EQUIPMENT MODIFICATION FOR INCREASED SAFETY

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INTRODUCTION

This paper is a progress report on the work performed to date under the Federal Bureau of Mines "Inherently Safe Mining Systems" contract.

The concept of initiating a large action-oriented contract, directed towards obtaining coal-mining systems with greatly improved safety characteristics, was conceived by the Bureau in January 1971.

The concept of working demonstrable systems, rather than just a conceptual study, was felt to be necessary for two significant reasons. In the development of any new system, the translation from concept to working hardware is usually a costly and time-consuming process that acts as a deterrent to implementation. Second, many decisions in the mining community to change equipment or systems are based on first-hand observation of the new system, in operational practice, an attitude which is certainly understandable in view of the high capital costs of equipment.

Based on a competitive procurement process, the Inherently Safe Mining Systems contract was awarded to the FMC Corp., San Jose, Calif., on June 18, 1971. The major goal of this contract is to develop and demonstrate safer mining equipment and procedures that can be developed using existing state-of-the-art technology.

This program is aimed at demonstrating improved safety of operations in the area from the working face to the first point of coal transfer in underground bituminous coal mines with seam heights of 4 to 8 feet, with emphasis placed on the prevention of fatal and nonfatal accidents by avoiding, warning, or protecting against the physical hazards of machinery and against falls of roof and rib. Long-term health problems and catastrophes (for example, explosions) are not being directly addressed, although procedures and equipment developed for this project will be evaluated to verify that they do not aggravate these problems.

The program is being conducted in three phases. Phase I, which has been completed, involved data accumulation and analysis leading to problem definition and the development of concepts to alleviate these problems. We are currently well into Phase II of the program, in which all the basic equipment elements are to be procured and modified and new equipment fabrications completed. Subsequent portions of this paper present the status of these major equipment developments. Phase III, the 1-year operational demonstration, is scheduled to begin in August of this year for the conventional section and later for the continuous section.

PROBLEM DEFINITION

A brief review of the magnitude of the safety problem associated with those activities within the scope of this program is of interest. This work in problem definition was performed during the first phase of the program and has been reported in detail in a report entitled "Accident Analysis by Functional Classification for Bituminous Coal Mines in 4-Foot to 8-Foot Seam Heights." This report was completed on

September 11, 1972, and has been placed with the National Technical Information Service.

Data on fatal and nonfatal accidents in underground bituminous coal mines operating in 4- to 8-foot seams was gathered to evaluate the problem and to assist designers in developing designs for equipment and procedures, which will reduce the incidence of these accidents. The data was structured in a form that would identify --

The types of accidents that are occurring

The causes of these accidents

The aspects of the job or equipment that contribute to these accidents

The nature and duration of the hazards to which workers are exposed.

The fatal accident data base consisted of 283 accidents resulting in 302 fatalities.

Nonfatal accident data was gathered in the field from company records on file at various mining company offices. The specific accident information sources have been masked to preserve their identities. Information on 65 conventional mining sections and 155 continuous-mining sections is contained in the data base. This sample represents 10,907,757 total annual man-hours in 4- to 8-foot seams, which is about 14% of the industry wide total annual labor hours in 4- to 8-foot seams.

Table 1 is an overall summary of the frequency and severity of nonfatal accidents, the incidence of fatal accidents, and the industry-wide expectation of lost man-days per year by system function.

Worthy of notice is the total of 220,500 estimated man-days lost each year as a result of compensable and noncompensable accidents. This is equivalent to a labor force of approximately 890 men, enough men to mine coal in 75 to 90 underground mining sections.

Table 2 provides information on the principle causes of injury for each of the major system functions.

Based on the results of accident studies and unit operation analysis, criteria for concepts to improve the safety of the conventional and continuous mining systems were developed. These criteria were made available to design personnel through accident study conclusions, operation analysis study conclusions, and recommended design approaches.

