Information Circular 9282

Evaluation of Continuous Haulage Systems for Computer-Assisted Continuous Mining Machines

By Suresh K. Bhatt

UNITED STATES DEPARTMENT OF THE INTERIOR
Manuel Lujan, Jr., Secretary

BUREAU OF MINES
T S Ary, Director

Library of Congress Cataloging in Publication Data:

Bhatt, S. K. (Suresh K.)

Evaluation of continuous haulage systems for computer-assisted continuous mining machines / by S. K. Bhatt.

p. cm. — (Information circular; 9282)

Includes bibliographical references.

1. Mine haulage—Evaluation. 2. Coal-mining machinery—Automation. I. Title. II. Series: Information circular (United States. Bureau of Mines); 9282.

TN295.U4 [TN331] 622 s—dc20 [622'.6'0285] 90-22806 CIP

CONTENTS

ILLUSTRATIONS

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	s	second
ft/min	foot per minute	st	short ton
hp	horsepower	st/min	short ton per minute
in	inch	st/worker-day	short ton per worker-day
MHz	megahertz	$/ft	dollar per foot
min	minute	$/st	dollar per short ton

OTHER ABBREVIATIONS USED IN THIS REPORT

C.H.	continuous haulage	S.C.	shuttle car
C/PTM	clean and prepare to mine	WTD AV	weighted average
CPU	central processing unit		

EVALUATION OF CONTINUOUS HAULAGE SYSTEMS FOR COMPUTER-ASSISTED CONTINUOUS MINING MACHINES

By Suresh K. Bhatt[1]

ABSTRACT

This U.S. Bureau of Mines report reviews major developments in continuous haulage technology for underground coal mines. Haulage systems, both in use and under development, were investigated through a comprehensive literature search and visits to mines and manufacturers. The systems include flexible conveyor train, mobile conveyor, monorail bridge conveyor, multiple-unit continuous haulage, extensible, and belt turning systems. Strengths and weaknesses of the systems are assessed in light of their operating under remote control and their application to the computer-assisted continuous mining machine research being conducted by the Bureau. Through mining scenarios, candidate haulage systems are conceptualized to be consistent with the capabilities of the mining machine.

[1]Mining engineer, Pittsburgh Research Center, U.S. Bureau of Mines, Pittsburgh, PA.

INTRODUCTION

In underground coal mining, continuous face haulage has been recognized for years as a major requirement to make the continuous mining machines truly "continuous." Shuttle cars in the haulage system make the flow of coal from the mining machine to the section belt intermittent. In a normal mining cycle at a working face, the coal cutting-loading time is approximately equal to the non-productive, but essential, "shuttle car change" time. In other words, half of the face mining cycle time is lost because of this conventional haulage.

A successful continuous haulage system offers a significant increase in output per unit shift, potentially up to two times that achieved with the intermittent shuttle car haulage system. Other advantages include increased worker safety and reduced operating costs. Some 90% of underground coal mines in the United States use shuttle cars mainly in room-and-pillar mining or development panels of a longwall mine.

The appendix includes relevant production and cost models to simulate an efficient mine. Pertinent criteria, parameters, and assumptions used in the simulations are provided in the U.S. Bureau of Mines Information Circular (IC) entitled "Cost-Benefit Analysis of Computer-Assisted Mining Through Production and Cost Modeling" (*1*).[2]

This Bureau report attempts to provide continuous haulage system(s) design and guidance technology consistent with the Bureau's computer-assisted mining machine (CAMM) research (*2*). The integration of the continuous haulage system with the mining machine is necessary; the positional information obtained by the extended haulage system could provide information for guidance of the continuous miner.

Seven haulage systems, both in use and under development, were investigated through a comprehensive literature search and visits to various mines and manufacturers. The systems include flexible conveyor train, mobile conveyor, monorail bridge conveyor, multiple-unit continuous haulage, extensible, and belt turning systems. Strengths and weaknesses of the systems are assessed in light of their operating automatically or under remote control and their application to the Bureau's CAMM. One or more candidate haulage systems are conceptualized, through mining scenarios, that meet the required capabilities. An attempt is made to identify the technology needs to further the success of continuous mining haulage systems. Appendix B, which consists of backup computer printouts, showing the model output format, is included in this report to assist users in understanding the modeling technique and its application for their particular needs. This research will help the Bureau to attain its goal of improving worker health and safety, as well as mine productivity.

SELECTION CRITERIA

COAL RESERVES

The demonstrated reserve base (DRB) of coal is an estimate of U.S. coal tonnage considered commercially minable. As of January 1, 1988, the Energy Information Administration (EIA) of the U.S. Department of Energy estimated the DRB at 475 billion st, about half being recoverable (*3*). Some 68% of the DRB or 321 billion st is estimated to be underground minable. About 56% of the underground minable reserves are located in the States east of the Mississippi River. Approximately half of the DRB is bituminous coal, which is primarily in the Eastern United States coalfields. According to EIA, some 65% of these recoverable reserves are comprised of coal seams ranging between 4 and 6 ft in thickness. Reasonable minimum mining height for the continuous haulage system, therefore, is about 48 in.

COMPUTER-ASSISTED MINING MACHINE

The Bureau's CAMM for experiments, both on the surface and underground, is a Joy[3] 14CM 9-10 D model. The model can cut coal seams of varying thicknesses, from 44 to 126 in, covering the desired coalbed thickness group of 4 to 6 ft. The technology, once it becomes evaluated for this model of mining machine, can be applied to other models and manufacturers.

PRODUCTION FORECAST AND MINING TRENDS

DRI/McGraw-Hill Coal Review, in its spring 1989 issue (*4*), estimates that underground coal production from the Eastern United States will double, from the 1987 level of 346 million st to about 689 million st, in the year 2010. This Eastern coal represents approximately 90% of the

[2] Italic numbers in parentheses refer to items in the list of references preceding the appendix at the end of this report.

[3] Reference to specific products does not imply endorsement by the U.S. Bureau of Mines.

total U.S. deep-mined coal projection (774 million st in 2010).

Traditionally, coal-producing States east of the Mississippi River have been leaders in the underground production. In 1986 and 1987, for example, some 94% of the total underground production in the United States came from the East. Also, in recent years, some 62% of the deep-mined coal came from coal seams below 5-1/2-ft thickness. In 1987, the 4- to 6-ft coalbed thickness group produced the highest tonnage of the various seam thickness groups, i.e., 161 million st or 43% of total underground production (*3*, p. 33). The 6- to 8-ft thickness group produced about 20% of the total production.

CONTINUOUS HAULAGE SYSTEM CHARACTERISTICS

Major characteristics for which the continuous haulage system is evaluated include the following:

- Capacity—steady state and surge flow.
- Simplicity in design and operation.
- Dimensions—length (reach), height, and width.
- Maneuverability-adaptability (flexibility) to various layouts.
- Cost—capital and operating.
- Reliability-availability.
- Ruggedness and weight.
- Operating life.
- Size of product handled, spillage, and carry back.
- Traction-tracking ability.
- Tram speed—advance and retract.
- Dust and noise generation.
- Automatic, remote operation and labor.
- Inherent safety.

Coal-handling capacity, both steady and surge flow of a haulage system, should match the rates of the mining machine. Studies (*5*) have shown the surge flow of up to 25 st/min for a period of 20 s in continuous mining operations.

Simple system design and operating capabilities are important for continuous production flow with minimum interruptions.

Dimensions dictate seam mining height, maneuverability, and adaption to a mining layout. The system should be capable of negotiating multiple 90° turns for desired heading and crosscut widths without spillage and breakdowns.

Flexibility-adaptability to a wide range of mining layouts, from three-heading to eight-heading room-and-pillar sections (reach varying between 300 and 1,000 ft) with crosscuts at varying angles, is required.

Both operating and capital costs need to be reasonable. Technoeconomic viability of a continuous haulage system only can justify its superiority over the noncontinuous systems.

Reliability-availability is a criterion that differentiates a continuous system from the noncontinuous one. A system that is available for all the production shifts and operates without breakdowns is desirable.

The system should be tough or rugged to withstand the mine environment, but also light enough to prevent excessive pressure-related problems on the mine floor-roof.

The system's operating life, based on normal tonnage handled or operating hours, is critical in achieving the long-term productivity gains. Frequent breakdowns, conveyor or structure, are expensive both in terms of lost production and maintenance-supplies and overall operating costs.

Large lumps of coal or rock can block the continuous coal flow and damage the conveyor structure. The system spillage and carry back of the coal handled should be minimum. A clean system is safe and productive.

Traction-tracking ability is necessary for proper guidance, navigation, and maneuverability of a haulage system.

High tram speed (advance and retreat) makes a mining cycle efficient and productive.

Reducing dust and noise levels underground improves the health of mine workers underground.

The degree to which a system can be automated and remotely operated with a minimum of direct human involvement determines the success of a computer-assisted continuous mining haulage system.

The system should be safe to operate and maintain in a coal mine, meeting necessary regulatory requirements of the U.S. Mine Safety and Health Administration (MSHA) and respective State mine departments. An efficient section haulage is *only* acceptable when it incorporates high safety standards.

Overall, the haulage system should be compatible with the Bureau's CAMM. The compatibility is desired in terms of capacity and ability to follow the mining machine, among others. To achieve total success, both the mining and haulage systems should be able to work productively and simultaneously, at their best, for sustaining time periods.

DESCRIPTION OF SEVEN REPRESENTATIVE CONTINUOUS HAULAGE SYSTEMS

The haulage systems are described in two general categories: Available (commercial) and under development.

The specifications of all systems were obtained from manufacturers' brochures and literature. Salient data, for a quick comparative reference, are presented in table 1. This information was refined for its contents based on discussions with the representatives of the manufacturers or the mining companies (with operating system) as better data became available.

SYSTEM A

The Kloeckner-Becorit (KB) development of the intermediate drives concept for chain conveyors is the basis of this haulage system (fig. 1). The main features are as follows:

1. The mobile conveyor is self-tramming.
2. The mined material is hauled continuously when not tramming.
3. Negotiation of corners and curves is possible.

For tramming, the mobile conveyor utilizes its bottom chain strand as a track. Like a caterpillar track, the chain is covered by a flexible cover-plate assembly, providing good force transfer to the floor, enabling inclines to be negotiated without the conveyors losing their grip.

For conveying, the mobile conveyor is raised on pneumatic legs so that the bottom chain strand comes free off the floor. The material is then conveyed along the same path as previously trammed by the conveyor. Depending on the width and height restrictions of the roadways, for transferring the conveyed material on the section belt, two designs are possible:

1. Designs where the mobile conveyor is able to move while it is supported above the main belt.
2. Designs where the mobile conveyor trams parallel to the main belt and is equipped with a side discharge.

The extreme flexibility of the conveyor enables it to negotiate tight curves. Steering is via steering cylinders mounted only at each end of the conveyor. These cylinders force that end of the conveyor, facing into the tramming direction, into a curve while remaining pans of the conveying system follow this once-laid track without any deviations.

This high flexibility of the mobile conveyor is achieved by the pinned pan connection on the central axis of the conveyor, the relatively short length of the pans, and the small chain forces. The tightest achievable horizontal curve radius is approximately 14 ft, measured at the inside edge of the conveyor.

By being able to achieve concave and convex curves of approximately 50-ft radius, the mobile conveyor is able to follow the continuous miner in a vertical plane.

A master control station is located at the discharge end of the conveyor. The station communicates with local control units, located at intervals along the conveyor length, and the inby control station with a serial data bus. Single-board computers are used to monitor and control gear box speed, direction, cylinder position, and drive motor conditions. Component failures stop conveyor operation, and the problem and location is indicated at the master control station. The conveyor can also be controlled, for troubleshooting, at the local control units with a plug-in umbilical control.

Table 1.—Summary of salient data of representative continuous haulage systems

System	Manufacturer	Model	Width, in	Height, in	Length, ft	Power, hp	Speed, ft/min: Convey	Speed, ft/min: Tram	Capacity, st/min	Weight, st	Cost, $/ft
Available:											
A	Kloeckner-Becorit	Mobile conveyor	43	41	600	400	197	71	13	NA	3,600
B	Joy	3FCT	36	36	402	196	500	60	12	100	3,000
C	Untertage-Westfalia	UFC 2.3	25	51	820	175	150	60	8	NA	3,000
D	DM Enterprises	Belt bender snake	75	61	600	250	500	60	20	70	3,200
E	Long-Airdox	Full dimension, 36B, 2 MBCs+, 3PBs+, RFM.	90	37	183	230	620	54	11	40	2,000
Under development:											
F	Bureau, Foster-Miller, Long-Airdox.	ABCT	92	44	276	105	276	50	12	88	NAp
G	Bureau, Jeffrey	MUCH	78	56	250	245	280	80	12	58	NAp

ABCT Automated bridge conveyor train.
FCT Flexible conveyor train.
MBC Mobile bridge carrier.
MUCH Multiple-unit continuous haulage.
NA Not available.
NAp Not applicable.
PB Piggyback.
RFM Rigid-frame modular.

