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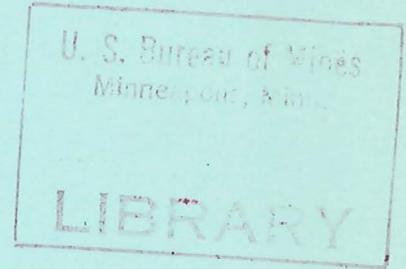
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REPORT SO 346123



REMOTE CONTROL FOR CONTINUOUS MINERS:  
A STATE-OF-THE-ART REVIEW

John T. Boyd Company  
430 Oliver Building  
Pittsburgh, Pennsylvania 15222



September 1975

Final Report

"The views and conclusions contained in this document are those of the authors 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."

Prepared For

UNITED STATES BUREAU OF MINES  
4800 Forbes Avenue  
Pittsburgh, Pennsylvania 15213

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<p>This report reviews the current state of the art of remote control techniques for underground continuous miners. A delineation of aspects requiring additional data is presented. Also a summary and delineation are presented in overview form for the related section functions: roof control, haulage, ventilation, power supply and rock dusting.</p> <p>The automated remotely controlled continuous miner project is a long-range research effort. However, the program has been divided into intermediate steps resulting in incremental production increases throughout the program. Data are developed relating the impact of our proposed research and development accomplishments to potential productivity impact.</p>			
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## FOREWORD

This final report was prepared by the John T. Boyd Company of Pittsburgh, Pennsylvania, under a U.S. Bureau of Mines (USBM) Contract No. S0346123. The contract was initiated under the Coal Mine Health and Safety Research program. It was administered under the technical direction of the Pittsburgh Mining and Safety Research Center, with Mr. Howard E. Parkinson acting as Technical Project Officer. The purpose of the study was to provide a determination of present and projected developments by mining machine manufacturers and coal operators on the area of remotely controlled underground face mining systems.

# JOHN T. BOYD COMPANY

MINING AND GEOLOGICAL ENGINEERS

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United States Bureau of Mines  
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Attention: Mr. Howard E. Parkinson  
Technical Project Officer

Subject: Contract SO 346123  
Automated Remotely Controlled Continuous Miners

Gentlemen:

In accordance with provisions of the contract, herewith is our final report concerning our engineering assistance on research proposals related to the design, development, construction, testing, and demonstration of automated remotely controlled continuous miners.

This report reviews the current state of the art of remote control techniques for underground continuous miners. A delineation of aspects requiring additional data is presented. Also, a summary and delineation are presented in overview form for the related section functions: roof control, haulage, ventilation, power supply, and rock dusting.

The automated remotely controlled continuous miner project is a long-range research effort. However, the program has been divided into intermediate steps resulting in incremental production increases throughout the program. Data are developed relating the impact of our proposed research and development accomplishments to potential productivity.

The compilation and assessment of continuous miner remote control techniques have been achieved through literature search, personal visits or telephone conversations with individuals in the industry, manufacturers, and mine operators.

Very truly yours,



L. D. Gent  
Executive Vice President



## GENERAL STATEMENT

In 1974, approximately 170 million tons or 60% of United States underground coal production was mined by continuous mining machines. Almost all of this continuous mined production was done by miner operators working beside the machine (on site) within 20 to 25 ft. of the newly mined face and manually performing each of the repetitive cycle operations of,

- (a) machine movement
- (b) mining
- (c) material transfer.

The leading manufacturers of continuous mining machines have recently introduced remote control equipment by which the miner operator can direct the mining machine movements from a distance limited only by his vision. The majority of these devices are connected to the machine by electric or hydraulic cable; radio control also is used. Performance to date indicates removal of the machine operator from the hazardous face area can be accomplished with present technology. However, very little has been done to concurrently improve unit section production and safety through a phased program of,

- 1) Automation or semiautomation of continuous mining machine sequence control functions.
- 2) Application of sensors and guidance controls to continuous mining machine operation.
- 3) Continuous mining systems analyses based on automatic or semi-automatic face machine operation.
- 4) Interface between automated or semiautomated related section job functions.

Modern continuous mining machines are equipped with some built-in automated operations including,

- (a) Methane gas warning by a signal light when certain methane limits are exceeded (1%). Also, power to the machine is shut off when concentrations of methane gas become critical (2%).
- (b) Water sprays turned on or off by certain machine movements.
- (c) Greasing devices activated by machine movements (i.e., conveyor swing).
- (d) Cutting motors start in sequence.

Present indicators show the trend toward increased use of continuous mining machines will continue. While automation and remote control are largely applied in modern industry, the question of why automation and remote control are not being applied in mining can be answered as follows:

- (a) Automation and remote control are best suited to "static" industries. Those are industries where one specific process is repeated over and over again, is not influenced by "external" factors, and the replacement of the human element by automation presents advantages to the operation.
- (b) Present coal mining, however, is a "dynamic" industry. External factors, such as geological conditions, dictate frequent changes. Necessary continuing adjustments and changes limit presently known automation and remote controls.
- (c) Reasons are to be found in external problems not directly in the mining machine, but directly related to its application. Improvements of utilization could be found through a "system" approach whereby some external problems are being resolved before design changes of the machine are made.

The presently known greatest accomplishment in combining several work phases of coal extraction into one machine is the continuous miner. This machine

has been developed to a credible reliability in the industry. Although the production capability is extremely high, its utilization rate has decreased during the last years and, at present, rarely exceeds 30% of total available time.

Modern type continuous mining machines are reasonably adaptable to programmed mining cycles. However, to automate continuous mining machine operations, (1) movement, (2) mining, and (3) material transfer, requires adequate sensing, sequencing and control functions. Since little information has been disclosed, it is reasonable to assume extensive work has not been performed in this area.

The accomplishments in automated remotely controlled continuous miners must be successfully aligned with other mining section job functions, such as roof control and haulage, for major production benefits to be realized.

This Automated Remotely Controlled Continuous Miner subprogram, hereinafter referred to as ARCCM, is of such magnitude and potential impact on mining productivity, cost reduction and safety improvements that it requires full involvement of industry including equipment designers and manufacturers, mining operators and consultants in order to insure the accomplishment of stated objectives. Manufacturing areas requiring special coordination include

- Mining equipment
- Automated and remote control equipment
- Sensors equipment
- Communication and monitoring equipment

Historically, many of the innovations in machine design have been developed by mining operators. Therefore, the demonstration and development aspects of this subprogram should be subjected to coal industry participation and

review. The broad scope, knowledge, and experience of consultants in the field of mining engineering, automated and remote control equipment, sensors, and communications, must be utilized and coordinated through technology transfers.

The accomplishments of this subprogram are expected to be of vital interest to all in the coal mining industry and related bedded deposit industries (e.g., potash). Therefore, periodic technology transfer seminars and mine demonstrations are recommended. Due to the myriad of working prototypes possible in the subprogram and the integral relationship that must be established with the other section job functions, it is vitally important that simulated mining conditions be available for work progress evaluation and review in an accessible, convenient, controlled and semi-realistic environment.

It should be recognized that separate machine parameters may result for the low coal range (approximately 2 to 4 ft. machine height) due to a number of restrictions; however, these limitations should be defined in initial experimental machine models and subsequent working machine models.

It is thought that a simulation chamber having approximate mining entry dimensions and cross entry features could be constructed either above ground or in the Bruceton Safety Research Mine with both low coal and high coal features. The mining or excavation of material could be accomplished by extracting an artificial media, such as a suitable mixture of fly ash, limestone, gypsum, or cement aggregate. Prototypes performing satisfactorily in the simulation chamber would be incorporated into experimental and working machine models for testing in mine operations.

Before working machine models are placed at Bruceston, contract experimental mines, or cooperative operators' mines, the prototype would be reviewed to insure MESA acceptable standards and an industry acceptable product developed for commercial applications.

The long-term goal of the ARCCM envisions a future automated mining system operating approximately 120 minutes continuously during the first half of the shift and 120 minutes during the second half. A machine maintenance and face supply period would be scheduled between the two operating periods.

The ARCCM will be accomplished through a series of integrated steps. Each step is the successful completion of a particular job function contract. As the contracts are completed, the particular job function should become commercially available and adaptable to present mining systems. Therefore, it is expected that an incremental production increase should be forthcoming after three to five years of research in prototype development. It is recognized that the rate of productivity increase in the subprogram is vitally related to the extent job functions can be combined in the ultimate automated remote continuous miner sections.

Increased use of continuous miners should warrant the development of Automated Remotely Controlled Continuous Mining Systems. This report will show

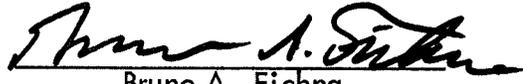
the present state of the art of continuous miner remote control and related steps  
to be taken to improve production in the coal mining industry .

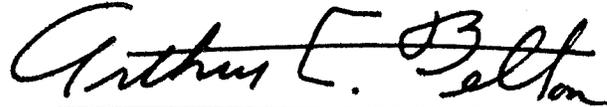
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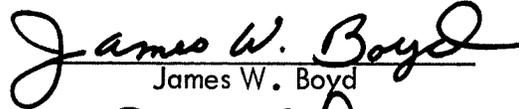
JOHN T. BOYD COMPANY

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## SUMMARIZED FINDINGS

The following sections of this report, with the plates, tabulations, schedules, and appendices, support these summarized statements.

1. Our efforts have been directed to the determination of present and projected developments by mining machine manufacturers and coal operators in the area of remotely controlled underground face systems.
2. There are a number of machine functions requiring further development in order to substantially increase machine productivity without sacrifice of mined product quality or safety, if automated remote machine operation is to be performed. The functions are:

- Machine control
- Sequence control
- Sensing control
- Auxiliaries control
- Communication
- Observation

Performance to date of machine operators remotely controlling a continuous miner indicates remote operation produces some benefits in production and recovery during retreat operations but is doing very little or nothing at all for advancing operations. The operator has a loss of sensation and when operating remotely during advancing operations he sometimes moves to the back of the machine and places the control box on the machine to restore sensation. To utilize a major improvement of the unit section production through automation and remote control it will require extensive research in the following areas:

## 2. (Continued)

- (a) Application of sensors and guidance controls to continuous mining machine operation.
- (b) Automation or semiautomation of continuous mining machine sequence control functions.
- (c) Continuous mining system analyses based on automatic or semiautomatic face machine operations.
- (d) Collaboration between automated or semi-automated mining functions of:

- Extraction
- Roof control
- Haulage
- Ventilation
- Cleanup and dust control
- Rock dusting
- Power
- Water systems
- Maintenance
- Communications and control

3. The present State of the Art of continuous miner remote control techniques can be summarized by the following systems:

- (a) Portable hydraulic control panel
- (b) Portable control panel - multiple electrical conductors
- (c) Radio control - coaxial cable
- (d) Radio control

4. Reasons for the remotely controlled continuous miners not producing substantial quantities of coal today are found not only on the machinery and technology. Present limiting factors are interrelated and are analyzed as follows:

## 4. (Continued)

(a) Coal Dust and Cleanup

Present remotely controlled continuous miners leave loose coal on the floor and along the ribs; the ribs and roof have to be rock dusted within 40 ft. of the working face.

(b) Ventilation

Ventilation within 10 ft. of face must be maintained.

(c) Methane Testing

Methane gas tests are required to be taken at 20 minute intervals by the miner operator.

(d) Power and Fresh Water Supply

The handling of trailing cables and water hoses in conjunction with the advancing remotely controlled miner is done manually.

(e) Visibility

The operator's view of the coal face is limited.

## 5. Presently, the advantages of remote control continuous mining are:

- (a) Increased safety
- (b) Increased reserve recovery
- (c) Increased production on retreat mining.

6. The long-term goal of ARCCM subprogram envisions a future automated mining system operating approximately 120 minutes continuously during the first half and 120 minutes during the second half of the shift. A machine maintenance and face supply period would be scheduled between the two operating periods. The basic parameters utilized in deriving the

## 6. (Continued)

proposed machine guidelines are tabulated below; however, these parameters are flexible, pending future developments.

Entry Height (feet)	6
Entry Width "	14
Tons per Foot Entry Advance	3.4
Entry Advance per Hour	60
Tons per Minute Average Production	3.4
Roof Bolt Row Spacing (feet)	4
Rows of Roof Bolts Installed per Hour	15
Roof Bolts per Row	3
Minutes per Roof Bolt Row	4.0
Minutes per Shift, Machine Operation	240
Tons per Unit Shift	816

The ARCCM will be accomplished through a series of integrated steps. Each step is the successful completion of a particular job function contract.

The orderly succession to an automated remotely controlled continuous miner should include development in machine and remote control and a phased program of accomplishment in:

On-site	Manual
Remote	Manual
On-site	Semiautomatic
On-site	Automatic
Remote	Semiautomatic
Remote	Automatic

## 6. (Continued)

Individual work functions under each of these projects would include:

- (a) Mining
- (b) Mining and sensing
- (c) Machine movement
- (d) Machine movement and sensing
- (e) Material transfer
- (f) Material transfer and sensing
- (g) Programmed and sequenced

7. Before working machine models are placed at Bruceston, contract experimental mines, or cooperative operators' mines, the prototype would be reviewed to insure MESA acceptable standards and an industry acceptable product developed for commercial applications.

8. The major integrated steps to accomplish the ARCCM are listed below. Only the major foreseen proposed tasks are listed; there will be a myriad of additional smaller version contracts resulting from yet to be defined problem areas of the listed proposed tasks.

Automated Continuous Miners:

Design to incorporate automation of functions listed below as developed.

Cutting, Sump, Shear: Programmed and controlled by sensing devices.

Steering: Programmed for forward, reverse, and positioning at the face.

Cutting Crosscut Angles: Programmed for proper distance and angles.

## 8. (Continued)

Automated Roof Bolter:

Design to incorporate automation of all operations, including those listed below.

Steering and Tram: Programmed to follow continuous miner and install support at correct pattern.

Roof Support: Capacity to accept programming for variety of lengths and types of roof support.

Automated Haulage: Connected to and controlled by movement of continuous miner or roof bolter and material transfer.

Extension of Underground Services:

Ventilation: Complete atmospheric monitoring and automatic extension of face ventilation in conjunction with entry development

Rock Dust and Cleanup: Develop new methods to permit uninterrupted continual entry advancement.

Power and Water Supply: Designed for complete automation and mechanical handling of electrical cables and water hose. Presently, semiautomated when in conjunction with extensible conveyors.

Monitoring and Control: All connections to automated systems, including visual face observation.

Maintenance: Special maintenance centers and complete technical information on all equipment.

9. The estimated costs and time periods to complete each of the foregoing integrated steps of ARCCM are summarized below.

Year:	(Dollars in 000's)					Total
	Allotted Time: 5 Years					
	1	2	3	4	5	
<u>Continuous Miner</u>						
Automated Continuous Miner	\$1,000	\$1,000	\$1,000	\$2,000	\$1,000	\$ 6,000
Cutting, Sump, Shear	600	600	600	300	300	2,400
Steering - Forward and Reverse	300	500	500	200	200	1,700
Cutting Crosscut Angles	100	300	300	100	100	900
Subtotal	<u>2,000</u>	<u>\$2,400</u>	<u>2,400</u>	<u>2,600</u>	<u>1,600</u>	<u>11,000</u>
<u>Roof Bolters</u>						
Automated Roof Bolter and Material Transfer	300	300	300	500	500	1,900
Automated Steering and Tram	200	200	200	200	200	1,000
Automated Roof Support (various roof pin lengths)	300	300	300	300	300	1,500
Subtotal	<u>800</u>	<u>800</u>	<u>800</u>	<u>1,000</u>	<u>1,000</u>	<u>4,400</u>
<u>Automated Haulage System</u>	1,000	1,000	2,000	4,000	3,000	11,000
<u>Extension of Underground Services</u>						
Ventilation, Rock Dust and Cleanup	400	400	400	400	400	2,000
Power Distribution	200	200	200	200	200	1,000
Water Supply and Drainage	100	100	100	100	100	500
Monitoring and Control	500	500	1,000	1,000	1,000	4,000
Maintenance and Miscellaneous	500	500	500	500	500	2,500
Subtotal	<u>1,700</u>	<u>1,700</u>	<u>2,200</u>	<u>2,200</u>	<u>2,200</u>	<u>10,000</u>
<b>Total Cost (1st 5 Years)</b>	<b>\$5,500</b>	<b>\$5,900</b>	<b>\$7,400</b>	<b>\$9,800</b>	<b>\$7,800</b>	<b>\$36,400</b>

At the end of five years, it is expected that the program would result in the development of commercial type machines adaptable to remote and automatic controls that could be applied to present mining systems, including continuous miners, roof bolters, and haulage system.

The necessary work to fully integrate these units into a completely automated mining system is estimated to require an additional five years and cost \$14 million. A cost estimate by year shows:

Year	Job Function	Est. Cost (000's)
1976-80	First 5 Years - Research and Development	\$36,400
1981	Integration engineering	2,000
1982	Achieve automatic remote working system prototype	2,000
1983	Develop programming and sequence devices, control station	4,000
1984	Develop, test and demonstrate experimental system	2,000
1985	Develop, test and demonstrate working system	<u>4,000</u>
<b>TOTAL ARCCM</b>		<b>\$50,400</b>

10. The following future research activities in underground coal mining are expected to have the greatest direct benefit on coal production in United States. Major subheadings for each activity also are presented. Judgment of the estimated potential productivity impact on mining for the major areas of the continuous mining system is presented in a relative weighted percentage relationship, using 100 as a base. We also have estimated the relative influence of ARCCM on these areas based on a scale ranging from 1 to 10, with number 1 indicating the greatest impact.

	<u>Major Direct Productivity Benefit</u>	<u>Estimated Potential Productivity Impact Percent</u>	<u>Relative Influence of ARCCM</u>
A.	Improvement of personnel procedures and requirements	17	7
B.	Promotion of major revisions in face mining machine concept	15	1
C.	Improved roof support concepts	13	2
D.	Improvement of mined material transportation	13	3
E.	Accelerated and improved extension of underground services to the newly mined area	11	5
F.	Development of overall mining systems	10	4
G.	Communications and systems monitoring	8	6
H.	Auxiliary methane extraction and recovery	7	10
I.	Alternate energy sources for underground mobile equipment	3	9
J.	Production engineering and system analysis	3	8

ARCCM should indirectly affect Item A, which has been assigned the highest relative value, through the reduction of underground labor and the increased output per man.

