were determined indirectly by referring electron microprobe analyses of the austenitic matrix to the appropriate isothermal solid-state sections of the Fe-Cr-C phase diagram and directly by microprobe analyses of exposed secondary carbides. The nucleation, growth, and morphology of these carbides were studied by a combination of selective removal of the austenitic matrix and subsequent scanning electron microscopy of the exposed carbides.

OP 19-92. Technologies To Identify Scrap Metals, by W. D. Riley and A.R. Rule. Paper in Process Mineralogy XI: Characterization of Metallurgical and Recyclable Products, ed. by D.M. Hausen, W. Petruk, R.D. Hagni, and A.H. Vassiliou. TMS, 1991, pp 181-197. The U.S. Bureau of Mines has conducted research to better identify, segregate, and recycle scrap materials containing vulnerable strategic and critical materials. This paper describes some of the techniques such as X-ray and optical emission spectroscopy, thermoelectric response, and the Bureau's new automated spark testing technique, developed for the identification and sorting of scrap metals. Results are reported that show the efficacy of these techniques on the identification of metallic scrap, consisting of stainless steels and Co- and Ni-base superalloys, in both a laboratory and a field setting. An important phase of the work was a full-scale technology transfer demonstration study conducted at a Department of Defense scrap yard in Cherry Point, NC. Using Bureau-developed technology, the Department of Defense was able to improve the average return received for the sale of scrap metals from $0.09/kg to $0.95/kg.

OP 20-92. Measurement of Dielectric Properties in the Frequency Range of 300 MHz to 3 GHz as a Function of Temperature and Density, by Johanna B. Salsman. Ceramic Trans., v. 21, 1991, pp 203-214. As part of the research effort on investigating the effects of microwave energy on the chemical and physical properties of minerals and ores, the U.S. Bureau of Mines, Tuscaloosa Research Center, has conducted an extensive research program on identifying those properties of minerals that are affected by microwave energy, namely, the dielectric constant and loss tangent. The objective was to establish a reliable data base for predicting the effects of microwave heating on minerals. The dielectric constant and loss tangent of minerals, commonly referred to as the dielectric properties, were determined utilizing the theory of microwave propagation through an open-ended air-filled coaxial line that was terminated at its open end with the particular mineral under investigation and measuring the reflection coefficient of the mineral with a network analyzer. From the measured values of the reflection coefficient, the dielectric properties of the mineral could be determined. The dielectric properties of powdered minerals with medium to high electrical conductivities (tandW.01) were measured in the frequency range of 300 MHz to 3 GHz. Since the minerals were prepared as powders, techniques were used to relate the measured dielectric properties of the powdered minerals to the dielectric properties of the mineral at its theoretical or natural density. Also, these measurements were performed as a function of temperature, from 25 to 325° C. The results of the dielectric constants and loss tangents using this method were determined to be precise within −5 pct. This report describes the method of measurement and discusses the results of the Bureau's investigations into dielectric properties of minerals with the inclusion of typical measured data.

OP 21-92. The Effect of Particle Size on Treating Fine Waste Generated in the Coal Preparation Plant, by Bernard J. Scheiner and Joseph B. Peterson. Paper in Proceedings of the First International Conference on Environmental Issues and Waste Management in Energy and Minerals Production, ed. by T.M. Yegulalp and K. Kim. Battelle, 1992, pp 199-207. The U.S. Bureau of Mines has investigated dewatering techniques for fine coal refuse in both laboratory and field tests. Data indicate that present technology now being used in the industry will have difficulty in achieving high solids content and low polymer dosage for ultrafine waste expected from new coal-cleaning technologies. Experimental data are presented to show that dewatering of fine refuse will be difficult. Factors pertaining to these problems and recommendations for future research are discussed.

OP 22-92. Analysis of the Constituents of Coalbed Gas, by Michael A. Trevits, Steven J. Schatzel, and John C. LaScola. Abstract in 1991 Abstracts With Programs. Geol. Soc. America, 1991, p. A39. Since the early 1960's, the U.S. Bureau of Mines has maintained a comprehensive program of research into the occurrence, characteristics, and control of coalbed gas. Gas samples were collected at various underground and surface drill site locations in nearly every coal-producing area in the United States. Coalbed gas is generated as a byproduct of the coalification process. Throughout this process, chemical reactions occur at different temperatures and produce a range of gaseous byproducts. The evolved gases may escape or be partially captured in the coal or adjacent stratigraphic units. Geologic events following the formation of coal units can produce additional reactions which may alter the composition of the associated coalbed gas. A statistical analysis of 470 samples collected from 12 different coalbeds shows that methane is the primary constituent of coalbed gas, comprising 96.9 pct. The remaining hydrocarbons contribute about 0.2 pct. Nitrogen and carbon dioxide constitute the majority of the remaining gases at average concentrations of 1.4 and 1.2 pct, respectively. In the Pittsburgh Coalbed, a wide range of carbon dioxide concentrations was observed. This range of variation is about 12 pct.

ARTICLES IN OUTSIDE PUBLICATIONS

OP 23-92. The Effect of Surface Topography on the Stability of Coal Mine Openings, by Gregory M. Molinda. Abstract in Eastern Section Meeting Program. Am. Assoc. Petrol. Geol., 1991, p. 39. Coal mine roof quality has long been observed to appear to deteriorate when mining progresses beneath surface valleys. A survey of seven Appalachian coal mines shows a clear correlation between mining beneath stream valleys and hazardous roof conditions. Of all bad-top occurrences in the surveyed mines, 52 pct happened directly beneath the bottom-most part of a valley. This relationship can be due to a number of associations, ranging from structural control of drainage to stress concentrations beneath the valley apex. U.S. Bureau of Mines research has recently produced evidence of valley stress relief as a significant mechanism for the production of poor rock mass quality beneath stream valleys. Bedding plane slips and thrust faults, due to horizontal compression perpendicular to the valley trend, have been observed beneath a number of valleys. This "valley effect" may be due to transfer of load from the adjacent hillsides or relief of regional stress in the valley due to low confinement. Horizontal stress measurements in a coal mine roof beneath a valley with poor roof conditions confirm partial stress relief. Additionally, numerical modeling of a number of valleys over a single mine property calculates the "valley effect" on the stress field. The model also demonstrates the influence of depth of cover and orientation of the valley to the direction of principal stress on the likelihood of shear failure in the roof.

OP 24-92. There's More Than Gold in Them Thar Hills: South Dakota's Thriving Gemstone Production, by Gordon T. Austin. Colored Stone Mag., v. 5, No. 2, Mar./Apr. 1992, p. 38. During the five years prior to 1991, the value of gemstone production averaged $112,000 per year, but in 1991 a single new producer, International Rose Quartz and Minerals Inc., entered the scene, producing gem materials worth millions of dollars. This firm's production catapulted the State from 25th into 2nd place in the United States in terms of value of gemstones produced. The value of South Dakota's gemstone production in years to come will depend greatly upon the ability to market materials such as rose quartz. If a stable market for carving quality rose quartz can be established, then the future of South Dakota gemstone production is very bright.

OP 25-92. The Development of Cost Models Using Regression Analysis, by T.W. Camm. SME Preprint 92-48, 1992, 4 pp. The use of cost models developed using regression analysis allows the U.S. Bureau of Mines to run multiple cost scenarios for a wide range of deposit sizes and capacities, given limited deposit information. This allows economic analysis to be performed on an area-wide basis, providing policy makers with information on potential land withdrawals that would otherwise be unavailable.

OP 26-92. Assessing Presplit Blast Damage With Crosshole Seismic Tomography, by Calvin I. Cumerlato, Virgil J. Stachura, and Daryl R. Tweeton. Paper in Expanded Abstracts With Biographies, 1991 Technical Program. Soc. Exploration Geophysicists, 1991, v. 1, pp. 914-917. The U.S. Bureau of Mines has conducted crosshole seismic surveys to assess blast-induced damage at a large western surface coal mine. Surveys were conducted both before and after presplit blasts where standard and modified blasthole loads were used. Data from these surveys were processed using a curved-ray tomographic analysis program developed by the Bureau to produce cross-sectional velocity tomograms of rock masses centered on the presplit blast line. Drillers' logs and postmining stereo photography of resulting highwalls were used to help substantiate results. Preblast tomograms show velocity layering and structures consistent with lithology and other features known from drillers' logs. In the postblast tomogram produced from data collected where the standard blasthole load was used, low-velocity zones are prominent features indicating intense fracture damage to the rock masses on either side of the presplit line. In contrast, the postblast tomogram produced from data collected where the modified blasthole load was used shows little change in seismic velocity, indicating that much less fracture damage had occurred. These results demonstrate that crosshole seismic tomography can be an effective analytical tool for assessing blast-induced fracture damage in the subsurface.

OP 27-92. Geochemical Effects on the Hydrology of In Situ Leach Mining of Copper Oxide Ore at the Cyprus Casa Grande Mine, Arizona, by Drummond Earley III and Perry M. Jones. SME Preprint 92-242, 1992, 30 pp. The hydrology of in situ leach mining operations is being studied by the U.S. Bureau of Mines using a variety of techniques, and the Bureau has made significant advances in tracking and modeling the flow of leach solutions in rock formations. However, the influence that leach solution composition has on the hydrology of these systems is poorly understood, and geochemically controlled changes in the hydrologic characteristic of ore deposits during in situ leach mining of porphyry-hosted, copper oxide ores have not been previously studied. The Cyprus Casa Grande in situ leach mining operation mines fracture-hosted and disseminated copper oxides (predominantly chrysocolla) hosted by granodiorite porphyry using a pattern of underground wells. The injection solution consists of sulfuric acid raffinate from a solvent extraction-eletrowinning plant. Chemical anaylsis of representative injection and recovery solutions reveals that gangue cation concentrations in these solutions are high, and geochemical modeling shows that the solutions are saturated or nearly saturated with respect to gypsum, jarosite, and various amorphous oxides. Precipitation of these solids is evoked by calcium-exchange reactions, rising pH, and perhaps locally rising redox potential, as the leach solution reacts with the ore minerals, host rocks, and the atmosphere. Mass and volume balance calculations show that approximately 25 cm^3 of precipitates are formed per gram of copper recovered at Cyprus Casa Grande. The results of geochemical modeling agree with petrologic examination of pre- and post-leach core samples from the leached horizon. Moreover, hydrochemical modeling and hydrologic field data suggest that chemical precipitation causes significant decreases in porosity and permeability during in situ leach mining of porphyry-hosted, copper oxide ore.

OP 28-92. Reducing Back Injuries in Low-Seam Coal Mines Through Task Redesign, by Sean Gallagher, Thomas G. Bobick, and Richard L. Unger. Ch. 30 in Proc. SME, 1992, pp. 309-323. This paper describes research by the U.S. Bureau of Mines on alternative materials-handling strategies for reducing the costs and incidence of back injuries in low-seam coal mines. Strategies recommended for redesigning materials-handling tasks include elimination of tasks, mechanization of tasks, and matching lifting tasks to the physical capabilities of underground miners. The report also

discusses other methods that can be used by management to reduce the costs associated with back injuries. More detail can be found in Bureau of Mines Information Circular 9235.

OP 29-92. Color Measurements of Minerals and Mineralized Froths, by J.E. Gebhardt and J.H. Ahn. SME Preprint 92-232, 1992, 4 pp. Color measurements were made for pure minerals, mineral mixtures, and flotation froths loaded with different minerals. The research objective was to correlate colors with the composition of mineral streams. An industrially available system consisting of a fiber-optic-based illuminator and detector was used to measure color. Color values of binary mineral mixtures varied according to the type and proportion of minerals in the mixture. Measured color values of mineralized froths in the laboratory and in a commercial flotation circuit were dependent on the amount and type of minerals present.

OP 30-92. A Computerized Approach for Assessing the Visibility From Underground Mobile Mining Equipment, by Audrey F. Glowacki, Richard L. Unger, and E. William Rossi. Ch. 4 in Proc. SME, 1992, pp. 29-41. The U.S. Bureau of Mines has developed a graphics-based computer model to assess operator visibility for continuous miners, shuttle cars, and scoops. Using digitized drawings of the machine, the program can analyze visibility for both 5th percentile female and 95th percentile male operators. This model was used to predict 95th percentile male operator visibility for two shuttle car designs. These results were then compared to those obtained from a manual assessment of visibility using the actual shuttle cars. The methods showed good correlation except for several cases that were attributed to imprecise digitization of the machines.

OP 31-92. Scandium Recovery From a Tantalum Waste Residue: A Status Report, by D.D. Harbuck and G.R. Palmer. Paper in Rare Earths: Resources, Science, Technology and Applications, ed. by R.G. Bautista and N. Jackson. TMS, 1991, pp. 107-118. The U.S. Bureau of Mines recently identified a significant new source of scandium in an Oklahoma tantalum waste residue (approximately 0.24 pct Sc). Because scandium is a strategic and critical metal which the Department of Defense has classified for special consideration, the Bureau is researching methods of recovering scandium and associated metals from this and other process residues. A variety of operating parameters were evaluated to determine the best technique for recovering scandium. Testing showed that by sulfating the residue at temperatures as low as 150° C for reaction times as short as 0.5 h over 94 pct of the scandium converted to a water-soluble form. Solvent extraction using DEHPA selectively recovered 100 pct of the scandium from the water leach solution.

OP 32-92. Exploration of New Techniques for Thin-Seam Mining, by J.S. Jaspal and J.P. DuCarme. SME Preprint 92-63, 1992, 10 pp. Mining thin coal seams is both difficult and uneconomical. As a result, most thin-seam coal reserves in the United States are not being mined. It is estimated that nearly 910 Gt of coal reserves exist in 355- to 710-mm-thick seams. The U.S. Bureau of Mines is attempting to develop new techniques for mining 150- to 1,065-mm-thick coal seams. This paper summarizes the research work on existing thin-seam mining techniques, testing on small- and full-scale physical models of the Bureau slot mining concept, and computer modeling of the full-scale process.

OP 33-92. Biosorption of Metal Contaminants From Acidic Mine Waters, by Tom H. Jeffers, Christian R. Ferguson, and Paul G. Bennett. Paper in Mineral Bioprocessing, ed. by R.W. Smith and M. Misra. TMS, 1991, pp. 289-298. The Bureau of Mines Salt Lake City Research Center has developed porous polymeric beads containing immobilized nonliving biological materials for extracting metal contaminants from wastewaters. Immobilized biological materials include peat moss, algae, biological polymers, and other materials that demonstrate high affinities for heavy metals. The beads, designated as BIO-FIX beads, have distinct advantages over traditional methods of utilizing biological materials in that they have excellent handling characteristics and can be used in conventional processing equipment or low-maintenance systems. Toxic metals such as copper, cadmium, zinc, lead, and mercury are among the many heavy metals effectively removed from mine wastewaters using BIO-FIX beads. Continuous cyclic testing indicated that the beads continued to produce treated effluents which met National Drinking Water Standards after 175 loading-elution cycles. Adsorbed metals were removed from the beads using dilute mineral acids. In many cases, the extracted metals were further concentrated to enable processors to reclaim the metals, thus minimizing the generation of a hazardous sludge. Tests indicated that use of the beads in a low-maintenance system was particularly effective for treating remote acid mine drainage waters and small toxic seeps from hardrock districts.

OP 34-92. Elutriation-Flotation for Recycling of Plastics From Municipal Solid Wastes, by C.E. Jordan, G.D. Hood, F.J. Susko, and B.J. Scheiner. SME Preprint 92-83, 1992, 7 pp. The U.S. Bureau of Mines investigated a simultaneous elutriation and flotation technique for separating polyethylene terephthalate (PET) from polyvinylchloride (PVC). The Tuscaloosa Research Center, through a cooperative agreement with a recycling company, devised an elutriation-flotation method for beneficiating the mixed heavy plastics portion of municipal solid wastes, which is composed of polystyrene (PS), PET, and PVC. A sodium carbonate brine was used to remove the lighter PS from the heavier PET and PVC. Over 98 pct of the PS was recovered in a high-purity PS concentrate containing 99.7 pct PS. The remaining PET and PVC mixture was washed to remove the brine salts that would be harmful to the flotation process. The clean PET and PVC mixture was conditioned in a solution of 45 g/t gelatine and floated in a short (1-m) column flotation cell in an upward flow of water. In a single flotation step, over 75 pct of the PET was recovered in a high-purity product containing 99.8 pct PET. The bubbles attached to the PET lowered the effective density of the PET-bubble agglomerate and allowed successful separation of these agglomerates from the PVC plastic pieces. This method separated two-thirds of the mixed plastics fraction into high-purity PS and PET products suitable for recycling and left only one-third of the plastics in the mixed plastics product.

OP 35-92. Real-Time pH Control Using Fuzzy Logic and Genetic Algorithms, by C.L. Karr and E.J. Gentry. SME Preprint 92-49, 1992, 5 pp. Establishing suitable control of pH, a requirement in a number of mineral and chemical industries, poses a difficult problem because of

inherent nonlinearities and frequently changing process dynamics. Researchers at the U.S. Bureau of Mines have developed a technique for effectively controlling such systems. This technique successfully combines the process control capabilities of fuzzy logic and the search capabilities of genetic algorithms, Fuzzy logic offers an effective mechanism for handling nonlinearities, while genetic algorithms can provide fuzzy logic controllers with real-time adaptive capabilities. This Bureau-developed technique is applied to a laboratory acid-base neutralization experiment. Nonlinearities in the laboratory system are associated with the logarithmic pH scale and the changing process dynamics are due to alterations in pH and buffering capacity input solutions. Results indicate fuzzy logic controllers augmented with genetic algorithms offer a powerful alternative to conventional process control techniques in such nonlinear, rapidly changing systems.

OP 36-92. **Teleoperated Cutting and Haulage for Thin Seams**, by A.J. Kwitowski, W.D. Monaghan, and A.L. Brautigam. SME Preprint 92-62, 1992, 10 pp. Remote control for mining machines ordinarily means the operator is not seated on the machine, but is located within direct view of the machine and work area. Thus, remote control operators are exposed to the hazards of roof and/or rib falls and dust and/or methane explosions. The U.S. Bureau of Mines has developed a method to disassociate remote operators from these hazards. Off-board, computer-based "teleoperational" systems are utilized that station the operators 100-m or more distant from the working faces. Details are provided for teleoperated systems for thin-seam extraction and haulage equipment in highwall and deep, room-and-pillar coal mines.

OP 37-92. **Treatment of Alaskan Refractory Gold and Silver Ores**, by W.R. McDonald, J.L. Johnson, and R.G. Sandberg. Paper in Process Mineralogy XI: Characterization of Metallurgical and Recyclable Products, ed. by D.M. Hausen, W. Petruk, R.D. Hagni, and A. Vassiliou. TMS, 1991, pp. 107-116. The U.S. Bureau of Mines investigated treatment of gold and silver refractory ores and concentrates that respond poorly to conventional cyanidation techniques owing to the complex mineralogy of the ore. Three types of ores were investigated: gold-locked placer sands, gold locked in sulfides, and gold that is robbed from the pregnant cyanide solutions by minerals in the ore. Ore treatment was selected according to the mineral type. Increased grinding, as a treatment for gold encapsulated in quartz, raised the recovery from 43 to 97 pct. Mild air preoxidation treatment for gold locked in sulfide minerals increased the recovery from 65 to 83 pct. Carbon-in-leach treatment, for gold lost from cyanide leach solution to carbonaceous minerals in the ore, increased the recovery from 85 to 89 pct. Acid pressure leaching, as a treatment for gold locked in sulfide minerals, increased the recovery from 64 to 95 pct. Other treatments discussed are flotation, hypochlorite oxidation, and roasting.

OP 38-92. **Bioleaching of Manganese From Ores Using Heterotrophic Microorganisms**, by E.G. Noble, E.G. Baglin, D.L. Lampshire, and J.A. Eisele. Paper in Mineral Bioprocessing, ed. by R.W. Smith and M. Misra. TMS, 1991, pp. 233-245. The potential for using heterotrophic microorganisms to solubilize manganese from low-grade domestic ores is being assessed at the Reno Research Center, U.S. Bureau of Mines. More than 90 pct of the manganese has been extracted from a variety of oxide ores in shake-flask tests using molasses as a source of nutrients for the microorganisms. It has also been demonstrated that high recoveries of manganese can be obtained from a domestic wad ore using column bioleaching. The isolation and identification of organisms responsible for manganese extraction is discussed, as are the mechanisms responsible for manganese solubilization.

OP 39-92. **Post Dewatering Kinetics of Clay-Polymer Floc Decay**, by S.K. Sharma and D.A. Stanley. SME Preprint 92-126, 1992, 4 pp. The U.S. Bureau of Mines' rapid method of dewatering fine-particulate slurries uses extremely high-molecular-weight polymers. These polymers form large, strong flocs that can be dewatered by sieving or sedimentation. However, sometimes these flocs deteriorate rapidly if water is not removed immediately. During field tests, clay slurries have been encountered that could have been dewatered economically if it were not for the rapid floc deterioration. A kinetics study was conducted to determine the rate of kaolin-PEO floc degradation in which polymer addition, to bring the flocs back to their original condition, was used to determine the extent of floc decay. Results showed that the amount of polymer added, to replace polymer lost by spreading, was less for the lower PEO concentrations. For this clay-polymer system, floc breakage as judged by polymer additions followed first-order kinetics. It was also found that the addition of fluoride ion stabilized the kaolin flocs.

OP 40-92. **Criteria for Safe Surface Mine Blasting in the USA**, by David E. Siskind. Explosives Eng., Sept. 1991, pp. 9-18. In the early 1980's, the U.S. Bureau of Mines published four reports of structural response and damage from surface mine blasting, vibration monitoring, and analysis methods. These findings replaced simpler and less restrictive Bureau criteria dating back to 1962 for ground vibration and 1943 for airblast. Although these studies were done in response to industry needs, the reports received a mixed reception by the mining industry. In particular, Report of Investigations 8507 on ground vibration appeared to support more restrictive regulations, while also increasing the complexity of analyses by emphasizing the importance of vibration frequency for both measurement and structure response. All this resulted from an attempt to provide technically realistic and selective criteria based on key vibration characteristics. In spite of the concerns about increased restriction back in 1981, these studies have since been widely adopted by the users and regulators of explosives to develop and demonstrate safe blasting practices. In the 10 years since their publication, nothing has appeared to replace them or even significantly add to the data base. These Bureau studies were milestones in blasting technology, but some important work still remains to be done. The industry "knows" what is safe but needs guidance on how to obtain safe levels through blast design. Blast designs for vibrations control received limited study by the Bureau (e.g., RI 9026). Bureau publications and other studies hint at ways to control vibrations (as well as fragmentation and throw) by precision initiation timing and other design changes. In addition, vibration criteria for nonresidential cases are needed: concrete, power poles, pipelines, bridges, etc. Without reliable criteria for such cases, regulation is often based on relatively strict levels required to prevent cosmetic damage to residences.

OP 41-92. **Structure Vibrations From Detonations of Surface Explosives**, by D.E. Siskind and J.W. Koop. Paper in Proceedings of the 62nd Shock and Vibration

Symposium. Shock and Vibration Information Analysis Center, Arlington, VA, 1991, pp. 199-211. The U.S. Bureau of Mines studied airblast and ground vibrations generated by munitions disposal blasts at the Army McAlester Ammunition Plant and Depot in Oklahoma to determine if such blasts, limited to 205 kg, could produce cracking in houses in nearby communities. Eleven structures were monitored over a period of 18 months in and around the base. Blasting seismographs and individual airblast and vibration sensors were used in the manner routinely applied to the regulation of surface mining and for blast effects research. Researchers found groundborne vibrations two orders of magnitude below minimum thresholds for cosmetic cracking at all the structures, including the closest at 3 miles from the disposal range. These thresholds are 1 to 5 cm/s. Airblasts, although significant at 115 to 120 dB (system response 0.1 to 16,000 Hz), were also too low to produce damage of any kind. However, unlike direct ground vibration, they were perceptible at times as far away as 11 miles. This resulted from the relatively small amount of munitions confinement and the irregular influences of weather conditions on the airwave propagation.

OP 42-92. Some Aspects of the Hydrodynamics and Polymer Conformation in Polyacrylamide Flocculation of Chromite Ore, by D.R. Spears, D.A. Stanley, and B.J. Scheiner. SME Preprint 92-93, 1992, 6 pp. As part of its mission to develop technology to assure a continuing supply of minerals, the U.S. Bureau of Mines has investigated the flocculation of a Stillwater, MT, chromite ore. The ore was flocculated at different solids contents and at different stirring speeds to determine the importance and effect of hydrodynamic factors. In acidic and basic pH, the chromite ore was flocculated with high-molecular-weight polyacrylamides differing in degree of hydrolysis. Polyacrylamides were found to bind chromite ore particles through hydrogen bonding. The anionicity of the polymer and the pH affected the degree of polymer-particle interaction, which in turn affected polymer conformation at the surface. A polymer conformation with many loops and tails was used to explain high flocculation efficiency. It was found that such a conformation could compensate for poor hydrodynamic conditions.

OP 43-92. Changing Powder Distribution in the Highwall Holes Reduces Overbreak and Rockfall Hazards, by Virgil J. Stachura and Calvin L. Cumerlato. Paper in Proceedings of the Fifteenth Annual Conference on Explosives and Blasting Technique. Soc. Explosives Eng., 1989, pp. 11-24. The U.S. Bureau of Mines conducted a series of tests to develop a blasting method that would reduce overbreak and rockfall hazards at a limestone quarry in northeastern Wisconsin. Reductions in overbreak were achieved by shortening the main explosive column and reducing the explosive load in shortened stemming zones in shotholes which were to form the highwalls. Two blasthole diameters, 3 and 4 in, were used with 7- by 7-ft and 9- by 12-ft burdens and spacings respectively. ANFO, Comsol 300, or PowerAN were used in the body of the shots, and Gelmax or 40 pct extra dynamite cartridges were used in the reduced-load zones. Smoother highwalls were visually apparent; however, further analyses by seismic refraction techniques were performed as an aid to studying overbreak within the rock mass.

OP 44-92. Rapid Bubble-Pulp Separation for Improved Flotation Kinetics, by F.J. Susko and C.E. Jordan. SME Preprint 92-50, 1992, 9 pp. The U.S. Bureau of Mines investigated rapid bubble-pulp separation to improve flotation kinetics. A shallow-depth froth separator was employed to quickly recover the mineral-laden bubbles from a mixture of ore, water, and air bubbles. The shallow depth minimized the rising distance required to recover even the smallest size bubbles (100m). Therefore, the slurry remained in the unit only long enough to recover the bubbles before the pulp exited through the conical bottom. Joining this unit with a rapid bubble-particle attachment unit, a rapid flotation system was formed that floated silica from phosphate in one-fifth of the retention time for conventional mechanical cells. The hydrodynamics of the rapid flotation system along with fundamental parameters for scale-up are presented in this paper.

OP 45-92. Decontamination of Lead Wastes From Superfund Sites, by Ann M. Wethington, Agnes Y. Lee, and Michael G. Gorman. Paper in Proceedings of HMC-South '92. Hazardous Materials Control Resources Institute, 1992, pp. 117-122. From 1946 to 1980, discarded lead-acid batteries were processed on a 25-acre site in Ohio to reclaim lead components for resale. This processing left 55,000 yd^3 of waste battery casings mixed with lead sulfate-oxide sludge and metallic lead. An additional 85,000 to 100,000 yd^3 of soil surrounding the waste piles were also contaminated with lead compounds. Subsequently, the site was declared a Superfund site. On the basis of the U.S. Bureau of Mines technology for electrolytically recycling scrap batteries that received the IR-100 Award in 1984, an interagency agreement was entered into with the U.S. Environmental Protection Agency to develop a treatment method to remove the lead contamination from this site and other lead-contaminated Superfund sites. Separate battery casing wastes and lead-contaminated soil samples were received from the Superfund site. The primary contaminant on the casing waste was metallic lead and residual lead sludge clinging to the surface. The casing wastes analyzed 900 to 3,000 ppm lead, the sludge adhering to the casing was 20 to 36 pct lead (by weight), and the lead content of the soil ranged from 0.05 to 2 pct. The two criteria established by the EPA to determine successful cleanup of the wastes were that the soil had to pass the extraction procedure (EP) toxicity test and the lead concentration had to be reduced to <500 ppm in the soil and in the casings. The general treatment approach for cleanup of the casings involved wet screening, removal of metallic lead and loosely adherent sludge, size reduction, carbonation to change $PbSO_4$ to acid-soluble $PbCO_3$, acid leaching, and rinsing. The sludge removed from the chips, representing approximately 31 pct of the total mass, was dewatered and set aside for further treatment. Similar to the treatment of the battery casings, the soil was carbonated and wet-screened to remove rocks, wood, etc. The minus 18-mesh fraction (approximately 70 pct of the soil, containing 93 pct of the lead) was acid-leached and rinsed. For the acid leach, two acids (nitric and fluosilic) were investigated. After treatment, the lead concentration in the casings and soils met both of the EPA criteria.

OP 46-92. Acid-Alcohol Leaching of Western Phosphate Ores, by G.M. Wilemon, B.J. Scheiner, and C.E. Jordan. SME Preprint 92-127, 1992, 4 pp. The U.S. Bureau of Mines has conducted preliminary investigations on the leaching of phosphate ores obtained from deposits in the Western United States using sulfuric acid (H_2SO_4 in the presence of methanol. Phosphate extractions in excess of 80 pct were obtained on an

ore sample from Pocatello, ID. Initial leaching studies using the ore as received yielded extraction levels of approximately 35 pct. However, when the sample was ground for as little as 5 min in a rod mill, in methanol, and then treated with H_2SO_4, 82-pct extraction was achieved. The R_2O_3-P_2O_5 (R_2O_3 – Al_2O_3 + Fe_2O_3 ratio of the starting material was 0.11. Solubilized products after leaching exhibited an R_2O_3 – P_2O_5 ratio of 0.02, which is well within desired limits. These results illustrate the potential of acid-alcohol leaching for recovering phosphate values from marginal-grade ores and as an alternative to methods involving current beneficiation techniques that yield lower phosphate recoveries.

OP 47-92. Extracting Platinum-Group Metals From Stillwater Complex Flotation Concentrate by a Two-Stage Bacterial Oxidation/Chemical Treatment Process, by D.L. Yopps and E.G. Baglin. Paper in Mineral Bioprocessing, ed. by R.W. Smith and M. Misra. TMS, 1991, pp. 247-260. In this U.S. Bureau of Mines research, platinum-group metal (PGM) flotation concentrate from the Stillwater Complex, Montana, was subjected to biooxidation using Thiobacillus ferrooxidans in an effort to break down the sulfide minerals and liberate the associated PGM's for subsequent chemical leaching. Bacterial treatment oxidized up to 94 pct of the sulfide present, destroyed the PGM-bearing pentlandite [(Ni, Fe)9S8] mineralization, and dissolved most of the nickel in the concentrate. Results showed that increased sulfide oxidation during the biological stage led to improved PGM recovery in the subsequent chemical leaching stage. Cyanidation at 80° C proved to be the best chemical leachant tested. It removed 76 pct of the palladium, 94 pct of the rhodium, and 97 pct of the gold, but only 34 pct of the platinum from the biooxidized concentrate.

OP 48-92. Effects of Oxygen on Yttrium and Bismuth-Type Superconductors, by N.A. Gokcen, W. Wong-Ng, L.H. Bennett, C.-H. Hsu, J.E. Schirber, D.L. Overmyer, and L.L. Oden. Paper in High-Temperature Superconducting Compounds III: Processing and Microstructure Property Relationships, ed. by S.H. Whang, A. DasGupta, and E. Collings. TMS, 1991, pp. 419-431. The effects of oxygen pressure on $MeBa_2Cu_3Ox$ (Me = Y, Sm, or Gd) and on Bi-based superconductors were investigated for enhancing the superconductivity of new ceramic compounds. Each sample was treated in pure oxygen at various temperatures and pressures, carefully weighed before and after oxygenation, and its superconductivity determined by susceptibility measurements. Pressures up to about 180 atm enhance the critical onset temperatures for superconductivity by about 4 K, and 3,000 atm, by about 7 K. At 3,000 atm, the $SmBa_2Cu_3Ox$ sample partially dissociated, while the Gd sample remained stable. Bi-based superconductors are completely dissociated under oxygen pressures as low as 125 atm at 700° C. This research is a joint effort by the U.S. Bureau of Mines, the National Institute of Standards and Technology, E.I. DuPont de Nemours and Co., and Sandia National Laboratories.

OP 49-92. Expendable-Pattern Casting Makes a Better Armor Plate, by J.S. Hansen and P.C. Turner. Advanced Materials and Processes V. 139, No. 4, Apr. 1991, pp. 12, 16. This "News at a Glance" article describes the expendable-pattern casting process that has been modified by the U.S. Bureau of Mines to make thin-wall steel armorplate to provide added protection to the rear of the turret on the Bradley Fighting Vehicle.

OP 50-92. A Successful Field Demonstration of Jet Assisted Rock Cutting, by Michael Hood, Peter Salditt, Geoffrey C. Knight, and Edward D. Thimons. AUA News, v. 6, No. 4, Winter 1991-92, pp. 5-6. When rock is cut mechanically, as opposed to a drill and blast system, a single machine can break, load, and often transport the rock from the working area in a continuous mechanized process. Often the rock encountered in hardrock mining operations is too hard to cut with conventional mechanical cutting technology. Mining and Construction Technologies, through a cooperative research project with the U.S. Bureau of Mines, and with funding from the State of California, is investigating whether the application of water-jet-assisted cutting to mechanized cutting bits can improve this cutting process. Several attempts to reduce cutting forces through the use of water-jet-assisted cutting at pressures of 70 MPa (10,000 psi) or less proved unsuccessful underground. In this project, a novel drag bit was designed, and an arrangement for mounting the water jet nozzles close to the rock face was developed. In underground tests, cutting two types of hard rock ranging in unconfined compressive strength from 105 to 245 MPa (15,000 to 35,000 psi), the use of the water jet assist significantly reduced bit force reductions in the range of 30 to 40 pct. Another advantage noted was a reduction in bit wear when the jet-assisted cutting was employed.

OP 51-92. Alternate Fuels for Cupola Operations, by R.H. Nafziger. AFS Trans., v. 99, 1991, pp. 25-31. Several years ago, the U.S. Bureau of Mines investigated the use of alternative fuels in cupola ironmaking operations. The purpose was to evaluate the feasibility of conserving foundry coke because it is becoming more difficult to obtain this material owing to obsolescent equipment and environmental restrictions on coke manufacture. This paper represents a review of previously reported research. In early plant tests using calcined anthracite, it was demonstrated that this substitute could be used satisfactorily in some foundries, provided that a higher windbox pressure is used to supply adequate air input and that smaller size ranges of the reductants are used. In later pilot-scale experiments, it was demonstrated that anthracite or bituminous coals can replace coke up to 40 pct. Briquetted materials prepared from fuel fines and other waste products can be used only up to 20 pct as replacements for coke. Pitch-bonded coal fines or petroleum coke failed to produce metal that met gray iron specifications. Natural gas also was used as a partial replacement for coke in preliminary trials. Results showed that the melting rate can be increased significantly. Some scrap can be upgraded using this alternate fuel.

OP 52-92. Carbothermic Reduction and Leaching of Manganese Ores From the West-Central Arkansas District, by W.K. O'Connor, J.C. White, and P.C. Turner. Paper in EPD Congress 1992: Proceedings of Symposia Sponsored by the Extraction and Processing Division, ed. by J.P. Hager. TMS, 1991, pp. 379-396. The U.S. Bureau of Mines has conducted beneficiation, carbothermic reduction, and leaching tests of Mn oxide ores as part of its evaluation of the Mn and Co resources of the West-Central Arkansas District. The major Mn oxides in the ore include cryptomelane, psilomelane, pyrolusite, and lithiophorite. Cobalt is contained within the Mn oxides. Nonbeneficiated ore was reduced at 800° C with coal and leached in ammonium sulfate and ammonium carbonate leach liquors. Ore concentrates were calcined at 600° C prior to reduction under the same conditions as the raw ore. Head analyses reported up to 21 pct Mn and 0.11 pct Co.

Extractions of 70 to 90 pct Mn and 40 to 60 pct Co were achieved.

OP 53-92. Reply to "Comment on 'Contribution to the Phase Diagram Al_4C_3-AlN-SiC'", by Laurance L. Oden. J. Am Ceram. Soc., v. 74, No. 9, Sept. 1991, p. 2329. Addresses questions raised by R.J. Oscroft and D.P. Thompson in their review of the noted paper.

OP 54-92. Effect of Grinding Media-Chalcopyrite Interaction on the Self-Induced Flotation of Chalcopyrite, by J.A. Ahn and J.E. Gebhardt. Int. J. Miner. Processing, v. 33, 1991, pp. 243-262. U.S. Bureau of Mines research to understand the surface chemical mechanisms of flotation showed that galvanic interactions between grinding media and chalcopyrite influence the self-induced floatability of chalcopyrite in simulated process water. Galvanic interactions were characterized by several electrochemical techniques, including rest potential, combination potential, and polarization measurements. Chalcopyrite floatability was similar from a synthetic chalcopyrite-quartz mixture and a natural ore, and floatability was dependent on the electrochemical conditions in grinding, conditioning, and flotation stages. Nitrogen-purged and open-to-air atmospheres in grinding, conditioning, and flotation were investigated for chalcopyrite ground with high-carbon and stainless steel media. For grinding with high-carbon steel in a nitrogen-purged atmosphere, low grinding solution pH was detrimental to chalcopyrite recovery at constant flotation pH. As grinding solution pH was increased, chalcopyrite floatability was enhanced as a result of lower galvanic interaction during grinding in higher pH solution. Electrochemical measurements substantiated that high-carbon steel was passivated at higher pH. When the mineral was ground with high-carbon steel in the presence of air, chalcopyrite flotation was not significantly affected by grinding solution pH. This was consistent with chalcopyrite and high-carbon steel electrochemical polarization measurements, which were not significantly affected by pH changes in the presence of air. Stainless steel was more easily passivated than high-carbon steel, and chalcopyrite floatability was significantly higher after air or nitrogen-purged grinding with stainless steel media. Increased chalcopyrite floatability was observed with more positive flotation pulp potentials. For given grinding conditions, the type of flotation gas had a strong effect on recovery, and flotation with air yielded higher chalcopyrite recovery than flotation with nitrogen. For the natural ore, chalcopyrite was depressed while molybdenite was floated with nitrogen, and chalcopyrite was subsequently recovered by flotation with air.

OP 55-92. Advances in Biological Cyanide Detoxification, by P.B. Altringer, R.H. Lien, and B.E. Dinsdale. Paper in Randol Gold Forum, Vancouver '92 Proceedings. Randol International, Ltd., 1992, pp. 395-400. The U.S. Bureau of Mines is investigating biodegradation of cyanide as a means of decommissioning heap leach operations. Biological oxidation decreased weak acid dissociable (WAD) cyanide in process solutions from 50 to 170 ppm down to 0.1 ppm. The tests were conducted both in trickling column reactors, using quartz as the growth surface, and in upflow columns, using activated carbon as the growth surface. In addition, exploratory tests indicated that bacteria will destroy residual cyanide in leached ore. A flowsheet has been proposed for closure of heap leach operations in which the metals-processing portion of the plant, possibly the carbon adsorption columns, or a collection pond is used as a bioreactor. The cyanide in the process solution is destroyed in the bioreactor, and the treated water is used to rinse residual cyanide from the spent heaps. The water is recycled until the effluent WAD cyanide concentration meets discharge standards.

OP 56-92. Quartz to Diamonds: Arkansas' Significant Gemstone Production, by Gordon T. Austin. Colored Stone, v. 5, No. 3, May/June 1992, pp. 26-27. This U.S. Bureau of Mines article reviews Arkansas' gem stone production, which includes quartz crystals, freshwater mussel shells and pearls, agates and petrified wood, and potential commercial production of diamond.

OP 57-92. An Object-Oriented Expert System for Underground Mining Method Selection and Project Evaluation, by Thomas W. Camm and Martin L. Smith. Ch. 88 in 23rd Application of Computers and Operations Research in the Mineral Industry, ed. by Y.C. Kim. SME, 1992, pp. 909-916. A WINDOWS-based object-oriented expert system for prefeasibility evaluation of hard rock mines is being developed at the Western Field Operations Center of the U.S. Bureau of Mines. Designed for use with the Bueau's Cost Estimating System, this expert system assists an evaluator in choosing an underground mining method and the related design parameters. The system provides the engineering and design guidelines necessary for an evaluator to perform a prefeasibility-type cost estimate.

