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GEOLOGIC AND ENGINEERING DATA ACQUISITION FOR UNDERGROUND COAL MINE GROUND CONTROL

prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

by

DAVID R. ALISON
EDVARD T. OHLSSON
KEVIN V. WHITNEY

CONTRACT NO. J0395010

ADL REFERENCE C-82800

ARTHUR D. LITTLE, INC.
CAMBRIDGE, MASS. 02140

JANUARY 1980

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Disclaimer

The views and conclusions contained in this report are those of the author's and should not be interpreted as necessarily representing the official policies or recommendations of the Interior Department's Bureau of Mines or of the U.S. Government.

FOREWARD

This final report was prepared by Arthur D. Little, Inc., Cambridge, Massachusetts, under USBM Contract No. J0395010, initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of the Roof Support Group, Pittsburgh Mining and Safety Research Center (PMSRC) with Noel N. Moebs acting as Technical Project Officer. Alan G. Bolton, Jr., was the contract administrator for the Bureau of Mines.

This final report is a summary of work recently completed as a part of this contract during the period January 1979 to November 1979. This report was submitted by the authors on January 1980.

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16. Abstract This study was conducted using field interview methods to determine the data and information requirements of the underground coal mining industry for improving mine ground control procedures in existing and future mines. The establishment of a central geologic and engineering information resource center with computer searchable abstract files that can locate and supply descriptive and case-study literature addressing specific mining problems is recommended. Research done under Bureau of Mines Contract J0395010, includes a Bibliography of Underground Coal Mine Ground Control Literature.			
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EXECUTIVE SUMMARY

A. OVERVIEW

Underground coal mine operators sometimes encounter abnormal conditions in the roof, rib or floor which are difficult to control and may be hazardous to employees. The Bureau of Mines is considering the establishment of a resource center which is capable of providing descriptive geologic and engineering information that will assist the mining industry in dealing with these ground control problems.

The objective of this contract was to determine the ground control data requirements of all segments of the coal mining industry--including mine operators, consultants, educators, researchers, regulatory agencies and equipment manufacturers. The Bureau further required the development of a logical and systematic plan of approach for establishing a data base management system (DBMS) for acquisition, storage and retrieval of relevant geologic and engineering information. This system would provide a central repository which would assist the coal mining industry, the Bureau, and other researchers in the design and development of safer, more efficient mining methods and equipment, better operations at existing and new mines, and the safe, economic development of coal reserves at greater depths.

The objectives of this report are to present the results of our extensive field interview program determining the industry's need for a Ground Control Data Repository, to identify potential users of this resource and their data requirements, and to evaluate available DBMS alternatives.

B. FINDINGS AND CONCLUSIONS

The first phase of this program required determination of the need for proposed repository, those segments of the underground coal mining industry that would be most likely to use the repository, and the data items that would be most likely requested. As the result of extensive field and telephone interviews, it was found that the management and engineering personnel directly involved in mine operations had the greatest need for (and interest in) a geologic and engineering data repository. During these interviews, the types of data most often recommended for inclusion in the repository were:

- Reports describing the relationship or affect of natural conditions on mining/roof control experience.
- Specific design criteria for barrier and chain pillars based upon geological and geotechnical factors.
- Case studies describing the methods used at different mines in dealing with a specific ground control problem.
- The results of experimental testing of new ground control techniques or equipment (e.g., roof-trusses and split-set bolting).

The second phase of the study, which developed concurrently with the latter stages of the interviews, was designed to identify the potential sources and availability of information to be included in the proposed repository. All of the mining companies consider in-house studies, drill logs and other raw data as proprietary information that would not be available for the proposed repository; the companies were, however, very helpful in identifying--and in some cases providing--copies of studies which had been

presented to professional society meetings, published in technical or trade journals, or which had received public funding support. The other industry sources were also willing to provide only previously published information.

After careful evaluation of numerous repository organization alternatives and information acquisition, storage and retrieval options, it was concluded that, to be most responsive to industry needs, the repository should:

1. Be an independent repository established within the Roof Support Research Group at PMSRC.
2. Acquire available information from existing Bureau of Mines files, mining libraries, major authors, mining companies, leading researchers and universities, professional societies, technical publications and other identified resources.
3. Store the data and information in the following formats:
 - All textual documents and data records to be kept in microform when the documents are commercially available in this format;
 - Graphic documents where scalar relationships or color-coded information is not critical should be retained only on microfiche;
 - Scaled and/or color drawing and maps should be retained in hard-copy;
 - Bibliographic information for all documents should be retained in a computer searchable citation/abstract file.

4. Identify and retrieve requested information using a computerized Data Base Management System (DBMS) with a coordinate-type Primary Subject Index and Data Finder.

A procedure for storing acquired information and data in the repository is illustrated in Figure A, and a retrieval process in Figure B. Utilizing a computerized index in the illustrated storage/retrieval system would require an addition to the staff at the PMSRC Roof Support Research Group of only one full-time repository administrator/librarian. Assuming the commercial availability of microfiche copies of most documents, the physical space requirements for information storage would be limited to one modest-sized office equipped with microfiche storage files, a reader/printer and a remote computer terminal.

C. RECOMMENDATIONS

Based upon the interest expressed in the proposed repository during the field and telephone interviews, it is recommended that the Bureau of Mines establish an aggressive Ground Control Repository. This repository would be capable of rapidly providing geologic and engineering case-study reports and other relevant information to mining engineers and mine operating personnel when specific ground control problems arise.

It is further recommended that the computer and File Management System (FMS) software currently available at the PMSRC Computer Center be utilized as an efficient, cost-effective method of information indexing, storage and retrieval. This system would provide for the rapid identification and location of all information in the Ground Control Repository which dealt with any specific subject; it would also provide the capability of easy conversion

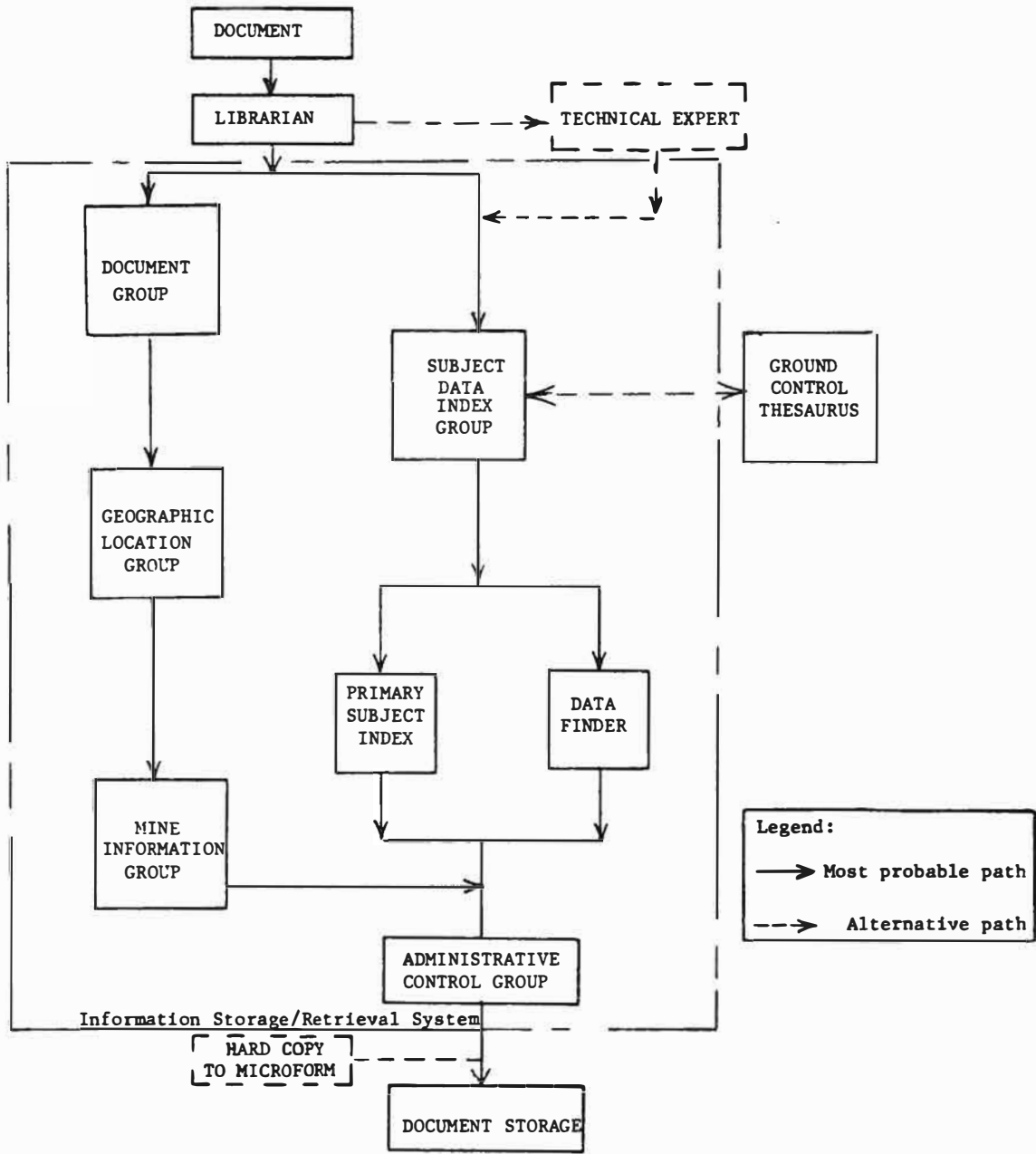


FIGURE A - DOCUMENT ACQUISITION, INDEXING AND STORAGE

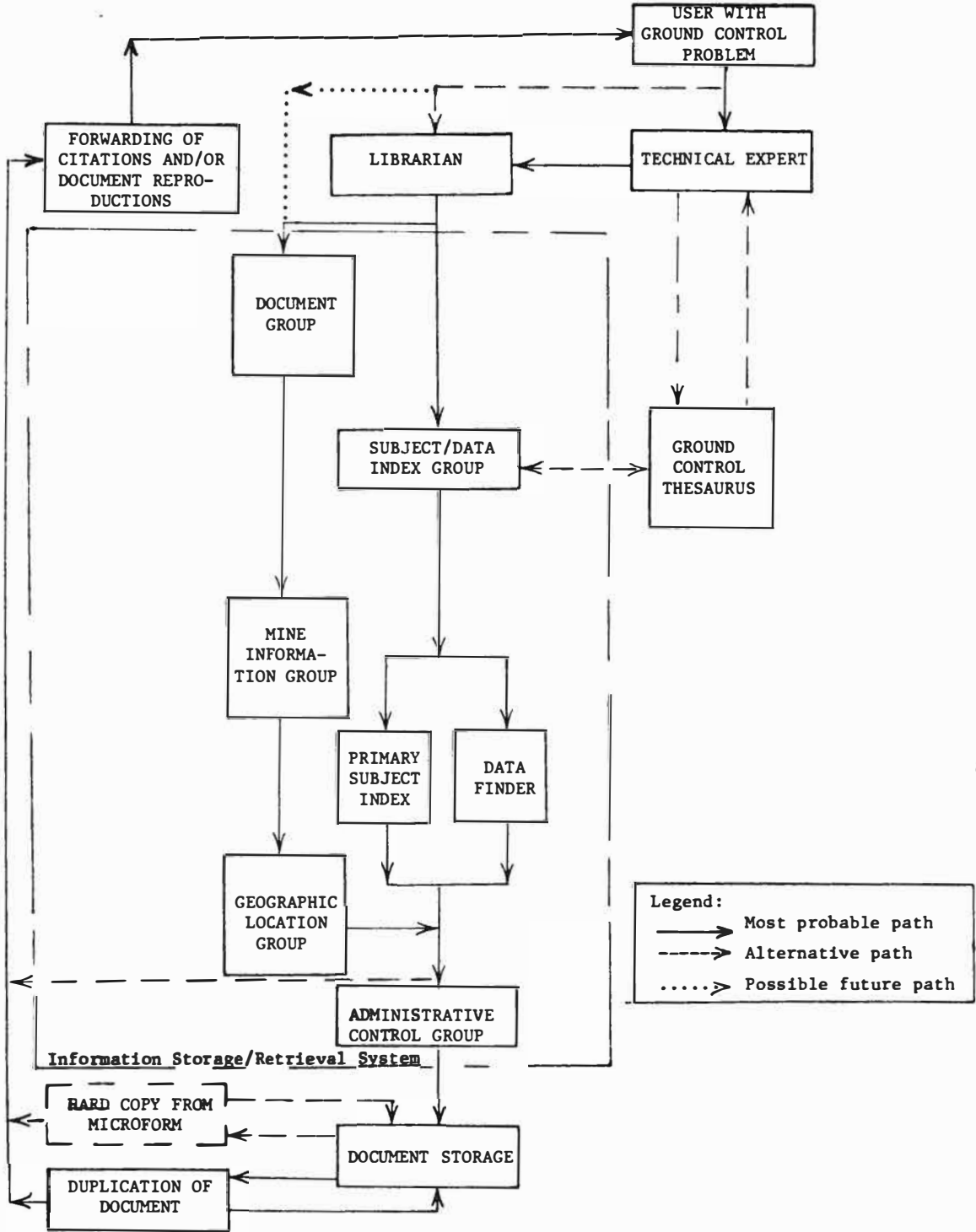


FIGURE B - INFORMATION REQUEST AND DOCUMENT RETRIEVAL

to a more dynamic DBMS (possibly on a national timesharing network) if the information demands placed on the recommended system became too great.

INTRODUCTION

The design of safe and stable openings in underground coal mines is one of the primary goals of the mine engineer. The objective of this investigation was to assist the Bureau of Mines in developing a central repository of geologic and engineering data which will provide engineering and physical property information on mining conditions and ground control procedures needed for proper design of new underground coal mines, the expansion of existing underground coal mines, selection of safer and more efficient mining methods and equipment, and the safe, economic development of coal reserves at greater depths.

To achieve the objectives of this investigation, four general topics were included in this study:

- User Requirements -- The potential users of a geologic and engineering data repository for underground coal mine roof control information were identified and their information requirements defined during extensive field and telephone interviews.
- Data Availability and Collection -- The sources from which the required data and information can be acquired were identified, and the type of available information categorized.
- Data Organization -- A systematic and logical data collection procedure and recording format were developed.
- Storage and Retrieval -- A systematic method of organizing the acquired geologic and engineering information which permits the rapid retrieval of ground control information was recommended.

The Pittsburgh No. 8 Seam in Pennsylvania and West Virginia, and the Herrin (No. 6) Coal in Illinois, which have been mined by many different underground methods over a long period of time, were selected as the primary focus for this investigation. It was believed that there have been many detailed studies of these two coalbeds which would provide the greatest range of geologic and engineering data from the broadest cross-section of potential information sources. The Pittsburgh and Herrin seams were used as examples for determining user requirements and data availability, and the recommended data acquisition program and organization format were tested using the information available from these two coalbeds.

I. USER REQUIREMENTS

Potential users of a central repository of geologic and engineering data for underground coal mine ground control may include the operating and development divisions of coal mining companies, mine planning consultants, equipment manufacturers, mining research organizations, and regulatory agencies. The interests of potential users in these industry segments range from pure rock mechanics research, through design of new mines and implementation of new mining systems, to solution of a specific roof control problem in an operating mine.

To determine the degree of interest in the proposed repository and the data which would most likely be required by each type of user, a number of in-depth personal and telephone interviews were conducted with the people in the various segments of the industry. (The organizations contacted are listed in Appendix A.) It was determined from these interviews that the industry need was for a central resource which contained narrative, case-study information describing the experiences of other mining people in solving practical mining problems, developing mine design criteria, performing pre-mining investigations, and mine subsidence prediction and control.*

*It should be noted that, at the outset of this program, the repository was envisioned to contain geologic and physical property data obtained from drill logs, rock mechanics testing, and other similar sources. It became apparent in the earliest interviews that this type of data was available in only limited quantities, on differing and inconsistent reporting bases, and only used for a few specific studies. Most people interviewed considered this type of data to be proprietary in nature and, if they needed specific information they would develop it themselves but not release it to anyone else.