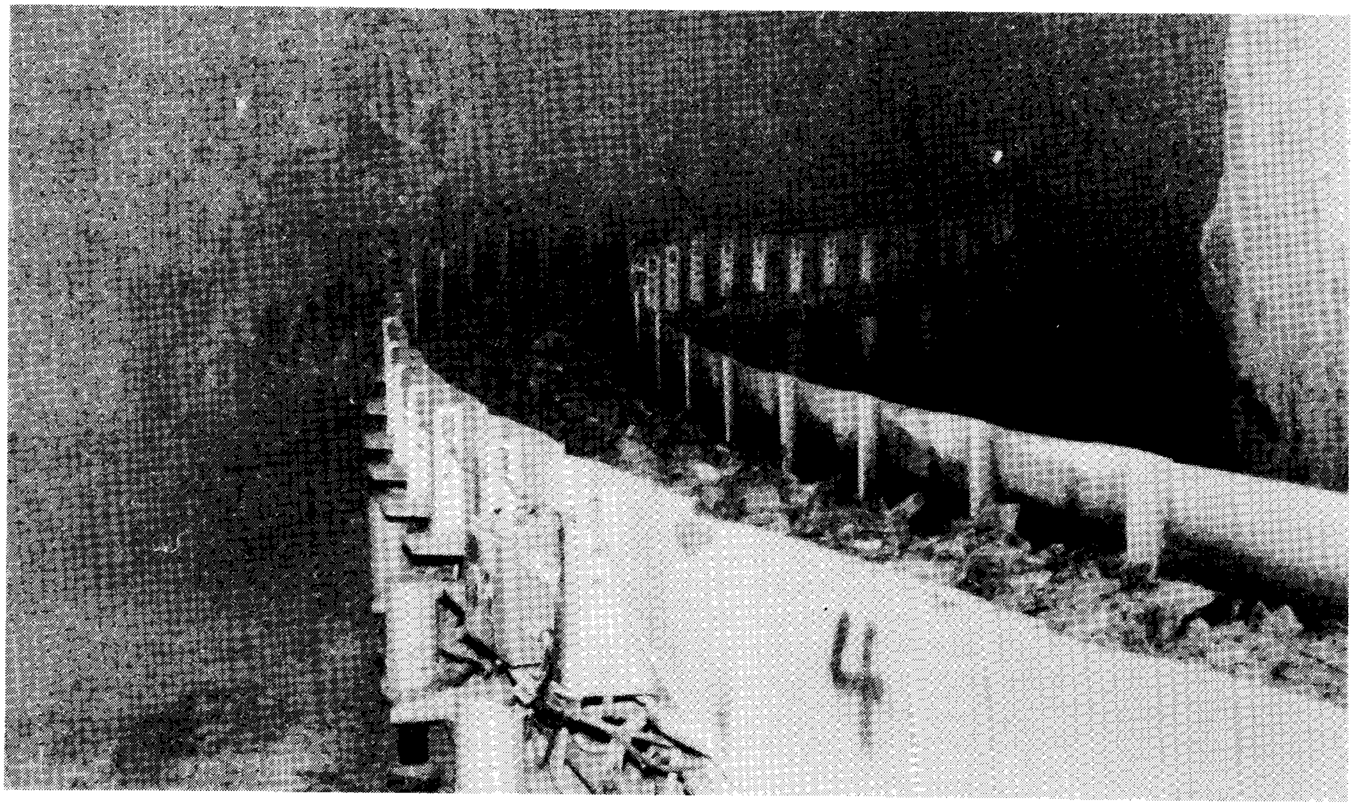

Figure 1.—Kloeckner-Becorit mobile conveyor.

An operator at the loading end of the vehicle controls steering, direction, and mode of operation (i.e., tram or convey) with a plug-in umbilical or radio control station. The operator steers the nosepiece, and the conveyor uses the chain as a track; thereby, guidance of the intermediate units is accomplished mechanically while tramming.

The computer initiates, controls, and interlocks the functional relationships of conveyor operation. For the tram mode, the units are lowered, low speed is engaged on the gear boxes, and steering and tram direction are enabled. For the convey mode, the units are raised, high speed is engaged on the gear boxes, and conveyor direction inby or outby is selected. The motors also have a manually selected neutral position such that one motor or drive sprocket can be set to free wheel without stopping production until the motor can be repaired or replaced.

Automation of this system is possible by extending the guidance of the continuous miner such that the steering and direction control commands are communicated between the systems. Since the conveyor follows the track of the lead unit and is essentially autonomous, this system would appear to need little additional computer control other than the communications with the mining machine and docking-type control, mechanical linkage, or both.

A specially designed overlap of all moving parts ensures that the conveyor is sealed against any spillage of material.

Currently, there are four units operating underground—two in trona mines in Wyoming and two in coal mines of Australia. One highwall unit (250 ft) is operating in West Virginia, and two underground coal haulage systems are being built—one for a Kentucky mine and the other for a Canadian mine (600 ft).

In a typical mine, three headings were developed with a continuous miner and shuttle car haulage. The KB continuous haulage system was installed along with a boring machine to drive 60° rooms approximately 200 ft long on both sides of the developed section, retreating one side at a time. The continuous miner operator uses lasers to guide the mining machine.

A jack leg module is mounted on the continuous haulage system for roof bolting. A single row of roof bolts is placed in the center of the heading for roof support. Therefore, the haulage system is placed in the left side of the heading to facilitate roof bolting during mining operations.

The system discharges its output to a feeder breaker prior to the section belt. The belt consists of DM Enterprises (DME) movable stands with a 1,200-ft belt takeup unit located beyond the discharge point to the main-line belt. The haulage system movement is coordinated between the feeder breaker and haulage system. The power cable and water supply to the boring machine are in a separate heading. The haulage system can, therefore, be moved without tramming the borer.

The present control system is an analog input system with the computer and display located at the discharge end. The system is good at indicating errors and faults; however, the coded error and diagnostic messages are sometimes difficult to interpret. The plug-in controller and programmer is useful in setting conveyor functions and parameters at the work area.

A major U.S. coal producer has developed a continuous haulage system on a principle similar to that of the KB. The system has successfully operated for about 2 years in underground coal mines and is currently being installed in a highwall operation.

SYSTEM B

The flexible conveyor train (FCT) by Joy Technologies (Joy) is a flexible, crawler-mounted belt conveyor that can negotiate 90° turns, side pitches, and swag due to the innovative design of its belt conveyor. This concept permits the FCT (fig. 2) to be used in longwall development entries, as well as room-and-pillar mining.

The system is composed of an inby and outby unit joined together by a series of standard crawler and traction units. The traction units power a crawler chain similar to a longwall conveyor chain, but with detachable flights mounted on it. This flexible crawler carries a prestretched flexible conveyor. Steering is provided by rubber tires mounted on the inby and outby units. Angles between cars for articulation varies between 5° for horizontal and 6° for vertical. The train can be roof hung on monorail or floor mounted.

Guidance of the system is provided by wheeled steering with crawlers acting as a track for the remainder of the train. The system can be designed for top or side discharge of the section belt.

The FCT needs one operator, and either radio (standard) remote or cable remote control is used. An important feature of this system is that conveying of material and tramming of the FCT can be performed simultaneously. In the United States, there are currently three units operating—two in coal (West Virginia and Illinois), and one in trona (Wyoming). The West Virginia unit is 550 ft long and a cable remote operation.

In a standard system, the operator at the inby end controls and steers the unit (3FCT model) with a hand-held, battery-powered radio remote control station. Programmable controllers are located at the discharge, center, and inby end. The number of controllers is determined by the length of the train. An 8- by 12-in lighted display is located at the inby operator station.

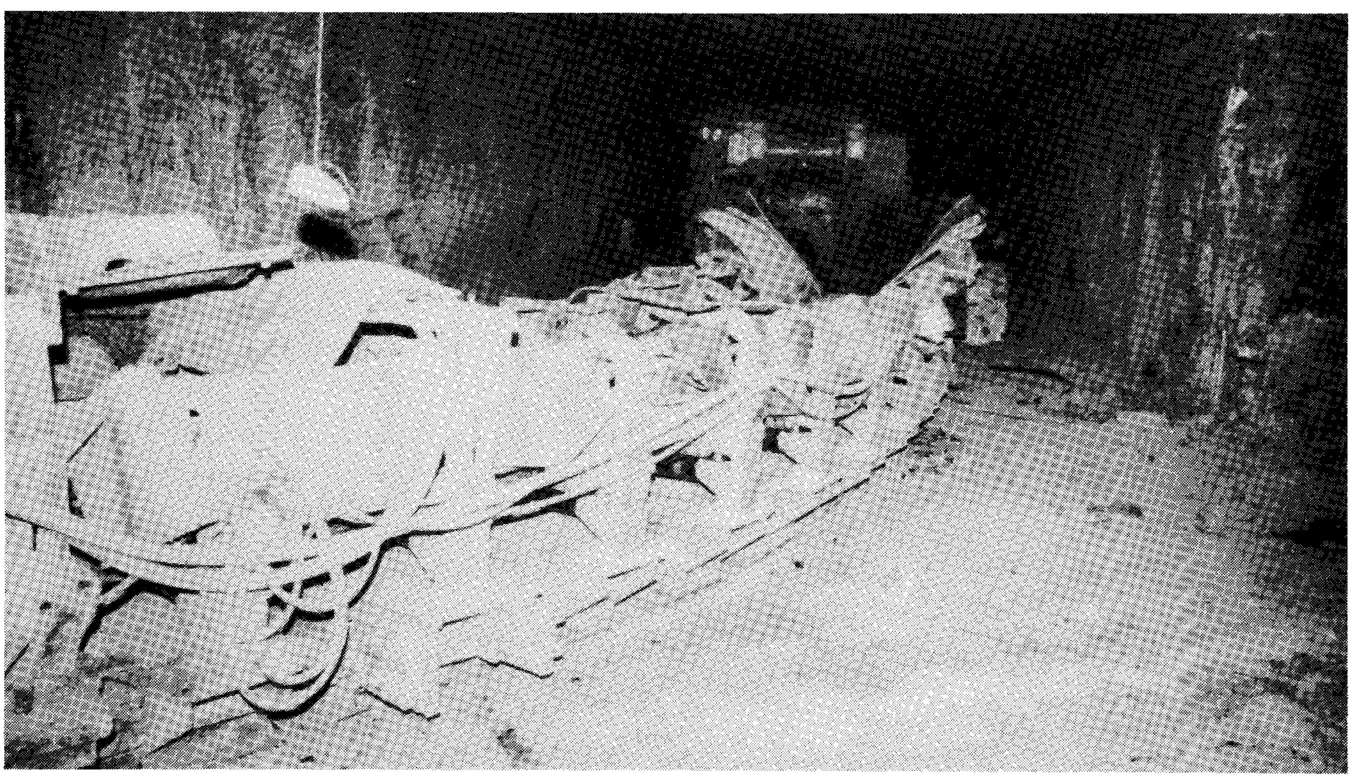

Figure 2.—Joy flexible conveyor train.

Identical computers housed in explosion-proof enclosures are used at each of the controller locations. Each computer has a personality module called a "tag" that defines its function and location within the system. The computers can be interchanged, but the tags must remain at their locations. Each computer location is equipped with a radio receiver to enable control of the haulage system with the radio transmitter from any of the computer stations. A fiber-optics bidirectional transceiver and fiber-optics cable are used for communication and control of the system. To reduce the possibility of production loss due to a damaged fiber-optics cable, the computers are connected in a loop. If one leg of the communications loop is severed, this condition is reported to the operator control panel, and the communication is automatically established through the remaining connection. However, if two legs of the loop are severed, the computer will shut down operations.

The computer is a Matrix Microboard with a 10-MHz 68HC00CPU. The boards are equipped with auxiliary connections of RS-422, RS-485, Serial I/O, and four RS-232 ports. The computer can support C, Basic, Pascal, and Forth programming languages.

The display at the front of the 3FCT can be used to display conveyor belt and tram unit activity and error and diagnostic information. The last eight messages are retained and can also be displayed. An auxiliary readout and printer unit can be connected to the system to retrieve stored conveyor and drive unit operating data. However, operating and default parameters can only be changed by replacing the tag module.

Automation of the system is possible by extending the guidance of the continuous miner such that conveying, steering, and direction control commands are communicated between the systems. Since the conveyor rides on a crawler track and follows the lead unit, this system would appear to need little additional computer control other than communications with the mining machine and docking-type control, mechanical linkage, or both.

The mine visited has a mine plan similar to the one with the KB system. The 400-ft Joy 3FCT is installed with a mine belt structure slightly longer than the 3FCT, enabling the haulage system to ride over and discharge the mined product onto the section belt. The boring machine's power cable and water hose are attached and carried along the conveyor train.

Changing operating parameters of the haulage system requires opening the explosion-proof box and replacing the personality module. The diagnostics of the system are good. The haulage system is easy to operate.

The Joy 2FCT system was installed and operated in an Australian coal mine for 18 months in 1985-87 (*6*). The demonstration proved the practicality and benefits of the concept. Also, plans were indicated for installing a 3FCT floor-mounted version in the near future.

SYSTEM C

Untertage-Westfalia (Westfalia) has developed a continuous haulage or self-propelled curved conveyor (UFC 2.30 model) (fig. 3). The concept is considered as one of the latest developments in curved-chain conveyors that can be made up to 800 ft long.

The UFC 2.30 is so designed that it can be equipped with a drive unit at the receiving end, allowing the conveyor to follow the mining machine under its own power. If not fitted with a drive unit, the conveyor is coupled to the mining machine for being pulled forward. It is made up of short-length pans so that it can negotiate up to 10-ft radius curves. A hydraulic supporting structure, movable along the conveyor, provides the necessary stability for the curved section. The supporting elements can be stored at the end, where the haulage unit is attached. The unit providing power to the conveyor chain is fitted at the discharge end of the system. It rides on a platform over the subsequent belt or chain conveyor. A set of wheels, connected to every third pan, allows the conveyor to travel on the floor and on the platform of the subsequent conveyor. This conveyor is designed to negotiate 90° turns.