OP 58-92. Recommendations Concerning the Maintainability of Underground Coal Mining Equipment, by Kirk Conway and Richard L. Unger. Ch. 29 in New Technology in Mine Health and Safety, ed. by A.W. Khair. SME, 1992, pp. 297-308. The U.S. Bureau of Mines conducted a research project to analyze the design of underground mining equipment with respect to ease of maintenance and maintainer safety. The work included a review of maintainability design literature, an analysis of maintenance-related accident data, field reviews of equipment designs, and interviews with mine maintenance personnel and equipment manufacturers. Based on the findings, a set of maintainability design recommendations have been prepared. The final recommendations document includes maintainability engineering information for equipment designers, as well as a buyers' guide to aid purchasers of mining machinery in evaluating the maintainability of equipment.

OP 59-92. Recent Research on Ni-Hard 4, by Gordon Cox and George Laird II. Foundry Trade J., v. 166, No. 3450, Mar. 30, 1992, pp. 155-158. Recent work by the U.S. Bureau of Mines and others has detailed how the microstructure of Ni-Hard 4 (ASTM A532-87 Class I, Type D-white cast iron) is influenced by solidifcation and solid-state transformation kinetics. Studies using differential thermal analysis, electron microprobe analysis, X-ray diffraction, and electron and optical microscopies have clarified factors that influence carbide structure and morphology. The effects of silicon and nickel in promoting M_7C_3 as opposed to M_3C carbides in these irons is explained by their effects on hindering the growth of M3C carbide during solidification. Transformations that occur on destabilisation and subsequent air cooling are also described, and it is shown that the hardenability of these irons may be calculated. It is further shown how such air hardening, subzero

treatments, or combined or special heat treatments may be used to develop high-hardness Ni-Hard 4. Lastly, the improvements in abrasive wear life obtainable from using castings of high hardness are briefly discussed.

OP 60-92. **Detector Response to Both Fire and Non-Fire Contaminants**, by Margaret R. Egan and Charles D. Litton. Ch. 7 in Proceedings, SME Annual Meeting. SME, 1992, pp. 69-80. To reduce the number of nuisance fire alarms in underground mines that use diesel-powered equipment, the U.S. Bureau of Mines has developed a diesel-discriminating fire detector (DDD). It was designed to discriminate between smoke produced by a fire and the smoke-laden exhaust of a diesel engine. Welding and cutting with arc or flame can also produce combustion products capable of triggering nuisance alarms. In this report, the response of the DDD to the emissions from diesel exhaust, arc welding, and flame cutting are compared to the response of conventional smoke and carbon monoxide (CO) detectors. The data show that when the DDD is set at an alarm threshold of 0.05 V, it will reliably detect a developing conveyor belt fire while remaining insensitive to other sources of nuisance combustion products. The alarm times of the three types of detectors were also compared. The DDD alarmed first in response to a smoldering conveyor belt in two of four experiments.

OP 61-92. **Automated Geophysical Sensing and Data Processing Roof Drill**, by E.M. Frizzell, W.L. Howie, and T.W. Smelser. Ch. 30 in 23rd Application of Computers and Operations Research in the Mineral Industry, ed. by Y.C. Kim. SME, 1992, pp. 297-305. Decisions affecting ground control design require detailed knowledge of roof rock geology. This is especially true when weak roof materials and anomalies create hazardous conditions and, if not properly supported, result in roof falls. The U.S. Bureau of Mines has developed a system to evaluate geological conditions by using a roof drill that will provide an estimate of the compressive strength of the roof rock in real time. Through the use of sensors and a microcomputer on the roof drill, critical drilling parameters can be interpreted and analyzed almost instantaneously, making it possible to inform an operator of hazardous roof conditions, such as voids and changes in strata, during the drilling process. Geotechnical data can be downloaded to a portable semiconductor memory device, which is brought to the surface so that data can be directly accessed with a personal computer for further analysis. Results from field tests are presented.

OP 62-92. **Designing and Sizing Passive Mine Drainage Treatment Systems**, by Robert S. Hedin and Robert W. Nairn. Paper in Proceedings, Thirteenth Annual West Virginia Surface Mine Drainage Task Force Symposium. WV Min. and Reclamation Assoc., 1992, 11 pp. The passive treatment of contaminated coal mine drainage is a rapidly growing and evolving technology. Passive systems typically require less operation and maintenance efforts and are less expensive than conventional treatment systems. Three principal types of passive technologies currently exist for the treatment of coal mine drainage: the aerobic system, the compost wetland, and the anoxic limestone drain. In aerobic systems, oxidation reactions occur and metals precipitate as oxides and hydroxides. Most aerobic systems are simple wetlands; they contain cattails growing in a clay or spoil substrate. However, plantless systems have also been constructed and function similarly to systems containing plants. Compost wetlands are similar to aerobic wetlands in form, but also contain a thick organic substrate. This substrate promotes chemical and microbial processes that generate alkalinity and neutralize acidic components of mine drainage. Typical substrates used in these wetlands include spent mushroom compost, peat moss, haybales, and manure. The term "compost wetland" is general and is meant to include any wetland that contains an organic substrate in which biological alkalinity generating processes occur. The anoxic limestone drain (ALD) adds alkalinity to the mine water for forcing it to flow through a buried bed of limestone. By keeping the limestone and mine water anoxic, limestone dissolution can occur without armoring reactions that make limestone useless in a surface environment. ALD's are intended to generate alkalianity and must be followed by an aerobic system in which metal oxidation and precipitation reactions occur. Each of the three passive technologies is most appropriate for a particular type of mine water problem. Often, they are most effectively used in combination with each other. In this U.S. Bureau of Mines paper, a model is presented to aid reclamationists in deciding whether their mine water problem is suited to passive treatment and in designing and constructing effective passive treatment systems. The model uses mine drainage chemistry to determine system design, and contaminant loadings to define system size. This paper details the use of this flow chart and discusses uncertain aspects of the model that are currently under investigation.

OP 63-92. **Optimum Mine Designs To Minimize Coal Bumps: A Review of Past and Present U.S. Practices**, by Anthony T. Iannacchione and Matthew J. DeMarco. Ch. 24 in New Technology in Mining Health and Safety. SME, 1992, pp. 235-247. Coal bumps have presented serious mining problems in the United States throughout the 20th century. Fatalities and injuries have resulted when these destructive events occur at the working face. Persistent bump problems can result in abandonment of large reserves or lead to premature mine closure. Through the years, alternative techniques such as artificial supports, extraction sequencing, destressing, pillar design changes, and specific pillar retreat practices have been successfully implemented to mitigate coal mine bumps. Several techniques have evolved for room-and-pillar operations that control the way the roof rock breaks, regulating the manner in which stresses are redistributed in the mined section. Special mine layouts employed in longwall mines have also proved to be successful in safely redistributing or containing excessive loadings. However, with ever-increasing production rates, greater overburdens, and new mining systems, the need to evolve even more effective bump control designs will continue to challenge the U.S. coal industry.

OP 64-92. **Abandoned Mined Land Fire Survey and Evaluation**, by Ann G. Kim and Robert F. Chaiken. Paper in Proceedings: 12th Annual NAAMLP Conference-Returning Mined Land to Beneficial Use. Nat. Assoc. of Abandoned Mine Land Programs, 1990, pp. 19-44. Abandoned mined-land (AML) fires occur in abandoned mines, in waste banks, and in unmined outcrops. AML fires occur in every coal-producing State and present a serious health, safety, and environmental hazard. The emission of toxic fumes, subsidence, and the deterioration of air quality create an unsafe and unpleasant atmosphere that can depress property values for affected land and for adjacent areas. Between 1949 and 1972 the Federal mining agencies were involved in 75 fire control

projects in the eastern bituminous region, 21 projects to control 15 fires in the anthracite region, and 158 fire control projects in the Western United States. The 1989 AML inventory listed 225 surface fires and 99 underground fires, affecting an estimated 7,000 acres. The cost of controlling these fires is estimated to exceed $780 million. Factors affecting the occurrence, propagation, and extinguishment of AML fires include the geology, the extent of previous mining, the rank of the coal, and the type and condition of adjacent strata. Conventional fire control methods include excavation, sealing, and excavated or flushed barriers. The probable effectiveness of these methods is less than 70 pct. Current research on improving standard methods and on developing new technology may significantly increase the effectiveness of AML fire control. Recent improvements in AML fire control include the U.S. Bureau of Mines mine fire diagnostic methodology to locate and monitor remote fires and the Burnout Control method of fuel removal.

OP 65-92. Mine Fire Diagnostics, Recent Developments, by Ann G. Kim, Louis E. Dalverny, and Thomas R. Justin. Paper in Proceedings of the Symposium on Evolution of Abandoned Mine Land Technologies. WY Dept. Environ. Qual., Abandoned Mine Land Rec. Program, 1989. 20 pp. Laboratory results and field studies support the effectiveness and applicability of the U.S. Bureau of Mines Mine Fire Diagnostic technique to the problems of locating and monitoring abandoned mine fires. For the bituminous samples studied, values of the concentration ratio, R1, increased with increasing temperature and decreased during cooling. Although values of R1 do not correspond to a particular temperature, elevated values of R1 are due only to the presence of heated coal. Time-dependent monitoring of changes in R1 reflect changes in the average temperature of the coal. The ratio, R1, was not applicable to anthracite samples because of the lower rate of hydrocarbon emission and the very low concentration of higher hydrocarbons. However, variations in the absolute concentration of methane seemed to be indicative of changes in temperature. The Mine Fire Diagnostic method incorporates a sampling method that increases the detection zone of normal point source measurements through a gas movement scheme. Measuring one of the characteristics of this moving gas, in this case changes in hydrocarbon concentration, and plotting the results as vectors (magnitude and direction) rather than point source (magnitude) measurements, expands and bounds the area(s) affected by combustion, as well as the area(s) not affected by combustion. These factors make the Bureau's methodology a significant improvement in locating and monitoring abandoned mine fires.

OP 66-92. Biological Treatment of Mine Water-An Overview, by R.L.P. Kleinmann, R.S. Hedin, and H.M. Edenborn. Paper in Proceedings, Second International Conference on the Abatement of Acidic Drainage. 1991, pp. 27-42. Biological treatment of coal mine drainage is typically conducted in a series of excavated ponds that resemble small marshes. The ponds are engineered to facilitate the aeration of water and the bacterial oxidation of iron. In some systems, this is followed by an anaerobic step, in which the water flows through a composted organic substrate that supports a population of sulfate-reducing bacteria. The anaerobic bacterial sulfate reduction process can raise the pH. During the past 4 years, over 400 wetland water treatment systems have been built on mined lands. In general, mine operators have found that the wetlands reduce chemical treatment costs enough to repay the cost of wetland construction in less than a year. Biological treatment of metal mine drainage to date has been limited to pilot-scale experiments. Two basic approaches are currently being examined: wetland systems modified to enhance bacterial sulfate reduction and enclosed sulfate reduction reactors.

OP 67-92. The Two Faces of Smoke, by Charles D. Litton. Ch. 10 in Proceedings, SME Annual Meeting. SME, 1992. pp. 95-104. This U.S. Bureau of Mines paper presents a description of the hazards of smoke from fires, the detectability of smoke using smoke sensors, and the operational characteristics of such detectors. It places in perspective the advantage that smoke detectors have over other forms of fire detection and also provides a discussion of smoke as a significant fire hazard.

OP 68-92. Radio Remote Control Continuous Miner Operator Positioning, by Arnold C. Love and Robert F. Randolph. Ch. 34 in New Technology in Mine Health and Safety A.W. Khair. SME, 1992, pp. 357-360. This U.S. Bureau of Mines study describes the positioning strategies used by operators of radio-controlled underground mining machines. The observations have implications for task design to ensure adequate visibility and task performance. Radio-controlled continuous coal mining machines have allowed many mines to increase safety and production by placing human operators away from the hazards of an unsupported mine roof. The operator is no longer confined to an operator's compartment, and visibility can be enhanced with proper positioning. Also, the operator is no longer subjected to the shocks and vibrations of the mining machine. The operator's ability to move freely about the worksite requires a careful analysis of several competing safety and production considerations. Thirty-five operators of remotely controlled continuous mining machines were observed using work sampling followed by interviews to determine where the operator was positioned and what he or she was watching. These observations were separated according to the task being performed by the continuous mining machine and summarized as position density plots. The specific task of tramming in reverse through a crosscut is analyzed, along with more general summaries of the time miners spend outside the policy-defined operating positions while performing other production tasks. The operators were observed to frequently vary from company standard operating procedures (SOP). Many of the variations from company SOP's were based on task demands. Interview responses indicated that portions of the mining task place visibility demands on the operators that are difficult to accommodate within existing procedures. An improved task design process would include these visibility requirements. Also, the operator's vision can be augmented through video cameras in future teleoperated mining systems, and the operator can be increasingly isolated from environmental hazards.

OP 69-92. Two Synergic Pairs for the Extraction of Ammoniacal Ni, by L.R. Penner, J.H. Russell, and M.J. Campbell. Paper in Solvent Extraction 1990, ed. by T. Sekine. Elsevier, 1992, pp. 423-428. The U.S. Bureau of Mines has studied extraction of Ni from ammoniacal sulfate solution for two solvent extraction systems that show extraction synergy. The first system uses the extractants 2-hydroxy-5-nonyl benzophenone oxime (LIX 64N) and 7-(4-ethyl-1-methyloctyl)-8-hydroxyquinoline (Kelex 100). At pH 10, Ni extraction synergy is seen for this chelate-chelate pair in both equilibrium

tests and kinetic tests. The second system used Kelex 100 and dinonylnaphthalene sulfonic acid (DNNSA), a chelate-acid pair. No equilibrium extraction synergy is observed for the second pair at pH 10, but of more practical importance, kinetic synergy is found. In only 10 min of mixing with 0.10 M extractant, Ni extraction is 53 pct for the best LIX 64N/Kelex ratio (3:1) and 87 pct for the best Kelex/DNNSA ratio (4:1), but none of the three extractants alone extracts more than 43 pct of the Ni under identical test conditions.

OP 70-92. **Human Factors of High Technology Mining**, by Robert F. Randolph. Ch. 28 in New Technology in Mine Health and Safety, ed. by A.W. Khair. SME, 1992, pp. 287-295. New technologies confront mining organizations with unprecedented human factors challenges. Likely problem areas range from the design of the human-machine interface to the design of work groups and mine organizational structures. However, these human design considerations are commonly ignored in most industries, resulting in a failure rate of 75 pct for advanced technology programs. The U.S. Bureau of Mines is addressing these concerns through a program of research on the human side of high-technology mining systems. Interviews with mining industry participants and researchers have identified concerns in several areas, including training and equipment design. Although new mining technologies promise to improve overall safety by relocating miners away from hazardous areas, data from accident reports and other sources suggest that certain types of new hazards may be created. Many of these new hazards can be reduced through a systems approach to ergonomic design of equipment, tasks, and work processes. This evidence, combined with reviews of high-technology human-machine systems in other industries, can help in the design of safe and efficient future mining technologies.

OP 71-92. **Human Factors and New Mining Technology: The Importance of Organizational and Management Change**, by Robert F. Randolph and Richard S. Fowkes. Paper in Proceedings: International Symposium on Mine Mechanization and Automation, Volume II. CO Sch. Mines, 1991, pp. 16-9 to 16-18. New technologies confront mining organizations with unprecedented human factors challenges. Likely problem areas range from the design of the human-machine interface to the design of work groups and mine organizational structures. However, these human design considerations are commonly ignored in most industries, resulting in a failure rate of 75 pct for advanced technology programs. The U.S. Bureau of Mines is addressing these concerns through a program of research on the human side of high-technology mining systems. Interviews with mining industry participants and researchers have identified concerns in several areas, including training and equipment design. Based on these interviews and a review of the research, the Sociotechnical Systems Analysis (SSA) approach has been selected as a comprehensive and systematic approach to melding the human and technological aspects of new, complex technologies. SSA has been widely used, frequently with significant success. It advocates joint optimization of the social system (people and their interactions) and the technical system (tools, techniques, knowledge), since optimizing these independently does not lead to peak performance. Also, some of the formative research on SSA was performed in British longwall coal mines and a U.S. continuous mining operation. SSA provides specific organizational manipulations and techniques that can be tailored to each organization and its technology.

OP 72-92. **A Method To Evaluate the Effectiveness of Coal Fire Extinguishing Agents**, by Mark W. Ryan, Alex C. Smith, and Charles P. Lazzara. Ch. 11 in Proceedings, SME Annual Meeting. SME, 1992, pp. 105-114. The U.S. Bureau of Mines developed an experimental method to evaluate the relative effectiveness of water additives on the extinguishment of coal fires. The experiments were conducted in the fire zone of the multiple-entry section of the Bruceton Experimental Mine. Chambers filled with 180 kg of Pittsburgh seam coal were ignited and allowed to burn until well-developed fires were achieved. Extinguishing agent-water solutions were then applied to the fires and the quantity required to extinguish the fires compared to the amount of water alone required to extinguish similar fires. A 20-pct diammonium phosphate-water solution required an average of 22 L to extinguish the coal fires, while two commercially available additive-water solutions required averages of 30.6 and 30.3 L. The average amount of water required to extinguish the fires was 28 L. An analysis of covariance, using the thermal energy of the coalbed, Q, to quantify the fire at the time of estinguishment, showed that the diammonium phosphate-water solution was slightly more effective at extinguishing these coal fires than water alone, while the two commercially available additive-water solutions were statistically equivalent to water alone.

OP 73-92. **Evaluation of Coal Mine Roof Supports Using Artifical Intelligence**, by Stephen P. Singer and Roger L. King. Ch. 86 in 23rd Application of Computers and Operations Research in the Mineral Industry, ed. by W.C. Kim. SME, 1992, pp. 889-895. The U.S. Bureau of Mines is developing an intelligent system for roof control that uses both an expert system and neural networks to improve the capability of mining engineers to evaluate roof support effectiveness for ground control in coal mines. The expert system compares roof support capacities with the support requirements estimated to be necessary to maintain entry stability. It does this by evaluating the results of tests on various types of roof support and establishing the maximum allowable load according to anchorage capacity and yield strength of the support. After the user enters geological information (rock properties, geometry of the opening, in situ stresses, bolt pattern parameters, etc.), the expert system compares the predicted required loading to the roof support capacity and gives the operator advice on the adequacy of the design and how improvements could be made. A good source of the real-time data necessary to allow the expert system to make decisions will come from a roof bolting machine being developed by the Bureau of Mines. Researchers have collected data from a western coal mine on drill bit position, penetration rate, thrust, torque, and rotation rate. Using this information, two neural networks were developed to identify different types of strata and features in a mine roof, such as rock type, rock compressive strength, and joint characteristics. The result is a system that can assist a mining engineer with design information that can be constantly updated as mining progresses.

OP 74-92. **A Control System for Roof Drilling**, by George A. Takach, Jr., Steven P. Morris, and Gregory G. Miller. Ch. 28 in 23rd Application of Computers and Operations Research in the Mineral Industry, ed. by Y.C. Yim. SME, 1992,

pp. 277-285. The U.S. Bureau of Mines is conducting research with the goal of automating underground coal mine roof bolters for greater mine safety. In the project described here, the Bureau has focused on automating the drilling portion of the drilling and bolting cycle. A drill monitoring system designed and developed by Parvus Corp. of Salt Lake City, UT, was placed on a Bureau model roof-bolting drill. The drilling parameters of torque, thrust, rotation rate, penetration rate, and position are monitored through sensors connected to an asynchronous, control-oriented local area network (LAN) that communicates with data-accumulating and data-processing nodes. By placing microprocessors at the two data nodes and at the valve control nodes, and combining these nodes with a personal computer (PC), the monitoring and control system can achieve parallel processing capabilities. Such capabilities are referred to as locally intelligent distributed processing. Only data that have changed significantly are reported through the LAN to a supervisory control and data acquisition (SCADA) system mounted on an IBM-compatible 80286 PC. The SCADA system displays the values of the drilling parameters and calculates the specific energy of drilling, which is then used as an indicator of the type of rock being drilled. Besides monitoring the drilling process, an operator at the computer can control the rotation and thrust of the drill from a remote location through the SCADA program and can set drilling parameters on the basis of observed values of the specific energy of drilling.

OP 75-92. Multivariate Statistical Analysis of Vadose and Saturated Zone Pore Waters of Sulfidic Mine Waste Tailings, by Barbara C. Williams. Ch. 10 in Emerging Process Technologies for a Cleaner Environment ed. by S. Chandler. SME, 1992, pp. 63-70. U.S. Bureau of Mines researchers conducted field studies at an abandoned copper-gold mine tailings impoundment. Pore water quality was analyzed in the vadose and saturated zones. Three statistical procedures were employed to summarize the variability within and between the two zones. The results indicated that linear combinations of those variables reflecting sulfide oxidation and aluminum-silicate weathering best summarized the variability in each zone, and that the zones were most different on the basis of sulfide oxidation variables. The geochemical computer code WATEQ4F was used to assess the solubility status (saturation index) of minerals. Saturation indices of sulfide oxidation and aluminum-silicate weathering minerals were different in the two zones. It was demonstrated that the statistical analyses produced similar and complementary results to the geochemical code.

OP 76-92. Evaluation of Tri-Sets for Roof-Fall Areas, by Richard A. Allwes and C.P. Mangelsdorf. Ch. 26 in Proceedings of New Technology in Mine Health and Safety. SME, 1992, pp. 263-276. At the request of the U.S. Department of Labor, Mine Safety and Health Administration (MSHA), the U.S. Bureau of Mines evaluated the suitability of using tri-sets for protecting mine personnel in roof-fall-prone areas. A steel-set arch provided by MSHA served as a basis for evaluating the performance of the tri-sets. All tests and analyses were conducted according to the arch canopy test and design procedures developed by the Bureau. Theoretical resistance functions were established for the steel-set arch and tri-set and were representative of their experimental behavior. The resistance functions were used to determine the energy absorption capacity of the structures and to predict their dynamic response to impact loading. The dynamic tests demonstrated that the arch canopy design procedure is appropriate for tri-sets and yields conservative designs for both steel-set arches and tri-sets. As a result of this work, it is recommended that tri-sets may be considered for protection against roof falls, provided that the arch canopy design procedure is utilized for each application and that the principles underlying the design procedure are understood.

OP 77-92. Electronic and Optical Minerals, by W.N. Marchant and D.L. Barna. Ch. in Concise Encyclopedia of Semiconducting Materials & Related Technologies, ed. by S. Mahajan and L.C. Kimerling. Pergamon, 1992, pp. 140-143. Minerals have been an essential component of human society since the discovery that, when properly struck, flint could be used to start a fire; however, the explosion in high-technology uses for minerals probably can be traced to early twentieth century experiments with crystal oscillators that were the forerunners of the modern communications industry. Since those pioneering uses of quartz, galena, and germanium crystals, technological uses for minerals have multiplied rapidly. Minerals from altaite (lead telluride) to zincite (zinc oxide) have been used to exploit their special optical or electronic properties. It is ironic that the same developments that led to so many applications for minerals also led to requirements of size, shape, and purity such that only a few minerals are suitable for use as they occur in nature. For this reason, synthetic crystal growing techniques now provide most of the highly pure, sometimes exotic, minerals used in photoconducting devices (cadmium sulfide, gallium arsenide), infrared spectrophotometers, (sodium chloride, zinc selenide), lasers (aluminum oxide), and similar instruments. The following discussion will emphasize those commercially important minerals that can be used as they occur naturally. Quartz is included because of its technical importance, and because natural quartz crystal continues to be the feedstock for synthetic crystal growth. Also featured are asbestos, calcite, and mica.

OP 78-92. Rock Mechanics Research Decreases Longwall Bump Potential at a Southern Appalachian Coal Mine, by T.M. Barton, A.A. Campoli, and M. Guana. Min. Eng., v. 44, No. 4, Apr. 1992, pp. 347-351. Coal mine bumps, the violent failures of overstressed coal, present a safety hazard to miners when longwall mining is conducted in deep, bump-prone coal mines. The U.S. Bureau of Mines evaluated two different longwall gate entry systems in a southern Appalachian coal mine located in the Pocahontas No. 3 coalbed under approximately 610 m (2,000 ft) of overburden that included a massive sandstone member. Both gate entry systems employed a center abutment pillar flanked by yield pillars. The original design used a 24.4-m (80-ft) square abutment pillar, while the new design employed a 36.6- by 54.9-m (120- by 180-ft) abutment pillar. Rock mechanics instrumentation data analysis and in-mine observations indicated that this increase in abutment pillar size significantly decreased bump potential. The new design in worst-case conditions increased effective bearing area 62 pct, with only a 9-pct increase in gate entry system width, and eliminated face bumps that were experienced with the original gate entry design.

OP 79-92. Continuous Haulage Systems for Computer-Assisted Continuous Miner, by S.K. Bhatt. Min. Eng., Oct. 1990, pp. 1184-1190. This paper reviews major developments in continuous haulage technology for underground coal mines. Haulage systems in use and development are investigated

through a comprehensive literature search and visits to mines and manufacturers. The systems include flexible conveyor train, mobile conveyor, multiple-unit continuous haulage, and extensible and belt turning systems. Strengths and weaknesses of the systems are assessed in light of their operating under remote control and their application to the computer-assisted continuous mining machine being developed by the U.S. Bureau of Mines. Through mining scenarios, candidate haulage systems are conceptualized to be consistent with the capabilities of the mining machine.

OP 80-92. **Cost-Benefit Analysis of Computer-Assisted Mining Through Production and Cost Modeling**, by Suresh K. Bhatt. SME Preprint 91-197, 1991, 13 pp. A mathematically simulated modeling technique is used in this U.S. Bureau of Mines paper to represent a hypothetical mining operation with existing mining technology and prevalent mining costs. Mining scenarios are prepared and evaluated for potential benefits and costs available through computer-assisted mining. Base criteria, parameters, and methodology are described.

OP 81-92. **On-Line Diagnostic Maintenance Systems for Continuous Mining Machines**, by J.C. Cawley. Min. Eng., Dec. 1991, pp. 1444-1448. Improvements in today's maintenance practices are mandatory as more complex and productive machines evolve in the mining industry. By keeping machine reliability high through improved maintenance procedures, overall mining costs can be reduced. The U.S. Bureau of Mines is investigating diagnostic maintenance systems for underground mining machinery. A hydraulic expert diagnostic system and an electric motor predictive diagnostic system have been designed and installed on a Joy 16CM continuous miner. An electrical diagnostic system has been designed and installed on a Joy 14CM continuous miner. Each system is functionally described, and the relative merits of expert diagnostic systems versus algorithmic diagnostic systems are discussed.

OP 82-92. **A Radar Coal Thickness Sensor**, by Robert L. Chufo and Walter J. Johnson. Paper in 1991 IEEE Industry Applications Society Annual Meeting, Volume II. IEEE Service Center, 1991, pp. 1182-1191. A radar coal thickness sensor is being developed by the U.S. Bureau of Mines to measure both the dielectric constant and thickness of a coal seam as part of a sensor array supporting a computer-assisted coal mining machine. The noncontacting stepped-CW radar sensor measures the complex reflection coefficient of the coal-shale interface to resolve the coal thickness to subwavelength accuracies. The technique uses a monostatic antenna configuration. Transfer function errors are identified by using spacial modulation created by antenna motion. Synthetic range gating is used for clutter rejection. Finally, polarimetric scattering matrix techniques are used to calculate the dielectric constant and thickness of the multilayered coal-shale media. Data taken both in the laboratory and in an underground mine, in the 0.6- to 1.4-GHz range, with a network analyzer and dipole antenna, have validated the technique. Accurate in situ measurements were made of a coal seam 6 in (15.2 cm) thick with a dielectric constant of 4. The coal thickness was confirmed by a physical measurement. An independent measurement of the coal dielectric constant was made by measuring the interaction of the coal with the fringing field of an open-ended dielectric probe. This measurement confirmed the accuracy of the noncontacting dielectric measurement technique. The one-dimensional spherical wave scattering matrix model, the data reduction process, and field test results are presented.

OP 83-92. **An Overview of Coal Rock Interface Detection Research**, by Harry Dobroski, Jr. Paper in Automation in Mining, A Workshop Taught at the 1990 National Symposium on Mining. Univ KY Office of Engineering Continuing Education, 1990, 4 pp. The U.S. Bureau of Mines is conducting research on a computer-assisted mining machine. Such a machine holds great promise for increased productivity and improved health and safety in the working section. A key element of such a machine is a coal interface detection (CID) system that can distinguish coal from noncoal material, no matter how complex the geology. Although much research has been done in the past by others in this area, there is still no general solution to the problem. Present Bureau CID research is focused on adaptive signal discrimination methods for analyzing the vibration of the mining machine, advanced infrared thermography, modern video systems, natural gamma emissions, advanced radar methods, and geological conditions. It appears that a suite of sensors with associated data analysis may result in a practical system.

OP 84-92. **Distributed Temperature Sensing for Underground Belt Lines**, by Harry Dobroski, Jr., and Ronald S. Conti. Ch. 3 in 6th Annual International Longwall Mining Conference and Exhibition. Longwall U.S.A., 1991, pp. 143-156. Reliable monitoring for fires is essential for the safe operation of underground mines. Usually, the parameters of interest are heat and products of combustion. Since products of combustion, such as carbon monoxide and smoke, are carried along by the ventilation, they are easily detected by fixed-point sensors at some distance from the source. However, the detection of heat must be accomplished close to the source if rapid information is required. This paper reviews distributed temperature-measuring systems that can detect heat sources anywhere along their continuous length. These systems use distributed thermocouple, thermistor, resistive, or fiber optics effects. An in-mine test was conducted at the U.S. Bureau of Mines Lake Lynn Laboratory to assess the performance of an advanced state-of-the-art distributed fiber optics system to a slowly developing coal and/or conveyor belt fire. The data show that the distributed fiber optic temperature sensor system may work well for underground fire detection applications.

OP 85-92. **Fiber Optics for Atmospheric Mine Monitoring**, by T.H. Dubaniewicz, J.E. Chilton, and H. Dobroski. Paper in 1991 IEEE Industry Applications Society Annual Meeting, Volume II. IEEE Service Center, 1991, pp. 1243-1249. Fiber optic technology is progressing rapidly, including the development of fiber optic sensors for a wide variety of applications. These sensors have the advantage of high sensitivity, light weight, small size, high bandwidth, and freedom from electromagnetic influences. The U.S. Bureau of Mines is investigating the application of fiber optic technology to monitoring mine atmospheres. This paper describes work done to address methane, carbon monoxide, and distributed temperature monitoring. A review is made of the potential and problems of using fiber optics for mine monitoring systems. Methane detection is based on differential absorption of infrared

light. A methane monitor is described that can detect concentrations as low as 0.2 pct as far away as 2 km via fiber optic cable. The upper range is 100 vol pct methane. Since the system requires no electrical power within the mine, it is intrinsically safe. A carbon monoxide monitoring system is described that combines a low-powered electrochemical cell with fiber optic telemetry. Testing has shown the system can operate maintenance-free for several months. Finally, a distributed fiber optic temperature-monitoring system is being investigated for possible application in mine fire detection. Performance of this system at the Bureau's Lake Lynn Laboratory is reported. The sensor employs optical time domain reflectometry techniques that allow the entire length of fiber (up to 2 km) to function as a distributed temperature sensor. Distributed temperature sensors have considerable potential for monitoring areas such as conveyor beltways.

OP 86-92. Mathematical Model of Flame Spread Along a Confined Horizontal Fuel Surface, by John C. Edwards and Charles D. Litton. Paper in Proceedings, 1992 Technical Meeting, Central States Section, the Combustion Institute, Combustion Fundamentals & Applications. OH State Univ., 1992, pp. 162-167. This U.S. Bureau of Mines paper presents a quasi-steady-state mathematical model of fire growth along a ventilated horizontal fuel surface. The model couples an equilibrium state combustion zone confined by the roof above the pyrolyzing surface with a tilted flame front that preheats the fuel surface ahead of the combustion zone in a transient mode and is used to predict the growth of the pyrolyzing surface. Radiative and convection heat transfer to the fuel surface ahead of the flame front are included. The total flame emissivity includes gas emissivity for the CO_2 and H_2O in the product-of-combustion gas and the particulate emissivity. Material burn-through is included. Predicted transient fire growth along a styrene butadiene rubber material is analyzed for the effect of ventilation and entrainment and is in reasonable agreement with measurements.

OP 87-92. Using Simulation To Prepare for Emergency Mine Fire Evacuation, by Audrey F. Glowacki. Paper in 1992 International Emergency Management and Engineering Conference: Managing Risk With Computer Simulation, ed. by J.D. Sullivan. Soc. for Computer Simulation, 1992, pp. 79-83. The U.S. Bureau of Mines is currently developing a stochastic, graphics-based computer model to investigate the probability that miners would be able to safely evacuate a longwall mine section in the event of a fire. When complete, this model will be capable of considering many variables that affect the outcome of an underground emergency situation. Included among these factors are severity and initial location of the fire, mine design, stability of the mine structures, physical characteristics and performance of the miners, and the availability and reliability of protective equipment. Using this model to evaluate the risks associated with specific longwall systems, supportable decisions could be made concerning modifications to those systems that maximize worker safety and productivity.

OP 88-92. Characterizing Mine Emergency Response Skills: A Team Approach to Knowledge Acquisition, by Launa Mallett and Charles Vaught. Paper in 1992 International Emergency Management and Engineering Conference: Managing Risk With Computer Simulation, ed. by J.D. Sullivan. Soc. for Computer Simulation, 1992, pp. 75-78. This paper presents an ongoing U.S. Bureau of Mines research effort that focuses upon the management of large-scale underground mine emergencies. Included is an outline of the methodology being used to extract information from domain experts who have gained extensive knowledge while dealing with mine emergencies in the past. The document also contains a description of interview data that have been acquired to this point and explores some potential uses of these data for characterizing response behavior during mine emergency situations. Finally, concluding comments center upon a discussion about the significance of forming one -composite knowledge engineer- by teaming two skilled social scientists with a computer scientist in order to create an emergency response simulation.

OP 89-92. Software for Hydrologic Monitoring of In Situ Leaching Operations, by Peter K. Mathison, F. Brendan Murphy, Eric Level, and Michael E. Salovich. Ch. 89 in Proceedings of the 23rd International Symposium on the Application of Computers and Operations Research in the Mineral Industry. SME, 1992, pp. 917-923. The U.S. Bureau of Mines is developing a hydrologic monitoring system for in situ leaching operations. A working prototype of this system was installed and tested at the Cyprus Casa Grande copper mine. Requirements specific to in situ leaching operations were identified by researchers. The system has been a useful tool for researchers and for mine personnel. Observations of the hydrologic monitoring system, including details of the development process, the design of the system, and the software developed at the Bureau, have resulted in new ideas for an enhanced design of the system.

OP 90-92. Research Into a Sensor-Based Diagnostic Maintenance Expert System for the Hydraulics of a Con-tinuous Mining Machine, by Julie Mitchell. Paper in 1991 IEEE Industry Applications Society Annual Meeting, Volume II. IEEE Service Center, 1991, pp. 1192-1198. The U.S. Bureau of Mines is completing development of a diagnostic maintenance system as part of its investigation into using expert system techniques to diagnose and predict hydraulic problems on a continuous mining machine. Machine breakdowns due to hydraulic system failures are well-known contributors to sometimes prolonged maintenance delays, resulting in lost production time and increased operating expenses. The Bureau's effort to apply sensor-based expert system techniques to mining machine diagnostics will result in the availability of an effective new type of maintenance tool. This tool will help reduce the frequency of equipment failures and repair times, in turn increasing productivity and decreasing costs. The Bureau has developed an expert knowledge base to diagnose hydraulic problems on a Joy 16CM continuous mining machine. This diagnostic system is interfaced to machine-based sensors that monitor various hydraulic systems parameters, such as pressures, flows, temperatures, fluid level, and ferrous debris present in the oil. The status of these parameters is updated periodically and transmitted via a distributed interface to the diagnostic knowledge base. All diagnostic decisions are made based upon the available sensor information. This paper describes this sensor-based diagnostic maintenance tool and its components. The testing and evaluation plans for this system on the 16CM will also be outlined.

OP 91-92. Horizon Control Holds Key to Automation, by Gary L. Mowrey. Coal, Dec. 1991, pp. 44-48 (pt.

I); Jan. 1992, pp.47-51 (pt. II). A coal-rock interface detector (CID) system is integral in providing coal seam tracking capability for mining machines. The CID system must be able to measure one or more properties of coal and adjacent formations and, subsequently, must be able to identify the geologic material being cut, to locate the coal-rock interface, and/or to determine the thickness of the coal remaining below the roof or above the floor. Various types of commercial and experimental CID systems are being used, and novel CID concepts are being investigated by the U.S. Bureau of Mines and other research organizations throughout the world. CID systems can be used for both manually operated and computer-assisted mining equipment. A reliable CID system can offer significant economic and safety advantages, including higher coalbed extraction, reduced dilution of mined material by minimizing the amount of roof or floor material cut, less ash and sulfur, increased coal-cutting rates, decreased maintenance of the machine due to reduced rock-induced vibration, reduced quartz dust levels, and relocation of the operator from the hazardous face area. More than 20 types of CID concepts have been investigated in the United States and abroad during the past 30 years. Of these, only the natural gamma radiation concept has been successful enough to be made into a commercially available system. It is being used on longwall shearers and continuous miners in Britain and on some highwall mining machines in the United States. This technique is also being evaluated on a limited basis in the United States on continuous miners and longwall shearers. Several CID systems contain proprietary features. Technical information on some of these systems has been published, but details on other systems have been closely guarded. Consequently, it is difficult to accurately describe and assess the performance of every CID system.

OP 92-92. **An Overview of Coal Interface Detection Methods**, by Gary L. Mowrey, Slavoljub D. Maksimovic, and Michael J. Pazuchanics. Ch. in 6th Annual International Longwall Mining Conference and Exhibition. Longwall U.S.A., 1991, 15 pp. A coal-rock interface detector (CID) system is of major importance in providing coal-seam-tracking capability for mining machines. The CID system must be capable of measuring one or more properties of coal and adjacent formations. Subsequently, it must be able to identify the geologic material being cut, locate the coal-rock interface, and/or determine the thickness of the coal remaining below the roof or above the floor. This paper provides a brief practical overview of various types of commercial and experimental CID systems currently being used and novel CID concepts being investigated by the Bureau and other research organizations throughout the world. In addition, two systems designed for noncoal operations are identified.

OP 93-92. **Research & Development**, by J.N. Murphy. Min. Eng., May 1992, pp. 457-459. This article discusses recent U.S. Bureau of Mines studies in health and safety improvements and environmental issues related to current and past mining operations.

OP 94-92. **Controlled Cutting Experiments for Longwall Coal Interface Detection Applications**, by Michael J. Pazuchanics and Gary L. Mowrey. Ch. in Conference Record. Longwall U.S.A., 1990, 9 pp. The U.S. Bureau of Mines has recently initiated a series of controlled cutting experiments for the purpose of collecting accurate sensory data in order to establish performance levels for coal-rock interface detection (CID) systems. The experiments consist of measuring bit forces, vibration, and thermal information as a linear cutting apparatus (LCA) makes constant-depth cuts in coal and rock materials. Data from these tests will be used to train, evaluate, and test CID systems that utilize adaptive signal discrimination to identify the type of material being cut. Initial tests are being conducted utilizing simple geological materials (e.g., coal without hard bands or significant cleats). Following these tests, sensory data for more complex geological materials and interface conditions will be similarly collected and processed. This paper describes the LCA, test instrumentation, and sample preparation, and presents some preliminary cutting force data obtained from a coal sample.

OP 95-92. **An Investigation of the Ignition Hazards Associated With Various Materials in the Breakflash Apparatus**, by Jeffrey Shawn Peterson. Paper in 1991 IEEE Industry Applications Society Annual Meeting, Volume II. IEEE Service Center, 1991, pp. 1254-1262. The U.S. Bureau of Mines Pittsburgh Research Center has completed an investigation of the degree to which various disk materials affect the probability of igniting a methane-air atmosphere using the breakflash machine. Data were generated for estimating currents (resistor or inductor circuits) and voltages (capacitor circuits) associated with a particular ignition level. Further analysis of these data was used to assign hazard levels for each material, with cadmium used as a reference material. From this, a safety factor was associated with each material. Presently, there are no construction requirements with regard to materials of construction. The worst case is always assumed (i.e., cadmium). Laboratory test results confirmed cadmium as the worst case material among those tested for resistor and inductor circuits but not for capacitor circuits.