A summary of the major user classes and their information requirements include:

- Mine Planning Consultants -- Both the independent consulting firms and the central engineering departments of major mining companies fall into this user class. They would like to have access to geotechnical data in areas where little exploration or previous mining has taken place, state-of-the-art studies which accurately correlate geologic information with mining conditions, and entry/pillar design criteria based on geotechnical and geologic data.

- Mine Operators -- The personnel involved with day-to-day mining operations and engineering are included in this class. Those operators which can draw upon the resources of a central engineering group may not use the proposed repository as extensively as those that operate the smaller mines; however, all potential users in this class expressed the need for help in solving specific problems which do not occur during normal operations. Some of these problem areas mentioned were coal pillar size and design criteria, descriptions of how other mines have solved roof control problems similar to the one which they are currently experiencing, or the effects of lateral stresses on mine roof and floor rock.

- Mine Equipment Manufacturers -- The manufacturers of mining machinery and roof control products, and their sales representatives, are included in this class. This group expressed little interest in a repository, but it is expected that geomechanical data (e.g., compressive strength, hardness, etc.) would be of some interest to equipment designers, and the identification of mines with unresolved ground control problems would be of assistance to sales representatives.
- Educational Institutions -- College and university mineral engineering departments are primarily interested in developing and analyzing statistical data on rock mechanics properties and the basic geologic environment. Some university researchers are also interested in attempting to correlate mining experience with geologic and geophysical logs and rock mechanics properties. To maintain a desired level of confidence in their studies, most researchers insisted on using only data which they had developed or for which there was extensive documentation.
- Government Organizations -- In addition to the Bureau of Mines, other federal organizations which may use the repository are DOE, USGS, MSHA, EPA, and OSM; state agencies in this class include state mine inspectors, geologists, and environmental agencies (i.e., those agencies concerned with mine subsidence control, land reclamation, acid mine drainage, etc.). This class would use the repository for a variety of reasons including mine safety research, mine productivity improvements and regulatory activities.

Table 1 lists the specific types of geologic and engineering data within each of the four general categories which the various organizations use in their ground control studies. Based on the interviews, a repository of statistical data was not considered as useful to any of the potential user classes as a problem-oriented repository of case studies would be.

TABLE 1

UNDERGROUND COAL MINE GROUND CONTROL DATA AND INFORMATION REQUIREMENTS
OF DIFFERENT ORGANIZATION TYPES

	Type of Organization Concerned with Underground Coal Mines Ground Control ^{1/}				
	Planning and Design	Operating	Equipment Manufacturing	Research	Regulatory
<u>I. PRE-MINING INVESTIGATIONS</u>					
A. Remote Sensing					
1. Lineament Analysis	✓	S	0	✓	✓
2. Geophysical Exploration	S	0	0	✓	0
B. Geologic Data					
1. Borehole Lithology Log	✓	S	0	✓	S
2. Mechanical Log	S	S	0	✓	0
3. Rock Quality Classification	S	S	S	✓	0
4. Irregularities and anomalies	✓	✓	S	✓	S
C. Geologic Mapping					
1. Topography	✓	S	0	✓	S
2. Rock Type					
a. Surface	S	0	0	✓	0
b. Coalbed roof	✓	✓	S	✓	S
c. Coalbed floor	✓	S	S	✓	0
3. Structural					
a. Coalbed roof	S	S	0	✓	S
b. Coalbed floor	✓	✓	0	✓	0
c. Basement rock	S	0	0	✓	0
4. Lineaments					
a. Faults	✓	✓	0	✓	S
b. Joints	✓	S	0	✓	S
c. Cleats	✓	✓	0	✓	0
5. Lithologic Profile/Cross-Section	✓	S	0	✓	S
6. Isopack/Thickness					
a. Coalbed	✓	✓	✓	✓	S
b. Overburden	✓	S	0	✓	0
D. Other Concerns					
1. Methane drainage/recovery	S	S	✓	✓	✓
2. Hydrology	S	0	0	✓	S
<u>II. MINE DESIGN</u>					
A. Rock Mechanics Data					
1. Measured Properties					
a. Compressive Strength	S	0	S	✓	0
--uniaxial or unconfined					
--triaxial					
b. Shear Strength	S	0	S	✓	0
c. Tensile Strength	S	0	0	✓	0
d. In-Situ Stress Field	S	0	0	✓	S
-- Direction and magnitude of					
maximum horizontal stress					
-- Magnitude of minimum					
horizontal stress					
e. Shore Hardness	S	S	✓	✓	0
f. Specific Gravity	S	0	0	✓	0
g. Porosity, Water Content	S	S	0	✓	S
2. Calculated Properties					
a. Coefficient of Internal Friction	0	S	0	✓	S
b. Poisson's Ratio	0	0	0	✓	0
c. Modules of Elasticity	S	0	0	✓	0
(Young's Modules)					
d. Modules of Rigidity	S	0	0	✓	0
e. Bearing Capacity/Strength	S	✓	S	✓	S
3. Theoretical Evaluation Procedures					
a. Finite Element Modeling	S	S	0	✓	0
b. Photo-elastic Models	0	S	0	✓	0
B. System Roof Control					
Methods					
1. Temporary Supports					
a. Jacks	S	✓	0	S	✓
b. Beams	S	✓	0	S	✓
c. TRS Systems	✓	S	✓	✓	✓
2. Timber Supports	S	✓	0	S	✓
3. Roof Bolts					
a. Mechanical	✓	✓	S	S	✓
b. Grouted					
-- Resin	✓	✓	S	✓	✓
-- Inorganic Cement	S	✓	S	✓	✓

Table 1 Cont'd.

<u>Table 1 - Continued</u>	<u>Planning and Design</u>	<u>Operating</u>	<u>Equipment Manufacturing</u>	<u>Research</u>	<u>Regulatory</u>
c. Split-set	S	✓	S	✓	✓
d. Roof Truss	S	✓	✓	✓	✓
e. Wooden pins	O	O	O	S	S
4. Longwall					
a. Frames	O	S	✓	S	S
b. Chocks	✓	✓	✓	✓	S
c. Shields	✓	✓	✓	✓	S
d. Chock-shields	✓	✓	✓	✓	S
e. Packwall	S	S	S	✓	S
f. Yielding pillar	S	S	O	✓	S
5. Steel Supports					
a. Rigid beams and cracks	S	✓	S	✓	S
b. Yielding arches	✓	✓	S	✓	S
c. Tunnel Arches	✓	S	S	✓	S
6. Support Patterns					
a. MSHA Requirements	✓	✓	S	S	✓
b. Roof Control Plans	S	✓	O	S	✓
c. Fall Bolting Procedures	O	✓	O	S	✓
C. Mining Methods					
1. Room/Entry-and-pillar					
a. Partial recovery	✓	✓	O	S	✓
b. Pocket-and-wing	✓	✓	O	S	✓
c. Retreat	✓	✓	O	✓	✓
2. Longwall					
a. Advancing	✓	✓	O	✓	✓
b. Retreat	✓	✓	O	✓	✓
c. Advancing-retreat	S	S	O	✓	S
3. Other					
a. Shortwall	S	S	S	✓	✓
b. Hydraulic	O	O	O	✓	S
D. Mining Dimensions					
1. Regulatory Requirements	✓	✓	O	S	✓
2. Physical Design Criteria					
a. Pillar	✓	✓	O	✓	✓
b. Barrier	✓	✓	O	✓	✓
c. Entry, crosscut, room	✓	✓	O	✓	✓
d. Longwall/shortwall panel	✓	✓	S	✓	S
E. Equipment Applications and Specifications					
1. Conventional					
a. Cutter	S	✓	✓	S	S
b. Face drill	S	✓	✓	S	S
c. Blasting					
--explosive	✓	✓	O	✓	✓
--airtox	✓	✓	S	S	✓
--cardox	✓	✓	S	S	✓
d. Mobil loader	S	✓	✓	S	S
2. Continuous					
a. Continuous miner					
--Milling	✓	✓	✓	✓	S
--Boring	✓	✓	✓	✓	S
--Auger	✓	✓	✓	✓	S
b. Face Haulage					
--Shuttle car	✓	✓	✓	✓	S
--Mobile belt	✓	✓	✓	✓	S
c. Roof Bolter	✓	✓	✓	✓	✓
3. Longwall					
a. Plow	✓	S	✓	✓	✓
b. Shear					
--Fixed or ranging	✓	✓	✓	✓	✓
--Single or double drum	✓	✓	✓	✓	✓
c. Supports					
--Frame	S	S	✓	✓	✓
--Chock	✓	✓	✓	✓	✓
--Shield	✓	✓	✓	✓	✓
--Chock-Shield	✓	✓	✓	✓	✓
d. Armoured Conveyor					
4. Transportation					
a. Rail					
--Trolley	✓	✓	✓	S	✓
--Battery	✓	✓	✓	✓	✓
--Diesel	✓	✓	✓	✓	✓
--Monorail	✓	S	✓	✓	✓
b. Rubber Tired	✓	✓	✓	✓	✓
c. Conveyor	✓	✓	✓	✓	✓
d. Pipeline					
--Hydraulic	S	S	✓	✓	✓
--Pneumatic	O	O	✓	✓	✓

Table 1 Cont'd.

<u>Table 1 Concluded</u>	<u>Planning and Design</u>	<u>Operating</u>	<u>Equipment Manufacturing</u>	<u>Research</u>	<u>Regulatory</u>
F. Special Systems/Applications					
1. Difficult Geology					
a. Thick Seam	✓	S	S	✓	S
b. Steeply Dipping Seam	✓	S	S	✓	S
c. Multiple Seams	✓	✓	S	✓	✓
2. Methane Drainage					
a. Pre-mining	✓	✓	✓	✓	S
b. During Mining	✓	✓	S	✓	✓
c. Post-mining	✓	S	S	✓	✓
3. Water/Hydrology Problems	S	S	O	✓	✓
III. MINING PROBLEMS					
A. Roof Falls					
1. Unintentional	✓	✓	S	✓	✓
2. Pillar Recovery	✓	✓	S	✓	✓
3. Longwall	✓	✓	S	✓	S
B. Pillar Crushing	✓	✓	S	✓	✓
C. Floor Heave or Squeeze	✓	✓	O	✓	✓
D. Geologic Anomalies	✓	✓	O	✓	✓
E. Bumps and Gas Outbursts	✓	✓	O	✓	✓
IV. MINE SUBSIDENCE					
A. Regulatory Requirements	✓	✓	S	S	✓
B. Instrumentation	S	S	✓	✓	S
C. Measurements					
1. Vertical Displacement (profile)	✓	S	O	✓	✓
2. Horizontal Displacement	S	O	O	✓	S
3. Relationship to Mining	S	S	O	✓	✓
4. Surface Features					
a. Cracks	S	S	O	✓	✓
b. Bulges	S	O	O	✓	✓
c. Troughs	S	S	O	✓	✓
d. Sink-holes	S	S	O	✓	✓
D. Calculated Data					
1. Angle of Break or Draw	✓	S	O	✓	S
2. Bulking/Swell Factor	✓	S	O	✓	S
E. Subsidence Modeling/Prediction	S	O	O	✓	✓

NOTES: ✓ = Major Interest.
 S = Secondary Interest.
 O = Little or No Interest.

Source: Arthur D. Little Interviews.

II. DATA AVAILABILITY

To determine the availability of engineering data and case study information, two different avenues of investigation were followed:

- During the latter stages of each interview we requested representative examples of information types which the respondent felt should be included in the repository, and
- A search of four on-line literature data bases was conducted to determine the extent of the published literature on underground coal mine ground control in the Pittsburgh and Herrin coalbeds.

The majority of the interview respondents were very willing to provide copies of technical papers and journal articles which they or others in their organization had developed. All those interviewed were very reluctant to provide basic, raw data items (e.g., drill core logs, geomechanical test results, etc.) for these reasons:

1. Mining companies considered drill logs and core analysis to be proprietary information that could not be released.
2. Much data was unorganized--it was usually spread-out in numerous different file cabinets--and to satisfy a request for more than two or three specific items would require much time and considerable effort.
3. No one could see any significant advantage (but numerous disadvantages) to making their data available to other people.

A brief on-line search of Chemical Abstracts, Engineering Index, Geological Index and the NTIS data base was performed using the key-word descriptors listed in Table 2. Based on this on-line search and in-house information, a Bibliography of Underground Coal Mine Ground Control Literature was developed, and is included as Appendix B.

As a result of the interview responses from potential repository users--particularly their concerns with proprietary information and the potential dangers from the indiscriminant use of inappropriate or improperly selected data values--the expressed need for a comprehensive resource with case-study and mining experience descriptions, and the apparently large number of published studies which examine numerous ground control problems--it was determined that a repository of underground coal mine ground control literature would effectively fill a specific need of the coal mining industry.

TABLE 2

KEY-WORD DESCRIPTORS USED FOR LITERATURE SEARCH

Set	Items	Description	
1	711	COAL(W) MINING	
2	3816	COAL(W)MINES	
3	1	COAL MINING	
4	2	COAL MINES AND MINING	
5	711	COAL(W)MINING	
6	3970	10R20R3	
7	2558	ROOF?	
8	509	BAND7	
9	81523	CONTROL	
10	195	BAND9	Coal mine roof control
11	55	PITTSBURG	
12	10	HERCIN	
12	5	ILLINOIS(W)6	
14	1	BAND11	
15	2	BAND12	
16	0	BAND13	
17	5630	PITTSBURGH	
18	0	BAND16	
19	42	BAND17	
20	8225	GEOLOG?	
21	6	19R120	
22	0	6AND12AND20	
23	14	6AND17AND20	
24	8	2300121	
25	114	GROUND(W)CONTROL	
26	4	6AND20AND25	
27	37	6AND20AND25	
28	33	27R1126	
29	29	20R1123	
30	5691	110R120R130R17	
31	0	29AND30	
32	6	20AND20AND20	
33	447	SUBSIDENCE	
34	1078	SETTLING	
35	138	6AND33OR34	Coal mine subsidence
36	2	30AND35	
37	2430	ROCK(W)MECHANICS	
38	2371	ROCK MECHANICS	
39	2430	37OR38	
40	11933	COAL	
41	314	39AND40	Coal rock mechanics
42	9	30AND41	
43	37	20AND41	
44	36	43NOT42	

III. REPOSITORY ORGANIZATION

The successful establishment of a functional information repository or library is dependent on the interaction of many complex factors. To assure that these factors are adequately evaluated, the following questions must be carefully considered and the resulting conclusions incorporated in the repository organization:

- Who will be the primary users of the repository?
- What information will they require?
- Should the repository stand alone or be part of a larger repository/library system?
- Should the repository store basic raw data values, complete copies of textual and/or graphical information (and in what format), or just citation data with brief abstracts?
- From what sources should the information be acquired?
- Should the information indexing system be a recognized, formal system (i.e., Dewey Decimal or Library of Congress), patterned after other existing index systems (e.g., Bureau of Mines libraries, NASA library, NTIS index, etc.) or a system specifically designed for this repository?
- Should the repository index be restricted to data items (i.e., locations, numbers, measures, etc.), case study descriptions of specific topics, or some combination of these?
- How will users gain access to the repository?
- Should document copies, document citations and/or document locations be supplied to repository users?
- What is the most efficient organizational structure for the repository?

The following sections discuss these and other questions, some preliminary conclusions are reached and guidelines are recommended to the Bureau of Mines for the establishment of a Repository for Geologic and Engineering Information Relating to Underground Coal Mine Ground Control.

A. Repository Users and Information Needs

The potential users of this repository and their particular information needs were discussed previously in this report.