STATE OF THE ART  
REMOTELY CONTROLLED CONTINUOUS MINERS

In 1974, 352 continuous miners were shipped from manufacturers to the mining industry; this is an all time record. Manufacturers and users of mining machinery believe that the trend to increased use of continuous miners will continue. The following table shows by underground mining method the annual production tons and respective percentage for the past 10 years, 1965 through 1974. This table illustrates the past usage of continuous miners, that is, 1965 at 43% increasing through 1974 to 60% of the total underground production.

Bituminous Coal and Lignite Production By Underground Methods of Mining In the United States 1965 - 1974							
Methods:		Continuous Miners	Longwall	Loading Machines	Hand Loaded Conveyors	Hand Loading	Total Underground
Year							
1965	Tons	141.9*	-	151.8	3.0	36.0	332.7
	(%)	42.7	-	45.6	.9	10.8	100
1966	Tons	152.8	2.3	152.7	2.5	28.2	338.7
	(%)	45.1	.7	45.1	.7	8.4	100
1967	Tons	165.6	3.2	158.4	2.7	19.2	349.1
	(%)	47.4	.9	45.4	.8	5.5	100
1968	Tons	163.8	4.6	159.7	1.2	14.8	344.1
	(%)	47.6	1.3	46.4	.4	4.3	100
1969	Tons	172.6	6.3	155.4	1.1	11.7	347.1
	(%)	49.7	1.8	44.8	.3	3.4	100
1970	Tons	169.9	7.1	152.2	-	9.6	338.8
	(%)	50.2	2.1	44.9	-	2.8	100
1971	Tons	152.9	6.6	111.4	-	5.0	275.9
	(%)	55.4	2.4	40.4	-	1.8	100
1972	Tons	178.4	7.8	114.9	-	3.0	304.1
	(%)	58.7	2.5	37.8	-	1.0	100
1973	Tons	178.6	9.4	109.3	-	2.1	299.4
	(%)	58.7	2.5	37.8	-	1.0	100
1974**	Tons	170.0	8.5	101.0	-	2.0	281.5
	(%)	60.4	3.0	35.9	-	.7	100

\*The longwall tonnage in 1965 was included with continuous miners.

\*\*Preliminary figures of continuous miner production.

Remote control has been designed and tested for over 15 years with only limited marketing success.

Our efforts have been directed to the determination of present and projected developments by mining machine manufacturers and coal operators in the area of remotely controlled underground face systems. Appendix A contains general interview remarks from mining industry personnel contacted during this study.

The Jeffrey Manufacturing Company reported that a remote control device for use on the Colmol continuous mining machine was designed in 1957. However, it was not developed because there seemed to be no particular demand for it at that time.

In 1959, Joy Manufacturing Company developed a device that programmed the cutting cycle of its ripper type continuous miner. The device would move the machine ripper bar through the necessary cycles to extract a complete room width (five or six cuts 18 in. deep, 42 in. wide, in the height of the seam).

The following functions were controlled and automated,

- (a) bar sump
- (b) cut-up
- (c) stop and retract boom
- (d) lower boom and swing to new position
- (e) stop at floor and sump.

After the full face width was cut the continuous mining machine would be manually trammed to the face to start another cycle.

The device was never offered commercially for many reasons including the lack of interest on the part of mine operators, the fact that continuous miner design was not stabilized, and the lack of adequate sensors to monitor and regulate the movements within the cut.

The Joy PBM (Push Button Miner) was a full face boring type miner applied to underground mining from strip mining highwalls at the Peabody Coal Company's Sunnyhill area during the period 1961 through 1965. It utilized several different sensing devices that reported visually to the single remote operator via meters and cathode-ray tubes. The operator was located in a control room outside the mine underneath the Heli-Track lower frame and beside the launching platform. The machine could mine in a single direction up to approximately 1000 ft. from the operator. However, due to its limited application, the lack of adequate sensors, and a cumbersome launching platform, the miner was abandoned.

The present State of the Art of continuous miner remote control techniques can be summarized by the following systems

- (a) Portable hydraulic control panel
- (b) Portable control panel - multiple electrical conductors
- (c) Radio control - coaxial cable
- (d) Radio control

Portable Hydraulic Control Panel:

This method, tested by Lee-Norse, Charleroi, Pennsylvania, was too cumbersome and did not prove to be a commercial success; it was replaced by electric controls. The hydraulic control used small valves and small control hoses grouped into one umbilical cable. These operated the main control valves by use of slave cylinders.

### Portable Electric Control Panel - Multiple Conductors:

Jeffrey, Joy, and Lee-Norse use this system of remote control exclusively with success. This system is limited by the length of the umbilical cable and the distance from which the operator can see the face.

### Radio Control, Coaxial Cable:

The radio control coaxial cable system has the advantage of a smaller umbilical cable and the number of controlled functions can be increased with the same size cable.

### Radio Control:

The radio control system available from the major manufacturers has proven to be very successful. Apparent limitations are the operator's view of the face and loss of feel sensation. The operator's control box is easily handled and, from tests made, can operate machine controls from a distance of over 300 ft.

Tabulation 1, following this text, summarizes remote control State of the Art for continuous mining systems.

The reasons remotely controlled continuous miners are not producing substantial quantities of coal today are not to be found only on the machinery and technology. While machine reliability has been improved over the past years, utilization rates of the machines have decreased. Some of the factors reducing utilization are to be found in related operations necessary to support a continuous miner. Present limiting factors are interrelated and are analyzed as:

1. Coal Dust and Cleanup:

Remotely controlled continuous miners should advance entries continuously. It must be anticipated that the continuous miner will not leave loose coal on the floor and along the ribs and the ribs and roof will be rock dusted within 40 ft. of the working face. Present machines, however, leave loose coal on the floor and along the ribs. The cleanup of this coal behind the miner, presently done by loading machines or scoops, should be done in a manner that does not interrupt the miner.

2. Ventilation:

Ventilation within 10 ft. of the face must be maintained on the remotely controlled system. This needs to be done with an extensible portable ventilation system.

3. Methane Testing:

Methane gas tests are required to be taken at 20 minute intervals by the miner operator. This requires the machine to stop and posts be set at the face to insure operator safety during methane testing. The interruptions offset some of the advantages of the remote control system.

4. Power and Fresh Water Supply:

The handling of trailing cables and water hoses in conjunction with the advancing remotely controlled miner requires a practical solution.

## 5. Visibility:

Visibility of the coal face is a limitation of remote control. If the face is seen by the operator, he can react to any unexpected change in mining conditions.

## 6. Advantages of Remote Control:

Presently, the advantages of remote control continuous mining are:

Increased safety  
Increased reserve recovery  
Increased production on retreat mining.

Mining companies have reported a production gain on pillar extraction utilizing remotely controlled continuous miners. By remote operation, a complete pillar extraction with no protecting fenders (coal stumps) remaining is obtained. The operator is behind the machine under a supported roof. Safety is increased considerably by the use of remote control. Production has increased in pillar work due to remote control but has not increased during the advance, or development, cycle.

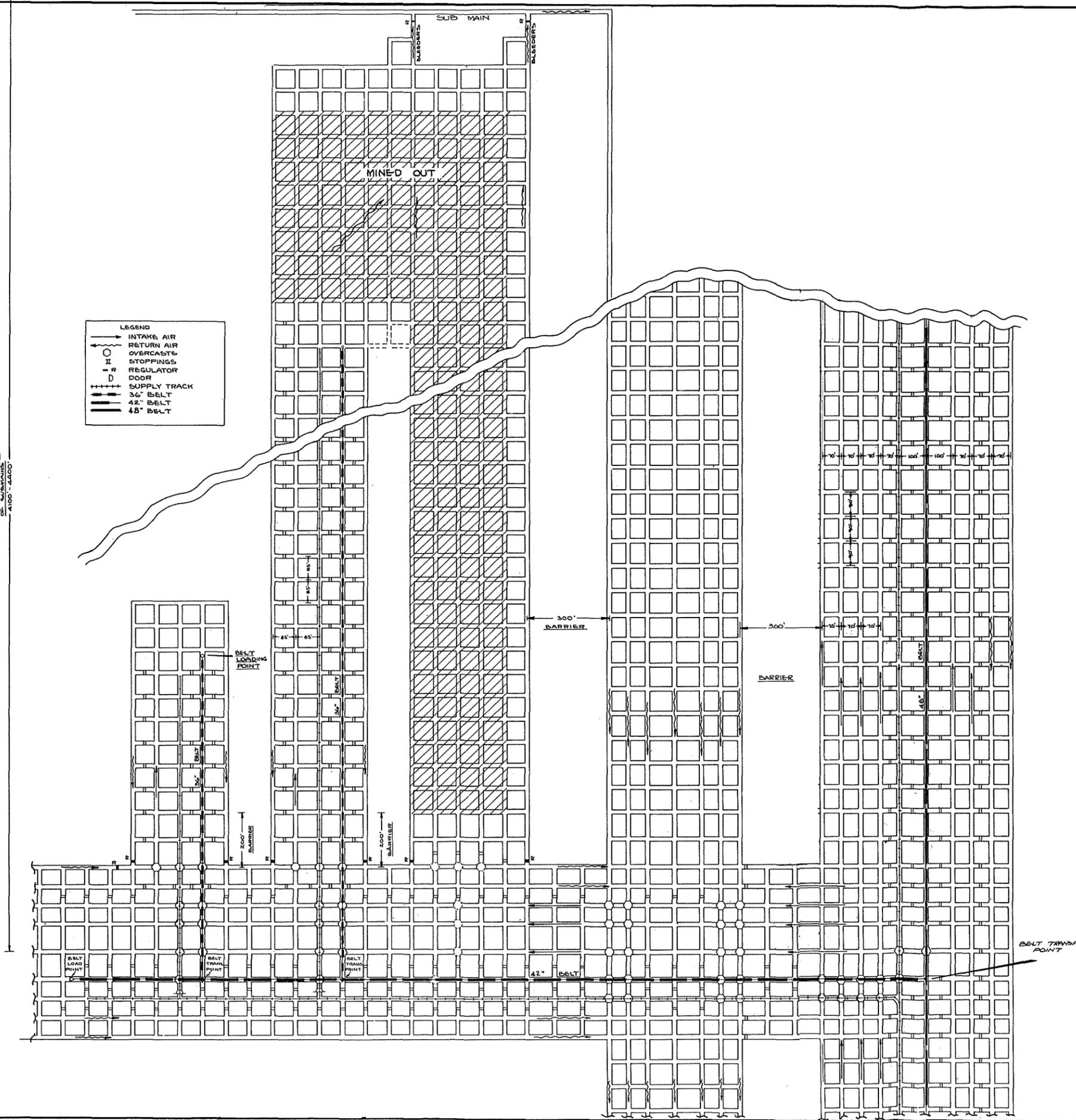
Following this text are plates illustrating a typical continuous mining system and are described as follows:

### Plates

- 1: A typical mine layout for a continuous miner system with 5 to 7 ft. seam height.
- 2 and 3: Remote control retreat mining sequences for two pillar sizes. Either pillar size is compatible with the Plate 1 general mining layout.

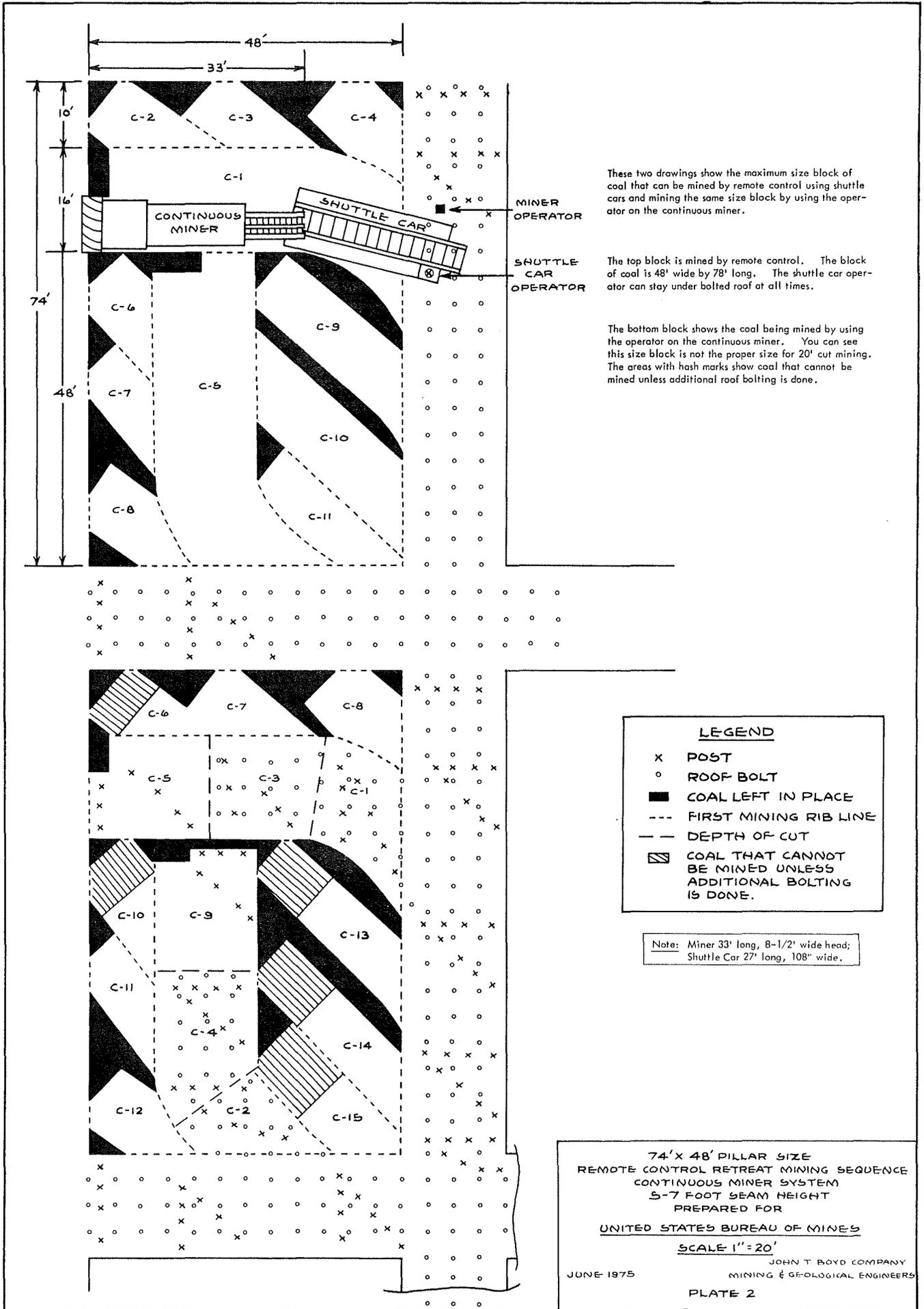
Also, following this text is:

Tabulation 1: State of the Art Summary, Continuous Mining Systems



PANEL LENGTH  
 50' - 100' - 150' - 200' - 250' - 300' - 350' - 400' - 450' - 500' - 550' - 600' - 650' - 700' - 750' - 800' - 850' - 900' - 950' - 1000'

TYPICAL MINE LAYOUT  
 CONTINUOUS MINER SYSTEM  
 5-7 FOOT SEAM HEIGHT  
 PREPARED FOR  
 UNITED STATES BUREAU OF MINES  
 SCALE 1" = 400'  
 JOHN T. BOYD COMPANY  
 MINING & GEOLOGICAL ENGINEERS  
 JUNE 1975  
 PLATE I



These two drawings show the maximum size block of coal that can be mined by remote control using shuttle cars and mining the same size block by using the operator on the continuous miner.

The top block is mined by remote control. The block of coal is 48' wide by 78' long. The shuttle car operator can stay under bolted roof at all times.

The bottom block shows the coal being mined by using the operator on the continuous miner. You can see this size block is not the proper size for 20' cut mining. The areas with hash marks show coal that cannot be mined unless additional roof bolting is done.

**LEGEND**

- X POST
- o ROOF BOLT
- COAL LEFT IN PLACE
- FIRST MINING RIB LINE
- - - DEPTH OF CUT
- ▨ COAL THAT CANNOT BE MINED UNLESS ADDITIONAL BOLTING IS DONE.

Note: Miner 33' long, 8-1/2' wide head; Shuttle Car 27' long, 108" wide.

