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Surface Evaluation of the 4M Miniminer System

By August J. Kwitowski

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS--Continued

ILLUSTRATIONS--Continued

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

A	ampere	kV•A	kilovolt ampere
dB	decibel	lb	pound
dBA	decibel, A-weighted	min	minute
dBC	decibel, C-weighted	mg/m^3	milligram per cubic meter
cfm	cubic foot per minute	µm	micrometer
ft	foot	pcf	pound per cubic foot
ft•lb	foot-pound	pct	percent
fpm	foot per minute	psi	pound per square inch
gal	gallon	psig	pound per square inch, gage
gpm	gallon per minute	rpm	revolution per minute
h	hour	s	second
hp	horsepower	s/c	second per cycle
Hz	hertz	tpm	ton per minute
in	inch	V ac	volt, alternating current
kW•h/t	kilowatt-hour per ton	W	watt

SURFACE EVALUATION OF THE 4M MINIMINER SYSTEM

By August J. Kwitowski [1]

ABSTRACT

This report presents the results of a joint Bureau of Mines-U.S. Department of Energy project that evaluated a newly developed low-coal mining system: the 4M miniminer system. The evaluation took place from April through October 1981 and determined potential health, safety, and productivity factors for the mining system using the surface test facilities at Bruceton, PA. The planning, testing, results of testing, and a summary evaluation of the 4M miniminer system are included in the report.

The miniminer system was found to be a very good concept with future potential for safe, healthful, and economic production in thin-seam mining. The mining system was also judged to have considerable potential for use in some coal seams that are presently considered unminable by other existing mining equipment.

The preproduction, prototype version of the miniminer system that was tested suffered from several safety and production problems. These problems are also described, along with suggested remedies.

[1] Civil engineer, Pittsburgh Research Center, Bureau of Mines, Pittsburgh, PA.

INTRODUCTION

The hazards and difficulties normally associated with underground coal mining are further complicated by low-seam conditions. Because the vertical dimension is limited, such low-seam mining takes place in a highly confined environment. The mining equipment presently used in low seams often contributes to the confining conditions, as it is typically a version of higher seam designs that has been dimensionally reduced to the point of fitting within the low seams. Thus, the majority of present low-seam continuous miners, haulage vehicles, roof bolters, etc., are massive when referenced against typical low-coal entry dimensions. This is particularly evident when the percentage of low and higher seam cross-sectional entry area that is occupied by typical mining equipment is compared. Furthermore, present low-seam mining equipment requires power systems that are proportioned to the equipment's size and mass and not necessarily to the actual tasks of extracting and transporting coal. Therefore, the size, mass, and power of typical, present low-seam mining equipment contribute to health and safety hazards imposed on low-seam section workers.

Given the above, it is not inconceivable that new equipment could be designed and built specifically for low-seam coal-mining applications and could result in improved health and safety conditions. To be of practical value, such new equipment would also need to be economically attractive in terms of capital outlay, production capacity, and associated operating costs.

The Montgomery Mining Machinery Manufacturing Co. (4M), a small, independent mining equipment manufacturer located in Damascus, VA, recently developed a low-coal mining system that is claimed to be an improvement over present equipment in the areas of health, safety, and economic attractiveness. Because the Bureau is responsible for investigating new mining equipment that may offer health, safety, and productivity improvements, a miniminer system was secured for evaluation of these factors.

Early in the joint Bureau of Mines-U.S. Department of Energy[2] project, the decision was made that initial testing of the miniminer system would be done on the surface using the surface test facilities located at Bruceton, PA. Because the purchased miniminer system was deemed as "preproduction, prototype equipment," the surface testing would permit the determination of many of the important characteristics of the mining system, yet also allow for the efficient correction of design and mechanical problems that are inherent to prototype equipment.

4M MINIMINER SYSTEM DESCRIPTION

The miniminer system consists of a small continuous miner, the miniminer, and a continuous haulage system for conveying cut coal away from the face and outby to a section's main haulage belt. The various components of the miniminer system, of which the miner, the mobile bridge carrier, and the crossover dump are motorized units, are depicted in figure 1.

Although all of the components of the miniminer system differ at least somewhat from conventional equipment in design and size, the miniminer itself is the most unusual. As is evident in figure 2, the miner is small. With the gathering augers folded (fig. 2*A*), the miniminer measures 10 ft wide by 14 ft long. With the exception of the 24-in-diam cutting head, the profile of the miner is held to 20 in. When the gathering augers are extended to transport cut coal (fig. 2*B*), the mining unit measures 18 ft across.

[2] Effective September 10, 1982, the relevant U.S. Department of Energy staff and facilities were transferred to the Bureau of Mines.