The pulls required for moving the conveyor are introduced into the pans by a specially arranged haulage chain in order not to subject the conveyor chain to any undue stresses and strains when the system is moved. This ensures that material can be transported even when the conveyor system is tramming. The pans are connected by bolts, allowing the assemblies to articulate. The gaps formed between the pans when curves are negotiated are closed by overlapping spill plates. The deck plates are also made to overlap. Transport of any spillage to the return unit is in the closed bottom section.

The haulage drive unit is normally crawler mounted. Hinged elements at the inlet end allow the size of the hopper to be varied for any type of continuous miner. For setting the hydraulic supporting structure, a connection is made to the main hydraulic power supply unit.

The system is operated by remote control, employing one person. At present, there is one operating system in the Federal Republic of Germany. Westfalia is in the process of designing the first system for a U.S. coal mine.

SYSTEM D

The DME belt-bending principle, first tested in 1985, is the key to its continuous haulage systems. It is a technique for changing the horizontal direction of a conveyor belt, replacing the need for separate conveyor drives and associated equipment. The required change in horizontal direction is achieved by stepping the conveyor belt vertically between two rollers and rotating the bend rollers relative to each other. Standard conveyor belt material

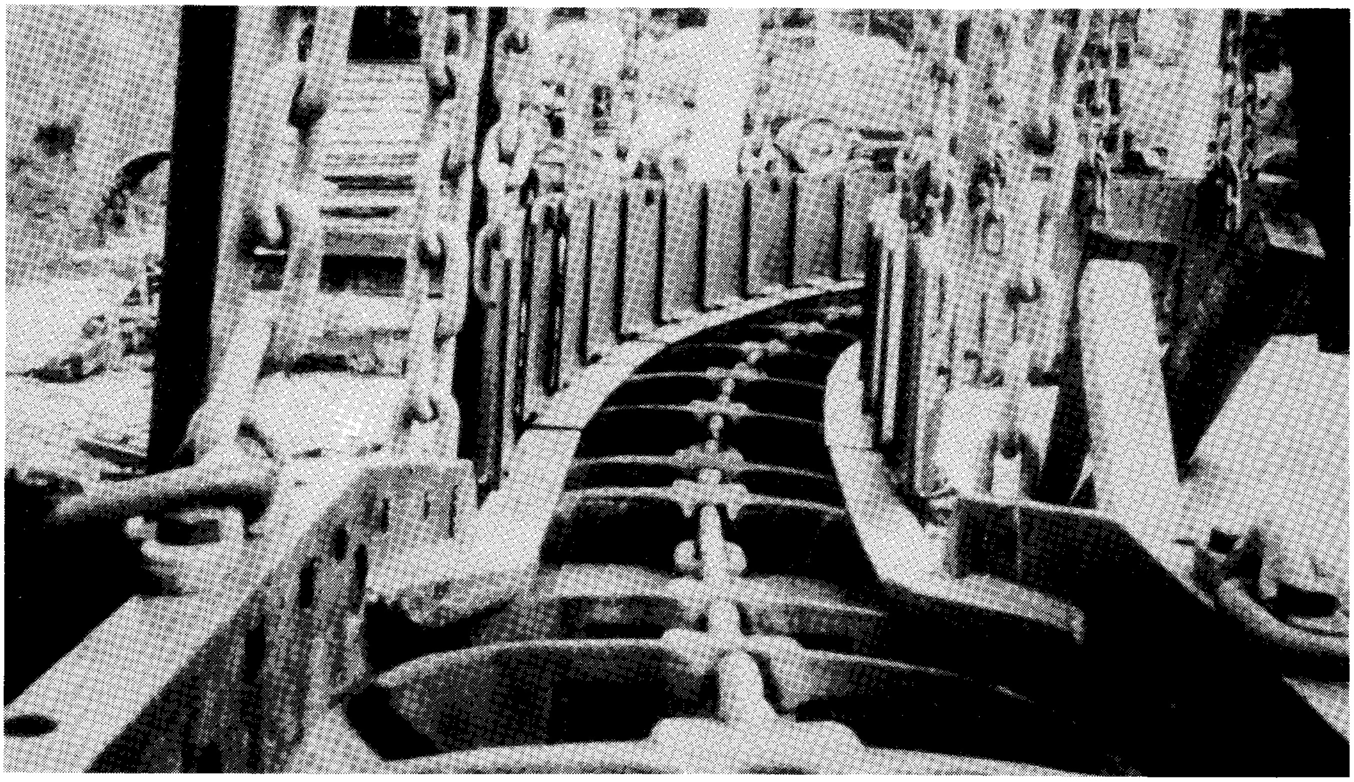

Figure 3.—Westfalia curved conveyor.

and splices can be twisted in this manner by up to 30° with no adverse effect. Greater angles are achieved by putting multiple pairs of bend rollers in a series in a frame.

The belt bender "snake" was developed in 1988; this system is better suited than other DME haulage systems, especially where many corners have to be negotiated. It is a mobile, flexible conveyor, which consists of linked cars of between 12- and 20-ft length each as shown in figure 4. It is fully self-propelled, with individual cars having a single powered axis. Articulation of up to 30° is achieved between cars by a simple linkage system. A single conveyor belt runs the length of the snake conveyor; bend rollers at car intersections handle the change in direction of the belt. In addition to its anticipated application in room-and-pillar mining, this system will be capable of performing the "predevelopment" work commonly done using shuttle cars. DME has also developed several concepts to achieve the interface between the snake conveyor and the section panel belt; however, these concepts need to be tested. Belt bender rollers, employed in deflecting the belt, mean absence of transfer points along the length of snake and, therefore, minimize spillage.

A typical 600-ft belt snake can be operated by one person. Prototypes of the system have been tried in potash mines in Canada. At present, there is no operating system; however, one is proposed for a coal mine in the United States and one for a potash mine in Canada in the near future.

SYSTEM E

A Long-Airdox (LA) full-dimension system (fig. 5) consists of three different units—mobile bridge carrier (MBC), piggyback (pig) bridge conveyor, and rigid-frame modular (RFM) tailpiece as described below.

The MBC is the "heart" of the full-dimension continuous haulage system. It provides the means to articulate the system around corners and move it in concert with the mining machine. The MBC-36B is a belted model that is crawler mounted and designed to work efficiently in seam heights as low as 42 in. It is the supporting unit for the pig bridge conveyor of the full-dimension system. The discharge end of an inby pig is connected to a moving dolly on the MBC. The receiving end of an outby pig is connected to the MBC's discharge boom.

The receiving end of the first inby pig attaches to a yoke on the tail of a continuous miner and connects to the discharge boom of the MBC in every subsequent unit. The discharge end of the last outby pig moves on an RFM tailpiece.

The RFM tailpiece, in 9-ft length, permits the entire system, including continuous miner, to retract alongside when moving from one heading or crosscut to another. The tailpiece length equals that of a full system plus the mining machine, with two additional lengths (18 ft) for overrun on retracting. The sections are pinned together through male and female connections at each end. These pinned joints act as hinges in a vertical plane to allow the

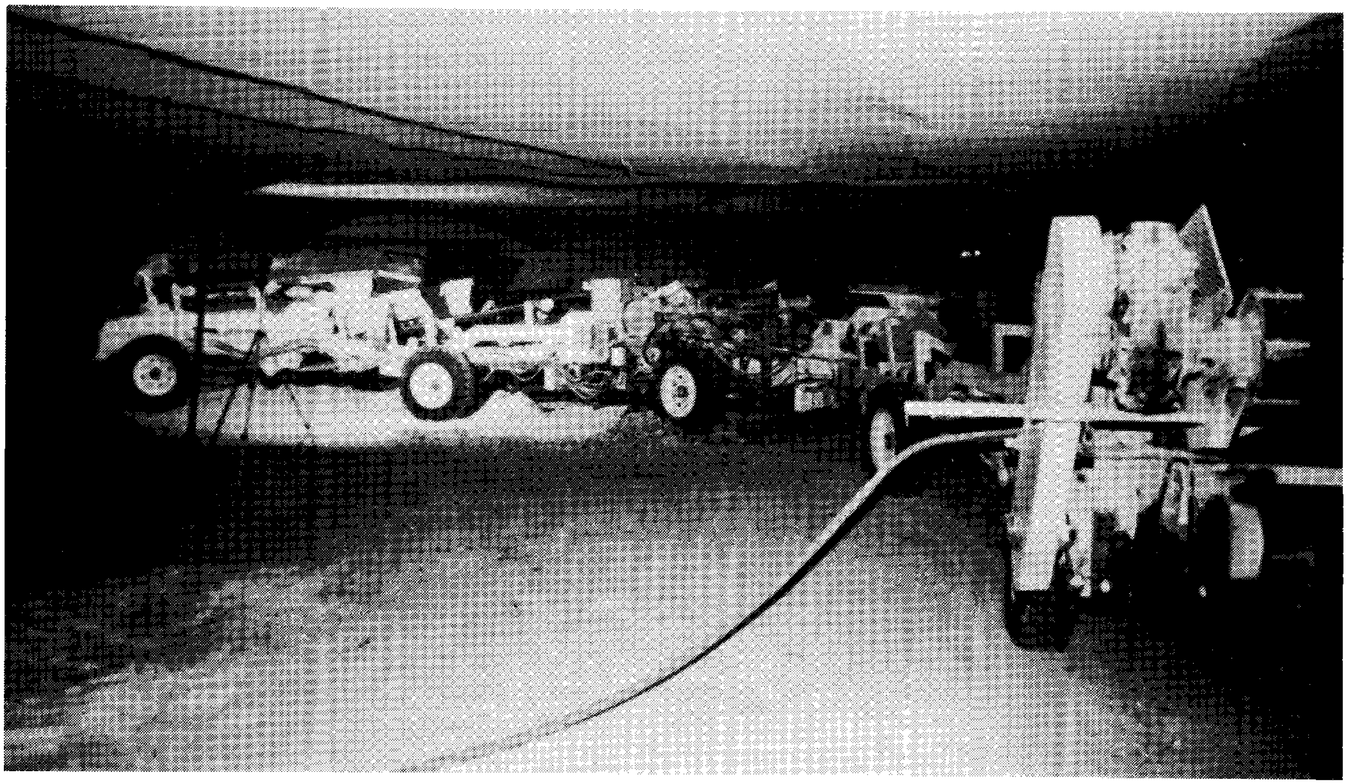

Figure 4.—DM Enterprises belt bender snake.

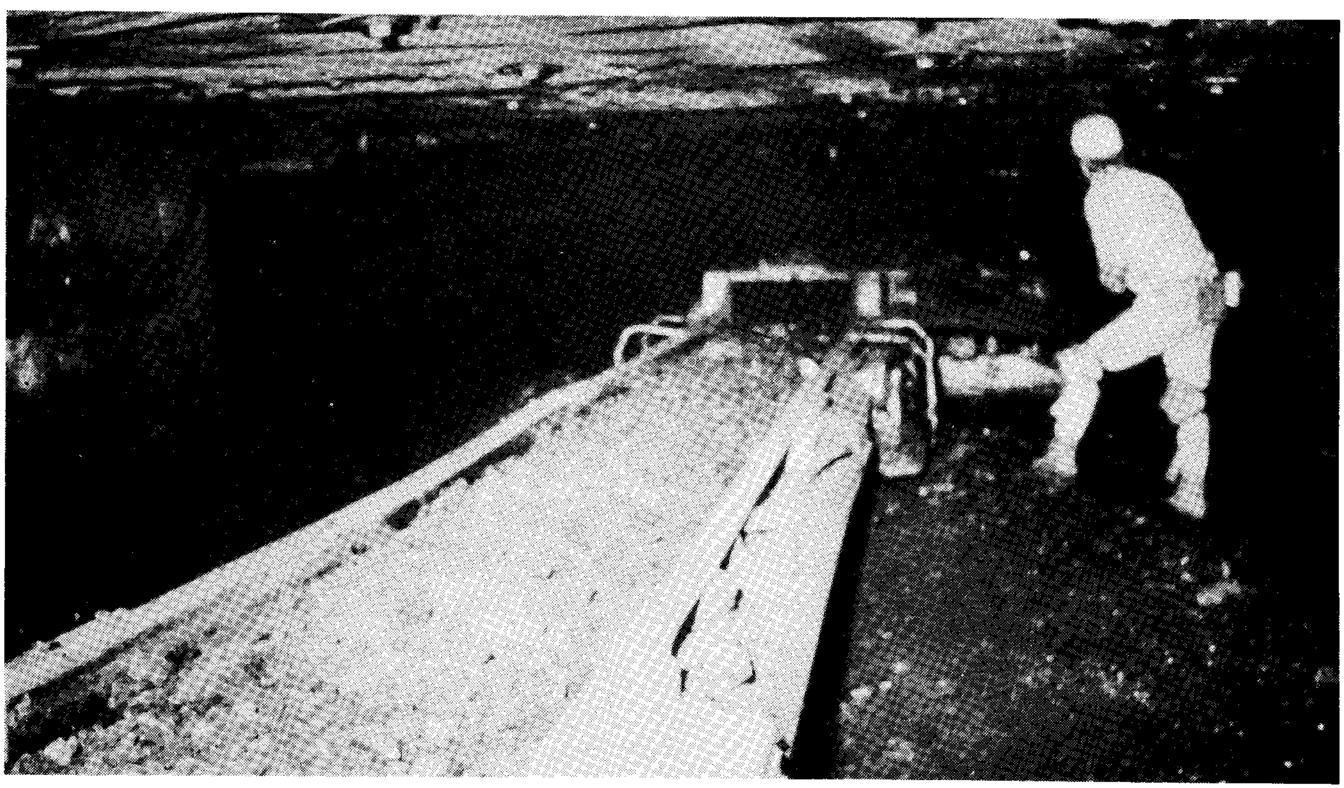

Figure 5.—Long-Airdox full-dimension haulage system.

sections to conform to undulations in the mine floor. A standard five-heading system consists of three pigs, two MBC's, and one RFM tailpiece.