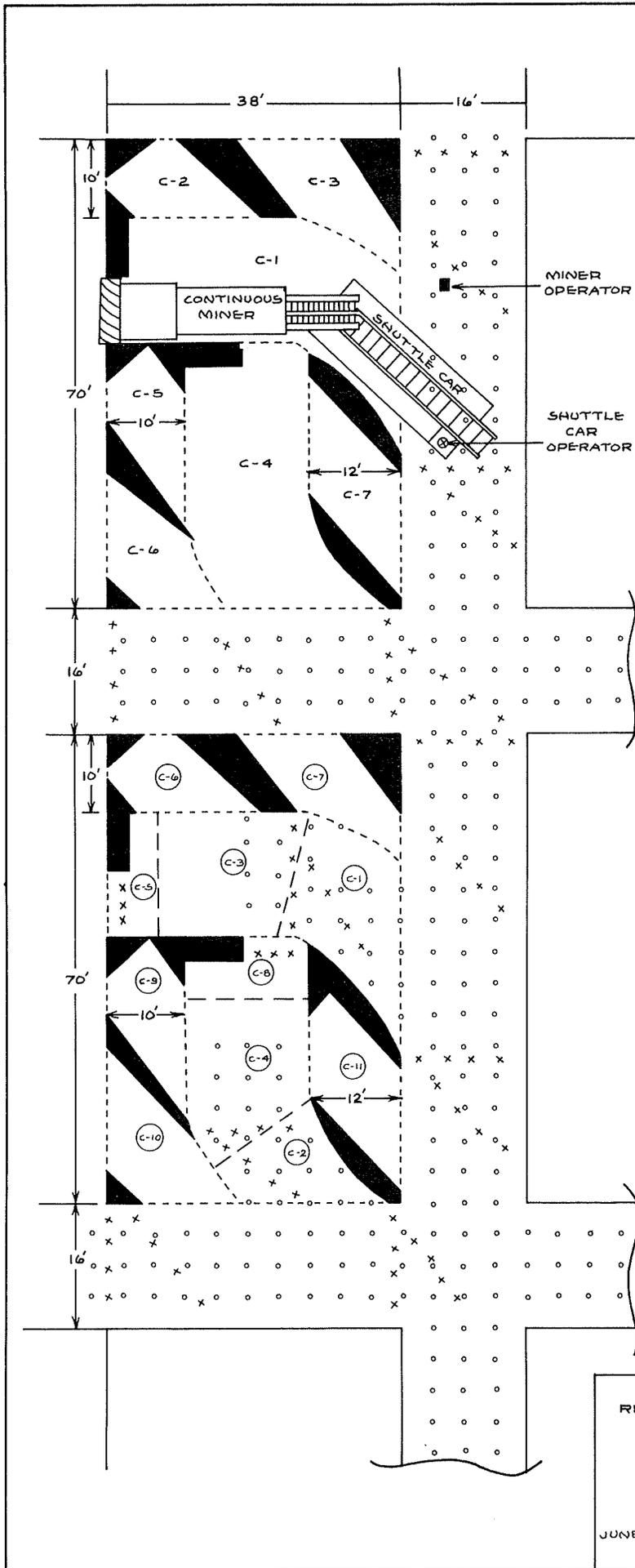
74' x 48' PILLAR SIZE  
 REMOTE CONTROL RETREAT MINING SEQUENCE  
 CONTINUOUS MINER SYSTEM  
 5-7 FOOT SEAM HEIGHT  
 PREPARED FOR  
 UNITED STATES BUREAU OF MINES

SCALE 1" = 20'

JOHN T. BOYD COMPANY  
 MINING & GEOLOGICAL ENGINEERS

JUNE 1975

PLATE 2



These two drawings show the maximum size block that can be mined with the minimum amount of bolting. The top block is mined out by remote control with no bolts and no post set inside the block area.

The bottom block is shown mined by the standard way with operator on the mining machine. The block was so designed to allow the 10' ribs to be extracted without any extra bolting.

The blocks are 38' by 70' and entries are 16' wide. The miner has an 8-1/2' wide cutting drum and is 33' long from end of cutting drum to the end of discharge boom. The shuttle car is 27' long and the operators deck is 3' long located 3' from the end of the discharge boom.

By mining with remote control a total of 32 posts and no roof bolts are used. Mining the standard way with an operator on the machine a total of 46 roof bolts and 54 posts are used.

The remote control system accumulated tram distance for taking out one block and traming to the next block is a total of 365'. By leaving the operator on the miner the total tram distance 885'.

	Remote Control	Conventional	Difference
Total Tram Dist.	365'	885'	520'
Frequency	7	11	4
Bolts Installed	0	46	46
Posts Set	32	54	22

- Remote Control Method Savings:
- Cost of 46 bolts complete.
  - Cost of 22 posts, wedges, cap blocks.
  - Four trams for total of 520'.
  - Delay time setting the additional 22 posts.
  - Delay time loading and hauling post to face.
  - Labor for loading and delivering additional supplies from surface to section.

**LEGEND**

- x POST
- o ROOF BOLT
- COAL LEFT IN PLACE
- FIRST MINING RIB LINE
- - DEPTH OF CUT

**NOTE:** MINER 33' LONG 8 1/2' WIDE HEAD  
SC 27' LONG 108" WIDE

70' X 38' PILLAR SIZE  
REMOTE CONTROL RETREAT MINING SEQUENCE  
CONTINUOUS MINER SYSTEM  
5-7 FOOT SEAM HEIGHT  
PREPARED FOR  
UNITED STATES BUREAU OF MINES  
SCALE 1" = 20'  
JUNE 1975 JOHN T BOYD COMPANY  
MINING & GEOLOGICAL ENGINEERS  
PLATE 3

TABULATION 1  
 STATE OF THE ART SUMMARY  
 CONTINUOUS MINING SYSTEMS  
 For  
 UNITED STATES BUREAU OF MINES  
 By  
 John T. Boyd Company  
 Mining and Geological Engineers  
 June 1975

<u>Method</u>	<u>Sources of Information</u>	<u>Remarks</u>
<u>CONTINUOUS MINERS</u>		
<u>Remotely Controlled</u>		
Additional set of controls detached from the continuous miner. When not in use can override by using standard controls on machine.		
(a) With umbilical electrical cable connected to control system and all valves and other controls operated by solenoid.	Jeffrey, Lee-Norse and Joy, coal companies and machine operators.	An acceptable method to operate a continuous miner. Limited by umbilical cable restrictions.
(b) Radio control with control box power furnished by rechargeable easily changed battery. Battery receiver built into frame of machine.	Jeffrey and National Steel Company, Wayland, Kentucky.	The best system observed, provides greatest flexibility.
(c) Radio control with control box power furnished by a tap on the miner operator's cap lamp battery. Receiver box in cab of machine plugged to same receptacle as used by umbilical cable.	Joy and Shamrock Coal Company, Beverly, Kentucky.	This is a very good system but it appears the separate rechargeable battery is best. When the cap lamp battery gets low, the control can be erratic.
(d) Hydraulic with small hoses contained in a large hose as the umbilical connection.	Lee-Norse, Charleroi, Pennsylvania	Never very practical and was not a commercial success. Too cumbersome and replaced by electric controls.
<u>Complete Remote Control</u>		
Without controls on Operator's Platform		
By radio or umbilical electrical cable.	Jeffrey has this on their low type continuous miner. There is no operator platform or cab on this machine. Low coal operation does not give room enough for a useful operator's cab.	See no reason for the extra cost. The operator can always take his remote to the cab or platform. This would save critical space on the machine for other use and would simplify the control system as better locations could be found for the hydraulic valves. This has been proven in low coal machinery.

TABULATION 1 (Continued)

<u>Method</u>	<u>Sources of Information</u>	<u>Remarks</u>
	<u>HAULAGE</u>	
	<u>Shuttle Car</u>	
Some work has been done on an automated shuttle car to be used behind a continuous miner without a shuttle car driver. Miners load either directly into a shuttle car which hauls to belt feeder or to mine car, or dump the coal on the ground; from there pickup loader puts it into a shuttle car.	U.S.B.M. contract.	Most commonly used and perfected method is dumping directly into the standard shuttle cars. Miner dumping onto the ground is practiced in some high coal to obtain surge capacity for the intermittent shuttle car haulage. In both systems, the production drops as the length of haul increases.  Remote control studies should be continued; an automated car could be applied to either system.
	<u>Conveyor</u>	
	Full dimension chain or belt system.	
Consists of a bridge conveyor from the continuous miner to a series of short conveyors to a main room or entry belt.	Long-Airdox belt system, Jeffrey chain system. Both systems are similar in operation except one uses belt and the other chain conveyors.	This method gives real continuous mining until a move from one place to the next is made. It shows great promise and has been developed further than any other conveyor system. It has the advantage of a good main cable and water hose handling system for any continuous miner.
	<u>Flexible Conveyor Train</u>	
The most vital and new part of this is the flexible belt being developed for this application. Consists of special belting mounted on steering idlers; has five steel cables in center for strength and to pull the load. The belt is formed to a shape similar to a standard conveyor trough; it has a receiving hopper and at the discharge end a cross belt to dump onto a section belt. The full length of conveyor travels along the side of the main belt as it follows the continuous miner. At the Ireland Mine there is a loader between the continuous miner and the flexible train conveyor.	Under a U.S.B.M. contract now being tested at Ireland Mine, Consolidation Coal Company, Moundsville, W.Va.	This appears to have promise for success, but will require development. This may be incorporated into a fully operated mining system. Various system components need redesigned. Also the grooves or belt webbing grinds and carries coal which is discharged on the return side of the conveyor requiring major cleanup efforts. The cross belt discharging onto the section belt is an inadequate design, thus a major problem area.
	<u>Cascading Conveyors</u>	
Train of cascading conveyors. Each conveyor is mounted on a two wheel car with traction power. Cars steered around turns by jack mounted wheels at each turn. This unit design and the pilot model being manufactured. Each conveyor has hydraulic belt drive and hydraulic traction drive. Each conveyor has a complete hydraulic power unit consisting of electric motor, starter, pump and oil tank.	Designer, Dave Fisher of Mineral Engineering Company, Oakland, Maryland. First test unit presently being manufactured. They expect to put the first one in operation at one of their mines in Preston County, W.Va.	Has good possibility of being successful. We consider this a good system and should work when put in operation. The cost of a 300 ft. conveyor system may be excessive. We do not believe it as flexible as the flexible conveyor train.

TABULATION 1 (Continued)

<u>Method</u>	<u>Sources of Information</u>	<u>Remarks</u>
<u>HAULAGE - Continued</u>		
<u>Serpentex Roof Mounted Conveyor</u>		
Consists of a monorail track carrying on all steel flexible track from yokes hung on trolley wheels from the roof monorail. The conveyor has steel buckets that run on the flexible track. This requires many parts having wearing points.	Being tested at (Peabody) No. 10 Mine, Peabody Coal Company, Pawnee, Illinois.	Operator reports good preliminary results. Our initial impression is that this is very complicated and expensive to maintain. The cost of mounting the roof supported carrying track will be excessive. There are too many wear points in the conveyor. This type has been used in Germany as a permanent installation but never as a portable conveyor system.
<u>Hydraulic Transportation</u>		
Phase 1: Slurry transport replaces belt and rail haulage. Phase 2: Includes a flexible, extensible hose system replacing the shuttle car for face haulage.	Consolidation Coal Company experimenting at Robinson Run Mine, Mountaineer Division.	Present operation includes approximately 3000 ft. of pipeline from mine to preparation plant. Shuttle car discharges into a breaker. Mixing sump receives crushed coal and water and suction pump feeds slurry into pipe system. Project in Phase 1 developmental stage.
<u>VENTILATION</u>		
<u>Mine Atmosphere Monitoring</u>		
The objective is to monitor several parameters of mine atmosphere, namely, carbon monoxide, methane, oxygen, differential pressure, and mine temperature. Currently, two underground working sections are monitoring at one fresh air intake and each of two return air stations.	West Virginia University, Contractor tested in Eastern Associated Coal Corporation's Federal No. 2 Mine, Fairview, West Virginia.	Atmospheric monitoring was successful and the system should be included in the Automatic Continuous Mining Systems with possible additions.
<u>Methane Detection</u>		
Testing head on a probe that can be extended to the face at timed intervals. Wired controls on the continuous miner. Monitor with readout data sent to main control center of section or outside by telemetry.	Fixed testing head back from face. Manual with flame safety lamp.	Monitoring system has been proven by testing done at Eastern Associated Coal Company's Federal No. 2 Mine. Test conducted under 1970 contract. Pennsylvania law presently requires a test being made at the face and the flame safety lamp is the current method used.
<u>Methane Degasification</u>		
Remove the methane gas hazard from the coal seam and adjacent strata prior to mining and recover methane from mined over areas.	U.S.B.M. project with Eastern Associated Coal Corporation at Federal No. 2 Mine, Fairview, West Virginia	Major obstacles to methane recovery are not entirely in the technical aspect. Arrangements have to be established utilizing the recovered methane and the legal ownership determined for this energy source so that operations of this type may move forward with more economic security.

## TECHNOLOGY DISCUSSION

One objective of this contract is to provide engineering assistance regarding future research proposals related to the design, development, construction, testing, and demonstration of automated remotely controlled continuous miners. There is need for investigations concerning the section crew, mining equipment, and job function relationship for a typical continuous mining section. The interdependency of the mining section job functions should be defined for magnitude of impact on expected production improvements in future research. There is considerable need for systems analysis of automated remotely controlled job functions compared to the present mining systems to optimize efficiency of production, mining economics, and safety. This project renders engineering assistance regarding research proposals to accomplish these subtasks.

There is a need for detailed investigation and definition of the machine motions included in the continuous mining operations. Examples are:

Machine maneuverability:

- Forward and backward movement
- Directional turning

Mining motions:

- Cutting head movements, including up and down, forward and lateral

Material movement:

- Gathering device
- Conveyor
- Conveyor boom

The continuous mining control sequence offers a variety of operating arrangements; these would include:

- On-site - Manual
- Remote - Manual
- On-site - Semiautomatic
- On-site - Automatic
- Remote - Semiautomatic
- Remote - Automatic

Most continuous mining machines are presently operated on-site manually.

There are a number of machine functions requiring further development to substantially increase machine productivity without sacrifice of mined product quality or safety if automated remote machine operation is to be performed. The machine functions are:

- Machine control
- Sequence control
- Sensing control
- Auxiliaries control
- Communication
- Observation

Many of the continuous miner machine movements presently not being performed in an automated or remote manner could be approached on a subtask basis with extensive improvement being possible in some areas more rapidly than others.

Individual work functions under each of the listed continuous mining control sequences would include:

- Mining
- Mining and sensing
- Machine movement
- Machine movement and sensing
- Material transfer
- Material transfer and sensing
- Programmed and sequenced

Upon completion of the scheduled objectives, the newly developed control projects should be adaptable to presently operating continuous miners. This should provide an orderly progression of accomplishment resulting in production increases.

On-site manual is the present standard method. Remote-control manual is standard on the Jeffrey 101 Miner; it is also used on many Jeffrey, Joy and Lee-Norse continuous miners and can be applied to the National Mine Service equipment. On-site semiautomatic control is projected to be on the Automated Extraction System being developed by National Mine Service for the USBM; Lee Engineering has had an active part in this development.

There has been no commercial success in on-site automatic, remote semi-automatic and remote automatic control modes.

The section job functions of particular production importance to the continuous mining operation are roof control, haulage and ventilation. Equally important, but having less direct production relationship, are cleanup and dust control, power, water systems, maintenance and monitoring and control.

#### General - Continuous Miners:

Various machine limit switches can be installed on a continuous miner to provide repetitive cutting cycles. However, there are no fully developed roof, floor and horizon sensing devices available.

Sensing bits or other devices on the cutting head must be developed before there can be complete automation of the cutting cycle. These must indicate when the top or bottom of the seam is approached. The Joy PBM used a strain

gauge bit mounting with partial success. In a hard seam of coal this type was not sensitive enough to differentiate between the coal and a soft parting on the roof. More work should be done on this device.

The horizontal guidance can be developed utilizing a "laser" beam. Joy used an inertial guidance control on the push button miner which worked well.

The Eickhoff firm has developed a horizon control device which should detect harder cutting strata in the roof and the floor. This device has not been field tested, thus the concept can be considered as in the preliminary stage. Other devices have been field tested in Western Europe. At the present time, longwall shearing machines are being computer programmed for varying horizons at the face. Also, the use of laser beams is well known for maintaining longwall alignment. Both known concepts might be incorporated in ARCCM.

Programmed control of the miner cutting head must control the sump, cutting down to bottom, back up to cut bottom cusp, raise to top, and repeat the cycle. The raising to top, sump-in, etc., can be controlled by various sensors. The movement of machine must be controlled by guidance controls.

The sensing control requires the ability to override the programmed controls in the event of cutting into clay veins or other hard material in the seam which might dull a number of bits.

Auxiliary controls should operate the continuous miner loading device and conveyor and be connected to operate when the main cutting motors are started. The water spray and suppression equipment also should be activated when the main cutting motors are started.

Monitoring on the continuous miner should include the following applications: machine operation, heat, humidity, voltage, amperage, oil level, pressure and flow, noise, methane and air velocity. Visual observation of the face operations require good dust control and lighting. The ability to have a continual review of production operations, equipment conditions and safety aspects of the mine should result in improved coal production. Tabulation 2, following this text, lists the proposed machine's general specifications.

The long-term goal of ARCCM is an automated continuous miner section, hence, related section operations are reviewed. Projects involving these related operations must be compatible to the various proposed continuous miner projects.

#### Roof Control:

Roof control must be designed for uninhibited advancement of continuous miners. The prototype development is envisioned to be a separate machine for design and experimentation simplicity. The roof bolting machine should be capable of either directly following the continuous miner or operating in a separate entry. Roof support by this method may require, under bad roof conditions, the use of a canopy for protection of the continuous miner.

Our proposed roof bolting machine concept would have the following general design parameters:

- Capable of operating in a 14 ft. entry
- Design width of 10 ft.
- Two to four roof bolt units, each with lateral movement
- Hydraulic percussion (impulse) drills
- Wet drilling
- 150 Bolt storage
- Bolt bending apparatus
- Standard roof bolt or resin pin
- Bolt within 4 ft. of face or miner
- Bolt on 4 ft. centers
- 60 ft. Entry advance per hour
- 2.5 Minutes installation time per row of bolts

See Tabulation 2 for details.

The continuous miner equipped with a canopy concept is being further developed via National Mine Service's Automated Extraction System, and this concept is warranted as an interim step to continuous entry advancement. An independent self-advancing-type canopy in each face should result in greater safety to the continuous miner operator and augment unit production performance by increasing the size of each cut, thus decreasing required miner moves per shift for equivalent production. This system has the potential for further amplification to include a means of providing permanent roof support while performing the temporary roof support duty during actual mining. Such a system would be applied to present narrow head continuous miners, hence better utilization of present equipment.

Gullick Dobson has developed a continuous miner support system as a walking shield (canopy), which could be elaborated in this interim approach to the total goal of ARCCM. It was primarily designed for straight headings without

the ability to negotiate turns as required for crosscuts, etc.; it does, however, have the facility for correction on line of advance. This is done by the use of short stroke rams attached to the main cross beams permitting a deflection either right or left as the longitudinal bars are advanced. See Appendix C for details.