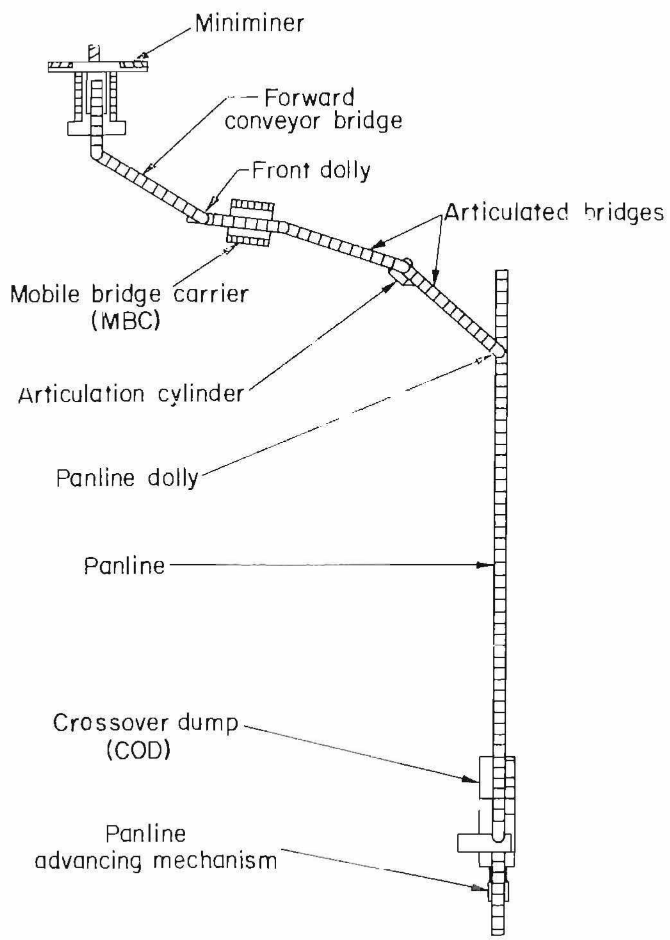


FIGURE 1. - Plan view of 4M miniminer system.

Upon sumping in to take a cut, the coal face is attacked by the circular section of the cutting head. A chain-driven, slide-bar feed mechanism forces the cutting head across the face while the body of the miner remains stationary in the middle of the entry. The cutting head assembly can be raised or lowered to allow a lift to be taken in two or more horizontal passes of the cutting head. The vertical motion of the cutting head assembly permits the miner to cut coal from 2 in below the floor level to 52 in above. The depth of a lift is limited by the length of the cutting head to a maximum of 27 in. The width of cut is also limited by design and is 18 ft. This width is dictated by the range of the cutting head's slide-bar feed mechanism and also by the extension of the folding gathering augers. The gathering augers move cut coal to a centrally located, double-stranded, chain conveyor that extends to the outby end of the miner.

The miniminer is electrically powered and hydraulically driven. Two 35-hp, 400-V ac, three-phase, 60-Hz, electric, squirrel-cage motors power the miner. Each motor drives two hydraulic pumps: a piston pump rated at 18.5 gpm at 3,000 psi and a gear-type, two-section pump having each section independently rated at 13.5 gpm at 1,800 psi. All functions on the miniminer are hydraulically operated. A bank of electrically controlled solenoid valves activate the various hydraulic circuits. The solenoid valves are actuated by the miner operator through switches located on the remote control console. This console is shown in figure 3 and extends from the miner on a 20-ft-long umbilical cord. Detailed specifications for the miniminer, as supplied by the manufacturer, are given in appendix A.

With the exception of roof bolting functions, the miniminer system, as tested, is a truly continuous mining and coal transport system. Cut coal is discharged from the miner onto a forward bridge connecting the miner to the mobile bridge carrier. The forward bridge attaches to a cantilevered receiving section of the bridge carrier by a wheeled dolly.

This arrangement allows the forward bridge to move short distances with the miner while the mobile bridge carrier remains stationary. Cut coal coming from the outby end of the bridge carrier is fed onto a pair of articulated bridges and then onto a panline. The paired bridges attach to the panline through another wheeled dolly. The panline, which the manufacturer specifies as being up to 300 ft long, extends to a crossover dump unit that contains a unique mechanism for advancing and retreating it. Movement of the panline is provided to allow continued connection to the rest of the system as face changes and entry advances occur. The crossover dump unit also lifts cut coal from the panline and