OP 96-92. **Graphic Algorithms in an Object-Oriented Hydrology Model**, by Michael E. Salovich, Peter K. Mathison, Daniel C. Hollar, and Jeffrey D. Conrad. Ch. 65 in 23rd Application of Computers and Operations Research in the Mineral Industry, ed. by Y.C. Kim. SME, 1992, pp. 679-690. The U.S. Bureau of Mines has developed a prototype version of a computer application that combines hydrologic analysis with object-oriented graphics. This software is unique in that it presents analytic element analysis within an object-oriented CAD environment. Its user interface employs mouse handling, scrolling windows, dialog boxes, palettes, and pull-down menus. It can import scanned images of maps and overlay these images within the same window. This application was developed using object-oriented programming techniques. Several programming issues concerning graphics had to be resolved during development of this system. These include (1) how to represent hydrologic elements as graphical objects, (2) how to translate screen coordinates to map coordinates, (3) how to implement "zooming" (changing the magnification level of a window), (4) how to overlay layers of images, and (5) how to import scanned images of maps. An object library was used to implement graphical user interface features such as scrolling windows and pull-down menus. Algorithms or CAD features such as map coordinate translation, zooming, and the layering of images were developed by Bureau researchers. The application has a modular source code structure and can be modified for use in other research applications.

OP 97-92. Flocculation and Dewatering, by B.J. Scheiner. Min Eng., May 1992, pp. 465-466. This U.S. Bureau of Mines paper reviews recent developments in flocculation and dewatering.

OP 98-92. A Flexible Control, Communication, and Data Collection Network for Mining Machines, by William H. Schiffbauer. Paper in Proceedings of the 1991 IEEE International Symposium on Intelligent Control. IEEE, 1991, pp. 353-358. The U.S. Bureau of Mines has integrated off-the-shelf components into a microcomputer-based control, communication, and data collection network that provides a base for computer-controlled mining machine research and coal production applications. Functions provided by the network include closed-loop control, teleoperation, navigation, data collection, and diagnostics. These functions are all provided to help pursue the Bureau's goal of moving the man off of the machine and to a safer area. The installation of the network or a Joy 14CM continuous mining machine has accelerated the collection of data and the generation of navigation and control algorithm. The demonstrated functions of the system lend themselves to potential use on other mining machine types.

OP 99-92. Overview of the U.S. Bureau of Mines Computer-Assisted Mining Research Program, by G.H. Schnakenberg, Jr., and J.J. Sammarco. Paper in Proceedings, International Symposium on Mine Mechanization and Automation, Volume II, ed. by L. Ozdemir, R. King, and K. Hanna. CO Sch. Mines, 1991, pp. 9-9 to 9-30. The U.S. Bureau of Mines is pursuing computerization in mining to provide a means to reduce health and safety risks to workers along with opportunities to increase competitiveness. The Bureau's short-term research is directed to providing computer-assisted, remote supervisory operation of present mining equipment; the long-term goal is the development of progressively more intelligent mining systems. Current efforts are directed towards computer-assisted operation of a continuous mining machine. A new machine was prepared for sensor-based, computer-controlled operation. The machine is ready for initial underground mine tests under a cooperative agreement at a West Virginia mine complex. Many areas of research are needed for continued support of the continuous miner and to allow evolution and expansion of computer-assisted mining to realize the long-term goal of intelligent mining systems. The Bureau's program encompasses diverse areas such as research in navigation and guidance technology, machine control systems, tele-remote control, computer systems and architectures, coal-rock interface sensing technology, and expert systems for machine system fault diagnostics and predictive maintenance. This paper presents a brief background and the current status of these research areas. Research progress in other equipment and systems critical to achieving long-term goals, such as roof bolting and continuous haulage, is briefly reviewed.

OP100-92. Modeling of the Capillary Suction Time of Kaolin Slurries Using Chemometrics, by S.K. Sharma and D.A. Stanley. Ch. in Advances in Filtration and Separation Technology, Volume 5: Separation Problems & the Environment, ed. by B. Scheiner. Am. Filtration Soc., 1992, pp. 319-326. For this investigation, eight different concentrations of kaolin slurry were evaluated. Factor analysis of the data showed that there were two physically significant factors affecting the experiment. The first factor was applicable to the data below x = 3 cm and had an exponential characteristic, while the second factor applied to the data between x = 3 to 6 cm. The data between 3 and 6 cm were reproduced adequately by Tiller's equation. A regression equation was used to predict the data between 0 and 3 cm. The combination of both equations reproduced the results to within ^F4 pct. It was found that the average specific resistance is inversely proportional to the clay slurry concentration and that as the concentration increases, the average resistance decreases. Finally, this investigation showed that factor analysis was successful in finding significant factors that had physico-chemical meaning; therefore, it could be applied to future dewatering studies.

OP 101-92. Mining Waste Research in the U.S. Bureau of Mines, by Valois R. Shea-Albin and William N. Fitch. Paper in Proceedings of 1991 SME Environmental Symposium. SME, 1991, pp. 199-205. In 1976, the Resources Conservation and Recovery Act (RCRA) aroused concern in the mining community about the regulation of mine waste streams under RCRA. In response, the U.S. Bureau of Mines initiated research in the late 1970's that addressed mine and minerals processing waste. Research included investigating improved environmental technology for metal, coal, nonmetal, and emerging industries such as oil shale, tar sands, peat, and lignite. Environmental issues escalated in the 1980's. Proposed regulations addressing control technology for mining and mineral processing wastes prompted the Bureau of Mines to become involved in 1985 in an advisory capacity to the regulatory agency, the Environmental Protection Agency. In fiscal year 1988, the Bureau of Mines initiated a research program designed to provide the minerals industries with cost-effective solutions for ameliorating environmental effects of mining. Bureau research has led to advances in the areas of acid mine drainage control and mitigation, subsidence prediction and control, and control and treatment of sold wastes resulting from mining and mineral beneficiation. The Bureau also conducts research seeking new methods to remediate abandoned mine lands. A discussion of mine waste issues is presented, followed by a summary of past and present research conducted by the Bureau of Mines.

OP 102-92. Health and Safety Issues Related to Extended Longwalls, by Edward D. Thimons, Robert A. Jankowski, Gerald L. Finfinger. Paper in Proceedings, 22nd Annual Institute on Coal Mining, Health, Safety and Research. Dept. of Min. and Miner. Eng. VPI and State Univ., 1991, pp. 101-111. Longwall mining has always been associated with high productivity and increased resource recovery. To optimize these benefits, there has been a trend in the industry to increase the size of longwall coal panels. These extended longwall panels, sometimes referred to as "super longwalls", offer some major benefits in terms of fewer panel moves, less entry development, and increased resource recovery. However, the use of extended longwalls does change the mining environment, and this may positively or negatively impact health and safety concerns. For example, fewer panel moves could reduce injury rates since more accidents occur during moves than during actual longwall mining. Also, the frequency of accidents in longwall mining is lower than in continuous mining. Since extended longwalls reduce the amount of continuous miner development, accident rates should be lower. On the other hand, extended panels could introduce concerns in the areas of dust, methane, ground control, ventilation, and fire and escape. This U.S Bureau of Mines paper looks at these issues and at what

some current extended longwall operations are doing in terms of operating changes to address them.

OP 103-92. Low Incendive Explosives for Sulphide Ore Blasting, by Eric S. Weiss, James S. Morrison, George Beattie, and Michael J. Sapko. J. Explosives Eng., v. 5, Jan.-Feb. 1992, pp. 15-27. Sulphide dust explosions in underground mines have caused fatalities, serious injuries, and significant damage to equipment. The U.S. Bureau of Mines has engaged in an extensive research project to help alleviate this problem in both the United States and Canada. Hundreds of tests have been conducted in the Bureau's Lake Lynn Laboratory Cannon Gallery to evaluate the incendivity characteristics of both commercially available and experimental explosive products. The Cannon Gallery test results have clearly identified several low-incendive explosives that can significantly reduce the secondary dust ignition hazards associated with blasting in noncoal mines. Explosives Technology International, Inc. (ETI), working in conjunction with the Bureau, has developed several low-incendive explosives and inert stemming materials that show promise in reducing the probability of secondary dust ignitions following underground blasting in noncoal mining operations. The Bureau, with technical support from ETI, has field-tested a new low-incendive pumpable emulsion-ANFO blend product at Union Oil's oil shale project at Parachute Creek, CO. A low-incendive water gel product is currently undergoing testing at Kennecott's Greens Creek sulphide ore mine on Admiralty Island southwest of Juneau, AK. Results of the field testing with the low-incendive products are most encouraging. No secondary dust ignitions have occurred when using these low-incendive products in sulphide ore mines.

OP 104-92. In Situ Mining, by Jon K. Ahlness. Ch. in MinTech -91: The Annual Review of International Mining Technology and Development, ed. by T.L. Carr. Sterling, 1991, pp. 25-27. In situ mining is a relatively new mining technique which has been successfully used on a commercial basis to mine uranium, and has the potential to lower production costs and significantly reduce surface disturbance when compared with conventional open pit and underground mining methods. These two potential benefits have provided incentives for the U.S. Bureau of Mines to conduct research to develop this technology for copper oxide mineralization that is hosted by fractured, hardrock deposits. If successful, this mining method could be used to recover copper from small, deep, and/or low-grade deposits that are uneconomic to mine by conventional methods, and provide mineral production in a more environmentally acceptable manner. Other commodities, such as manganese, gold, and silver, also have potential to be mined by in situ methods.

OP 105-92. Relative Contribution of Behavior to Slip and Fall Accidents in Mining Maintenance, by Thomas F. Albin. Paper in Proceedings of the Human Factors Society 32nd Annual Meeting. Human Factors Soc., 1988, pp. 511-514. U.S. Bureau of Mines research has indicated that slip and fall accidents are a major cause of injuries during the maintenance of surface mining equipment. All such injuries during 1985, 1986, and the first half of 1987 were studied for information as to accident causes, particularly whether the nature of the causes was worker behavior or machine design. Accidents judged to be solely caused by behavior of the injured individual constituted only 11 pct of a total of 1,384 accidents. An interaction of machine design and behavior was found to be involved in 31 pct of the accidents. The information presented in this study as to antecedent events to slip and fall accidents may be useful in designing intervention strategies to decrease slip and fall injuries.

OP 106-92. Slip and Fall Accidents During Equipment Maintenance in the Surface Mining Industry, by Thomas J. Albin and Wayne P. Adams. Paper in Advances in Industrial Ergonomics and Safety I, ed. by A. Mital. Taylor & Francis, 1989, pp. 585-591. U.S. Bureau of Mines research has found that injuries resultant from slips and falls are frequent during maintenance of surface mining equipment, accounting for 20 percent of such accidents. This study utilized relative risk ratios to assess the hazards associated with using access system elements such as ladders and stairs and with various behaviors known to be associated with slip and fall accidents. Access system elements were found to be relatively more hazardous than behaviors.

OP 107-92. Noise Reduction Potential of a Variable Speed Driven Coal Mining Conveyor, by J. Alton Burks and Roy C. Bartholomae. Ch. 5 in New Technology in Mine Health and Safety. SME, 1992, pp. 43-51. The chain conveyor is utilized extensively in underground mining to convey raw ore, especially coal. It is estimated that several thousand loading and continuous mining machines rely on this type of conveyance. Although the chain conveyor is both efficient and highly reliable, its use is generally associated with the production of noise levels that often exceed 105 dBA at the operator's position. Thus, it is one of the most significant contributors to the occupational noise problem experienced by miners in the underground coal mining environment. Conventional engineering noise controls that result in an average reduction of 4 dBA have been previously designed and implemented. However, a novel solution involving a change in conveyor operation has been proposed that takes advantage of two aspects of conveyor noise: (1) conveyor noise has an approximately cubic dependence on conveyor chain speed and (2) due to the damping provided by coal, a full conveyor is 5 dBA quieter than an empty one. An engineering analysis by the U.S. Bureau of Mines has shown that a significant reduction in the operating noise level of a typical continuous miner can be achieved through the use of an adjustable-speed drive automatically controlled by a coal-loading sensor that maintains a full conveyor at all times. The potential reduction depends primarily on the mining conditions (coal seam thickness and the presence of either rock or water) and ranges from 7 to 18 dBA. Other benefits to be derived from the use of a variable-speed drive include reductions in power consumption, dust, and maintenance costs.

OP 108-92. Hazard Analysis of Mining Equipment by Mine Type and Geographical Region, by Shail J. Butani. Ch. 14 in Engineering Health and Safety in Coal Mining. SME, 1986, pp. 158-173. This U.S. Bureau of Mines paper analyzes the 1982 coal mine accident data collected by the Mine Safety and Health Administration (MSHA) for key equipment types, by mine type, and by geographic region. The differences in hazards associated with the various equipment types are studied both in absolute (i.e., total number of incidences) and relative (i.e., incidence rate or the number of incidences per 200,000 employee or exposure hours) terms. The paper compares and contrasts the total number of incidents as

well as incidence rates classified by several types of severity measures such as lost workdays cases, mean number of lost workdays per lost workdays case, fatal cases, nonfatal cases without lost workdays, total number of cases, and total number of lost workdays. This statistical analysis shows that significant differences in hazards exist not only due to equipment type but also due to mine type and geographic region.

OP 109-92. Relative Risk Analysis of Injuries in Coal Mining by Age and Experience at Present Company, by Shail J. Butani. J. Occupational Accidents, v. 10, 1988, pp. 209-216. In 1986, the U.S. Bureau of Mines conducted a probability sample survey to measure the characteristics of the U.S. mining industry workforce. This paper shows how demographics survey data are utilized to ascertain whether the observed variations in the injury (includes illness and fatality) risk for the coal mining industry in 1986 correlate with age or with experience at present company or both. This analysis found that injuries in the coal industry vary more by experience at present company than by age. That is, the workers were experiencing injuries at the same rate when grouped by worker's age, but not when grouped by worker's experience at present company. Employees with 1 year or less of experience were at a considerably higher-than-average risk, while employees with more than 15 years of experience were at a lower-than-average risk. This was true for each age group as well as for all age groups combined.

OP 110-92. Which Subpopulations of the Mining Industry Are at a Higher- or Lower-Than-Average Risk for Back Injury Problems?, by Shail J. Butani. Paper in Trends in Ergonomics/Human Factors V, ed. by F. Aghazadeh. Elsevier, 1988, pp. 741-748. The U.S. Bureau of Mines in 1986 conducted a probability sample survey to measure the characteristics of the U.S. mining industry workforce. This paper discusses the importance of collecting demographics data for the purposes of analyzing existing injury and illness data. In particular, it shows how demographics survey data are utilized in identifying subpopulations of the 1986 mining workforce (by sex, age, experience at present job, and job title or occupation) that exhibited a disproportionately higher- or lower-than-average number of work-related back injuries, as well as lost workdays due to back injuries. These injuries in 1986 accounted for 19 pct of all mining incidents and 29 pct of all lost workdays. The results of the analysis show that of all the subpopulations studied, continuous miner and related machinery operators in the coal industry had the highest risk for back injuries and related lost workdays, about four times the average. For both coal and metal and nonmetal sectors (metal, stone, sand and gravel, and nonmetal), the workers in the age group 30 to 39 were at a higher than average risk, whereas those age 50 and over were the least prone (below average) to back injury problems.

OP 111-92. Distributed Temperature Sensing for Underground Belt Lines, by Harry Dobroski, Jr., and Ronald S. Conti. Ch. 3 in Mine Health and Safety. SME, 1992, pp. 21-28. Reliable monitoring along an underground mine belt is of great concern because of combustibles, electrical apparatus, and friction. Belt entries are strategically located where a fire can have rapid and disastrous consequences. This paper reviews conventional distributed temperature-sensing systems based on resistive, thermistor, and thermocouple effects. These are shown to provide limited benefits. A new system tested by the U.S. Bureau of Mines, based on fiber optics and time domain reflectrometry, promises much better temperature and spatial resolution, faster response, inexpensive cable, longer distance, and comprehensive data analysis. Test results in a small, controlled, in-mine fire are given.

OP 112-92. Evaluation of Two Work Schedules in a Mining Operation, by James C. Duchon. Paper in Trends in Ergonomics/Human Factors V, ed. by F. Aghazadeh. Elsevier, 1988, pp. 151-160. Research in the area of shift work has found that it produces a variety of negative consequences, specifically, sleep deficiencies, performance decrements, fatigue, gastrointestinal disorders, and social and marital problems. Therefore, management needs to be able to objectively measure the degree of worker satisfaction and the adequacy of particular shift schedules. This paper presents results of a method designed by the U.S. Bureau of Mines to assess these problems in a taconite mining company. The site is divided into two groups of plant and pit workers, having two different rotating shift schedules. Informal conversation, a plantwide vote, and survey items clearly indicate that the continuous 28-day-phase advance shift schedule is less accepted by the workers than is the discontinuous 21-day-phase advance shift schedule. Results indicate differences between the two groups on certain variables such as sleep quantity and quality, eating, and physical and mental exhaustion. It is concluded that the survey represents a valid instrument in that it is sensitive to variables known to be affected by working irregular hours, and that it discriminates between the workers on the two different work schedules.

OP 113-92. The Adjustment to a Slowly Rotating Shift Schedule: Are Two Weeks Better Than One?, by James C. Duchon and Christopher M. Keran. Paper in Proceedings of the Human Factors Society 34th Annual Meeting. Human Factors Soc., 1990, pp. 899-903. The U.S. Bureau of Mines is examining alternative rotating work schedules that are more conducive to the health and safety of mining shiftworkers. The question asked in this study is whether or not there is an advantage to working the second week of a 2-week cycle, as would be indicated by reports of more positive health, mood, and sleep items on the second week as compared to the first week. Forty-two workers at a surface mine in the Midwest filled out a work, food, and sleep diary for 4 to 6 weeks. They rotated every 2 weeks, going from days to nights to afternoons with all weekends off. The dependent measures were defined as (1) health-the daily frequency of reported symptoms, (2) mood-based on a self-evaluation of four descriptors, ALERT, SLEEPY, GROUCHY, and RELAXED, and (3) total sleep length and sleep quality. Results indicated that on the second week of the night shift workers reported significant improvements in all four mood descriptors for the second half of their shift. Also, sleep quality as measured by awakenings during sleep improved on the second week of the night shift. None of the variables showed a worsening on the second week of the night shift. These results do not support a "cumulative trauma" effect for the schedule studied in this paper. On the basis of this study it could be recommended that two-week cycles are superior to one-week cycles.

OP 114-92. Relationships Among Shiftworker Eating Habits, Eating Satisfaction, and Self-Reported Health in a Population of US Miners, by James C. Duchon

and Christopher M. Keran. Work & Stress, v. 4, No. 2, 1990, pp. 111-120. As part of a larger study on the health and safety of shiftworkers in the mining population by the U.S. Bureau of Mines, the association between meal frequency, meal regularity, eating satisfaction, and a self-reported health index was examined. Although the link between shiftwork and some health complaints, such as gastrointestinal disorders, has been established, the research needed to understand why this occurs has not been fully undertaken. Specifically, academic nutritional research has substantially ignored the question of how working irregular hours affects the eating behavior of industrial workers such as miners. In this study the eating habits of 101 surface mine workers were studied. It was found that working the day, afternoon-evening, and night shifts was related to the number of meals eaten on those shifts and to the consistency of timing of those meals. The lowest eating satisfaction levels were reported by those who ate at different times on all shifts and who changed the number of meals eaten per day on each shift. Lowest self-reported health ratings were reported by those who changed the number of meals taken on each shift, rather than by those who ate one, two, or three meals per day. These results are discussed in relation to the possible mechanisms contributing to gastrointestinal disorders and to coping mechanisms that could be adopted by shiftworkers.

OP 115-92. The Effects of Sleep Strategies on the Health, Length and Quality of Sleep of Rotating Shiftworkers on the Night Shift, by James C. Duchon and Christopher M. Keran. Paper in Proceedings of the IX International Symposium on Night and Shift Work. Peter Lang, 1989, pp. 461-466. As part of an effort to improve the health and safety of shiftworkers in the mining industry, the U.S. Bureau of Mines is studying their sleep and work habits. Whereas shiftworkers on the day shift are more or less job-bound, i.e., they normally go to bed between 9 and 11 pm and wake up in time to go to work, shiftworkers on the night rotation employ a variety of sleep strategies. Given this variability in sleep behavior, professional shiftwork researchers and consultants have promulgated "preferred" sleep strategies, but often with little agreement. This study is a further attempt to associate shiftworkers- sleep strategies with sleep quantity and quality, physical tolerance to the night shift, and health complaints.

OP 116-92. The Consideration of Human Factors in the Design of a Backing-Up Warning System, by James C. Duchon and Linneas W. Laage. Paper in Proceedings of the Human Factors Society 30th Annual Meeting. Human Factors Soc., 1986, 4 pp. Despite the use of automatic backing-up warning systems, large mobile equipment is still involved in reversing collisions, causing injuries, fatalities, and property damage. This paper discusses specific human factors that contribute to the failure of this type of system as used on front-end loaders in the surface mining industry. The use of the backing-up automatic alarm causes the operators to lose the perception of responsibility for vigilant behavior, while the ground crew predictably becomes habituated to the alarm. These human factors and their interaction with the noise pollution created by the alarms sets up a potentially unsafe condition. U.S. Bureau of Mines research into discriminating backup warning systems could provide an effective alternative to the conventional backup alarm.

OP 117-92. Softening-Melting Characteristics of Taconite Pellets, by L.A. Haas, J.A. Aldinger, and R.K. Zahl. Skillings-Min. Rev., v. 79, No. 35, Sept. 1, 1990, pp. 4-14. This U.S. Bureau of Mines research was initiated to delineate the influence of the experimental variables on high-temperature softening-melting properties of pellets. The goals were to (1) investigate the influence of the starting metallization temperature, CO content of the reducing gas, and the flux level on the HTSM indices, and (2) relate these indices to the physical and chemical properties of the pellets. The raw materials consisted of taconite concentrate, bentonite, dolomite, and limestone.

OP 118-92. Magnetite Oxidation of Acid and Fluxed Taconite Pellets, by Larry A. Haas and John C. Nigro. Paper in Proceedings of 75th Steelmaking, 51st Ironmaking, and 10th Process Technology Divisions. Braun-Brumfield, Ann Arbor, MI, 1992, 17 pp. The U.S. Bureau of Mines, in cooperation with Cleveland-Cliffs, Inc. (Hibbing, MN), investigated ways of enhancing the quality (compressive strength, after-tumble, and reducibility) of domestic acid and fluxed magnetite pellets by modifying the oxygen content during the preheat and induration periods of the firing operation. Oxidation of magnetite was best accomplished when sufficient oxygen and time were available before the peak induration temperature was reached. The rate of magnetite oxidation increased directly with the gas oxygen content during the preheat period. With 30 pct (or more) O_2 and a preheat rate of 200° C/min, most of the magnetite was oxidized during the preheat period. At lower oxygen levels and/or higher preheat rates, more coalescing (sintering) of the magnetite particles occurred in the pellet core. This coalescing action resulted in the shrinking and cracking of the magnetite in the pellet core, which often pulled away from the hematite shell. With this duplex structure, cracks were observed and the pellets were weaker. With laboratory tube and minipot furnace tests, oxygen enrichment during the preheat period improved the pellet properties more in the simulated grate-kiln tests than in the simulated straight-grate tests. The longer induration period with the grate-kiln test resulted in more sintering of the residual magnetite and its reaction with the silicon compounds. When flux was present in the pellets, calcium silicates and calcium and magnesium ferrites were formed. More calcium ferrite was formed when the magnetite was oxidized early and less iron ended up in the fayalitic calcium silicate slag. Both the acid and the fluxed pellets had higher compressive strengths, after-tumble values, and reduction rates when the magnetite was oxidized early during the firing operation. In the minipot tests with the simulated grate-kiln procedure, increasing the oxygen content during the preheat period from 15 to 30 pct O_2 resulted in pellets with higher compressive strengths and after-tumble values. When the preheat rate was increased from 150 to 300° C/min, the compressive strength of the acid and fluxed pellets decreased more with 15 pct than with 30 pct O_2 during the preheat period. Further larger scale tests will be required to determine if increasing the oxygen content, along with the preheat rate, can result in increased pellet production.

OP 119-92. A Psychophysical Method To Determine Ingress/Egress Dimensions for Mobile Underground Mining Equipment, by Christopher A. Hamrick, Kim M. Cornelius, E. William Rossi, and Richard L. Unger.

Paper in Advances in Industrial Ergonomics and Safety IV, ed. by S. Kumar. Taylor & Francis, 1992, pp. 561-567. In this U.S. Bureau of Mines study, 16 male and 16 female subjects were tested in order to determine appropriate ingress and egress opening dimensions for mobile underground mining equipment. Opening dimensions were determined for seating configurations used in five different seam heights: 81, 95, 123, 135, and 160 cm. A psychophysical methodology was used whereby each subject entered and exited a mockup of a cab and adjusted the width of a sliding door to the minimum width that allowed for safe and comfortable ingress and egress. The mean opening widths, from lowest to highest seam height, are 132, 122, 112, 98, and 78 cm. The 95th percentile opening widths, from lowest to highest seam height, are 162, 149, 140, 122, and 101 cm.

OP 120-92. Effects of Electrode and Atmospheric Variables on EAF Performance, by A.D. Hartman, T.L. Ochs, and P.E. King. Iron and Steelmaker, v. 19, No. 5, May 1992, pp. 51-53. Three U.S. Bureau of Mines test series showed statistically that there was no advantage for gas injection through the electrode tip, and that the geometry of the electrode should be smooth shaped (conical) to make a significant difference in the amount of energy consumed. Also affecting energy and electrode consumption was the furnace atmosphere composition. An inert composition of 95 pct He and 5 pct Ar saved on both energy and electrode consumption when compared with an air atmosphere. Electrode tips with an axial hole but no gas injection, and in an Ar atmosphere, appeared to provide a good initial arc rooting surface. This type of electrode tip promoted uniform electrode tip wear and more efficient heat transfer. The axial holed electrodes transferred energy approximately 2 and 3 pct more efficiently than either solid electrodes or axial holed electrodes with gas injection, respectively. The center hole did not adversely affect electrode consumption or energy consumption. This could indicate that the addition of an axial hole to electrodes could improve heat transfer efficiency without any adverse effects. This especially could be true in ladle metallurgy, where a smooth surface metal bath is present. Other studies have indicated that hollow electrodes also reduce refractory wear in ladle operations.

OP 121-92. A Review of Jet Assisted Rock Cutting, by M. Hood, G.C. Knight and E.D. Thimons. Trans. ASME, v. 114, May 1992, pp. 196-206. High-volume, low-pressure water jets have been employed for erosion of loosely consolidated rocks for centuries, and this excavation method finds application in specialized circumstances even today. The use of high-pressure, low-volume water jets for rock cutting is more recent and was made possible by the development of high-pressure water pumps. Despite the benefits often claimed for these systems, high-pressure water jets still have not found widespread application. This paper reviews the various methods that have been employed using water jets to break rock, focusing on jet-assisted cutting, which seems closest to commercial development.

OP 122-92. Performance Analysis of Acute Exposure to Hand-Arm Vibration Among Underground Drillers, by Stephen D. Hudock. Paper in Proceedings of the Human Factors Society 34th Annual Meeting. Human Factors Soc., 1990, pp. 734-737. The U.S. Bureau of Mines, the Ontario Mining Health and Safety Branch, and an underground gold mining operation cooperated in a research study to evaluate the pre- and post-shift response to hand-arm vibration (HAV) exposure among underground drillers. The acute effect of HAV exposure was evaluated using three distinct measurement tools, including a test of sensitivity to varying levels and frequencies of vibration using a vibrometry system, a test of hand strength using a grip strength dynamometer, and tests of both gross movements of hands and arms and fine fingertip dexterity using the Purdue Pegboard tasks. Paired T-tests found no significant differences between pre-shift and post-shift vibrometry scores among shifts. Right-hand pegging, assembly, and the combined pegging scores were significantly higher for the post-shift testing when shifts were combined. None of the three measurement tools used appeared to be adequately sensitive to determine the effects of acute exposure to hand-arm vibration.

OP 123-92. A Safety Risk Evaluation of Vigilance Tasks in the US Surface Mining Industry, by S.D. Hudock and J.C. Duchon. Paper in Off-Highway Haulage in Surface Mines, ed. by T.S. Golosinski and V. Srajer. Balkema, 1989, pp. 191-195. The U.S. Bureau of Mines has conducted research on the safety risk associated with the performance of vigilance tasks in surface mining occupations. One-third of all surface mining occupations were judged to require high levels of vigilance for proper task performance. Through analysis of all mining accidents for the year 1986, it was determined that the occupational accident severity level for those employed in high-vigilance surface mining jobs was about twice that for low-vigilance surface mining occupations. It was shown that accident severity is higher for employees in high-vigilance jobs, even when their activities at the time of the accident only require low vigilance to perform. These findings support the conclusion that vigilance demands in mining represent a distinct safety risk which may persist for different types of tasks and activities.

OP 124-92. Optimizing Continuous Miner Scrubbers for Dust Control in High Coal Seams, by N.I. Jayaraman, R.A. Jankowski, and K.L. Whitehead. Ch. 20 in New Technology in Mine Health and Safety. SME, 1992, pp. 193-205. Most continuous miner sections utilizing flooded-bed scrubbers also use blowing face ventilation. Blowing ventilation, however, interferes with dust capture and minimizes scrubber effectiveness. To enhance the efficiency of the scrubber system and reduce dust concentrations, the U.S. Bureau of Mines tested various combinations of operating parameters. Experiments for system efficiency took place in a full scale model mine at 3.05-m roof height. In general, higher values for scrubber and face airflows resulted in lower dust concentrations. In addition, optimum dust controls would include a face ventilation to scrubber airflow ratio of 1. When the airflow ratio was either less than or greater than 1, the dust levels in the return and at the operator locations increased. No single dust control technique was the most effective one at all locations because of mutual interaction among techniques.

OP 125-92. Synthesis of a Controllable Circuit Breaker Mechanism, by C.C. Jobes, G.M. Palmer, and K.H. Means. Trans. ASME, v. 112, Sept. 1990, pp. 324-330. This U.S. Bureau of Mines paper addresses, for the first time, the synthesis, optimization, simulation, and analysis of a controllable circuit breaker mechanism. Type synthesis is performed by finding the mechanisms conforming to topological requirements set forth in the problem definition and evaluating them to determine whether they satisfy the stated functional requirements. Dimensional synthesis is performed upon these

mechanisms by designating the equality and inequality constraints, assigning the variable types, and then searching the specified design space to determine if any solutions exist. An optimization is performed on any mechanisms found to determine which of the mechanism configurations is optimal with respect to the specified criteria of desirability. Simulation and analysis is then performed on the optimal mechanism to verify that it meets all specified requirements and constraints. The result of this design is a controllable residential circuit breaker that can be used in a residential load management scheme.

OP 126-92. **Flotation Process Analysis**, by R.A. Seitz and C.E. Jordan. Min. Eng., 1991 Annu. Rev., May 1992, pp. 468-470. This U.S. Bureau of Mines paper discusses developments in the flotation area in 1991.

OP 127-92. **Rapid Bubble-Pulp Separation for Improved Coal Flotation Kinetics**, by C.E. Jordan and F.J. Susko. Paper in Advances in Filtration and Separation Technology, Volume 5: Separation Problems & the Environment, ed. by B. Scheiner. Am. Filtration Soc., 1992, pp. 137-146. Coal was used to demonstrate the effectiveness of the rapid flotation system. The best operating conditions of 1.5-mL/g air-to-ore ratio, 49-W mixing intensity, and 31-cm^2 * min/L ratio of froth separator surface area to flow rate recovered 93 pct of the coal in a concentrate containing only 8.1 pct ash. For the fine-coal material used in this study at 4.5 pct solids, the rapid flotation system was 18 times faster than the conventional coal flotation system. The mixing intensity in the air-injected hydrocyclone bubble-particle attachment unit could be adjusted to obtain the best results. In addition, there was an optimum ratio of froth separator surface area to flow rate for the froth separator. Each of the two unit operations could be independently optimized to provide a rapid flotation process with improved flotation kinetics.

OP 128-92. **Shift-Related Effects on Psychophysiologic Performance in Underground Mineworkers**, by Christopher M. Keran, Thomas J. Smith, James C. Duchon, Dan Robinson, and David Trites. Paper in Advances in Industrial Ergonomics and Safety III, ed. by W. Karwowski and J.W. Yates. Taylor & Francis, 1991, pp. 645-652. How does shiftwork influence variability in work performance? There is extensive evidence that relative to day and afternoon shiftworkers, night shiftworkers tend to work at a reduced level of effectiveness, as measured both by various indices of job performance and by standard behavioral and physiological function tests. Between-shift variability in work performance thus may be explained as a consequence of circadian dissonance, in which night shiftworkers are asked to fulfill their job responsibilities in the face of depressed behavioral and physiological functioning. Another dimension of work performance variability concerns the consistency or reliability with which a shiftworker is able to perform his or her work during a shift. Possible shift-specific effects on such within-shift variability have not been closely examined. That is, night shiftworkers conceivably could be more or less consistent in performing at a reduced level across the shift, relative to the within-shift consistency in performance at a higher level displayed by workers on day or afternoon shifts. Further, there may be shift-specific differences in within-shift variability between physiological relative to behavioral measures of performance. Clearly, a comprehensive understanding of the interaction between work performance variability and the work shift must address both between- and within-shift manifestations of variability. This U.S. Bureau of Mines report presents findings from the first phase of a study designed to compare the performance of mineworkers on rotating 8-hour shifts to that on rotating 12-hour shifts. Only findings from 8-hour shifts are given.

OP 129-92. **Multiple-Seam Longwall Gate Road Pillar Design Using Modeling Techniques**, by Jeffrey M. Listak and Gregory J. Chekan. Ch. 25 in New Technology in Mine Health and Safety. SME, 1992, pp. 249-261. The U.S. Bureau of Mines, in an effort to improve coal conservation and utilization, is currently investigating longwall panel layouts to maximize coal recovery and minimize interactive problems in multiple-seam operations. When longwalling coalbeds in descending order, the transfer of stress from overlying gate roads is a major design constraint affecting pillar stability in the lower mine. The lower mine gate road pillars must be properly designed to withstand the additional load transfer if gate roads are superpositioned in successive seams. The Bureau-s MULSIM/NL model was used to analyze load transfer mechanics for superpositioned gate road pillars. Analysis of Longwall Pillar Stability (ALPS), which is an empirically based design method for longwall gate road pillars, was used to calibrate model input parameters. The attributes of both the MULSIM/NL model and ALPS were combined to develop a modified method for estimating pillar stress for multiple-seam cases. The modified method uses a multiple-seam (MS) factor to estimate the stress on the lower mine gate road pillars when superpositioning is practiced. Numerical analysis shows that the MS factor is dependent upon the interburden thickness and pillar width and is presented in a series of graphs relating these two parameters. Several examples are included to illustrate the use of the MS factor for estimating lower mine pillar stress and resulting stability factors.

OP 130-92. **Continuous Miner Operators Situate Themselves for Safety and Better Visibility**, by Arnold C. Love and Robert F. Randolph. Coal, Apr. 1992, pp. 63-64. Many mines have significantly increased safety and production by placing miner operators away from the hazards of unsupported roof using radio-remote-controlled continuous miners. Most mines have a standard operating procedure (SOP) outlining continuous miner operator positioning. Sometimes the situation requires the operator to vary from SOP. Such situations pose positioning questions to management. The U.S. Bureau of Mines has been conducting research on radio-remote-controlled miner operator positioning. The research has primarily examined the relationship between SOP and actual positioning. Differences between the two help determine information that the operator needs when performing certain tasks.

OP 131-92. **Significance of Bolt Tension in Ground Control**, by Hamid Maleki. Paper in Rock Support in Mining and Underground Construction, ed. by P.K. Kaiser and D.R. McCreath. Balkema, 1992, pp. 439-449. Bolt installation tension is considered to be one of the most important factors contributing to rock reinforcement when mechanically anchored roof bolts are used. To evaluate the influence of uniform tensioning on roof stability, 13,000 mechanically anchored roof bolts were installed in an operating coal mine using both a conventional and a thrust-torque-

controlled bolting machine. Geological and mine conditions were monitored when the bolts were installed and for 2 months afterward, and limited monitoring of roof sag, bolt tension, and changes in entry stability continued for another 4 years. Eleven of 24 variables were quantified and statistically analyzed for significance and correlations; the important bolting variables influencing roof sag were coefficient of variation of bolt tension and standard deviation of bolt tension. Long-term monitoring gave inconclusive results regarding bolt tension reinforcement mechanisms at this site. Other studies in highly stressed or weak ground have confirmed the importance of bolt tension in rock reinforcement. These studies are being integrated to develop criteria for primary support selection.

OP 132-92. Diagnostic Expert System Techniques for Improving Hydraulic Maintenance of a Continuous Mining Machine, by J. Mitchell. Min. Eng., Apr. 1991, pp. 419-424. Machine breakdowns and maintenance delays are large contributors to lost production and increased operating costs in the mining industry. The U.S. Bureau of Mines is investigating the applications of expert system technology to diagnostic and predictive maintenance for mining equipment. This will help increase mining productivity and decrease operating costs by reducing the frequency of equipment failures and repair times. The Bureau has begun this effort by applying export system techniques to the diagnosis of hydraulic system problems on a continuous mining machine. This paper discusses the development of the hydraulic expert system.

OP 133-92. Computer-Assisted Mining, by J.N. Murphy, G.H. Schnakenberg, and A.J. Kwitowski. The Mining Engineer, v. 150, No. 348, Sept. 1990, pp. 99-106. The U.S. Bureau of Mines is investigating the application of state-of-the-art computer technology to improve coal extraction. The opportunity to remove workers from high-risk areas offers attractive health and safety benefits as well as reductions in delay time. Studies include improved remote control of continuous miners, the development of fundamental technologies such as vertical guidance of cutting operations, navigation of the continuous miner, and the application of expert systems to aid in diagnoses of equipment problems and in the planning of face operations. The Bureau has elected to evaluate these techniques on a continuous miner. While the contribution of longwall mining to underground production continues to grow, room-and-pillar systems for production and for longwall panel development are and will remain essential components of underground operations.

OP 134-92. An Evaluation of Service and Repair Manual Design, by Bruce C. Nelson and Wayne P. Adams. SAE Tech. Paper Series 881329, 1988, 15 pp. The U.S. Bureau of Mines evaluated 16 mining equipment service and repair manuals, not for technical content but for several variables important to the human factors design of the manuals in accordance with Society of Automotive Engineers (SAE) Recommended Practice J920, Military Specification Mil-M-38784B, and other significant research findings on these design variables. Interviews with maintenance workers in the mining industry were also conducted. Recommendations are identified that could improve existing manuals and the industry standards that have been established to guide them.

OP 135-92. User Interaction With Maintenance Information: A Performance Analysis of Hypertext Versus Hard Copy Formats, by Bruce C. Nelson and Thomas J. Smith. Paper in Proceedings of the Human Factors Society 34th Annual Meeting. Human Factors Soc., 1990, pp. 229-233. Four difference formats of an existing mining equipment repair manual were prepared for a U.S. Bureau of Mines comparative human performance test: (1) original hard-copy text, (2) improved hard-copy test with enhanced readability and indexing features, (3) computerized (hypertext) version of original text, and (4) hypertext version of improved text with interactive help features. Students in a diesel mechanics class (n=55) then were tested for proficiency in accessing and understanding information presented in these different formats. The results indicate that (1) although the users accessed the information less quickly using the computer compared with hard copy, they positively endorsed computerized hypertext presentation of maintenance information, and (2) enhanced text readability and indexing improved access to and understanding of maintenance information, but this improvement was not subjectively appreciated by the users relative to other manuals they had used. This test indicates that changes to computerized maintenance manuals should be made cautiously, and that more research is needed to measure different hypertext design and training factors.

OP 136-92. Workshop Safety: Maintenance of Mining Equipment Is Dangerous-Take Care, by Bruce C. Nelson and Thomas J. Smith. Eng. and Min. J., v. 192, No. 12, Dec. 1991, pp. 24-26. Tasks required for repairing mining equipment differ significantly from those required for most other mining work, especially in technical complexity and variety. For example, operation of mining equipment tends to be repetitive and routine, but maintaining that equipment is varied, complex and often urgent. Maintenance may be necessary in the field, forcing repair crews into awkward, cold, wet, dark, cramped, or dusty conditions. The nonroutine nature of mine-maintenance work means that each repair task presents unique characteristics and complexities. The challenges of mine maintenance can be characterized as human-factors difficulties. Improvement of both the safety and efficiency of maintenance represents a large, potential cost-saving. Maintenance typically accounts for a major percentage of mining costs; estimates vary from 30 to 50 pct of total operating costs. The U.S. Bureau of Mines has conducted safety research on human-factors difficulties related to surface-mine maintenance since 1985. This research indicates that more than one-third of all surface-mining accidents occur during equipment maintenance, and that overexertion and slip-and-fall injuries are responsible for 64 pct of all the injury lost time due to maintenance. Estimates of maintenance accident costs range from $12,000 to $14,000 per accident.