During the course of this investigation, the Bureau's primary objective has always been to develop a repository for the coal mining industry which would provide information on mine ground control conditions needed for proper design of new underground coal mines, the expansion of existing underground coal mines, selection of safer and more efficient mining methods and equipment, and the safe, economic development of coal reserves at greater depths. While it was recognized that other uses would be made of the repository, these were determined to be secondary to the requirements of the mining companies. As a result, it is recommended that the repository be organized primarily to help the mine operators rapidly locate information which specifically addresses particular ground control problems as they arise.

B. Independent Repository or Part of a Larger Library

If this repository were to become part of a larger repository/library system, the advantages would include:

- No additional staffing requirements;

- Little or no additional cost for shelf and storage space required;
- The location and access methods will be known to the users.

Disadvantages of adding this repository to an already established system include:

- It would be difficult to modify an established indexing system to include the special requirements of the new repository;
- The existing staff may not be willing or technically capable to assume the additional duties and responsibilities required by the new repository;
- The established information storage system and/or format may not satisfy the requirements of the repository or its users;
- It would be very difficult to provide electronic access to the ground control repository without reworking the complete library system.

If, on the other hand, the repository were established as an independent operation, the following problems would be encountered:

- A person knowledgeable in the technical subject area must be available for indexing the numerous citations and assisting repository users in finding the desired information;
- The tasks of document acquisition, abstracting, cataloging, storage, and retrieval will require a full-time librarian;
- The repository will require physical space which is easily accessible by potential users in addition to facilities and equipment which will provide adequate document cataloging and storage as the repository expands.

- The expense of a computerized storage/retrieval system could be significant.

The major advantages of an independent repository include:

- The repository can be tailored to efficiently respond to the specific needs of each user;
- The repository can be designed for easy expansion;
- Modern computer technology for information indexing, storage, retrieval and transmission can be included with only minimal operator training requirements;
- The repository will provide the industry with a needed, unique resource for solving significant health, safety, and productivity problems that exist in underground coal mines.

While it is difficult to place a value on many of the specific advantages or disadvantages of either the library associated repository or the independent repository, most mining companies interviewed indicated a preference for the independent repository. It was generally felt that an independent repository could better address the specific technical questions raised by the mine operators and would be better equipped to quickly provide detailed information which was relevant to the problem. It is, therefore, recommended that the establishment of an independent repository within the Roof Support Research Group at PMSRC be given priority over forming the repository as a sub-function of a large library such as the Bureau's main library in Pittsburgh.

C. Format for Information Storage in the Repository

The three types of information which could be stored in the repository are engineering data, textual and graphical.

The engineering data includes:

- Geologic drill log descriptions
- Core analysis (geologic, mechanical and chemical)
- Geophysical logs and strip-charts
- Physical property data
- Rock quality classification (RQD, Kiruna factor, Bienowski system)
- Field and laboratory notes
- Computer programs, input data and print-outs.

The textual type includes:

- Bureau of Mines research reports (i.e., Information Circulars, Reports of Investigation, Open-file Reports, etc.)
- Textbooks and magazine articles
- Theses
- Technical publications
- Professional papers
- Questionnaires and industry surveys
- Mining experience case studies

The graphical type of information includes:

- Geologic maps
- Mine maps
- Roof Control plans
- Photographs and diagrams

- Equipment specifications (e.g., blueprints or diagrams of mechanical, electrical and hydraulic systems).

The three information types can be stored in the repository in a number of different formats, including:

a) Citation/Abstract File -- This format would be the most efficient repository information storage system in terms of storage space and equipment requirements. This system would store only bibliographic information (i.e., author's name, title and date of publication), a brief descriptive abstract of the document, and possibly the location of a microform or hard copy of the referenced information. While this may be a low cost format, it will probably be considered unresponsive and of only very limited usefulness by all potential users except those who have access to a large technical library.

b) Hard copies -- Printed copies of data summaries and textual information are easily stored using the traditional library bookshelf system; maps, drawings and other graphical materials will require special storage equipment to protect and preserve these graphical documents.

c) Microform -- Data records and textual documents can be retained on microfilm or microfiche with a substantial savings of file space--and most government publications and technical journals are commercially available in this format today. Microfiche storage of graphical information permits a very large reduction in storage space but has two serious drawbacks when used with some specific document types: (1) the scaler character of maps is distorted or lost unless specific precautionary measures are taken, and (2) color information on geologic maps, equipment drawings and photographs is not retained.

d) Computerized -- Data records and textual information which are computerized provide the capability of very rapid statistical manipulation and/or searching (eliminating the need for indexing and filing systems), but requires the task of entering the information into the computer; the keypunch method of data entry for numerical and narrative information (excluding illustrations, maps, diagrams, figures, etc.) is the usual procedure, but optical scanning equipment can be used in some applications. Bureau of Mines experience with converting graphical information into a computer compatible format using both hand-coding sheets for keypunching and a digitizing device showed these methods to be very time-consuming; current optical scanners were found not to be suitable for digitizing mine maps (121)*.

While each of these formats has certain advantages, each also has some disadvantages. If, however, they are judiciously combined, the advantages of each format could be retained and the individual disadvantages minimized. The following combined format is recommended for this information repository:

1. Textual documents and data records should be stored on microform when that format is commercially available; hard-copies should be retained only when a commercial microform is not available--these hard-copy documents may be converted to microform at a later date if format consistency or space requirements within the repository becomes critical.
2. Graphic documents where scalar relationships or color-coded information is not critical should be retained only on microfiche whenever possible; only scaled and/or color drawings and maps should be retained in hard-copy.

*Underlined numbers in parentheses refer to items in the Bibliography (Appendix B).

3. All documents should be included in a cross-referenced Citation/Abstract File; this file should be established in a computerized format, speeding up the search and location process. Also included in this file should be citation, cross-indexed document identifiers and source location information on documents that are not available at this repository but which are relevant to the subject area (e.g., maps of abandoned mine workings available from the Bureau's Mine Map Repository in Pittsburgh, Mine Roof Control Plans available at MSHA district offices and mines, and proprietary data or studies--such as drill core analyses--which would not be available to the general public but may be released to the serious technical investigator).

D. Sources of Information

One of the first tasks a newly established library or repository faces is rapidly acquiring a large number of documents--a library with very few volumes is practically useless. It is expected that the Ground Control Repository will begin by acquiring all published Bureau of Mines research studies concerned with coal mine ground control. While the Bureau's publications are well regarded by the mining industry and thoroughly examine many ground control problems, there are only a limited number of these reports and they are generally available to mine operators directly from NTIS; they must, therefore, be supplemented by information from other sources.

These other sources include:

- Technical journals
- Trade magazines
- Professional society transactions, monographs and pre-prints
- Proceedings and papers presented at technical symposia
- Academic research and theses
- Studies funded by public agencies other than the Bureau of Mines
- Internal mining company studies (most are unpublished)
- Textbooks
- Bibliographies and lists of references included in most technical publications
- Articles in general circulation magazines and newspapers
- Drills logs reported to state agencies
- Mining applications, permits, plans and maps submitted to regulatory agencies
- Patents or patent applications for roof control equipment, materials, systems and concepts.

While documents within many of these areas are available from commercial sources, no one resource can provide them all. (If one could, this repository would not be necessary.) From the numerous potential sources, it is expected that the Bureau will have current subscriptions to many of the leading technical journals and trade magazines, and these periodicals should be used as the second document source.

The third document source should be the Bibliography of Coal Mine Ground Control Literature prepared as background information for this study and included as Appendix B to this report. The documents which were not included in the first two sources (Bureau reports and technical publications) should be available from the Bureau's main library in Pittsburgh.

These three sources can be expected to produce a core collection of at least 500 documents from which the repository can begin growing. After the core collection has been acquired and cataloged, there will be numerous paths of action which can be followed to gather more documents. Among these paths, many of which can be followed simultaneously, are:

- Requesting members of the PMSRC Roof Control Group to provide the repository with ground control reports, data and other documents, contained in personal files.
- Requesting members of other PMSRC and DOE-Bruceton research groups to provide reports and studies which deal with coal mine ground control problems.

- Request members of other Bureau research centers and other federal agencies (e.g., DOE, MSHA, OSM, USGS) to provide reports and studies dealing with underground coal mine ground control problems.
- Search NTIS, Superintendent of Documents and other federal government sources for ground control documents.
- Search commercially available general engineering indexes and abstracting services for ground control documents.
- Search Comprehensive Dissertation Abstracts for theses which address coal mine ground control problems.
- Write known authorities on the subject and request complete publication lists (and document copies, if available).
- Personally contact the senior engineering and management people within the mining industry to obtain information (and document copies, if available) on published reports and in-house studies which discuss underground coal mine ground control problems.
- Contact professors of geology and mining engineering to obtain publication lists, summaries of work-in-progress, instructional course material and other information on ground control.
- Contact professional societies, symposium sponsors, trade associations and similar organizations for copies of their publications which address coal mining ground control problems.
- Contact mining equipment and roof control material manufacturers for roof control equipment design and operating manuals, roof control material design specifications, application recommendations and testing results, lists of installations/customers, and any other relevant literature, publications, and documentation available.

- Contact labor union safety officials for copies of roof fall investigation reports and other information relating to ground control problems.

It is expected that all of these sources will be able to provide some input to the repository, but some will be more helpful than others. It is also expected that other sources in addition to those listed will be identified during the early stages of document acquisition that can also contribute to the repository.

Document acquisition will be a continuing program which will go through five stages of development. These stages are:

1. Rapid acquisition of recently published (1975 and later) case studies and reports of investigations.
2. Establishment of contacts for direct acquisition of newly published works.
3. Literature search and acquisition of older (pre-1975) and lesser known studies.
4. Location and acquisition of unpublished studies.
5. The addition of foreign language studies to the repository (with, at a minimum, an English language abstract).

E. Index Organization

The ground control problems most often mentioned by mine operating and engineering personnel during the earlier interview phase of this study fell into two basic categories: (1) coal pillar size/design criteria, and (2) the relationship or affect of natural conditions on mining and roof control experience. Since the repository will be established primarily to assist the mining industry in solving specific ground control problems as they arise, the index

must be tailored so as to be responsive to these problem areas.

A Primary Subject Index (Table 3) is therefore proposed which can be incorporated within a coordinate indexing system, includes both ground control problems and mine design subject areas of concern to mining personnel, and can be easily expanded to incorporate other ground control subjects as necessary.

This primary index should be supplemented with two additional reference aids: a roof control thesaurus and a data finder.

- Roof Control Thesaurus -- This is required because many specific natural conditions, mining practices and materials are given various differing names in different coal fields. (For example, an extremely hard concretion in the mine roof shaped like a flattened ball is called a "kettle bottom" in some locations and a "niggerhead" in others; but a cylindrical mass formed by a fossilized tree trunk at the top of the coal seam which is so poorly jointed to the roof as to drop out unexpectedly is also called a "kettle bottom" in some localities and a "horseback" in others. 12) The thesaurus can most easily be developed by the person who is responsible for document indexing and retrieval at the repository, and it could be based on an existing thesaurus such as Coal Thesaurus used to index the International Energy Agency's (IEA) Coal Abstracts. The definition of any term that has an indeterminate or questionable usage and is encountered during the indexing of a document or as part of an information request should be looked up in the Bureau's Dictionary of Mining, Mineral, and Related Terms, and then added to the thesaurus.

TABLE 3
PROPOSED PRIMARY SUBJECT INDEX FOR THE REPOSITORY OF
UNDERGROUND COAL MINE GROUND CONTROL INFORMATION

I. MINING PROBLEMS

- A. Roof falls
- B. Pillar Crushing.
- C. Floor heave or squeeze.
- D. Geologic anomalies (faults, rolls, clay veins, slips, horseback, kettle bottom, coal ball, sulfur ball, dikes, etc.).
- E. Bumps and gas outbursts.

II. MINE DESIGN

- A. Entry/Pillar Size - Physical limits, regulatory requirements.
- B. Systematic Roof Control:
 - 1. Temporary supports - Jacks, beams, TRS systems.
 - 2. Timber Supports - Posts, cribs, crossbars.
 - 3. Roof Bolts - Mechanical, grouted (resin, inorganic cement, etc.) split-set, roof trusses, wooden pins.
 - 4. Longwall supports - Chocks, shields, packwall.
 - 5. Steel Supports - Rigid beams and arches, yielding arches, tunnel arches.
 - 6. Support Pattern - MSHA requirements, roof control plans.
- C. Mining Method:
 - 1. Room and Pillar - Partial, full recovery.
 - 2. Longwall - Advancing, retreat, advancing-retreat.
 - 3. Shortwall.
 - 4. Hydraulic.
 - 5. Other.
- D. Equipment Applications:
 - 1. Conventional - Cutter, face drill, blasting (explosive, Airdox, cardox), mobile loader, roof bolter, shuttle car.
 - 2. Continuous - Continuous miner (milling, boring or auger), face haulage (mobile belt or shuttle car), roof bolter.
 - 3. Longwall - Shearer (plow, fixed or ranging single or double drum shearer), supports (frame, chock, shield, chock-shield), armoured conveyor.
 - 4. Transportation - Rail (trolley, diesel or battery), rubber tired, conveyor, pipeline (hydraulic or pneumatic).

Table 3 Cont'd.

III. PRE-MINING INVESTIGATIONS

- A. Remote Sensing:
 - 1. Lineament Analysis.
 - 2. Geophysical Exploration.
- B. Geology:
 - 1. Rock Types - shale, slate, draw slate, sandstone, bone, limestone, soapstone, fire clay.
 - 2. Irregularities - Faults, slips, folds, joints, cleats, washouts.
 - 3. Rock Classification Systems - RQD, Kiruna Factor, Bienowski System.
- C. Geophysical Techniques:
 - 1. Borehole Logging.
 - 2. Surface Methods--Seismic, radar, sonic, P-Wave, etc.
- D. Rock Mechanics Relationships:
 - 1. Measured Properties - Compressive strength, shear strength, tensile strength, in-situ stress, hardness, specific gravity.
 - 2. Calculated Properties - Poisson's Ratio. Young's modulus, coefficient of internal friction.
 - 3. Theoretical Evaluations - Finite element modeling, photo-elastic models.

IV. OTHER GROUND CONTROL ISSUES

- A. Surface effects - Subsidence measurements, angle-of-break or draw, swell/bulking factor, OSM data requirements.
- B. Multiple seam mining problems.
- C. Thick seam mining problems.
- D. Steeply dipping seam(s).
- E. Methane drainage - premining, during mining.
- F. Water/Hydrology.

- Data Finder -- As an aid to some potential repository users who request specific data items, numerical measures of physical properties, regional geographic or coal seam-related studies, or similar information, a separate index or Data Finder should also be developed. Table 4 is a proposed list of items to be included in the Data Finder which can also be used in a matrix indexing system. The Primary Subject Index will reference more general subjects such as "room-and-pillar mining using a boring-type continuous miner" and the Data Finder will identify studies that quantify these general subjects (e.g., entry and pillar dimensions, pillar strength values, mining equipment manufacturers and/or model numbers, etc.). While the repository is not conceived as being dedicated to cataloging raw data and numerical measurements of physical properties, that data which is used as supporting information in analytical studies can easily be indexed with this Data Finder.