A standard pig has 41 ft of effective length, and the MBC about 30 ft. A three-heading system (one MBC and two pigs), therefore has an effective reach of 112 ft plus the length of the continuous miner, or 145 ft. This figure in a five-heading system becomes 183 ft plus continuous miner length, or approximately 215 ft.

To obtain maximum effectiveness, the "breaks" should be driven at 60° angle, since the complete system will articulate into a 60° turn, faster than a 90° turn. It is to be emphasized, however, that speed and facility are sacrificed to varying degrees on the tighter angles. For narrow widths, in the 16-ft range, it is necessary to shorten the bridges or piggybacks.

The electrical control system consists of breakers, line starter, overloads, and emergency stop. LA uses hydraulic drives and controls for the carriers and gear-reduced electric drives for the conveyors. Rubber-tire vehicles are not normally used because the crawlers are more maneuverable and provide better tractive effort. The standard conveyor is a chain.

For every 70-ft length of the system, one operator is needed, or for this standard (183 ft) system, about four persons are needed. Over 70 of these systems (chain and belt) are currently operating in the U.S. coal-mining industry, making this system the most prevalent (also least expensive) of the commercially available systems. This system, however, may require substantial effort to automate.

The automation of this system would require selecting a workable guidance and control scheme, transducers, computers, and interface hardware. The control system would have to be retrofitted to the haulage system and tested.

SYSTEM F

The automated bridge conveyor train (ABCT) is a series of mobile bridge carriers and bridge conveyors equipped with an automatic guidance system (7, pp. 46-48). It was designed and partially fabricated by Foster-Miller Associates, Inc., and Long-Airdox under a Bureau contract. With only one operator, an ABCT up to 500 ft long can track precisely along a guidance cable laid down by the inby carrier. As the train travels, each successive carrier centers itself about the cable through the use of cable sensors and an onboard microprocessor-controlled guidance system. The cable can be laid down and retrieved automatically by the lead vehicle as it follows behind the continuous miner. The system is capable of operating with only one operator located at the inby vehicle. This chain haulage system can negotiate 90° turns and employs proven hardware for the bridge and conveyor mechanisms.

The ABCT system is under development, with two units and a bridge (some 130 ft long) available, compared with the planned system of five units and a bridge (276 ft). The system needs to be completed and field tested.

SYSTEM G

The multiple-unit continuous haulage (MUCH) system was designed and manufactured by Jeffrey Manufacturing under a Bureau contract (7, pp. 40-46). Each MUCH vehicle has a chain conveyor mounted on a transporting vehicle that has four-wheel steering and two-wheel drive. The vehicles are connected by a unique mechanical self-tracking steering system, which connects adjacent vehicles into a train with automatic mechanical tracking and retracking. Coal cascades from conveyor to conveyor down the vehicle train from the face. The train of vehicles is steered by the operator in the lead vehicle, which follows the continuous mining machine; limited steering capability is also provided on the discharge vehicle to keep the vehicles parallel to the panel belt.

The MUCH system includes three types of vehicles: lead vehicle, intermediate vehicles (10 currently available), and discharge vehicle with a bridge conveyor. The length of the 12-unit system is 250 ft and can turn 90° angle crosscuts. Two operators are required—one in the lead vehicle and the other in a discharge vehicle.

A prototype of the system is currently being tested in a West Virginia highwall mining operation, employing remote control with one operator. The system is under development; it needs to be thoroughly field tested.

COMPARATIVE EVALUATION OF REPRESENTATIVE CONTINUOUS HAULAGE SYSTEMS

Selection criteria-system characteristics were evaluated for each commerically available system and are shown in table 2.

For characteristics that generally meet the requirements or which cannot be comparatively evaluated because of lack of data, no ratings are provided. As can be seen from table 2, each system has strengths and weaknesses. Selection of a system depends on the parameters desired for a particular mine.

Table 2.—Comparative ratings[1] of representative continuous haulage systems

	System A	System B	System C	System D	System E
System characteristics:					
Low-seam adaptability	E	E	G	F	E
Capacity, steady state and surge	E	E	G	G	G
Availability and reliability	E	G	G	G	G
Adaptability to varying room-and-pillar layouts	E	E	G	G	G
Automation, remote operation and labor	E	E	E	E	P
Cost, capital and operating	E	G	G	G	E
Dust and noise generation	G	E	G	E	G
Operating life	E	G	G	G	G
Ability to handle large pieces	E	G	G	G	G
Industry acceptance	E	G	F	G	E

[1]E—excellent, G—good, F—fair, P—poor.

ECONOMICS OF CONTINUOUS HAULAGE SYSTEM SCENARIOS

BASIC PRINCIPLES

The mining scenarios for a CAMM-continuous haulage system include an efficient, automated (teleoperated) roof bolting machine. All the coal extracted can only be transported out of the mine properly when the three major activities occur with minimal delays as planned: (1) mining a place (20 ft), (2) bolting a place (cut), and (3) hauling the mined coal.

The principle of an efficient, automated section is that roof bolting is not a bottleneck or place bolting cycle time is less than place mining cycle time. Equally important is the fact that the mined coal should be moved out of the section continuously as it is being mined. Activities such as machine tramming (including backing out from a cut) can be coordinated minimizing any delays; equipment maintenance can be scheduled in idle time as are other auxiliary activities like rock dusting, ventilation extension, belt moves, and power center moves, which can be performed optimally. These activities will have to be made more efficient to keep up with the fast coal extraction rate. A section is still not envisioned to be completely automated and human free; however, the mining, bolting, and haulage machines are operated remotely from a safe, secure, and pleasant control chamber near the section belt tailpiece in fresh intake air. The operator(s) has television contact with each machine; operations are under computer control. Figure 6 conceptualizes the "target" section.

COMPUTER-ASSISTED WORKING FACE

Mining scenarios were developed for a hypothetical mine with continuous and shuttle car haulage mix. During the base year, about 55% of total mine unit shifts were continuous haulage units (1,518 of 2,780) in the first three mining sections.

Typical improvement models—production and cost—were generated to approximate a computer-assisted mining section, i.e., computer-assisted continuous miner supported by computer-assisted continuous haulage and roof bolting machine. To realize full advantage of fast mining machines, both efficient haulage and roof bolting systems are very important.

Base production and cost models and seven improvement models are provided in the appendix. The criteria, parameters, and relevant details pertaining to computer-assisted mining are included in IC 9281 (*1*).

BENEFIT-COST ANALYSIS OF CONTINUOUS HAULAGE SYSTEMS

In the example mine, scenarios were developed showing the effect of continuous haulage on the mine by eliminating the shuttle car haulage delays from the place cycle time for the first three mining sections. In the production model, this line item is shown as "Misc. Haulage," which is the same as shuttle car change time or time lost in any haulage system (continuous haulage). In an efficient continuous haulage system, the mining of coal and its hauling out to the section belt conveyor is simultaneous as there is minimum delay because of face haulage. The efficiency of such a system takes time before being fully achievable; therefore, it is done in steps, by improving the miscellaneous haulage by 25%, 50%, 75%, and 100%, as shown by the appendix. A section with automated-computer-assisted mining, bolting, and haulage is a long-term realization, 10 to 15 years, and these models reflect the final achievable production improvement. Computer-assisted mining results in increased mining rate or efficiency (reduced mining time per cut) and overall increase in shift "uptime." Continuous haulage further improves productivity by reducing haulage delays. Table 3 summarizes the results of seven production and cost models as compared with the base case.

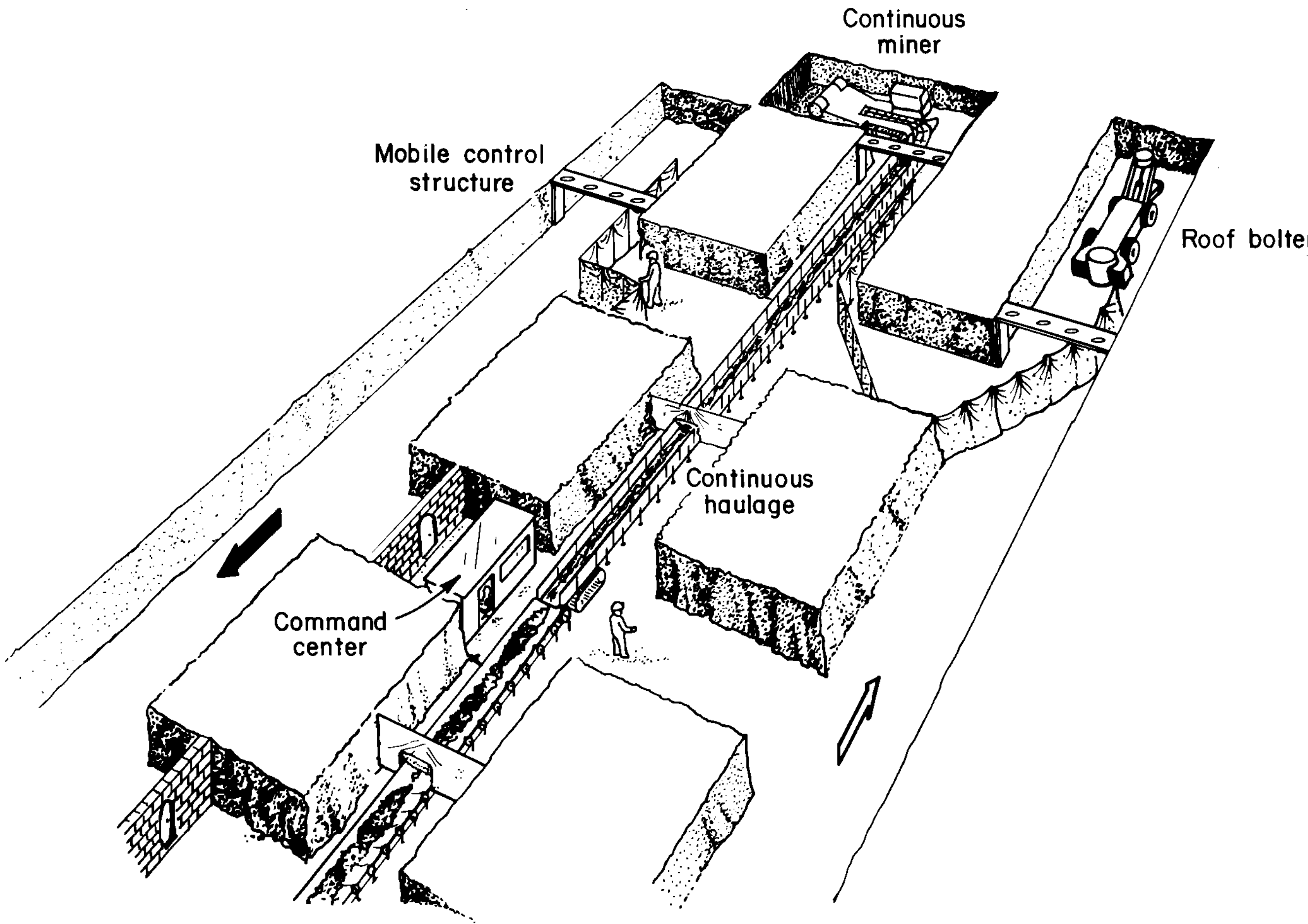

Figure 6.—Conceptualization of targeted room-and-pillar mining scenario.

Table 3.—Summary of results of seven production and cost models compared with base case

Mine model	Uptime increase, min	Haulage delay reduction, %	Annual production, clean st	Cost of mining, $/st
Existing technology (base case) . .	0	0	504,458	28.56
Computer-assisted mining:				
Normal efficiency	60	100	985,553	16.92
Increase efficiency by 25%	75	75	1,060,222	16.13
Increase efficiency by 50%	75	50	1,046,838	16.26
Do	90	75	1,207,804	14.85
Do	90	100	1,353,565	13.86
Increase efficiency by 75%	60	100	1,294,813	14.23
Increase efficiency by 100% . . .	90	100	1,531,723	12.91

Comparing the highest production and corresponding cost figures, 1,531,723 st and $12.91 to the base figures, 504,458 st and $28.56, the resultant improvements are 204% and 55% for production and cost, respectively.

Considering 75% attainment of the projected results, it can be assumed that the new mining and haulage system can potentially improve mine production by 153%, resulting in a cost-of-mining reduction of 41%.

These results are projected on a regular cut (20 ft) mining sequence where, after a cut is mined out, the mining machine trams to another location so that this place can be bolted. This "tramming time" is an essential loss of production time and its minimization will further improve mine productivity. Indepth investigations are required to study the deep-cut mining (40 to 80 ft) with continuous haulage systems.

COST OF MINING VERSUS PRODUCTIVITY

Cost of mining (in dollars per short ton) was plotted against productivity (in short tons per worker-day) for seven improvement models and the base model; the relationship is shown in figure 7. As the productivity increases, from 9.55 to 34.88 st, the cost of mining decreases, from $28.56 to $12.91. It is a very significant potential, which even makes a partially successful continuous mining-haulage system attractive.