CONVENTIONAL MINING SYSTEM CONCEPTS

Work is progressing on the modification of equipment for use in the conventional mining section demonstration. The specific modifications planned or underway are described in the following sections. The major common features in these modifications are all-around protective suspended cabs and improved and standardized controls. The cab suspension feature, incorporated in a variety of unique ways on the section equipment, has two advantages: first, in the event of a major fall the cab can deflect in a controlled manner to enable the machine frame to pick

Table 1 INDUSTRY IMPACT — ACCIDENT SURVEY SUMMARY

Underground Bituminous Coal Mines -Inby The Face
Seam Height 4 - 8 Feet

	NON-FATAL								FATAL
	Compensible				Non-Compensible				
SYSTEM FUNCTIONS	One Accident for Every X Man-Years	Estimated Accidents per Year	Severity: Man-Days per Accident	Estimated Man-Days Lost per Year	One Accident for Every X Man-Years	Estimated Accidents per Year	Severity: Man-Days per Accident	Estimated Man-Days Lost Per Year	Five Year Total Accidents
4.0.0 Support Roof Roof Bolter	5.7	1114	53.7	60000	3.8	1621	1.6	2600	50
52.0.0 Load Coal Loader	6.1	293	70.4	21000	2.6	673	1.5	1000	47
1.0.0 Extract Coal Continous Miner	16.5	447	56.1	25000	10.9	671	1.7	1100	43
3.0.0 Move & Load Coal Shuttle Car	25.8	320	51.0	16000	11.7	799	1.8	1400	38
9.0.0 Maintenance All Maintenance	10.6	468	48.8	23000	3.1	1560	1.4	2200	20
51.1.0 Cut Face Cutter	12.9	158	115.3	18000	7.7	252	1.7	400	14
			Sub-Total	163000			Sub-Total	8700	212
All Other Functions (At Face)	-	952	48.4	46000	-	1842	1.5	2800	71
	Totals	3752	-	209000	Totals	7418	-	11500	283

Table 2 ACCIDENT MATRIX

Summary of Analysis
By System Function
And Source Of Injury

Note: Percentages will not add to 100 because only major sources are listed.

System Function (Job)	Location	Analysis Factors	TOTAL	Roof Falls	Face & Rib Falls	Falling and Flying Objects	Person Falling	Handling Material	Hand Tools	Stepping on Object	Striking or Bumping	Electricity	Machinery	Bursts - (Pressure)
1.0.0 EXTRACT COAL (Continuous Miner)	Worker at Controls	% of Accidents % Man-Days Lost Average Severity	52.1 55.4 24.8	17.1 26.4 35.9	6.2 2.9 10.9	7.5 4.2 13.1					4.1 4.7 26.9		14.4 13.2 21.4	
	Worker in Support	% of Accidents % Man-Days Lost Average Severity	48.0 44.6 21.7	3.4 6.1 41.4	4.1 8.1 45.8	4.1 13.4 75.7		11.6 6.2 12.4	2.1 0.2 1.7				15.1 9.0 13.9	
51.1.0 CUT FACE (Cutter)	Worker at Controls	% of Accidents % Man-Days Lost Average Severity	73.2 71.6 43.3	23.2 13.8 26.4	14.3 15.0 46.5	10.7 0.4 1.5					7.1 7.2 44.5		16.1 35.2 97.1	
	Worker in Support	% of Accidents % Man-Days Lost Average Severity	26.8 28.4 47.0	1.6 22.2 one acc.			10.7 2.9 12.0	5.4 2.9 24.3					8.9 0.4 2.0	
51.2.0 DRILL FACE (Drill)	Worker at Controls	% of Accidents % Man-Days Lost Average Severity	75.0 86.5 19.0	14.3 14.3 19.0	12.5 13.7 20.9	8.[illegible] 25.[illegible] 55.0							35.7 26.8 14.3	
	Worker in Support	% of Accidents % Man-Days Lost Average Severity	25.0 13.5 10.3			5.4 0.7 2.3	7.1 4.5 12.0						5.4 5.2 18.3	
52.0.0 LOAD COAL (Loader)	Worker at Controls	% of Accidents % Man-Days Lost Average Severity	89.0 77.6 19.4	16.9 23.0 30.4	8.1 2.2 6.0	35.3 10.4 6.5	3.7 2.3 14.2				2.9 0.6 4.3		18.4 37.3 45.3	1.5 1.8 26.5
	Worker in Support	% of Accidents % Man-Days Lost Average Severity	11.0 22.5 15.4					3.7 15.2 92.4					3.7 2.4 14.6	
3.0.0 MOVE & LOAD COAL (Shuttle Car)	Worker at Controls	% of Accidents % Man-Days Lost Average Severity	81.8 59.7 14.5	15.3 18.2 20.4	3.5 3.4 17.7	15.[illegible] 7.[illegible] 9.7					26.5 27.1 17.5		19.4 11.1 9.8	
	Worker in Support	% of Accidents % Man-Days Lost Average Severity	18.4 39.0 28.[illegible]				6.5 19.0 50.2	2.4 10.5 76.5				4.1 0.9 3.0		
4.0.0 SUPPORT ROOF (Roof Bolt)	Worker at Controls	% of Accidents % Man-Days Lost Average Severity	92.9 75.6 23.0	39.8 43.[illegible] 24.5	2.6 4.[illegible] 40.7	6.[illegible] 4.[illegible] 15.[illegible]	3.4 2.0 13.1	2.4 1.1 10.8	1.6 0.2 3.0	1.[illegible] 0.3 5.4			32.2 36.3 25.2	
	Worker in Support	% of Accidents % Man-Days Lost Average Severity	7.1 4.3 13.4	2.4 2.0 18.8									2.4 1.7 15.7	