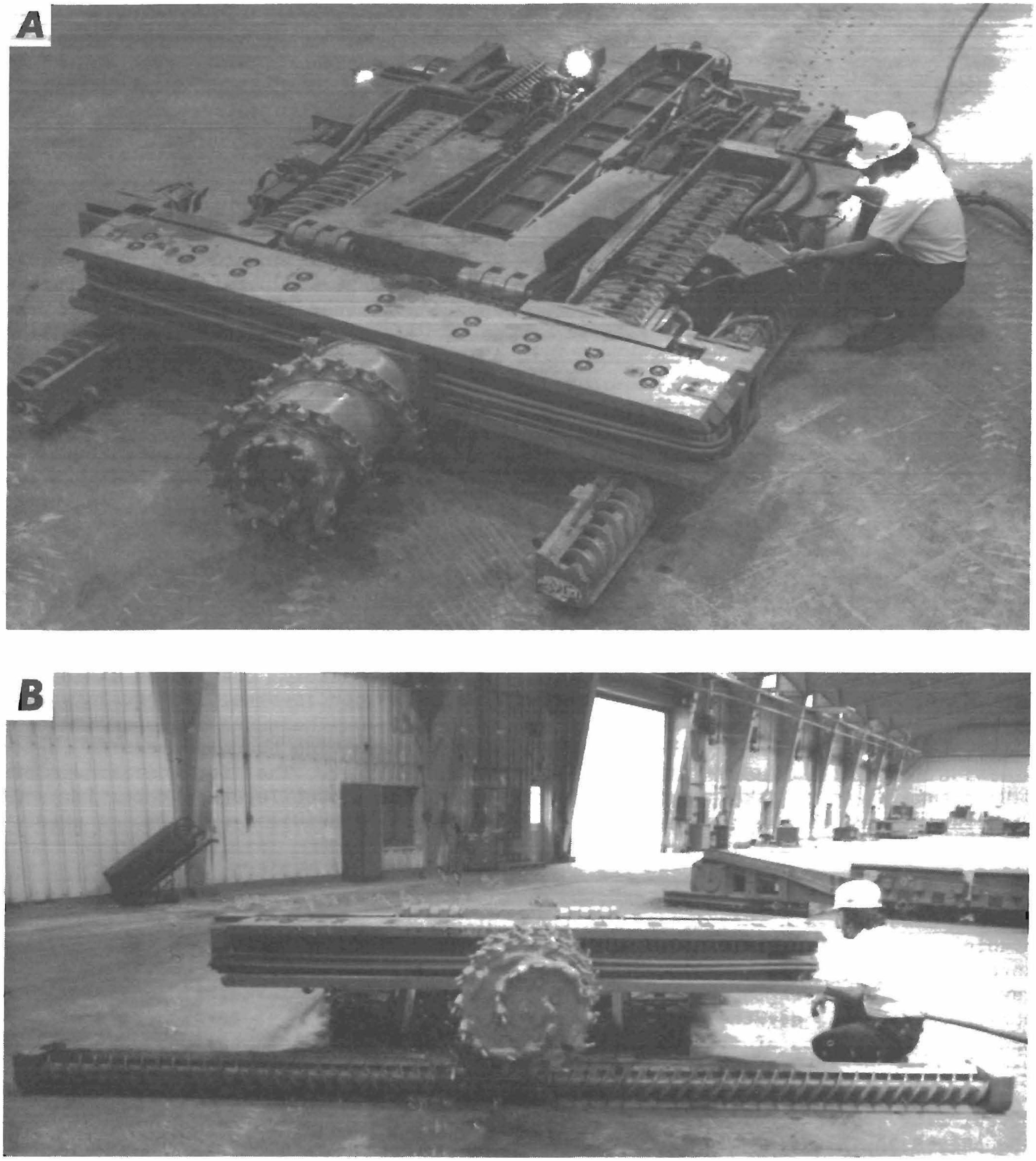


FIGURE 2. - Miniminer with gathering augers folded (*A*) and extended (*B*).