OP 137-92. Advanced Selective Mining Concepts, by James J. Olson. Paper in Proceedings, 15th World Mining Congress. World Min. Congr., 1992, pp. 79-89. One view of future mining operations envisions processes that are very selective in removing from the Earth only the desirable attributes of an ore body. The approach is to take what is desirable from within the Earth and bring it to the surface for processing without removing the valueless country rock. Such

selectivity might be physical or chemical in nature, employing inorganic reagents or possibly bacteria. These systems would have as their objectives minimum production costs and minimum environmental disturbance. The U.S. Bureau of Mines has underway a variety of research projects that have as their objective the realization of cost-effective, environmentally sound selective mining systems. This paper describes the status of such research activities with examples of their potential application. Two main focal points of this paper are cooperative field tests conducted by the Bureau and the mining industry in chemically selective mining, i.e., in situ leach mining of oxidized copper deposits in the Southwest United States. Access to the ore body for one of these experiments is through vertical wells drilled from the surface, and no explosive prefracturing or caving of the material is contemplated. The other copper leaching field test is a computer-assisted hydrologic analysis of in situ leaching recovery targeting a volume of undisturbed ore with wells drilled from an existing underground mine. In addition to summarizing results from these two field tests, advanced concepts such as the use of microwave energy to enhance permeability of mineral-bearing zones in support of in situ leach mining and abrasive jet borehole mining for narrow vein deposits are discussed.

OP 138-92. Estimation of Safety Factors Attributable to Electrode Materials in the Spark Test Apparatus, by J.S. Peterson and J.C. Cawley. Paper in Proceedings, 24th International Conference of Safety in Mines Research Institutes. 1991, pp. 75-84. Data that define the relative probability of spark ignition between common materials may estimate actual explosion hazards more precisely for realistic mining situations than do data generated using cadmium electrodes in the spark test apparatus. The U.S. Bureau of Mines has estimated the probability of spark ignition arising from the use of aluminum, brass, copper, lead, tin, and stainless and cold-rolled steel as disk electrodes in 8.3 pct CH_4-air using the standard spark test apparatus. By comparing currents and voltages that give the same probability of spark ignition, a safety factor relative to cadmium may be associated with each material. Partial results for resistor and inductor circuits were summarized in the Conference Proceedings of the 23rd International Conference of Safety in Mines Research Institutes. Complete results, including capacitor circuits, are presented here.

OP 139-92. Nitrogen Solubility and Nitride Formation in Fe-Cr-Mn-Ni Alloys, by J. Rawers, J. Bennett, R. Doan, and J. Siple. Acta Metall. et Mater., v. 40, No. 6, 1992, pp. 1195-1199. In this U.S. Bureau of Mines study a series of Fe-Cr-Mn-Ni alloys was melted under high nitrogen gas pressure. The nitrogen concentration in the solidified metal was found to be experimentally related to the melt pressures, which ranged from 0.1 to 200 MPa, to the alloy composition, and to alloy concentration. The nitrogen solubility followed Sievert's law. The activity coefficients determined at these higher pressures for the alloying elements Cr, Mn, and Ni were similar to those previously obtained at lower pressures. At the higher nitrogen melt pressures, the nitrogen concentration exceeded the interstitial nitrogen solubility, resulting in the formation of metal nitrides.

OP 140-92 The Human Factors of Workstation Telepresence, by Thomas J. Smith and Karl U. Smith. Paper in Third Annual Workshop on Space Operations and Robotics (SOAR '89), ed. by S. Griffin. NASA. Conf. Pub. 3059, 1990, pp. 235-250. Human-operated, remotely controlled robots (telerobots) are projected to play a privotal role in the performance of assembly, maintenance, and servicing manipulation tasks during construction and operation of the U.S. space station in the next decade. To reap the anticipated benefits of telerobotic systems—increased safety, efficiency, and productivity of task performance in space, accompanied by reduced costs—it is essential that the control requirements for telerobot operation be compliant with control capabilities and limitations of the human operator. The term "workstation telepresence" has been introduced to describe such human-telerobot compliance, which enables the human operator to effectively project his or her body image and behavioral skills to control of the telerobot itself. This report addresses major human factors considerations for establishing high-fidelity workstation telepresence during human-telerobot operation. Telerobot workstation telepresence is defined by the proficiency and skill with which the operator is able to control sensory feedback from direct interaction with the workstation itself, and from workstation-mediated interaction with the telerobot. Numerous conditions influencing such control have been identified. This raises the question as to what specific factors most critically influence the realization of high-fidelity workstation telepresence. The thesis advanced in this report is that perturbations in sensory feedback represent a major source of variability in human performance during interactive telerobot operation. Perturbed sensory feedback research over the past three decades has established that spatial transformations or temporal delays in sensory feedback engender substantial decrements in interactive task performance, which training does not completely overcome. Similar, more recent laboratory studies with remote telerobot manipulators have confirmed in part the earlier findings. The goal of effective and safe interactive telerobot operation therefore may benefit from development of techniques that enable the interactive computer to detect, and compensate for, perturbations in sensory feedback before presentation of such feedback to the operator. A recently developed social cybernetic model of human-computer interaction can be used to guide this approach, based on computer-mediated tracking and control of sensory feedback. The report will conclude by indicating how the social cybernetic model can be employed for evaluating the various modes, patterns, and integrations of interpersonal, team, and human-computer interactions that play a central role in workstation telepresence.

OP 141-92 The Social Cybernetics of Human Interaction with Automated Systems, by Thomas J. Smith and Karl U. Smith. Paper in Ergonomics of Hybrid Automated Systems I, ed. by W. Karwowski, H.R. Parsaei, and M.R. Wilhelm. Elsevier, 1988, pp. 691-711. The science of behavioral cybernetics deals with the analysis of human behavior as a closed-loop, self-governed process. Social cybernetics focuses upon the reciprocal feed-back interactions between two or more individuals in a group setting. With its dynamic software control capabilities, today's computer represents the first mechanical device in history with the potential for adaptive, integrated control of multiple modalities of sensory feedback from both itself and its human partner. The central thesis of this paper, therefore, is that behavioral cybernetics provides a comprehensive conceptual framework for understanding human-computer interaction as a social cybernetic process. Theoretical and experimental foundations for

this concept first are discussed. A social cybernetic model of human-computer interaction is then outlined, which specifies how human and machine are reciprocally yoked to one another through mutual, linked tracking and control of sensory feedback across the interface. The model subsequently is applied to a human factors analysis of advanced manufacturing systems. This analysis leads to three broad conclusions about ergonomic design of hybrid automated systems: (1) A hybrid computer represents a relatively impoverished social tracking target because of its deficient capabilities for both detecting and controlling sensory feedback, (2) consequently, hybrid system operation is characterized by a pervasive pattern of social tracking incompatibilities and spatial and temporal perturbations in feedback compliance with the human partner, which account for most if not all performance, safety, and health problems arising out of human interaction with automated systems, and (3) the social cybernetic model provides a set of concrete theoretical and experimental strategies for evaluating and redressing such problems.

OP 142-92. Interactive Performance in Space—The Role of Perturbed Sensory Feedback, by Thomas J. Smith, Randy L. Smith, Mark A. Stewart, Steven T. Smith, and Karl U. Smith. Paper in Work With Computers: Organizational, Management, Stress, and Health Aspects, ed. by M.J. Smith and G. Salvendy. Elsevier, 1989, pp. 484-495. This U.S. Bureau of Mines report addresses the phenomenon of perturbed sensory feedback as a potentially serious obstacle to optimal performance and safety of interactive human-computer and telerobotic tasks in extraterrestrial environments. Human factors considerations suggest that spatiotemporal perturbations plus other types of distortions in sensory feedback will arise during use of interactive telerobots for space station assembly, maintenance, and servicing. Potential consequences for the performance of the extraterrestrial operator include reduced fidelity of visual-manual tracking, impaired visual perception, problems with speech production and recognition, memory and learning decrements, impaired decision making, and elevated behavioral-physiological stress, with a concomitant increase in the risk of performance errors and accidents. Findings from laboratory research documenting these effects are summarized, followed by a discussion of how such effects may contribute in a major way to variability of interactive performance in space.

OP 143-92. Calculation of pH for High-Temperature Sulfate Solutions at High Ionic Strengths, by B.R. Staples, G.R. Holcomb, and S.D. Cramer. Corrosion, v. 48, No. 1, Jan. 1992, pp. 35-41. Corrosion studies at the U.S. Bureau of Mines on stainless steels in acid sulfate solutions prompted the development of procedures to calculate the pH for solutions at temperatures to 300° C. This general method for calculating the pH of high-ionic-strength aqueous solutions at elevated temperatures is an alternative to instrumental pH measurement techniques and is illustrated for the H_2O-Na_2SO_4-H_2SO_4 system. The pH is calculated from the partial dissociation of HSO_4^-, while accounting for the buffering effects of completely dissociated Na_2SO_4 and H_2SO_4. Modern values for the temperature-dependent second dissociation constant of H_2SO_4 and the extended Debye-Huckel limiting law slopes are used in the calculations. Uncritical selection of thermodynamic data can result in differences in calculated pH that exceed 0.5 pH unit in the temperature range 200 to 300° C.

OP 144-92. Controlling Worker Exposure to Noise on Longwall Faces, by Robert R. Stein and J. Alton Burks. Ch. 27 in New Technology in Mine Health and Safety. SME, 1992, pp. 279-285. This U.S. Bureau of Mines paper focuses on the noise exposure levels of miners employed on longwall production faces. Along with the increased production from longwall units has come the potential for greater noise exposures. Typical noise levels are given for the various noise sources that are present on modern longwall faces. Exposure times have typically increased since the introduction of longwall technology in this country. Representative exposure times and patterns are analyzed. Possible solutions are presented for generalized cases. Engineering controls developed by the Bureau are explained and their potential effectiveness is calculated for the cases presented. The role of hearing protectors in an overall hearing conservation program is also investigated. Recent Bureau research suggests that the actual performance levels of muff-type protectors may be less than the manufacturers' ratings under certain circumstances. The use of muff-type protectors is discussed and analyzed with respect to longwall operations.

OP 145-92. Extended Cut Face Ventilation for Remotely Controlled and Automated Mining Systems, by C.D. Taylor, G.V.R. Goodman, and T. Vincze. Ch. 1 in New Technology in Mine Health and Safety. SME, 1992, pp. 3-11. Effective coal mine face ventilation, for remotely controlled and automated mining systems, is essential for the control of methane. The evolution of new mining equipment and methods has required changes and improvements in face ventilation methods. One emphasis today is on the use of remotely operated and automated mining systems that can be used to make continuous cuts of 6 m (20 ft) and deeper. U.S. Bureau of Mines research is studying ways to more effectively ventilate these extended cuts. Two face ventilation techniques that utilize either blowing brattice or a jet fan for deep cutting are examined in this paper. Bureau procedures for evaluating face ventilation systems are also discussed.

OP 146-92. Shiftwork and Safety: A Review of Literature and Recent Research Results, by Jon A. Wagner. Pa-per in Trends in Ergonomics/Human Factors V, ed. by F. Aghazadeh. Elsevier, 1988, pp. 591-600. Of recent concern to many companies is the effect of shift-scheduling practices on accident rates and accident patterns. For this reason, the U.S. Bureau of Mines reviewed extensive literature on the subject of shiftwork and safety in an attempt to characterize the cause-and-effect nature of this phenomenon for various work tasks and job environments. In addition, the Bureau examined 10 years of accident data for a group of iron ore mining companies that operated on the same shift-rotation schedule. This paper summarizes some of the more important findings. Of special interest are the effects of particular workdays of the night shift and age of workers on the timing and frequency of accidents. In general, older workers tended to have a greater share of their accidents toward the end of the night shift series and during the last few hours of a night shift, compared to younger workers.

OP 147-92. Time-of-Day Variations in the Severity of Injuries Suffered by Mine Shiftworkers, by Jon A. Wagner. Paper in Proceedings of the Human Factors Society

32nd Annual Meeting. Human Factors Soc., 1988, pp. 608-611. One means of assessing the hazard risk associated with mine work is to study the severity of injuries that occur during the workday. Of special interest is the accident risk inherent in night work and rotating shiftwork. To better understand this risk, the U.S. Bureau of Mines studied accidents that occurred during a 10-year period in the taconite (iron) mining operations of the U.S. Lake Superior iron ore region. In general, accidents that occurred during the night shift resulted in more days lost per accident, compared with either the day or afternoon shifts. To control for the possibility of different accident types occurring on different shifts, part of this study focused on accidents involving equipment operation. Again, night shift accidents were shown to be significantly more severe than on the other two shifts. These results implicate work performance during night hours as being relatively impaired, perhaps owing to lowered states of psychophysiological arousal, coupled with the handicap of operating in a darkened environment.

OP 148-92. Trial Underhand Longwall Stope Instrumentation and Model Calibration at the Lucky Friday Mine, Mullan, Idaho, USA, by J.K. Whyatt, T.J. Williams, and W.G. Pariseau. Paper in Rock Mechanics, ed. by J.R. Tillerson and W.R. Wawersik. Balkema, 1992, pp. 511-519. The U.S. Bureau of Mines, in cooperation with Hecla Mining Co., has monitored back-fill performance and ramp stability during mining of several cuts of an experimental underhand longwall stope in the Lucky Friday Mine, Mullan, ID. This mining method was designed to increase productivity by introducing mechanized mining equipment and to reduce rock burst hazards associated with excavating isolated pillars. The data were also used to calibrate a three-dimensional, finite-element model of the lower portion of the Lucky Friday Mine and allowed the refinement of rock mass properties from an earlier two-dimensional model. The data collected, in conjunction with observations, ongoing mining experience, and the calibrated model, allowed researchers to demonstrate the geomechanical soundness of the method and led to its adoption throughout the mine. This case study demonstrated the desirability of building a model prior to specifying placing instruments.

OP 149-92. Colonization Bottlenecks on Acidic Coal Spoils, by Robert S. Hedin. Paper in Achieving Land Use Potential Through Reclamation (ASSMR9-92). Am. Soc. for Surface Min. and Reclamation, 1992, pp. 179-190. The U.S. Bureau of Mines tested the hypothesis that the establishment of volunteer aspen on acidic coal spoils is limited, by colonization problems by amending bare spoil with surface applications of limestone (5,500 kg/ha), fertilizer (750 kg/ha of 5-10-5), and root or stem wood chips (0.5 m^3/ha). The experiment was conducted on lower Allegheny spoils near Emlenton, PA. The amendments were applied in April 1989, 1 month before seed production by local aspens. The density of aspen seedlings in the experimental plots has been monitored since May 1989. Both limestone and fertilizer significantly increased the initial establishment of aspen during spring 1989. Plots receiving these treatments averaged 97 seedlings/m^2 in June 1989. With the onset of hot dry weather in July, 97 pct of the established seedlings died. Survival of aspens only occurred in plots that received fertilizer. Between September 1989 and August 1991, the number of seedlings only decreased by 26 pct. Currently, the highest densities of aspen seedlings, 8.1 seedlings/m^2, are in plots that received fertilizer, limestone, and wood chip treatments. The soil chemistry in these plots is returning to pre-experimental levels without outward deleterious effects on the established aspens. The amendment applications used in this experiment to stimulate aspen colonization onto bare spoils could be the basis of a low-cost reforestation strategy for abandoned mined lands in northern Appalachia.

OP 150-92. Generation of Alkalinity in an Anoxic Limestone Drain, by Robert W. Nairn, Robert S. Hedin, and George R. Watzlaf. Paper in Achieving Land Use Potential Through Reclamation (ASSMR 9-92). Am. Soc. for Surface Min. and Reclamation, 1992, pp. 206-219. The rate of limestone dissolution and alkalinity generation in an anoxic limestone drain is determined by many factors, including the quality of the limestone used and the partial pressure of carbon dioxide within the system. Carbon dioxide concentrations greater than 600 times atmospheric levels have been found within an anoxic limestone drain located in northwestern Pennsylvania. This situation greatly increases the solubility of limestone, making elevated alkalinity concentrations possible. Before construction of the drain, the mine drainage contained over 400 mg/L acidity as CaC_3 equivalent, but alkalinity concentrations of more than 300 mg/L have been found at the exit of the drain. Alkalinity generation rates of approximately 117 grams of alkalinity (as CaC_3 eq.) $meter^{3-}$ of drain (bulk volume) day^{1-} has been determined for this system. The anoxic limestone drain discharges the mine water into a settling pond-constructed wetland system where metal oxidation, hydrolysis, and precipitation occur in a strongly buffered, alkaline solution. The use of the anoxic limestone drain resulted in substantial cost savings compared to conventional chemical treatment of this drainage.

OP 151-92. Pyrite Oxidation in Saturated and Unsaturated Coal Waste, by George R. Watzlaf. Paper in Achieving Land Use Potential Through Reclamation (ASSMR 9-92). Am. Soc. for Surface Min. and Reclamation, 1992, pp. 191-205. Currently, the main strategy used to limit acid mine drainage (AMD) from pyritic coal waste materials (i.e., spoil and refuse is to minimize the contact of these materials with water. An alternative approach, not generally practiced in the coal industry, is to keep the pyritic material inundated with water. Concerns with this latter technique include the potential detrimental effects of dissolved oxygen and ferric iron on pyrite oxidation, as well as the ability to maintain complete and continuous water saturation. The U.S. Bureau of Mines conducted laboratory tests to determine the effects of dissolved oxygen and ferric iron on pyrite oxidation. These tests used small columns (5.1 cm diameter by 46 cm) filled with 590 g each of coal refuse (2.54 cm by 10 mesh) that contained 10.1 pct (by weight) pyritic sulfur. Triplicate columns of four different hydrologic scenarios were studied: leaching with deionized water under unsaturated and saturated conditions and leaching with a ferric-iron-laden AMD under unsaturated and saturated conditions. Results indicate that maintaining the pyritic material under water virtually stops pyrite oxidation. After 189 days, sulfate loads removed from the columns averaged (± 1 standard deviation) 34.5 ± .9 g for the unsaturated columns leached with deionized water; 34.2 ± 5.8 g for the unsaturated columns leached with AMD; 0.15 ± 0.04 g for the saturated columns leached with deionized water; and −0.46 ± 0.06 g for the saturated columns leached with AMD. The negative sulfate load indicates that sulfate was retained in the columns. Results from this and other studies, theoretical

calculations, and experience from the metal mining industry show that disposal under saturated conditions can significantly reduce contaminant concentration from pyritic material.

OP 152-92. Solubilization of Manganese From Ores by Heterotrophic Micro-organisms, by E.G. Baglin, E.G. Noble, D.L. Lampshire, and J.A. Eisele. Hydrometallurgy, v. 29, 1992, pp. 131-144. The potential for using heterotrophic micro-organisms to solubilize manganese from low-grade domestic ores is being assessed at the Reno Research Center, U.S. Bureau of Mines. More than 90 pct of the manganese has been extracted from a variety of oxide ores in shake-flask tests using molasses as a source of nutrients for the micro-organisms. It has also been demonstrated that high recoveries of manganese can be obtained from a domestic wad ore using column bioleaching. The isolation and identification of organisms responsible for manganese extraction are discussed, as are the mechanisms responsible for manganese solubilization.

OP 153-92. Removal of Heavy Metals From Missouri Lead Mill Tailings by Froth Flotation, by F.W. Benn and W.L. Cornell. Ch. 12 in Emerging Process Technologies for a Cleaner Environment. SME, 1992, pp. 81-85. The U.S. Bureau of Mines investigated froth flotation techniques to remove heavy metals (Pb, Cu, and Zn) from southeast Missouri lead mill tailings. It has been estimated that southeast Missouri contains between 200 and 300 million st of Pb tailings stored aboveground. The tailings were classified as two distinct types: (1) pre-1968 tailings from the Old Lead Belt (some more than 100 years old) and (2) post-1968 tailings from the New Lead Belt. The objectives of the investigation were to reduce the Pb remaining in the tailings to <500 ppm (<0.05 pct Pb) and to attempt to recover a marketable concentrate to offset a portion of the remediation costs. The remaining dolomite-limestone would then be used as mining backfill or agricultural limestone. Bench-scale froth flotation removed, in percent, 95 Pb, 84 Cu, and 54 Zn, leaving 94 pct of the original weight containing, in parts per million, 400 Pb, 40 Cu, and 300 Zn from the Old Lead Belt tailings. Separate flotation tests also removed, in percent, 85 Pb, 84 Cu, and 80 Zn, leaving 75 pct of the original weight containing, in parts per million, 400 Pb, 200 Cu, and 500 Zn from the New Lead Belt tailings. Concentrates recovered from the Old Lead Belt were retreated to produce a final Pb concentrate containing 72 pct Pb with a cleaner flotation recovery of 79 pct. Froth flotation proved to be a viable method to remove the heavy metals.

OP 154-92. High-Frequency Acoustic Emissions in a Coal Mine, by D. Jan Black. Paper in Proceedings—33rd U.S. Symposium on Rock Mechanics, Balkema, 1992, pp. 1063-1070. The U.S. Bureau of Mines has maintained a continuing study of high-frequency acoustic emissions (ultrasonics), 30 to 150 kHz, in relation to coal mine bumps and outbursts for several years. As part of the research effort to evaluate the nature of possible precursors based on high-frequency acoustic emissions, raw data signals that occur during mining were recorded and analyzed. A total of 753 AE (acoustic emission) events were obtained during three different recording periods in 1991 in a coal mine in eastern Kentucky. Seven different categories based on signal waveform characteristics were observed. Frequency analysis was conducted on several events from each category. This paper presents the results of the analysis and concludes that (1) higher frequencies than previously reported, up to 350 kHz, are present in these signals, (2) the rate of high-frequency acoustic emissions may be used to study the stress transfer process in a coal mine, (3) seven different categories of ultrasonic signals were identified and described, and (4) continuous emission signals appear to be present that may be critical in studying precursors to ground failure in coal mines.

OP 155-92. Investigation of Metal and Nonmetal Ion Migration Through Phosphogypsum, by O.C. Carter, Jr., and B.J. Scheiner. Ch. 27 in Emerging Process Technologies for a Cleaner Environment. SME, 1992, pp. 205-210. The U.S. Bureau of Mines is investigating the effects of rainfall and gypsum-cooling pond water on the rate of metal and nonmetal ion mobility through phosphogypsum stacks located in central Florida. Since leachate contains metal and nonmetal ions that have the potential for migration into surface and ground water, laboratory column leach tests were conducted. Synthetic rain water was passed through the column, and metal and nonmetal ion migration was monitored. Similar experiments were conducted using a number of synthetic solutions which simulated a number of different compositions of gypsum-cooling pond water. Results indicate that within the first five pore volumes most of the mobile metals and nonmetals were removed.

OP 156-92. Mining in Space: Concepts and Issues, by Peter G. Chamberlain, Egons R. Podnieks, and F. Michael Jenkins. Paper in Proceedings of the 15th World Mining Congress. World Min. Congr., 1992, pp. 43-49. The United States has announced a new national Space Exploration initiative: the manned exploration of Mars and other planets using a permanent Moon base as an intermediate station. Mission planners have identified mining and processing for fuel, life support elements, and construction materials as key components of this effort. Two schools of thought have emerged regarding the form of the mining technology: (1) simple surface mining equipment based on present terrestrial construction practice and (2) fresh innovative mining methods. The U.S. Bureau of Mines staff believe that both have a role in research and development for lunar resources. It is premature to project technology for lunar mining and processing, considering the shortage of information on the geological and engineering properties of the Moon. This paper describes leading candidate mining and processing systems, including those based on available technology and several innovative concepts. The paper also identifies key issues that must be resolved by scientific study and engineering analysis before lunar mining can proceed.

OP 157-92. Mining Technology for the 21st Century, by Peter G. Chamberlain and William O. Stewart. Paper in Proceedings of the 15th World Mining Congress. World Min. Congr., 1992, pp. 35-41. All types of mining are likely to change significantly in the 21st century. With concerns about the environmental health of the world growing steadily and the invasion of computers into all facets of our lives, mining as we know it today must change or become destined to be part of our history. The only way mining can remain a part of our future world is by development of new ideas, concepts, and technology. Computers have already become a part of many aspects of our lives. They help control the exhaust emissions from our cars, the airplanes that we fly in, and even some of the processing in our minerals production. We have just begun to explore areas where computers can help us in the minerals

industry. In the future computers will free us from requiring our workers to expose themselves to dust, noise, and unacceptable environmental conditions. Designers of mining systems can then move the workers to safe and healthy areas. At the same time, the efficiencies of mining will increase significantly. This paper will explore some of the many computer applications that mining researchers expect to see in the future. Another area of concern is the environment of the world we live in and how mining must change to survive in it. Acres of mining waste are no longer tolerated in some areas of the world, and acid mine drainage is controlled. The only choices we have are to develop better methods to clean up these wastes so they do not cause environmental damage or to find new ways of mining that never produce these waste products. The U.S. Bureau of Mines has been diligently pursuing new mining methods that lessen or eliminate the negative aspects of mineral extraction. These include selective techniques such as in situ mining and borehole slurry mining that use pipes and pumps to extract only the minerals, leaving the waste rock undisturbed. Other innovative mining techniques, such as the use of laser cutting techniques and microwave technologies, are discussed.

OP 158-92. **Characterization of Overburden Response to Longwall Mining in the Western United States**, by Khamis Y. Haramy and Alan J. Fejes. Paper in Proceedings-11th International Conference on Ground Control in Mining, ed. by N.I. Aziz and S.S. Peng. Univ. of Wollongong, NSW, Australia, 1992, pp. 334-344. The U.S Bureau of Mines installed surface and subsurface instruments at a mine site in Colorado to monitor and characterize the overburden response to longwall mining. Instrumentation included a time-domain reflectometry cable, a multiple-point borehole extensometer, vertical-deformation surface monuments, and in-mine pressure cells for monitoring abutment, pillar, and gob loads with respect to the longwall face position. The purpose of the study was to collect data that could be analyzed to correlate the design of the mine layout to the resulting overburden failure response. Determining the extent of caving and fracturing is important in the arid and semiarid Western United States because of the possible consequences to the fragile underground hydrologic systems upon which the land owners and users depend. This study differs from past investigations because the overburden contains massive sandstone members that impose special conditions on the caving process and pressure redistribution above the longwall panels.

OP 159-92. **Two-Filter Radon Detectors With Aerosol Chambers: A Progress Report**, by R. F Holub and R.F. Droullard. Paper in Proceedings-Conference on Radiation Safety in Uranium Mines. Saskatchewan Environmental Society and Saskatchewan Research Council, Saskatoon, Canada, 1992, pp. 1-9. The U.S. Bureau of Mines has developed a continuously measuring environmental radon monitor that is about 50 times more sensitive than commercially available instruments. The monitor is suitable for measuring low levels of radon around uranium and other mines, as well as in any environment where radon levels are of concern. Using standard aerosol science techniques and by means of two simple experiments, all relevant parameters necessary for a complete theoretical description were determined. The monitor has performed successfully outdoors for more than 2 years.

OP 160-92. **Flotation of Mixed Plastics From Municipal Solid Wastes**, by G.D. Hood, F.J. Susko, and C.E. Jordan. Paper in Advances in Filtration and Separation Technology; Volume 5: Separation Problems & the Environment, ed. by B. Scheiner. Am Filtration Soc., 1992, pp. 29-40. The U.S. Bureau of Mines used a combination brine separation and flotation process to obtain high-purity polystyrene (PS) and polyethylene terepthalate (PET) products from mixed plastics. The best overall process sequence for the low-PET feed was Na_2CO_3 brine separation of the PS, followed by flotation of PET from the mixture of PET and polyvinyl chloride (PVC). The Na_2CO_3 brine separation produced a 99.7-pct PS concentrate that recovered 98 pct of the PS. After three wash cycles, 53 pct of the PET was recovered in a 99.7-pct PET flotation concentrate. For the high-PET feed, both process sequences (brine separation-flotation, and flotation-brine separation) gave comparable results. In both processes over 98 pct of the PS was recovered in a 99.7-pct-PS concentrate and 75 pct of the PET was recovered in a 99.7-pct-PET concentrate. The PVC-rich flotation tailings could not be effectively treated to recover a clean PVC product.

OP 161-92. **Cross Well Acoustic Tomography To Locate Abandoned Underground Mines and Subsidence Failure**, by Linda K. Killoran. Paper in Proceedings-11th International Conference on Ground Control in Mining, ed. by N.I. Aziz and S.S. Peng. Univ. of Wollongong, NSW, Australia, 1992, pp. 499-505. The U.S. Bureau of Mines has developed a prototype cross-well acoustic logging system and complementary tomographic image reconstruction software for the detection and delineation of abandoned underground mines and associated subsidence failure in relatively shallow environments. The logging system uses a piezoelectric, cylindrical bender as an acoustic source. A triaxial accelerometer assembly, designed to be rigidly locked in the borehole, is the receiver portion of the logging system. Both the source and receiver probes operate at high frequencies, thus providing short wavelengths capable of resolving small features in most rock types. A modified van with a dual-drum wireline winch, four-channel data acquisition system, power amplifiers, and waveform generator supports field operation of the logging system. A field study was conducted at a test site in San Antonio, TX, to demonstrate the cross-well acoustic logging system. The underlying rock at the test site is similar to stratified sediments in coal measures. First-arrival travel times were interpreted by tomographic reconstruction of the velocity field in the two-dimensional cross section between the source and receiver boreholes. The resulting image correlates well with geological borehole logging data for the test site.

OP 162-92. **Pillar Design in Bump-Prone Deep Western U.S. Coal Mines**, by N.P. Kripakov and R.O. Kneisley. Paper in Proceedings-11th International Conference on Ground Control in Mining, ed. by N.E. Aziz and S.S. Peng. Univ. of Wollongon, NSW, Australia, 1992, pp. 72-83. This U.S. Bureau of Mines paper presents a brief overview of current bump mechanics theories and pillar design methodologies, and relates these concepts to experiences at two mines in a north-central Utah coalfield where different pillar designs were used to control mountain bumps. Experiences gained at the first mine demonstrated the successful implementation of a two-entry, 9.8-m (32-ft)-wide, yield-pillar design. A Bureau field study quantified the timing of chain pillar yielding and resulting load transfer from the gateroad. In-mine pillar response, although apparently sensitive to site-specific conditions, compared favorably to estimates derived using two yield-pillar design

methods. A second study, conducted at another mine located in the same district, but subjected to different geologic conditions, documents the unsuccessful attempts to employ progessively narrower three-entry pillar designs based on successes achieved at the first mine site. This second mine never achieved a true yield-pillar design. Use of pillar widths ranging between 9.1 m (30 ft) and 27.4 m (90 ft) always resulted in violent bumps in the tailgate pillars. The pillars were either too large to yield or too small to support peak operational loads. Hypothetical gateroad systems were evaluated using both analytical and empirical approaches for configurations comprised of two rows of conventional pillars, and systems incorporating both yield and abutment pillars. Analysis concluded that yield pillars less than 6.1 m (20 ft) wide and abutment pillars ranging between 30.5 m (100 ft) and 39.6 m (130 ft) square would be required to achieve a stable gateroad design. However, results of a field study conducted on a two-entry, 36.6-m (120-ft)-wide abutment pillar concluded that abutment pressures from the first panel overrode the pillar, and that a still larger pillar may be required to preclude bumps in the tailgate during second panel mining. Without the benefit of a demonstrated in-mine success, it is not clear which design would ensure elimination of gateroad bumps.

OP 163-92. Copper-Catalyzed Thiosulfate Leaching of Low-Grade Gold Ores, by J.W. Langhans, Jr., K.P.V. Lei, and T.G. Carnahan. Hydrometallurgy, v. 29, 1992, pp. 191-203. Copper-catalyzed thiosulfate leaching is being investigated by the U.S. Bureau of Mines as a potentially economical and environmentally safe method for heap leaching or in situ leaching of low-grade oxidized gold ores. Six variables were investigated in fractional factorial screening tests, including thiosulfate ($_{S}20^{2-}{}_{3}$), sulfite ($S0^{2-}{}_{3}$), copper (Cu^{2+}), and ammonia (as NH_4OH) concentrations; air-inert atmosphere; and leaching time. Thiosulfate and sulfite concentrations and leaching time influenced gold extraction, while copper affected thiosulfate consumption. Ammonia concentration and leach atmosphere had no significant effect within the experimental region tested. The data from the fractional factorial screening tests were used in face-centered cubic (FCC) surface response experiments to determine the optimum leach conditions for high gold extraction and low thiosulfate consumption. Two models were generated from the data for predicting gold extraction and low thiosulfate consumption within the experimental region. The models predicted 90-pct gold extraction and a consumption of 0.2 kg $S_2O^{2-}{}_3$/ t ore at 0.20*M* $S_2O^{2-}{}_3$, 0.00625*M* $SO^{2-}{}_3$, 0.001*M* Cu^{2+}, 0.09*M* NH_4OH, and leaching for 48 h. Actual tests resulted in 83-pct gold extraction with 0.4 kg $S_2O^{2-}{}_3$ consumed / t ore. These results compare favorabley to 86-pct gold extraction and 0.21 kg CN^- consumption / t ore using standard cyanidation methods and 24 h leaching time.

OP 164-92. A GIS Technique To Classify Lineaments, by Willie A. Larry, Jr., and Douglas C. Peters. Paper in Proceedings of the Twelfth Annual ESRI User Conference. Environmental Systems Research Institute, v. 2, 1992, pp. 89-98. As part of cooperative research between Jackson State University and the U.S. Bureau of Mines, a combination of image processing and geographic information system software has been developed to classify lineaments (linear features) derived from remote sensing data. Lineament analysis has proven to be a valuable tool for prediction of potentially hazardous geologic conditions in underground coal mines. The purpose of the current research effort is to partially automate the process of deriving lineaments from remote sensing data (e.g., satellite images) and determine whether such lineaments represent geological or manmade features on the Earth's surface. The first phase of processing with the new software extracts all linear features from an image file produced through the U.S. Geological Survey's Mini Image Processing System package. The second phase uses ARC Macro Language programs to input the extracted lineaments into ARC/INFO and compute the degree to which each lineament is manmade or geological, or that a lineament's origin cannot be determined from the available data. Digital line graphs, digital elevation models, and other user-supplied data sets are used in this comparison process to define the characteristics of each lineament.

OP 165-92. A Sealed Flask Test for Evaluating the Self-Heating Tendencies of Coal, by Yael Miron, Alex C. Smith, and Charles P. Lazzara. Paper in International Coal Testing Conference: Proceedings of the 9th Conference. Coal Testing Conf., 1992, pp. 13-17. In parallel tests conducted with six coals in the adiabatic oven and in a static oxygen adsorption test in sealed flasks, the U.S. Bureau of Mines determined that the sealed-flask test can be used reliably to evaluate self-heating tendencies of coals. A field unit was constructed and is being evaluated. Statistical analysis of the data from the parallel tests resulted in a formula that predicts the minimum self-heating temperature of a coal from the total pressure change in the sealed flask during the 7-day test period.

OP 166-92. Effects of Longwall Subsidence on Escarpment Stability, by Valois R. Shea-Albin. Paper in Proceedings, Third Workshop on Surface Subsidence Due to Underground Mining, ed. by S.S. Peng. WV Univ., 1992, pp. 272-279. Increasing pressure from State and Federal agencies to mitigate mining-induced subsidence damage to overlying structures has presented a unique problem to the coal industry in the Western United States. Because sandstone escarpments are an environmental issue, millions of tons of coal reserves that underlie these escarpments risk being classified as unminable by regulatory agencies. At this time, the effect of subsidence on escarpments has not been well documented or characterized. The U.S. Bureau of Mines is using numerical modeling techniques to analyze escarpment response to longwall mining. Two- and three-dimensional finite element models have been constructed for a study area near Price, UT, where longwall panels were mined near an escarpment. This status report includes preliminary results showing that the pattern of subsidence surrounding the escarpment can be simulated through numerical modeling. Models that include such structural details as joint and fracture patterns will better simulate subsidence patterns and magnitude. By locating longwall panels strategically in relation to the escarpment, stability may be preserved throughout the mining process. Numerical modeling provides a method to analyze relatively quickly the effects of longwall panel location and resulting subsidence on escarpment stabllity. The goal is to provide a relatively accurate predictive tool for mine planning to determine if escarpment stability can be maintained while maximizing extraction of the coal reserves.

OP 167-92. An Expert System for the Prediction of the Spontaneous Combustion Potential of Coal, by Alex C. Smith. Paper in International Coal Testing Conference: Proceedings of the 9th Conference. Coal Testing Conf., 1992, pp. 63-67. The use of the expert system "SHT" (self-heating

temperature) allows the assignment of the self-heating potential of a coal sample without the need for detailed laboratory experiments. The program requires only the input of a coal's proximate and ultimate analyses and heating value and can evaluate the self-heating tendency of a single sample, an entire database of samples, or a select group from a database. The program evaluates only the relative reactivity of a coal sample, and does not take into account other important factors in the self-heating process, such as mining conditions and practices and geologic conditions. However, it is an important first step in determining the self-heating risk of a mining operation and can have an impact on the prevention of spontaneous combustion mine fires. The program is available through the authors.

OP 168-92. Prospects for Liberian Iron Ores, by Solomon H. Toweh. Liberian Diaspora, v. 3, No. 7, June 1992, pp. 23-24. Prospects for the Liberian iron ore industry are examined considering changing patterns of supply and demand in the world iron ore industry. The performance of the Liberian iron ore industry is observed from 1951 through 1985 in regards to competition for global markets by iron ore producers. The iron ore market is perceived as one that is relatively competitive due mainly to the large number of rival producers. Thus, the prospects for Liberian iron ores would be tied to regions in which their delivered prices are low. The industry's contribution to the Liberian economy is emphasized, noting that it has contributed about 15 pct of gross domestic product between 1981 and 1985. The industry has been a major source of foreign exchange earnings since its inception. Cumulative Liberian export earnings from 1951 to 1985 were $8,381 million (U.S. dollars), while that for the iron ore industry was $5,062 million. Prospects for the Liberian iron ore industry depend on the quality of its remaining ore reserves and on the realization of the Mifergui-Nimba project. This project would require the use of Liberian infrastructure and facilities and high-grade Guinean iron ores. The success of this project would depend on cooperation between the Governments of Liberia and Guinea.

OP 169-92. Performance Evaluation of Irrigated Filters, by McClelland, J.J.; Colinet, J.F.; Paper in SME Trans., v. 290, 1992, pp. 1828-1832. A filter consisting of a synthetic fibrous material has been determined to be a viable alternative to the wire mesh panels currently used in irrigated filter dust collection systems. An extensive laboratory investigation of the material showed that it removed a higher percentage of both respirable coal and quartz dust from the air entering a collector than did the flat and pleated wire mesh panel designs. This improvement in dust collection efficiency reduced the amount of coal and quartz dust discharged from the collector exhaust by approximately 44 pct. Since continued exposure to excessive levels (>5 pct) of respirable quartz dust presents a severe health hazard, this alternative filter medium could be of use to those mines required to comply with more stringent dust standards due to quartz.

OP 170-92. Acceptable Workloads for Three Common Mining Materials, by Gallagher, Sean; Hamrick, Christopher A.; Ergonomics, v. 35, No. 9, 1992, pp. 1013-1031. A series of psychophysical lifting studies was conducted to establish maximum acceptable weights of lift (MAWL) for three supply items commonly handled in underground coal mines (rock dust bags, ventilation stopping blocks, and crib blocks). Each study utilized 12 subjects, all of whom had considerable experience working in underground coal mines. Effects of lifting in four postures (standing, stooping under a 1.5-m ceiling, stooping under a 1.2-m ceiling, and kneeling) were investigated together with four lifting conditions (combinations of lifting symmetry and lifting height). The frequency of lifting was set at four per minute, and the task duration was 15 min. Posture significantly affected the MAWL for the rock dust bag (standing MAWL was 7 pct greater than restricted postures, and kneeling MAWL was 6.4 pct less than stooped); however, posture interacted with lifting conditions for both of the other materials. Physiological costs were found to be significantly greater in the stooped postures compared with kneeling for all materials. Other contrasts (standing versus restricted postures, stooping under 1.5-m ceiling versus stooping under 1.2-m ceiling) did not exhibit significantly different levels of energy expenditure. Energy expenditure was significantly affected by vertical lifting height; however, the plane of lifting had little influence on metabolic cost. Recommended acceptable workloads for the three materials are 20.0 kg for the rock dust bag, 16.5 kg for the ventilation stopping block, and 14.7 kg for the crib block. These results suggest that miners are often required to lift supplies that are substantially heavier than psychophysically acceptable lifting limits.