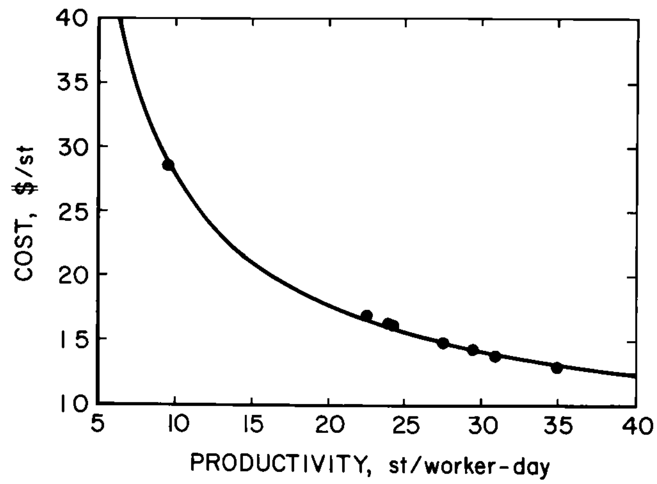

Figure 7.—Relationship of productivity and cost of mining.

PROPOSED CONTINUOUS HAULAGE SYSTEMS

The candidate haulage systems for the Bureau's CAMM can be either a chain conveyor-based system or a belt-type system. Both these systems have to be further evaluated for the two mining layouts: (1) three-heading longwall development section with 90° crosscuts, and (2) five-heading submains-room-and-pillar section with right-angled crosscuts.

The indepth scenarios will consider complete mining, bolting, and hauling cycles, including effective section predevelopment plan, deep cuts, and varying pillar and opening sizes. Also, auxiliary activities such as ventilation extension, power center moves, belt moves, handling supplies, and rock dusting need to be investigated in light of a continuous haulage system.

CONCLUSIONS

Continuous haulage systems appear promising for the Bureau's CAMM. These systems, however, need further evaluation based on experience gained in foreign countries and additional U.S. mines, before a particular system can be selected.

A longwall development scenario with a 50-50 mix of continuous and noncontinuous face haulage systems shows a potential productivity increase of up to 153%, resulting in a 41% improvement in the cost of mining, as compared with an all-conventional haulage mine.

Indepth mine scenarios should be developed to include the following:

- Deep cut mining (40 to 80 ft).
- Varying pillar and opening sizes.
- Presection development.
- Coordination of functions such as ventilation extension, belt and power center moves, handling supplies, and rock dusting.
- Interface of continuous haulage with the mining machine and section belt conveyor.
- Coordination of bolting machine and continuous haulage drive.

REFERENCES

1. Bhatt, S. K. Cost-Benefit Analysis of Computer-Assisted Mining Through Production and Cost Modeling. BuMines IC 9281, 1991, 41 pp.

2. Schiffbauer, W. H. Automating Continuous Mining Machines. Soc. Min. Eng. AIME preprint 90-89, 1990, 9 pp.

3. U.S. Energy Information Administration (Dep. Energy). Coal Production, 1987 Rep., 1989, 240 pp.

4. McGraw-Hill. DRI/McGraw-Hill Coal Review. Appendix, spring 1989, 91 pp.

5. Cowan, D. M. Study of Face Haulage Systems (contract HO242025, Joy Manufacturing Co.). BuMines OFR 86-76, 1975, 221 pp.; NTIS PB 255 841.

6. O'Beirne, T., and A. Napper. Joy Flexible Conveyor Train Demonstration at Box Flat Colliery. Aust. Coal Ind. Res. Lab. Ltd. Rep. 88-1, May 1988, 39 pp.

7. Evans, R. J., and W. D. Mayercheck. Coal Extraction, Transport and Logistics Technology for Underground Mining. BuMines IC 9181, 1988, 81 pp.

APPENDIX

MINE PRODUCTION MODEL
BY CONTINUOUS MINER SECTION

ITEM IDENTIFICATION	SECTION 1	SECTION 2	SECTION 3	SECTION 4	SECTION 5	SECTION 6	TOTAL/WTD AV
Minutes Per Shift	480.0	480.0	480.0	480.0	480.0	480.0	480.0
Travel Time	60.0	62.0	65.0	58.0	62.0	64.0	61.7
Lunch Time	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Service Time	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Remaining Operating Time	390.0	388.0	385.0	392.0	388.0	386.0	388.3
Downtime							
Miner	52.8	55.0	48.0	59.4	40.0	60.0	52.9
S.C.	15.0	10.2	12.0	15.5	12.0	18.2	13.7
Belt	21.0	22.2	28.0	18.5	21.0	19.5	21.9
Bolter	4.8	5.0	6.0	5.9	8.0	4.6	5.7
Feeder	3.0	3.8	4.2	3.6	5.0	6.8	4.3
C/PTM	60.5	61.0	52.0	58.8	65.0	68.0	60.2
Power	1.8	1.0	2.0	2.5	2.8	1.9	2.0
Timber & Rail	2.0	2.9	3.0	5.0	5.3	3.0	3.5
Conditions	5.0	5.8	6.0	2.5	4.2	2.8	4.5
Safety	18.0	15.5	16.8	20.0	17.0	15.1	17.2
Model Adjust Delays	20.0	18.5	17.8	22.0	15.0	19.5	19.0
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Downtime	203.9	200.9	195.8	213.7	195.3	219.4	204.7
Remaining Uptime	186.1	187.1	189.2	178.3	192.7	166.6	183.6
Unit Shifts/Year	502	480	536	528	354	380	2,780
Cubic Feet/Place	1,710.7	1,731.7	1,857.4	1,880.0	1,642.8	1,409.4	1,724.9
Density	94.50	94.50	94.50	94.50	94.50	94.50	94.50
Raw Tons/Place	80.8	81.8	87.8	88.8	77.6	66.6	81.5
Raw Tons/S.C.	7.0	7.0	7.0	7.0	7.0	7.0	7.0
No. S.C./Place	11.5	11.7	12.5	12.7	11.1	9.5	11.6
Reject %	22.80	22.80	22.80	22.80	22.80	22.80	22.80
Clean Tons/S.C.	5.40	5.40	5.40	5.40	5.40	5.40	5.40
Place Time							
Mining	22.52	22.79	24.45	24.75	21.62	18.55	22.70
Maneuvering	3.46	3.51	3.76	3.81	3.33	2.85	3.49
S.C. Change	20.68	20.90	25.20	19.44	16.50	18.00	20.46
Gas Test & Safety	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Ventilation & Posts	8.60	8.60	8.60	8.60	8.60	8.60	8.60
Tram	5.80	6.20	6.38	7.80	5.30	6.85	6.44
Total Place Time	63.06	64.00	70.39	66.39	57.35	56.86	63.69
Roof Bolting Place Time	53.06	54.00	60.39	56.39	47.35	46.86	53.69
Places/Unit Shift	2.951	2.923	2.688	2.686	3.360	2.930	2.92
Productivity - Clean Coal							
Tons/Unit Shift	184.2	184.7	182.1	184.2	201.3	150.6	181.5
Tons/Hour	59.4	59.2	57.8	62.0	62.7	54.3	59.3
Tons/Minute	0.990	0.987	0.963	1.033	1.045	0.904	0.988
Annual Production, st	92,445	88,638	97,613	97,240	71,277	57,245	504,458

COST OF MINING STATEMENT
Base Year 1988

Basis of Estimates	Adj. Time St. Data	
Days of Operation	240	
Total Production (Clean st) (000)	504.458	
Daily Production (Clean st)	2,102	
Approx. st/worker-day	9.550	
Cost basis	**Dollars(000)**	**$/st**
A. Direct Operating Costs		
* 1. Labor - Salaried	1,000.000	1.982
* 2. Labor - Hourly	3,500.000	6.938
* 3. Benefits - Salaried	46.000	0.091
* 4. Benefits - Hourly	900.000	1.784
5. Supplies - Operating	1,513.374	3.000
* 6. Supplies - Maintenance	1,800.000	3.568
* 7. Power	340.000	0.674
* 8. FICA & Unemployment Taxes	400.000	0.793
* 9. Workmen's Compensation Insurance	175.000	0.347
* 10. Black Lung Compensation Insurance	340.000	0.674
* 11. Welfare - Hourly	300.000	0.595
12. Welfare - Tonnage	711.790	1.411
* 13. Safety Expenses	150.000	0.297
* 14. Production & Safety Incentives	250.000	0.496
* 15. Accident Costs	200.000	0.396
16. Reclamation Fee	75.669	0.150
17. Federal Black Lung Fee	252.229	0.500
* 18. Other Costs	0.000	0.000
Total	11,954.062	23.697
B. Other Cash Costs		
* 1. Overhead	500.000	0.991
2. Royalties	302.675	0.600
3. Miscellaneous Taxes	0.000	0.000
* 4. Equipment Leasing Costs	600.000	1.189
* 5. Interest Expense	500.000	0.991
* 6. Miscellaneous Income	0.000	0.000
Total	1,902.675	3.772
C. Other Costs		
* 1. Depreciation	550.000	1.090
2. Amortization of Development Costs	0.000	0.000
3. Depletion	0.000	0.000
Total	550.000	1.090
Total Cost of Mining	14,406.737	28.559

* Fixed Dollars Per Year

MINE PRODUCTION MODEL
BY CONTINUOUS MINER SECTION
IMPROVED UPTIME BY 60 MINUTES
MISC. HAULAGE ENTRY ELIMINATED - PARTIAL MINE

ITEM IDENTIFICATION	SECTION 1	SECTION 2	SECTION 3	SECTION 4	SECTION 5	SECTION 6	TOTAL/WTD AV
Minutes Per Shift	480.0	480.0	480.0	480.0	480.0	480.0	480.0
Travel Time	60.0	62.0	65.0	58.0	62.0	64.0	61.7
Lunch Time	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Service Time	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Remaining Operating Time	390.0	388.0	385.0	392.0	388.0	386.0	388.3
Downtime							
Miner	22.8	25.0	18.0	29.4	10.0	30.0	22.9
S.C./C.H.	15.0	10.2	12.0	15.5	12.0	18.2	13.7
Belt	21.0	22.2	28.0	18.5	21.0	19.5	21.9
Bolter	4.8	5.0	6.0	5.9	8.0	4.6	5.7
Feeder	3.0	3.8	4.2	3.6	5.0	6.8	4.3
C/PTM	30.5	31.0	22.0	28.8	35.0	38.0	30.2
Power	1.8	1.0	2.0	2.5	2.8	1.9	2.0
Timber & Rail	2.0	2.9	3.0	5.0	5.3	3.0	3.5
Conditions	5.0	5.8	6.0	2.5	4.2	2.8	4.5
Safety	18.0	15.5	16.8	20.0	17.0	15.1	17.2
Model Adjust Delays	20.0	18.5	17.8	22.0	15.0	19.5	19.0
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Downtime	143.9	140.9	135.8	153.7	135.3	159.4	144.7
Remaining Uptime	246.1	247.1	249.2	238.3	252.7	226.6	243.6
Unit Shifts/Year	502	480	536	528	354	380	2,780
Cubic Feet/Place	1,710.7	1,731.7	1,857.4	1,880.0	1,642.8	1,409.4	1,724.9
Density	94.50	94.50	94.50	94.50	94.50	94.50	94.50
Raw Tons/Place	80.8	81.8	87.8	88.8	77.6	66.6	81.5
Raw Tons/S.C.	7.0	7.0	7.0	7.0	7.0	7.0	7.0
No. S.C./Place	11.5	11.7	12.5	12.7	11.1	9.5	11.6
Reject %	22.80	22.80	22.80	22.80	22.80	22.80	22.80
Clean Tons/S.C.	5.40	5.40	5.40	5.40	5.40	5.40	5.40
Place Time							
Mining	22.52	22.79	24.45	24.75	21.62	18.55	22.70
Maneuvering	1.73	1.75	1.88	1.90	1.66	1.43	1.75
Misc. Haulage	0.00	0.00	0.00	19.44	16.50	18.00	8.25
Gas Test & Safety	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventilation & Posts	8.60	8.60	8.60	8.60	8.60	8.60	8.60
Tram	3.48	3.72	3.83	4.68	3.18	4.11	3.86
Total Place Time	36.33	36.87	38.76	59.37	51.57	50.69	45.17
Roof Bolting Place Time	36.00	36.00	38.00	39.00	35.00	32.00	36.28
Places/Unit Shift	6.774	6.703	6.430	4.014	4.901	4.470	5.67
Productivity - Clean Coal							
Tons/Unit Shift	422.7	423.4	435.6	275.3	293.7	229.8	354.5
Tons/Hour	103.1	102.8	104.9	69.3	69.7	60.9	86.9
Tons/Minute	1.718	1.713	1.748	1.155	1.162	1.014	1.449
Annual Production, st	212,204	203,220	233,504	145,337	103,953	87,335	985,553