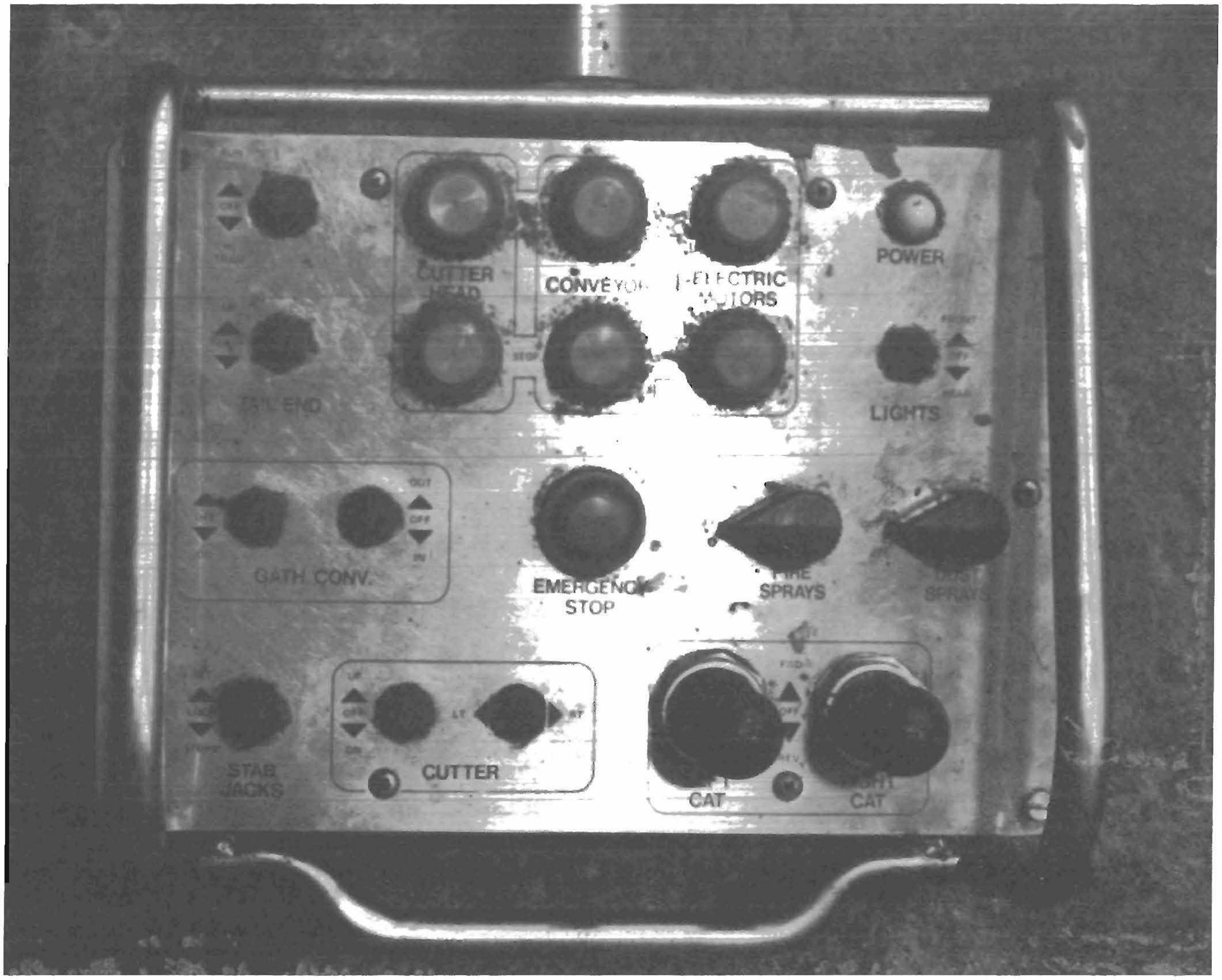


FIGURE 3. - Miniminer's remote control console.

dumps it onto a transverse conveyor belt for delivery to a section's main haulage belt.

Figure 4A shows the mobile bridge carrier, while figure 4B presents a view of the crossover dump. These machines are powered by the same electric motors used in the miniminer, with the difference being that only one motor powers each machine. The machines each contain a pair of two-section gear pumps rated at 13.5 gpm at 1,800 psi per section. These pumps are also the same as those used in the miner. The operator's controls for the mobile bridge carrier are located on the left, inby side of the unit. Here, as shown in figure 5, handles attach to cables and actuate the various hydraulic valving and circuits. The controls for activating the advance or retreat of the panline are located on a 10-ft-long umbilical cord that extends from the crossover dump. The on-off control for the transverse belt is located adjacent to the belt. Additional specifications and descriptions of the mobile bridge carrier and crossover dump are given in appendix A and were supplied by the manufacturer.

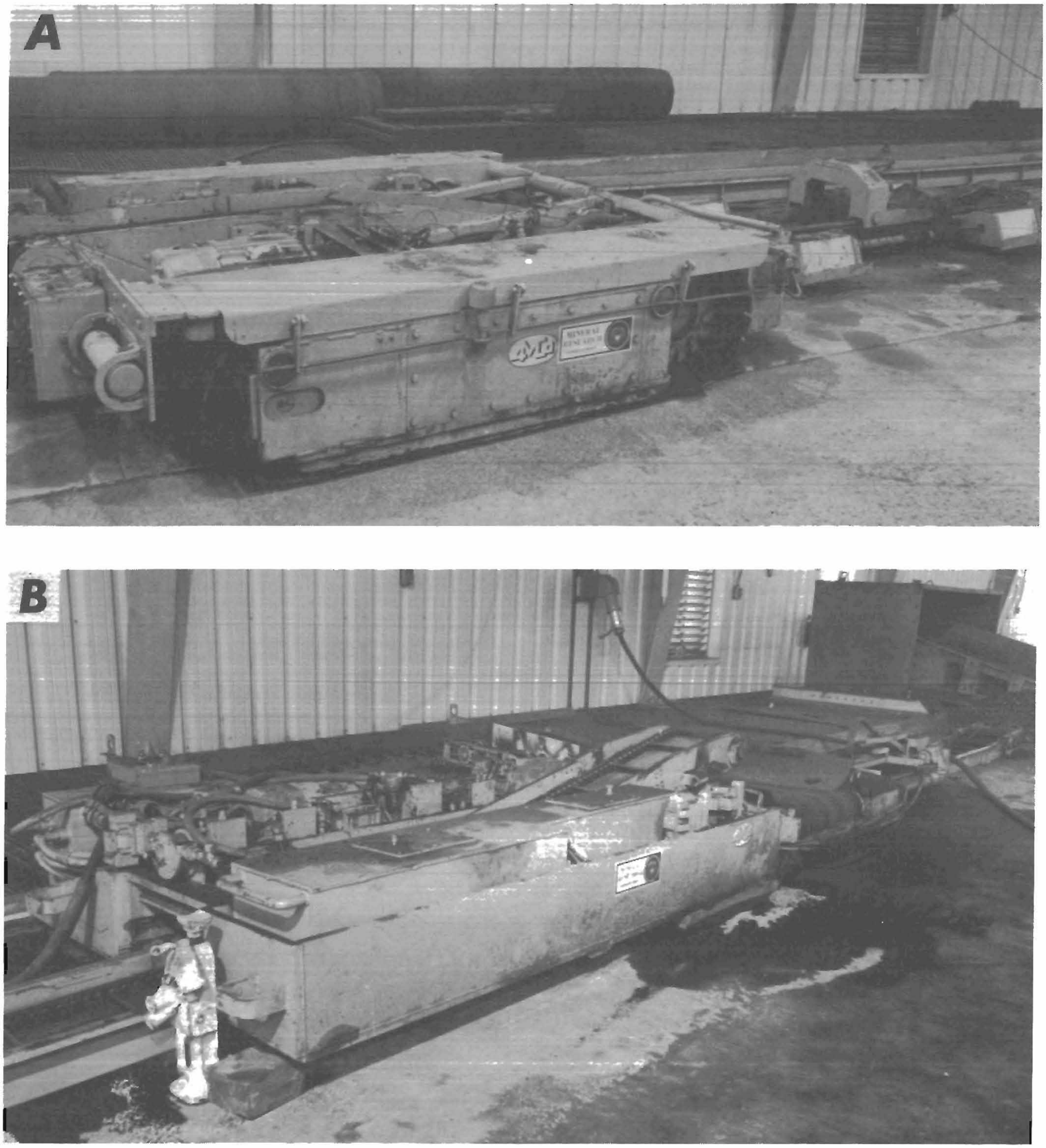


FIGURE 4. - View of mobile bridge carrier (*A*) and crossover dump (*B*).