TABLE 4

PROPOSED DATA FINDER FOR GROUND CONTROL INFORMATION
IN THE GEOLOGIC AND ENGINEERING DATA REPOSITORY

I. BACKGROUND INFORMATION

- A. Geographic
 - 1. State
 - 2. County
 - 3. Coalbed

- B. Mining Operation
 - 1. Operating Company
 - 2. Mine Name
 - 3. Identification Number:
 - MSHA Mine Number
 - USBM Mine Map Repository

II. GEOLOGIC DATA

- A. Borehole/Core Logging
 - 1. Lithologic Log
 - 2. Mechanical Log
 - 3. Rock Quality Classification
 - RQD
 - Kiruna Factor (Coates)
 - Bienowski System
 - 4. Geophysical Testing
 - Borehole
 - I-ES, Electrical Resistivity
 - SP, Sonic Porosity
 - SNP, Sidewave Neutron Porosity
 - BHC, Borehole Compensated Sonic
 - FDC, Formation Density Compensated
 - γ D, Gamma-ray Deflection
 - TDR, Time Domain Reflectometry
 - PR, Point Resistivity
 - Surface
 - Seismic
 - Radar
 - Sonic
 - P-Wave

- B. Mapping
 - 1. Topographic
 - 2. Rock Type
 - Surface
 - Coalbed Roof
 - Coalbed Floor
 - 3. Structural
 - Coalbed Roof
 - Coalbed Floor
 - Basement Rock
 - 4. Joints and Lineaments
 - 5. Lithologic Profile/Cross-section
 - 6. Isopach/Thickness
 - Coalbed
 - Overburden

TABLE 4 Cont'd.

III. ROCK MECHANICS DATA

- A. Measured Properties
 - 1. Compressive Strength
 - uniaxial or unconfined
 - triaxial
 - 2. Shear Strength
 - 3. Tensile Strength
 - 4. In-Situ Stress Field
 - Direction and magnitude of maximum horizontal stress
 - Magnitude of minimum horizontal stress
 - 5. Shore Hardness
 - 6. Specific Gravity
 - 7. Porosity, Water Content
- B. Calculated Properties
 - 1. Coefficient of Internal Friction
 - 2. Poisson's Ratio
 - 3. Modules of Elasticity (Young's Modules)
 - 4. Modules of Rigidity
 - 5. Bearing Capacity/Strength
- C. Theoretical Evaluation Procedures
 - 1. Finite Element Modeling
 - 2. Photo-elastic Models
- D. Geophysical Tests
 - 1. Seismic Velocity Survey
 - 2. P-Wave Test
 - 3. Microseismic Monitoring in Mine
 - 4. Radar Imagery

IV. MINE SUBSIDENCE

- A. Subsidence Measurements
 - 1. Vertical Displacement (profile)
 - 2. Horizontal Displacement
 - 3. Relationship to Mining
 - 4. Surface Cracks or Bulges
- B. Calculated Subsidence Data
 - 1. Angle of Break or Draw
 - 2. Bulking/Swell Factor
- C. Instrumentation

V. MINING METHODS/EQUIPMENT

- A. Roof Control Plan
 - 1. Bolting Pattern
 - 2. Bolt Length
 - 3. Anchoring Method
 - 4. Unintentional Roof Falls

TABLE 4 Concl'd.

B. Mining Dimensions

1. Entry, Crosscut, Room Size
2. Pillar, Barrier Size
3. Panel Width

C. Mining Equipment (Models and Specifications)

1. Conventional (Cut, Drill, Blast, Load, Bolt, etc.)
2. Continuous (Continuous Miner, Bolter, etc.)
3. Longwall (Shear, Supports, etc.)
4. Transportation (Shuttle Car, Rail, Conveyor, etc.)

IV. STORAGE/RETRIEVAL SYSTEM

Before an efficient and cost effective information storage and retrieval system was identified, the type and form of the data items to be stored were considered. The limitations and capabilities of various data and information storage and retrieval systems relative to the items to be processed, the query volume and access methods were also examined.

A. DATA ITEM GROUPS

Table 5 shows the five groups of related data items proposed for the index. The Document Group contains information that identifies the document and includes bibliographic and abstract data. The Subject/Data Index Group contains the Primary Subject Index and Data Finder in a three level cataloging scheme (major subject area, classification and subclassification), standard keywords and a textual description; this data group is the most important part of the index. The Geographic Location Group and Mine Information Group are self-explanatory. The Administrative Control Group is for repository management control and contains the location of this document in the Ground Control Repository and the media (microfiche, map, book, etc.) in which it is stored.

Six types of data are also identified in Table 5. As previously discussed, a "group" is a collection of related data items. "Alphabetic only" data items can contain just that: the letters A through Z and blank. "Alphanumeric" data items can contain any letter, number, punctuation, etc., within the limits of the system employed. "Text" data items can contain any character and may be long in length. "Numeric" data items can contain only numbers and "date" data items can contain a date in a specific format.

TABLE 5

PROPOSED DATA ITEMS

<u>Name of Data Item</u>	<u>Data Type</u>	<u>Multiple Occurrences Allowed Within</u>
<u>1. Document</u>	Group	None
Title	Alphanumeric	None
Author	Alphanumeric	Document
Publication Name	Alphanumeric	None
Volume Number	Numeric	None
Date of Publication	Date	None
Publisher	Alphanumeric	None
Page Number	Numeric	None
Remarks	Text	None
<u>2. Subject/Data Index</u>	Group	Document
Major Subject Area	Alphanumeric	Subject/Data Index
Classification	Alphanumeric	Major Subject Area
Subclassification	Alphanumeric	Classification
Standard Key Words	Alphanumeric	Subject/Data Index
Description	Text	None
<u>3. Administration Control</u>	Group	Document
Date of Last Update	Date	None
Librarian/Cataloger	Alphanumeric	None
Location	Alphanumeric	None
Media	Alphanumeric	None
<u>4. Geographic Location</u>	Group	Document
State	Alphabetic only	Geographic Location
County	Alphabetic only	State
Coal Seam	Numeric	Geographic Location
<u>5. Mine Information</u>	Group	Document
MSHA Mine Number/ BOM Mine Repository ID	Numeric	None
Mine Name	Alphanumeric	None
Mine Owner	Alphanumeric	None
Mine Operator	Alphanumeric	None
Coal Bed	Alphanumeric	Mine Information

The relationships between the groups are depicted in Figure 1. The Document Group is the major link in the group relationships as it is the inventory of the Repository. The other groups will be used to locate specific documents. There may be multiple references to a specific document and this is indicated by the "one-to-many" in Figure 1. The number of Administrative Control Groups per documents is implementation dependent. For simplicity it is assumed that there is one per document.

Many of the data items may have multiple occurrences or values within a group. Consider the Subject/Data Index Group as an example. As indicated earlier, there may be more than one Subject/Data Index Group for each document. However, there may be only one major subject area within each Subject/Data Index Group. If more than one major subject area is covered in a document, then multiple Subject/Data Index groups would be used. Each major subject area may have as many classifications (i.e., minor subject areas) as are necessary to describe the document. Each of these classifications may have as many subclassifications (detailed subject areas) as are required. Accordingly, the number of combinations of major subject area, classification and subclassification for a specific document may be one or many, with the latter more likely. Continuing the example, each Subject/Data Group may have as many standard keywords as are required to describe the document with respect to the major subject area, but there is only one textual description in which the documents' relevance to the major subject area may be discussed.

The data structure indicates that there is much data that may be used to describe a document. Table 6 shows which data would be optional and which would be required for input.

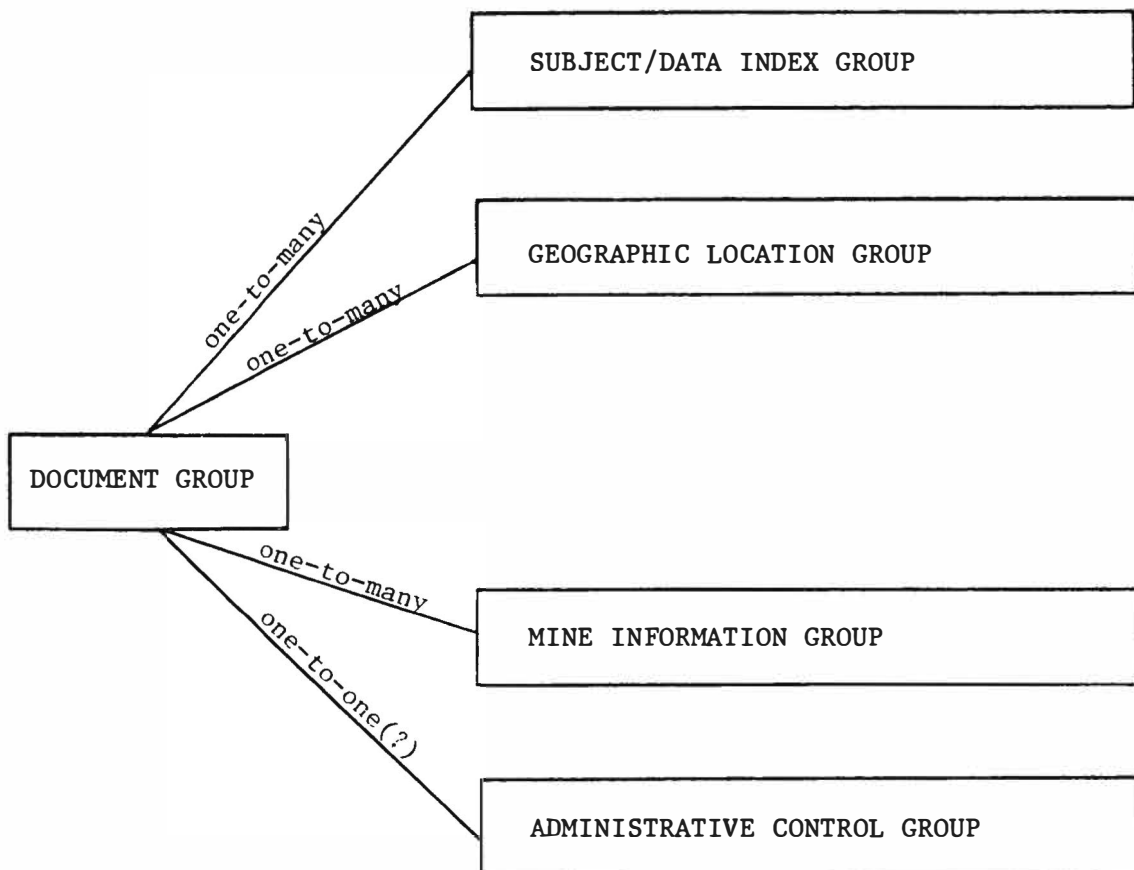


FIGURE 1 - RELATIONSHIPS BETWEEN DATA GROUPS

TABLE 6

DATA INPUT REQUIREMENTS

<u>Data Group</u>	<u>Data Items - Input Required</u>	<u>Data Items - Input Optional</u>
Document (Required Group)	Title Author Publication Name Date of Publication	Volume Number Publisher Page Number Remarks
Subject/Data Index (Required Group)	Major Subject Area Classification Standard Keywords	Subclassification Description
Geographic Location (Optional Group)	State	County Coal Seam
Mine Information (Optional Group)	Mine Number Mine Name Mine Owner Mine Operator	Coal Bed
Administrative Control (Required Group)	Date of Last Update Librarian/Cataloger Location Media	Request count

Certain data items will also be used when trying to locate a document. These are shown in Table 7. All data items can be used for reporting purposes.

B. INDEX FORMAT

For any library or information repository to be a useful tool for the prime users, these users must be able to identify and locate the information needed--it is the function of a repository indexing system to provide a fast, simple method for doing this. For an indexing system to be responsive to the needs of the user it should be able to respond in the same manner as it is addressed and the index should not prejudge the problem by limiting each document to one specific subject area.

Most large, general subject libraries rely on either the Dewey Decimal or Library of Congress system of indexing and organizing their resources. These and other similar systems are designed for the handling of a very large number of documents which cover many widely differing topics. Because of the highly structured nature of these systems they are quite rigid and inflexible; these systems require each document to be classified according to one single, relatively broad topic area. This "pigeon hole" effect severely limits the ability to cross-reference a document to the several specific subjects it may cover within the broad topic area.

An alternative indexing methodology has recently been developed as an outgrowth of the rapidly expanding computer data processing technology. This is the matrix or coordinate-type system which permits the rapid cross-indexing of a document under many of the subjects discussed within a topic area; many recently established libraries which are dedicated to a limited but highly complex technical topic area (such as the NASA and Polaroid libraries) utilize this method of document indexing.

TABLE 7

DATA ITEMS FOR SEARCHING AND REPORTING

<u>Data Group</u>	<u>Data Items for Searching & Reporting</u>	<u>Data Items for Reporting Only</u>
Document	Title Author Publication Name Date of Publication	Volume Number Publisher Page Number Remarks
Subject/Data Index	Major Subject Area Classification Subclassification Standard Keywords	Description
Geographic	State County Coal Seam	
Mine Information	Mine Number Mine Name Mine Owner Mine Operator Coal Bed	
Administrative Control	Date of Last Update Librarian/Cataloger Request Count	Location Media

There are also manual storage and retrieval procedures available which use this coordinate index system. These manual procedures are usually used for very small and/or newly established document collections and are designed to be converted to computer-based systems after the repository has grown and matured. One such manual system, which uses edge-notched index cards, is described in Appendix C. These manual systems typically require no capital investment, and supply costs are limited to commercially available index cards, a card punch and a sorting tool.

C. ALTERNATIVE STORAGE/RETRIEVAL SYSTEMS

At the outset, a manual index system for the Ground Control Repository could be employed, but indexing would be cumbersome. All data would have to be re-coded from the manual system to a computerized form at a later date since there is little doubt that the repository index will eventually require computerization to support the breadth of the data structure shown in Table 5. For these reasons and because of the ready availability and low cost of computers, we considered a computerized system be used from the outset.

Four computerized systems for managing the Underground Coal Mine Ground Control Repository are described and compared for this study. For each of these four alternatives, we have estimated certain fundamental costs and discuss the basic features. The four systems considered are:

- 1) A microcomputer dedicated to the repository index;
- 2) The Bureau's Bruceton PDP-11/70* with Datatrieve* software;
- 3) A timesharing service with bibliographic search software (Lockheed's DIALOG*); and
- 4) A PDP-11/70 based system integrating text, data and map storage with indexing and retrieval.

*Reference to specific brands, equipment or trade names in this report is made to facilitate understanding and does not imply endorsement by either Arthur D. Little, Inc. or the Bureau of Mines.

Each of these four types of systems would be suitable for the Underground Coal Mine Ground Control Repository and each provides the same basic functions, but with varying degrees of sophistication. Each has facilities to load the data base, to process queries against the data base and then to dispatch the results of the queries to the final user. The four types of systems analyzed are: a microcomputer system, a system based on a data management system primarily oriented toward numeric and fixed field text information, a system based on bibliographic index retrievals, and a combined system permitting both numeric and bibliographic data to be used in conjunction with each other. The data base system alternatives could be either Datatrieve on the PDP-11/70 running at the PMSRC-Bruceton facility or another DBMS system such as System 2000* running on a time sharing service bureau. (The Datatrieve package may not be ideally suited for the data structure discussed but would be adequate with little extra effort; strictly speaking, Datatrieve is a user-oriented file management system and not a DBMS--with a DBMS, there would be no data redundancy, but with Datatrieve data redundancy could be significant.) The bibliographic system we considered is the DIALOG service available from Lockheed; a similar bibliographic search facility could be based on the PDP-11/70 at Bruceton with the purchase of an appropriate bibliographic search software system. The combined system evaluated is a UNIS based system similar to the Integrated Information System (IIS) under development at Lawrence Livermore Laboratories by Victor Hempel and his staff. Such a system must be regarded as a developmental system rather than a fully debugged production system and will require more sophisticated technical support than the other system alternatives to take advantage of its additional facilities. (128, 129).

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For each of the four systems, we have categorized in Table 8 a number of different features and benefits to the potential users of the system. These features illustrate the key differences among the four systems with respect to the type of query which can be performed by the systems, the classes of data stored on-line by the systems, the recommended method of document delivery, the availability and convenience of numeric data analysis, the degree of user training needed, and the flexibility of the system for accommodating future needs.