The manufactured prototype support worked satisfactorily in a development of 4500 ft. at Horden Colliery in Durham. This was the basic support having no forward hydraulic capsulated bars and without steerage rams. It was withdrawn on completion of the roadway then was reinstalled in the North Staffs Area. Unfortunately, the roadway ran into faulted ground after 90 ft. advance and was abandoned.

At present, a continuous miner modified by FMC to carry four semi-automated roof bolter units is to be tested at Peabody Coal Company's No. 10 Mine. Testing might show this to be the correct way, but it is questionable at present. Roof bolting prototype development on a continuous miner does not appear to be the logical sequence of development.

Drilling technology to date includes the ability to sense the hardness of the material being penetrated. The drill speed and thrust can be controlled automatically by sensing the material being penetrated.

The application of anhydrite as a roof grouting system is worth mention. Synthetic anhydrite with accelerator can be hydromechanically transported over long distances. The hardening process begins 30 minutes after application which might be too slow for ARCCM; however, a combination with roof bolts may be applicable. A new chemical, polyurethane, consisting of cement and hardening compounds

would have a much faster hardening process. The two compounds in plastic bags are inserted into the hole, then a wooden needle is penetrated through the compounds and turned until the mixing process is completed. The material expands several times its original volume. The process is presently being applied in Western Europe.

#### Face Haulage:

The shuttle car has survived for over 30 years and is the dominant mover of coal from the face. Continuous haulage with a steady flow of coal is desirable; however, the shuttle car, a noncontinuous transportation system, has attained high production rates in the past.

Some shuttle car advantages are:

- (a) Mobility to follow the mining machine, loader or continuous miner.
- (b) Flexibility to adapt to most mining projections.
- (c) Compatibility with other face mining equipment, seam height, and entry width.

Some disadvantages of the shuttle car are:

- (a) More delay at the loader or continuous miner because of intermittent haulage.
- (b) High operating labor cost unless production is high.
- (c) Less safety than other primary haulage systems.

The Bureau of Mines is proceeding with Bendix Corporation on the shuttle car guidance system. The laser guidance system was tested in a simulated mine. The system's obstacle detector gives a warning or stops the shuttle car if an object - roof or rib fall or a man - is in the path of the shuttle car. The guidance system

would appear to be presently applicable in thin seams because of the restrictive visibility and maneuverability of the operator. The guidance system is to be semiautomatic when tested underground. The shuttle car operator will signal the guidance system to make turns and will manually operate the car when the coal is either being loaded or discharged.

Presently, there are three commercial methods in operation for continuous haulage receiving coal directly from the continuous miner; none of these is automated or remotely controlled. These are the Long-Airdox and West Virginia Armature belt systems and the Jeffrey chain system.

There are other systems being developed, the Joy Serpentex and the Joy flexible conveyor train, also the Fisher cascading conveyor system; all are in the development stage and it is too early to test or estimate the possibility of automation to these units (see Tabulation 1 for details). At present, there are sensing devices for fire protection and overloads that could be used on any of these conveyors.

Consolidation Coal Company is experimenting with hydraulic transportation at Robinson Run Mine, Mountaineer Division. The project consists of two phases:

1. Slurry transport replaces belt and rail haulage.
2. Includes a flexible, extensible hose system replacing the shuttle car for face haulage.

Present operation includes approximately 3000 ft. of pipeline from mine to preparation plant. Shuttle car discharges into a breaker. Mixing sump receives crushed coal and water, and suction pump feeds slurry into pipe system. Project is in Phase 1 developmental stage.

Eastern Associated Coal Corporation's Grant Town Mine is installing a Joy flexible conveyor train with a monorail belt system as an intermediary system between the flexible conveyor train and the section panel belt. The monorail belt is installed over the section panel belt, with the ability to extend beyond the panel belt tailpiece for approximately 350 ft. The overhead 5 in. monorail and belt system allows a uniform, straight alignment material transfer to the section panel belt.

Our proposed face haulage concept would have the following general design parameters:

- Capable of operating in a 14 ft. entry
- Capacity of transporting 15 tons per minute
- Travel alongside, or preferably over, 36 in. panel belt
- Traction on discharge for conveyor retraction
- Conveyor drive for 500 ft. of 36 in. belt
- Control line, miner cable, and water spray and hose handling
- Discharge end with drive, crawler mounted

See Tabulation 2 for details.

#### Ventilation:

Methane monitoring is now available on the continuous miner to indicate methane percent concentration in the atmosphere and to remove power from the machine in the event a 2% methane concentration is reached.

Face ventilation is being advanced with mining by vent tubes and curtains. This system requires updating the present operations and eventual automation. Possibilities exist for ventilation tubing and fans built into the proposed miner. However, a separate project should be initiated to develop an advancing compact flexible face ventilation system.

Auxiliary face ventilation for automated remotely controlled continuous miners may be a combination of a blower and exhaust system. The ventilating tubes in the exhaust system could be transported on rubber-tired ventilation tube carriers on an overhead monorail-type system and be pulled forward as the continuous miner advances.

A typical tube for an exhaust fan within a combination blower/exhaust system consists of five to eight strands of 100 ft. of 30 in. tubing. More than 6000 cu. ft. per minute can be delivered through this tubing when it is connected with a fan of adequate horsepower. In combination with automatic remotely controlled continuous mining, the tubing extension for ventilation is integrated into the system. Five to eight runs of 100 ft. tubing are installed on portable tubing and fan carriers. The miner advances 240 ft. per shift; therefore, for one shift advance, only three tubing carriers need to be moved. For convenience of minimum installation effort, all five to eight runs of tubing, the maximum length of the auxiliary ventilation system, are permanently installed on the tubing carriers, which, in turn, move forward as the miner advances.

Combination systems have all the advantages of both blower and exhaust systems. The exhaust fan is located beyond the last crosscut and the tubing is close to the face through ventilation duct work on the miner. The blower fan is mounted on the continuous miner. The air from the blower sweeps the face and enters the exhaust tubing (approximately 3000 cfm); the remaining 3000 cfm enters directly from the entry into the exhaust tubing, for a total exhaust fan capacity of 6000 cfm. This system provides effective ventilation during the cutting cycle at

the immediate face and avoids any recirculation of air. Approximately 10 to 20 ft. of blower tubing and the exhaust tubing connection between the miner and trailing unit are mounted in one unit, alongside or over the extensible belt conveyor, forming an integrated ventilation/haulage system with the mining unit.

Automated remote mine air monitoring has been developed in recent years through a USBM contract, GO 101702, with West Virginia University, Morgantown, West Virginia. Air flow and quality data can be monitored and transmitted to a central point under or above ground.

The removal of methane from the coal seam and adjacent strata prior to mining is presently being attempted by the USBM. Major obstacles to methane recovery are not entirely in the technical aspect. Arrangements have to be established for utilizing the recovered methane and the legal ownership determined for this energy source so that operations of this type may move forward with more economic security.

#### Power and Water Supply:

Semiautomatic advancement of cable and waterline at the face has been accomplished by the use of carrier brackets on all the face conveyor systems. The Long-Airdox Company has a very simple loop take-up device on the "bridge carrier" unit which handles the cable and waterline movement as the continuous miner moves about the face during its operation.

The shuttle car-type of face haulage restricts any semiautomatic mechanical advance of the miner power cable and waterline. Power cable and waterline advancement is done manually for this type of mining system.

Rock Dusting:

The rock dusting job function is connected with the roof bolter unit in the final ARCCM concept. However, independent development with monitoring and guidelines to allow adaptation to the ARCCM is advised. Initial rock dusting research contracts should be directed toward an automated system of dusting during advancement. The preliminary concept is a 200-pound rock dust slurry tank and pump receiving via pipeline bulk rock dust and water to mix and spray ribs during advancement.

USBM Current Projects:

This report has presented areas requiring further research and development for mining machine and section job functions. The Bureau of Mines currently has numerous research programs related to continuous mining systems. Findings of these programs should be incorporated into ARCCM where applicable. Appendix B is a tabulation of these programs.

Short-Range Development:

The previously discussed proposed job functions are listed on Tabulation 2, ARCCM's Proposed Projects, Continuous Mining Systems, and it is believed the progress of completing these projects will attribute to short-range productivity benefits. The majority of projects should be adaptable to present continuous mining systems. General specifications and guidelines have been included, which can serve as a basis for discussion with interested contractors.

The short-range objectives in underground coal mining should be to regain the productivity levels attained as recently as 1969. The underground productivity in 1974 was 11.4 tons per man day, a sharp decline from the 1969 productivity of 15.6 tons per man day (see Plate 4 following this page). On the basis of improving 1974 underground mining to the 1969 level of productivity and using the same work force, the 1974 total underground production would have shown an increase of 104.0 million tons over the actual production of 281.5 million tons.

This amount of lost coal production is equivalent to approximately 440 million barrels of oil annually. Therefore, the potential economic payout and the contribution to the nation's energy shortage by a massive research program in mining to improve both total production and productivity are self-evident.

The continuous miner productivity in 1974 was 11.9 tons per man day, a sharp decline from the 1969 productivity of 17.0 tons per man day (see Plate 4). On the basis of improving 1974 underground mining to the 1969 level of productivity and using the same work force, the 1974 continuous miner production would have shown an increase of 73 million tons over the actual production of

Historical data relative to continuous miner operation are tabulated below.

<u>Continuous Miners</u>	<u>1969</u>	<u>1970</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974*</u>
Tons (000,000's)	173	170	153	178	179	170
Number of units	1,571	1,566	1,781	1,849	1,866	2,000
Tons (000's)/unit	110	109	86	96	96	85
Tons/man	17.0	13.0*	12.5*	12.5	12.3	11.9

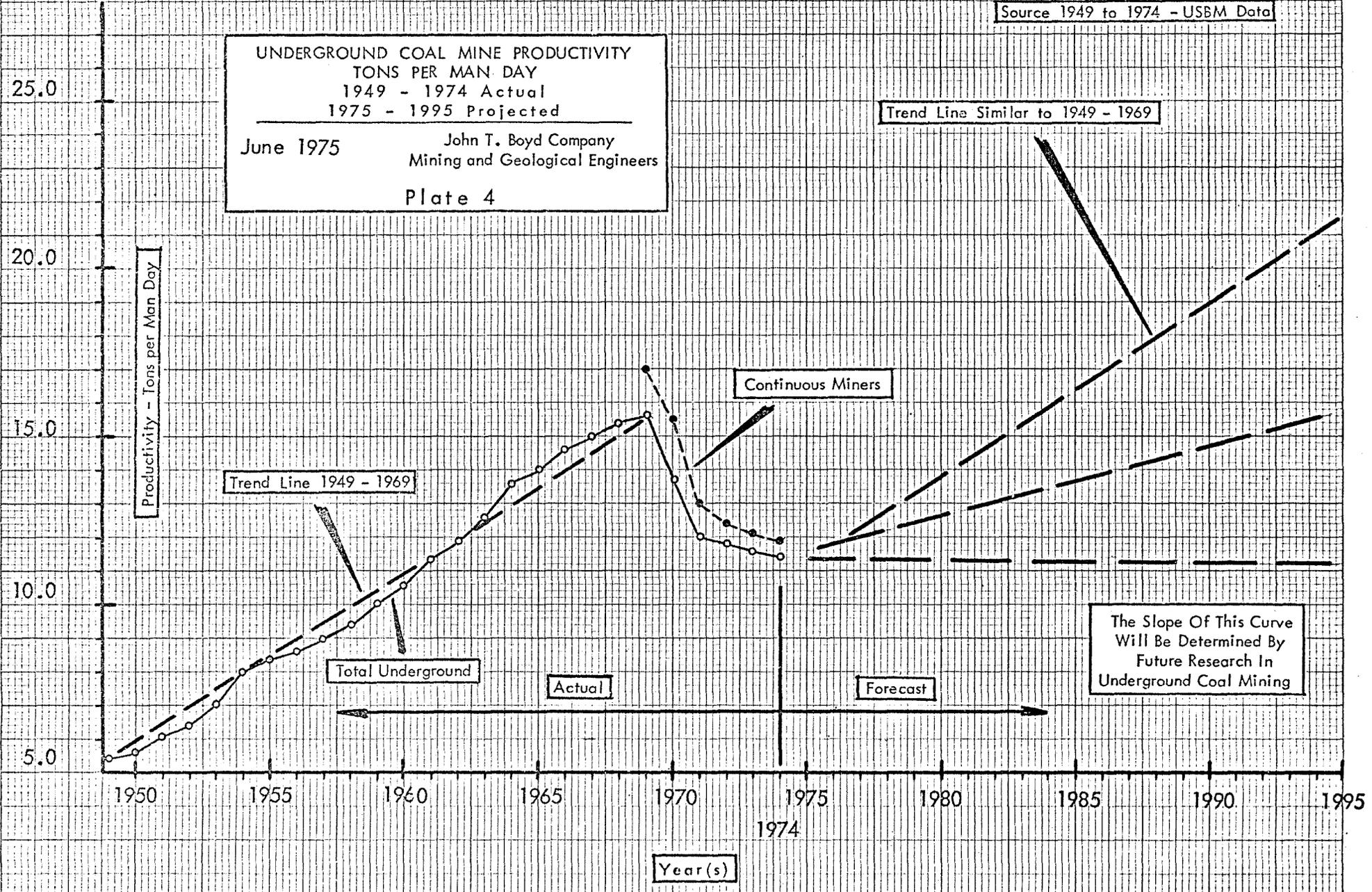
\*Estimated

Source: Coal Age Magazine, February 1975

UNDERGROUND COAL MINE PRODUCTIVITY  
 TONS PER MAN DAY  
 1949 - 1974 Actual  
 1975 - 1995 Projected

June 1975  
 John T. Boyd Company  
 Mining and Geological Engineers  
 Plate 4

Source 1949 to 1974 - USBM Data



### Long-Range Development:

The continuous miner produced 60% of the total 1974 underground production. An analysis of production data indicates approximately 1900 to 2200 continuous miner units were in operation. Average life of a continuous miner is eight years; therefore, each presently operating continuous miner will be replaced at least once before the full impact of the ARCCM is realized.

The equipment manufacturers and the coal operators, in their quest for better production, have developed mining machines that have nameplate rated production rates of from 4 to 15 tons per minute but, in actual performance, produce tonnages often in the range of 200 to 600 tons per unit shift. At the lower range of production (4 tons per minute), this calculates to be only 50 minutes of cutting time out of a normal available face time of 350 to 400 minutes per shift; in actual practice, these cutting times are higher. This illustrates the serious imbalances existing in the continuous mining systems today.

The following basic parameters have been used to determine a typical time allotment for a continuous miner unit shift operation. Two typical time allotments are shown, one for a miner place changing after each cut that is 18 ft. of entry advance. The other is for a miner equipped with roof bolters permitting advancement under supported roof, as is typical with the Joy ICM ripper miner.

#### Basic Parameters

Entry height	6 ft.
Entry width	14 ft.
Tons per shift production	400
Roof bolt row per 4 ft. advance	1
Rows of roof bolts per shift	30
Minutes per roof bolt installation	2.5

Continuous Miner System:	Minutes	
	<u>Place Changing</u>	<u>With Roof Bolters</u>
Total Shift Time	480	480
Portal Travel Time	90	90
Lunch	30	30
Available Face Time	360	360
Loading Time	130	130
Haulage Delays	30	20
Roof Control Delays	<u>10</u>	<u>80</u>
Total Face Time	170	230
Machine Tram	90	30
Routine Equipment Service	30	30
Abnormal Delays	70	70

When first introduced in the United States in the late 1940's, the continuous miner had a production capacity of 2 tons per minute compared to the 4 to 15 tons per minute capacity of modern machines. However, the utilization rates have not increased significantly. The industry norm is less than 40% of available loading time, and only a few mines are able to achieve greater than 50%. While other factors, including the Federal Coal Mine Health and Safety Act of 1969, have influenced the utilization rate, the principal reasons are the inadequacy of the transportation system available and the lack of roof support capacity.

In partial mining systems, extensible belt conveyors and full dimension bridge conveyor units have been successful, but shuttle car haulage is still the method normally employed for moving the coal from the working face to main line transportation.

The long-term goal of the ARCCM envisions a future automated mining system operating approximately 120 minutes continuously during the first half of the shift and 120 minutes during the second half of the shift. A machine maintenance and face supply period would be scheduled between the two operating periods. The basic parameters utilized in deriving the proposed machine guidelines are tabulated below; however, they are flexible pending future developments:

Basic Parameters

Entry height	6 ft.
Entry width	14 ft.
Tons per foot entry advance	3.4
Entry advance per hour	60 ft.
Tons per minute average production	3.4
Roof bolt row spacing	4 ft.
Rows of roof bolts per hour	15
Roof bolts per row	3
Minutes per roof bolt row	4.0
Minutes per shift, machine operation	240
Tons per unit shift	816

The Projected Time Allotment for the ARCCM System follows:

	<u>Minutes</u>
Total Shift Time	480
Portal Travel Time	90
Lunch	-
Available Face Time	390
Loading Time	240
Haulage Delays	-
Roof Control Delays	-
Total Face Time	240
Machine Tram	15
Routine Equipment Service	65
Abnormal Delays	70

All crew personnel are scheduled at the operator's pay rate, and it is anticipated their job assignments would be interchangeable; therefore, no total system shutdown for a lunch period is planned.

Presently, the restricting element in the proposed mining system is the roof bolting. The mining rate could be increased if the 4.0 minute installation time per roof bolt row is decreased. The technological advancement of a liquid chemical compound to replace the standard roof bolt may not greatly reduce the roof support scheduled time allotment. However, it would provide a roof control method which should be easier to automate. Further studies are necessary to determine if the handling and installation of liquids could be more effectively remotely controlled than the handling and installation of bolts.

The major integrated steps to accomplish the ARCCM are listed on Schedule 1 following this text; this schedule includes the estimated cost and time period to complete each step or task. Only the major foreseen proposed tasks are listed; there will be many additional smaller version contracts resulting from yet to be defined problem areas of the listed proposed tasks. The estimated monies scheduled for the listed tasks should cover the resulting additional development work.