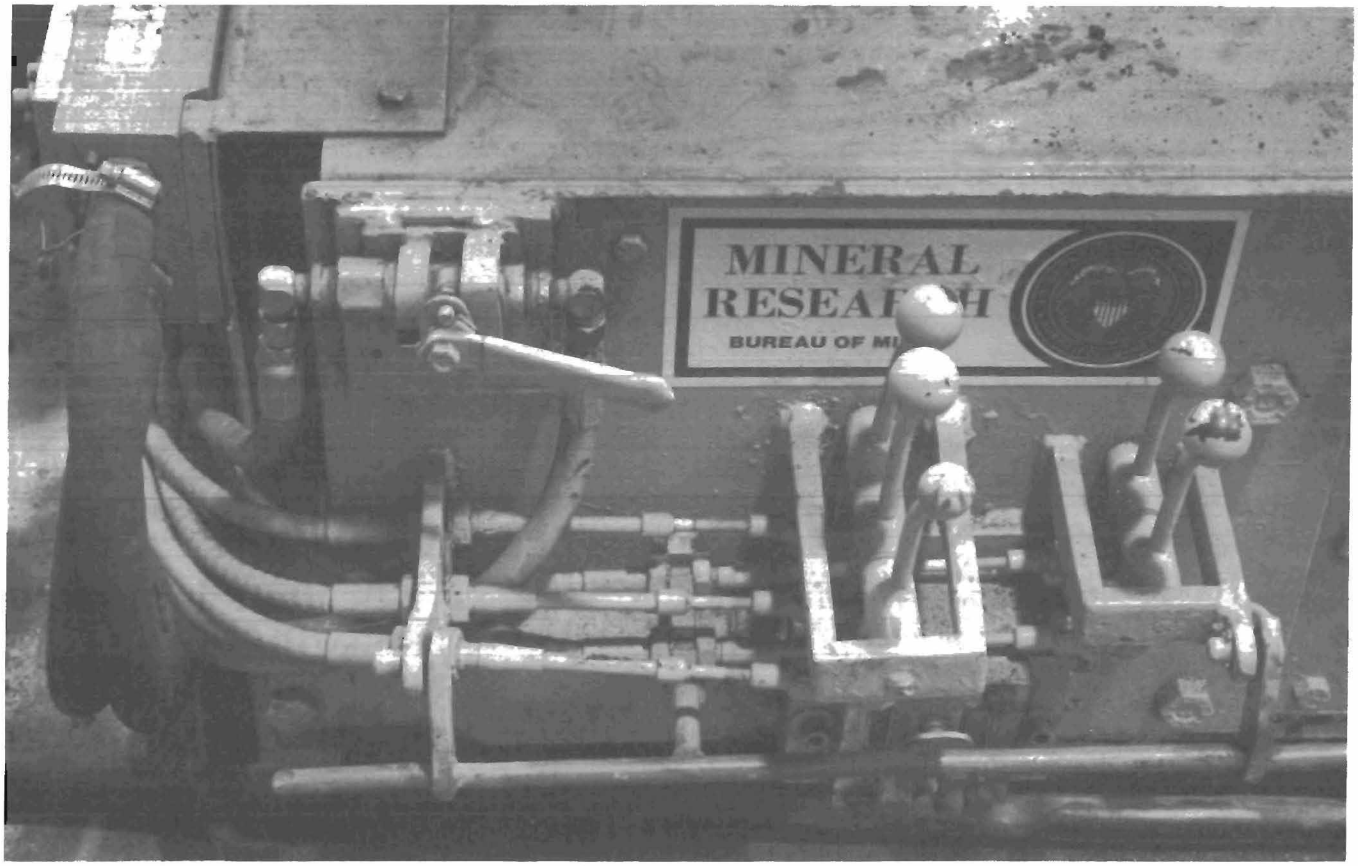


FIGURE 5. - Controls for mobile bridge carrier.