OP 171-92. Evaluating Coal Pillar Mechanics Through Field Measurements, by Iannacchione, Anthony T.; Mark, Christopher; Paper in Proceedings 11th International Conference on Ground Control in Mining, ed. by N.I. Aziz and S.S. Peng. The Univ. of Wollongong, NSW, Australia, 1992, pp. 38-47. Designing coal pillars to provide resistance against overburden loads has long been an aim of rock mechanics engineers. The need for accurate pillar strength models has become more urgent as greater overburdens are encountered and pillar sizes grow larger. Current pillar design models differ widely in their predictions of the trend in pillar strength with increasing pillar width-to-height ratio. The goal of this paper is to evaluate current pillar strength theories, using a comprehensive data base of stress measurements from coal pillars. The stress measurements indicate that coal pillars maintain relatively high stresses near the ribline, and that the stress gradient within the yield zone can be approximated as a straight line. Several problems are identified for further research, including calibration procedures for different types of stress cells, strain softening behavior in the yield zone, and measurement of stresses in the cores of very wide pillars.

OP 172-92. Design of Underground Mine Structures To Resist Roof-Fall Impact Loadings, by Allwes, Richard A.; Mangelsdorf, C.P.; Paper in Rock Support in Mining and Underground Construction, ed. by P.K. Kaiser and D.R. McCreath. Balkema, 1992, pp. 565-572. The U.S. Bureau of Mines paper presents the results of structural analyses and full-scale tests conducted on a steel-set arch and tri-set. This purpose of this work was to evaluate the suitability of using these structures in roof-fall areas. Theoretical resistance functions were established for both structures and were representative of their experimental behavior. The resistance functions were used to determine the energy absorption capacity of the structures and to predict their response to impact loading. The dynamic tests demonstrated that the arch canopy design procedure developed by the Bureau is appropriate for tri-sets and yields conservative designs for both steel-set arches and tri-sets. As a result of this work, it is recommended that these two structures may be considered for use in roof-fall-prone areas

and for rehabilitation work, provided that the arch canopy design procedure is utilized for each application and that the principles underlying the design procedure are understood.

OP 173-92. Encourage Self-Protective Employee Behavior, by Peters, Robert H.; Nat. Safety Council Newsletter—Min. Sec., July-Aug. 1992, pp. 1-4. Various strategies have been used to convince employees to avoid unsafe acts and/or adopt self-protective behaviors. The goal of this article is to provide guidance to mine operators on four techniques for influencing mine employees to work safely: (1) incentives, (2) disciplinary actions, (3) fear communications, and (4) employee surveys.

OP 174-92. An Absorption/Desorption Model of Solids Leaching, by Chaiken, Robert F.; Geochimica et Cosmochimica Acta, v. 56, Aug. 1992, pp. 2589-2593. A simple heuristic approach to describing leaching under intraparticle diffusion control conditions is described. The approach, based on the use of distribution theory to describe the heterogeneity of porous solids such as coal and metal ores, can ascribe the appearance of observed induction times and rate maxima to the intraparticle diffusion process itself. Rate of leaching and extent of leaching derived from a modified lognormal distribution function have been applied successfully to reported data on five diverse two- or three-phase reaction systems involving pyrite removal, copper recovery, methane desorption, and ethyl acetate elutriation.

OP 175-92. Design Aspects in Multiple-Seam Mining: Case Studies, by Chekan, G.J.; Paper in Proceedings of the 9th International Conference on Ground Control in Mining, ed. by S.S. Peng. WV Univ., 1990, pp. 12-21. Developing a coal seam that has been influenced by previous mining in seams either above or below can result in severe ground control problems. In many instances, interactions between operations are inevitable, but improvements in ground stability can usually be achieved by predicting potential problem areas in advance and adjusting the mining plans accordingly. This report investigates four case studies involving interactions between operations that used both room-and-pillar and longwall mining methods. In each case, geologic and mine design parameters are addressed, and those parameters found critical to the interaction are further defined in relation to observed ground problems.

OP 176-92. Optimum Design of Roof Truss Installations Based on Bending Strain Energy, by Mangelsdorf, C.P.; Paper in Proceedings, 28th U.S. Symposium on Rock Mechanics. Balkema, 1987, pp. 1115-1122. Questions asked by mine operators about the installation of roof trusses frequently deal with optimum position, slope, and initial tension of the inclined chords. The purpose of this paper is to examine the effects of those chord parameters on the strain energy of bending and to offer optimum values which will minimize the strain energy of the immediate roof. The method of solution involves calculating strain energy in bending for a roof beam partially supported by a roof truss. The beam is treated as homogeneous and isotropic. The strain energy contours are then plotted as functions of the truss uplift force and its position. Approximate optimum conditions can usually be achieved without specific knowledge of the material properties of the roof. The results are compared with current practice.

OP 177-92. Escape From a Mine Fire: Emergent Perspective and Work Group Behavior, by Vaught, Charles; Wiehagen, William J.; J. Appl. Behavioral Sci., v. 27, No. 4, Dec. 1991, pp. 452-474. Fire (destructive burning on a scale that threatens serious harm) is an important sociotechnical problem. This article analyzes miner responses to a 1988 coal mine fire from a symbolic interaction perspective. Lengthy qualitative interviews were conducted with 21 miners caught in the blaze studied. The data show that workplace culture (e.g., the buddy system) conditions participant responses to a fire emergency and, in the case of miners, largely facilitates their efficient and effective escape to safety. The orientation shift away from routine work behavior into the short-term perspective associated with an emergency is problematic. Theoretical implications for organizational behavior and practical implications for mine safety are discussed.

OP 178-92. Overview of U.S. and European Longwall Strata Stabilization Techniques and Materials, by Babich, Daniel R.; Ch. 3 in Proceedings of the 2nd International Conference on Stability in Underground Mining. SME, 1984, pp. 35-48. The inability to control the longwall roof and face can result in injury, loss of production, and increased operating costs. Problems such as falls of rock from the roof in front of or above supports as they are advanced and sloughing of coal from the face, along with geologic anomalies such as faults and clay veins, must be controlled before maximum safety and production can be realized from the longwall system. In Europe and the United Kingdom, coal operators have for many years been using a variety of injection and/or doweling techniques and materials for stabilizing their roof and face. In recent years similar technology has been made available to U.S. coal operators through U.S. companies which have been supplying stabilization materials and providing application technology and equipment. The Bureau of Mines, through its in-house and contract research efforts, has reviewed both foreign and domestic longwall stabilization techniques and materials. Although some problems with cost, safety, and application still exist, use of stabilization materials and techniques to address ground control problems on U.S. longwalls has increased dramatically in the last several years.

OP 179-92. Other Novel Mining Methods, by Chamberlain, Peter G.; et al., ; Ch. 22.9 in SME Mining Engineering Handbook. SME, v. 2, 1992, pp. 2028-2047. Previous chapters of this section feature new methods that are beginning to play a strong role in mining. Each chapter presents a novel mining method that is moving from development into commercial practice. Other less-developed methods, however, are slowly gaining acceptance in the mining community. Some of these may have an important role in future mining. Others may vanish. With their development still in infancy, it is simply too early to determine their future impact on mining. The purpose of this chapter is to present enough information on these other methods to identify possible applications. Sources of further information are listed at the end of the chapter.

OP 180-92. Remedial and Strata Replacement Techniques on Longwall Faces: A State-of-the-Art Report, by Dalzell, Robert S.; Curth, Ernest A.; Ch. 27 in Proceedings of the 2nd International Conference on Stability in Underground Mining. SME, 1984, pp. 473-494. Following the introduction of

shields to the U.S. longwall mining scene and the steady increase in the number of shield faces during recent years, the occurrence of longwall-ground-control-associated accidents has shown a welcome downward trend. But even though the accident experience is favorable, problems exist. New mining systems, however efficient, have run afoul of roof control. Shield faces have suffered extended stoppages because of roof cavities. Therefore, the Bureau of Mines has reviewed foreign remedial techniques to evaluate their potential for domestic application. Such technology includes cribbing, strain- absorbent modules (SAM's), inflatables, wire meshing, chemical rock stabilization, synthetic foams, and monolithic fills.

OP 181-92. The Effect of Oxygen, Iron-Oxidizing Bacteria, and Leaching Frequency on Pyrite Oxidation, by Watzlaf, George R.; Hammack, Richard W.; Paper in Proceedings of the Ninth Annual West Virginia Surface Mine Drainage Task Force Symposium. WV Univ., 1989, 18 pp. Acid mine drainage (AMD) contaminates thousands of miles of streams and rivers in the Appalachian coal region. AMD results from the oxidation of pyrite, which is exposed to air and water by surface mining activities. The major objective of this study was to examine the rate of pyrite oxidation in column leaching tests and to relate these results to commonly used field abatement techniques. Specific objectives included determining the effect of oxygen, leaching frequency, and weathering on the biotic oxidation rate as well as the effect of oxygen on the abiotic rate. Pyrite oxidation was studied under various conditions using small (40-cm-long by 2.54-cm-ID) and large (1.92-m-long by 0.29-m-ID) column leaching tests. The small columns contained 5 g of pyrite mixed with 100 g of inert silica sand. The large columns were filled with 175 kg of unweathered pyritic shale containing 3.5 pct sulfur. In the small-column experiments, biotic oxidation of pyrite was faster than abiotic oxidation at all levels of oxygen level tested, with the largest difference occurring at the lowest oxygen level tested (0.5 pct). Biotic oxidation of pyrite at applied oxygen levels of 0.5, 1.0, 5.0, and 10.0 pct measured 12.9, 15.2, 13.2, and 16.0 mg SO_4^{2-}/day respectively. Abiotic oxidation rates of 1.9, 8.3, 11.0, and 14.8 mg SO_4^{2-}/day were observed for columns exposed to 0.5, 5.0, 9.6, and 14.5 pct oxygen. This suggests that unless the bacteria are inhibited, pyrite oxidation proceeds at approximately the same rate at any oxygen level above 0.5 pct. In the large-column experiments, pyrite oxidation, based on sulfate release, was calculated at 18.2 g SO_4^{2-}/day for unsaturated leaching. After the material was saturated with water, the rate of pyrite oxidation resulting from biweekly flushing with oxygenated (8 mg O_2/L) water was reduced to 0.7 g SO_4^{2-}/day. In another test, comparison of water quality of leachates from fresh material to weathered (26 pct less sulfur) material showed no difference in release rates of sulfate (14.4-13.1 g/day), iron (4.26-4.20 g/day), or aluminum (0.29-0.27 g/day). Release rates for manganese, calcium, magnesium, and sodium were reduced by weathering to values 12.6, 23.2, 4.3, and 56.2 pct of the values from the fresh leaching tests, respectively. Partial pressures of carbon dioxide were reduced from between 0.8 and 3.2 to 0.01 and 0.4. Weathering caused oxygen to penetrate deeper into the material, implying the downward movement of the active pyrite oxidation zone with time. Additionally, four different leaching schedules were tested: 1 L every day, 7 L every 7 days, 14 L every 14 days, and 21 L every 21 days. The results indicated that leaching frequency did not have a significant effect on any water quality parameter or on pore gas composition.

OP 182-92. Optimum Mine Designs To Minimize Coal Bump: A Review of Past and Present U.S. Practices, by Iannacchione, A.T.; DeMarco, M.J.; Paper in Conference on Deposit Exploitation in Natural Hazard Conditions. Academy of Mining and Metallurgy, 1991, pp. 73-87. Coal bumps have presented serious mining problems in the United States throughout the 20th century. Fatalities and injuries have resulted when these destructive events occur at the working face. Persistent bump problems can result in abandonment of large reserves or lead to premature mine closure. Through the years, alternative techniques such as artificial supports, extraction sequencing, destressing, pillar design changes, and specific pillar retreat practices have been successfully implemented to mitigate coal mine bumps. Several techniques have evolved for room-and-pillar operations that control the way the roof rock breaks, regulating the manner in which stresses are redistributed in the mined section. Special mine layouts employed in longwall mines have also proved to be successful in safely redistributing or containing excessive loadings. However, with ever-increasing production rates, greater overburdens, and new mining systems, the need to evolve even more effective bump control designs will continue to challenge the U.S. coal mine industry.

OP 183-92. The Effects of Roof and Floor Interface Slip on Coal Pillar Behavior, by Iannacchione, A.T; Paper in Proceedings of the 31st United States Symposium on Rock Mechanics. Balkema, 1990, pp. 153-160. Designing coal pillars to provide resistance against overburden and gob loads has long been an aim of rock mechanics engineers. This requirement has become more imperative as greater overburdens are encountered and when mining in stiff coal-bearing strata. Current design procedures rely on theories of coal pillar behavior that take into consideration a common hypothesis. This hypothesis states that the elastic core is surrounded by an inelastic yield zone. The distribution of stress at low-to-moderate pillar loads has been effectively defined by this hypothesis. However, it suffers greatly when applied to large width-to-height (w/h >10) coal pillars under considerable overburden (>500 m). In these situations, the hypothesis says the elastic core can achieve unrealistic stress states, giving the pillars extremely high calculated strength. A growing body of field studies has shown this is not the case. It has become clear that some other mechanism must be involved. It is the purpose of this paper to discuss the importance of an interface slip mechanism between the coalbed and the surrounding strata in controlling the extent and pattern of stresses and deformations in a coal pillar.

OP 184-92. Longwall Mining of Thin Seams, by Curth, Ernest A.; Paper in Proceedings of the 1st Annual Conference on Ground Control in Mining. WV Univ., 1981, pp. 239-259. An estimated 49 billion tons, or 29 pct, of the coal reserve base to a depth of 1,000 ft in the Eastern United States fall in the 28- to 42-in range. Often left out as a consequence of selective mining, it is a paramarginal source that will become increasingly important. At present (1981), all active thin-seam longwalls are located in the Eastern Coal Province, and a number of operations have been suspended due to the erosion of the market for metallurgical coal. Extensive premining studies, appropriate mine planning, reliable equipment that is designed with ergonomics in mind, adequate roof support, intensive training, and strong face discipline are the ingredients that provide a measure of consistency in

production for the last 10 to 16 years, particularly in the Pennsylvania bituminous coalfield where single-drum shearers dominate. Plows, which were found to be very productive in suitable strata in Europe, are used in the Pocahontas field. Low-seam four- and six-legged shields have been introduced recently. The future holds automation at progressive levels. The first step is batch control with the benefits of quickly applied roof support and reduction of workmen exposure to environmental hazards.

OP 185-92. Faster Shifting of Longwall Equipment, by Bauer, Eric R.; Listak, Jeffrey M.; Coal, v. 26, No. 3, Mar. 1989, pp. 69-70. One drawback to longwall mining is the time consumed in moving the face equipment from one panel to the next. The average move time in U.S. longwall operations is 20 days, while moves taking as long as 30 days are not unusual. BethEnergy Mines Inc., working with the Bureau of Mines, looked for ways to speed up this phase of longwall operations for its Mine No. 60 in southwestern Pennsylvania. Engineers from BethEnergy and the Bureau found that by using predriven longwall recovery rooms and specially constructed roof-supporting piers, which are subsequently mined by the longwall, the mine is able to complete panel extraction by an average of 12.5 days faster and reduce face-equipment move time by 30 pct. In addition, longwall production is maintained right to the end of the panel. Although the predriven room recovery technique increased support costs by two to four times over those of conventional methods, the use of such recovery rooms boosted the mine's productivity.

OP 186-92. New Technology for the 1990s—Research and Development for the Coal Industry Continues To Focus on Productivity and Safety, by Listak, Jeffrey M.; Bauer, Eric R.; Coal, v. 96, No. 3, Mar. 1990, pp. 42-43. This paper describes the use of a predriven recovery room to reduce longwall transfer time.

OP 187-92. Longwall Shield Support Research With a Mine Roof Simulator, by Barczak, Thomas M; MinTech '89 Annual Review. Sterling Publications Ltd., 1989, pp. 43-46. The Bureau of Mines constructed a mine roof simulator in 1980 to conduct research on full-scale roof support structures under precisely controlled load conditions. The simulator is a bidirectional active load frame that can uniquely apply controlled forces or displacements in both the vertical and horizontal directions. Using this simulator, the Bureau of Mines has been conducting research on various types of underground roof support structures. The objective of these research efforts is to evaluate load transfer mechanics in order to develop methods to improve the selection and design of these support systems. This article presents a synopsis of the parameters investigated and research results for longwall shield supports. It is concluded that through these research efforts, the Bureau of Mines has advanced the understanding of shield mechanics and developed improved methods for performance testing of longwall supports.

OP 188-92. Chromite, by Papp, John F; Am. Ceramic Soc. Bull., v. 71, No. 5, May 1992, pp. 791-793. This article reviews developments affecting chromite in 1991.

OP 189-92. Cu-C and Al-Cu-C Phase Diagrams and Thermodynamic Properties of C in the Alloys From 1550° C to 2300° C, by Oden, L.L.; Gokcen, N.A.; Metall. Trans. B, v. 23B, Aug. 1992, pp. 453-458. The Cu-C and Al-Cu-C phase diagrams were determined at 1550° C to 2300° C by chemical and X-ray diffraction analyses of alloys saturated with carbon within sealed graphite crucibles. Isothermal sections for the ternary system were determined at intervals of 150° C over the range of temperatures investigated.

OP 190-92. Stress Relief Jointing in Eastern Kentucky, by Sames, G. P; Moebs, N. N; Paper in Rock Mechanics Contributions and Challenges. Proceedings of the 31st U.S. Symposium, ed. by W.A. Hustrulid and G.A. Johnson. Balkema, 1990, pp. 439-446. This paper is the result of a Bureau of Mines program to characterize roof conditions near outcrop in drift coal mines of eastern Kentucky. Joints occur throughout the shallow overburden of eastern Kentucky, separating the strata in blocks or wedges. Except for bedding planes, they are the most important structural feature in the characterization of shallow rock mass in the region.

OP 191-92. The Influence of an Oxidation Catalytic Converter and Fuel Composition on the Chemical and Biological Characteristics of Diesel Exhaust Emissions, by McClure, B.T.; Bagley, Susan T.; Soc. Automotive Eng. No. 920854, 1992, pp. 271-288. The U.S. Bureau of Mines and Michigan Technological University are collaborating to conduct laboratory evaluations of oxidation catalytic converters and diesel fuels to identify combinations which minimize potentially harmful emissions. The purpose is to provide technical information concerning diesel exhaust emission control to the mining industry, regulators, and vendors of fuel and emission control devices.

OP 192-92. Evaluation of a Disposable Diesel Exhaust Filter, by Ambs, Jeffrey L.; Cantrell, Bruce K.; Paper in Advances in Filtration and Separation Technology: Volume 4, Fine Particle Filtration and Separation, ed. by K.L. Rubow. Am. Filtration Soc., 1991, pp. 287-291. The underground mining industry recognizes that diesel-powered equipment has many advantages over its electric counterparts such as greater mobility, flexibility, and high power density, which result in increased productivity. There is, however, an attendant health risk for miners exposed to diesel exhaust. A miner working in an underground mine using diesel equipment is exposed to a wide array of pollutants from the diesel exhaust. These include carbon monoxide, carbon dioxide, nitric oxide, nitrogen dioxide, sulfur dioxide, diesel exhaust aerosol, and a variety of hydrocarbon compounds. Diesel exhaust aerosol consists mainly of carbonaceous soot, sulfates, trace metals, and adsorbed or condensed soluble organic compounds. A quantitative definition of the health risk resulting from these exposures remains elusive, but during the past several years progress has been made in defining the problem.

OP 193-92. Synergistic Wetting of Coal by Aqueous Solutions of Anionic Surfactant and Polyethylene Oxide Polymer, by Kilau, Howard W.; Voltz, Jon I.; Colloids and Surfaces, v. 57, Aug. 1991, pp. 17-39. The relation between surfactant-polymer interaction and coal wettability was determined experimentally with capillary, drop, viscosity, surface tension, and zeta potential tests. The results demonstrated that synergistic wetting enhancement occurred when anionic surfactant-polymer combinations were applied to hydrophobic coal samples. When applied to a hydrophilic sample of coal there was negligible improvement in wetting.

Combinations of non-ionic surfactant with polymer also showed no wetting improvement over surfactant alone. Low-molecular-weight polymer showed similar wetting enhancements to high-molecular-weight polymer, but excessive addition of high-molecular-weight polymer resulted in wetting reduction. A model is proposed which satisfactorily explains the wetting behavior observed experimentally.

OP 194-92. **Why Is Diesel Particulate in Mines An Issue and How Can It Be Controlled?**, by Watts, Jr., Winthrop F.; Waytulonis, Robert W.; Ch. 33 in Proceedings of the Environmental Management for the 1990's Symposium. SME, 1991, pp. 247-253. During the 1980's, the Mine Safety and Health Administration proposed new regulations for the use of diesel equipment in underground coal mines, and the National Institute for Occupational Safety and Health recommended that whole diesel exhaust be regarded as "a potential occupational carcinogen," and that reductions in exposure to exhaust pollutants would reduce excess risk. During the same time, the Bureau of Mines tested new emission control technology to minimize diesel emissions. The objectives of this paper are to discuss the major issues regarding diesel exhaust emissions, especially diesel particulate matter, and to highlight emission controls that will be available.

OP 195-92. **Pollutant Levels in Underground Coal Mines Using Diesel Equipment**, by Cantrell, B.K.; Rubow, K.L.; SME Preprint 91-35, 1991, 8 pp. The use of diesel equipment in underground coal mines is controversial because "whole diesel exhaust" is regarded as "a potential occupational carcinogen" by the National Institute for Occupational Safety and Health. Threshold limit values (TLVs) are recommended for the gaseous pollutants CO, CO_2, NO, NO_2, SO_2, and some hydrocarbons emitted in diesel exhaust. There is, however, no TLV recommended for diesel exhaust aerosols, nor is there a standard method for sampling these aerosols. The University of Minnesota and the Bureau of Mines have collaborated to develop a personal diesel exhaust aerosol sampler which utilizes size-selective, inertial impaction and gravimetric analysis. During the field test of this sampler, numerous air quality measurements were conducted in underground coal mines using diesel equipment. The objective of this report is to present these data and to assess the impact of diesel face haulage equipment on mine air quality.

OP 196-92. **Effects of a Catalyzed Diesel Particulate Filter on the Chemical and Biological Character of Emissions From a Diesel Engine Used in Underground Mines**, by Bagley, S.T.; et al., ; Soc. Automotive Eng., No. 911840, 1991, pp. 1-12. This report presents results from a collaborative study conducted by Michigan Technological University and the U.S. Department of the Interior, Bureau of Mines. The objective was to assess the effects a catalyzed diesel particle filter and low-sulfur fuel have on emissions. Emphasis was placed on determining the chemical and biological character of diesel particulate matter from a diesel engine used in underground mining.

OP 197-92. **Respirable Dust Trends in Coal Mines With Longwall or Continuous Miner Sections**, by Watts, Winthrop F. Jr.; Niewiadomski, George E.; Paper in Proceedings of the VIIth International Pneumoconioses Conference—Part 1. NIOSH Pub. 90-108, 1990, pp. 94-99. This paper summarizes the recent trends in respirable dust levels in sections using longwalls or continuous ripper miners. The analysis includes the large amount of compliance data collected by coal mine operators and Mine Safety and Health Administration inspectors. Recent data are compared with data reported for fiscal year 1978 to determine the changes that have occurred in dust levels and coal production. Data from mines using both methods of mining are also compared. In addition, operator data are compared to inspector data to determine if different trends exist.

OP 198-92. **Revegetation of Coarse Taconite Tailing Using Organic Amendments**, by Veith, David L.; Norland, Michael R.; Paper in Proceedings 65th Annual Meeting of the Minnesota Section of the Society of Mining Engineers. 1992, pp. 67-82. Surface mine waste stabilization has long been a concern of the Bureau of Mines, and particularly since the Bureau's Division of Environmental Technology was created with a mission to develop the technology necessary to reclaim surface wastes associated with major mining ore producers. Since Minnesota is the major domestic supplier of iron ore, and therefore a major waste producer in the minerals industry, it was natural for the Bureau to initiate a waste stabilization-reclamation program on the Mesabi Iron Range of northeastern Minnesota. Developing a permanent vegetative ground cover stabilization technique for coarse taconite tailings is the subject of this paper.

OP 199-92. **Computer-Aided Design of Stream Diversion**, by Martin, L.A.; Brady, T.M.; Paper in Mining in the Arctic. Proceedings of the 2nd International Symposium on Mining in the Arctic, ed. by S. Bandopadhyay and M. Nelson. Balkema, 1992, pp. 127-133. Researchers at the U.S. Bureau of Mines are demonstrating the use of computer-generated, three-dimensional topographic plots as design tools for planning permanent stream diversions and contouring in alpine placer mine environments. Following a plane table survey, slope configurations and stream course design changes can be made by a mine operator before submitting a plan to the permitting agency. Regulatory and review agency personnel can then visualize the final configuration in three dimensions, giving them the opportunity to recommend design changes to fit permitting requirements before any earth is moved. This computer-aided design assists mine operators by decreasing permit processing time. In the first trial, the speed at which the paperwork was processed and the minimal amount of the bond greatly benefited the mine operator and allowed the necessary earth moving to be completed during the fall dry season.

OP200-92. **Bauxite & Alumina**, by Sehnke, Errol D.; Min. Eng., v. 43, No. 6, June 1991, pp. 593-594. This article reviews developments affecting bauxite and alumina in 1990.

OP 201-92. **Bauxite**, by Sehnke, Errol D.; Am. Ceramic Soc. Bull., v. 70, No. 5, May 1991, pp. 852-854. The United States remained highly dependent on foreign sources of bauxite in 1990. Almost all of the relatively small domestic mine output was used for nonmetallurgical products, including abrasives, chemicals, proppants, and refractories. Domestic production of bauxite for the year was projected to have been 26 pct less than in 1989. This significant reduction was attributed partly to the permanent closure of the last remaining bauxite mining operation in Arkansas during the second quarter

of 1990. In recent years, bauxite has been produced primarily from surface mines in Arkansas, Alabama, and Georgia, with only the latter two States producing and processing refractory-grade product. In 1990, the refractory-grade bauxite mine production from Alabama and Georgia was estimated to have declined by approximately 16 pct, and imports continued to dominate the U.S. market.

OP 202-92. Refractory Grade Bauxite: An Overview, by Sehnke, Errol D.; SME Preprint 92-146, 1992, 11 pp. The refractory materials industry provides the largest commercial market for nonmetallurgical-grade bauxite. Refractory-grade bauxite is prepared from bauxites having low iron, titania, and alkali content by calcining at temperatures near 1,650° C. Although there are substantial bauxite reserves in the world, premium-grade bauxite ores suitable for use in refractory applications are limited to only a few specific sources, primarily in Guyana and the People's Republic of China. Consumption of bauxite for refractory use is closely associated with the production and consumption of primary metals, in particular iron and steel. Barring major disruptions within the principal producer nations, sufficient supplies of refractory bauxite will be available to meet world demand well into the next century, and raw material costs will continue to determine the availability of markets for bauxite-based refractory products.

OP 203-92. Bauxite & Alumina, by Sehnke, Errol D.; Min. Eng., v. 44, No. 6, June 1992, pp. 551-553. This article reviews developments affecting bauxite and alumina in 1991.

OP 204-92. Bauxite, by Sehnke, Errol D.; Am. Ceramic Soc. Bull., v. 71, No. 5, May 1992, pp. 788-790. In recent years the United States has become extremely dependent on foreign sources of bauxite, and this supply balance is expected to continue well into the foreseeable future. Open-pit mining operations in Alabama and Georgia are the only active sources of bauxite remaining within the United States. All of the bauxite mined domestically in 1991 was used for nonmetallurgical products, such as abrasive, chemical, proppant, and refractory applications. Domestic production for the year was only about one-tenth the 1990 level, a result of the final closure of all mining operations in Arkansas and a protracted national economic recession. Imports continued to dominate the U.S. market.

OP 205-92. Characterization of Stainless Steels Melted Under High Nitrogen Pressure, by Rawers, J.C.; Dunning, J.S; Metall. Trans. A, v. 23A, July 1992, pp. 2061-2068. Mechanical properties of stainless steel increase with increasing nitrogen concentration. Currently, the maximum nitrogen concentration in commercial stainless steel is 0.8 wt pct. In this study, type 304 and 316 stainless steels were melted and cooled in a hot-isostatic-pressure (HIP) furnace using nitrogen as the pressurizing gas, producing alloys with nitrogen concentrations between 1 and 4 wt pct. These nitrogen levels exceeded the alloys' solubility limits, resulting in the formation of nitride precipitates with several different microstructures. A new phase diagram for high-nitrogen stainless steel alloys is proposed. Several properties of these nitrogen stainless steel alloys with chromium nitrides present were studied: tensile strength was proportional to the interstitial nitrogen concentration; hardness, wear, and elastic modules were proportional to the total nitrogen concentration.

OP 206-92. Danger! Unsupported Roof, by Peters, Robert H.; Holmes Safety Assoc. Bull., Apr. 1992, pp. 7-15. Mining companies try various strategies to convince employees to avoid unsafe acts and to adopt self-protective behaviors. This article evaluates five strategies to discourage miners from going under unsupported roof. These strategies include incentives and feedback, disciplinary action, fear communication, employee participation, and expression of management concern.

OP 207-92. Use of Bacterial Sulfate Reduction for Removing Nickel From Mine Waters, by Hammack, Richard W.; Edenborn, Harry M. Ch. 19 in Proceedings of the SME Symposium on Emerging Process Technologies for a Cleaner Environment (Phoenix, AZ, February 24-27 1992). SME, 1992, pp. 141-147. Experiments were done to determine if a mushroom compost-based sulfate reduction system could be used to treat nickel-contaminated mine waters. Sulfate reduction systems were established in columns containing acid-washed mushroom compost. Simulated mine waters containing 2,000 mg/L sulfate and 50 to 1,000 mg/L nickel were adjusted to pH 4.5 and pumped through the columns at flow rates between 15 and 25 mL/h. During the first 9 days of operation, virtually all influent nickel was removed in the columns by sorption and ion exchange mechanisms. The nickel removal rate then dropped to 18 to 30 mg Ni/day (7.8 to 12.8 nmol/g-substrate/day), probably due to low sulfate reduction rates. When sodium lactate was added to the inflow, a sustained and sevenfold increase in the nickel removal rate was observed. Results of this study indicate that bacterial sulfate reduction can effectively treat nickel concentrations up to 500 mg/L if labile carbon is nonlimiting.

OP 208-92. Cryogenic Extinguishment of Waste Bank Fires, by Kim, Ann G.; Kociban, Andrew M. Paper in Proceedings of the 14th Annual Abandoned Mined Land Conference (Chicago, IL, August 23-27, 1992). National Association of Abandoned Mined Land Programs, 1992, pp. 277-289. The Bureau of Mines has developed a cryogenic heat transfer method of controlling wastebank fires. A slurry of liquid N_2 and granular CO_2 is used as the heat transfer medium. Because of its extremely low temperature (-180° C), the cryogenic slurry absorbs large quantities of heat. Changes in state from the solid and/or liquid to the gas phase also absorb heat. The phase change produces over a 500-fold increase in volume, creating a cold pressure wave that moves isotropically away from the injection point. The cold wave absorbs heat, produces an inert atmosphere, and forces smoke and fumes from the combustion zone to the surface. Thus, the injected slurry causes a relatively quick cooling of the burning material, while the expansion of the evaporating gas maintains the cool atmosphere for an extended period. The movement of the inert gas is controlled by pressure and buoyancy. To evaluate limiting parameters and operating conditions, the Bureau has conducted injection and heat transfer tests. It is currently developing specifications for a full-scale test to control a wastebank fire with a cryogenic slurry of liquid N_2 and granular CO_2. Preliminary estimates indicate that the cost of injecting a cryogenic slurry is comparable to the cost of more conventional control methods for abandoned mined land fires.

OP 209-92. Rock Mechanics Research Decreases Longwall Bump Potential, by Barton, T.M.; Campoli, A.A.; Gauna, M. SME Preprint 91-79, 1991, 6 pp. Coal mine

bumps, the violent failures of overstressed coal, present a safety hazard to miners when mining is conducted in deep, bump-prone coal mines. Two different longwall gate entry systems were evaluated in a Southern Appalachian coal mine located in the Pocahontas No. 3 Coalbed under approximately 610 m of overburden which included a massive sandstone member. Both gate entry systems employed a center abutment pillar flanked by yield pillars. The original design employed a 24.2-m-square abutment pillar, while the new design employed a 36.6- by 54.9-m abutment pillar. Rock mechanics instrumentation data analysis and in-mine observations indicated that this increase in abutment pillar size significantly decreased bump potential. The new design in worse case conditions increased effective bearing area 62 pct with only a 9-pct increase in gate entry system width and eliminated face bumps that were experienced with the original gate entry design.

OP 210-92. Effects of Surface Topography on the Stability of Coal Mine Openings, by Molinda, Gregory M.; Heasley, Keith A.; Oyler, David C. Paper in Proceedings of the 10th International Conference on Ground Control in Mining (Morgantown, WV, June 10-12, 1991). West Virginia Univ., 1991, pp. 151-160. An investigation was conducted to determine the nature and frequency of coal mine roof failure beneath valleys. A mechanism for this failure and suggestions for controlling this problem are presented. Hazardous roof conditions identified in a number of mines were positively correlated with mining activities beneath stream valleys. Mine maps with overlays of unstable roof and locations of stream valleys show that 52 pct of the instances of all unstable roof in the surveyed mines occurred directly beneath the bottom-most part of the valleys. The survey also showed that broad, flat-bottomed valleys were more likely to be sites of hazardous roof than narrow-bottomed valleys. Evidence of valley stress relief was found beneath a number of valleys in the form of bedding-plane faults and low-angle thrust faults. This type of failure, previously believed to be only a shallow phenomenon, was found at mining depths as great as 300 ft. In situ horizontal stress measurements in a mine beneath a valley and the adjacent hillsides confirmed valley stress relief. Underground mapping showed that roof falls in excess of 100 ft in length and up to 25 ft high closely aligned with the valley axis. Numerical analysis of 13 valleys overlying one mine property showed the effect of the valley excavation on horizontal and vertical stress. Thickness of cover, valley shape, and the orientation of the valley relative to the maximum regional horizontal stress all influence the "valley effect" on roof stability.

OP 211-92. Gate Design Key to Bump Control, by Campoli, A.A; et al., Coal Magazine, v. 95, No. 9, 1990, pp. 54-58. The Bureau of Mines conducted on-site investigations to determine if gate road design could be used to control bumps. Two different gate road designs, located within the Pocahontas No. 3 seam on Island Creek Coal property, were evaluated using two detailed instrument arrays and in-mine observations. The state-of-the-art instrumentation arrays consisted of stainless-steel, borehore platened flatjacks used to indicate changes in pillar stress, coal extensometers for measuring pillar dilation, convergence stations for measuring roof-to-floor closure, a differential roof-sag indicator, and a differential floor-heave indicator. A permissible data acquisition system was employed to continuously monitor coalbed stress and roof-to-floor convergence in hazardous areas.

OP 212-92. Effect of Physico-Chemical Parameters on Dewatering: A Case Study, by Sharma, Sandeep K.; Scheiner, B.J. Fluid/Particle Separation J., v. 4, No. 3, Sept. 1991, pp. 162-166; also appears in Advances in Filtration and Separation Technology, v. 4, Fine Particle Filtration and Separation, Gulf Publ. Co., 1992, pp. 167-180. The Bureau of Mines Tuscaloosa Research Center is investigating solid-liquid separation with the goal of improving the dewatering of mineral slurries. This study investigated the effect of physical and chemical parameters such as mixing and polymer type on dewatering of mineral slurries. Small-scale laboratory tests, using an in-line mixer, were conducted to investigate the effect of variation in Reynolds number on the dewaterability of a bentonite slurry. These tests showed that lower polymer dosages were required with polyethylene oxide (PEO) than with Photofloc 1027 and that the PEO-treated slurries can withstand more shear than those treated with Photofloc 1027. Similar studies using tank mixers showed that only PEO produced strong flocs and that higher PEO dosages were required with this mixer than with the in-line mixer. Based on the positive laboratory results, large-scale studies were conducted at various placer gold mines in Alaska. These studies confirmed that mixing is a major factor in flocculation. Results also showed that in three out of four field tests, in-line mixing produced better solid-liquid separation than conventional tank mixing and that PEO produced water with low turbidity.

OP 213-92. Removal of Toxic Metals From an Industrial Wastewater Using Flocculants, by Carter, Jr., Olice C.; Scheiner, B.J. Fluid/Particle Separation J., v. 4, No. 4, Dec. 1991, pp. 193-196; also apears in Advances in Filtration and Separation Technology, v.4, Fine Particle Filtration and Separation, Gulf Publ. Co., 1992, pp. 190-199. The Bureau of Mines investigated the removal of two toxic and/or heavy metals (cadmium and lead) from a brass foundry wastewater. Polymers, copolymers, guars, and gums were used in conjunction with calcium hydroxide and magnesium oxide to remove the metals from solution. Several polymers were successful in removing Cd and Pb from the wastewater. The concentrations of Cd and Pb were lowered from 19 to 0.01 ppm and from 20 to less than 0.01 ppm, respectively. The methods investigated could easily be adapted to many existing wastewater treatment facilities and/or be used independently.

OP 214-92. Advances in Filtration and Separation Technology: V.5. Separation Problems and the Environment., by Scheiner (ed.), Bernie. Gulf Publ. Co., 1991, 425 pp.

OP 215-92. Producing Ultrafine, High Purity Ceramic Powders by Turbomilling, by Hoyer, Jesse. JOM, v. 44, No. 3, Mar. 1992, p. 54. In the 1960's, the U.S. Bureau of Mines developed a turbomill and evaluated it in grinding studies of materials such as clay, mica, talc, manganese dioxide, and powders of aluminum and copper. Recently, studies were completed for use of the turbomill in processing ultrafine, high-purity powders.

OP 216-92. A Review of Electrooxidation Technology, by Scheiner, B.J. High Temperature Materials and Processes, v. 9, No. 2-4, 1990, pp. 249-259. The U.S. Bureau of Mines has successfully demonstrated that an oxidizing environment can be generated in ore pulps using bipolar cells.

The technique, called electrooxidation, has been tested on a variety of ores and concentrates in both small-scale and prototype cells. This paper reviews this technology for carbonaceous gold ores and molybdenum concentrates.

OP 217-92. Investigation of Metal and Nonmetal Ion Migration Through Phosphogypsum, by Carter, O.C.; Scheiner, B.J. Ch. 27 in Emerging Process Technologies for a Cleaner Environment, ed. by S. Chandler, P.E. Richardson, and H. El-Shall. SME, 1992, pp. 205-210; also appears in Proceedings of the International Symposium on Waste Processing and Recycling in Mining and Metallurgical Industries, pub. by the Canadian Institute of Mining, Metallurgy, and Petroleum, 1992, pp. 267-274. The Bureau of Mines is investigating the effects of rainfall and gypsum/cooling pond water on the rate of metal and nonmetal ion mobility through phosphogypsum stacks located in central Florida. Since leachate contains metal and nonmetal ions that have the potential for migration into surface and groundwater, laboratory column leach tests were conducted. Synthetic rainwater was passed through the column, and metal and nonmetal ion migration was monitored. Similar experiments were conducted using a number of synthetic solutions which simulated a number of different compositions of gypsum/cooling pond water. Results indicate that within the first five pore volumes most of the mobile metals and nonmetals were removed.

OP 218-92. Optimization of Supplemental Support for Open-Entry Longwall Equipment Recovery, by Listak, Jeffrey M.; Bauer, Eric R. Papers in Proceedings of 1989 Longwall USA, June 19-22, 1989. Industrial Presentations, Inc., 1989, pp. 20-27. This report describes a study, conducted jointly by BethEnergy Mines, Inc., and the Bureau of Mines, to assess the effects of longwall front abutment loading on various supplemental support materials utilized in a predriven recovery room. The purpose of the predriven recovery room is to reduce longwall equipment transfer time by eliminating the premove preparation associated with conventional recovery methods. In addition, the room provides a large area in which face salvage equipment can maneuver. Results of four recovery-room study areas show the progression and influence of the front abutment on the longwall panel and supports and their subsequent behavior. The best performance (i.e., the support that most facilitated recovery) of support material was achieved through the use of a concrete mixture that had a sand content of 35 pct by volume. The longwall transfer time was reduced by 30 pct, which translates to a production advantage of 37,000 raw tons of coal per panel.