COST OF MINING STATEMENT
Base Year 1988

Basis of Estimates	Adj. Time St. Data		Uptime by 60 Minutes Without Mine Haulage Partial Mine	
Days of Operation	240		240	
Total Production (Clean st) (000)	504.458		985.553	
Daily Production (Clean st)	2,102		4,106	
Approx. st/worker-day	9.550		22.440	
Cost basis	Dollars(000)	$/st	Dollars(000)	$/st
A. Direct Operating Costs				
* 1. Labor - Salaried	1,000.000	1.982	1,000.000	1.015
* 2. Labor - Hourly	3,500.000	6.938	2,800.000	2.841
* 3. Benefits - Salaried	46.000	0.091	46.000	0.047
* 4. Benefits - Hourly	900.000	1.784	720.000	0.731
5. Supplies - Operating	1,513.374	3.000	2,956.659	3.000
* 6. Supplies - Maintenance	1,800.000	3.568	1,800.000	1.826
* 7. Power	340.000	0.674	340.000	0.345
* 8. FICA & Unemployment Taxes	400.000	0.793	400.000	0.406
* 9. Workmen's Compensation Insurance	175.000	0.347	175.000	0.178
* 10. Black Lung Compensation Insurance	340.000	0.674	340.000	0.345
* 11. Welfare - Hourly	300.000	0.595	240.000	0.244
12. Welfare - Tonnage	711.790	1.411	1,390.615	1.411
* 13. Safety Expenses	150.000	0.297	150.000	0.152
* 14. Production & Safety Incentives	250.000	0.496	250.000	0.254
* 15. Accident Costs	200.000	0.396	200.000	0.203
16. Reclamation Fee	75.669	0.150	147.834	0.150
17. Federal Black Lung Fee	252.229	0.500	492.776	0.500
* 18. Other Costs	0.000	0.000	0.000	0.000
Total	11,954.062	23.697	13,448.884	13.646
B. Other Cash Costs				
* 1. Overhead	500.000	0.991	500.000	0.507
2. Royalties	302.675	0.600	591.332	0.600
3. Miscellaneous Taxes	0.000	0.000	0.000	0.000
* 4. Equipment Leasing Costs	600.000	1.189	600.000	0.609
* 5. Interest Expense	500.000	0.991	700.000	0.710
* 6. Miscellaneous Income	0.000	0.000	0.000	0.000
Total	1,902.675	3.772	2,391.332	2.426
C. Other Costs				
* 1. Depreciation	550.000	1.090	835.720	0.848
2. Amortization of Development Costs	0.000	0.000	0.000	0.000
3. Depletion	0.000	0.000	0.000	0.000
Total	550.000	1.090	835.720	0.848
Total Cost of Mining	14,406.737	28.559	16,675.936	16.920

* Fixed Dollars Per Year

MINE PRODUCTION MODEL
BY CONTINUOUS MINER SECTION
IMPROVE UPTIME BY 75 MINUTES FOR 25% EFFICIENCY
MISC. HAULAGE REDUCED BY 75% - PARTIAL MINE

ITEM IDENTIFICATION	SECTION 1	SECTION 2	SECTION 3	SECTION 4	SECTION 5	SECTION 6	TOTAL/WTD AV
Minutes Per Shift	480.0	480.0	480.0	480.0	480.0	480.0	480.0
Travel Time	60.0	62.0	65.0	58.0	62.0	64.0	61.7
Lunch Time	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Service Time	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Remaining Operating Time	390.0	388.0	385.0	392.0	388.0	386.0	388.3
Downtime							
Miner	12.8	15.0	8.0	19.4	0.0	20.0	12.9
S.C./C.H.	15.0	10.2	12.0	15.5	12.0	18.2	13.7
Belt	21.0	22.2	28.0	18.5	21.0	19.5	21.9
Bolter	4.8	5.0	6.0	5.9	8.0	4.6	5.7
Feeder	3.0	3.8	4.2	3.6	5.0	6.8	4.3
C/PTM	30.5	31.0	22.0	28.8	35.0	38.0	30.2
Power	1.8	1.0	2.0	2.5	2.8	1.9	2.0
Timber & Rail	2.0	2.9	3.0	5.0	5.3	3.0	3.5
Conditions	5.0	5.8	6.0	2.5	4.2	2.8	4.5
Safety	13.0	10.5	11.8	15.0	12.0	10.1	12.2
Model Adjust Delays	20.0	18.5	17.8	22.0	15.0	19.5	19.0
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Downtime	128.9	125.9	120.8	138.7	120.3	144.4	129.7
Remaining Uptime	261.1	262.1	264.2	253.3	267.7	241.6	258.6
Unit Shifts/Year	502	480	536	528	354	380	2,780
Cubic Feet/Place	1,710.7	1,731.7	1,857.4	1,880.0	1,642.8	1,409.4	1,724.9
Density	94.50	94.50	94.50	94.50	94.50	94.50	94.50
Raw Tons/Place	80.8	81.8	87.8	88.8	77.6	66.6	81.5
Raw Tons/S.C.	7.0	7.0	7.0	7.0	7.0	7.0	7.0
No. S.C./Place	11.5	11.7	12.5	12.7	11.1	9.5	11.6
Reject %	22.80	22.80	22.80	22.80	22.80	22.80	22.80
Clean Tons/S.C.	5.40	5.40	5.40	5.40	5.40	5.40	5.40
Place Time							
Mining	18.01	18.23	19.56	19.80	17.30	14.84	18.16
Maneuvering	1.73	1.75	1.88	1.90	1.66	1.43	1.75
Misc. Haulage	5.17	5.28	6.36	19.44	16.50	18.00	11.33
Gas Test & Safety	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventilation & Posts	8.60	8.60	8.60	8.60	8.60	8.60	8.60
Tram	3.48	3.72	3.83	4.68	3.18	4.11	3.86
Total Place Time	37.00	37.59	40.23	54.42	47.24	46.98	43.70
Roof Bolting Place Time	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Places/Unit Shift	7.058	6.973	6.568	4.655	5.667	5.143	6.11
Productivity - Clean Coal							
Tons/Unit Shift	440.4	440.5	445.0	319.2	339.6	264.4	381.4
Tons/Hour	101.2	100.8	101.1	75.6	76.1	65.7	88.2
Tons/Minute	1.687	1.680	1.684	1.260	1.268	1.094	1.470
Annual Production, st	221,082	211,419	238,511	168,534	120,204	100,471	1,060,222

COST OF MINING STATEMENT
Base Year 1988

Basis of Estimates	Adj. Time St. Data		Uptime by 75 Minutes for 25% Efficiency Mine Haulage Reduced by 75% Partial Mine	
Days of Operation	240		240	
Total Production (Clean st) (000)	504.458		1,060.222	
Daily Production (Clean st)	2,102		4,418	
Approx. st/worker-day	9.550		24.140	
Cost basis	Dollars(000)	$/st	Dollars(000)	$/st
A. Direct Operating Costs				
* 1. Labor - Salaried	1,000.000	1.982	1,000.000	0.943
* 2. Labor - Hourly	3,500.000	6.938	2,800.000	2.641
* 3. Benefits - Salaried	46.000	0.091	46.000	0.043
* 4. Benefits - Hourly	900.000	1.784	720.000	0.679
5. Supplies - Operating	1,513.374	3.000	3,180.666	3.000
* 6. Supplies - Maintenance	1,800.000	3.568	1,800.000	1.698
* 7. Power	340.000	0.674	340.000	0.321
* 8. FICA & Unemployment Taxes	400.000	0.793	400.000	0.377
* 9. Workmen's Compensation Insurance	175.000	0.347	175.000	0.165
* 10. Black Lung Compensation Insurance	340.000	0.674	340.000	0.321
* 11. Welfare - Hourly	300.000	0.595	240.000	0.226
12. Welfare - Tonnage	711.790	1.411	1,495.973	1.411
* 13. Safety Expenses	150.000	0.297	150.000	0.141
* 14. Production & Safety Incentives	250.000	0.496	250.000	0.236
* 15. Accident Costs	200.000	0.396	200.000	0.189
16. Reclamation Fee	75.669	0.150	159.034	0.150
17. Federal Black Lung Fee	252.229	0.500	530.111	0.500
* 18. Other Costs	0.000	0.000	0.000	0.000
Total	11,954.062	23.697	13,826,784	13.041
B. Other Cash Costs				
* 1. Overhead	500.000	0.991	500.000	0.472
2. Royalties	302.675	0.600	636.134	0.600
3. Miscellaneous Taxes	0.000	0.000	0.000	0.000
* 4. Equipment Leasing Costs	600.000	1.189	600.000	0.566
* 5. Interest Expense	500.000	0.991	700.000	0.660
* 6. Miscellaneous Income	0.000	0.000	0.000	0.000
Total	1,902.675	3.772	2,436.134	2.298
C. Other Costs				
* 1. Depreciation	550.000	1.090	835.720	0.788
2. Amortization of Development Costs	0.000	0.000	0.000	0.000
3. Depletion	0.000	0.000	0.000	0.000
Total	550.000	1.090	835.720	0.788
Total Cost of Mining	14,406.737	28.559	17,098.637	16.127

* Fixed Dollars Per Year

MINE PRODUCTION MODEL
BY CONTINUOUS MINER SECTION
IMPROVE UPTIME BY 75 MINUTES FOR 50% EFFICIENCY
MISC. HAULAGE REDUCED BY 50% - PARTIAL MINE

ITEM IDENTIFICATION	SECTION 1	SECTION 2	SECTION 3	SECTION 4	SECTION 5	SECTION 6	TOTAL/WTD AV
Minutes Per Shift	480.0	480.0	480.0	480.0	480.0	480.0	480.0
Travel Time	60.0	62.0	65.0	58.0	62.0	64.0	61.7
Lunch Time	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Service Time	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Remaining Operating Time	390.0	388.0	385.0	392.0	388.0	386.0	388.3
Downtime							
Miner	12.8	15.0	8.0	19.4	0.0	20.0	12.9
S.C./C.H.	15.0	10.2	12.0	15.5	12.0	18.2	13.7
Belt	21.0	22.2	28.0	18.5	21.0	19.5	21.9
Bolter	4.8	5.0	6.0	5.9	8.0	4.6	5.7
Feeder	3.0	3.8	4.2	3.6	5.0	6.8	4.3
C/PTM	30.5	31.0	22.0	28.8	35.0	38.0	30.2
Power	1.8	1.0	2.0	2.5	2.8	1.9	2.0
Timber & Rail	2.0	2.9	3.0	5.0	5.3	3.0	3.5
Conditions	5.0	5.8	6.0	2.5	4.2	2.8	4.5
Safety	13.0	10.5	11.8	15.0	12.0	10.1	12.2
Model Adjust Delays	20.0	18.5	17.8	22.0	15.0	19.5	19.0
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Downtime	128.9	125.9	120.8	138.7	120.3	144.4	129.7
Remaining Uptime	261.1	262.1	264.2	253.3	267.7	241.6	258.6
Unit Shifts/Year	502	480	536	528	354	380	2,780
Cubic Feet/Places	1,710.7	1,731.7	1,857.4	1,880.0	1,642.8	1,409.4	1,724.9
Density	94.50	94.50	94.50	94.50	94.50	94.50	94.50
Raw Tons/Place	80.8	81.8	87.8	88.8	77.6	66.6	81.5
Raw Tons/S.C.	7.0	7.0	7.0	7.0	7.0	7.0	7.0
No. S.C./Place	11.5	11.7	12.5	12.7	11.1	9.5	11.6
Reject %	22.80	22.80	22.80	22.80	22.80	22.80	22.80
Clean Tons/S.C.	5.40	5.40	5.40	5.40	5.40	5.40	5.40
Place Time							
Mining	15.01	15.20	16.30	16.50	14.42	12.37	15.14
Maneuvering	1.73	1.75	1.88	1.90	1.66	1.43	1.75
Misc. Haulage	9.90	10.45	12.60	19.44	16.50	18.00	14.28
Gas Test & Safety	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventilation & Posts	8.60	8.60	8.60	8.60	8.60	8.60	8.60
Tram	3.48	3.72	3.83	4.68	3.18	4.11	3.86
Total Place Time	38.72	39.72	43.21	51.12	44.36	44.50	43.62
Roof Bolting Place Time	38.00	38.00	40.00	40.00	35.00	35.00	37.97
Places/Unit Shift	6.743	6.599	6.115	4.955	6.035	5.429	6.04
Productivity - Clean Coal							
Tons/Unit Shift	420.8	416.8	414.3	339.8	361.6	279.1	376.6
Tons/Hour	96.7	95.4	94.1	80.5	81.1	69.3	87.2
Tons/Minute	1.611	1.590	1.568	1.341	1.351	1.155	1.453
Annual Production, st	211,219	200,076	222,060	179,412	128,017	106,055	1,046,838