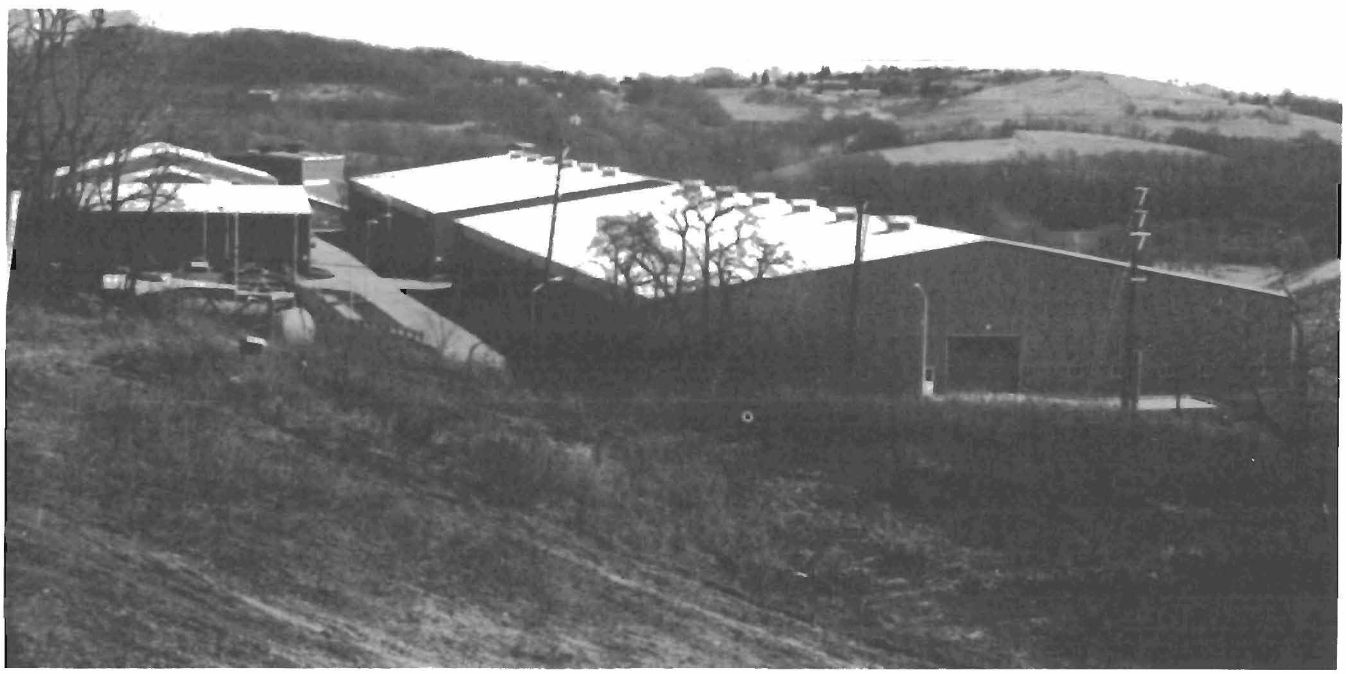


FIGURE 6. - Exterior view of the Mining Equipment Test Facility.

SURFACE TEST FACILITIES AND TEST PROGRAM

The overall facility that was used to conduct the surface evaluation of the miniminer system is known as the Mining Equipment Test Facility (METF) and is located in Bruceton, PA. A subset of the METF was used in the surface evaluation and consists of Building 151, the Equipment Maneuverability Trials Area (EMTA), and Building 152, the Cutting Trials Area (CTA). The EMTA and the CTA are collectively known as the Mine Production Test Facility (MPTF). An exterior view of the facility is shown figure 6.

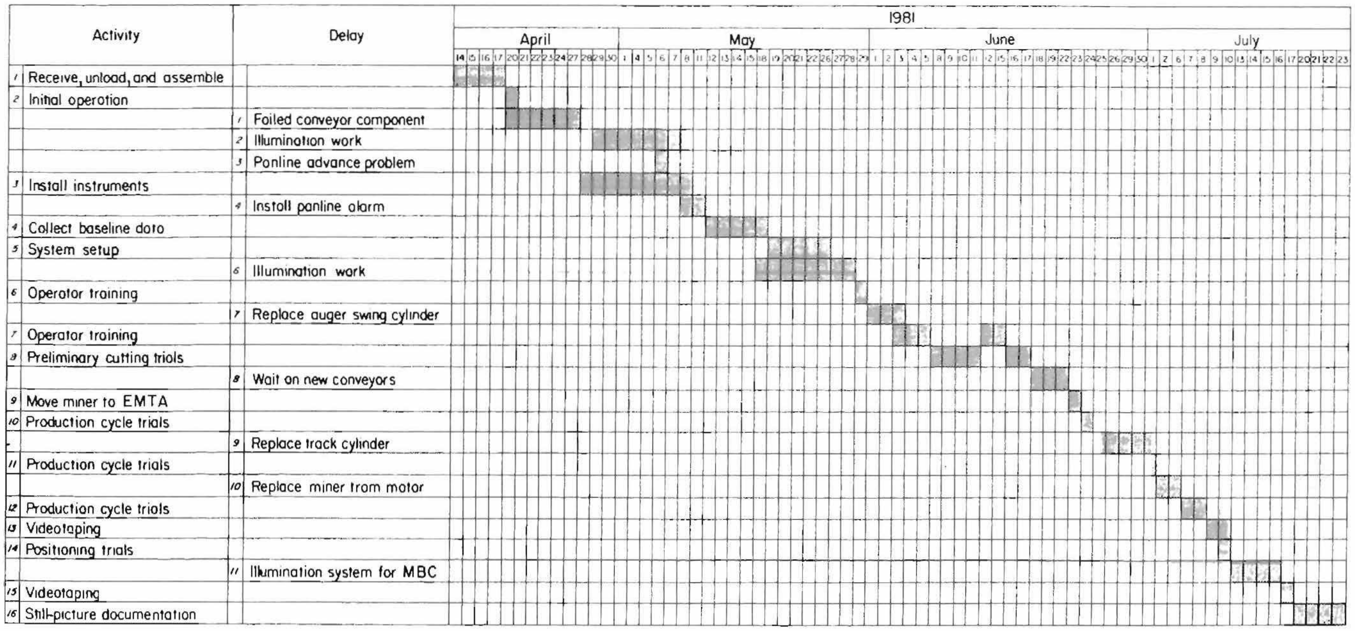


FIGURE 7. - Chronology of maneuverability evaluation major events.