Table 2 ACCIDENT MATRIX

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By System Function
And Source Of Injury

Notes: Percentages will not add to 100
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System Function (Job)	Location	Analysis Factors	TOTAL	Roof Falls	Face & Rib Falls	Falling and Flying Objects	Person Falling	Handling Material	Hand Tools	Stepping on Object	Striking or Dumping	Electricity	Machinery	Bursts - (Pressure)
51.3.0 SHOOT FACE (Explosive)	All	% of Accidents	100	15.8	21.1	21.1	10.5	10.5					10.5	
		% Man-Days Lost	100	2.3	59.0	14.2	3.0	16.1					5.2	
		Average Severity	38.5	5.7	107.4	26.0	11.0	59.0					19.0	
51.3.6 SHOOT FACE (Airdox)	All	% of Accidents	100	19.5		14.6	12.2						46.3	
		% Man-Days Lost	100	15.8		23.7	6.9						47.8	
		Average Severity	8.2	6.6		16.0	4.6						8.4	
4.90.0 SUPPORT ROOF (Posts, Timbers, etc.)	All	% of Accidents	100	9.8		13.7		51.0	15.7				3.9	
		% Man-Days Lost	100	5.9		6.2		39.0	5.4				40.4	
		Average Severity	7.3	4.4		3.3		5.6	2.5				75.5	
5.0.0 SAFETY	All	% of Accidents	100	75.9					10.3					
		% Man-Days Lost	100	95.0					1.6					
		Average Severity	38.2	47.9					6.0					
6.0.0 VENTILATION	All	% of Accidents	100		11.5			23.1			19.2		23.1	
		% Man-Days Lost	100		19.0			11.9			57.2		5.9	
		Average Severity	23.1		19.3			6.0			35.0		3.0	
7.0.0 FIRE CONTROL (Rock Dust)	All	% of Accidents	100	14.3				11.9					4.8	
		% Man-Days Lost	100	43.8				8.3					7.6	
		Average Severity	11.9	58.8				13.4					30.5	
8.0.0 MATERIAL SUPPLY	All	% of Accidents	100			2.8	8.3	77.0			2.8			
		% Man-Days Lost	100			0.3	10.2	79.5			0.8			
		Average Severity	11.2			1.0	13.7	11.4			3.0			
9.0.0 MAINTENANCE	All	% of Accidents	100	6.5		7.6	5.0	4.3	23.7			7.6	40.3	
		% Man-Days Lost	100	19.5		1.8	11.6	2.6	10.1			5.5	27.0	
		Average Severity	12.1	36.4		3.0	28.4	7.4	5.5			8.9	8.3	
10.0.0 SUPERVISION	All	% of Accidents	100	20.0		17.8	17.8	6.7					17.8	
		% Man-Days Lost	100	50.3		38.7	4.5	0.8					4.7	
		Average Severity	19.6	74.3		64.3	7.5	3.7					7.9	
	All	% of Accidents												
		% Man-Days Lost												
		Average Severity												
	All	% of Accidents												
		% Man-Days Lost												
		Average Severity												
	All	% of Accidents												
		% Man-Days Lost												
		Average Severity												

up a portion of the load; and secondly, the elevation can be adjusted to obtain the maximum visibility allowable under existing seam height and roof conditions.