COST OF MINING STATEMENT
Base Year 1988

Basis of Estimates	Adj. Time St. Data		Uptime by 75 Minutes for 50% Efficiency Mine Haulage Reduced by 50% Partial Mine	
Days of Operation	240		240	
Total Production (Clean st) (000)	504.458		1,046.838	
Daily Production (Clean st)	2,102		4,362	
Approx. st/worker-day	9.550		23.835	
Cost basis	Dollars(000)	$/st	Dollars(000)	$/st
A. Direct Operating Costs				
* 1. Labor - Salaried	1,000.000	1.982	1,000.000	0.955
* 2. Labor - Hourly	3,500.000	6.938	2,800.000	2.675
* 3. Benefits - Salaried	46.000	0.091	46.000	0.044
* 4. Benefits - Hourly	900.000	1.784	720.000	0.688
5. Supplies - Operating	1,513.374	3.000	3,140.514	3.000
* 6. Supplies - Maintenance	1,800.000	3.568	1,800.000	1.719
* 7. Power	340.000	0.674	340.000	0.325
* 8. FICA & Unemployment Taxes	400.000	0.793	400.000	0.382
* 9. Workmen's Compensation Insurance	175.000	0.347	175.000	0.167
* 10. Black Lung Compensation Insurance	340.000	0.674	340.000	0.325
* 11. Welfare - Hourly	300.000	0.595	240.000	0.229
12. Welfare - Tonnage	711.790	1.411	1,477.088	1.411
* 13. Safety Expenses	150.000	0.297	150.000	0.143
* 14. Production & Safety Incentives	250.000	0.496	250.000	0.239
* 15. Accident Costs	200.000	0.396	200.000	0.191
16. Reclamation Fee	75.669	0.150	157.026	0.150
17. Federal Black Lung Fee	252.229	0.500	523.419	0.500
* 18. Other Costs	0.000	0.000	0.000	0.000
Total	11,954.062	23.697	13,759.047	13.143
B. Other Cash Costs				
* 1. Overhead	500.000	0.991	500.000	0.478
2. Royalties	302.675	0.600	628.103	0.600
3. Miscellaneous Taxes	0.000	0.000	0.000	0.000
* 4. Equipment Leasing Costs	600.000	1.189	600.000	0.573
* 5. Interest Expense	500.000	0.991	700.000	0.669
* 6. Miscellaneous Income	0.000	0.000	0.000	0.000
Total	1,902.675	3.772	2,428.103	2.319
C. Other Costs				
* 1. Depreciation	550.000	1.090	835.720	0.798
2. Amortization of Development Costs	0.000	0.000	0.000	0.000
3. Depletion	0.000	0.000	0.000	0.000
Total	550.000	1.090	835.720	0.798
Total Cost of Mining	14,406.737	28.559	17,022.870	16.261

* Fixed Dollars Per Year

MINE PRODUCTION MODEL
BY CONTINUOUS MINER SECTION
IMPROVE UPTIME BY 90 MINUTES FOR 50% EFFICIENCY
MISC. HAULAGE REDUCED BY 75% - PARTIAL MINE

ITEM IDENTIFICATION	SECTION 1	SECTION 2	SECTION 3	SECTION 4	SECTION 5	SECTION 6	TOTAL/WTD AV
Minutes Per Shift	480.0	480.0	480.0	480.0	480.0	480.0	480.0
Travel Time	60.0	62.0	65.0	58.0	62.0	64.0	61.7
Lunch Time	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Service Time	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Remaining Operating Time	390.0	388.0	385.0	392.0	388.0	386.0	388.3
Downtime							
Miner	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S.C./C.H.	15.0	10.2	12.0	15.5	12.0	18.2	13.7
Belt	21.0	22.2	28.0	18.5	21.0	19.5	21.9
Bolter	4.8	5.0	6.0	5.9	8.0	4.6	5.7
Feeder	3.0	3.8	4.2	3.6	5.0	6.8	4.3
C/PTM	30.5	31.0	22.0	28.8	35.0	38.0	30.2
Power	1.8	1.0	2.0	2.5	2.8	1.9	2.0
Timber & Rail	2.0	2.9	3.0	5.0	5.3	3.0	3.5
Conditions	5.0	5.8	6.0	2.5	4.2	2.8	4.5
Safety	11.0	8.5	9.8	13.0	10.0	8.1	10.2
Model Adjust Delays	20.0	18.5	17.8	22.0	15.0	19.5	19.0
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Downtime	114.1	108.9	110.8	117.3	118.3	122.4	114.8
Remaining Uptime	275.9	279.1	274.2	274.7	269.7	263.6	273.4
Unit Shifts/Year	502	480	536	528	354	380	2,780
Cubic Feet/Place	1,710.7	1,731.7	1,857.4	1,880.0	1,642.8	1,409.4	1,724.9
Density	94.50	94.50	94.50	94.50	94.50	94.50	94.50
Raw Tons/Place	80.8	81.8	87.8	88.8	77.6	66.6	81.5
Raw Tons/S.C.	7.0	7.0	7.0	7.0	7.0	7.0	7.0
No. S.C./Place	11.5	11.7	12.5	12.7	11.1	9.5	11.6
Reject %	22.80	22.80	22.80	22.80	22.80	22.80	22.80
Clean Tons/S.C.	5.40	5.40	5.40	5.40	5.40	5.40	5.40
Place Time							
Mining	15.01	15.20	16.30	16.50	14.42	12.37	15.14
Maneuvering	1.73	1.75	1.88	1.90	1.66	1.43	1.75
Misc. Haulage	5.17	5.28	6.36	19.44	16.50	18.00	11.33
Gas Test & Safety	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventilation & Posts	8.60	8.60	8.60	8.60	8.60	8.60	8.60
Tram	3.48	3.72	3.83	4.68	3.18	4.11	3.86
Total Place Time	33.99	34.55	36.97	51.12	44.36	44.50	40.67
Roof Bolting Place Time	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Places/Unit Shift	8.116	8.078	7.417	5.374	6.080	5.923	6.96
Productivity - Clean Coal							
Tons/Unit Shift	506.5	510.3	502.5	368.5	364.3	304.5	434.5
Tons/Hour	110.1	109.7	110.0	80.5	81.1	69.3	95.1
Tons/Minute	1.836	1.828	1.833	1.341	1.351	1.155	1.585
Annual Production, st	254,247	244,936	269,367	194,569	128,973	115,712	1,207,804

COST OF MINING STATEMENT
Base Year 1988

Basis of Estimates	Adj. Time St. Data		Uptime by 90 Minutes for 50% Efficiency Mine Haulage Reduced by 75% Partial Mine	
Days of Operation	240		240	
Total Production (Clean st) (000)	504.458		1,207.804	
Daily Production (Clean st)	2,102		5,033	
Approx. st/worker-day	9.550		27.500	
Cost basis	Dollars(000)	$/st	Dollars(000)	$/st
A. Direct Operating Costs				
* 1. Labor - Salaried	1,000.000	1.982	1,000.000	0.828
* 2. Labor - Hourly	3,500.000	6.938	2,800.000	2.318
* 3. Benefits - Salaried	46.000	0.091	46.000	0.038
* 4. Benefits - Hourly	900.000	1.784	720.000	0.596
5. Supplies - Operating	1,513.374	3.000	3,623.412	3.000
* 6. Supplies - Maintenance	1,800.000	3.568	1,800.000	1.490
* 7. Power	340.000	0.674	340.000	0.282
* 8. FICA & Unemployment Taxes	400.000	0.793	400.000	0.331
* 9. Workmen's Compensation Insurance	175.000	0.347	175.000	0.145
* 10. Black Lung Compensation Insurance	340.000	0.674	340.000	0.282
* 11. Welfare - Hourly	300.000	0.595	240.000	0.199
12. Welfare - Tonnage	711.790	1.411	1,704.211	1.411
* 13. Safety Expenses	150.000	0.297	150.000	0.124
* 14. Production & Safety Incentives	250.000	0.496	250.000	0.207
* 15. Accident Costs	200.000	0.396	200.000	0.166
16. Reclamation Fee	75.669	0.150	181.171	0.150
17. Federal Black Lung Fee	252.229	0.500	603.902	0.500
* 18. Other Costs	0.000	0.000	0.000	0.000
Total	11,954.062	23.697	14,573.696	12.066
B. Other Cash Costs				
* 1. Overhead	500.000	0.991	500.000	0.414
2. Royalties	302.675	0.600	724.683	0.600
3. Miscellaneous Taxes	0.000	0.000	0.000	0.000
* 4. Equipment Leasing Costs	600.000	1.189	600.000	0.497
* 5. Interest Expense	500.000	0.991	700.000	0.580
* 6. Miscellaneous Income	0.000	0.000	0.000	0.000
Total	1,902.675	3.772	2,524.683	2.090
C. Other Costs				
* 1. Depreciation	550.000	1.090	835.720	0.692
2. Amortization of Development Costs	0.000	0.000	0.000	0.000
3. Depletion	0.000	0.000	0.000	0.000
Total	550.000	1.090	835.720	0.692
Total Cost of Mining	14,406.737	28.559	17,934.099	14.849

* Fixed Dollars Per Year

MINE PRODUCTION MODEL
BY CONTINUOUS MINER SECTION
IMPROVE UPTIME BY 90 MINUTES FOR 50% EFFICIENCY
MISC. HAULAGE ENTRY ELIMINATED - PARTIAL MINE

ITEM IDENTIFICATION	SECTION 1	SECTION 2	SECTION 3	SECTION 4	SECTION 5	SECTION 6	TOTAL/WTD AV
Minutes Per Shift	480.0	480.0	480.0	480.0	480.0	480.0	480.0
Travel Time	60.0	62.0	65.0	58.0	62.0	64.0	61.7
Lunch Time	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Service Time	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Remaining Operating Time	390.0	388.0	385.0	392.0	388.0	386.0	388.3
Downtime							
Miner	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S.C./C.H.	15.0	10.2	12.0	15.5	12.0	18.2	13.7
Belt	21.0	22.2	28.0	18.5	21.0	19.5	21.9
Bolter	4.8	5.0	6.0	5.9	8.0	4.6	5.7
Feeder	3.0	3.8	4.2	3.6	5.0	6.8	4.3
C/PTM	30.5	31.0	22.0	28.8	35.0	38.0	30.2
Power	1.8	1.0	2.0	2.5	2.8	1.9	2.0
Timber & Rail	2.0	2.9	3.0	5.0	5.3	3.0	3.5
Conditions	5.0	5.8	6.0	2.5	4.2	2.8	4.5
Safety	11.0	8.5	9.8	13.0	10.0	8.1	10.2
Model Adjust Delays	20.0	18.5	17.8	22.0	15.0	19.5	19.0
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Downtime	114.1	108.9	110.8	117.3	118.3	122.4	114.8
Remaining Uptime	275.9	279.1	274.2	274.7	269.7	263.6	273.4
Unit Shifts/Year	502	480	536	528	354	380	2,780
Cubic Feet/Place	1,710.7	1,731.7	1,857.4	1,880.0	1,642.8	1,409.4	1,724.9
Density	94.50	94.50	94.50	94.50	94.50	94.50	94.50
Raw Tons/Place	80.8	81.8	87.8	88.8	77.6	66.6	81.5
Raw Tons/S.C.	7.0	7.0	7.0	7.0	7.0	7.0	7.0
No. S.C./Place	11.5	11.7	12.5	12.7	11.1	9.5	11.6
Reject %	22.80	22.80	22.80	22.80	22.80	22.80	22.80
Clean Tons/S.C.	5.40	5.40	5.40	5.40	5.40	5.40	5.40
Place Time							
Mining	15.01	15.20	16.30	16.50	14.42	12.37	15.14
Maneuvering	1.73	1.75	1.88	1.90	1.66	1.43	1.75
Misc. Haulage	0.00	0.00	0.00	19.44	16.50	18.00	8.25
Gas Test & Safety	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventilation & Posts	8.60	8.60	8.60	8.60	8.60	8.60	8.60
Tram	3.48	3.72	3.83	4.68	3.18	4.11	3.86
Total Place Time	28.82	29.27	30.61	51.12	44.36	44.50	37.60
Roof Bolting Place Time	28.00	29.00	30.00	31.00	27.00	26.00	28.73
Places/Unit Shift	9.572	9.536	8.959	5.374	6.080	5.923	7.78
Productivity - Clean Coal							
Tons/Unit Shift	597.3	602.3	607.0	368.5	364.3	304.5	486.9
Tons/Hour	129.9	129.5	132.8	80.5	81.1	69.3	106.5
Tons/Minute	2.165	2.158	2.214	1.341	1.351	1.155	1.775
Annual Production, st	299,850	289,122	325,339	194,569	128,973	115,712	1,353,565

COST OF MINING STATEMENT
Base Year 1988

Basis of Estimates	Adj. Time St. Data		Uptime by 90 Minutes for 50% Efficiency Mine Haulage Eliminated Partial Mine	
Days of Operation	240		240	
Total Production (Clean st) (000)	504.458		1,353.565	
Daily Production (Clean st)	2,102		5,640	
Approx. st/worker-day	9.550		30.819	
Cost basis	Dollars(000)	$/st	Dollars(000)	$/st
A. Direct Operating Costs				
* 1. Labor - Salaried	1,000.000	1.982	1,000.000	0.739
* 2. Labor - Hourly	3,500.000	6.938	2,800.000	2.069
* 3. Benefits - Salaried	46.000	0.091	46.000	0.034
* 4. Benefits - Hourly	900.000	1.784	720.000	0.532
5. Supplies - Operating	1,513.374	3.000	4,060.695	3.000
* 6. Supplies - Maintenance	1,800.000	3.568	1,800.000	1.330
* 7. Power	340.000	0.674	340.000	0.251
* 8. FICA & Unemployment Taxes	400.000	0.793	400.000	0.296
* 9. Workmen's Compensation Insurance	175.000	0.347	175.000	0.129
* 10. Black Lung Compensation Insurance	340.000	0.674	340.000	0.251
* 11. Welfare - Hourly	300.000	0.595	240.000	0.177
12. Welfare - Tonnage	711.790	1.411	1,909.880	1.411
* 13. Safety Expenses	150.000	0.297	150.000	0.111
* 14. Production & Safety Incentives	250.000	0.496	250.000	0.185
* 15. Accident Costs	200.000	0.396	200.000	0.148
16. Reclamation Fee	75.669	0.150	203.036	0.150
17. Federal Black Lung Fee	252.229	0.500	676.783	0.500
* 18. Other Costs	0.000	0.000	0.000	0.000
Total	11,954.062	23.697	15,311.393	11.312
B. Other Cash Costs				
* 1. Overhead	500.000	0.991	500.000	0.369
2. Royalties	302.675	0.600	812.140	0.600
3. Miscellaneous Taxes	0.000	0.000	0.000	0.000
* 4. Equipment Leasing Costs	600.000	1.189	600.000	0.443
* 5. Interest Expense	500.000	0.991	700.000	0.517
* 6. Miscellaneous Income	0.000	0.000	0.000	0.000
Total	1,902.675	3.772	2,612.140	1.930
C. Other Costs				
* 1. Depreciation	550.000	1.090	835.720	0.617
2. Amortization of Development Costs	0.000	0.000	0.000	0.000
3. Depletion	0.000	0.000	0.000	0.000
Total	550.000	1.090	835.720	0.617
Total Cost of Mining	14,406.737	28.559	18,759.252	13.859