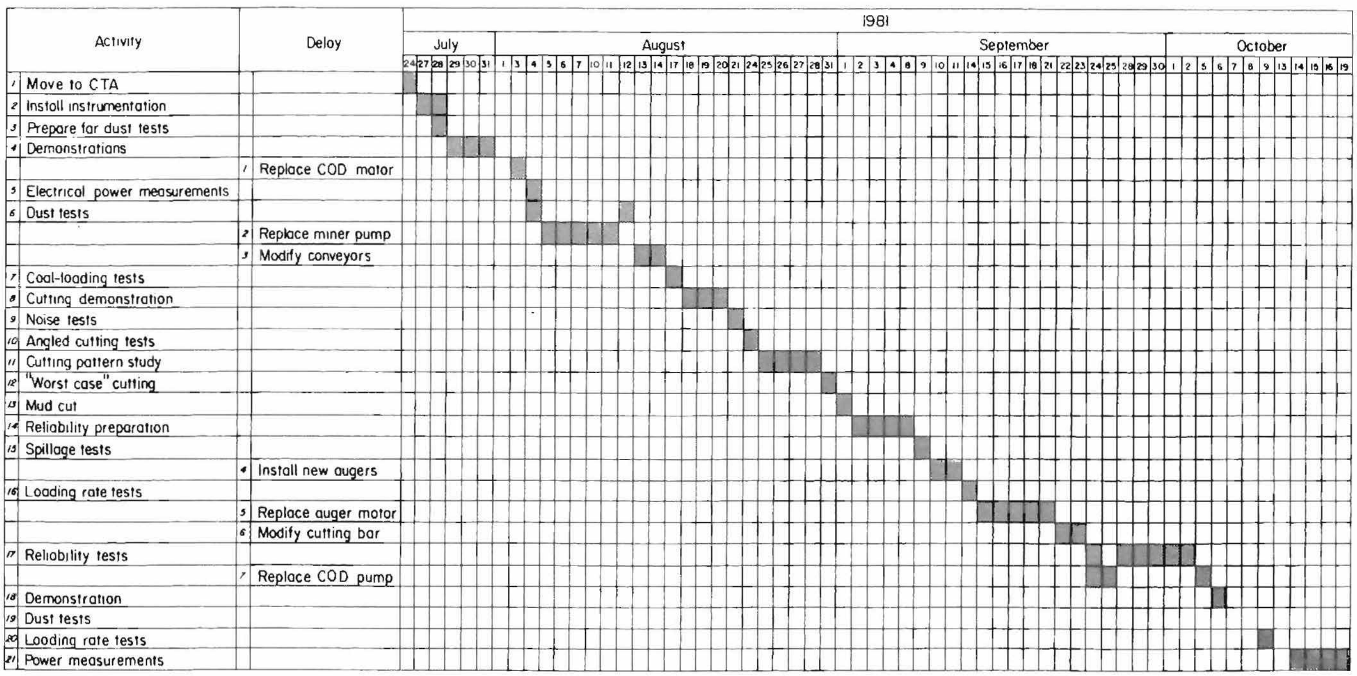


FIGURE 8. - Chronology of cutting evaluation major events.

The test program was divided into two phases: maneuverability evaluation and cutting evaluation. The maneuverability evaluation covered the areas of face-to-face place-change time trials, positioning ability testing, human factors evaluation, and determination of the system's compatability with roof support hardware. The cutting evaluation covered the following areas: verification of the cutting hardware; determination of coal loading and coal cutting rates; open-end, angled cutting; study of various cutting patterns; worst case cutting; noise generation; dust generation; sumping ability on mud; mechanical reliability; electrical power consumption; and determination of power levels for the haulage drive motors.

Although the test areas cover some subjects that may not be the primary concern of all underground coal mine operators, the attitude taken during the preparation of the test program was that the obvious, primary concerns must be covered; and additional, secondary concerns would be covered unless doing so would involve inordinate amounts of time or cost. Figures 7 and 8 present a chronology of various major events.

As is evident from the figures, the surface evaluation was subjected to numerous delays caused by equipment failures, minor on-the-spot equipment modifications, exchanges of equipment for redesigned versions, demonstrations for visitors, and many "one-of-a-kind" delays that are normally encountered by all large-scale projects. Also, several preparatory and exploratory activities involving considerable effort both preceded and accompanied the actual testing.

PREPARATION FOR MANEUVERABILITY EVALUATION

In order to insure that the surface testing approximated the real-world, low-coal, underground situation as closely as possible, both the miniminer system and the surface testing facilities required modifications. For the maneuverability evaluation, this amounted to providing the mining system with an illumination system that met Mine Safety and Health Administration (MSHA) regulations for underground face equipment and modifying the simulated room and pillar workings of the EMTA to match the entry dimensions in which the miniminer system was expected to mine.