Controls on all section equipment have been examined from a human engineering control function and consistency viewpoint and similar motions and locations have been established to the maximum extent possible. This was considered to be of importance in view of the learning experience required when an operator is new to a piece of equipment or is called upon to operate temporarily a different equipment element. It has been shown that this learning experience is often attendent with a higher accident rate.

All section equipment with the exception of the DC shuttle cars will employ 950-volt power. This permits the utilization of shielded cable with safety grounds without any increase in cable size or wei ht.

SHUTTLE CAR

Two National Mine Service Lokar's have been procured and are being identically modified for this program. To a large degree, the modifications being performed identify what can be accomplished when sufficient space is available on the basic machine. The basic modification is a human engineered swing-around suspended cab. This cab will elevate or depress under power from a nominal 6-inch to a maximum of 16-inch ground clearance. In the event of a fall, the cab will deflect to the floor in a controlled fashion.

The operator is not required to leave the cab when the direction of shuttle car travel is reversed. This is accomplished by the release of an underseat latch, powered rotation of the cab about an axis near the operator's center of gravity, and latch reengagement when rotation is complete. The controls travel with the operator and are automatically reversed when the new position is reached. Steering by means of an automotive-type wheel is always consistent with the direction of travel. Tram and brake controls are also consistent with automotive practice and rotate with the cab.

Cab side clearance in the 90^{o} rotated position is 31 inches beyond the outer edge of the existing machine structure. In the fore and aft position, cab side extension is 4 inches. This was required in the interest of additional operator comfort.

FACE DRILL

The face drill procured for this program was a Long Airdox model TDF-24C. Control modifications will consist of a reduction in the number of control valves by means of combined joystick controls. The drill frame swing and elevate controls will be combined as will the drill arm swing and elevate functions thus reducing the number of levers in the operators compartment. Additionally, automotive wheel-type steering will be utilized, the tram and brake controls will remain unchanged. An operators cab similar to that employed for the shuttle cars will be used with a 10-inch nominal adjustable height.

UNDERCUTTER

The cutting machine employed in this system will be a Joy model 15RU-6B. Joystick boom and bar controls and wheel steering similar to the face drill will be used. Since insufficient space for a suitable cab existed on the standard machine, it was modified by relocation of the hydraulic tram motor in order to provide leg room for the operator.

The machine will be equipped with forced air to the end of the cutter bar for slot ventilation and water spray nozzles for dust control.

LOADING MACHINE

The loading machine will be a Joy model 14BU10. Some of the special features of this machine are an oblique mounted operator's cab with limited reel cable storage and simplified cab mounted controls. The existing standard loading machine does not provide sufficient space for installation of a cab of adequate dimensions. The availability of this space to provide a comfortable cab is felt to be important since this is the one location where a worker can be protected, and everything possible should be done to make it desirable and practical for the operator to remain in the cab.

The cab, as configured, will elevate and depress about a horizontal pivot at the operator's feet. The additional side clearance was required because of oblique mounting of the cab to facilitate the operators view of the tail boom during the loading operation.

Cable reel storage for approximately 100 feet of cable will be provided in the rear of the operator's cab. The reel, which will be controlled by a cab-mounted, foot-operated valve, should ease the cable handling requirements.

AUTOMATED TEMPORARY ROOF SUPPORT BOLTER

A piece of equipment that will be built in two versions, one for use in the conventional section and one in the continuous section, is an automated roof bolter incorporating temporary roof support. The basic machine chassis will be a Galis model 3510. The key features of this machine will be an automated magazine supplied bolter that can be remotely operated by the worker from the protective cab position to bolt a 20-foot-wide place without local repositioning of the machine.