The query capability of the microcomputer system is limited to performing a search of all the records for values of specific keys (e.g., authors, keywords or index terms). In addition, a manual search of the entire file is possible, but it would be quite time consuming. For data base management systems, in addition to the search by keys, arithmetic range search and a variety of Boolean combinations of keys used in the search are also possible. The bibliographic system permits searching for records on the basis of combinations of keywords and also a search through the text of the abstract for relevant terms. Since the combined systems are essentially programmed by the user, they can provide even more complex search patterns including those based on arithmetic functions of data in the data base.

The data stored in the system is different in each case. For the microcomputer system, encoded values of the keys, keywords, authors' names, and so on are stored in on-line diskettes, but the citation, abstract, and text must be maintained manually. For the data management system an on-line file is created for the keys, citations, and numeric fields used for searching; neither the abstract nor the text is necessarily on-line, although the abstract could be kept on-line in a file separate from the retrieval data. For the bibliographic system, the keys, citation, and abstract are all stored on-line to permit each

TABLE 8

GROUND CONTROL REPOSITORY COMPUTER SYSTEM ALTERNATIVES

<u>Feature</u>	<u>Representative System Type*</u>			
	<u>MICROCOMPUTER</u>	<u>DBMS</u>	<u>BIBLIOGRAPHIC</u>	<u>COMBINED</u>
Computer:	APPLE-II	PDP-11/70	timesharing	PDP-11/70
Software:	BASIC	Datatrieve	DIALOG	Customized
Query type:	Keys	key, range searches	keys, abstract searches	keys, complex searches
Storage/ Search Method:				
Keys/Keywords	on-line	on-line	on-line	on-line
Citation	manual	on-line	on-line	on-line
Abstract	manual	on-line/manual	on-line	on-line
Full text	manual	manual	manual	on-line
Data	manual	manual	manual	on-line
Maps	manual	manual	manual	on-line/manual
Delivery Method:				
Citation	copy & mail	print on-line	print on-line	print on-line
Abstract	copy & mail	print on-line	print on-line	print on-line
Document	copy & mail	copy & mail	copy & mail	print on-line
Data Analysis:	none	on same machine	none	integrated
User Training Needed:	low	medium	very low	very high
Flexibility:	low	medium	very low	high

Source: Arthur D. Little estimates.

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of them to be searched during the query process. For the combined system in addition to the keys, citations and abstracts, full text and data may also be stored in the on-line system. Naturally, this additional storage of full text and data on-line requires a considerable amount of additional storage which may be as much as three orders of magnitude larger than that necessary for only the keys, citations, and abstracts.

Except for the combined system, the document delivery process is the same: the original source documents are copied and mailed. The bibliographic systems generally permit on-line printing of the abstracts and the citations. The combined system could permit on-line printing of the entire document and very advanced systems with graphic capability could also print figures, graphs, and maps. Were the data to be on-line in this latter case, then it could also be printed automatically at remote sites.

The wide range of capabilities for data analysis and flexibility of retrieval is reflected in the range of user training requirements. The micro-computer system has no automatic data analysis and low flexibility; it, therefore, requires a small amount of user training. The data management system permits analysis on the same machine and a medium degree of flexibility with respect to new keywords and new types of data; moderate degree of training is required to use these capabilities. The bibliographic systems do not permit data analysis and have only a small degree of flexibility for adding new keywords. Naturally, these are easy to use and require little user training. The combined systems permit virtually unlimited integrated data analysis and a high degree of flexibility for modifying the system to suit special needs of the users; this requires very significant, sophisticated user training.

For each of these four systems, the first part of Table 9 summarizes the estimated technical setup cost, the cost of loading 2,000 records, the cost of processing 100 queries, and the cost of producing 1,000 hard copy responses to those queries. The technical setup cost includes the training necessary to learn how to use the system plus any special software (i.e., programs) or hardware (e.g., terminals or computers) which is required to use that system. According to Donald N. H. Chi, Supervisory Research Physicist at PMSRC-Bruceton, (13 and personnel communications) the Bureau's PDP-11/70 computer and Datatrieve are available with no charge for computer time. The cost of loading and storing 2,000 records is therefore based on the assumption that free computer time will also be available for the preparation of computer files. More data entry and storage cost details are shown in Part B of Table 9.

The cost of processing 100 queries is based on 430 for each hour of professional time to establish a query and process the raw data into a better organized form. Computer time on a service bureau was also priced at \$30 per query. Assuming that an average of ten documents are requested by each query, the cost of preparing 1,000 hard copy documents (based on fifteen minutes per document plus \$5 per mailing) is approximately \$2,000.

Some costs have not been included in Table 9. We are assuming for the data base management system that the Datatrieve software is available on the Bruceton PDP-11/70. If another package were needed, an additional software charge would be required. Similarly, the DIALOG bibliographic system is provided free on the Lockheed service, but a similar software package might be purchased for use on Bruceton's 11/70. The price of such a software package has not been included in the table. Should a package for a bibliographic search system be purchased for the 11/70, the free computer time

TABLE 9

RELATIVE SYSTEM COSTS AND STORAGE REQUIREMENTSA. ALTERNATIVE SYSTEM COSTS

	<u>MICRO-COMPUTER</u>	<u>DBMS</u>	<u>BIBLIOGRAPHIC</u>	<u>COMBINED</u>
<u>Start-Up Cost</u>				
Technical Setup	\$10,000	\$ 5,000	\$ 3,000	\$50,000
Computer Purchase	Included	None	None	Excluded
Load Data (2000)	<u>1,750</u>	<u>1,750</u>	<u>3,750</u>	<u>45,750</u>
	\$11,750	\$ 6,750	\$ 6,750	\$95,750
<u>Operating Cost</u>				
Queries (100)	\$ 3,000	\$ 3,000	\$ 6,000	\$ 3,000
Document Preparation (10 per query)	<u>2,000</u>	<u>2,000</u>	<u>2,000</u>	<u>2,000</u>
Total per 100	\$ 5,000	\$ 5,000	\$ 8,000	\$ 5,000

B. STORAGE REQUIREMENTS

<u>Type of Data</u>	<u>Length in Characters</u>	<u>COST OF 1000 DOCUMENTS</u>	
		<u>Data Entry¹</u>	<u>Storage per year²</u>
Document citation (author, title, reference no. etc.)	200	\$500	\$60
Ten index terms or keywords	100	\$250	\$30
Abstract or Summary	1,000	\$1,000	\$300
Text of Document	10,000	\$8,000	\$3,000
Digitized Maps ³	100,000	\$36,000	\$30,000

- NOTES: 1. At rate of \$6.00/hour for text entry and map digitizing.
2. At rate of \$25/million characters/month.
3. One map per document. These estimates are likely too low for some complex and detailed mine maps.

Source: Arthur D. Little estimates.

would somewhat offset the purchase price of the software. Also not included are the royalty costs of reproducing copyrighted material which would be equivalent for each system.

For the combined system, we have estimated technical setup time to cost about \$50,000. This assumes the availability of an appropriate computer environment, namely a PDP-11/70 system with the UNIS operating system available from Bell Telephone Laboratories. Should it prove impractical to run the UNIS operating system on the existing 11/70 at Bruceton, a second machine or rented time on another computer would be required; the cost of acquiring this additional computer access is not included in the estimates given in the table.

Looking back over these features and costs we see that a wide range of capabilities is possible and that the more sophisticated systems are considerably more expensive than the less sophisticated systems. We recommend an initial phased installation for the Underground Coal Mine Ground Control Repository that permits later expansion to provide additional, more sophisticated inquiry and data analysis facilities. The recommended phased installation has five basic steps:

- Collect the documents for the repository and prepare the proper keywords and index terms for each document.
- Store the keywords, author, title, and other retrieval fields in an on-line file suitable for the Datatrieve system. Store the abstract of each document in a separate on-line file.
- Install the Datatrieve inquiry system for use in the bibliographic retrievals from the on-line files.
- Make the repository service available to the users and study the usage patterns during the first year.

- At the end of the first year, review the use of the service to decide which more sophisticated options should be chosen for further development of this facility.

A variety of future options in this phased installation are possible. It would be easy to extract a data tape from the PDP-11/70 at Bruceton and load the contents of that tape on a bibliographic retrieval service such as DIALOG from Lockheed Corporation or RECON from the Department of Energy's Oak Ridge facility. It would also be simple to acquire and install bibliographic retrieval software on the PDP-11/70 at the facility in Bruceton to provide searching of the abstract or more sophisticated multiple keyword retrieval capabilities. Finally, having prepared the data in an on-line, machine readable format, it would also be possible to acquire the hardware and software environment necessary for a sophisticated combined data management and bibliographic retrieval facility such as the IIS system at the Lawrence Livermore Laboratory. This more sophisticated system could be managed either at the Bruceton Laboratory or on similar computer facilities located at another location. All of these options are made possible by the initial preparation of the documents and their indexing fields in a machine readable on-line form.

For each document in the repository, we recommend that an abstract, the citation information, and keywords be stored in on-line medium but that the complete text, tables, maps, charts and so on be kept in hard-copy or microfiche format. Table 9 shows our estimates of the storage required for each of these types of data for a source document. Storing maps or charts requires significantly more storage space (and considerable expense if that storage is on a time sharing bureau). The extra benefit of having a text and the maps or charts stored on-line would be the possibility of remote printing of this information. It seems to us that the benefit of such remote printing does not

warrant the additional expense. Since each query must be processed manually by a trained individual at the Bruceton facility, that individual can easily supervise the reproduction and distribution by mail of the text, maps, and charts.

D. DATA VOLUME AND USER ACCESS

At the outset, there will be many documents to catalogue but none indexed for retrieval. Therefore, the volume of data entry will be high and query volume will be very low. When the backlog of documents to be catalogued is worked down, data entry activity will normalize to low levels because new documents will be catalogued as they are received. At this point, query volume should be increasing and may normalize at a high level shortly thereafter, as illustrated in Figure 2.

Currently, most information requests come to the Bureau of Mines staff at the Pittsburgh Mining and Safety Research Center (PMSRC) by telephone; relatively few requests first come by mail or a personal visit. While this trend is expected to continue, it must be recognized that verbal communication and transfer of technical information over the telephone is very inefficient and prone to misinterpretation. Both mail correspondence and personal visits greatly reduce the possibility of misinterpretation, but are much slower and more costly.

During the initial development of the repository, it is expected that there will be relatively few information requests; these requests can probably be handled by the three methods discussed above. After the repository has become firmly established and well known to the industry, the volume of information requests could tax the capabilities of these common communications systems. The recommended repository system has the capability of adding high-

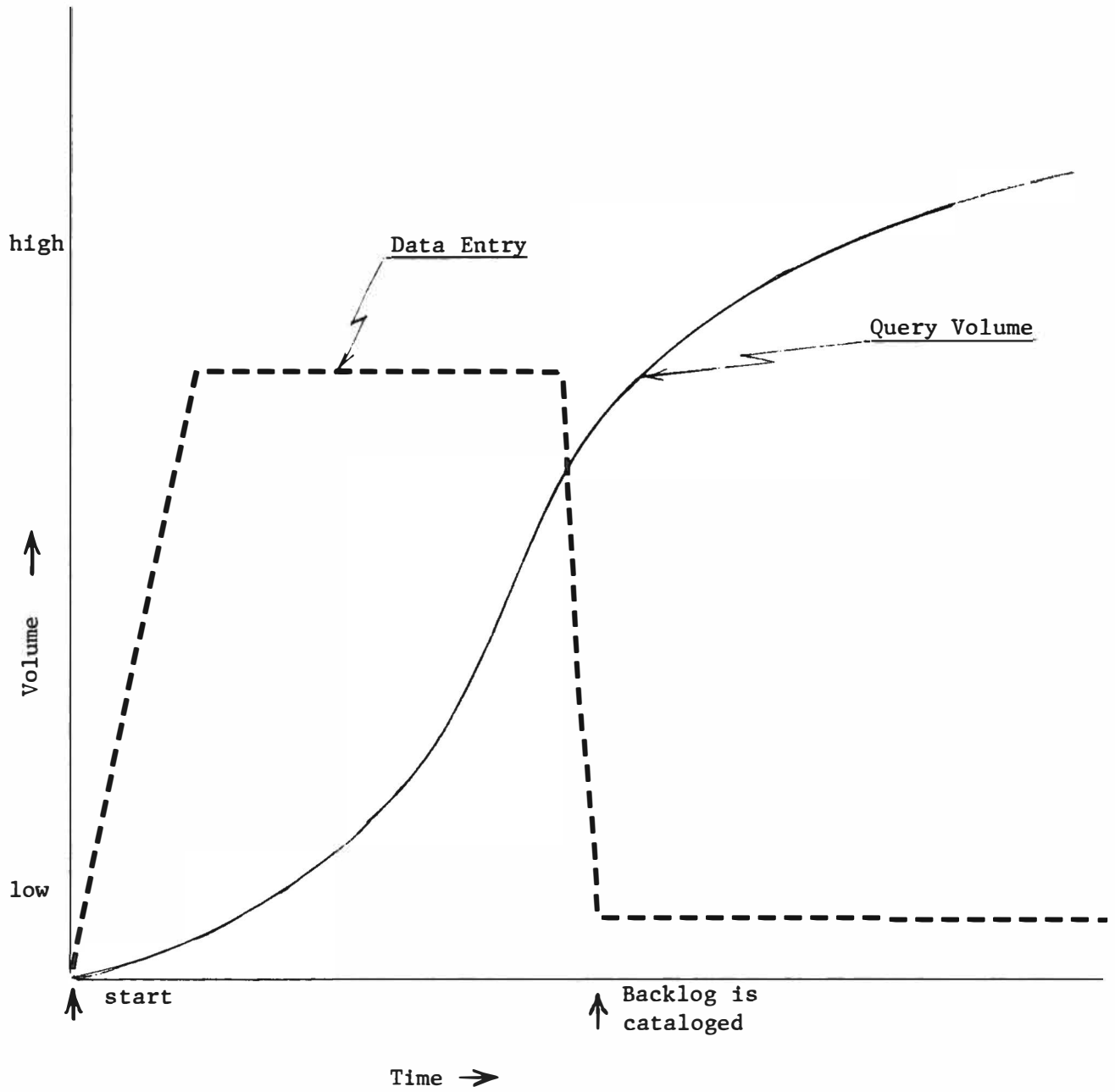


FIGURE 2 - DATA ENTRY AND QUERY VOLUMES OVER TIME

speed electronic communication systems (e.g., telecopier, data-phone, telephone terminal reader/printer, cathode-ray tube (CRT) remote display) in the future. While the repository organization includes the provision for adding advanced communications technologies, the available systems should be reviewed prior to being incorporated in the repository for compatibility with systems available to the mine operators at that time.

It has been recommended that the initial repository indexing system be a computerized system. The addition of remote access to the repository would then make it possible for a mine operator to search the repository index directly from a remote terminal located at his mine, and to retrieve complete document citations and abstracts on the specific problem area without having to wait for mail service or travel to the repository.

E. INFORMATION PROVIDED TO USERS

The ground control repository could operate as a data collection center which provides document citation information when requested. Or it could become the major authoritative source for all ground control information provided to the mining industry. The first alternative would be a passive office which only responds to information requests; the second would be an aggressive operation that could effectively help increase mine safety and efficiency.

A passive repository would provide, at most, citation/abstract information, document sources or locations, and possibly a reference copy of the document for examination at the repository. The document acquisition costs for this type of repository would be relatively low because there would be no need for document copying for redistribution to the mine people requesting the

information. Lockheed's DIALOG, the New York Times "Information Bank", and SDC's "Orbit" systems* are examples of passive citation/abstract repositories designed for on-line computer-searching that are commercially successful.