The component steps of the ARCCM are estimated to be completed in 1980. These will be combined into an integrated automatic remotely controlled continuous mining system; this final phase is scheduled for completion in 1985.

The ARCCM Program is projected to increase unit shift production. The example unit shift time allotments presented indicate an increase from 400 to 816 tons per unit shift. Also, a reduction in the number of men at the working face

is expected. A typical manpower breakdown by general mine groupings and projected manpower for the ARCCM Program are tabulated as follows; these manpower levels assume similar tons per unit shift production for comparison purposes.

	<u>Labor Force</u>			
	<u>Continuous Miner Operation</u>			
	<u>Present</u>		<u>ARCCM</u>	
	<u>No.</u>	<u>%</u>	<u>No.</u>	<u>%</u>
Face Activities	42	42	23	28
Underground Services	22	22	22	27
Outside Facilities	11	11	11	14
Underground Transportation	8	8	8	10
Underground Construction	7	7	7	9
Roof Control (Outby Face)	5	5	5	6
General Office & Administrative	5	5	5	6
Total	<u>100</u>	<u>100</u>	<u>81</u>	<u>100</u>

For similar circumstances, the projected manpower indicates 19 fewer men with the complete reduction occurring in the Face Activities category. This reduction was developed from the following projected job classifications:

	<u>Labor Force</u>	
	<u>Present</u>	<u>ARCCM</u>
Miner Operator	1	-
Miner Helper	1	-
Shuttle Car Operators	2	-
Roof Bolters	2	-
Utility Men	1	1
Mechanics	1	3*
Foremen	<u>1</u>	<u>1</u>
Total	9	5

\*Systems monitor and control operators.

A large, typical underground mine, continuous miner operation, has a labor cost of approximately \$96.00 per day per payroll man, excluding the UMWA Welfare and Retirement Fund. Utilizing the \$96.00 per man day and 11.9 tons per man day, a present day labor cost of \$8.07 per ton is derived. The resulting labor cost savings through higher production with fewer men are shown below:

	Tons per Man		Labor Cost per Ton
	Present	ARCCM	
Present	11.9	-	\$8.07
Same Production with 19 Fewer Men	11.9	14.7	<u>6.53</u>
Net Productivity Savings	-	2.8	1.54
Additional 416 Tons per Unit Shift	14.7	30.0	<u>3.20</u>
Net Production Savings		15.3	3.33
Total Savings		18.1	\$4.87

The UMWA Welfare and Retirement Fund is not included in the above labor costs. The increased ton per man productivity would result in an approximate \$0.30 per ton savings from the present average \$1.35 per ton cost for the Welfare and Retirement Fund at 11.9 tons per man day productivity.

A mining plan should be developed in order to eliminate time losses due to machine movement between entries. Roof bolting, haulage and ventilation should be realistically coordinated with coal extraction and present legal requirements.

Potential Productivity Impact:

The following future research activities in underground coal mining are expected to have the greatest direct benefit on coal production in the United States. Major subheadings for each activity are also presented. Our judgment of the estimated potential productivity impact on mining for the major areas of the continuous mining system is presented in a relative weighted percentage relationship, using 100 as a base. We have also estimated the relative influence of ARCCM on these areas based on a scale ranging from 1 to 10, with number one indicating the greatest impact.

<u>Major Direct Productivity Benefit</u>	<u>Estimated Potential Productivity Impact Percent</u>	<u>Relative Influence of ARCCM</u>
<u>1. Improvement of personnel procedures and requirements</u>	17	7
(a) Acquisition of employees		
(b) Indoctrination and training		
(c) Utilization		
(d) Compensation - (Incentive)		
<u>2. Promotion of major revisions in face mining machine concept</u>	15	1
(a) Mining plan analysis		
(b) Mining recovery techniques		
(c) Optimize the components of major mining system		
<u>3. Improved roof support concepts</u>	13	2
(a) Poor roof condition detection system		
(b) Personnel roof shield or protection system		
(c) Synthetic roof support material		
(d) Roof bolt designs		
<u>4. Improvement of mined material transportation</u>	13	3
(a) Attainment of some measure of continuous face haulage services		
(b) Reliable extensible belt systems		
(c) Mobile bridge systems		
(d) Elimination of electrical trailing cables for mobile hauling equipment		
(e) Hydraulic continuous		
(f) Pneumatic continuous		

<u>Major Direct Productivity Benefit</u>	<u>Estimated Potential Productivity Impact Percent</u>	<u>Relative Influence of ARCCM</u>
<u>5. Accelerated and improved extension of underground services to the newly mined area</u>	11	5
(a) Ventilation		
(b) Rock dust cleanup		
(c) Power distribution		
(d) Water supply and drainage		
(e) Communication		
(f) Maintenance		
<u>6. Development of overall mining systems</u>	10	4
(a) Balanced production capability with remainder of system		
(b) Integral roof support system		
(c) Ventilation and illumination		
(d) Dust, noise suppression, and fire control		
(e) Maintenance through unitization and accessibility		
(f) Programmed cycle operation		
(g) Standardization		
<u>7. Communications and systems monitoring</u>	8	6
(a) Normal operation voice communication		
(b) Emergency communication		
(c) System operations monitoring		
(d) Equipment operations monitoring		
<u>8. Auxiliary methane extraction and recovery</u>	7	10
(a) Premining		
(b) Post-mining		
<u>9. Alternate energy sources for underground mobile equipment</u>	3	9
(a) Diesel		
(b) Inertia system		
<u>10. Production engineering and system analysis</u>	3	8
(a) Data development		
(b) Simplified computer arrangement		

Following this text are:

Tabulation 2: ARCCM Proposed Projects

Schedule 1: Program Development

TABULATION 2

ARCCM PROPOSED PROJECTS  
CONTINUOUS MINING SYSTEMS

For  
UNITED STATES BUREAU OF MINES

By  
John T. Boyd Company  
Mining and Geological Engineers  
June 1975

Proposed Method

Present

Remarks

CONTINUOUS MINERS

Automated Continuous Miner

Milling type head, 8 - 10 ft. wide, 38 in. diameter. Positive cleanup device, 30 in. discharge conveyor, 45° swing each side of center, 8 in. deep, 2-5/8 in. Universal chain. Low pressure hydraulic system, 1200 psi maximum. Gear pumps, 140° maximum oil temperature, 10 micron filter in return line. Power fill for oil tank. Electrical, 950 v. AC, horsepower range (continuous rating) by function:

- 200 - 400 hp cutting
- 1 - 50 - 75 hp loading
- 1 - 50 hp pump motor, hydraulic
- AC - DC three tram speed, 50 - 75 hp
- 400 - 650 total hp

Minimum machine capacity rating, 8 tons/minute  
Panic bar - manual and remote

Remote control with self-contained power for operator's control station. Wired to accept automation or override to remote manual receiver built into machine with antennae on each side. Control 200 ft. range.

Tram, cats, 25 psi ground pressure. Wet dust suppression system with scrubber discharge into conveyor.

Canopy over cab.

Tram interlocks with main motors to limit to low speed tram when cutting. All functions to be electrically controlled.

Sequence control of the mining functions  
sump, cut, retreat, raise bar, tram repeat cycle.

Milling type and chain type with remote or umbilical electrical control or with radio remote control.  
Power take off, bolter feeder.

The remote control box need be the only control station as it can be used anywhere. The overall automated control could be a unit in itself on the section.

Cutting, Sump, Shear

Interfacing sensing devices to determine top and bottom rock with present or improved remote controls and to have them repeat until overridden.

Manual only.

Need a project to design and test a good sensing system that can determine what the head is cutting at all times. Some experimenting accomplished on Joy Push Button Miner using strain gauge on bits with indication on cathode ray tubes.

Steering - Forward and Reverse Direction

Laser beam guidance.

Has been done on Joy Push Button Miner with inertial guidance system.

It appears the laser would be more practical and economical.

TABULATION 2

ARCCM PROPOSED PROJECTS  
CONTINUOUS MINING SYSTEMS

For  
UNITED STATES BUREAU OF MINES

Sheet 1 of 3

TABULATION 2 - Continued

Proposed Method

CONTINUOUS MINERS - Continued

Remarks

Steering - Turning Corners While Cutting Operation Continues

<p>Programming the turns on tape such as used by the machine tool builders on boring machines to locate holes. Narrow head miner; guidance system to maintain any predetermined cross cut angle, interlock to prohibit excessive drive Cat slippage.</p>	<p>Manual only.</p>	<p>For development simultaneous with machine sensing, the continuous miner need only be equipped with repetitive sequence functions. Main thrust of project to accomplish turning cross cuts on predetermined angles, maintaining guidance independent of hardness variations in cutting.</p>
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Other Functions such as Starting Motors

<p>Suggest these could all be computer tape operated with override ability.</p>	<p>Manual only.</p>	<p>The tape control need not be on the machine as the signals from tape control to machine could be by radio.</p>
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ROOF BOLTERS

Automated Remotely Operated Roof Bolter

Proposed Method

Present

Remarks

<p>Capable of operating in a 14 foot entry, design width of 10 feet. Two roof bolt units - each with lateral movement. Hydraulic percussion (impulse) drills. Wet drilling for roof bolting. Roof bolt storage for 75 bolts per bolter unit. Roof bolt bending apparatus for installation of 10 foot bolts. Standard roof bolt or resin pin (5 ft.) installation. Roof bolt within 4 feet of face or rear of miner. Roof temporary support jacks. Ability to set a row of four bolts across the entry for each 4 feet of advance. Roof bolt installation to allow 60 feet of entry advance per hour. Canopy for manual operators. Hydraulic system: 140° F. maximum oil temperature, oil level indicator. Work area lights. Panic bar - manual and remote. Fire suppression system. 950 v. AC power. Power take off. Electric actuated machine controls. Radio remote control. Coal receiving hopper and feed through conveyor, 15 tpm. Coal breaker. Coal discharge boom adaptable to the sectional conveyance system. Electric tram. Machine mounted on Cats. Motive power to pull the sectional conveyance system.</p>	<p>Manual independent underground machine. Manual units on the continuous miner.</p>	<p>The machine should be capable of continuously advancing under supported roof and capable of directly following a continuous miner. The automated roof bolting machine design should be flexible enough to allow the machine to directly follow the continuous miner in the production entry. Therefore, bolting within four feet of the face or outby end of miner and the motive power to pull the trailing coal conveyance system are required. Possibly leave rock dusting system out of this contract.</p>
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TABULATION 2 - Continued

<u>Proposed Method</u>	<u>Present</u>	<u>Remarks</u>
<u>HAULAGE SYSTEM</u>		
<u>Automated Remotely Operated Portable Conveyor</u>		
Automated conveyor system connecting continuous miner to entry belt. Must be able to work in 14 ft. entry, capacity 15 tpm. Travel alongside, or preferably over, the 36 in. entry belt. Self-propelled, pulled by the continuous miner or bolter unit as the continuous miner advances. Have traction on discharge and capable of retracting on signal from the continuous miner or roof bolting unit. Conveyor drive capable of driving 500 ft. of 36 ft. belt. Traction capable of moving 500 ft. of conveyor. Each conveyor section has facility to carry continuous miner cables, control cables and waterline. Discharge end with drive to be crawler mounted. 950 v. AC power. Water spray system for fire control. Work area lights.	Shuttle cars, full dimension, flexible train, and serpentex.	The capacity shown is to cover surges in the machine cutting cycles and differing mining systems, for example, on pillars in retreat work.

SUPPORT SERVICES

Extension of Underground Services

Possibly several contracts to study variously related but presently independent operations. The service operations are: (a) ventilation, (b) rock dust and cleanup, (c) power and water extension, (d) drainage, (e) communications, (f) maintenance.	All manual and independent operations.	These contracts should provide results that are compatible with the above proposed projects. These services have to be integrated into the total system and its designated equipment components. Better to study independently than combine too many other job functions.
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SCHEDULE 1  
 PROPOSED BUDGET  
 ARCCM PROGRAM DEVELOPMENT  
 CONTINUOUS MINING SYSTEMS

For  
 UNITED STATES BUREAU OF MINES

By  
 John T. Boyd Company  
 Mining and Geological Engineers  
 June 1975

(Dollars in 000's)  
 Allotted Time: 5 Years

Year:	1	2	3	4	5	Total
<u>Continuous Miner</u>						
Automated Continuous Miner	\$1,000	\$1,000	\$1,000	\$2,000	\$1,000	\$ 6,000
Cutting, Sump, Shear	600	600	600	300	300	2,400
Steering - Forward and Reverse	300	500	500	200	200	1,700
Cutting Crosscut Angles	100	300	300	100	100	900
Subtotal	<u>2,000</u>	<u>\$2,400</u>	<u>2,400</u>	<u>2,600</u>	<u>1,600</u>	<u>11,000</u>
<u>Roof Bolters</u>						
Automated Roof Bolter and Material Transfer	300	300	300	500	500	1,900
Automated Steering and Tram	200	200	200	200	200	1,000
Automated Roof Support (various roof pin lengths)	300	300	300	300	300	1,500
Subtotal	<u>800</u>	<u>800</u>	<u>800</u>	<u>1,000</u>	<u>1,000</u>	<u>4,400</u>
<u>Automated Haulage System</u>	1,000	1,000	2,000	4,000	3,000	11,000
<u>Extension of Underground Services</u>						
Ventilation, Rock Dust and Cleanup	400	400	400	400	400	2,000
Power Distribution	200	200	200	200	200	1,000
Water Supply and Drainage	100	100	100	100	100	500
Monitoring and Control	500	500	1,000	1,000	1,000	4,000
Maintenance and Miscellaneous	500	500	500	500	500	2,500
Subtotal	<u>1,700</u>	<u>1,700</u>	<u>2,200</u>	<u>2,200</u>	<u>2,200</u>	<u>10,000</u>
<b>Total Cost (1st 5 Years)</b>	<b>\$5,500</b>	<b>\$5,900</b>	<b>\$7,400</b>	<b>\$9,800</b>	<b>\$7,800</b>	<b>\$36,400</b>

At the end of five years, it is expected that the program would result in the development of commercial type machines adaptable to remote and automatic controls that could be applied to present mining systems, including continuous miners, roof bolters, and haulage system.

The necessary work to fully integrate these units into a completely automated mining system is estimated to require an additional five years and cost \$14 million. A cost estimate by year shows:

Year	Job Function	Est. Cost (000's)
1976-80	First 5 Years - Research and Development	\$36,400
1981	Integration engineering	2,000
1982	Achieve automatic remote working system prototype	2,000
1983	Develop programming and sequence devices, control station	4,000
1984	Develop, test and demonstrate experimental system	2,000
1985	Develop, test and demonstrate working system	<u>4,000</u>
<b>TOTAL ARCCM</b>		<b>\$50,400</b>

APPENDIX A

INTERVIEW SUMMARY

CONTINUOUS MINING SYSTEMS  
For  
UNITED STATES BUREAU OF MINES

By  
John T. Boyd Company  
Mining and Geological Engineers  
June 1975

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Designers and/or Inventors

- (1) A pioneer in the development of underground coal mining equipment presently is working on a new continuous miner design; this work is being funded by private sources. A newly designed conveying system is being considered for use with this continuous miner. He suggested a program for a remotely controlled continuous miner could be accelerated by a conference of recognized designers and inventors.
- (2) A recognized designer suggests the Bureau's program should include upgrading of present equipment production capacities and evaluating new ideas on a 10-year basis.
- (3) A prominent designer of longwall systems conceives using four 18 foot diameter tunnel boring machines to drive to the property line and then retreat with one or two longwalls on each side of main entries. The length of main entries will determine the number of walls on each side. He believes this system will make continuous mining systems obsolete, except for the longwall and shortwall systems using hydraulic jacks for roof support. The economics of such a system should be studied independently.

(4) The head of a research organization advised they are combining a roof bolter, scoop, and rock duster into one unit. The unit has three control joints and heavy roof supports for the protection of the operator and two roof bolters. They have done nothing on remote or automated controls.

#### Manufacturers

(1) Not working on any roof drills for continuous miners or any automated types. Have all the work they can do and will study the developments of others.

(2) Not interested in going into automation; believe the majority of roof drilling in the future will utilize epoxy-type pinning. Inserting the epoxy container and then the bolt requires more accuracy than shell-type roof bolting. They will wait and study the developments of others.

(3) Are developing remote control systems for continuous miners (cable or radio). Also, are doing design studies on remote and automated roof drilling and think the bolter should be on a hopper feeder behind the continuous miner.

(4) Have done some work on automation of the continuous miner to the extent of developing controls to repeat a cutter head cycle after the first pass is made manually. With this control a machine can be programmed to continue mining using the radio-coaxial cable method operating on sound signals.

They are pleased with the results of their remote control efforts and insist the radio control should get its power from the cap lamp battery. This limits the number of operators as compared with the battery in the operating box, but they believe their method is safer.

At present, they are working on the following projects relative to automation of face production units:

- (a) A portable control panel with a cable to the machine.
- (b) A radio control unit with a coaxial cable connection to the machine.
- (c) Straight radio control.

(5) This company is working on a study of automated bolting in connection with a continuous miner. This would include the carousel drill pipe handling device and high-speed pulsating hydraulic drills. It could be possible to bolt the soft rock by slowing the impulse rate and increasing the rotation speed and power. The same unit would drill the hard rock now drilled with pneumatic drills. The normal percussion type roof drill uses 100 pounds air pressure. High pressure air rock drills use 250 to 300 pounds. The hydraulic type can reach as high as 3,000 pounds pressure applied at a greater frequency. It will be possible to run the drill as a percussion or a rotary.

(5) Continued

A heavy duty Lee-Norse miner is being tested at the Joanne Mine of Eastern Associated Coal Corporation. The main features of this machine are its rear jacks which are the anchor for a hydraulic sump. The shear pressure is from a head jack against the roof. By using these two jacks, a high bit penetration is possible. The miner's cutting head bit speed can be varied and in conjunction with the hydraulic jacks increasing bit penetration, extremely high tonnages can be obtained at 600 feet per minute bit speed in the Joanne Mine. The slower bit speeds possible in this machine should produce much less coal dust when cutting.