In the remote-control operational mode, the capability will exist to drill holes and install bolts with a length of from 5 to 6 feet, depending on the machine version. The machine can also be utilized with the operator working at the head end under the remotely actuated temporary support canopy. In this mode, the capability will exist to drill holes and install bolts of whatever length required.

For tramming, the bolts and drill steel are removed from the magazine and the protective canopy is then collapsed to a maximum height of approximately 3 feet.

CONTINUOUS-MINING SYSTEM CONCEPTS

The scheduled start date for the underground demonstration of the continuous-mining system is about 4 months later than for the conventional section. The equipment development is, therefore, not as far advanced as in that discussed for the conventional section.

The principle thrust for this equipment is to develop the capability to install a full bolting pattern automatically from the continuous-mining machine in order to obtain permanent support installation as rapidly as possible and allow the convenient utilization of continuous-belt haulage systems. The benefits of success in this development are apparent, but the problems encountered are also quite significant. The major obstacle is, of course, the space constraints. Existing continuous-mining machines are large and encumbered with considerable necessary machinery components, and the dimensions of the working space are, of course, limited. The on-board space available to accommodate equipment to drill and bolt a full three- or four-bolt pattern without restricting equipment maneuverability or effecting complete machine redesign is, therefore, extremely limited.

What has been developed through the preliminary design phase is illustrated by the sketch in figure 1. The basic machine to be employed is a Joy 12CM1-15B full-face miner capable of driving a 15-1/2-foot entry. Four on-board bolters are shown which would permit the installation of a four bolt pattern with a maximum center-to-center spacing of 4-1/2 feet. The bolting machine would employ a single drilling bolting

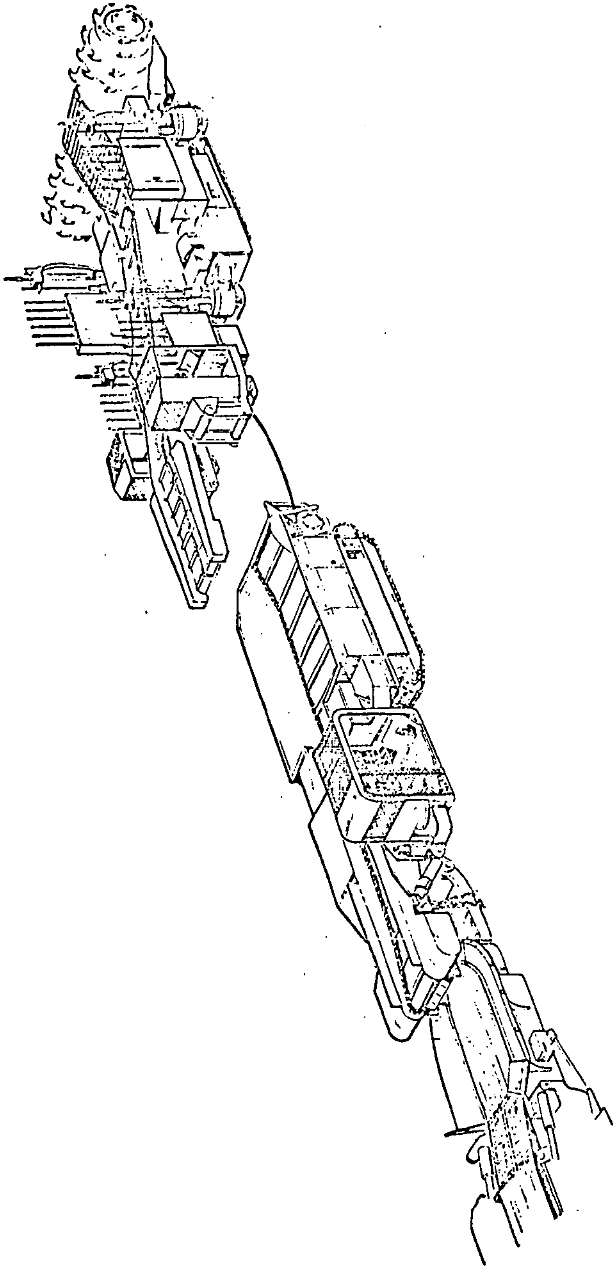

Figure 1
CONTINUOUS MINING SYSTEM

head with magazine storage and should be able to install a bolt approximately 2 feet less than the seam height.