An aggressive repository would, in addition to citation and abstract information, be capable of providing copies of published documents to the requestors. This would be of significant benefit to the mine operators because it would provide a quick response to the problem in addition to simplifying the document location and acquisition process. It would, however, add substantially to the cost of the repository unless document copying and shipping expenses could be billed to the requestor. Repository document acquisition costs would also be higher because this would require additional journal subscriptions, microfilming and reproduction of stored documents, detailed technical update literature searches, and acquisition from sources to which the repository cannot normally subscribe (principally low-circulation monographs, open-file reports, theses, text books and foreign language publications). An example of a commercially available repository that provides document copies to requestors is the Institute for Scientific Information's OATS* systems.

Since many of the advantages of an aggressive repository are intangible benefits which cannot be quantified, a rigorous cost/benefit comparison of the passive and aggressive repositories is not possible. In telephone interviews with mine personnel, we discussed these intangible benefits in order to obtain a better understanding of the value mine operators may place on either a passive or aggressive repository. Most potential users preferred an aggressive repository to a passive one.

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F. ORGANIZATION STRUCTURE AND MANPOWER

This discussion is limited to the internal organization of the repository operation and assumes that this repository will operate as recommended earlier (i.e., within the Roof Support Research Group at PMSRC, Bruceton). The organizational structure and manpower requirements of the repository can be described by considering the processes and procedures which would be followed when a new document is acquired and when a user requests information on a specific ground control problem.

Figure 3 schematically illustrates the processing received by a new document after acquisition by the repository. First, the Document Group data (including the bibliographic citation and abstract) will be prepared. The subject areas for the Index Citation Group using the keys in the Primary Subject Index and specific data items from the Data Finder, would be developed concurrently with the Geographic Location and Mine Information Group. This work would be performed by a repository administrator/librarian who would draw upon the technical expertise of selected professional members of the Roof Control Research Group when necessary. Any unique regional or otherwise uncommon terms would be referenced according to an established authority file (i.e., the Ground Control Thesaurus.) The document will then be cataloged and filed using an Administrative Control Group, converted to microform if necessary and stored in the repository.

When a user requests information on a specific ground control problem, an information retrieval process such as that shown in Figure 4 will be followed. As was discussed earlier under "User Access", it is expected that a mine operator will first contact a professional member of the Roof Control Research Group for information that will help solve his ground control problems. In working with the user to define the problem, the professional and/or the

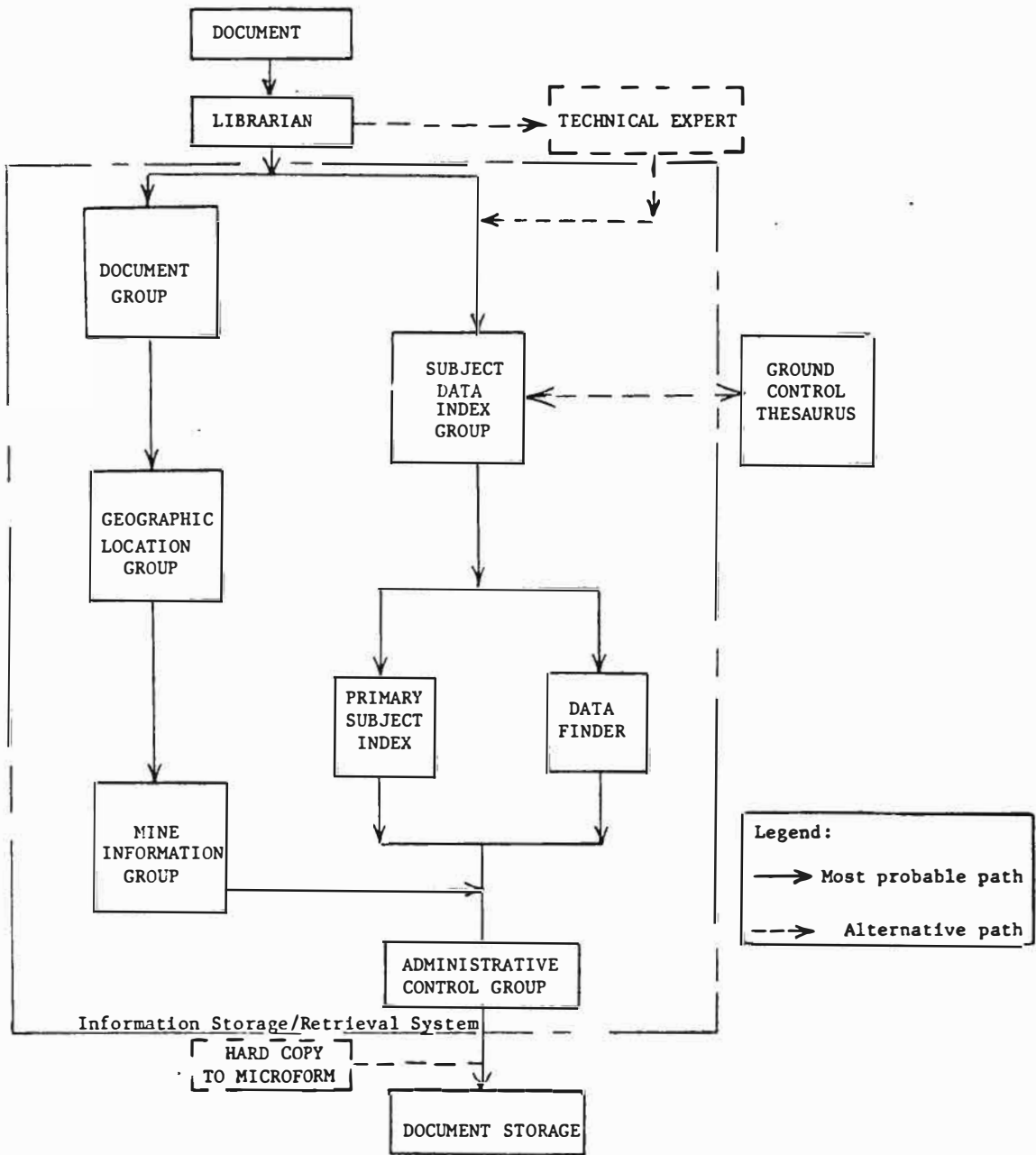


FIGURE 3 - DOCUMENT ACQUISITION, INDEXING AND STORAGE

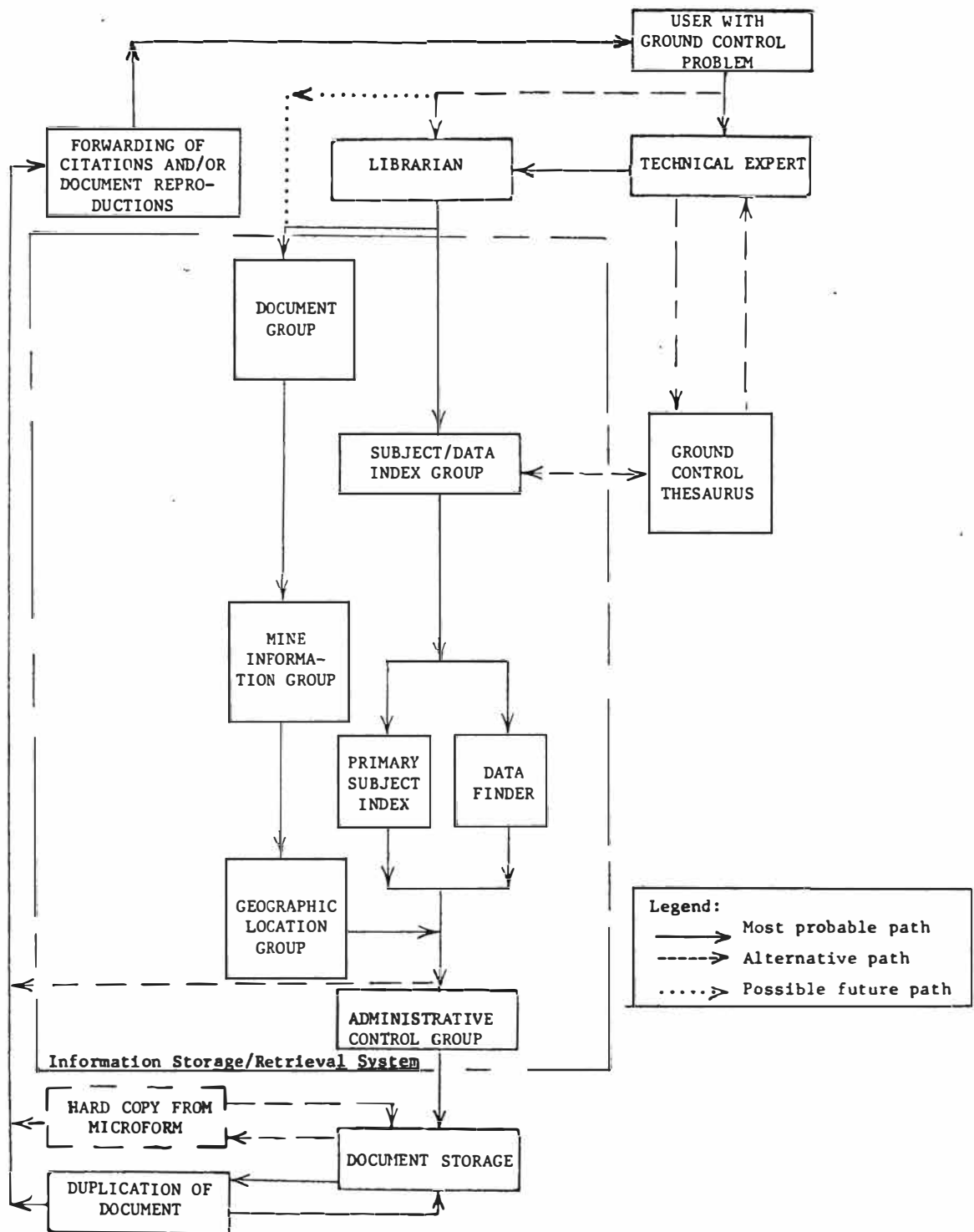


FIGURE 4 - INFORMATION REQUEST AND DOCUMENT RETRIEVAL

librarian may consult the Thesaurus for appropriate keywords before beginning to identify and retrieve the relevant documents. The librarian will take the information provided by the user (and the professional) as a starting point for searching the Subject/Data Index Group (and also the Document, Geographic Location and/or Mine Information Group if appropriate). The user may be able to obtain many documents on his own with the aid of only Citation/Abstract information; if not, the librarian will use the Administrative Control Group to identify the document location, retrieve the document from the appropriate storage area, make a reproduction of the document, return the document original to storage, and send the document copy to the requesting user.

In the future, the Document Group (i.e., the Citation/Abstract File) may be transferred to an on-line, remote computer searchable format, where it could be directly addressed from a mine office or other remote terminal locations. This would reduce the time the professional and the librarian would be required to devote to relatively unproductive file searching; the professional would be able to devote more time to technical areas and the librarian to adding more documents to the repository. After the user has identified relevant documents he had not previously acquired, he could also be able to request those documents from the repository, again using the remote terminal.

V. CONCLUSIONS AND RECOMMENDATIONS

Many of the coal mine operating, engineering, consulting and research people we interviewed expressed a strong interest in (and need for) a central information resource which could, on demand, supply descriptive and case-study information which addressed specific underground coal mine ground control problems. A repository of geologic rock mechanics and other ground control related data items was not considered by most people interviewed to be very useful; a resource where information which addressed specific ground control problems could be rapidly retrieved was preferred.

Drill logs, physical property tests, mine maps and plans, finite-element models, computer programs, and other similar data was considered proprietary information by most organizations interviewed and would, therefore, not be available for inclusion in the proposed repository. Many organizations, however, were willing to provide professional papers and technical journal articles which they had prepared. Other available information includes U.S. Bureau of Mines studies and reports, and the large, but widely disseminated, body of published technical studies.

In considering many facets of the proposed repository of underground coal mine ground control information, the following organizational format is recommended:

- The repository should be organized primarily to help the mine operators rapidly locate information which specifically addresses particular ground control problems as they arise.
- Most potential users expressed a preference for an aggressive repository (one that is able to provide document copies to the user) over a passive one (which provides only citation/abstract information).

- An independently established repository within the PRC Ground Control Research Group will be more responsive to user needs than a repository which is only a subfunction of a larger library.
- The form in which information should be stored depends on the type of information:
 - Textual information should be stored in hard-copy only when microform (i.e., microfiche or microfilm) is not commercially available.
 - Graphical information should be stored on microfiche unless scalar or color information would be lost.
- Documents for the repository collection should initially be identified and/or acquired from these three sources:
 - current U.S. Bureau of Mines publications,
 - technical journals and trade magazines,
 - the attached bibliography of coal mine ground control literature (Appendix B).

Additional document sources are also discussed.
- A Primary Subject Index which includes both ground control problems and mine design areas within a coordinate indexing system will be the most useful index type. This subject index should be supplemented with a thesaurus or authority file of roof-control terms and a numerical/location Data Finder.
- A computerized coordinate index system using the file management package available on the computer at PRC-Bruceton is recommended as the initial information storage/retrieval system for the repository. Unorganized geologic and engineering data could be added after the bibliographic information is loaded and fully operational.

- User access to the repository will initially be from telephone requests, mail correspondence and personal visits; the repository should, however, be designed with the capability to add remote electronic access to the Citation/Abstract File as user demand increases.
- A repository administrator/librarian will be required full time for document acquisition, abstracting, cataloging, storage, retrieval, duplication and distribution. The librarian will occasionally draw upon the technical knowledge of professional members of the Roof Control Research Group for assistance in document indexing or problem definition (including, when necessary, interaction with a requestor).

APPENDIX A
INTERVIEW RESPONDENTS

Bethlehem Mines Corp., Ellsworth Division, Eightyfour, Pennsylvania.
D. F. Patterson, Chief Engineer.

John T. Boyd Co., Pittsburgh, Pennsylvania. Bruno Fichna, Mining Engineer,
John Bobella, Mining Engineer.

Consol, Headquarters Office, Pittsburgh, Pennsylvania. Doug Dahl, Director
of Underground Mine Planning.

Consol, Midwest Region, St. Clairsville, Ohio. Nick Bozic, Tech. Assistant,
Underground Operations.

Delta Mining Co., Jennerstown, Pennsylvania. Charles Davis, Jr., Chief
Engineer.

Eastern Associated Coal Corp., Pittsburgh, Pennsylvania. R. R. Snyder,
Chief Engineer.

Eastover Mining Co., Highsplint, Kentucky. Sam Halloway, Chief Engineer.

Florence Mining Co., Seward, Pennsylvania. Bob Browning, V.P. Engineering.

Freeman United Coal Co., West Frankfort, Illinois. William Mullins,
V.P. Engineering.

Illinois State Geological Survey, Urbana, Illinois. Dr. Heinz Damberger,
Head of the Coal Section, Stephen Hunt, Geologist.

Inland Steel Co., Sesser, Illinois. Douglas Dwosh, Asst. Chief Engineer,
Chris Watson, Project Mining Engineer.

Kaiser Steel Corp., Sunnyside, Utah. Lloyd Heath, General Supt.

Arthur D. Little, Inc., Technical Library, Cambridge, Massachusetts.
Kathy Long, Librarian.

A. T. Massey, Richmond, Virginia. O. B. Bucklin, V. P. Engineering.

Mead Coal Co., Bessemer, Alabama. Robert L. Argent, Mining Engineer.

North American Coal Co., Cleveland, Ohio. Charles H. Daub, V. P. Engineering.

Old Ben Coal Co., Benton, Illinois. John Janes, Mgr. Industrial Engineering,
Mike O'Day, Safety Director.

Pennsylvania Bureau of Bituminous Mine Subsidiaries, McMurry, Pennsylvania.
Thomas Alexander, Mining Engineer.

Rochester and Pittsburgh Coal Co., Indiana, Pennsylvania. Gene Jones,
Chief Engineer.

Southern Illinois University, Carbondale, Illinois. Yogander P. Chugh,
Assoc. Prof. Mining Engineering.