(6) Have developed a cable handling system consisting of a sheave to double the travel on the cable and a double spring to keep tension on the sheave and cable.

(7) Have developed a transportation system consisting of a series of cascading conveyors in a train 400 feet long. This will allow a development of seven entries with angle crosscuts utilizing a 16 ft. 6 in. head full face continuous miner and is designed to be used in 48 inch coal. Each conveyor section is 20 feet long with a 36 inch belt running on limber rollers. Each has two stub axle-mounted wheels with the swivel connection for the adjacent conveyor between the wheels. Each conveyor has a hydrostatic drive for the wheels and belt; both are driven by a 20 horsepower motor. The control is with solenoid-operated valves.

(7) Continued

The train is connected to the miner with a bridge having a 6 foot slide attached to the discharge conveyor on the miner. The bridge uses a chain conveyor as on the miner. The discharge end of the train uses a bridge running on a track over the main section belt. The bridge is mounted on a set of crawlers which are intended to pull the train away from the face with help from the individual conveyor traction drives. Rubber-tired wheels mounted on 50-ton jacks guide the train around the turns.

(8) The machine in the present concept would have an integral roof support system utilizing hydraulic support and roof bolting equipment mounted on the rear. The continuous miner in this design concept would be stationary during the roof bolting cycle.

Roof protection consists of two canopies over the machine. Power for sump is from jockeying against canopies. Making turns of any angle will be difficult and time consuming.

Milling type head is impressive and gives complete coverage of the face at any width of extension. Angle of ends of drum is attained by a constant velocity joint. This design allows large supporting rib for head and large drive shaft through rib.

The entire machine is well designed and uses many parts standard to their other miners.

(9) Have designed and built a new cable reel, articulated, self-loading shuttle car with an extensible body. The main feature is the loading part which is similar to an end loader. The basic components are also being used on a roof support system under a USBM contract. The roof support system is a wire rope support spanning the entry. They are also working on a crusher feeder on the same chassis.

### Coal Operators

Beth Elkhorn Mine No. 22  
Hendrix, Kentucky

#### Shortwall Mining System

The shortwall mining system is in the Elkhorn No. 3 Seam part of Mine No. 22. The coal is 48 in., and they are taking 6 to 8 in. top rock due to the chocks requiring a minimum of 54 in. seam height.

Equipment consists of Gullick chocks, Joy 11 CM miner, Joy 21 SC shuttle cars, belt feeder, 36 in. section belt, 42 in. main belt for two miles, and mine cars.

The shortwall is 150 ft. from entry to entry. They mine this with standard equipment using no permanent support other than in the entries. The cave line is about 10 ft. behind the chocks and appears almost straight, paralleling the chock line.

As mining along the shortwall progresses, the miner and shuttle car operator are always under steel roof support. In order to see the cutting head better, they keep about 6 ft. open before advancing the chock. The miner is retreated to the starting point after cutting the length of the shortwall. The previous miner cut is cleaned with a scoop tractor before the miner starts a new cycle. The miner move

to the new starting point and cleanup time requires approximately 25 minutes. The time to cut the wall at a 10 ft. width is approximately 1-1/2 hours.

Advantages of the shortwall system are: safety, as the workmen are always under a steel canopy; a dust-free working condition, as the air sweeps the wall in the direction of cutting; the miner does not require as much water for dust suppression; no rock dusting except in the return airway; no roof bolting required except in development entries; greater coal recovery.

The entire section has a total of eight men. It would appear that six or seven men may eventually do the entire job. The worker's mental attitude of the system is good.

With adequate sensing devices on the head of the miner, this unit could be automated and produce 1,000 tons per shift easily in this mine.

Consolidation Coal Company  
Ireland Mine  
Moundsville, West Virginia

An underground visit to inspect the Joy flexible conveyor train included:

J. Matovich, Assistant Mine Foreman  
G. Heard, Mine Foreman  
Gene Stacey, Lee Engineering Company  
Harry Becker, Joy Manufacturing Company

The conveyor train is in the Pittsburgh Seam; it is approximately 300 ft. long but will soon be lengthened to 350 ft. It consists of a drive unit with 40 hp motor and two 10 hp traction motors for a four-wheel drive with "cat" type steering. On the head drive there is a short conveyor at a 90° angle to the flexible conveyor train which discharges the train to the section belt. The intermediate belt sections are on 8 ft. two-wheel cars connected in the center at each end and, with a radius rod on

each car to control the belt turns, track each other around the turns. The tail piece has a 40 hp conveyor drive, but no power traction. The entire train is pulled by a Joy 14BU-10-C loader and can be helped by the traction motors on the head, if needed. Until now, the loader has had ample power to pull the entire train forward and the head traction has pulled it away from the face. According to Gene Stacey, tramming and making the turns has been easy. They have used a roller on the inside of the turn in some cases. This is set with a jack pipe between the seam top and bottom.

The 36 in. Goodrich flexible belt is running at 650 fpm. The greatest problem is spillage at the short discharge belt; they expect to overcome this problem with work being done now.

They are able to make 90° turns on a 30 ft. radius. The belt has been run with four 90° turns. They are driving all the places 16 ft. wide with the breaks on 80 ft. centers. The miner is a Joy 11CM with a roof drill on the front of the "cat" frame. A wood header is set every 4 ft.

The mine management seems well pleased and expects good tonnage when they have enough length to reach every working face. According to Stacey, their best day was 400 tons with about two hours working time.

The 36 in. wide flexible belt has a 6 in. wide center section comprised of five 1/4 in. steel cables and two layers of steel mesh. The two layers of steel mesh extend the entire width of the belt. Motive power is transferred to the belt by using a compression roller applied to the 6 in. wide middle section forcing the belt against the drive roller.

The mining plan consists of driving four panel entries 16 ft. wide on 80 ft. centers. Angle cross cuts are driven and rooms are to be driven off the panel entries when the conveyor train is lengthened.

Island Creek Coal Company  
Jenny Mine near  
Prestonsburg, Kentucky

ISMS Program for USBM

Tour conducted by Mr. Frank McCall, USBM

There was limited production through the duration of the visit due to clutch trouble on a shuttle car.

They are driving six entries in the Stockton Seam. The belt and track entry is 23 ft. wide, the others are 20 ft. with 60 ft. entry centers and 80 ft. centers on the cross cuts which are also 20 ft. wide. This is all conventional mining: cut, drill, shoot, load, and bolt. The shuttle cars dump into a belt feeder discharging onto a 36 in. section belt conveyor.

The controls on all of these machines have been modified to a "Joy stick" type of control for the various movements. The steering on all equipment is automotive type. These features work very well and do not complicate the machines. All the equipment have cabs containing hydraulic controls to raise, lower and tilt. The shuttle car also has a swing out 180° turn cab. These hydraulic actuated features are complicated and expensive to build and maintain.

The brake on all equipment is foot-operated and appears well designed.

The loading machine, Joy 14BU-10SC is equipped with a cab, "Joy stick" for tram, and a double cable reel. The main reel is for power and the top for water hose. The reels and cab add width to the machine and inhibit production.

All of the equipment is equipped with Mercury vapor lamps. These are bulky but time and improvement should remedy this. They do give good light.

The roof bolter is a Galis with the FMC automated head. This is quite complicated and has many adjustment points. It will hold the drill steel and six bolts in a chain carrier device. They were not using it during the visit because the coupling on the dust collector drive was broken. From the demonstration given, its performance, as presently designed, is doubtful and the structural components need further development.

National Steel Corporation  
Beaver Creek Coal Company  
Wayland, Kentucky

Stinson No. 5 Mine of Beaver Creek Coal Company was visited on August 8. The mine is in the Elkhorn No. 3 Seam and is located at Wayland, Kentucky.

They are successfully using radio remote control on the continuous miners and have additional units on order.

The haulage consists of four parts: (1) Piggy-back bridge, (2) mobile bridge conveyor, (3) intermediate structure, and (4) pony belt. These, plus the miner, give a total fixed length of 160 ft. The extension of the pony belt is done in 60 ft. increments and requires about two hours to complete. This is actually an extension of the main belt and must be lined up well; the belt extension time will be improved with experience.

Production rates are modest as they are still training people to operate the equipment. The record shift advance is 139 ft., or approximately 560 tons. The crew consists of a miner operator, mobile bridge operator, roof bolter, scoop, and mechanics.

The method of handling the miner trailing cable under the bridge conveyor is semi-automated.

The mine is driving three main entries using Jeffrey 120L Heliminer and Long-Airdox continuous haulage system. Seam height, including partings, ranges from 48 to 54 inches. The headings, 22 ft. wide, are driven on 60 ft. centers and 22 ft. wide cross cuts are on 60 ft. centers. The present mining plan does not include pillar mining because of seams above and below which they do not want to damage.

Peabody Coal Company  
Mine No. 10 near  
Taylorsville, Illinois

Peabody No. 10 Mine is in the Illinois No. 6 Seam and is located near Taylorsville, Illinois.

They are successfully using the Serpentex haulage from the face. Presently the haulage system is 200 ft. long and does not permit room work due to its length. A Serpentex haulage system of 400 ft. is needed and is being planned.

Production rates have been good and the foreman in charge is very optimistic about its future.

The section is being developed by driving five main entries with the cross cuts on an angle. A Joy 10CM miner is being used.

The seam height is approximately 8 ft. thick and full seam mining is being done. All places are bolted after the miner advances 20 ft.

On the day of the visit, the section was being moved to start a butt entry and no mining was being done.

Also located at Peabody No. 10, FMC under their ISMS contract is installing a Joy 12CM continuous miner with four roof bolting drills designed and mounted on the miner by FMC. Presently, this equipment is dismantled and being taken underground; therefore, was not available for inspection. They also have a single drill with automated controls on the drilling head; this unit is not in operation.

Shamrock Coal Company  
Beverly, Kentucky

Mine No. 18 was visited on August 7. The mine, working in Hazard No. 4A Seam, is located at Beverly, Kentucky. Four Joy 12 continuous miners are operating two shifts per day. Three of the miners are equipped with cable type remote control units and the fourth with a radio controlled unit. The supervisors like both units but prefer the radio system and have ordered three additional units.

The advantage of the system includes: (a) operator efficiency, (b) safety, and (c) productivity.

The mining plan consists of driving rooms off a standard room and pillar section. Entries, cross cuts and rooms are 20 ft. wide on 80 ft. centers.

## Other Persons

### Dust Control:

Slower bit speed and deeper penetration obtained good results. Introducing water at the bit was not a practical solution because of the size of the seals needed in the drum. They also tried foam, but the results were not worth the effort. Careful placement of the spray heads with low water pressure gave the best results.

Working on a fan-type dust collector with a venturi and separator to drop the collected dust and water. There is a very definite relation between the air moved by the dust collector and face ventilation. Also working on a vacuum head for cleanup work along belts and other machines where spillage of coal must be cleaned; the head would work on wet coal.

### Transportation of coal from face to outside:

Thinks it is possible to build a hopper car to be used with, but not connected to, continuous miners. This would be a surge car and would carry drills for roof bolting, a cleanup device, rock duster, and connected to the main belt with a bridge conveyor; it would be crawler-mounted and have an operator to drill and rock dust.

They are also working on a center-guided belt conveyor.

APPENDIX B

SELECTIVE ACTIVE RESEARCH CONTRACTS  
UNITED STATES BUREAU OF MINES

By  
John T. Boyd Company  
Mining and Geological Engineers  
June 1975

Number	Contractor	Title	Initiation Completion	TPO
<u>Continuous Miner</u>				
HO111194	Bendix Corp. Southfield, Michigan	Automatic or Remote Control on Coal Mining Machines	6-10-71 41 months	M. Bowser PMSRC
HO122039	Ingersoll-Rand Res., Inc. Princeton, New Jersey	Design and Construction of Continuous Mining Machine	1-1-72 32 months	R. Schmidt TCMRC
HO210050	Bituminous Coal Res., Inc. Monroeville, Pennsylvania	Technique to Water-Flush Bits on a Fixed-Drum Continuous Mining Machine	6-18-71 41 months	K. Strebig TCMRC
HO220061	Bituminous Coal Res., Inc. Monroeville, Pennsylvania	Study of Continuous Mining Machine Bit Technology	6-22-72 9 months	K. Strebig TCMRC
SO144087	Bendix Corp. Ann Arbor, Michigan	Logistic Performance of a Continuous Miner	6-29-74 13 months	J. Ault PMSRC
HO357000	Foster-Miller Associates, Inc. Waltham, Massachusetts	Report on Evaluation of Coal Thickness Sensors	1-27-75 15 months	M. Pazuchanics PMSRC
JO357055	Roger Protas Associates, Inc. Pittsburgh, Pennsylvania	Design an Automated Model of a Continuous Mining Section and Construction of a Non-Working Model	2-21-75 2 months	H. Parkinson PMSRC
HO155037	National Mine Service Co. Indiana, Pennsylvania	Design, Manufacture, and Field Development of an Automated Extraction System (Mining Miner)	3-25-75 32 months	H. Parkinson PMSRC
<u>Roof Control</u>				
HO111413	University of Alabama University, Alabama	Correlation of Mine Roof Failure with Time Elapse before Support Installation	6-1-71 36 months	R. Statshan DMRC
HO232041	Envirotech Corp. EIMCO Tunneling & Mining Salt Lake City, Utah	Field Test of Pumpable Roof Bolts	6-25-73 17 months	R. Thompson SMRC
<u>Continuous Miner-Roof Bolter</u>				
HO242053	Bendix Corp. )	) - Miner-Bolter Systems	Original 6-24-74 Modification 2-4-75	M. N. Mahaffey PMSRC
HO242057	F.M.C. )			
HO242051	Ingersoll-Rand Res., Inc. )			
HO242056	Jeffrey Mining Machinery Div.)			
	Dresser Industries )			
<u>Ventilation</u>				
HO155016	Foster-Miller Associates Waltham, Massachusetts	Extensible Line Curtain or Duct System for Face Ventilation	9-23-74 10 months	E. Divers PMSRC
HO230023	Foster-Miller Associates Waltham, Massachusetts	Optimizing Diffuser Fan Flow and Location in Coal Mine Working Face Areas	5-17-73 30 months	F. Kissell PMSRC
HO230019	Bendix Corp. Baltimore, Maryland	Improved Methane Sampling System	5-8-73 18 months	M. Pazuchanics PMSRC

APPENDIX B - Continued

Number	Contractor	Title	Initiation Completion	TPO
<u>Face Haulage</u>				
HO242025	Joy Manufacturing Co. Pittsburgh, Pennsylvania	Study of Continuous Face Haulage Systems	6-14-74 15 months	W. Kleysteuber PMSRC
JO155177	Joy Manufacturing Co. Pittsburgh, Pennsylvania	Demonstration of Roof Mounted Flexible Conveyor Train	6-30-75 19 months	W. Kleysteuber PMSRC
HO357102	M. B. Associates San Ramon, California	Development of a Conveyor Belt Extender	6-25-75 30 months	G. Susko PMSRC
HO155157	Foster-Miller Associates Waltham, Massachusetts	Develop and Demonstrate an Auto- Track Bridge-Conveyor Train for Continuous Face Haulage	6-16-75 28 months	W. Kleysteuber PMSRC
HO155123	Jeffrey Mining Machinery Div. Columbus, Ohio	Development of a Multiple-Unit Continuous Haulage System, Phases I and II	6-25-75 17 months	W. Kleysteuber PMSRC
<u>Systems and Other</u>				
HO346067	Collins Radio Co. Cedar Rapids, Iowa	Mine Wireless Communication System	6-26-74 26 months	R. Chufo PMSRC
HO232056	Collins Radio Co. Cedar Rapids, Iowa	Coal Mine Communication System	6-21-73 10 months	H. Parkinson PMSRC
HO242007	J. J. Davis Associates McLean, Virginia	Methods to Improve Pillar Extraction Practices in Underground Coal Mines	1-11-74 17 months	P. McWilliams SMRC
HO242015	M. B. Associates San Ramon, California	System for Handling Underground Mine Supplies and Materials	5-17-74 30 months	W. Kleysteuber PMSRC
SO144115	Pennsylvania State Univ. University Park, Pennsylvania	Study of Human Factor Aspects of an Automated Continuous Mining Section	6-29-74 23 months	J. Powell PMSRC
HO122057	Envirotech Corp. EIMCO Tunneling & Mining Salt Lake City, Utah	Coal Mine Vacuum Sweeper	4-21-72 32 months	E. Divers PMSRC

APPENDIX C

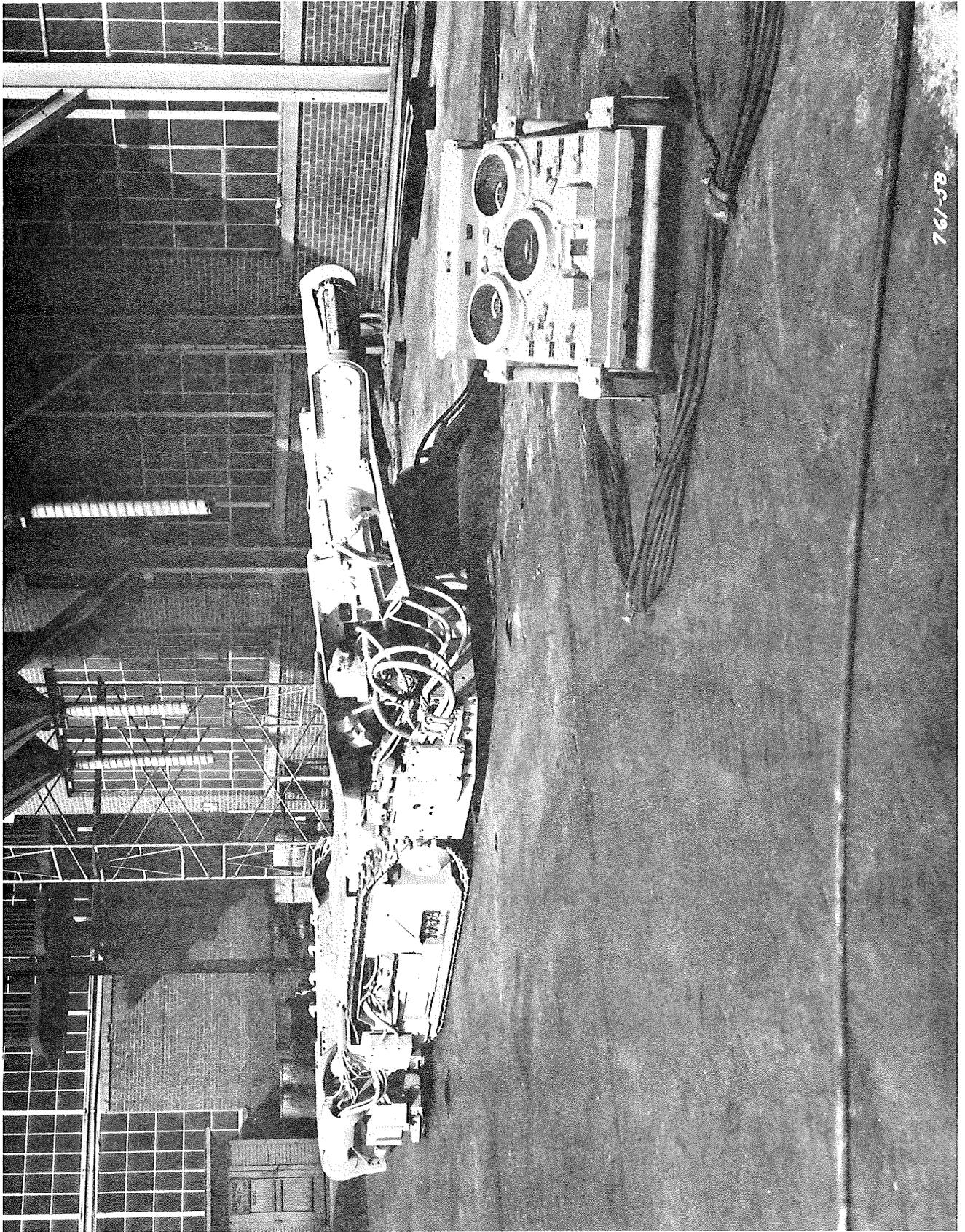
REFERENCE LITERATURE  
CONTINUOUS MINING SYSTEMS  
UNITED STATES BUREAU OF MINES

By

John T. Boyd Company  
Mining and Geological Engineers  
June 1975

The following plates have been included for reference; these are reproduced from various manufacturers' brochures.