OP 219-92. Field Evaluation of Longwall Stress Distribution in Bump-Prone Strata, by Barton, Timothy M.; Campoli, Alan A. Paper in Proceedings of the 1992 Longwall USA Conference. Maclean Hunter, 1992, 17 pp. How the geologic setting and dimensions of the underground workings of a retreat longwall influenced the stress distribution across the longwall face, active gob, gate pillars, and adjacent unmined panel was not fully known. At the VP No. 3 Mine of Island Creek Coal Co., the U.S. Bureau of Mines previously investigated the performance of a promising gate pillar design that decreased the potential of longwall face bumps. The longwall stress environment was further defined at this mine by measuring stress over two consecutively mined panels with Bureau-designed stress cells. The floor rock beneath two longwall panels and coal pillars in the gate road between them was instrumented. Panel and gob stress distributions were continuously monitored by a data acquisition system. Maximum stress was observed immediately in front of the longwall face, and a significantly greater portion of peak stress was imposed on the tailgate side of the current panel than on its headgate side. The pressure then quickly dropped as the face moved past the instruments. After the face passed, the center of the longwall panel regained significant overburden load; however, the instruments located less than 100 ft from the headgate edge of the panel showed little or no increase in pressure due to gob reloading.

OP 220-92. Diesel Exhaust Control, by Waytulonis, Robert W. Ch. 11.5 in SME Mining Engineering Handbook, v. 1, ed. by H.L. Hartman. SME, 2d ed., 1992, pp. 1040-1052. This chapter deals with the control of exhaust emissions from diesel-powered equipment operated in confined spaces, such as mines.

OP 221-92. Treatment of Metal-Contaminated Water Using Bacterial Sulfate Reduction: Results From Pilot-Scale Reactors, by Dvorak, Darryl H.; Hedin, Robert S.; Edenborn, Harry M. Biotechnology and Bioengineering, v. 40, 1992, pp. 609-616. Simple anaerobic reactors were installed to treat metal-contaminated water in an underground coal mine and at a smelting residues dump in Pennsylvania. The reactors consisted of barrels and tanks filled with spent mushroom compost, within which bacterial sulfate reduction became established. Concentrations of Al, Cd, Fe, Mn, Ni, and Zn were typically lowered by over 95 pct as contaminated water flowed through the reactors. Cadmium, Fe, Ni, and some Zn were retained as insoluble metal sulfides following their reaction with bacterially generated H_2S. Aluminum, Mn, and some Zn hydrolyzed and were retained as insoluble hydroxides or carbonates. Reactor effluents were typically circumneutral in pH and contained net alkalinity. The principal sources of alkalinity in the reactors were bacterial sulfate reduction and limestone dissolution. This article examines the chemistry of the reactor systems and the opportunities for enhancing their metal-retaining and alkalinity-generating potential.

OP 222-92. Reduction of Surface Mineral Waste Through Underground In Situ Leaching of Fragmented Ore and Fill Material, by Boreck, D.L.; Goris, J.M. Paper in Environmental Issues and Waste Management in Energy and Minerals Production, ed. by R. Singhal, A. Mehrotra, K. Fytas, and J.L. Collins. Balkema, v.2, 1992, pp. 951-959. Environmental protection is increasingly more important in the design and development of mining operations. Research on mining systems for future operations must consider the effects on and explore ways of protecting the environment. As part of its in situ leach mining program, the U.S. Bureau of Mines is conducting research on underground ore processing that reduces surface waste disposal problems. One such technique is leaching of ore or mineralized backfill in open stopes or rooms. Major obstacles to implementing stope and backfill leaching are solution control and leaching chemistry. Geologic and hydrologic characterization of the site prior to leaching is a critical part of effective solution control. In lixiviant selection, the lixiviant must leach metal from the ore, yet maintain a low toxicity and have the least adverse effects on the surrounding area.

OP 223-92. Remediation of Radiological Contamination at Operable Units IV/V of the Denver Radium Superfund Site: A Case Study, by Killoran, Linda K.; Allgaier, Fred K. Paper in Environmental Issues and Waste Management in Energy and Minerals Production, ed. by R. Singhal, A. Mehrotra, K. Fytas, and J.L. Collins. Balkema, 1992, pp. 1065-1074. The Denver Radium Superfund Site consists of over 44 properties, constituting 11 Operable Units, along the South Platte River within the City of Denver, CO, that were contaminated with radioactive residues resulting from the processing of radium in the years 1913 to 1923. The site was added to the Superfund National Priorities List (NPL) in 1983. The Robinson Brick Company (ROBCO) property and the adjacent Denver and Rio Grande Western Railroad right-of-way form Operable Units IV and V of the Denver Radium Superfund Site. The radiological cleanup of these units was completed in March 1991, approximately 9 years after the initial site assessment, at an estimated cost of $22.3 million. Had a historical review been conducted in conjunction with the initial site assessments, the presence of heavy metals would have been known and more appropriate site characterization methods could have been applied, thus reducing the cleanup costs in terms of both time and money.

OP 224-92. Investigation of Structural Geology and Coal Mine Subsidence Potential in Colorado Springs Area Using Remote Sensing and GIS Technology, by Peters, Douglas C. Paper in Proceedings of GeoTech '92 (Denver, CO, August 29 to September 1, 1992). GeoTech, Inc., 1992, pp. 258-278. The purpose of this research was to determine the extent to which remote sensing lineament analysis techniques can be used to identify geologic structures that may affect the location and migration of subsidence over abandoned underground coal mines in the Colorado Springs area. Ultimately, these techniques could be useful for identifying such geologic structures at other abandoned mine land sites. Landsat satellite images and aerial photographs were used to interpret the geologic structure of the area. A geographic information system was used to integrate the diverse data sets involved in the study and to allow reliable and reproducible spatial registration and analysis of the data.

OP 225-92. A Program To Correct Errors in DEM Data, by Smith, Marie A.; Peters, Douglas C. Paper in Proceedings of GeoTech '92 (Denver, CO, August 29 to September 1, 1992). GeoTech, Inc., 1991, p. 412. Although digital elevation model (DEM) data obtainable from the U.S. Geological Survey generally represent the topography of a 7.5-min quadrangle, a number of error types can occur in the data. These errors can occur during data collection or through introduction of anomalies by the elevation model generation process. Anomalies and errors include holes (below-topography anomalies), spikes (above-topography anomalies), mismatches in elevation where two quadrangles meet, and surface roughness variations unrelated to actual topography. Manual editing (ASCII text editing) of the DEM data to correct such errors is tedious, time consuming, and prone to the missing of less obvious error locations. A program has been developed at the Bureau of Mines in FORTRAN to search for and identify the locations of errors within a DEM data set. This presentation discusses the various types of errors and their impact on use of DEM data and the search logic used to locate errors.

OP 226-92. Solubility of Ni in Spent Pickling Solutions, by Horter, G.L.; et al. Paper in Residues and Effluents—Processing and Environmental Considerations. TMS, 1992, pp. 801-813. Nickel solubilities in spent pickling solutions (i.e., HF-HNO_3-H_2O solutions) were measured as a function of HF and HNO_3 acid concentrations. The chemical analysis of the industrial pickling solutions and sludges were made. The stable phases observed in the sludges are FeF_3*$3H_2O$ and (FeCr)F_3*$3H_2O$. Pure Ni and stainless steel type 316 were used in this study. The results showed that the solubility of Ni increased with increase in concentrations of HF in pickling solution at a fixed concentration HNO_3. An excellent agreement between the experimental solubility data and the theoretical data was obtained. X-ray diffraction analysis showed that the solid solubility product formed is mainly NiF_2*$4H_2O$ compound.

OP 227-92. Micromechanics of Compressive Fracture In Particulate Reinforced Ceramics, by Laird II, George; Kennedy, T.C. Paper in Proceedings of the 16th Annual Conference on Composites and Advanced Ceramic Materials (Cocoa Beach, FL, January 7-10, 1992). Am. Ceram. Soc., Westerville, OH, 1992, pp. 107-120. SIC, Si_3N_4, and M-glass reinforced with TiB_2, SiC, and Ni, respectively, were modeled using finite element analysis. Debonding between the matrix and particle was assumed; interfacial friction was modeled with friction coefficients (^H) from 0.0 to 0.25. Stress intensity factors (K_1) were calculated for an annular crack parallel to compressive loading. Numerical results showed that with a frictionless interface, stiff particles tended to force open the crack. Conversely, with ^F = 0.1 and 0.2, the crack flanks were restrained against the particle and K_1 was decreased at the crack tip. This toughening effect was more pronounced as the elastic moduli mismatch was increased.

OP 228-92. Using Geophysical Methods To Characterize Environmental Effects of Abandoned Mining and Milling Operations, by Lepper, C. Mel. Paper in Environmental Issues and Waste Management in Energy and Mineral Production, ed. by R. Singhal, A. Mehrotra, K. Fytas, and J.L. Collins. Balkema, 1992, pp. 813-821. The U.S. Bureau of Mines is actively involved in environmental assessment of mine and mill tailings refuse piles left by operations in the late 1800's to about 1950. Abandoned mill tailings near Buena Vista, CO, are believed to be polluting an adjacent stream. The mine operation extracted gold, silver, lead, zinc, copper, and iron and left behind tailings piles covering approximately 30,000 square meters of the surface adjacent to Chalk Creek. Erosional processes have caused the fine tailings to enter the creek, and surface and under-deposit water flows carry leached metals into the creek. In an attempt to define and characterize the source of the creek water pollution, the Bureau conducted geophysical investigations on the mill tailings in October 1990 and again in June 1991. The results of these studies are the subject of this presentation.

OP 229-92. Laboratory Tests on High-Temperature Cyanide Leaching of Automobile Catalysts, by Atkinson, G.B.; Kuczynski, R.J.; Walters, L.A. Paper in Proceedings of the Precious Metals Recovery and Refining Seminar (September 11-13, 1991, Tempe, AZ), ed. by Dr. Martin T. Durney. International Precious Metals Institute, Allentown, PA, 1991, pp. 1-9. The U.S. Bureau of Mines

investigated leaching automobile catalysts with sodium cyanide (NaCN) solutions at high temperatures to recover platinum-group metals (PGM). The feed was virgin monolith rejects, used monolith, and used pellet catalysts. Leaching with a 5-pct NaCN solution for 1 h at 160° C dissolved over 97 pct of the PGM in the virgin monolith, over 85 pct of the PGM in the used monolith, and over 90 pct of the PGM in used pellet catalyst. Over 99.8 pct of the dissolved PGM was recovered as a precipitate by heating the solution to 250° C for 1 h in an autoclave. The cyanide complexes were decomposed and free cyanide was destroyed.

OP 230-92. COALVAL: A Prefeasibility Software Package for Evaluating Coal Properties Using Lotus 1-2-3, Version 2.2, by Plis, Matthew N.; Rohrbacher, Timothy J.; Teeters, Dale D. Paper in Proceedings of the GeoTech '92 Geocomputing Conference. ExpoMasters, Englewood, CO, 1992, pp. 180-186. This report highlights COALVAL, a coal property evaluation software package developed by the U.S. Bureau of Mines (USBM) on Lotus 1-2-3, version 2.2, spreadsheets. The software is also compatible with version 3.1, and provisionally with version 2.01.

OP 231-92. Static and Dynamic Subsidence Prediction in the Northern Appalachian Based on the Use of a Variable Subsidence Coefficient, by Adamek, Vladimir; Jeran, Paul W.; Trevits, Michael A. Paper in Proceedings of the 3rd Workshop on Surface Subsidence Due to Underground Mining (Morgantown, WV, June 1-4, 1992). West Virginia University, 1992, pp. 10-21. Due to the variability of subsidence characteristics across the U.S. coalfields, it was concluded that it would be practically impossible to develop a universal predictive model for mining-induced subsidence based on theoretical assumptions. Therefore, an effort was made to find a procedure to develop an empirical subsidence predictive model based on a sufficient amount of field data from one mining area (in this case the Northern Appalachian Coal Region). It was also thought that this procedure, if successful, could be used as the template for developing predictive capabilities for other coalfields with different subsidence characteristics given a reasonable amount of field data. It has been found, in the Northern Appalachian Coal Region, that the variability of subsidence characteristics can be expressed by a polynomial equation developed through regression analysis of the variable subsidence coefficient and derived directly from the field data. In this study, field data were obtained from 11 Bureau longwall panel studies (16 half profiles) for static subsidence and 14 panels for dynamic subsidence. The effects of lithology, expressed in the form of a variable subsidence coefficient, have been separated for each test site by introducing a correlation between hypothetically homogeneous overburden an existing lithological conditions. For each longwall panel, the characteristics of the variable subsidence coefficient was defined along individual static profiles. The definition of mean values with acceptable deviations is the substance of the predictive method. The same procedure was used to develop a predictive model for dynamic substance, since it was discovered that the rate of longwall face advance is not a necessary functional parameter. This paper presents the theory, development, and application of the static and dynamic subsidence prediction models.

OP 232-92. Development of Dynamic Subsidence Over Longwall Panels in the Northern Appalachian Coal Region, by Adamek, Vladimir; Jeran, Paul W.; Trevits, Michael A. Paper in Proceedings of the 33rd U.S. Symposium on Rock Mechanics (Santa Fe, NM, June 8-10, 1992). West Virginia University, 1992, pp. 243-251. It is a common perception that an increased rate of longwall face advance will result in a flatter dynamic subsidence trough above the panel thus diminishing the magnitude of surface deformations: inclination, curvature and horizontal strain. However, a thorough analysis of centerline field data from 14 Bureau longwall panel studies (where the average rate of face advance ranged between 6.3 to 44.6 ft/day) revealed the only effect of the differing rates of face advance on dynamic subsidence was the duration of its development. There was no effect on either the magnitude or the distribution of the surface deformations. Since the rate of face advance does not play a role in dynamic subsidence development, it has been determined that the prediction of dynamic subsidence can be approached using a methodology developed for static subsidence prediction. The position of the face at a given time for dynamic prediction plays the same role as the edge of the panel for static prediction. An alternate method, based upon the distribution of the percentage of the maximum subsidence of any point versus the ratio of the distance from the face to overburden thickness is also proposed. Both prediction methods produce acceptable results.

OP 233-92. Degradation of Ceramic Cutting Tools, by Bennett, James. Ch. 16 in Proceedings of the Corrosion of Glass, Ceramics, and Ceramic Superconductors. Noyes Publications, 1992, pp. 455-480. Cutting tools, although small in size and price compared to the machine tools on which they are used, form the critical link in the man-machine productivity chain. In addition, they pose a very challenging application for materials. The cutting tool in its usage encounters abrasion, high temperature, mechanical and thermal shock, and chemical interaction with the workpiece material. It is important to understand the nature of the degradation that occurs in the tool material. This will permit selection of the proper tool material for a particular application and the design of better cutting tool materials. The degradation of cutting tools directly impacts manufacturing productivity, which in turn is linked to the cost of every manufactured product. Careful analysis reveals that cutting tools are used directly or indirectly in the manufacturing cycle of almost every product. Everything from aircraft to kitchen appliances to ships have cutting tools used their manufacturing cycle. Thus the degradation of the cutting tool is an important factor contributing to manufacturing productivity.

OP 234-92. SCSR Proficiency Requires Hands-on Practice, by Brnich, Michael J.; Vaught, Charles; Mallett, Launa G. Coal—Operating Ideas, July 1992, pp. 52-54. Based on Bureau of Mines Field evaluations of self-contained self-rescuer (SCSR) donning proficiency and interviews with miners who have used the devices in mine emergencies, there appears to be a clear need for companies to carefully appraise their SCSR training protool. The purpose of training workers on these oxygen breathing apparatus should not be just to comply with Federal regulations but to ensure that workers are adequately prepared to put on and use a device for its intended purpose: to escape an unbreathable mine atmosphere.

OP 235-92. Methods for Maintaining Self-Contained Self-Rescuer Donning Proficiency, by Brnich, Jr.,

Michael J.; Vaught, Charles; Wiehagen, William J. Paper in Proceedings of the Training Resources Applied to Mining (TRAM XVIII) (University Park, PA, August-12-24-91). The Pennsylvania State University, 1991, pp. 145-154. There is a growing body of empirical research relating to miners' self-contained self-rescuer (SCSR) donning proficiency. Performance data is derived from two sources: (1) random sampling of miners and evaluation of their donning skills; and (2) interviews with miners who have used the apparatus to escape a mine fire. Two issues are important: the first relates to initial training; the second deals with methods for maintaining acceptable proficiency over time.

OP 236-92. **A Field Study to Assess Natural Degradation of Cyanide Species in an Inactive Leached Ore Heap**, by Comba, P.B.; Dix, R.B.; McGill, S.L. Paper in Environmental Issues and Waste Management in Energy and Mineral Production, ed. by R.K. Singhal, A.K. Mehrotra, K. Fytas, and J.L. Collins. Balkema, v. 1, 1992, pp. 535-543. The U.S. Bureau of Mines is conducting an ongoing field study to monitor the natural degradation of cyanide in a one-million-ton spent silver ore heap at which leaching operations ceased in October 1990. Samples of the spent ore were taken at three-month intervals during the first year, and will be taken at six-month intervals in the second and third years. The cyanide concentrations in the heap as a function of depth and time are presented and discussed. The report describes field sampling procedures, sample preservation methods, and the laboratory investigation which was concurrently conducted to develop a sample preparation technique and a procedure for solids cyanide analyses. Water leach tests on heap samples were conducted to simulate the effect of precipitation from meteoric storm events. Results of these studies showing soluble cyanide and metal concentrations as a function of depth and time are presented and discussed.

OP 237-92. **Biological Arsenic Removal From Mining and Milling Waters by Anaerobic Sulfate-Reducing Bacteria**, by Dinsdale, B.E.; Belin, D.D.; Altringer, P.B. Paper in Proceedings of the Second International Conference on Environmental Issues and Management of Waste in Energy and Mineral Production (Calgary, Alberta, Canada, September 1-4, 1992) ed. by R.K. Singhal, A.K. Mehrotra, K. Fytas, and J.L. Collins. Balkema, v. 2, 1992, pp. 1,389-1,400. The U.S. Department of the Interior, Bureau of Mines Salt Lake City Research Center, is investigating biological decontamination of arsenic-bearing mining waste waters. Preliminary research indicates that biological arsenic removal is possible using anaerobic sulfate-reducing bacteria indigenous to sulfate-contaminated tailings. The bacteria grown in synthetic media containing 100 ppm As and phosphate buffer, reduced the sulfate to sulfide, and removed 88 pct of the arsenic. An arsenic sulfide compound was formed and precipitated out of solution. Although using bacteria directly is viable, the arsenic sulfide precipitates eventually redissolved at the pH levels required for cell growth. Tests have shown that remediation can be greatly enhanced by employing bacteria in a 2-stage continuous flow bioreactor which maximizes sulfide production and decreases residence time from 8 days to less than 3 hours. These promising exploratory results could lead to a practical biological process for arsenic removal from contaminated water.

OP 238-92. **Laboratory Rinsing Behaviors of Spent Ores**, by Dix, R.B.; Comba, P.G.; McGill, S.L. Paper in Proceedings of the Second International Conference on Environmental Issues and Management of Waste in Energy and Mineral Production (Calgary, Alberta, Canada, September 1-4, 1992) ed. by R.K. Singhal, A.K. Mehrotra, K. Fytas, and J.L. Collins. Balkema, v. 2, 1992, pp. 917-924. Environmental regulations have been adopted in recent years by gold producing States requiring the rinsing of spent heaps to remove residual cyanide. The final heap rinse effluents must meet criteria for pH, cyanide and metals content. Laboratory column rinsing studies on three different ore types were conducted by the U.S. Bureau of Mines. Rinse profiles for cyanide as a function of volume of rinse solution passed through the spent ore are presented. Fresh water rinsing of two agglomerated ores at flowrates between 0.003 to 0.010 gal/min–ft^2 of ore surface showed the cyanide removal was independent of the rinse solution application rate during the initial phases of rinsing. Interrupted rinsing with a dormant period between applications showed varying results. In rinse tests using fresh water on agglomerated ores, the effluents met the criteria for cyanide detoxification by pH levels were above the maximum limits. Use of a chemical oxidant to destroy cyanide in the rinse effluents with recycle of the neutralized solution reduced the volume of waste solution generated. Recycle of untreated rinse effluents reduced the volume of waste solution generated through natural degradation of cyanide by the volume of solution recycled to the ore was approximately three times the volume of fresh water required to obtain the same concentration of cyanide in the effluent solutions. The volume of fresh water required per tonne of ore in a 20-foot laboratory column test to meet cyanide detoxification criteria was approximately 50 pct of the volume required per tonne of ore in a 6-foot laboratory column test conducted at the same flowrate on the same ore.

OP 239-92. **The Gravity-Pressurized Reactor as a Means to Efficiently Carry Out Metallurgically Important Reactions**, by Gerdemann, S.J.; Landsberg, Arne. Paper in Proceedings of the 1st International Conference on Gas-Liquid-Solid Reactor Engineering (Columbus, OH, September 13-16, 1992). Chemical Engineering Science, v. 47, No. 13/14, 1992, pp. 3,753-3,760. Many industrially important reaction rates benefit from increased temperature, but often the accompanying higher pressures complicate reactor operation and increase costs. Using gravity to pressurize a very long, vertical reactor simplifies construction enhances heat transfer as well as reaction kinetics. The U.S. Bureau of Mines is determining the chemical kinetics of metallurgically important reactions to show the possibility of using the gravity-pressurized reactor (GPR) concept to carry out reactions involving gas, liquid, and solid phases.

OP 240-92. **The Removal of Nickel From Mine Waters Using Bacterial Sulfate Reduction**, by Hammack, Richard W.; Edenborn, Harry M. Applied Microbiology and Biotechnology J., v 37, 1992, pp. 277-289. Experiments were done to determine if a compost-based sulfate-reduction system could be used to treat nickel-contaminated mine waters. Sulfate-reduction systems were established in columns containing acid-washed mushroom compost. Simulated mine waters containing 2000 mg sulfate l^{-1} and 50-1000 mg nickel l^{-1} were adjusted to pH 4.5 and pumped through the columns at flow rates between 15 and 25 mlh^{-1}. Initially, almost all of the influent nickel was removed in the columns by sorptive and ion exchange mechanisms. The nickel removal rate then dropped to 18-30 mg nickel day (7.8 to 12.8 nmol g^{-1}

compost day), where it remained relatively constant. The mechanisms responsible for the low and sustained rates of nickel removal on unamended compost are unclear. When sodium lactate was added to the inflow, sulfate reduction rates between 250 and 650 nmol day cm^{-3} compost were obtained and a sevenfold increase in the nickel removal rate was observed. The maximum nickel removal rate observed was 540 mg Ni kg^{-1} compost day (92 nmol Ni g^{-1} compost day) for columns receiving 1000 mg Ni l^{-1}.

OP 241-92. Mine Subsidence Insurance Programs, by Ingram, David K. Coal Magazine (Maclean September 1992), pp. 130-132. An estimated seven million acres of U.S. land has been undermined. Already, approximately 1.9 million of those acres have been effected by surface subsidence. Of the 100,000 underground coal mines that exist, 90,000 are presently abandoned or inactive, leaving nearly 5.2 million acres of undermined area that has not yet subsided. Of that figure, about 500,000 acres are situated under urban, populated areas.

OP 242-92. Rapid Flotation Using a Modified Bubble-Injected Hydrocyclone and a Shallow-Depth Froth Separator for Improved Flotation Kinetics, by Jordan, C.E.; Susko, F.J. Minerals Engineering J., v. 5, No. 10-12, 1992, pp. 1,239-1,257. As a part of the Bureau of Mines' efforts to improve the efficiency of the United States' domestic minerals industry, the Bureau has developed a rapid froth flotation system which divides flotation into two discrete unit operations: bubble-particle attachment and bubble-pulp separation. Modified bubble-injected hydrocyclone developed by the Bureau of Mines was used as the bubble-particle attachment unit which mixed a bubble slurry with an ore slurry under highly turbulent conditions. Then the mixture immediately flows into a relatively quiescent froth separation unit where the bubbles quickly separated from the ore pulp. A shallow-depth froth separator was used to minimize the rising distance required to recover even the smallest size bubbles (100 ^Hm) and to quickly recover the mineral laden bubbles. The tailings pulp only remained in the froth separator long enough to recover the bubbles and then exited through the conical bottom. Combining these two units, a rapid flotation system was formed that successfully floated silica from phosphate in one ninth of the retention time for conventional mechanical cells and floated coal from ash in one eighteenth of the retention time for conventional mechanical cells. The hydrodynamics of the rapid flotation system along with fundamental parameters for scale-up are presented in this paper.

OP 243-92. Bacterial Oxidation of Acid-Forming Materials, by Kleinmann, Robert L.P. Paper in Proceedings of the Acid Forming Materials Symposium, (Reclamation Research Unit, Montana State University, Bozemant, MT). Billings Symposium, 1987, pp. 34-46. Although several genera of bacteria live in acidic mine water, Thiobacillus ferrooxidans appears to play the most critical role in the oxidation of pyrite. Inhibition of T. ferrooxidans improves water quality 60-95 pct by reducing the overall rate of pyrite oxidation. Anionic surfactants are effective inhibitors and inexpensive of T. ferrooxidans in coal refuse, and have potential for application in other mine environments where acid generation is localized and accessible.

OP 244-92. Teleoperation for Continuous Miners and Haulage Equipment, by Kwitowski, A.J.; Mayercheck, W.D.; Brautigam, A.L. Paper in Proceedings of the IEEE Transactions on Industry Applications. The Institute of Electrical and Electronics Engineers, Inc., v. 28, No. 5, 1992, pp. 1,118-1,125. Hard-wired or radio remote control of continuous mining machines has been available since the early 1970's. This type of remote control situates the machine operator off board but within direct view of the underground coal face. The operator is positioned under permanent roof support but is still exposed to the hazards of roof and rib falls, dust, and methane explosions. Since 1979, the U.S. Bureau of Mines has researched alternative methods to remove the machine operator from these hazards. Working with a private cooperator since 1985, the Bureau has developed an off-board, computer-based remote control system that stations the operator hundreds of feet away from the working face in a highwall mining operations. Details of this new remote control or "teleoperated" highwall mining system (continuous miner plus continuous haulage) at a West Virginia field trial site are described, along with plans to incorporate this technology for thin-seam extraction and haulage equipment in deep, room-and-pillar coal mines.

OP 245-92. In-Depth Characterization of Lead: An Environmental Contaminant, by Vierrether, C.W.; Hicks, G.W.; Cornell, W.L. Paper in Proceedings of the Second International Conference on Environmental Issues and Management of Waste in Energy and Mineral Production (Calgary, Alberta, Canada, September 1-4, 1992) ed. by R.K. Singhal, A.K. Mehrotra, K. Fytas, and J.L. Collins. Balkema, v. 1, 1992, pp. 555-565. Lead contamination is critical environmental concern. Present remediation technology includes land filling, soil washing, vitrification, stabilization, storage and/or capping, and rare instances of recycling to a secondary lead smelter (Jacobson 1991). In many instances the specific lead-bearing species are never identified. Due to the large number of sites to be evaluated and/or cleaned up, accurate, inexpensive, and relatively quick identification of lead species is needed. Complete characterization is essential in gaining valuable information which can guide development of the remediation techniques. Several lead-contaminated samples have been characterized with all lead phases identified and quantified. These samples consist of battery breaker soil, lead mill gravity tailings, lead mill flotation tailings, and naturally-occurring lead mineral phases for use as standards. Classical methods including light microscopy, electron microscopy, and x-ray diffraction are used in conjunction with chemical analysis for these identifications. These study methods are enhanced by innovative staining which helps to differentiate the minerals cerrusite ($PbCO_3$) and anglesite ($PbSO_4$). Additional phases identified are lead oxides, PbS, metallic Pb, and several lead-iron intermediate phases.

OP 246-92. Application of Aquifer Testing in Surface and Underground Coal Mines, by Aljoe, William W.; Hawkins, Jay W. Paper in Proceedings of the Focus on Eastern Regional Ground Water Issues (Newton, MA, Oct. 13-15, 1992), No. 13. National Ground Water Association, 1992, pp. 541-555. The generation and transport of contaminated (acid) drainage from Appalachian coal mines depends heavily on the mechanisms by which water moves through surface mine

spoils, underground mine openings, and the overlying fractured strata. To gain a better understanding of these flow mechanisms, slug tests, constant-discharge (pumping) tests, and chemical tracer tests have been employed at surface and underground mine sites.

OP 247-92. **Diamond (Industrial)**, by Austin, Gordon T. Am. Ceram. Soc. Bull., v. 71, No. 5, May 1992, p. 794. Diamond is the hardest substance known to humankind. Because of its hardness, it is often more effective and efficient than other abrasives in many industrial applications. Industrial diamond can be natural diamond that does not meet the standards of gem diamond because of its color, size, or some other imperfection; gem diamond used in an industrial application; or synthetic diamond that is tailor-made for industrial applications. Both natural and synthetic industrial diamonds can be used in grinding, drilling, cutting, wire drawing, abrasive lapping and polishing, or in the manufacture of polycrystalline diamond.

OP 248-92. **Fabulous Feldspar**, by Austin, Gordon T. Colored Stone Magazine, v. 5, No. 6, Nov.-Dec. 1992, pp. 32-33. Of all of the minerals in the Earth's crust, aluminosilicate feldspar is the most common. Feldspar is a handy industrial mineral used in making glass, plumbing fixtures, tile, and pottery. But it's also a gemstone—almost $1.5 million of which was mined last year in the United States.

OP 249-92. **Garnet**, by Austin, Gordon T. Am. Ceram. Soc. Bull., v. 71, No. 5, May 1992, pp. 798-799. Commercial production of industrial garnet in the United States is more than a century old. Almandite, the abundant iron-aluminum silicate variety of garnet, is the primary garnet used in industrial applications. The development of technology and applications for garnet abrasives is far greater in the United States than in other countries. One reason is the large, high-quality abrasive garnet deposit in Warren County, NY. This deposit was the first in the United States to be commercially developed, and is still producing today. (Production is from the same deposit, but not the same mine site.) Garnet is produced from another deposit in New York as a byproduct of wollastonite production. Additionally, Maine, Montana, North Carolina, and Idaho also have significant garnet deposits. Currently, garnet production is limited to deposits in New York and Idaho.

OP 250-92. **Gems**, by Austin, Gordon T. Min. Eng., v. 44, No. 6, June 1992, p. 560. In 1991, the value of natural gemstones, fresh water pearls, salt water pearls, coral, and synthetic and simulant gemstones from deposits in the United States was $128.2 million, according to the U.S. Bureau of Mines. The value of natural gem material produced was $109 million, an increase of 106 pct compared to 1990. The value of synthetic and simulant production was $19.2 million, essentially unchanged from 1990. U.S. production accounted for about 2 pct of the $2.9 billion of estimated U.S. consumption of gems and gemstones.

OP 251-92. **Gems From Alaska to Wyoming**, by Austin, Gordon T. Colored Stone Magazine, v. 5, No. 4, July-Aug. 1992, pp. 33-35. While Alaska is known for its snow, ice, cold, and polar bears, few realize that this State contains a number of notable gemstone deposits. The first nephrite jade discovered in place in North America was found in 1886 at Jade Mountain in Alaska. The Jade Mountain, Dalh Creek, and Promise Creek deposits are major ones in a jade-producing area along the Kubuk River inside the Arctic Circle.

OP 252-92. **California Gems Outshine Hollywood Stars**, by Austin, Gordon T. Colored Stone Magazine, v. 5, No. 1, Jan.-Feb. 1992, pp. 298-300. California is, or at least should be, as well known for its selection of fine gem materials as for its warm climate, athletic teams, and famous sights and attractions. The value of 1990 California natural gem material production was about $2.4 million, according to the most recent statistics released by the U.S. Bureau of Mines. Only Arizona produces a greater variety of gem materials than California.

OP 253-92. **U.S. Gem Production Rises**, by Austin, Gordon T. Colored Stone Magazine, v. 5, No. 5, Sept.-Oct. 1992, p. 77. Production of natural gemstones in the United States increased 60 pct to $84.4 million in 1991, according to estimates from the U.S. Bureau of Mines. The value of U.S. synthetic and simulated gem material production dropped, however, to $17.7 million, about 14 pct less than in 1990. In 1991, each of the 50 States produced at least $1,000 worth of gem materials, although 10 States accounted for about 93 pct of the total value.

OP 254-92. **There's More Than Gold in Them Thar Hills: South Dakota's Thriving Gemstone Production**, by Austin, Gordon T. Colored Stone Magazine, v. 5, No. 2, Mar.-Apr. 1992, p. 10. If asked to mention the things South Dakota is best known for, most people would cite Mount Rushmore, the scenic Black Hills, the city of Deadwood, and the town where Wild Bill Hickok was shot. South Dakota is also well known for its "Black Hills Gold" jewelry and its gold production. Although, little recognition is given to its production of gemstones, every year significant amounts of gemstones are produced from various deposits throughout the State. During the 5 years prior to 1991, the value of gemstone production averaged $112,000 per year, but in 1991 a single new producer, International Rose Quartz and Minerals Inc., entered the scene, producing gem materials worth millions of dollars. This firm's production catapulted the State from 25th into 2d place in the United States in terms of value of gemstones produced.

OP 255-92. **Quartz to Diamonds**, by Austin, Gordon T. Colored Stone Magazine, v. 5, No. 3, May-June 1992, pp. 26-27. Since the U.S. Bureau of Mines expanded its survey of gemstone producers in 1986, Arkansas has ranked as high as second in the value of gemstones produced, a ranking that it enjoyed in 1989 and 1990, and as low as fifth in 1991. The remaining 3 years, 1986, 1987, and 1988 the State ranked fourth. Over the years, Arkansas and quartz have been synonymous. Not only is Arkansas the major producer of gemstone and decorative quartz, but it is the only producer of"lacas," the feed material used to make synthetic quartz.

OP 256-92. **Application of Real-Time Monitoring to an Underground Mining Environment**, by Beus, M.J.; Orr, T.J. Paper in Proceedings of the 5th Canadian Symposium on Mining Automation (Sept. 27-29, 1992, Vancouver, BC). National Advisory Committee on Mining Automation, 1992, pp. 68-77. U.S. Bureau of Mines researchers are using computerized data acquisition systems and real-time monitoring to visualize underground metal mining operations,

including deep shafts, cut-and-fill mining in creeping ground, and drift-and-fill mining. Sensors monitor rock mass deformation and strain, support loads, temperature, SO_2 emissions, and blasting. Results from testing at several mines in South Dakota, Idaho, and Alaska show the system improves confidence in ground control measurements and could improve mine productivity and decrease mining costs.

OP 257-92. Leaching of Pyrite From Coal in a Trickle-Bed Reactor, by Dalverny, L.E.; Chaiken, R.F. Paper in Proceedings of the Ninth International Pittsburgh Coal Conference (Pittsburgh, PA, Oct. 12-16, 1992). Univ. of Pittsburgh, 1992, pp. 247-252. The U.S. Bureau of Mines used a large countercurrent trickle-bed column reactor to obtain data on the chemical and transport processes controlling the leaching of pyrite from coal and coal waste. There was apparent correlation between sulfate production and hydrocarbon desorption, in contrast to what had been previously observed in leaching experiments using coal preparation plant waste. Experimental data were used in the formulation of a theoretical absorption-desorption model of solids leaching that describes the rate-constraining intraparticle diffusion transport properties of this system.

OP 258-92. Leaching of Pyrite From Coal Wastes in a Trickle-Bed Reactor, by Dalverny, L.E.; Chaiken, R.F. Paper in Environmental Issues and Waste Management in Energy and Mineral Production: Proceedings of the Second International Conference on Environmental Issues and Management of Waste in Energy and Mineral Production (Calgary, Alberta, Canada, Sept. 2-4, 1992), ed. by R.K. Singhal, A.K. Mehrotra, K. Fytas, and J.L. Collins. Balkema, 1992, pp. 435-445. U.S. Bureau of Mines researchers used a large countercurrent trickle-bed column reactor to obtain data on the chemical and transport processes controlling the leaching of pyrite from coal wastes. Analyses indicated a correlation between hydrocarbon gas desorption and oxygen consumption.

OP 259-92. Diatomite, by Davis, Lawrence L. Am. Ceram. Soc. Bull., v. 71, No. 5, May 1992, p. 795. Diatomite, or diatomaceous earth, is a siliceous, sedimentary rock consisting principally of the fossilized skeletal remains of diatoms, unicellular aquatic plants related to algae. The United States is the world's largest producer and consumer of diatomite. Estimated production in 1991 was 621,000 metric tons valued at $136 million, from 6 companies with 10 processing facilities in 4 States—California, Nevada, Washington, and Oregon.

OP 260-92. Gypsum, by Davis, Lawrence L. Am. Ceram. Soc. Bull., v. 71, No. 5, May 1992, pp. 801-802. Gypsum is the most common of the naturally occurring sulfate minerals. It is found in very extensive, bedded sedimentary deposits all over the world and is associated with limestones, shales and sandstones, marls and clays. High-purity deposits of gypsum are relatively common, and, for most uses, little or no beneficiation is required. In the United States most gypsum rock is finely ground and partially calcined to drive off 75 pct of the chemically combined water, converting gypsum, $CaSO_4{-}2H_2O$, to the hemihydrate product, $CaSO_4{-}1/2H_2O$. Commonly called plaster of Paris, this material quickly sets and hardens back to gypsum when mixed with the appropriate amount of water.

OP 261-92. Mica, by Davis, Lawrence L. Am. Ceram. Soc. Bull., v. 71, No. 5, May 1992, pp. 810-811. The United States has no reserves of sheet mica. India is by far the largest producer and provides most of the U.S. and world supply. Scrap and flake mica is mica that is unsuitable for use as sheet mica. It is ground to various sizes and used as a filler and/or extender in wallboard joint compounds, paints, and plastics; as an ingredient in well-drilling muds; as a lubricant; and for various other uses. In 1991, estimated 94,000 metric tons of scrap and flake mica valued at about $5.1 million was produced in the United States. The mica was processed to produce an estimated 84,000 metric tons of ground mica valued at $19 million.

OP 262-92. Gypsum, by Davis, Lawrence L. Min. Eng., v. 44, No. 6, June 1992, pp. 561-562. In 1991, the United States consumed about 21 Mt (23 million st) of gypsum. Of that, about 70 pct was produced domestically and 30 pct was imported. About 15 Mt (17 million st) was calcined and consumed as plaster or wallboard, and 5 Mt (6 million st) was used in uncalcined form as a cement-setting retarder or as a soil conditioner. At least 80 countries are known to produce gypsum. Estimated world production in 1991 was about 98 Mt (108 million st), about the same as in 1990. The United States is the largest producer and consumer of gypsum. Canada is the second largest producer and exports a significant part of its production to the United States.

OP 263-92. Mathematical Modeling of Spontaneous Heating of Coal, by Edwards, John C. Paper in Proceedings of the Ninth International Pittsburgh Coal Conference (Pittsburgh, PA, Oct 12-16, 1992). Univ. of Pittsburgh, 1992, pp. 1101-1106. Several mathematical models of spontaneous heating were developed in support of the U.S. Bureau of Mines' research program directed toward the prevention of spontaneous heating in coal piles and/or gobs. Reaction kinetics associated with the oxidation of coal were used in a transient thermal transport model of spontaneous heating to estimate the thermodynamic stability of a coal pile of uniform porosity and particle diameter under the following assumptions: (1) A spherical zone within the coal pile is initially at a specified elevated temperature, and (2) an ambient oxygen supply is maintained in the pile.

OP 264-92. Maximum Acceptable Weights of Lift for Common Coal Mine Supply Items, by Gallagher, Sean; Hamrick, Christopher A. Paper in Proceedings of the 36th Annual Meeting. 1992 Innovations for Interactions (Atlanta, GA, Oct. 12-16, 1992). Human Factors Society, v. 1, 1992, pp. 654-658. A series of psychophysical lifting studies was conducted to establish maximum acceptable weights of lift (MAWL) for three supply items commonly handled in underground coal mines (rock dust bags, ventilation stopping blocks, and crib blocks). Each study utilized 12 subjects, all of whom had considerable experience working in underground coal mines. Effects of lifting in four postures (standing, stooping under a 1.5-m ceiling, stooping under a 1.2-m ceiling, and kneeling) were investigated together with four lifting conditions (combination of lifting symmetry and lifting height).

OP 265-92. The Effects of Lifting Posture on Trunk Muscle Activity, by Hamrick, Christopher A.;

Gallagher, Sean. Paper in Proceedings of the 36th Annual Meeting. 1992 Innovations for Interactions (Atlanta, GA, Oct. 12-16, 1992). Human Factors Society, v. 1, 1992, pp. 742-746. Trunk muscle activity of 12 healthy males with coal mining experience was examined while each subject lifted a box under various conditions. The independent variables were four levels of posture (kneeling, stooped under a 1.2-m roof, stooped under a 1.6-m roof, and standing), height to which the box was lifted, and weight of the lifting box. Consequently, many lifting guidelines and recommendations currently in use may not be directly applicable to work being performed in restricted postures.