In order to accommodate the rear bolters, the operators compartment has been removed, the conveyor extended, and the tailboom hinge pin moved forward. Two cabs have been added to the tailboom, one for the miner operator and one for the roof bolter. With the hinge pin relocation, the maneuverability of the machine is essentially the same as with the unmodified version.

Operation of the drilling bolting cycle is completely automated, and all four bolters are controlled from the operator's cab. All bolters are jack stabilized, and bolting should be possible during the shearing portion of the cycle. However, no slide-through capability is incorporated, and no drilling or bolting can be done during sumping. It is presently planned that the front bolters will have an eight-bolt magazine and the rear bolters, a four-bolt magazine. Reloading, which is a simple insertion process, would be required after about a 20-foot advance of the face. Bolting, in turn, is felt to be possible, although this will require some repositioning of the machine to accommodate bolt-spacing constraints. Some pick up bolting will be required when the machine is pulled out of a place since the forward bolts can be placed no closer than 12 feet from the face. This pick up bolting will be accomplished by means of a TRS bolter described previously.

The extensible belt haulage system to be used will be the Lee Norse system with one tram car and several drive storage units. Each drive storage unit will accommodate a maximum length of 150 feet of belt, which can be extended or retrieved at a rate of 140 feet per minute. System capacity is on the order of 12 tons per minute. Modifications to the extensible belt system include the addition of protective cabs or canopies to all units and revisions to the steering and tram controls.

ANCILLARY SYSTEMS

Given the time duration and extent of the demonstration phase of this program, it was considered desirable to integrate to the maximum extent all research and development results that could be incorporated in this phase. The additional items to be incorporated are those developed from the efforts of mining research, which is conducted both in-house and under contract programs other than the "Inherently Safe Mining Systems" contract. The following indicates some of the equipment and/or systems that will be incorporated in the areas of roof control, communications, illumination, dust control, and monitoring systems. The incorporation of these elements will include both demonstration, in those cases where the technology has already been proven, and test and evaluation where concepts are still under development.

The items under consideration for incorporation are as follows:

Roof Monitoring

1. Horizontal Roof Strain Indicator (HORSI) system
2. 3-in-1 roof deformation and failure warning device
3. U-type bolt tension indicator

Roof Monitoring (continued)

4. Micro seismic roof-fall warning system

5. Helix pressure gage

6. Hand held infrared scanner for detection of loose material

7. Mobile shield -- during experimental phases of system development in SRCM, Bruceton, and at ISMS mine, if applicable.

Monitoring, Communications, Lighting

1. Automatic monitoring of methane, air velocity, temperature, and CO

2. Advanced carrier phone systems and portable pocket paging equipment for section personnel

3. New lighting systems including wide-angle incandescent, mercury vapor, and, as development permits, polarized and/or flourescent for face area illumination and electroluminescent for machine identification. Hardware includes machine-mounted, portable, and personal units.

Dust Control and Monitoring

1. Application of foam in both coal cutting and handling

2. Air curtain respiratory device for personnel protection

3. Wet-drilling for automated roof drills

4. Continuous miner equipped with integral respirable dust scrubber and water sprays at cutter bits

5. Portable dust meters

6. Portable rock dust/coal dust analyzer, development permitting.

IN-MINE DEMONSTRATION

The precise demonstration start dates and location are currently under review and cannot be specifically identified at this time. As planned, the conventional section will be demonstrated in a seam of about 4 feet in height and the continuous section, in about 8 foot coal. Since both of these sections are to be operated for a years duration each, and numerous visitors are anticipated it is important that easy access to the sections be available both in a geographic and in-mine sense. Another important consideration is, of course, the cost of obtaining and operating these demonstration facilities over this time-frame desired.

A number of locations in West Virginia, Virginia, Illinois, and Kentucky have been examined and are currently being evaluated and it is anticipated that this question will be resolved shortly.