* Fixed Dollars Per Year

MINE PRODUCTION MODEL
BY CONTINUOUS MINER SECTION
IMPROVED UPTIME BY 60 MINUTES FOR 75% EFFICIENCY
MISC. HAULAGE ENTRY ELIMINATED - PARTIAL MINE

ITEM IDENTIFICATION	SECTION 1	SECTION 2	SECTION 3	SECTION 4	SECTION 5	SECTION 6	TOTAL/WTD AV
Minutes Per Shift	480.0	480.0	480.0	480.0	480.0	480.0	480.0
Travel Time	60.0	62.0	65.0	58.0	62.0	64.0	61.7
Lunch Time	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Service Time	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Remaining Operating Time	390.0	388.0	385.0	392.0	388.0	386.0	388.3
Downtime							
Miner	22.8	25.0	18.0	29.4	10.0	30.0	22.9
S.C./C.H.	15.0	10.2	12.0	15.5	12.0	18.2	13.7
Belt	21.0	22.2	28.0	18.5	21.0	19.5	21.9
Bolter	4.8	5.0	6.0	5.9	8.0	4.6	5.7
Feeder	3.0	3.8	4.2	3.6	5.0	6.8	4.3
C/PTM	30.5	31.0	22.0	28.8	35.0	38.0	30.2
Power	1.8	1.0	2.0	2.5	2.8	1.9	2.0
Timber & Rail	2.0	2.9	3.0	5.0	5.3	3.0	3.5
Conditions	5.0	5.8	6.0	2.5	4.2	2.8	4.5
Safety	18.0	15.5	16.8	20.0	17.0	15.1	17.2
Model Adjust Delays	20.0	18.5	17.8	22.0	15.0	19.5	19.0
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Downtime	143.9	140.9	135.8	153.7	135.3	159.4	144.7
Remaining Uptime	246.1	247.1	249.2	238.3	252.7	226.6	243.6
Unit Shifts/Year	502	480	536	528	354	380	2,780
Cubic Feet/Place	1,710.7	1,731.7	1,857.4	1,880.0	1,642.8	1,409.4	1,724.9
Density	94.50	94.50	94.50	94.50	94.50	94.50	94.50
Raw Tons/Place	80.8	81.8	87.8	88.8	77.6	66.6	81.5
Raw Tons/S.C.	7.0	7.0	7.0	7.0	7.0	7.0	7.0
No. S.C./Place	11.5	11.7	12.5	12.7	11.1	9.5	11.6
Reject %	22.80	22.80	22.80	22.80	22.80	22.80	22.80
Clean Tons/S.C.	5.40	5.40	5.40	5.40	5.40	5.40	5.40
Place Time							
Mining	12.82	12.97	13.92	14.09	12.31	10.56	12.92
Maneuvering	1.73	1.75	1.88	1.90	1.66	1.43	1.75
Misc. Haulage	0.00	0.00	0.00	19.44	16.50	18.00	8.25
Gas Test & Safety	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventilation & Posts	8.60	8.60	8.60	8.60	8.60	8.60	8.60
Tram	3.48	3.72	3.83	4.68	3.18	4.11	3.86
Total Place Time	26.63	27.05	28.23	48.71	42.25	42.70	35.39
Roof Bolting Place Time	26.00	27.00	28.00	29.00	25.00	24.00	26.73
Places/Unit Shift	9.242	9.136	8.829	4.892	5.981	5.307	7.44
Productivity - Clean Coal							
Tons/Unit Shift	576.7	577.1	598.2	335.5	358.4	272.8	465.8
Tons/Hour	140.6	140.1	144.0	84.5	85.1	72.2	114.1
Tons/Minute	2.343	2.335	2.400	1.408	1.418	1.204	1.902
Annual Production, st	289,499	276,990	320,630	177,142	126,869	103,681	1,294,813

COST OF MINING STATEMENT
Base Year 1988

Basis of Estimates	Adj. Time St. Data		Uptime by 60 Minutes for 75% Efficiency Mine Haulage Eliminated Partial Mine	
Days of Operation	240		240	
Total Production (Clean st) (000)	504.458		1,294.813	
Daily Production (Clean st)	2,102		5,395	
Approx. st/worker-day	9.550		29.481	
Cost basis	Dollars(000)	$/st	Dollars(000)	$/st
A. Direct Operating Costs				
* 1. Labor - Salaried	1,000.000	1.982	1,000.000	0.772
* 2. Labor - Hourly	3,500.000	6.938	2,800.000	2.162
* 3. Benefits - Salaried	46.000	0.091	46.000	0.036
* 4. Benefits - Hourly	900.000	1.784	720.000	0.556
5. Supplies - Operating	1,513.374	3.000	3,884.439	3.000
* 6. Supplies - Maintenance	1,800.000	3.568	1,800.000	1.390
* 7. Power	340.000	0.674	340.000	0.263
* 8. FICA & Unemployment Taxes	400.000	0.793	400.000	0.309
* 9. Workmen's Compensation Insurance	175.000	0.347	175.000	0.135
* 10. Black Lung Compensation Insurance	340.000	0.674	340.000	0.263
* 11. Welfare - Hourly	300.000	0.595	240.000	0.185
12. Welfare - Tonnage	711.790	1.411	1,826.981	1.411
* 13. Safety Expenses	150.000	0.297	150.000	0.116
* 14. Production & Safety Incentives	250.000	0.496	250.000	0.193
* 15. Accident Costs	200.000	0.396	200.000	0.154
16. Reclamation Fee	75.669	0.150	194.223	0.150
17. Federal Black Lung Fee	252.229	0.500	647.407	0.500
* 18. Other Costs	0.000	0.000	0.000	0.000
Total	11,954.062	23.697	15,014.049	11.596
B. Other Cash Costs				
* 1. Overhead	500.000	0.991	500.000	0.386
2. Royalties	302.675	0.600	776.888	0.600
3. Miscellaneous Taxes	0.000	0.000	0.000	0.000
* 4. Equipment Leasing Costs	600.000	1.189	600.000	0.463
* 5. Interest Expense	500.000	0.991	700.000	0.541
* 6. Miscellaneous Income	0.000	0.000	0.000	0.000
Total	1,902.675	3.772	2,576.888	1.990
C. Other Costs				
* 1. Depreciation	550.000	1.090	835.720	0.645
2. Amortization of Development Costs	0.000	0.000	0.000	0.000
3. Depletion	0.000	0.000	0.000	0.000
Total	550.000	1.090	835.720	0.645
Total Cost of Mining	14,406.737	28.559	18,426.657	14.231

* Fixed Dollars Per Year

MINE PRODUCTION MODEL
BY CONTINUOUS MINER SECTION
IMPROVE UPTIME BY 90 MINUTES FOR 100% EFFICIENCY
MISC. HAULAGE ENTRY ELIMINATED - PARTIAL MINE

ITEM IDENTIFICATION	SECTION 1	SECTION 2	SECTION 3	SECTION 4	SECTION 5	SECTION 6	TOTAL/WTD AV
Minutes Per Shift	480.0	480.0	480.0	480.0	480.0	480.0	480.0
Travel Time	60.0	62.0	65.0	58.0	62.0	64.0	61.7
Lunch Time	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Service Time	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Remaining Operating Time	390.0	388.0	385.0	392.0	388.0	386.0	388.3
Downtime							
Miner	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S.C./C.H.	15.0	10.2	12.0	15.5	12.0	18.2	13.7
Belt	21.0	22.2	28.0	18.5	21.0	19.5	21.9
Bolter	4.8	5.0	6.0	5.9	8.0	4.6	5.7
Feeder	3.0	3.8	4.2	3.6	5.0	6.8	4.3
C/PTM	30.5	31.0	22.0	28.8	35.0	38.0	30.2
Power	1.8	1.0	2.0	2.5	2.8	1.9	2.0
Timber & Rail	2.0	2.9	3.0	5.0	5.3	3.0	3.5
Conditions	5.0	5.8	6.0	2.5	4.2	2.8	4.5
Safety	11.0	8.5	9.8	13.0	10.0	8.1	10.2
Model Adjust Delays	20.0	18.5	17.8	22.0	15.0	19.5	19.0
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Downtime	114.1	108.9	110.8	117.3	118.3	122.4	114.8
Remaining Uptime	275.9	279.1	274.2	274.7	269.7	263.6	273.4
Unit Shifts/Year	502	480	536	528	354	380	2,780
Cubic Feet/Place	1,710.7	1,731.7	1,857.4	1,880.0	1,642.8	1,409.4	1,724.9
Density	94.50	94.50	94.50	94.50	94.50	94.50	94.50
Raw Tons/Place	80.8	81.8	87.8	88.8	77.6	66.6	81.5
Raw Tons/S.C.	7.0	7.0	7.0	7.0	7.0	7.0	7.0
No. S.C./Place	11.5	11.7	12.5	12.7	11.1	9.5	11.6
Reject %	22.80	22.80	22.80	22.80	22.80	22.80	22.80
Clean Tons/S.C.	5.40	5.40	5.40	5.40	5.40	5.40	5.40
Place Time							
Mining	11.20	11.34	12.16	12.31	10.76	9.23	11.29
Maneuvering	1.73	1.75	1.88	1.90	1.66	1.43	1.75
Misc. Haulage	0.00	0.00	0.00	19.44	16.50	18.00	8.25
Gas Test & Safety	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ventilation & Posts	8.60	8.60	8.60	8.60	8.60	8.60	8.60
Tram	3.48	3.72	3.83	4.68	3.18	4.11	3.86
Total Place Time	25.01	25.41	26.47	46.93	40.70	41.37	33.76
Roof Bolting Place Time	25.00	25.00	26.00	27.00	24.00	23.00	25.17
Places/Unit Shift	11.030	10.983	10.359	5.853	6.627	6.373	8.80
Productivity - Clean Coal							
Tons/Unit Shift	688.3	693.8	701.8	401.4	397.1	327.6	551.0
Tons/Hour	149.7	149.1	153.6	87.7	88.3	74.6	120.5
Tons/Minute	2.495	2.486	2.560	1.461	1.472	1.243	2.008
Annual Production, st	345,531	333,008	376,191	211,930	140,569	124,494	1,531,723

COST OF MINING STATEMENT
Base Year 1988

Basis of Estimates	Adj. Time St. Data		Uptime by 90 Minutes for 100% Efficiency Without Mine Haulage Partial Mine	
Days of Operation	240		240	
Total Production (Clean st) (000)	504.458		1,531.723	
Daily Production (Clean st)	2,102		6,382	
Approx. st\worker-day	9.550		34.875	
Cost basis	Dollars(000)	$/st	Dollars(000)	$/st
A. Direct Operating Costs				
* 1. Labor - Salaried	1,000.000	1.982	1,000.000	0.653
* 2. Labor - Hourly	3,500.000	6.938	2,800.000	1.828
* 3. Benefits - Salaried	46.000	0.091	46.000	0.030
* 4. Benefits - Hourly	900.000	1.784	720.000	0.470
5. Supplies - Operating	1,513.374	3.000	4,595.169	3.000
* 6. Supplies - Maintenance	1,800.000	3.568	1,800.000	1.175
* 7. Power	340.000	0.674	340.000	0.222
* 8. FICA & Unemployment Taxes	400.000	0.793	400.000	0.261
* 9. Workmen's Compensation Insurance	175.000	0.347	175.000	0.114
* 10. Black Lung Compensation Insurance	340.000	0.674	340.000	0.222
* 11. Welfare - Hourly	300.000	0.595	240.000	0.157
12. Welfare - Tonnage	711.790	1.411	2,161.260	1.411
* 13. Safety Expenses	150.000	0.297	150.000	0.098
* 14. Production & Safety Incentives	250.000	0.496	250.000	0.163
* 15. Accident Costs	200.000	0.396	200.000	0.131
16. Reclamation Fee	75.669	0.150	229.759	0.150
17. Federal Black Lung Fee	252.229	0.500	765.861	0.500
* 18. Other Costs	0.000	0.000	0.000	0.000
Total	11,954.062	23.697	16,213.050	10.585
B. Other Cash Costs				
* 1. Overhead	500.000	0.991	500.000	0.326
2. Royalties	302.675	0.600	919.034	0.600
3. Miscellaneous Taxes	0.000	0.000	0.000	0.000
* 4. Equipment Leasing Costs	600.000	1.189	600.000	0.392
* 5. Interest Expense	500.000	0.991	700.000	0.457
* 6. Miscellaneous Income	0.000	0.000	0.000	0.000
Total	1,902.675	3.772	2,719.034	1.775
C. Other Costs				
* 1. Depreciation	550.000	1.090	835.720	0.546
2. Amortization of Development Costs	0.000	0.000	0.000	0.000
3. Depletion	0.000	0.000	0.000	0.000
Total	550.000	1.090	835.720	0.546
Total Cost of Mining	14,406.737	28.559	19,767.805	12.906

* Fixed Dollars Per Year