OP 266-92. **Pseudokarst Groundwater Hydrologic Characteristics of a Mine Spoil Aquifer**, by Hawkins, Jay W.; Aljoe, William W. Mine Water and the Environment, June 1992, v. 11, No. 2, pp. 37-52. Aquifer tests of surface coal mine spoil indicate two distinctly different groundwater hydrologic characteristics exist. Slug tests empirically indicate the presence of discrete conduits within the spoil. Groundwater flow within conduits is pseudokarst, and flow between conduits is porous media. Under transient or stress conditions, pseudokarst groundwater flow in the spoil becomes prominent; under steady-state conditions, porous media flow dominates. Tracer testing indicates the average linear velocity of groundwater through spoil is close to pure porous media and significantly lower than true karst flow.

OP 267-92. **Geological Sensing—The Key To Increasing Miner Safety**, by Hill, J.R.M.; Briggs, R.C. Paper in Proceedings of the 11th International Conference on Ground Control in Mining, ed. by N.I. Aziz and S.S. Peng (Wollongong, NSW, Australia, July 7-10, 1992). Univ. of Wollongong, July 1992, pp. 376-383. This paper presents results from field trials of two research projects concerned with new technologies for geo-sensing. The goal of the first project was to develop a "smart" roof bolter drill so that it could probe into roof rock to evaluate rock conditions. The goal of the second project was to modify an existing minewide monitoring system in a continuous mining operation so that the system could interface with geotechnical instruments to provide near real-time geo-sensing.

OP 268-92. **Evaluation of New Techniques for Thin-Seam Mining**, by Jaspal, Jasinder S.; DuCarme, Joe P. Min. Eng., v. 44, No. 10, Oct. 1992, pp. 1237-1241. The United States has very large coal reserves in seams that are less than 1,065 mm (42 in) thick. These reserves are often not mined because of the difficulty of working in low heights; also, in most cases, the seams are beyond the technical or economical limits. The U.S. Bureau of Mines is attempting to develop new techniques for mining 150- to 1,065-mm (6- to 42-in) thick coal seams. Research has focused on existing thin-seam mining techniques, testing of small- and full-scale physical models of the Bureau's slot mining concept, and computer modeling of the full-scale process.

OP 269-92. **Wastewater Remediation Using Bio-Fix Bead Technology**, by Jeffers, T.H.; Bennett, P.G.; Corwin, R.R. Paper in Environmental Issues and Waste Management in Energy and Mineral Production: Proceedings of the Second International Conference on Environmental Issues and Management of Waste in Energy and Mineral Production (Calgary, Alberta, Canada, Sept. 1-4, 1992), ed. by R.K. Singhal, A.K. Mehrotra, K. Fytas, and J.L. Collins. Balkema, 1992, pp. 1379-1387. The U.S. Bureau of Mines has developed porous polymeric beads containing immobilized biological materials such as sphagnum peat moss for extracting metal contaminants from wastewaters. The beads, designated as BIO-FIX beads, have distinct advantages over traditional methods. In laboratory and field tests, the beads have removed toxic metals such as cadmium, lead, and copper from nearly 100 wastewaters. These include acid mine drainage waters from active and abandoned mining operations, metallurgical and chemical industry wastewaters, and contaminated groundwaters.

OP 270-92. **Acid Mine Water Treatment Using Engineered Wetlands**, by Kleinmann, Robert L.P. Int. J. Mine Water, v. 9, No. 1-4, 1990, pp. 269-276. The application of biotechnology to mine water can reduce the industry's water treatment costs and improve water quality in streams and rivers. Biological treatment of mine waste water is typically conducted in a series of small excavated ponds that resemble, in a superficial way, a small marsh area. The ponds are engineered to first facilitate bacterial oxidation of iron; ideally, the water then flows through a composted organic substrate that supports a population of sulfate-reducing bacteria. The latter process raises the pH. During the past 4 years, over 400 wetland water treatment systems have been built on mined lands as a result of research by the U.S. Bureau of Mines.

OP 271-92. **At Source Control of Acid Mine Drainage**, by Kleinmann, Robert L.P. Int. J. Mine Water, v. 9, No. 1-4, 1990, pp. 85-96. This paper emphasizes technology developed during the last decade that includes the addition of high volumes of alkalinity and/or phosphate, the use of surface geophysics to identify problem source areas, the sealing of fractured streambeds using polyurethane grout, and the use of anionic surfactants to inhibit the activity of iron-oxidizing bacteria.

OP 272-92. **Teleoperated Cutting and Haulage for Thin Coal Seams**, by Kwitowski, August J.; Monaghan, William D.; Brautigam, Albert L. Min. Eng., v. 44, No. 10, Oct. 1992, pp. 1231-1236. Work conducted by the U.S. Bureau of Mines has demonstrated that teleoperation is a viable method to remotely operate mining systems safely and effectively. Teleoperation has been successfully tried in a new highwall mining system and appears promising for a deep mining application under development.

OP 273-92. **Fractal Analysis of Carbide Morphology in High-Cr White Cast Irons**, by Laird II, George; Rawers, James C.; Adams, Arnold. Metall. Trans. A, v. 23A, Oct. 1992, pp. 2941-2945. Characterization of morphological features via analysis is rapidly becoming commonplace in material science. Application of this new technique has resulted in the quantitative analyses of the complex morphologies of metal carbides within high-Cr white cast irons.

OP 274-92. **Hydrochemical Impacts of Mine Waste Backfill in Underground Sulfide Mines**, by Levens, R.L.; Boldt, C.K.M. Paper in Environmental Issues and Waste Management in Energy and Mineral Production: Proceedings of the Second International Conference on Environmental Issues and Management of Waste in Energy and Mineral Production (Calgary, Alberta, Canada, Sept. 1-4, 1992), ed. by R.K. Singhal, A.K. Mehrotra, K. Fytas, and J.L. Collins.

Balkema, v. 2, 1992, pp. 891-902. The Underground Injection Control program (UIC) was promulgated in 1981 by the U.S. Environmental Protection Agency under the provisions of the Safe Drinking Water Act. The U.S. Bureau of Mines is investigating the environmental effects of backfill in anticipation of UIC regulations. Impacts on water quality that can be attributed to placement of different backfills are being investigated in three underground sulfide metal mines. Water samples are being gathered from seeps both before and after water contacts the backfill. Concentrations of major ions and trace metals are compared among sites to identify differences that can be attributed to the backfill material.

OP 275-92. Fire Detection for Conveyor Belt Entries, by Litton, Charles D.; Lazzara, Charles P.; Perzak, Frank J. Paper in Proceedings of the Fifth International Mine Ventilation Congress (Johannesburg, South Africa, Oct.-25-30, 1992). Mine Ventilation Society of South Africa, 1992, pp. 161-169. This paper details the results of a series of large-scale experiments, conducted by the U.S. Bureau of Mines, where small coal fires were used to ignite conveyor belting at air velocities ranging from 0.76 m/s to 6.1 m/s. Two nomographs are presented, which define sensor alarm levels and sensor spacings as a function of belt entry cross-sectional area and belt entry air velocity.

OP 276-92. Developing an In Situ Mining Method for Copper Oxide Minerals, by Millenacker, Daniel J. Paper in Environmental Issues and Waste Management in Energy and Mineral Production: Proceedings of the Second International Conference on Environmental Issues and Management of Waste in Energy and Mineral Production (Calgary, Alberta, Canada, Sept. 1-4, 1992), ed. by R.K. Singhal, A.K. Mehrotra, K. Fytas, and J.L. Collins. Balkema, v. 2, 1992, pp. 903-910. The U.S Bureau of Mines is conducting research to develop methods for mineral extraction that will allow domestic mining companies to remain competitive in world mineral markets into the 21st century. One of the technologies currently being evaluated is in situ, or in-place, extraction of copper from an oxide ore deposit. This paper summarizes the current status of the Santa Cruz In Situ Copper Mining Research Project.

OP 277-92. Influence of an Organic-Poor Landslide Deposit on the Early Diagenesis of Iron and Manganese in a Coastal Marine Sediment, by Mucci, Alfonso; Edenborn, Harry M. Geochimica et Cosmochimica Acta., v. 56, 1992, pp. 3909-3921. Sediments and pore waters were subsampled from two box cores collected at (approx.)135 m depth on the landward slope of the largest basin of the Saguenay Fjord (Quebec, Canada). The Saguenay Fjord sediments are composed mostly of eroded glaciomarine clays surrounding the fjord area. The sediments contain relatively large concentrations of organic carbon and are sulfide a few millimeters below the sediment-water interface. Non-steady-state sulfate reduction rates were established due to the nonuniform distribution of organic carbon with depth. Iron sulfide peaks reflect this distribution and the position of the relict redox boundary. A schematic representation of the sequence of diagenetic events that led to the postdepositional remobilization of Fe and Mn and the migration of the oxidation front following the deposition of the landslide material is proposed.

OP 278-92. An Automatic Guidance System for a Narrow Stope Mucking Machine, by Ruff, Todd M. Paper in Proceedings of the 5th Canadian Symposium on Mining Automation (Vancouver, BC, Sept. 27-29, 1992). National Advisory Committee on Mining Automation, 1992, pp. 234-244. A prototype mucking machine designed to operate in narrow vein stopes was developed. The machine, called a compact loader-trammer, or minimucker, was designed to replace slusher muckers in narrow-vein underground mines. The design and functions of the minimucker and its computer-based, remote-control system are reviewed, and a guidance system that uses ultrasonic ranging sensors is described.

OP 279-92. Crosswell and Geotomographic Methods in Mining, by Schneider, George; Williams, Earle; Westman, Erik. MinTech 92 (London), Aug. 1992, pp. 39-43. The concept of crosswell or cross borehole logging was introduced as early as 1929 when crosswell seismics were proposed in oilfield exploration. In the early 1980's, the introduction of new technologies made the use of crosswell logging feasible for application to petroleum, minerals (including coal mining), and geotechnical problems. At least two groups, BHP Engineering and Bolt Geophysical, have now announced the commercial availability of crosswell seismic tomography services for the minerals industry.

OP 280-92. Alternative Processing of Copper Smelter Flue Dust for Bismuth Control, by Steele, Donald K.; Gritton, Kenneth S. Paper in Preprints—First Separations Division Topical Conference on Separations Technologies, New Developments and Opportunities (Miami Beach, Fl, Nov. 2-6, 1992). Am. Inst. Chem. Eng., 1992, pp. 956-961. This investigation is on the leaching of copper-smelter flue dust to recover copper and separate deleterious components for recovery or safe disposal. Leaching of copper-smelter flue dust with dilute sulfuric acid solution, containing small amounts of chloride and fluorine, has extracted more than 90 pct of the copper, arsenic, and cadmium, and 80 pct of the bismuth. Selective stripping of arsenic and bismuth was accomplished with water, and molybdenum was stripped with ammonia. The copper-rich solutions produced should be suitable for recycle to the copper smelter.

OP 281-92. Judgement and Decision Making in a Mine Fire: A Case Study, by Vaught, Charles; Mallett, Launa G.; Brnich, Jr, Michael J. Paper in Proceedings of the Ninth U.S.-Korea Joint Workshop on Coal Utilization Technology (San Francisco, CA, Oct. 18-20, 1992). Korea Institute of Energy Research, 1992, pp. 124-141. This case study of workers' escape from a mine fire is used to illustrate a heuristic model of judgment and decision making. It is argued that two components of the model greatly influenced miners' attempts to make accurate assessments of their predicament.

OP 282-92. Applicability of Reference Electrode Types in Transient Electrochemical Experiments, by Watson, S.W.; Madsen, B.W. Corrosion, v. 48, No. 9, Sept. 1992, pp. 727-733. The high impedance associated with many reference electrodes can complicate transient electrochemical experiments. Transient studies were carried out to determine how the types of reference electrode affected the IR drop compensation when a current-interrupt technique was used. For these transient experiments, the dual electrode was determined

to be the best overall reference electrode for studying solutions over a wide conductivity range.

OP 283-92. Repassivation of 304 Stainless Steel Investigated With a Single Scratch Test, by Adler, Thomas A.; Walter, Richard P. Paper in Proceedings of the National Association of Corrosion Engineers (NACE) Corrosion '92 Conference (Nashville, TN, April 27-May 1, 1992). NACE, 1992, pp. 218/1-218/16. Reformation of the passive film on 304 stainless steel was investigated with a scratch test developed by the U.S. Bureau of Mines. Regrowth of the passive film was measured by recording the current that resulted from forming the scratch. Charge consumed during the reformation of the film was compared to wear produced by the scratch. Measured current transients were deconvoluted using the width of the scratch as a function of time, resulting in the current from an incremental area of the scratch. The maximum current density and the charge density were linearly dependent on the area fraction of bare surface. The other parameters used in the model of the current transients did not change as the area fraction of bare surface changed. The results showed that the passive film remained adherent to the surface of the stainless steel during the rubbing mode of wear.

OP 284-92. Corrosion and Wear of 304 Stainless Steel Using a Scratch Test, by Adler, Thomas A.; Walters, Richard P. Corrosion Science. Pergamon Press Ltd., v. 33, No. 12, 1992, pp. 1855-1876. A scratch test developed by the U.S. Bureau of Mines was used to wear the surface of 304 stainless steel. Corrosion of the freshly exposed surface was measured by the charge density consumed in reforming the passive film. Wear was measured by integrating the area between the profile of the scratch and the original surface. Neither scratch hardness nor wear were affected by the presence or absence of the passive film. For rubbing wear, a mode where the surface is plastically deformed and no debris is formed, the passive film remained adherent to the surface.

OP 285-92. Cyanide Leaching Method for Recovering Platinum Group Metals From a Catalytic Converter Catalyst, by Atkinson, Gary B.; Kuczynski, Robert J.; Desmond, Dennis P. U.S. Patent No. 5,160,711, Nov. 3, 1992. A method for recovering platinum group metals from a catalyst material comprises leaching the material with a cyanide solution at a temperature greater than about 100° C to form soluble platinum group metal-cyanide complexes in solution. Solids are removed from the resulting pregnant leach solution, and the pregnant leach solution is then heated to a temperature sufficient to decompose the platinum group metal-cyanide complexes and precipitate the platinum group metals.

OP 286-92. Reducing Dust Exposure, by Cecala, Andrew B.; Thimons, Edward D. Pit & Quarry Magazine, v. 85, No. 5, 1992, pp. 38-40. The Bureau of Mines has conducted research aimed at lowering the respirable dust exposures of mineral processing plant personnel. While performing this research, it has become obvious that to maintain a healthy working environment and to keep personnel in compliance with respirable dust regulations, plant managers need to consider all plant practices that can contribute to employees' personal dust exposures. Being aware of and controlling less obvious dust sources can have a major impact on reducing dust levels.

OP 287-92. Burnout Control at the Albright Coal Waste Bank Fire, by Chaiken, R.F.; Bayles, L.G. Paper in Environmental Issues and Waste Management in Energy and Mineral Production: Proceedings of the Second International Conference on Environmental Issues and Management of Waste in Energy and Mineral Production (Calgary, Alberta, Canada, Sept. 1-4, 1992), ed. by R.K. Singhal, A.K. Mehrotra, K. Fytas, and J.L. Collins. Balkema, 1992, pp. 331-347. Burnout Control is a process developed by the U.S. Bureau of Mines for accelerating the burning of wasted coal fires in situ, while at the same time controlling the heat and fumes produced. Through Burnout Control it would be feasible to have a coal fire burn to completion in an environmentally acceptable manner, and to convert the sensible heat produced (as hot gas) to useful energy such as steam and electricity. The Albright fire project was the first field trial of Burnout Control as applied to a coal waste bank. It is believed that with: (a) improvements in engineering design and construction; (b) better control of the afterburning process; and (c) the use of conventional stack gas air pollution controls; Burnout Control can be applied successfully to a coal waste bank fire.

OP 288-92. Shield Pressure Monitoring to Detect Longwall Ground Control Hazards, by Conover, David P.; Hanna, Kanaan. Paper in Proceedings of the Fourth Conference on Ground Control for Midwestern U.S. Coal Mines, ed Y.P. Chugh and G. Beasley (Mt. Vernon, IL, Nov. 2-4, 1992). Southern Illinois Univ. 1992, pp. 217-226. Continuously monitored shield-leg pressure changes have proven to be an indicator of certain longwall ground control hazards, including high-stress zones along the face and roof falls and floor heave in adjacent gateroads. Monitoring and analysis of shield load and gateroad stability data have been accomplished using the Ground Control Management System (GCMS) developed by the U.S. Bureau of Mines. The automated capabilities of the GCMS have enabled researchers and mining personnel to remotely monitor geostructural data and evaluate ground stability during the high-speed extraction of four longwall panels in a Colorado coal mine. This paper emphasizes the application of shield load monitoring for detecting and managing developing ground control hazards along the face and in the gateroads.

OP 289-92. Shield Pressure Monitoring to Detect Longwall Ground Hazards, by Conover, David P.; Hanna, Kanaan. Paper in Proceedings of the Midwest Mine Health and Safety Conference (Marion, IL, July 22-23, 1992), ed. E.M. Thomasson and J.O. Evers. Southern Illinois Univ., 1992, pp. 147-156. Continuously monitored shield-leg pressure changes have proven to be an indicator of certain longwall ground control hazards, including high-stress zones along the face and roof falls and floor heave in adjacent gateroads. Monitoring and analysis of shield load and gateroad stability data have been accomplished using the Ground Control Management System (GCMS) developed by the U.S. Bureau of Mines. The automated capabilities of the GCMS have enabled researchers and mining personnel to remotely monitor geostructural data and evaluate ground stability during the high-speed extraction of four longwall panels in a Colorado coal mine. This paper emphasizes the application of shield load monitoring for detecting and managing developing ground control hazards along the face and in the gateroads.

ARTICLES IN OUTSIDE PUBLICATIONS

OP 290-92. A Systems Approach to the Design of Advanced Electric Furnaces, by Ochs, Thomas L.; Hartman, Alan D.; King, Paul E. Paper in Proceedings of the Sixth International Iron and Steel Congress (Tokyo, Japan). Iron and Steel Inst. of Japan, v. 4, 1990, pp. 158-162. Electric arc furnace operation involves interactions of the furnace equipment and the furnace interior. These interactions produce feed-back that results in a nonlinear system response. To insure that improvements in furnace operation result from component modifications, component development must use a systems analysis approach that takes into account component interactions. Presently, there are no reliable methods for quantifying advantages or disadvantages of the application of a new technology to electric arc furnaces. The incursion of valuable new technology into the industry can be delayed by years if the results of the first melt-shop to use the technique are not conclusive. The combination of multivatiate design and testing can help to identify statistically significant changes in the furnace performance early in the testing cycle. These unambiguous results would help to quantify the gains expected from the use of new equipment and would speed industrial acceptance.

OP 291-92. Laboratory Evaluation of an Oxidation Catalytic Converter at Various Simulated Altitudes, by Culshaw, John R.; McClure, B. Thompson. Paper in Proceedings of the SAE Technical Paper Series: Diesel Combustion, Emission and Exhaust, After treatment (SP-931),(Milwaukee, WI, Sept. 14-17, 1992). SAE, No. 921675, pp. 183-190. The U.S. Bureau of Mines is conducting laboratory evaluations of the effectiveness of oxidation catalytic converters (OCC's) for application on diesel engines used in underground mines. It is important to evaluate exhaust control devices for application on mining vehicles at various altitudes because mines are located at a wide range of elevations. The objective of this work is to determine the characteristics and performance of an OCC at various altitudes as well as investigate an altitude simulation technique used in a laboratory setting.

OP 292-92. Leaching of Pyrite From Coal Wastes in a Trickle-Bed Reactor, by Dalverny, L.E.; Chaiken, R.F. Paper in Environmental Issues and Waste Management in Energy and Mineral Production: Proceedings of the Second International Conference on Environmental Issues and Management of Waste in Energy and Mineral Production (Calgary, Alberta, Canada, Sept. 1-4, 1992), ed. by R.K. Singhal, A.K. Mehrotra, K. Fytas, and J.L. Collins. Balkema, 1992, pp. 435-445. Bureau of Mines researchers used a large countercurrent trickle-bed column reactor to obtain data on the chemical and transport processes controlling the leaching of pyrite from coal wastes.

OP 293-92. Update on Longwall Dust Control Research, by Jayaraman, N.I.; Jankowski, R.A.; Organiscak, J. Paper in Proceedings of the Midwest Mine Health and Safety Conference (Marion, IL, July 22-23, 1992) ed. by E.M. Thomasson and J.O. Evers. Southern Illinois Univ., v. 1, pp. 47-60. The Bureau of Mines has introduced several techniques for enhanced dust control at longwall faces. The purpose is to minimize dust concentrations in the face area by suppressing the dust produced by the stage loader and shearer. Stage loader dust control is achieved by the installation of dust collectors and water sprays at the crusher. Bureau research has shown significant dust reductions through the use of new types of compact, high effective dust scrubbers. Shearer generated dust is the largest single dust source at the longwall face. Through the use of inward facing high pressure drum sprays and remote control the shearer operators are kept away from the dust cloud and in the intake air. In addition to the above, this paper discusses the use of foam and reverse drum rotation in dealing with longwall dust.

OP 294-92. History of Boron Production and Processing, by Lyday, Phyllis A. Industrial Minerals (London) J., No. 303, Dec. 1992, pp. 19, 21, 22, 24-25, 27, 30, 31, 33, 34 and 37. Boron minerals have been mined since the seventh century for use in glass and metallurgy. In addition, boron compounds and boric acid have been produced from brines associated with volcanic activity and salars. Different mineral compounds and different end uses require variations in the mineral processing. In addition, there are variable end uses of the compound or mineral. For example, glass processing can use borax, ulexite, colemanite, or boric acid. The paper discusses various locations of minerals and the processes by which the mineral was or could be processed. Locations include China, India, South America (Argentina, Bolivia, Chile, and Peru), the United States, and the U.S.S.R.; different minerals, such as, colemanite, szaibelyite, ulexite, tincal, probertite, and their usage would be discussed. The processes include evaporation, precipitation, carbonation, solvent extraction, flotation, solution mining, and air classification.

OP 295-92. Development of an Integrated Monitoring System for Evaluating Roof Stability, by Maleki, H.; Ibrahim, W.; Jung, Y. Paper in Proceedings of the Fourth Conference on Ground Control for Midwestern U.S. Coal Mines, ed Y.P. Chugh and G. Beasley (Mt. Vernon, IL, Nov. 2-4, 1992). Southern Illinois Univ. 1992, pp. 255-271. Cooperative research between U.S. Bureau of Mines and Colorado School of Mines investigators has resulted in the development of a seismic system to evaluate roof stability in underground mines. After a review of geologic, geophysical, and rock mechanics data from four mines, a field site was selected near Green River, WY. An instrumentation plan was developed for monitoring strata movement, pillar stresses, and changes in material properties during both development and retreat mining. This program was designed to complement seismic data with a precise picture of strata movement, fracturing, and stress distributions. Field testing of this integrated system has been completed.

OP 296-92. Geology and Mineral Processing of Manganese Deposits From the West-Central Arkansas District, by O'Connor, W.K; White, J.C.; Turner, P.C. Min. Eng. J., Nov. 1992, pp. 1361-1368. The U.S. Bureau of Mines is investigating the cobalt and manganese resource of the West-Central Arkansas District through field investigations, mineralogical characterization, beneficiation and hydrometallurgical tests. Chemical analyses of head samples reported up to 25 pct Mn and 0.17 pct Co. Magnetic separation yielded products containing up to 41 pct Mn and 0.22 pct Co at recoveries of 95 pct and 93 pct, respectively.

OP 297-92. Innovations in Shearer Technology, by Organiscak, John A.; Thimons, Edward D.; Jankowski, Robert A. Paper in Proceedings of the American Mining Congress Coal Convention (Cincinnati, OH, May 3-7,

1992). AMC, 1992, pp. 149-165. Many technological improvements have been made on longwall shearing machines since the introduction of fully mechanized longwall mining in the United States during the 1960's. Improving shearer design and its complementary equipment helped triple longwall production since 1980 (an annualized growth of over 13 pct) with roughly the same number longwall systems in operation. Immediate future trends of shearer design include smaller and higher-powered machines with employee directed semiautomated production features and improved machine diagnostic technology. Fully automated longwall shearer faces may not commonly be used before the end of this century because of a lack in reliable sensor and data transmission technologies and the lack of trained personnel to support these technologies.

OP 298-92. Design of an Equivalent-Material Modeling Facility for Underground Coal Mines, by Owens and others, J.K. Paper in Proceedings of the Fourth Conference on Ground Control for Midwestern U.S. Coal Mines, ed Y.P. Chugh and G. Beasley (Mt. Vernon, IL, Nov. 2-4, 1992). Southern Illinois Univ. 1992, pp. 239-254. The physical modeling facility being constructed at Southern Illinois University, Carbondale, IL, under contract with the U.S. Bureau of Mines will be able to simulate the vertical and horizontal stresses occurring at various depths in underground mines. Different coal seam thicknesses and inclinations will also be simulated. The physical model will be 10 ft long, 6 ft high, and 0.75 ft deep. Equivalent materials that can simulate coal measure rock and types of ground control problems that can be studied using the test facility were identified.

OP 299-92. Evaluation of Agglomerated Tailings From Flotation Mills, by Pool, D.L. Paper in Proceedings of the 22nd Biennial Conference: The Institute for Briquetting and Agglomeration (San Antonio, TX, Nov. 2-4, 1991), ed. D.L. Roth. Gannon Univ., v. 22, 1991, pp. 1-12. Mill tailings are commonly disposed by deposition in a tailings pond which dries into a body of fine particles. Old tailings ponds can be a source of dust pollution because the fine particles are easily scoured from the surface by the wind. Weathering of the minerals in the fine tailings may be rapid. If sulfidic components are present, incident precipitation may mobilize the contained metals in the acidic effluent. Disposal of tailings as backfill in mines will prevent dusting, but oxidation and subsequent metal mobilization may still occur. A means of alleviating these problems is to chemically and physically stabilize the tailings by agglomeration. The data presented in this paper was obtained by agglomerating sulfide flotation mill tailings with three concentrations of a binder. Chemical stability of agglomerates was quantified by acid consumption data. Agglomerate physical stability was characterized by wetting tests and resistance to point loading.

OP 300-92. Numerical Modeling Analyses of a Longwall Mining Gateroad System, by Riefenberg, Jennifer; Donato, Douglas; Sun, Meng-Cherng. Paper in Proceedings of the Fourth Conference on Ground Control for Midwestern U.S. Coal Mines, ed Y.P. Chugh and G. Beasley (Mt. Vernon, IL, Nov. 2-4, 1992). Southern Illinois Univ. 1992, pp. 167-177. This U.S. Bureau of Mines paper illustrates how numerical modeling analyses can be useful in evaluating the effectiveness of different mine designs toward reducing the occurrence of floor heave in the tailgate entry of an underground coal mine located in northwestern Colorado.

OP 301-92. The Influence of Wear on the Fatigue Failure of a Wire Rope, by Schrems, Karol K. Paper in Proceedings of the 24th Annual Convention of the International Metallographic Society: Microstructural Science (Monterey, CA, July 29-Aug. 1, 1991. ASM Int., v. 19, 1991, pp. 305-324. The fatigue failure of a wire rope used on a skip hoist in an underground mine has been studied as part of the ongoing research by the Bureau of Mines into haulage and materials handling hazards in mines. Fractography revealed multiple crack initiation sites to be located at other less noticeable wear sites or opposite the characteristic wear site. Microhardness testing revealed hardening, and some softening, at wear sites.

OP 302-92. Gateroads With Yield Pillars for Stress Control, by Tadolini, S.C.; Haramy, K.Y. Paper in Proceedings of the Fourth Conference on Ground Control for Midwestern U.S. Coal Mines, ed Y.P. Chugh and G. Beasley (Mt. Vernon, IL, Nov. 2-4, 1992). Southern Illinois Univ. 1992, pp. 179-194. Ground control problems associated with deep coal mines have increased interest in the design of longwall gateroads using yielding pillars. This paper presents a discussion of the yield pillar theory and assesses the stability of gateroads with yield pillar configurations. Case studies were conducted by the U.S. Bureau of Mines in two underground longwall mines using two- and three-entry yielding chain pillar configurations. Analysis indicates that gatetroad design using yield pillars can result in less stress concentrations in the entries and may reduce or eliminate some stress-related problems.

OP 303-92. Extended Longwalls: Is Bigger Better, by Thimons, Edward D.; Jankowski, Robert A.; Finfinger, Gearld L. Paper in Proceedings of Longwall USA (Pittsburgh, PA, June 16-18, 1992). Longwall USA, pp. 1-15. Since the first introduction of longwalls into the U.S. mining industry, longwall mining productivity has been continually on the increase. These productivity gains have resulted from a number of operational and equipment changes. One constant trend over the years has been to increase the size of longwall panels. Extended longwall panels offer some major benefits in terms of fewer panel moves, less entry development, and increased resource recovery. At the same time, large increases in panel dimensions result in changes in the mining environment, and these changes can have potential positive and negative health and safety implications. This paper will take a generalized look at how longwalls are getting bigger, how this can impact health and safety, and point out some practices implemented by current extended longwall operations to improve conditions.

OP 304-92. Extended Longwall Considerations, by Thimons, Edward D.; Jankowski, Robert R.; Finfinger, Gearld L. Paper in Proceedings of the American Mining Congress Coal Convention (Cincinnati, OH, May 3-7, 1992). AMC, pp. 167-183. Longwall mining productivity in the U.S. has been on the increase since its introduction in the 1950's. Productivity gains are resulting from a number of operational and equipment changes. One trend has been an increase in the dimensions of longwall panels. Over the past 5 years, several longwall operations have opted to significantly increase the size of their panels. This paper takes a generalized

look at how longwalls are changing in size, how this can impact health and safety, and point out what some current extended longwall operations are doing to improve health and safety.

OP 305-92. Asbestos Substitutes Matching Performance, by Virta, Robert L. Industrial Minerals J. Dec. 1992, pp. 47-51. An asbestos substitute is any material that replaces asbestos in a commercial product. There are many asbestos substitutes, each with its own unique physical and chemical properties. Substitutes can be inorganic or organic, fibrous or non-fibrous, and natural or synthetic. They also can be used as a direct substitute for asbestos or as a replacement product. Probably in no other field is the diversity of substitute materials so great.

OP 306-92. Continuous Microseismic Monitoring in a Deep Longwall Coal Mine, by Wilson, P.E.; Lemons, J.S. Paper in Proceedings of the Fourth Conference on Ground Control for Midwestern U.S. Coal Mines, ed Y.P. Chugh and G. Beasley (Mt. Vernon, IL, Nov. 2-4, 1992). Southern Illinois Univ. 1992, pp. 227-238. The U.S. Bureau of Mines, as part of its effort to control seam and strata failures, is investigating the use of real-time microseismic monitoring to forecast mountain bumps and to evaluate the success of bump prevention and mitigation efforts. An Automated Microseismic Monitoring System (AMMS) has been developed to collect mining-induced seismic event data. This technology has been employed in a deep eastern Kentucky coal mine experiencing infrequent, yet severe, coal bumps during longwall panel retreat. Analysis of the microseismic data suggests that information exists that may describe the "likelihood" of bump occurrence.

OP 307-92. Treatment Options for Acid Mine Drainage, by Kleinmann, Robert L.P.; Ackman, Terry E. Paper in Proceedings of the 23rd Annual Institute on Mining Health, Safety and Research (Blacksburg, VA, Aug. 24-26, 1992). Virginia Polytechnic Institute and State Univ., 1992, pp. 75-85. The basis of acid mine drainage (AMD) production is fairly well understood (Kleinmann et al., 1981; Nordstrom, 1982; and Onysko, 1986). Pyrite and other sulfide minerals, on exposure to oxygen and water, oxidize to produce dissolved metals, sulfate, and acidity. The process is catalyzed by iron-oxidizing bacteria such as Thiobacillus ferrooxidans. The resulting solution interacts with other mine waste constituents in secondary reactions such as neutralization, ion-exchange, and acid-induced metal dissolution. Consequently, the discharge water quality can range from the classic acid mine drainage (AMD) formula of high acidity, metals, and sulfate concentrations to a neutralized version of low metal and high sulfate content. Acid discharges often persist at unreclaimed sites for many decades; some can be considered a perpetual pollution source.

OP 308-92. Removal of Heavy Metals From Missouri Lead Mill Tailings by Froth Flotation, by Benn, F.W.; Cornell, W.L. Paper in Proceedings of the Seventh Symposium On Separation Science and Technology for Energy Applications. Marcel Dekker, Inc., v. 28, No. 1-3, 1993, pp. 733-746. The U.S. Bureau of Mines investigated froth flotation techniques to remove heavy metals (Pb, Cu and Zn) from southeast Missouri lead mill tailings. The objectives of the investigations were to reduce the Pb remaining in the tailings to <500 ppm and to attempt to recover a marketable concentrate to offset a portion of the remediation costs. Concentrates recovered were retreated to produce a final Pb concentrate containing 72 pct Pb with a cleaner flotation recovery of 79 pct. Froth flotation proved to be a viable method to remove the heavy metals.

OP 309-92. Oxidation and Corrosion Resistance of Two Fe-8Cr-16Ni-Si-Cu Alloys, by Bullard, S.J.; Larson, D.E.; Dunning, J.S. Corrosion J., v. 48, No. 11, Nov. 1992, pp. 891-897. The Bureau of Mines has developed a low-chromium stainless steel with low-temperature corrosion resistance in acidic media and elevated temperature oxidation resistance in air. Two alloys, nominally containing Fe-8Cr-16Ni-5Si-1Cu and 0 or 1 Mo, were evaluated for their potential as low-Cr substitutes for conventional stainless steel.

OP 310-92. Mine Aerosol Measurement, by Cantrell, B.K.; Williams, K.L.; Watts, Jr., W.F. Ch. 26 in Proceedings of the Aerosol Measurement Principles, Techniques, and Applications (New York, 1993), ed. by K. Willeke, P.A. Baron. Van Nostrand Reinhold, 1993, pp. 591-611. Exposure to mineral aerosol is an occupational health hazard in mining and mineral processing industries because of the risk of developing pneumoconiosis. This chapter summarizes aerosol measurement technology currently used in the U.S. mining industry. Because of the regulatory aspect, the application of aerosol measurement technology has evolved in two areas: compliance measurements, which support regulatory programs, and research measurements, which aid in the development of new compliance measurement techniques and assist in determining the fundamental properties of mine aerosol.

OP 311-92. Corrosion Behavior of Advanced Intermetallic Materials, by Covino, Jr., Bernard S.; Rhoads, Stanley C. Paper in Proceedings of the First International Symposium on Environmental Effects on Advance Materials (San Diego, CA, Nov. 1992). NACE, 1991, pp. 16-1 to 16-7. The Bureau of Mines has conducted research on the preparation and subsequent fabrication of iron and titanium-based intermetallics as part of its effort to develop alternate materials for use in the mining and minerals processing industries. Part of the research involved a study of the corrosion behavior of several of these materials in aggressive environments. Tests were conducted to determine the effects of composition, solution aeration, and exposure time on the corrosion rates of the intermetallic materials. Titanium had the lowest corrosion rate of all the metals tested. Of the intermetallics tested Ti_3Al had the lowest corrosion rate, TiAl has the second lowest corrosion rate, and FeAl had the highest corrosion rate.

OP 312-92. Fracture Mechanics and Finite Element Analysis, by Laird II, George; Epstein, Jonathan S. Mech. Eng. Mag., v. 114, No. 11, Nov. 1992, pp. 69-73. Fracture mechanics and finite element analysis are 20th-century technologies that have a profound impact on the way engineers design mechanical devices, structures, and material system. Although there is a wealth of literature in these two fields, the basic concepts of these technologies are simple. Fracture mechanics describes the transfer of mechanical energy toward the creation of crack surfaces. Finite element analysis is a numerical technique that solves continuum problems with an accuracy acceptable to engineers. Together these technologies provide powerful tools to predict critical loads or crack sizes that may cause fracture in proposed designs or existing

structures. The U.S. Bureau of Mines is using such an approach to solve fracture problems in wear-resistant materials and to prevent premature rock failures in mining environments.

OP 313-92. **A Personal Size-Selective Sampler for Respirable Diesel Aerosol and Coal Mine Dust**, by Rubow, K.L.; Marple, V.A.; Cantrell, B.K. Paper in Proceedings of the American Association for Aerosol Research Conference (Philadelphia, PA, June 16-22, 1992). Univ. of Minnesota, 1992, p. 319. Techniques are being developed for measuring the mass concentration of respirable diesel exhaust aerosol found in underground coal mines. This effort is in response to the current concerns associated with worker exposure to diesel exhaust and the prospect of pending industry regulation. The University of Minnesota and U.S. Bureau of Mines have been involved in cooperative studies over the past 4 years to study size selective sampler techniques to measure the respirable mass concentrations of diesel exhaust and mine dust aerosols in underground coal mines. Results from these studies have been used to develop design and performance criteria for a personal diesel exhaust aerosol sampler.

OP 314-92. **A Disposable Diesel Exhaust Filter for Underground Coal Mines**, by Ambs, Jeffrey L.; Watts, Jr, Winthrop F. Paper in Proceedings of the Midwest Mine Health and Safety Conference (Marion, IL, July 22-23, 1992). Southern Illinois Unv., 1992, pp. 60-69. The underground mining industry recognizes that diesel-powered equipment has advantages over its electric counterparts such as greater mobility, flexibility, and high-power density, which may increase productivity. However, there is a potential health risk for miners exposed to diesel exhaust. The U.S. Bureau of Mines collaborated with Donaldson Company, Inc., to develop a disposable diesel exhaust filter (DDEF) to remove soot from diesel exhaust. The principal application of the DDEF is on permissible diesel-powered haulage vehicles used in coal mines. In-mine tests show that the filter reduces diesel exhaust aerosol levels in the mine environment by up to 95 pct. The usable life of the filter is from 10 to 36 h, depending on the altitude, engine, and duty cycle of the vehicle.

OP 315-92. **Methanogenesis in Abandoned Mines and Its Oxidation of Methane for Safer Mining**, by Volkwein, Jon C. Paper in Proceedings of the 3rd Symposium on Biotechnology of Coal and Coal-Derived Substances (Essen, Germany, Sept. 23-24, 1991). (DGMK) Deutsche Wissenschaftliche Geselllschaft, 1991, pp. 287-299. The United States Bureau of Mines has been exploring the potential application of biological systems to mining. These include anaerobic microbial conversion of coal to methane and the conversion of methane to carbon dioxide. Initial work has identified certain abandoned mines as unique niches where organisms of interest may be found. The characteristics of these mines are being investigated and microbial methanogenic screening assays have been conducted. Initial data suggested methanogenisis was arising from the coal substate, but further analysis could not confirm that the coal substrate was in fact being depolymerized and converted to methane.

OP 316-92. **Mine Illumination**, by Whitehead, Kenneth; Bockosh, George R. Ch. 11.9 in Proceedings of the SME Mining Engineering Handbook (Littleton, CO, 1992). SME, 2nd ed., v. 1, 1992, pp. 1127-1138. The mining environment poses unique challenges to the illuminating engineer. It is unlike most other industrial settings, in that conditions cannot be designed but rather must be accommodate. Specifically, room dimensions and surface reflectance in underground mines are defined by the deposit mined and can only be modified at great expense. A potentially explosive atmosphere, dust, and the ever-changing nature of the underground environment further complicate the illumination task. It is these predetermined, and often adverse, conditions that cause extreme difficulty in providing adequate illumination in mines. The concerns that need to be addressed include adequate illumination for hazard and operational cue recognition, the quality of lighting, and health maintenance.

OP 317-92. **Overview of Research on Mine Emergency Skills**, by Brnich, Jr., Michael J.; Vaught, Charles; Cole, Henry P. Paper in Proceedings of the 23rd Annual Institute on Mining Health, Safety and Research (Blacksburg, VA, Aug. 24-26, 1992). Virginia Polytechnic Inst. and State Univ., 1992, pp. 175-186. The Bureau's research in human resource development combines social science and instructional theory and design. Part of this effort is concerned with how miners generally behave under life-threatening conditions. The present paper summarizes work intended to enhance individuals' responses to underground mine emergencies by developing innovative strategies to teach and measure "soft skill" competency at the mining site. The way in which workers respond to emergencies is placed within the practical confines of two key areas: 1) studies of how to teach and assess mine emergency skills; and; 2) investigations into how best to provide effective training for procedural tasks such as self-contained self-rescuer (SCSR) donning.