<u>Reference</u>	<u>Page</u>
Jeffrey Colmol with Remote Control, 1957	C-1
Joy Push Button Miner, 1961	C-2
Miner with Remote Electric Control, 1974	C-3
Serpentex Roof-Mounted Conveyor, 1974	C-4
Miner/Bolter Project at Peabody No. 10 Mine, 1975	C-5
Gullick Dobson Miner Support System, 1972	C-6
Long-Airdox Full Dimension Haulage System, 1973	C-7
Typical Shortwall Mining Panel, 1974	C-8

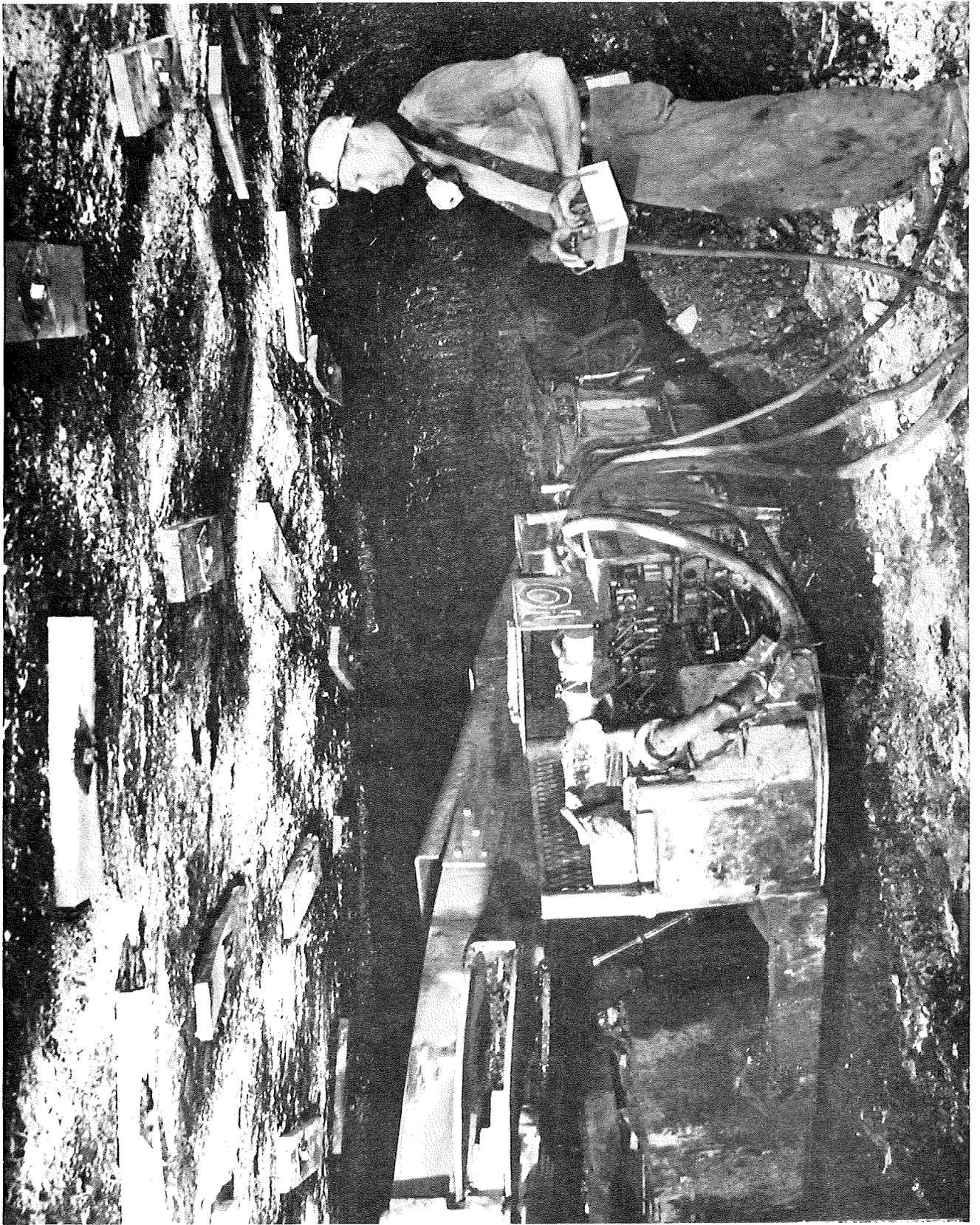


761-38

Appendix C-1

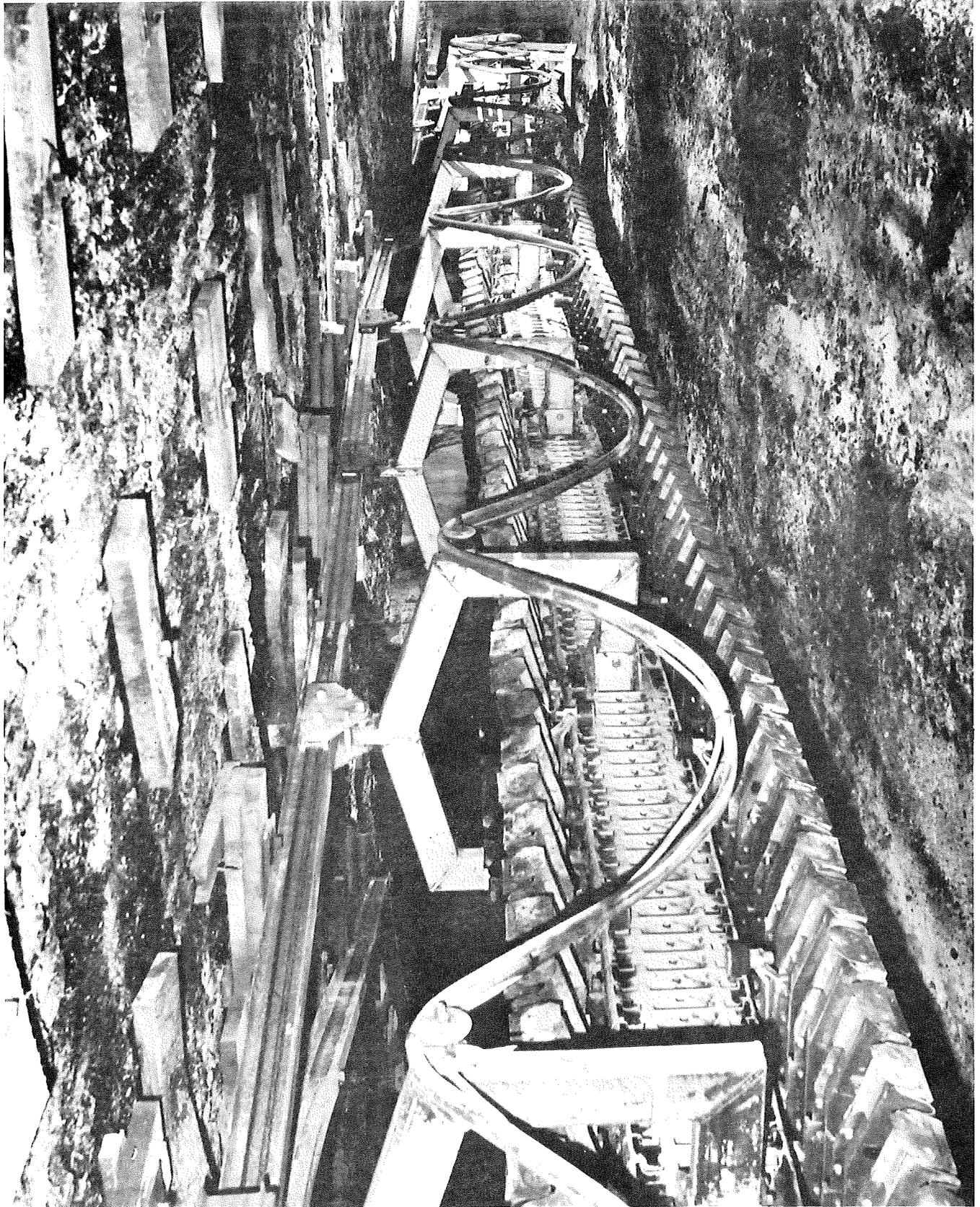
Jeffrey Colmol with  
Remote Control  
1957





Appendix C-3

Miner with Remote Electric Control  
1974



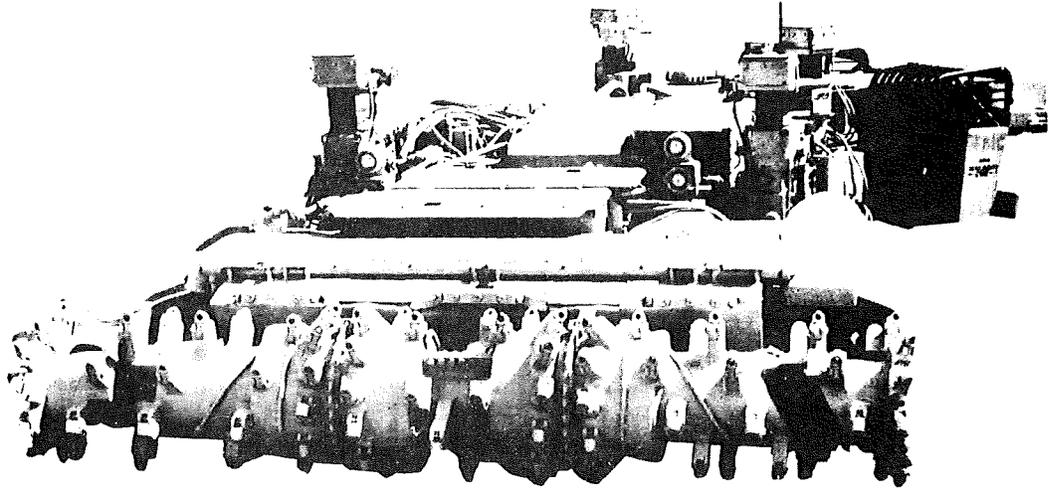
Appendix C-4

Serpentex Roof-Mounted Conveyor  
1974

# ISMS Equipment Modifications

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## Miner/Bolter



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### DESIGN FEATURES

- \* Mines coal continuously, and installs roof bolts while mining
- \* Operators remain in protective canopies during operation
- \* Dual controls permit the operator in either cab to control or stop the machine for maximum safety of operation
- \* All roof bolting is controlled remotely by an operator within a protective cab
- \* All bolting controls are intrinsically safe, including valve solenoids
- \* On-board rock dusting equipment allows advance uninterrupted for rock dusting, assures highest reflectance levels at the face
- \* High illumination level improves safety and allows essential monitoring of automatic roof bolters
- \* High-volume ventilation integral in cutting head provides full face ventilation and eliminates eddying of airborne dust
- \* The entire pattern of roof bolts is installed in the roof in by the operators' stations

Appendix C-5

Miner/Bolter Project of  
Peabody No. 10 Mine  
1975

# THE GULLICK DOBSON HEADING, DRIVAGE AND GENERAL PURPOSE SUPPORT

**Purpose:** This support was designed initially for application in Continuous Miner square workings.

The main objectives are to support over the Continuous Miner and provide early support to the new roof, thereby removing the functions of permanent support setting, or roof bolting, to an outbye the machine area which will not interfere with coal production.

THIS THEREFORE PERMITS NOT ONLY INCREASED PRODUCTION POTENTIAL BUT ALSO MORE EFFICIENT UTILISATION OF MANPOWER.

The support uses the roof as a datum and therefore the advance is not affected by soft floor.

By retaining 50% permanent support whilst part of the unit is moving forward into new ground, the stressing and de-stressing effect on the roof is minimised.

Early clamping of the roof beds keep them controlled until permanent support setting can take place behind the miner.

EFFECTIVE SUPPORT IS THEREFORE PROVIDED TO PERMIT MAXIMISATION OF PRODUCTION AND ALSO TO GIVE FULL PROTECTION TO THE OPERATORS.

**Principles of Operation:** Longitudinal bars at 12 inch centres support the roof in line of the drivage. One set of alternate bars is fixed to the two outer cross-beams (1 & 4) and the other set of alternate bars to the two inner cross-beams (2 & 3) (Fig. 1).

A 5 inch bore leg is located at each end of each cross-beam. The top of each leg is flexibly supported in its cross-beam, the bottom is located in an articulated pad which is in contact with the floor.

To move the unit forward, the legs under cross-beams 2 & 3 are retracted until the corresponding longitudinal bars have lowered 4 inches and come to rest on beams 1 & 4 and the legs have lifted to clear floor debris. The unit associated with cross-beams 2 & 3 can then be advanced by the two pairs of rams located between adjacent cross beams (Fig. 2). The stroke of each ram is 3'-9", but the increment can be selected to match the sumping and support setting distances.

A similar procedure follows for the advance of the unit associated with cross-beams 1 & 4.

Valve control is pilot operated adjacent with "Dead Man's Handle" safety feature. Each leg is independently isolated and the control valve for beams 2 & 3 is fixed to 1 & 4 and vice versa.

## Optional Extras:

1. Articulated sections fitted to the forward bars to ensure immediate roof contact.
2. Lifting device fitted to the rear of beam 4 for locating permanent supports to the roof until props can be set.
3. Side flushing protection hung from the ends of centre beams 2 & 3.
4. Lighting for forward and general illumination.

## Other Applications:

**FACE GATE INTERSECTION:** To support effectively the difficult area at the intersection of face and gate in longwall workings, whether retreating or advancing with advanced headings (Fig. 3) CONTINUOUS SUPPORT IS AFFORDED.

ADDITIONAL 50 TON LEGS CAN BE FITTED TO GIVE EXTRA SUPPORT IF REQUIRED.

THE CONVEYOR AND MACHINE CAN STILL BE BROUGHT ACROSS THE GATE TO ENSURE STABLEHOLE ELIMINATION.

EXTRA RAMS AND STAKER LEGS CAN BE FITTED TO ASSIST FACE CONVEYOR ADVANCE.

ADEQUATE ROOM IS AFFORDED FOR SALVAGE OF SUPPORTS OF RETREATING GATES.

REDUCED WIDTH: Widths are available to suit the particular headings.

It may also be felt that it is not necessary to assist the permanent supports at a face/gate intersection to the full gate width.

Half headings may also be considered.

REDUCED LENGTH: A three beam version is available, this is for applications where length is critical and also if it is required to negotiate minimum radius turns.

## Appendix C-6

Gullick Dobson Miner  
Support System  
1972

## Technical Specification:

Maximum load per leg – 50 tons.

Setting load at 2,000 p.s.i. – 141 tons.

Total support width on 18'-0" heading – 16'-0".

Closed length – 27'-0" (without top loading bars).

Tip loading bars increase the length by 2'-9½".

Tip load per extension bar – 75 tons at 2,000 p.s.i.

Leg to floor maximum contact pressure – 27.4 ton/ft².

Manoeuvrability depends on clearances, but if these are available it can turn within its own length.

Maximum load per support – 400 tons.

Setting load at 4,000 p.s.i. – 282 tons. (Leg Bore – 5 ins.).