U.S. Bureau of Mines, PMSRC, Bruceton, Pennsylvania. Don Chi, Res. Physicist,
Noel N. Moels, Geologist, Claude Goode, Supervisory Mining Engineer,
Lou Wade, Supervisory Mining Engineer.

U.S. Bureau of Mines, Pittsburgh, Pennsylvania. Robert Thomson, Chief,
Eastern Field Operations Center, Marjory Pass, Head Librarian.

U.S. Dept. of Energy, Mining Research Center, Bruceton, Pennsylvania.
Ernest A. Carth, Mining Engineer.

U.S. Dept. of Energy, Mining Research Operations, Carbondale, Illinois.
William Eichfield, Civil Engineer, Howard Parkinson, Research Supervisor.

U.S. Mine Safety and Health Administration, Pittsburgh, Pennsylvania.
Alex O'Rourke, Supervisory Mining Engineer, Charles Batistoni, Roof Control
Specialist, Curt Edgerton, Geologist.

United Pocahontas Coal Co., Beckley, West Virginia. Robert Shultz, Chief
Engineer.

U.S. Steel Co., Southern District, Fairfield, Alabama. J. Y. O'Neal,
Chief Engineer.

Univeristy of Missouri-Rolla, Rolla, Missouri. Dr. David A. Summers,
Prof. of Mining Engineering.

Valley Camp Coal Co., Tridelfhia, West Virginia. Wendell Bolden, Div.
Engineer.

Jim Walters Resources, Birmingham, Alabama. Charles Hagen, Senior V. P.

APPENDIX B
BIBLIOGRAPHY OF UNDERGROUND COAL MINE GROUND CONTROL LITERATURE
AND
REFERENCES ON DATA SYSTEM HARDWARE AND SOFTWARE

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APPENDIX C
MANUAL COORDINATE INDEX SYSTEM

APPENDIX C - MANUAL COORDINATE INDEX SYSTEM

A manual coordinate indexing system using edge-notched cards can be used in many different applications. One commonly available card type is shown in Figure C-1.*

Using the proposed Primary Subject Index and Data Finder as a starting point, various edge-notch combinations can be assigned to the major, secondary and minor subjects, or key words. Tables C-1 and C-2 represent one possible edge-notch combination for the Primary Subject Index and Data Finder, respectively. Table C-3 cross-indexes each notch position with the associated subject or key words, and also identifies the notch positions reserved for information on document authors and study area locations (including state, county and coalbed).

With the aid of a document coding form, such as the one in Figure C-2, a librarian should be able to prepare a bibliography, abstract, and index most documents in less than twenty minutes. Typing the bibliography and abstract on the card, and punching the edge-notches should require an additional ten minutes. These time estimates are based on the actual time required for the preparation of twenty abstract/index cards during a test-coding of roof-control studies performed during this contract. Figures C-3 a, b and c are three representative edge-notched cards with bibliography and abstract.

The information retrieval system using edge-notched cards involves simply inserting the sorting needle into the notch position corresponding to the subject of interest. All cards that then fall from the deck contain information relevant to the subject, and those retained on the needle can be searched for other related subjects or key words. A deck of 500 cards can thus be searched for all studies relevant to a specific subject in less than a minute.

* Reference to specific brands, equipment or trade names in this report is made to facilitate understanding and does not imply endorsement by either Arthur D. Little, Inc. or the Bureau of Mines.

TABLE C-1

MANUAL COORDINATE INDEX SYSTEM - PRIMARY SUBJECT INDEX

	<u>Notch Position</u>
<u>I. MINING PROBLEMS</u>	R16
A. Roof falls:	R06
Center/Tension Failure	T25 0
Rib/Shear Failure	T24 0
B. Pillar Crushing.	R5
C. Floor heave or squeeze.	R4
D. Geologic anomalies (faults, rolls, clay veins, slips, horseback, kettle bottom, coal ball, sulfur ball, dikes, etc.).	R3
E. Bumps and gas outbursts.	R2
<u>II. MINE DESIGN</u>	R15
A. Entry/Pillar Size - Physical limits, regulatory requirements.	B20 I
B. Systematic Roof Control:	B21 I
1. Temporary supports - Jacks, beams, TRS systems.	B10 I
2. Timber Supports - Posts, cribs, crossbars.	B 9 I
3. Roof Bolts - Mechanical, grouted (resin, inorganic cement, etc.) split-set, roof trusses, wooden pins.	B 8 I
4. Longwall supports - Chocks, shields, packwall.	T27 0
5. Steel Supports - Rigid beams and arches, yielding arches, tunnel arches.	B 7 I
6. Support Pattern - MSHA requirements, roof control plans.	B 6 I
C. Mining Method/Systems:	B22 I
1. Room and Pillar - Partial, full recovery.	B 4 I
2. Longwall - Advancing, retreat, advancing-retreat.	B 3 I
3. Shortwall.	B 2 I
4. Hydraulic.	B 1 I
5. Other.	B 1 I
D. Equipment Types:	B23 I
1. Conventional - Cutter, face drill, blasting (explosive, Airdox, cardox), mobile loader, roof bolter, shuttle car.	T29 0
2. Continuous - Continuous miner (milling, boring or auger), face haulage (mobile belt or shuttle car), roof bolter.	T28 0
3. Longwall - Shearer (plow, fixed or ranging single or double drum shearer), supports (frame, chock, shield, chock-shield), armoured conveyor.	T27 0
4. Transportation - Rail (trolley, diesel or battery), rubber tired, conveyor, pipeline (hydraulic or pneumatic).	T26 0

Table C-1 Cont'd.

	<u>Notch Position</u>
<u>III. PRE-MINING INVESTIGATIONS</u>	R14
A. Remote Sensing:	B24 I
1. Lineament Analysis.	B 1 0
2. Geophysical Exploration.	B 2 0
B. Geology:	R11
1. Rock Types - shale, slate, draw slate, sandstone, bone, limestone, soapstone, fire clay.	T24 0
2. Irregularities - Faults, slips, folds, joints, cleats, washouts.	R3
3. Rock Classification Systems - RQD, Kiruna Factor, Bienowski System.	T22 0
C. Geophysical Techniques:	B02 0
1. Borehole Logging.	T21 0
2. Seismic, radar, sonic, P-Wave.	B24 I
D. Rock Mechanics	R10
1. Measured Properties - Compressive strength, shear strength, tensil strength, in-situ stress, hardness, specific gravity.	B16 I
2. Calculated Properties - Poisson's Ratio. Young's modules, coefficient of internal friction.	B15 I
3. Theoretical Evaluations - Finite element modeling, photo-elastic models.	B14 I
4. Instrumentation Techniques	B11 I
<u>IV. OTHER GROUND CONTROL ISSUES</u>	R13
A. Surface effects:	R 9
- Subsidence measurements	B13 I
- Angle-of-break or draw	B25 0
- Swell/Bulking Factor, OSM data requirements.	B26 0
B. Multiple seam mining problems.	B25 I
C. Thick seam mining problems.	B26 I
D. Steeply dipping seam(s).	B27 I
E. Methane drainage - premining, during mining.	B28 I
F. Water/Hydrology.	B29 I

TABLE C-2
MANUAL COORDINATE INDEX SYSTEM - DATA FINDER

	Notch Position
<u>I. BACKGROUND INFORMATION</u>	
A. Geographic	
1. State	
2. County	
3. Coalbed	
B. Mining Operation	
1. Operating Company	
2. Mine Name	
3. Identification Number:	
-- MSHA	
-- USBM Mine Map Repository	
<u>II. GEOLOGIC DATA</u>	
A. Borehole/Core Logging	R11
1. Lithologic Log/Stratigraphy	B18 I
2. Mechanical Log	B 6 0
3. Rock Quality Classification	T23 0
-- RQD	T22 0
-- Kiruna Factor (Coates)	
-- Bienowski System	T21 0
4. Geophysical Log	
-- I-ES, Electrical Resistivity	
-- SP, Sonic Porosity	
-- SNP, Sidewave Neutron Porosity	
-- BHC, Borehole Compensated Sonic	
-- FDC, Formation Density Compensated	
-- γ D, Gamma-ray Deflection	
-- TDR, Time Domain Reflectometry	
-- PR, Point Resistivity	
B. Mapping	B17 I
1. Topographic	B 3 0
2. Geologic/Rock Type	B 4 0
-- Surface	
-- Coalbed Roof	
-- Coalbed Floor	
3. Structural	B 5 0
-- Coalbed Roof	
-- Coalbed Floor	
-- Basement Rock	
4. Joints, Lineaments & Faults	B 1 0
5. Lithologic Profile/Cross-section	B 6 0
6. Isopach/Thickness	B 7 0
-- Coalbed	
-- Overburden	

Table C-2 Continued

III. ROCK MECHANICS DATA

	R10
A. Measured Properties	B16 I
1. Compressive Strength	B 8 O
-- uniaxial or unconfined	
-- triaxial	
2. Shear Strength	B 9 O
3. Tensile Strength	B10 O
4. In-Situ Stress Field	B11 O
-- Direction and magnitude of maximum horizontal stress	
-- Magnitude of minimum horizontal stress	
5. Shore Hardness	
6. Specific Gravity	} B12 O
7. Porosity, Water Content	
B. Calculated Properties	E15 I
1. Coefficient of Internal Friction	E13 O
2. Poisson's Ratio	E14 O
3. Modules of Elasticity (Young's Modules)	E15 O
4. Modules of Rigidity	E16 O
5. Bearing Capacity/Strength	E17 O
C. Theoretical Evaluation Procedures	E14 I
1. Finite Element Modeling	E18 O
2. Photo-elastic Models	E19 O
D. Geophysical Tests	B02 O
1. Seismic Velocity Survey	
2. P-Wave Test	
3. Microseismic Monitoring in Mine	
4. Radar Imagery	
E. Instrumental	B20 O

IV. MINE SUBSIDENCE

	R9
A. Subsidence Measurements	B13 I
1. Vertical Displacement (profile)	B21 O
2. Horizontal Displacement	B22 O
3. Relationship to Mining	B23 O
4. Surface Cracks or Bulges	B24 O
B. Calculated Subsidence Data	B12 I
1. Angle of Break or Draw	B25 O
2. Bulking/Swell Factor	B26 O
C. Instrumentation	B20 O

V. MINING METHODS/EQUIPMENT

	F8
A. Roof Control Plan	E21 I
1. Bolting Pattern	
2. Bolt Length	
3. Anchoring Method	
4. Unintentional Roof Falls	

Table C-2 Concluded

B. Mining Dimensions	B20 I
1. Entry, Crosscut, Room Size	T21 O
2. Pillar, Barrier Size	T22 O
3. Panel Width	T23 O
C. Mining Equipment (Models and Specifications)	B23 I
1. Conventional (Cut, Drill, Blast, Load, Bolt, etc.)	T29 O
2. Continuous (Continuous Miner, Bolter, etc.)	T28 O
3. Longwall (Shear, Supports, etc.)	T27 O
4. Transportation (Shuttle Car, Rail, Conveyor, etc.)	T26 O

TABLE C-3

PROPOSED CARD EDGE-NOTCH FORMAT FOR GROUND CONTROL
REPOSITORY PRIMARY SUBJECTS AND DATA FINDER

Major Subjects		Pos ^{1/}	Topic	Minor Subjects/Data Finder		Pos ^{1/}	Topic
		R16	Mining Problems			B10 I	Temporary Roof Supports
		R15	Mine Design			B 9 I	Timber Supports
		R14	Pre-mining Investigation			B 8 I	Roof Bolts
		R13	Other Ground Control			B 7 I	Steel Supports
		R12	(Reserved)			B 6 I	Bolting/Support Patterns
		R11	Geology			B 5 I	(Reserved/Other)
		R10	Rock Mechanics			B 4 I	Room/Entry-and-Pillar
		R 9	Subsidence			B 3 I	Longwall
		R 8	Mining Methods/Equip.			B 2 I	Shortwall
		R 7	(Reserved)			B 1 I	Hydraulic
						T30 0	(Reserved/Other)
						T29 0	Conventional
						T28 0	Continuous
						T27 0	Longwall
						T26 0	Transportation
						T25 0	Center/Tension Cracks
						T24 0	Rub/Shear Cracks
						T23 0	Mechanical Log
						T22 0	Rock Quality Classification
						T21 0	Geophysical Log
				Location ^{2/}		T20 I	} State-Two Digit to FIPS Code (Ref. 120)
						T13 I	
						T12 I	} Coalbed-Three Digit to USBM Code (Ref. 117)
						T 1 I	
						T 1 0	} County-Three Digit to FIPS Code (Ref. 120)
						T12 0	
						T13 0	} Foreign Country-Three Digit to FIPS Code (first 2 digits above state, 3rd in Country T12 0 to T 9 0) (Ref. 120)
						to	
						T20 0	
Secondary Subjects		R 6	Roof Falls				
		R 5	Pillar Crushing				
		R 4	Floor Heave/Squeeze				
		R 3	Geologic Anomalies				
		R 2	Bumps and Outbursts				
		R 1	(Reserved/Other)				
		B19 I	(Reserved)				
		B20 I	Mining Dimensions				
		B21 I	Systematic Roof Control				
		B22 I	Mining Methods				
		B23 I	Equipment Types				
		B24 I	Remote Sensing				
		B25 I	Multiple Seams				
		B26 I	Thick Seam				
		B27 I	Steeply Dipping Seams				
		B28 I	Methane Drainage				
		B29 I	Water/Hydrology				
		B30 I	(Reserved/Other)				
		B18 I	Borehole/Core Logging				
		B17 I	Mapping				
		B16 I	Rock Mechanics Measurements				
		B15 I	Calculated Rock Properties				
		B14 I	Theoretical Evaluations				
		B13 I	Subsidence Measurements				
		B12 I	Calculated Subsidence Factors				
		B11 I	(Reserved/Other)				

Table C-3 Cont'd.

<u>3/</u>	<u>Pos</u> ^{1/}	<u>Topic</u>
<u>Authors</u>	L 1	Multiple Authors
	L 2	Single Author (first 3 letters to of last name) or
	L16	
	L17	Multiple Authors (first letter each last name) (Reserved)
<u>Minor</u>		
<u>Subjects/</u>	B 1 0	Lineament Analysis
<u>Data</u>	B 2 0	Geophysical Exploration
<u>Finder</u>	B 3 0	Topographic Maps
	B 4 0	Geologic Maps
	B 5 0	Structural Maps
	B 6 0	Lithologic profile/cross-section
	B 7 0	Isopack/Thickness maps
	B 8 0	Compressive Strength
	B 9 0	Shear Strength
	B10 0	Tensile Strength
	B11 0	In-Situ Stresses
	B12 0	Other Mechanical Properties
	B13 0	Coefficient of Internal Friction
	B14 0	Poisson's Ratio
	B15 0	Young's Modules/Elasticity
	B16 0	Modules of Rigidity
	B17 0	Bearing Capacity/Strength
	B18 0	Finite-element Modeling
	B19 0	Photo-Elastic Modeling
	B20 0	Instrumentation
	B21 0	Vertical Displacement
	B22 0	Horizontal Displacement
	B23 0	Relationship to Mining
	B24 0	Surface Cracks/Bulges
	B25 0	Angle of Break/Draw
	B26 0	Bulking/Swell Factor
	B27 0	(Reserved/Other)
	B28 0	(Reserved)
	B29 0	(Reserved)
	B30 0	(Reserved)

<u>Summary:</u>	<u>Notches Required</u>	<u>Notches Allocated</u>
Major Subjects	8	10
Secondary Subjects	22	25
Minor Subjects	49	64

	<u>Pos</u> ^{1/}	<u>Topic</u>
<u>Minor</u>	T21 I	Entry/Room/Crosscut Size
<u>Subjects/</u>	T22 I	Pillar/Barrier Size
<u>Data</u>	T23 I	Panel Width
<u>Finder</u>	T24 I	(Reserved)
	T25 I	(Reserved)
	T26 I	(Reserved)
	T27 I	(Reserved)
	T28 I	(Reserved)
	T29 I	(Reserved)
	T30 I	(Reserved)

NOTES: 1. Position codes, with corner cut in upper right, are:

T = Top edge
 B = Bottom edge
 R = Right edge
 L = Left edge
 I = Inner row
 O = Outer row

2. Numerical codes use four notches for each digit as follows:

0 = No Notch 5 = Notch 1&4
 1 = Notch 1 6 = Notch 2&4
 2 = Notch 2 7 = Notch 7
 3 = Notch 1&2 8 = Notch 1&7
 4 = Notch 4 9 = Notch 2&7

3. Alphabetic coding uses five notches for each letter as follows:

A = No Notch Q = Notch OC
 B = Notch B R = Notch OCB
 C = Notch C S = Notch OE
 D = Notch CB T = Notch OEB
 E = Notch E U = Notch OI
 F = Notch EB V = Notch OIB
 G = Notch EC W = Notch OIC
 H = Notch ECB X = Notch OICB
 I = Notch I Y = Notch OIE
 J = Notch IB Z = Notch OIEB
 K = Notch IC
 L = Notch ICB
 M = Notch IE
 Mc = Notch IEB
 N = Notch IEC
 O = Notch O
 P = Notch OB

Document No.