OP 318-92. **Bureau of Mines Ergonomic Research To Reduce Back Injuries and Improve Ergonomics Aspects of Mining Equipment**, by Gallagher, Sean; Unger, Richard L. Paper in Proceedings of the 23rd Annual Institute on Mining Health, Safety and Research (Blacksburg, VA, Aug. 24-26, 1992). Virginia Polytechnic Inst. and State Univ., 1992, pp. 165-173. In the past few years, several companies in the mining industry have come to realize that ergonomics is an effective method of controlling costs and improving the health and safety of workers. Benefits that may be derived through the ergonomics approach may include more efficient operation, fewer accidents, lower operating costs, and more effective use of personnel. This paper discusses the use of ergonomics to reduce the cost and incidence of back injuries and to improve the design of mining machinery in underground coal mines.

OP 319-92. **Understanding Miners' Hazard Recognition Skills: A Psychological Perspective**, by Kowalski, Kathleen M.; Barrett, Edward A. Paper in Proceedings of the 23rd Annual Institute on Mining Health, Safety and Research (Blacksburg, VA, Aug. 24-26, 1992). Virginia Polytechnic Inst. and State Univ., 1992, pp. 151-162. This paper presents selected perceptual concepts found in the literature that may be applicable for research on improving the hazard recognition skills of miners. The literature review includes the areas of psychology, the military literature, especially target detection, and the transportation and safety literature. The goal of this search was to target appropriate concepts, theories and principles to utilize as a basis for improving hazard recognition training and to enhance the perceptual skills of miners.

OP 320-92. Leachability of Lead From Selected Copper-Base Alloys, by Paige, J.I.; Covino, Jr, B.S. Paper in Proceedings of the National Association of Corrosion Engineers (NACE) Corrosion '92 Conference (Nashville, TN, April 27-May 1, 1992). NACE, v. 48, No. 12, 1992, pp. 1040-1046. The Bureau of Mines has conducted research on the selective leaching of lead from copper-base alloys in high-purity water. The alloys in this study were selected as representatives of those used in various plumbing system fixtures such as faucets and valves. The results show that, with the exception of the more complex yellow brasses, more lead is leached into water from alloys containing greater concentrations of lead and that the rate of lead leaching decreases with exposure time. Higher temperatures had relatively little effect on the leaching of lead. Lead was preferentially dissolved from all of the alloy groups.

OP 321-92. Responding to an Underground Mine Fire: A Case Study, by Vaught, Charles; Wooton, D.G. Paper in Proceedings of the 23rd Annual Institute on Mining Health, Safety and Research (Blacksburg, VA, Aug. 24-26, 1992). Virginia Polytechnic Inst. and State Univ., 1992, pp. 197-208. This manuscript presents an overview of emergency response and fire-fighting activities at an underground coal mine in the midwestern United States. Although efforts to contain the fire proved successful, there are lessons learned that may impact future responses. Regarding fires, prior assessment of such elements as water capacity and access to equipment (with correction of inadequate features) are critical. It is also recommended that particular attention be given to potential alternative strategies, e.g., sealing plans, rather than addressing them ad hoc. The authors conclude that it is important for operations to develop and test, under simulated conditions, a comprehensive mine emergency plan.

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OP 01-93. Magnetite Oxidation of Acid and Fluxed Taconite Pellets, by Haas, L.A.; Nigro, J.C.; Moe, R.L. Paper in 1992 Ironmaking Conference Proceedings (AIME/ISS, Warrendale, PA, Apr. 8, 1992). AIME/ISS, pp. 533-549. The U.S. Bureau of Mines and Cleveland-Cliffs, Inc. investigated ways of enhancing the quality of domestic acid and fluxed magnetite pellets by modifying the oxygen content during the preheat and induration periods of the firing operation.

OP 02-93. Electrochemical Study of SiC Particle Occlusion During Nickel Electrodeposition, by Watson, Sandra W. Conference proceedings of the American Institute of Chemical Engineers 1992 Annual Meeting, (Miami Beach, FL, Nov. 1-6, 1992,) by the Electrochemical Society, Inc. Previous work conducted by the USBM showed that chromium particle occlusion occurs as a result of particle collisions with the cathode surface. Conductive chromium particles within the electric field were also shown to cause a local rise in the cathodic current density on the area immediately adjacent to that particle. In order to research the effect of conductive particles versus semi-conductive particles on the occlusion process, nickel electrodeposition was studied in the presence of SiC particles and compared to previous studies on nickel electrodeposition in the presence and absence of Cr particles.

OP 03-93. Application of Fuzzy Control Techniques to a Chaotic System, by Karr, C.L.; Gentry, E.J. Emerging Computer Techniques for the Minerals Industry by the Society for Mining, Metallurgy, and Exploration, Inc. (pp. 371-376). Researchers at the U.S. Bureau of Mines have developed a control algorithm to efficiently manipulate chaotic systems. The control, based on both fuzzy logic and genetic algorithims, prescribes actions that drive the chaotic system to acceptable regions of state space. The use of fuzzy logic enables a person who has limited experience with a chaotic system to establish a set of rules for manipulating the problem environment, and a set of membership funtions that define terms used in a rule-set. Genetic algorithms are search algorithms based on natural genetics, and are used in the control algorithm to select membership functions that provide for a suitable level of control. The Bureau-developed algorithm controls the computer simulation of a ball bouncing on an oscillating table, a system that exhibits chaotic behavior.

OP 04-93. Minimum Explosible Dust Concentration Measured in 20-L and 1-M 3 Chambers, by Cashdollar, Kenneth L.; Chatrathi, Kris. Paper in Combustion, Science, and Technology, Vol. 87. pp. 157-171. Minimum explosible concentrations (MEC) of dusts were measured in the USBM 20-L chamber and in the Fike 1-m3 chamber. The MEC values for gilsolite dust and bituminous coal dust were measured in each chamber at several ignition energies. The MEC-values measured in the 20-L chamber with 2500-J ignitors were comparable to those measured in the 1-m3 chamber with 10, 000-J ignitors. At higher ignition energies in the 20-L chamber, there was evidence of overdriving.

OP 05-93. Deformation Apparatus For Use in High-Resolution, High-Temperature Studies of Mantle Rheology, by Hanson, David R.; Spetzler, H.A.; Getting, Ivan C. Paper in Review of Scientific Instruments a publication of the American Institute of Physics January-December 1993 vol. 64 pp. 211-217. A uniaxial dead weight creep apparatus has been used to investigate the low stress, low strain-rate rheologic behavior of refractory minerals. Displacement rate resolutions were measured on samples of 1.5-mm cross section and 3.0-mm length at temperatures up to 0.1 log unit, load to 0.1 N, and temperature to 5K. Maximum stresses applied were between 25 and 30 MPa. Use of this apparatus has allowed the investigation of the transient creep regime in olivine, an important mineral in the Earth's mantle.

OP 06-93. Software for Hydrologic Monitoring of In Situ Leaching Operations, by Mathison, Peter K.; Murphy, F. Brendan; Level, Eric. Paper in proceedings: APCOM 92 Conference, 23rd International Symposium on Computer Applications, University of Arizona, April 7-11, 1992. The U.S. Bureau of Mines is developing a hydrologic monitoring system for in situ leaching operations. A working prototype of this system was installed and tested at the Cyprus Casa Grande copper mine. Requirements specific to in situ leaching operations were identified by researchers. The system

has been a useful tool for researchers and for mine personnel. Observations of the hydrologic monitoring system, including details of the development process, the design of the system, and the software developed at the Bureau have resulted in new ideas for an enhanced design of the system.

OP 07-93. High-Pressure Wet Oxidation of Sphalerite Concentrate, by Gerdemann, S.J.; Landsberg, Arne Paper in Proceedings of Symposia Sponsored by Extraction and Proceedings Div., and held at TMS Ann. Meeting, Denver, Co, Feb. 21-25, 1993. The Minerals, Metals & Materials Society. The U.S. Bureau of Mines is studying the kinetics of wet oxidation of sphalerite concentrate (ZnS) as a possible process for a gravity-pressurized reactor (GPR). The effects of pressure, temperature, and particle size on the rate of reaction were investigated. Reaction rate was found to be limited by the amount of oxygen in solution. However, at 250 C and 1500 psia, over 90 pct of the zinc was solubilized in less than an hour. The conditions for maximizing the ZnS in solution, while minimizing oxysulfate formation, are discussed.

OP 08-93. High Nitrogen Concentration of Fe-Cr-Ni Alloys, by Rawers, J.C.; Gokcen, N.A.; Pehlke, R.D. A Paper appearing in Metallurgical Transactions vol 24 A January 1993. Increasing the nitrogen concentration in iron and iron alloys significantly improves their mechanical properties. A recent technique for melting in a hot-isostatic pressure furnance using nitrogen as the pressuring gas has been developed by U.S. Bureau of Mines researchers for making massive nitrogen additions to iron (up to 1.6 weight percent nitrogen) and iron-chromium-nickel alloys (up to 6.6 weight percent nitrogen). The total nitrogen concentration measured at atmospheric pressure and room temperture was determined to be the equilibrium nitrogen concentration in the molten alloy. Statistical fits of thermodynamic concentration data to the high-pressure melt nitrogen data require evaluating element concentration terms, interaction effect terms, pressure terms, and pressure-composition effect terms. Examination of the nitrogen concentration data suggests several methods of correlation.

OP 09-93. AEP Fuel Supply's Ergonomic Approach to Reducing Back Injuries, by O'Green, John E.; Peters, Robert H.; Cecala, Andrew B. Proceedings of the Twenty-Third Annual, Institute on Mining Health, Safety and Research (Publ. by the Dept. of Mining and Minerals Engr., Virginia Polytechnic Institute and State University) August 24-26, 1992 pp.187-195. Are employee problem-solving groups beneficial for improving miner's safety? Prior studies conducted at mining operations suggest that the answer is yes. This paper describes how American Electric Power (AEP) is using employee problem-solving groups, called "ergonomic committees," to discover new strategies for reducing back injuries at its coal mining operations.

OP 10-93. Reaction of Some Trioctahedral Micas with Copper Sulfate Solutions at 25 C and 1 Atmosphere: An Electron Microprobe and Transmission Electron Microscopy Investigation, by Ilton, Eugene S.; Earley III, Drummond; Marozas, Dianne. Paper appearing in Economic Geology vol. 87 in 1992 pp. 1813-1829. Reaction of biotite and phlogopite with acidic, CuSo4-rich aqueous solutions produced submicroscopic inclusions of a copper-rich, sulfur-absent phase, identified as native copper. The experiments support the suggestion that this mode of copper enrichment in biotite is produced during weathering of rocks with copper sulfide mineralization, such as prophyry copper systems.

OP 11-93. Rutile From Ilmenite by Thermal Processing, by Adam, M.J.; Swallow, K.A. Proceedings of symposia sponsored by the Extraction and Processing Division, and held at the TMS Annual Meeting 1993 EPD Conress pp. 371-382 February 21-25, 1993. The U.S. Bureau of Mines is investigating the partitioning of complex minerals to simpler phases using sulfidation reactions for selective extraction of mineral constituents of value from extraneous elements early in processing schemes. This report describes research in which thermal processing of the complex Ti-bearing mineral ilmenite ($FeTiO_3$) resulted in partitioning of the valuable Ti metal to the simpler compound rutile (TiO_2). Partitioning results and phase concentration data are reported relative to thermal treatment variables sand physical separation techniques.

OP 12-93. Recycling Stainless Steel Pickle Liquors by an Electrodialytic Metahesis Process, by Rivers, S.P.; Horter, G.L.; Schluter, R.B. Proceedings of symposia sponsored by the Extraction and Processing Division, and held at the TMS Annual Meeting pp. 1035-1046 February 21-25, 1993. The U.S. Bureau of Mines has been conducting research to develop a process for recycling depleted pickling solutions, thus reducing the quantity of byproduct acids generated. This report reviews on research efforts at the U.S. Bureau of Mines to apply electrodialytic recycling to HNO3/HF pickling solutions.

OP 13-93. Treatment of Lead Waste From Lead-Acid Battery Recycling Plants, by Lee, A.Y.; Wethington, Ann M.; Gorman, Michael G. Proceedings of symposia sponsored by the Extraction and Processing Division, and held at the TMS Annual Meeting February 21-25, 1993 pp. 927-942. The U.S. Bureau of Mines developed a method to treat lead-contaminated soil and ebonite battery casing wastes to produce a nonhazardous material. The cleanup procedure involves wet screening to separate a minus 18-mesh soil fraction; removal of metallic lead, rocks, wood, etc.; carbonation to change lead sulfate to acid-soluble lead carbonate; size reduction; acid leaching; and rinsing. Treated casing wastes and soils pass the Toxicity Characteristic Leaching Procedure (TCLP) test and can be reclassified as nonhazardous materials. Based on this process, a conceptual pilot plant has been designed which will be demonstrated on wastes from two Superfund sites.

OP 14-93. Determination of the Thermal Conductivity of Iron Aluminide as a Function of Temperature, by Wilson, Rick D.; Devletian, Jack H. Paper appears in J. Thermophysics and Heat Transfer in 1993 vol 7 pp. 185-187. In a Bureau of Mines study, the thermal conductivity of several iron aluminide alloys was determined as a function of temperature. Four point electrical resistivity data were used in conjunction with the Wiedemann-Franz-Lorenz equation to determine the thermal conductivity of Fe3Al. An identical sample of iron, along with literature data, was used to verify the accuracy of the method. The results indicate that the thermal conductivity of Fe3Al alloys is independent of composition and increases linearly as a function of temperature.

OP 15-93. TiAl Composites Formed Elemental Powders by Hot-Isostatic Pressing Processing, by

Maupin, H.E.; Rawers, J.C. This paper appeared in Journal of Materials Science Letters in 1993 vol. 12 pp. 165-167. The goal of this study by the Bureau of Mines was to make use of the higher pressures that can be obtained in a HIP furnace to produce fully-dense, near-net-shape intermetallics in shorter times at lower temperatures. It was determined that HIPing elemental powders of Ti and Al produced a fully dense metal-intermetallic composite. The Ti and Al partially reacted to produce a series of titanium aluminides. Additions of B, C, or Si did not produce second phase intermetallic precipitates. Addition of Fe or Ni resulted in the formation of iron-and nickel aluminide phases.

OP 16-93. Implications of Rock Mineralogy and Texture on the Feasibility of In Situ Leach Mining of Mn-Bearing Iron Formations of Central Minnesota, U.S.A., by Saini-Eidukat, B.; Marozas, Dianne C.; Blake, Roland L. Paper appears in Applied Geochemistry vol. 8 1993 pp. 37-49. The U.S. Bureau of Mines is investigating the feasibility of extracting Mn using in situ leach mining methods. Among the deposits being examined are the iron formations of the Cuyuna Range, Minnesota, which contain high-tonnage, low grade deposits of manganese oxides. Manganese minerals identified include pyrolusite, crytomelane-hollandite, manganite, braunite and lithiophorite. In batch leaching tests of Cuyuna Range ores, texture was shown to be of greater importance than thermodynamic reactivity in determining amenability to leaching. Predicting the practical potential for recovery of Mn by in situ leaching must involve identification of the effects of texture in addition to ore mineral reactivity.

OP 17-93. Geostatistical Analysis of Dynamic Transmissivity Conditions During In Situ Copper Leaching, by Friedel, Michael J.; Schmidt, Robert D.; Jones, Perry M. Proceedings: APCOM 92 Conference, 23rd International Symposium on Computer Applications, University of Arizona, April 7-11, 1992, pp. 49-61. As part of a study aimed at understanding the hydrology of in situ leach mining (ISLM), the Bureau of Mines, in cooperation with the Cyprus Casa Grande Corporation and the University of Arizona, is investigating dynamic transmissivity conditions during ISLM of a copper oxide ore deposit. Spatial and temporal variations in ore zone transmissivity during two years of ISLM operations at the Cyprus Casa Grande mine are evaluated during sixteen intervals of steady-state injection and recovery well operation. Geostatistical analyses reveal a dynamic and anisotropic transmissivity structure within the target ore zone, dependent upon spatial and temporal changes in injection pressure and well configuration.

OP 18-93. Graphic Algorithms in an Object-Oriented Hydrology Model, by Salovich, Michael E.; Mathison, Peter K.; Hollar, Daniel C. Proceedings: APCOM 92 Conference, 23rd International Symposium on Computer Applications, University of Arizona April 7-11, 1992 Chapter 65 pp. 679-690. The U.S. Bureau of Mines has developed a prototype version of a computer application that combines hydrologic analysis with object-oriented graphics. This software is unique in that it presents analytic element analysis within an object-oriented CAD environment. Algorithms for CAD features such as map coordinate translation, zooming, and layering of images were developed by Bureau researchers. The application has a modular source code structure and can be modified for use in other research applications.

OP 19-93. The Measurement of Activity-Weighted Size Distributions Studies, by Hopke, P.; Strydom, R.; Ramamurthi, M. Paper appears in Health Physics vol. 63 Series 5 pp. 560-570 November 1992. Over the past 5 years, there have been significant improvements in measurement of activity-weighted size distributions of airborne radon decay products. The modification of screen diffusion batteries to incorporate multiple screens of differing mesh number, called graded screen arrays, have permitted improved size resolution such that the size distributions can now be determined down to molecular sized activities. In order to ascertain the utility and reliability of such systems, several intercomparison tests have been performed in a radon chamber in which particles of varying size have been produced by introducing SO2 and H2O along with the radon to the chamber. Again, generaly good agreement among the various groups was obtained although some differences were noted. It is concluded that such systems can be constructed and can be useful in making routine measurements of activity-weighted size distributions with reasonable confidence in the results obtained.

OP 20-93. Mechanical and Microstructural Properties of Nitrogen-High Pressure Melted Fe-Cr-Ni Alloys, by Rawers, J.; Asai, G.; Doan, R. Paper appears in Jounal of Materials Research vol. 7 Series 5 May 1992 pp. 1040-1046. A series of iron-chromium-nickel alloys was melted under a nitrogen atmosphere at several different pressures. Nitrogen-high pressure melting was conducted under pressures ranging from 0.1 to 200 MPa. The total nitrogen concentrations achieved in these alloys were proportional to the square root of the nitrogen pressure used during melting. Nitrogen took the form of soluble interstitial nitrogen and metal nitride precipitates. Tensile properties of the alloys were directly proportional to the nitrogen concentration in the alloy.

OP 21-93. Atmospheric Corrosion Model for Galvanized Steel Structures, by Spence, J.W.; Haynie, F.H.; Lipfert, F.W. Paper appeared in Corrosion vol. 48 Series 12 in December 1992 pp. 1009-1019. This report develops a model for predicting the corrosion of galvanized steel structures based on two competing mechanisms: the formation and dissolution of the basic zinc-carbonate film that forms on zinc surfaces. The model consists of a diffusivity term that describes film growth and a dissolution term that describes the rate of film removal. The field data used in this evaluation were consistent with corrosion rates predicted by the model, within the limits of uncertainty of the environmental data.

OP 22-93. Laboratory and Large-Scale Dust Explosion Research, by Cashdollar, Kenneth L.; Weiss, Eric S.; Greninger, Nevin B. Paper appears in Plant/Operations Progress vol. 11 Series 4, pp. 247-255, in October 1992. This paper describes dust explosibility research in full-scale experimental mines a 20-L laboratory chamber at the U.S. Bureau of Mines and a 1-m3 laboratory chamber at Fike Corporation. Carbonaceous dusts with a wide range of volatilities and various particle size distributions were studied. Laboratory data on the minimum explosible concentrations of predispersed dusts were comparable to mine data for nominal dust loadings that were dispersed by the aerodynamic disturbance from a gas ignition zone. Recommendations are given on the limitations of small-scale testing such as "overdriving" by too strong an ignitor.

ARTICLES IN OUTSIDE PUBLICATIONS

OP 23-93. Progress Toward Low-Cost Titanium, by Turner, Paul C.; Hansen, Jeffrey S. Paper appeared in Advanced Materials & Processes vol. 143 Series 1 in January 1993 pp. 42-43. In the past, titanium has conjured up visions of exotic aircraft and submarines with very exotic prices. The primary titanium producers are introducing a host of lower cost industrial-grade titanium alloys that compare very favorably with their aerospace counterparts at significant savings. These lower cost alloys may open up vast new fields for titanium applications. The U.S. Bureau of Mines, in cooperaton with other Government agencies and the titanium industry, is planning and conducting research on new methods to produce still lower cost titanium and titanium alloys.

OP 24-93. The Changing Color of U.S. Sapphires, by Austin, Gordon T. Paper appeared in Colored Stone Magazine, vol. 6, No. 1, January-February 1993. The production of gem-quality sapphire has greatly increased in the United States. The commercial production is from three areas in Montana; Yogo Gulch, Rock Creek, and the Missouri River. Development of technology for heat-treatment of Montana sapphires has enhanced not only their value, but their acceptance by the gem industry.

OP 25-93. Characterization of Minnesota Manganese Deposits for In Situ Mining, by Dahl, Linda J. Paper appeared in Skillings Mining Review in vol. 81 Series 41 October 10, 1993 pp. 4-9. The USBM, in cooperation with the Minnesota Geological Survey, University of Minnesota and the Minnesota Department of Natural Resources, is conducting research to determine the potential of using in situ mining to recover manganese from deposits in Minnesota. Conventional mining techniques, such as open pit and underground mining, have not been economical for US manganese deposits because they are too low grade. In situ mining may be an economically attractive alternative for these low grade deposits because it requires less capital investment, staffing, and energy consumption than conventional mining does.

OP 26-93. Factors Affecting Residential Water Well Yield in the Vicinity of Room and Pillar Mines, by Schmidt, Robert D. In proceedings: 3rd Subsidence Workshop Due to Underground Mining. Morgantown, WV, June 1-4, 1992. The Bureau of Mines is conducting an investigation to develop remediation techniques for residential water wells whose yield has been affected in the long term by underground mining. Initial work relating to this project was conducted in 1984-1987 at a room and pillar mine in Indiana Country, Pennsylvania. The results suggest that permanently isolating well bore outflow fractures may remediate certain open-hole residential wells that have been affected by high extraction underground mining.

OP 27-93. Site Characterization of Minnesota Manganese Deposits to Evaluate the Potential for In Situ Leach Mining, by Dahl, Linda J.; Brink, Susan E.; Blake, Roland. Society for Mining, Metallurgy, and Exploration, Inc. 1992 SME Annual Meeting, Phoenix, AZ, February 24-27, 1992. vol. 92 Series 243, 31 pp. February 1992. The U.S. Bureau of Mines is developing a process to selectively extract manganese from oxide ores as part of its in situ leach mining research program. This paper focuses on stratigraphy, mineralogy, ore textures, fractures, permeability, and porosity as they relate to in situ leach mining.

OP 28-93. Longwall Shearers Gain in Power and Efficiency, by Organiscak, John A.; Thimons, E.D.; Jankowski, R.A. Paper appears in Coal Magazine, Maclean Hunter, vol. 98 Series 2. pp. 46/47, February 1993. Longwall production has tripled since 1980 with roughly the same number of systems in operation. This increase in productivity stems from many technological improvements in equipment design. Equipment became more robust and powerful and was found to be the main factor responsible for high production longwalls. Dust control technology was developed concurrently by the Bureau of Mines to alleviate the high concentrations of respirable dust associated with high production levels.

OP 29-93. Method for Recovering Anhydrous $ZnCl_2$ from Aqueous Solutions, by Eichbaum, B.R.; Schultze, L.E. Paper appeared in Separation Science and Technology. Vol 28 Series 1-3 693-717 pp. 1993. The process involves high energy requirements for evaporating the pregnant solution to produce anhydrous $ZnCl_2$ needed for electrolytic cell feed. An efficient hydrometallurgical process would facilitate treatment of lower grade ores that can be used in conventional processing and would render roasting unnecessary.

OP 30-93. The Effect of Oxidation on Sulfide Mineral Flotation, by Kotlyar, D.G.; Tolley, W.K. Preprint of SME-AIME Annual Meeting, No. 93-20, Reno, NV, February 15-18, 1993, published by the Society for Mining, Metallurgy, and Exploration,, Inc. Series 93-20. 8 pp. February 15-18, 1993. Oxidized sulfide minerals, commonly formed by weathering, increasingly are becoming important resources as primary sulfide deposits are depleted. Oxidation in general, reduces selectivity and recovery in flotation. The objective of this research was to determine the mechanism of oxidation and collector adsorption in sulfide systems as a step towards developing improved technologies for beneficiation of oxidized sulfides.

OP 31-93. Electrochemical Control of Sulfide Flotation Circuits, by Richardson, P.E.; Gebhardt, J.E.; Rice, D.A. Emerging Computer Techniques for the Minerals Industry, 1993 SME Symposium Proceedings, published by the Society for Mining, Metallurgy, and Exploration, Inc., Littleton, Co February 15-18, 1993. 307-317 pp. February 15-18, 1993. An improved understanding of the significant role of electrochemical reactions in sulfide flotation has evolved in the past 20 years. This understanding has been accompanied by a corresponding increase in attempts to control the electrochemical potential of flotation pulps for monitoring and controlling sulfide flotation circuits to improve metallurgical performance. This paper discusses the basic electrochemistry of sulfide flotation and the use of electrochemical potential as a control parameter.

OP 32-93. Selective Flocculation of Zinc Concentrate to Reduce Silica Contamination, by Hirt, W.C.; Rice, D.A. Preprint of SME-AIME Annual Meeting, Reno, Nevada, February 15-18, 1993, published by the Society for Mining, Metallurgy, and Exploration, Inc. Series 93-142, 9 pp. Selective flocculation was used to produce superclean zinc concentrate with minimized silica contamination. Research was carried out on a flotation concentrate from the Jersey Miniere Zinc Company (JMZ) in Gordonsville, Tennessee. This work has shown that selective flocculation offers a potential method

for cleaning flotation concentrates particularly where low products are required.

OP 33-93. Recycling of Contaminated Superalloy Scrap Via Electrochemical Processing, by Lutz, L.J.; Parker, S.A.; Stephenson, J.B. 1993 EPD Congress-Proceedings of symposia sponsored by the Extraction and Processing Division, and held at the TMS Annual Meeting. 1211-1220 pp. February 21-25, 1993. The U.S. Bureau of Mines has developed an electrorefining process to recover Ni, Co, Cr, and other metals from mixed and contaminated superalloy scrap is cleaned then directly electrodeposited as a Ni-Co deposit. The process recovers approximately 90 pct of the Ni-Co available from the scrap as a 99+ pct pure Ni-Co alloy. The economics of a facility producing 15mt/d of a Ni-Co alloy are also discussed.

OP 34-93. Electrodeposition of Lead Dioxide From Nitrate and Other Media, by Dattilo, M.; Bemelmans, C. ASM International Conference on Advanced Synthesis of Engineered Structural Materials 167-174 pp. August 31-September 2, 1992. The electrodeposition of lead dioxide on various substrates from nitrate and acetate media was studied by electrochemical techniques. This included scanning polarization curves and X-ray diffraction was used to show the relative amounts of the tetragonal (beta) and the orthorhombic (alpha) crystalline forms. High acid content in this electrolyte resulted in very brittle, poorly adherent coatings exhibiting larger grains and rougher surfaces.

OP 35-93. Fabrication of Composite and Net-Shape Materials by CVD From Iron Pentacarbonyl, by Visnapuu, A. ASM International conference on Advanced Synthesis of Engineered Structural Materials, August 31-September 2, 1992. Graphite and silicon carbide fiber-reinforced iron matrix composite and solid iron net-shape material was prepared by chemical vapor deposition (CVD) from $Fe(CO)_5$. multifilament SiC and graphite fiber strands and graphite fiber cloth were encapsulated in iron in a static, atmospheric pressure, single-chamber reactor. Results of metallographic, X-ray diffraction, Auger, electron microprobe, and chemical analyses of the nonequilibrium iron deposits are combined to present an interpretation of the deposit microstructure. Annealing treatments to enhance the structural properties of the composites are discussed.

OP 36-93. Biologically Mediated Depyritization of Large Sized Coal, by Sharp, Frederick A. Proceedings, Ninth Annual International Pittsburgh Coal Conference. October 12-16, 1992. 95-100 pp. The U.S. Bureau of Mines has previously shown that biologically mediated leaching could remove approximately 50% of the pyritic sulfur from coarse run-of-mine coal containing crystalline vein pyrite. In the current investigation, a conventionally cleaned and sized coal was leached in large heaps to remove finely disseminated pyrite. Based on leachate analysis, approximately 11.75% of the pyriite sulfur was removed from the coals in the heaps. Standard chemical analysis of the coal indicates that pyrite removal in the heaps varied from 18 to 29%. No significant change was observed in the coal's organic sulfur content or heating value.

OP 37-93. Beneficial Disposal of Fly Ash in Inactive Surface Mines, by Ackman, Terry E.; Kim, Ann G. Proceedings American Coal Ash Association, 10th Coal Ash Symposium, vol. 1 Series TR-101774. 23-1/23-4 pp. January 18-21, 1993. Within the Bureau's environmental program, fly ash has been evaluated previously for subsidence control and for fire barriers, and as an aid in revegetation. The current program focuses on the safe and economical disposal of coal-related wastes, such as fly ash, in abandoned surface or underground mines.

OP 38-93. Preparation of a Master Alloy From a Southern Oregon Laterite, by Nafziger, Ralph H. Extractive Metallurgy of Copper, Nickel and Cobalt, Vol 1. Fundamental Aspects (Proc. of the Paul E. Queneau Int. Symp., Feb. 1993, Denver, CO). The Minerals, Metals & Materials Society, ed. by R.G. Reddy and R.N. Weizenbach 653-658 pp. 1993. The feasibility of smelting a Ni-Co-Cr-bearing laterite ore from southern Oregon was evaluated by the Bureau of Mines. The objective was to prepare a master alloy for subsequent stainless steel production. A mixture of the ore with suitable reductants and flues was smelted in a 50-lb-capacity single-phase ac conditions. The smelting tests produced a metal in which most of the nickel was concentrated. High-chromium recoveries required an excess of carbon. The resulting metal alloys contain sufficient nickel for some stainless steels. Ferrochromium additions would be required to attain suitable chromium levels. This research was conducted under the Oregon Metals Initiative in cooperation with Walter B. Freeman.

OP 39-93. Upgrading Alabama Tantalum Concentrates, by Petersen, A.E.; O'Dell Jr., W.O.; Behunin, D.V. Preprint of SME-AIME Annual Meeting, 93-152, Reno, NV, February 15-18, 1993, published by the Society for Mining, Metallurgy, and Exploration, Inc. The Bureau of Mines conducted research on high-intensity magnetic separation methods for upgrading tantalum concentrates from Alabama. Process flow sheets were studied to maximize tin removal and minimize tantalum loss. Using laboratory-scale equipment, concentrates were produced which contained over 65% combined Ta_2O_5-Nb_2O_5. Up to 78% of the tin was recovered as a byproduct, Containing about 70% SnO_2. Only 1 to 5% of the tantalum reported with the tin byproduct. The producer subsequently incorporated high-intensity magnetic separation into its process flow sheet to provide concentrates for the National Defense Stockpile.

OP 40-93. Mathematical Modelling of Shear Flocculation Using a Genetic Algortithm, by Sharma, S.K.; Stanley, D.A.; Spears, D.R. Advances in Filtration and Separation Technology, Vol 6 New Filtration and Separation Equipment, American Filtraction Society February 1993. The U.S. Bureau of Mines has been studying the application of an in-line particle size analyzer for measuring particle size growth during both polymer and shear flocculation of mineral slurries. As part of the investigation a mathematical model was usedd to reproduce experimental data on floc growth. This model was applied to shear flocculation of a silica slurry and a different optimization technique was used. Also, more precise equipment was used to measure floc growth during testing.

OP 41-93. Hydrodynamics of Shear Floccuation, by Spears, D.R.; Stanley, D.A.; Sharma, S.K. Advances in Filtration and Separation Technology: New Filtration and Separation Equipment, American Filtration

Society Vol 6 433-443 pp. February 1993. The recovery of mineral values from slurries of fine particles is one of the most important problems facing the domestic industry today. Because of their size, fine particles cannot be efficiently separted in classifiers or gravity separators. Smaller particles have slow flotation. Kinetics, which result in poor separation efficiency. One approach to surmounting these problems has been to use polymers to selectively flocculate the mineral values from the nonvaluable portion of the slurry. The resulting mineral flocs can then be concentrated using conventional mineral separation processes.

OP 42-93. Dilution Considerations for the Rapid Flotation of Coal, by Susko, F.J.; Jordan, C.E. Advances in Filtration and Separation Technology, Vol 6 New Filtration and Separation Equipment American Filtration Society, February 1993. The U.S. Bureau of Mines has developed a rapid froth flotation system. Unlike conventional flotation, the rapid system separates the flotation process into two discrete unit operations: bubble-particle attachment and froth-pulp separation. In conventional flotation, the process of attaching the particle to the bubble and the subsequent separation of the bubble from the waste pulp interact significantly, making it virtually impossible to optimize one of the processes without sacrificing the effectiveness of the other. Separating the two processes makes it possible to optimize each process 926

OP 43-93. The Application of the Thrust Bolting Concept For Longwall Gateroad Support, by Tadolini, S.C.; Abshire, J.R. Proceedings Twenty-Third Annual Institute on Mining Health, Safety and Research, ed. Glenn Tinney, Alex Bacho, Michael Karmis, Publ. by VPI and State University, Blacksburg, VA. 137-145 pp. August 24-26, 1992. An innovation in coal mine roof support, developed by the Bureau of Mines, is currently being used in underground mines in the western United States. The technique, called "Thrust Bolting," converts a traditional passive roof support system, a full or partial column rebar bolt, into an active support system by following a specific installation process. The thrust bolting system provides two advantages for ground control. First, because the system is active, no roof movement is necessary to put the bolt in tension. This minimizes the possibility of strata separations in sedimentary roofs, minimizes progressive-type roof failures. Secondly, the tension placed on the system is independent of mechanical devices or torques. This eliminates the highlyvariable frictional losses that occur between the bearing plate and the bolt head and in thr threaded portions of traditional active support systems. These two improvements create a safer working environment for mining personnel.

OP 44-93. Principal Components Factors Analysis in Mineral Processing, by Stanley, Donald A.; Meredith, Donald L.; Harris, Jeffrey. Paper was published in Emerging Computer Techniques for the Minerals Industry, by the Society for Mining, Metallurgy, and Exploration, Inc. (83)-92 pp. 1993. Pricipal Components Analysis (PCA) is a versitile, multivariate statistical method that the Bureau of Mines is applying to mineral processing data to achieve data simplification and pattern recognition. The pricipal components are obtained from an eigenanalysis of the data matrix. To achieve data simplification PCA replacesa larger number of measured variables with a smaller set of pricipalcomponents and at the same time removes a significant amount of experimental error. Data simplification and error reduction make PCA useful in process control. Plots of the individual pricipal components form the basis of a pattern recognition technique that allows detection of significant variations in the structure of the data. These applications of PCA are illustrated with appropriate mineral processing data.

OP 45-93. Lineament Analysis to Evaluate Geologic Structure and Coal Mine Subsidence Potential in Colorado Springs, Colorado, by Peters, D.C.; Proceedings, Ninth Techmatic Conference on Geologic Remote Sensing, Pasadena, CA-Environmental Research Institute of Michigan Vol. 1, 579-580 pp. February 8-11, 1993. This research determines the extent to which lineament analysis can be used to identify geologic structures which may affect the location and migration of subsidence over abandoned underground coal mines in the Colorado Springs area. Ultimately, these techniques could be useful for identifying such geologic structures at other abandoned mine land (AML) sites. The results of this study indicate that the previously determined subsidence hazard zones (Dames & Moore, 1985) could be modified to take into account geologic structures as identified through remote sensing. Northwest-trending lineaments appear to have some impact on subsidence activity, probably by increasing the risk. Long, northeast-trending lineaments appear to decrease risk of subsidence, although the exact geological relationships are unclear. Other AML sites should be investigated through remote sensing and lineament analysis to aid in fully evaluating subsidence potential of the sites.

OP 46-93. Heavy Metals Removal from Small-Arms Firing Ranges, by Johnson, Jerold L.; Chirban, Denise D.; Karr, Leslie A. EDP Congress, 1993 (TMS Proceedings) 15 pp. Remediation of small-arms firing ranges is being investigated by the Naval Civil Engineering Laboratory and the U.S. Bureau of Mines. Scheduled closures of military installations, as well as the management of active ranges, require the development of methodologies for heavy metals removal to prevent their entering the surrounding environment. The impact berms contain high concentrations of metals, and the soil and vegetation surrounding the berms were found to have slightly elevated levels. Gravity beneficiation can remove liberated metal contamination effectively. Weak acetic acid leaching shows promise in lowering the final metal contamination to allow the soil to pass the EPA Toxicity Characteristic Leaching Procedure criteria.

OP 47-93. In-Line Static Mixer for Improved Flotation Kinetics, by Hood, G.D.; Jordon, C.E. Advances in Filtration and Separation Technology, Vol. 6, New Filtration and Separation Equipment, American Filtration Society 480-487 pp. February 1993. The U.S. Bureau of Mines has developed a rapid froth flotation system which separates flotation into two discrete unit operations: bubble-particle attachment and bubble-pulp separation. In the bubble-particle attachment unit, a bubble slurry is mixed with an ore slurry under highly turbulent conditions. The mixture is then rapidly fed into a quiescent bubble-pulp separation unit where the mineral laden bubbles are quickly separated from the pulp.

OP 48-93. High-Temperature Cyanide Leaching of Automobile Catalysts in a Process Development Unit, by Kuczynski, R.J.; Atkinson, G.B.; Walters, L.A. 1993 EPD Congress (Proceedings of Symposia sponsored by the

Extracting and Processing Division, and held at the TMS Annual Mtg. in Denver, CO, Feb. 21-25, 1993), ed. by John P. Hager, TMS Publications. 1005-1018 pp. The U.S. Bureau of Mines operated a batch process development unit for recovering platinum-group metals (PGM) from automobile catalysts. Virgin monolith, used monolith catalyst samples were tested. Leaching twice with 1-pct sodium cyanide (NaCN) solution in a pressure vessel dissolved over 95 pct of the PGM from virgin catalysts and over 90 pct from used pellet catalysts. PGM concentrates as metallic powder containing over 99.8 pct of the dissolved PGM and analyzing greater than 70 pct PGM Were recovered by heating the pregnant leach solutions from virgin catalysts and used catalyst. The solution after heating contained primarily sodium carbonate from cyanide decomposition and less than 0.2 ppm total cyanide.

OP 49-93. Removal of Metal Cations From Water Using Zeolites, by Zamzow, M.J.; Murphy, J.E. Separation Science and Technology (Special Issue on Application of Gas and Liquid Phase Adsorption), ed. by Orhan Talu and Shivaji, Marcel Dekker, Inc., NY. Vol. 27 Series 14 1969-1984 pp. 1992. Zeolites from abundant natural deposits were investigated by the Bureau of Mines for efficiently cleaning up mining industry wastewaters. Twenty-four zeolite samples were analyzed by x-ray diffraction and inductively coupled plasma. The 24 zeolites and an ion-exchange resin were tested for the uptake of Cd, Cu, and Zn. Of the natural zeolites, philipsite proved to be the most efficient, while the mordenites had the lowest uptakes. Sodium was the most efficient exchangeable ion for exchange of heavy metals. Wastewater from an abandoned copper mine in Nevada was used to test the effectiveness of clinoptilotite for treating a multi-ion wastewater. The metal ions in the copper mine wastewater were removed to below drinking water standards. Absorbed heavy metals were concentrated in the eluates up to 30-fold relative to the waste solution. Anions were not absorbed by the zeolites.

OP 50-93. Reduction of iron Oxides in a Novel Reactor Utilizing Rocket Technology, by Kazonich, G.; Gribben, T.P.; Walkiewicz, J.W. Proceedings of Paul E. Queneau International Symposium (sponsored by the Extraction and Processing Division of TMS and the Metallurgical Society of the Canadian Institute of Mining, Metal, and Petroleum (CIM), ed. by R.G. Reddy and R.N. Weizenbach. A prototype reactor incorporating rocket technology was designed and built. This rapid rate reactor was operated successfully and consistently made iron metal in less than 50 ms in a high temperature flow through reactor. Iron product was recovered inside the reactor and in a downstream cyclonic separator. The results of typical operation and how parametric changes affectedthe reduction of iron ore concentrates are discussed.

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ABBREVIATIONS

AML	Abandoned Mine Land Report
B	Bulletin
CP	Computer Product
IC	Information Circular
MCS	Mineral Commodity Summaries
MIR	Mineral Institute Report
MLA	Mineral Land Assessment Report
MP	Mineral Perspective
MYB	Minerals Yearbook
OP	Outside Publication
P	Patent
RI	Report of Investigation
SMS	State Mineral Summaries
SP	Special Publication

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