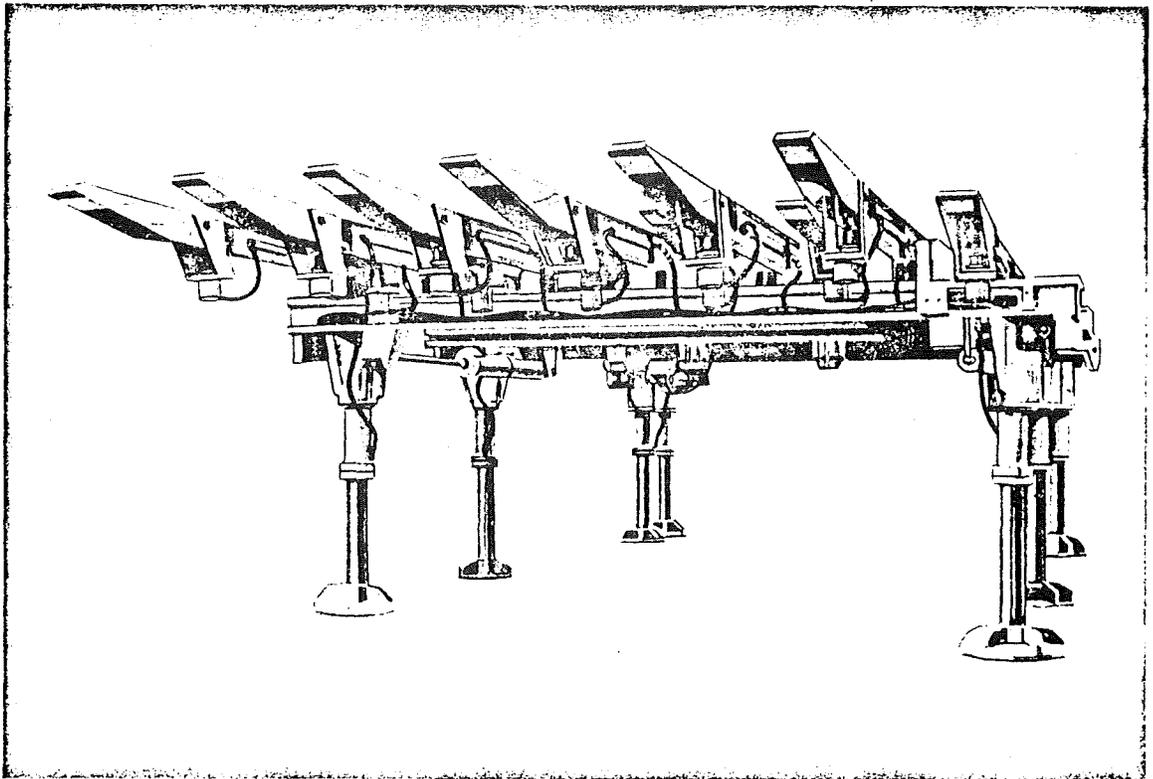
Total support width on 15'-0" heading – 14'-0".

Open length – 31'-0" (without top loading bars).

Bar to roof maximum contact pressure – 3.61 ton/ft².

Advancing rams maximum stroke – 3'-6".

Closed Height of Support		Open Height of Support		Clearance Height below Support	
inches	mm	inches	mm	inches	mm
47.5	1207	64.5	1638	46	1168
50.5	1308	69.75	1772	51.25	1302
53.5	1359	73	1854	56.5	1435
56.5	1435	80.25	2038	61.75	1568
59.5	1511	85.5	2172	67	1702
62.5	1588	90.75	2305	72.25	1835
65.5	1664	96	2438	77.5	1969
68.5	1740	101.25	2572	82.75	2102
71.5	1816	106.5	2705	88	2235
74.5	1892	111.75	2838	93.25	2369
77.5	1969	117	2972	98.5	2502
80.5	2045	122.25	3105	103.75	2635
83.5	2121	127.75	3245	109.25	2775



The information contained in this brochure is subject to revision without prior notice.

**GULLICK  
DOBSON**

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Appendix C-6 (continued)

Gullick Dobson Miner  
Support System  
1972

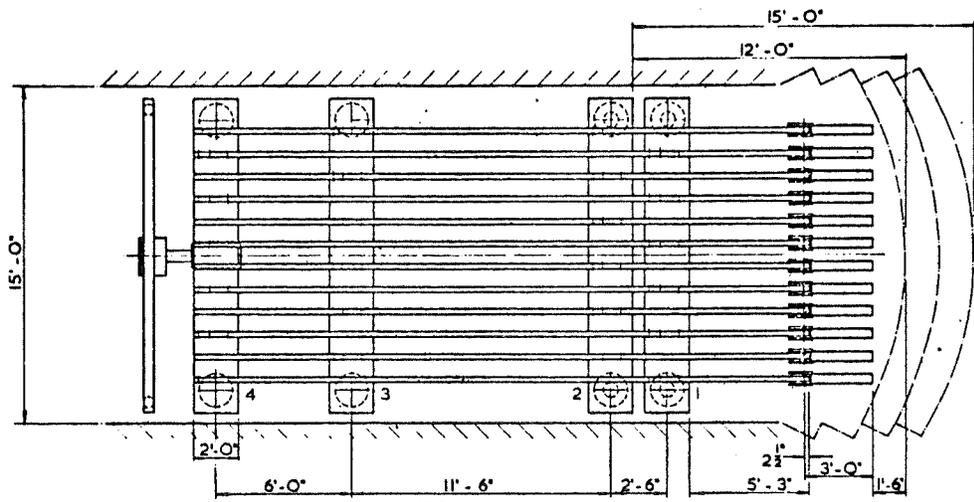


FIG. 1

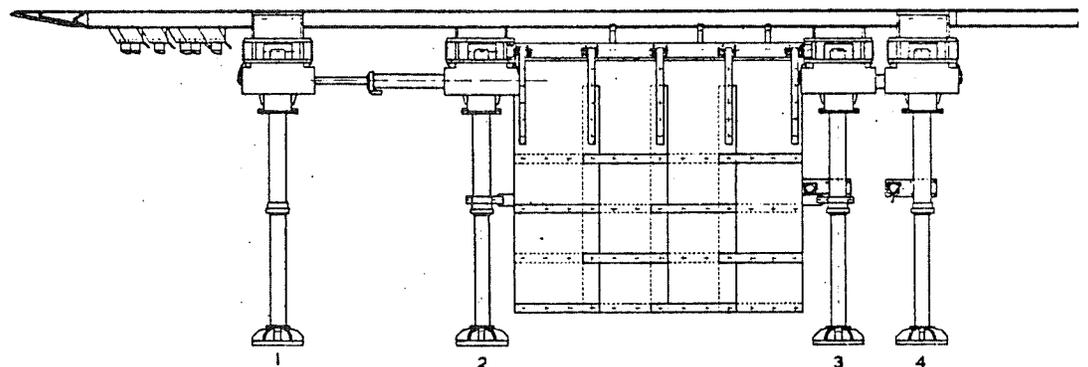


FIG. 2

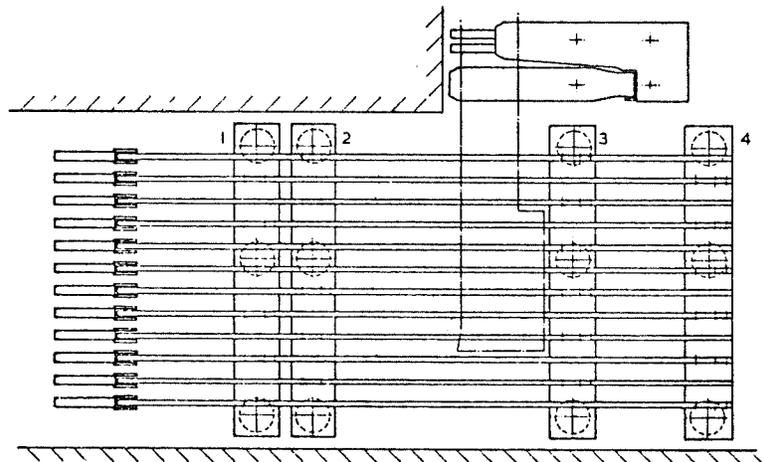


FIG. 3

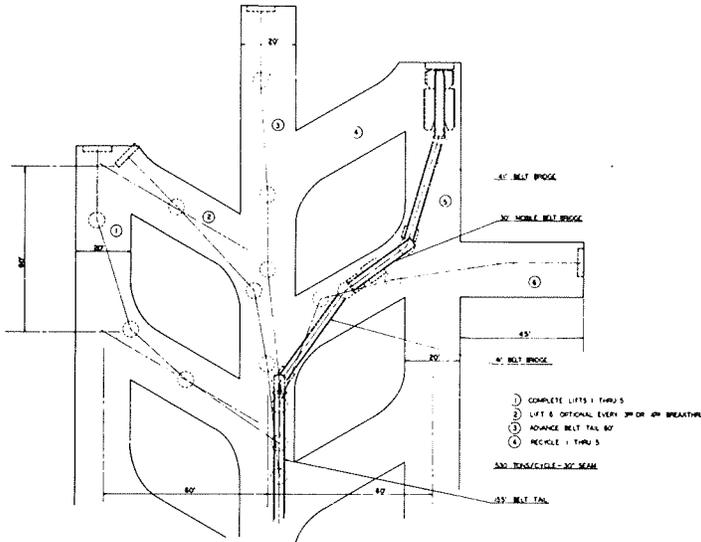
Appendix C-6 (continued)

Gullick Dobson Miner  
Support System  
1972

# TYPICAL MINE PROJECTIONS FOR FULL DIMENSION

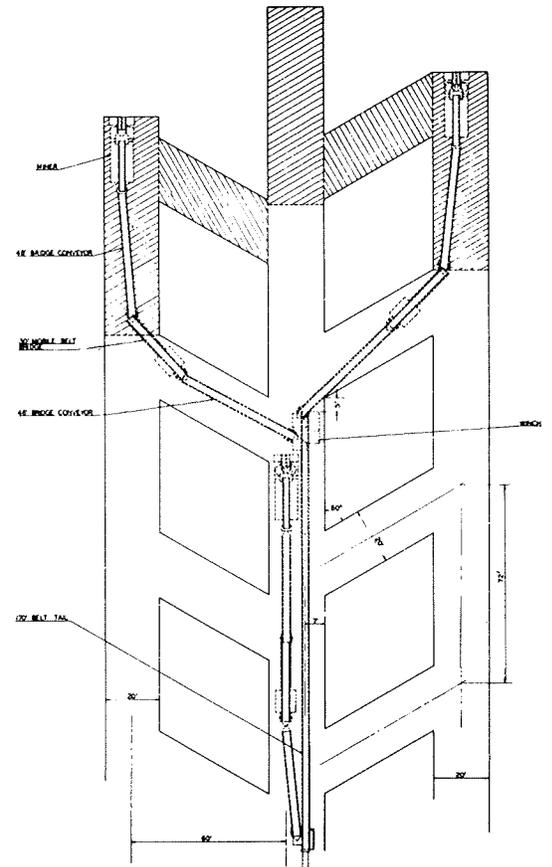
3 entries, 60' x 72' centers, 20' entries

3 entries, 60' x 60' centers, 20' entries



Requires: 2—41' Piggybacks  
1—30' MBC  
1—155' Belt tailpiece

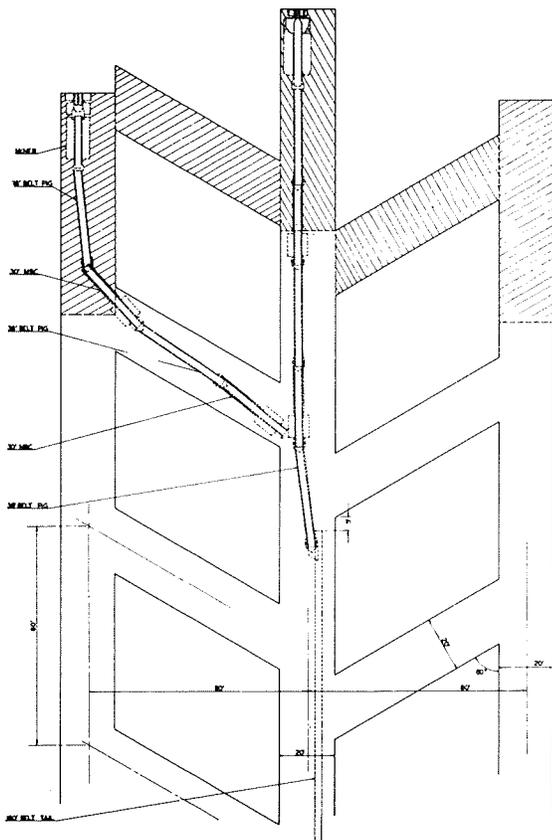
For one 60' cycle between each belt extension.



Requires: 2—46' Piggybacks  
1—30' MBC  
1—170' Belt tailpiece

For one 72' cycle between each belt extension.

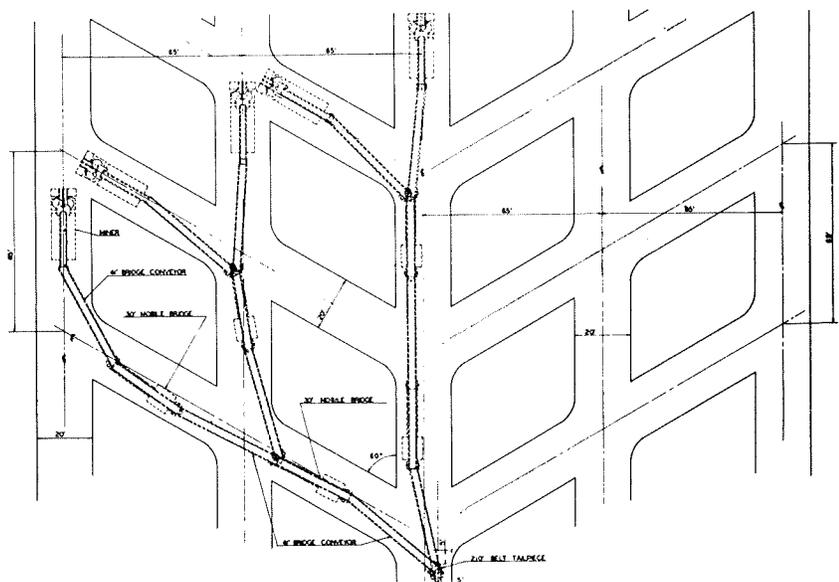
3 entries, 80' x 80' centers, 20' entries



Requires: 3—36' Piggybacks  
2—30' MBC's  
1—190' Belt tailpiece

For one 80' cycle between each belt extension.

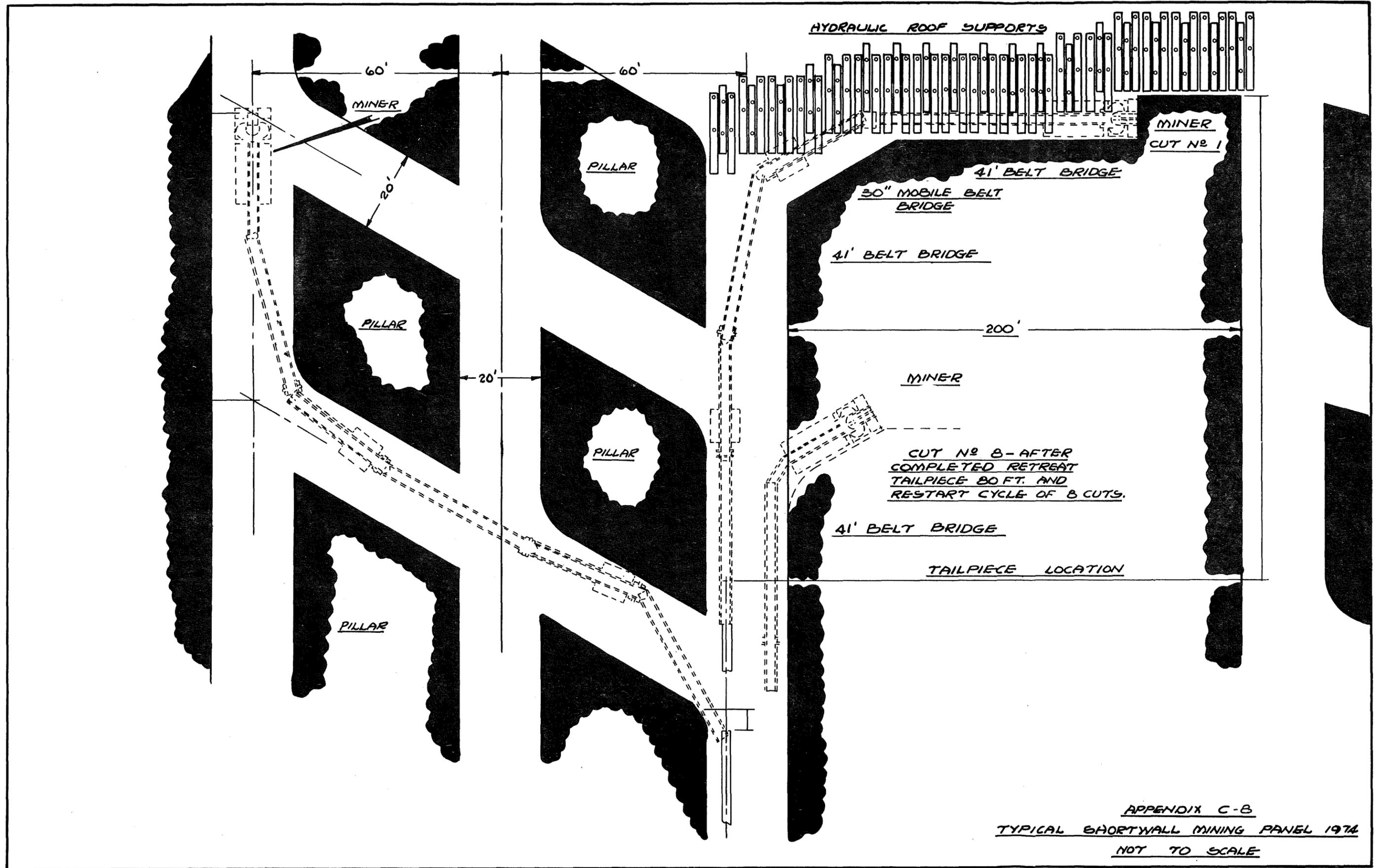
5 entries, 65' x 65' centers, 20' entries



Requires: 3—41' Piggybacks  
2—30' MBC's  
1—210' Belt tailpiece

For one 65' cycle between each belt extension.

## Appendix C-7



APPENDIX C-B  
 TYPICAL SHORTWALL MINING PANEL 1974  
 NOT TO SCALE