Title

Author(s)

Multi Code: _____

Company/Mine Name

MSHA (Map Repository) ID No.

City, State (Country)

County

Coalbed

Code: _____

Code: _____

Code: _____

Key Words

Subject Index

	✓	Pos.	Data Finder	✓	Pos.
1. Mining Problems		R16	1. Geology		R11
Roof Falls		R06	Borehole Logging		B18 I
Pillar Crushing/Spalling		R05	Mapping		B17 I
Floor Heave/Squeeze		R04			
Geologic Anomolies		R03	2. Rock Mechanics		R10
Outbursts/Bumps		R02	Measured Properties		B16 I
			Calculated Properties		B15 I
2. Mine Design		R15	Theoretical Evaluations		B14 I
Mining Dimensions		B20 I			
Systematic Roof Control		B21 I	3. Subsidence		R09
Mining Methods/Systems		B22 I	Measurements		B13 I
Equipment Types		B23 I	Calculated Factors		B12 I
3. Pre-mining Investigations		R14	4. Mining Methods/Equipment		R08
Remote Sensing		B24 I	Roof Control Plans		B21 I
Geology		R11	Mining Dimensions		B20 I
Rock Mechanics		R10	Equipment Types		B23 I
Geophysical Techniques		B02 O			
4. Other Ground Control Problems		R13	<u>Minor Key Words</u>	✓	<u>Pos.</u>
Subsidence		R09			
Multiple Seams		B25 I			
Thick Seams		B26 I			
Steeply Dipping Seams		B27 I			
Methane Drainage		B28 I			
Water/Hydrology		B29 I			

	By	Date	Chk'd.
Abstracted			
Coded			
Punched			
Microfilmed			

FIGURE C-2 - DOCUMENT CODING FORM FOR MANUAL COORDINATE INDEX

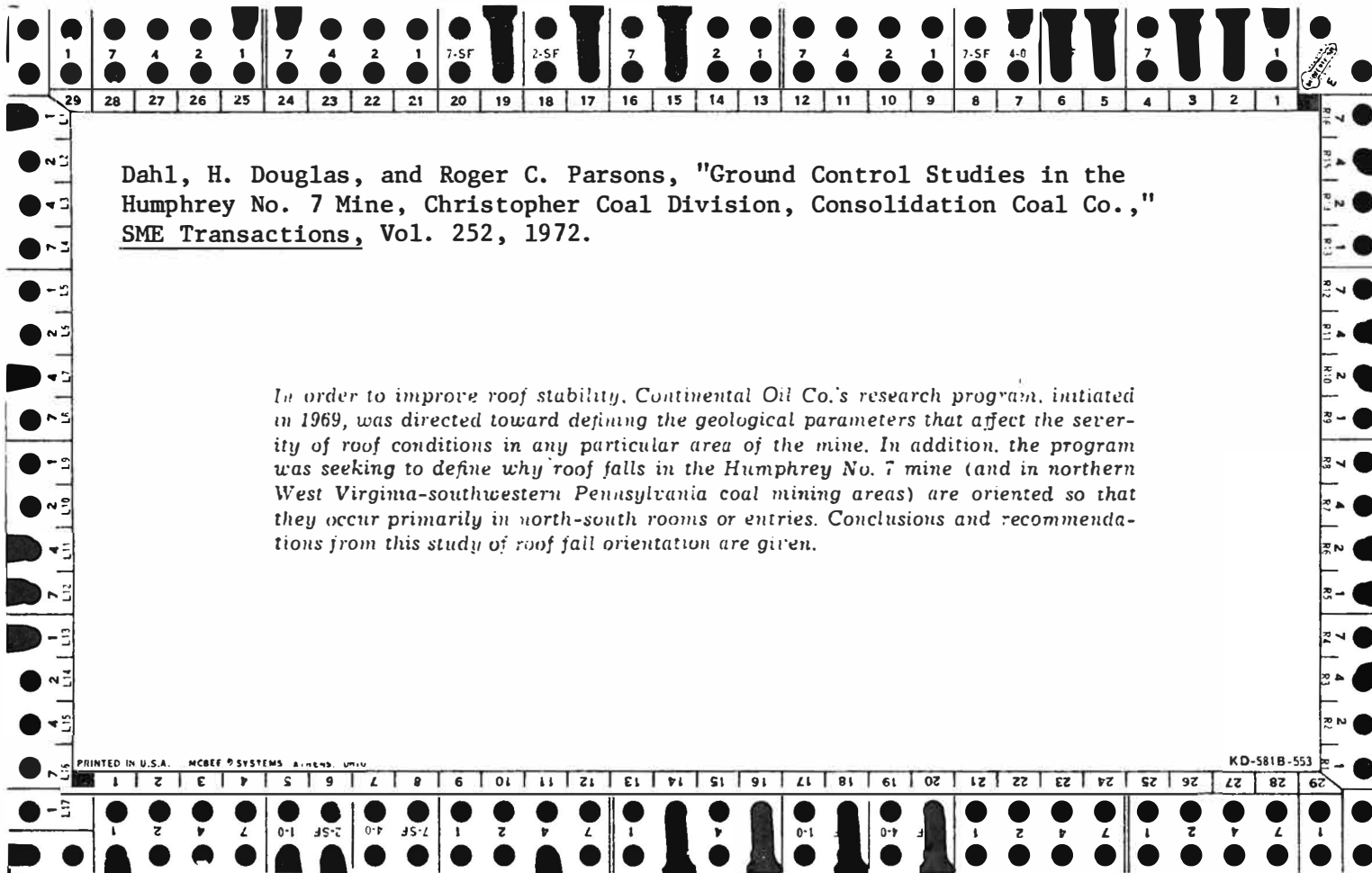


FIGURE C-3a - REPRESENTATIVE EDGE-NOTCHED CARD

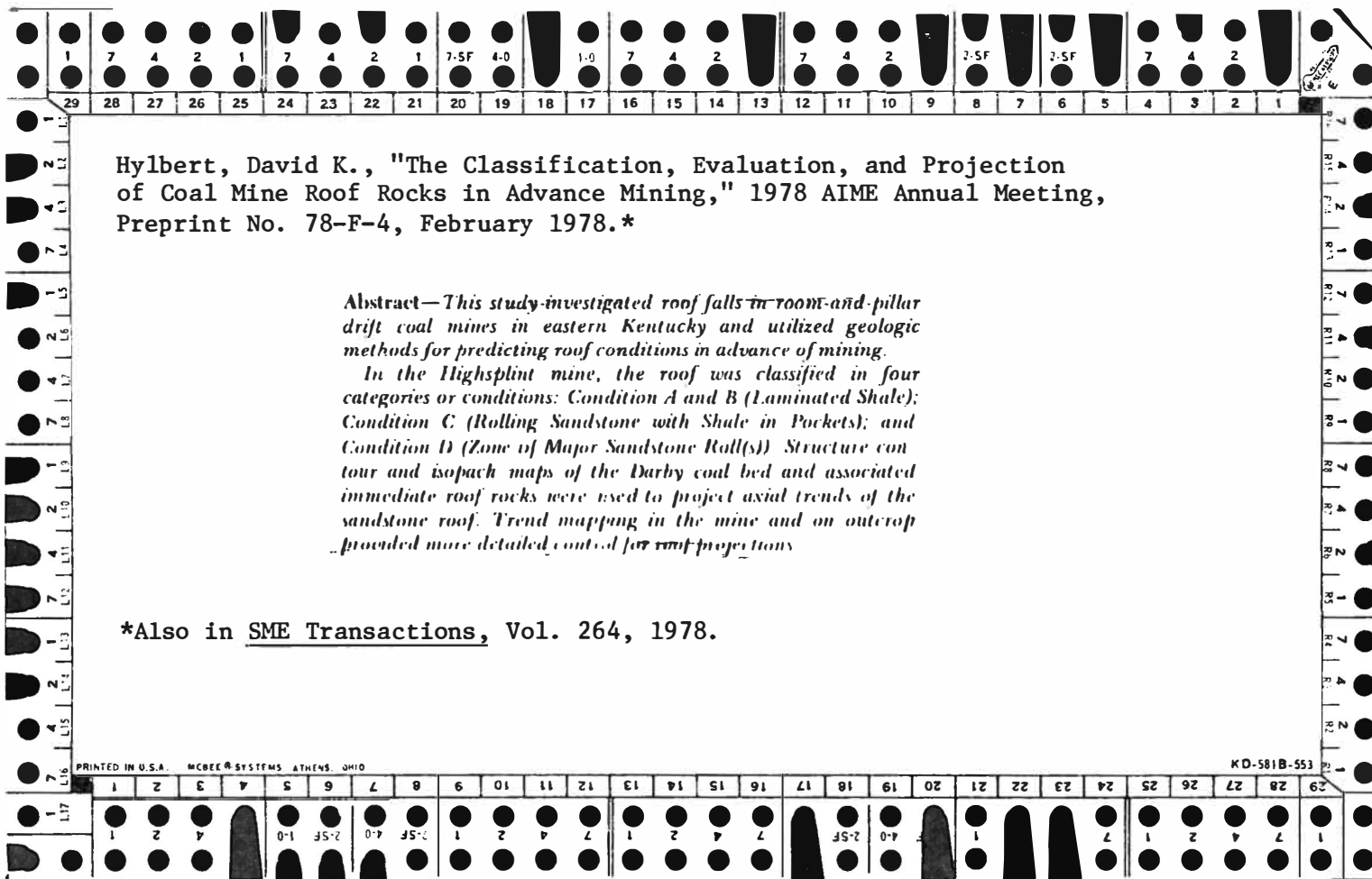


FIGURE C-3b - REPRESENTATIVE EDGE-NOTCHED CARD

Moebs, Noel N., "Roof Rock Structures and Related Roof Support Problems in the Pittsburgh Coalbed of Southwestern Pennsylvania," U.S. Bureau of Mines, Report of Investigations, RI 8230, 1977.

The Bureau of Mines investigated severe coal mine roof support problems along a section of main entries in the Pittsburgh coalbed in southwestern Pennsylvania to identify the causative factors. The mine roof was examined in detail, and various sedimentary structures are described that contributed directly to irregular and unstable roof. Small-scale paleochannels, scours, and related slickensides were identified as the leading cause of bad roof, and isopach maps were prepared to illustrate a method whereby the presence of these structures could be inferred in advance of mining. Probably second in importance was the occurrence of relatively incompetent flaggy, poorly cemented sandstone, weakened by coal and micaceous laminae. No effect of in situ stresses on roof stability was detected.

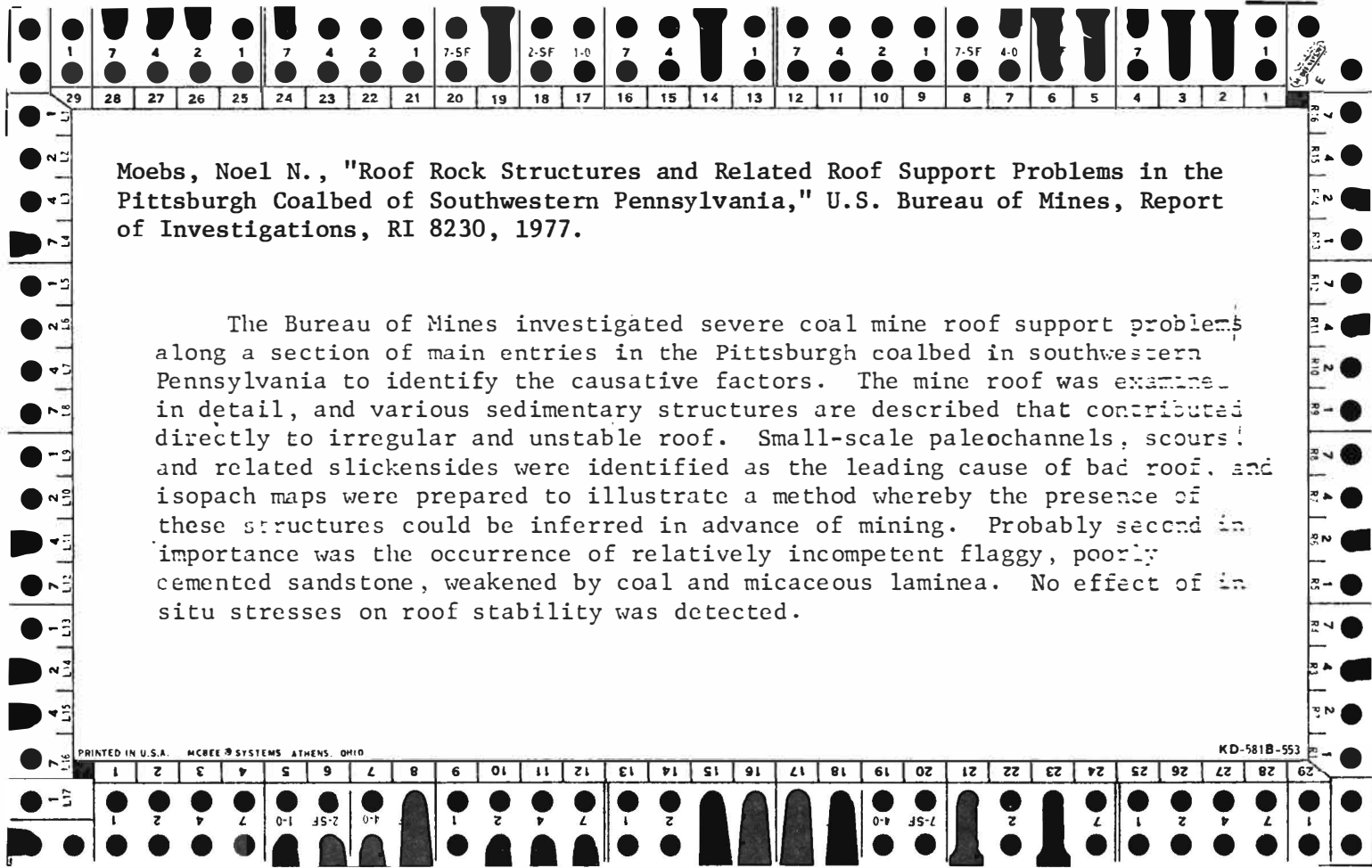


FIGURE C-3c - REPRESENTATIVE EDGE-NOTCHED CARD



CAMBRIDGE,
MASSACHUSETTS

• SAN FRANCISCO
WASHINGTON
ATHENS
BRUSSELS
LONDON
MADRID
PARIS
RIO DE JANEIRO
SÃO PAULO
TOKYO
TORONTO
WIESBADEN