The miniminer system, as supplied by the manufacturer, did not meet MSHA illumination requirements for underground face equipment. Because it was desired that the mining system be tested in the "mine-worthy" condition, the decision was made to design, fabricate, install, and test acceptable illumination systems before actual testing commenced.[3]

The resulting illumination systems are depicted in figures 9 and 10; they were designed to meet the following guidelines:

Maintain good low-glare visibility between the 2 machine operators.

Provide enhanced face illumination to improve the machine operator's major task visibility.

Avoid discomfort glare in all principle lines of sight between the two operators.

Provide good area and hazard visibility.

Provide trailing cable illumination for both operators.

Minimize interference with machine maintenance access.

Both the miniminer and the mobile bridge carrier illumination systems are considered very good examples of the success that is possible in providing low-glare lighting on low-coal face equipment.

[3]Design, fabrication, and testing were performed by C. Garbowsky, electrical engineering technician, and W. Lewis, electrical engineer, Pittsburgh Research Center, Pittsburgh, PA.

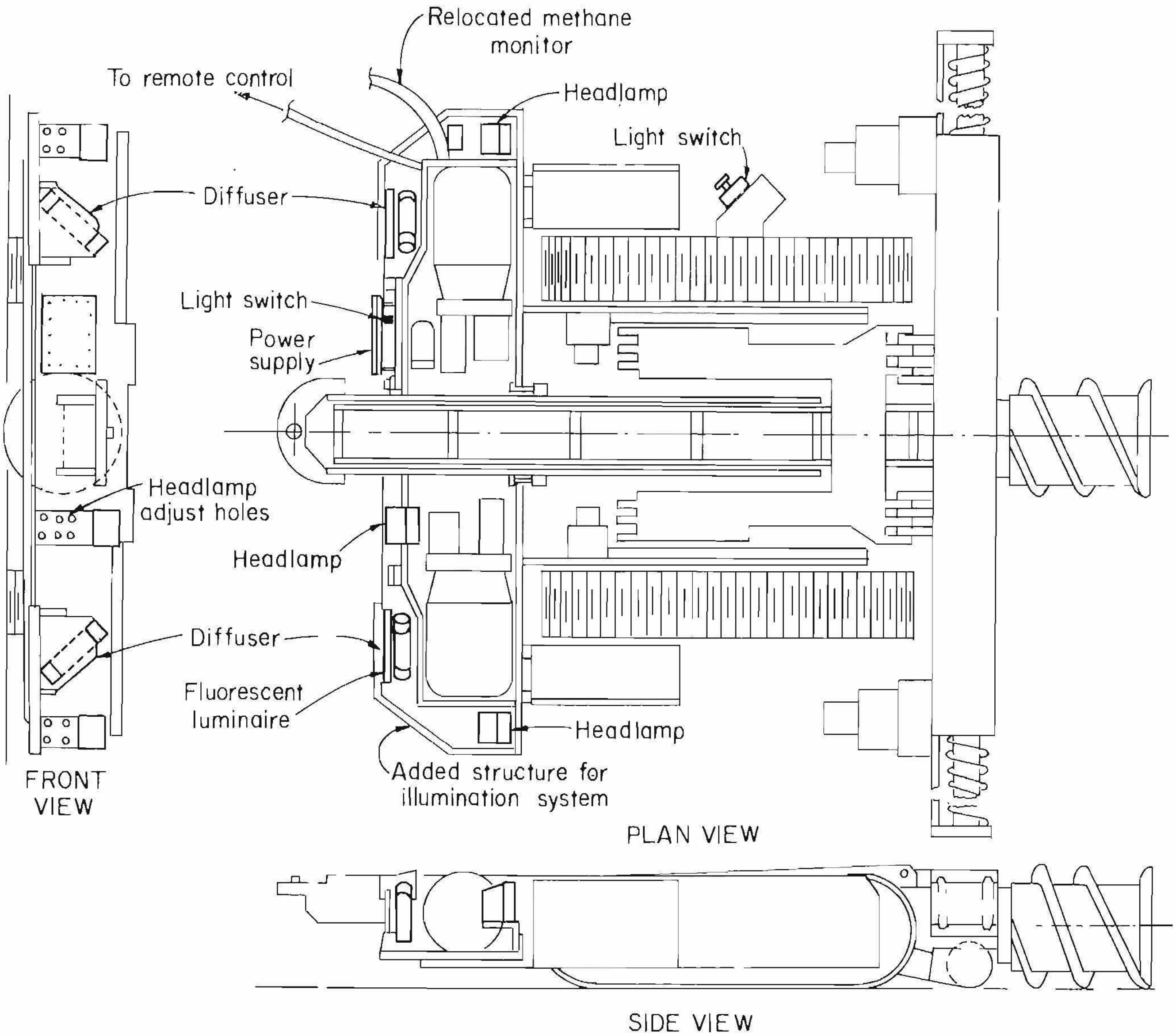


FIGURE 9. - Miniminer illumination system.

Figure 11 gives an interior view of the EMTA, Building 151. The simulated workings shown are constructed of fiberglass panels situated on a compacted clay floor and represent two entries with three crosscuts. The entries and crosscuts are 20 ft wide, the pillars are 48 by 48 ft; and the roof height is adjustable in 2-ft increments from 2 to 10 ft.

Because the miniminer system was designed for use in low-coal seams and it mines 18-ft-wide entries exclusively, the normal geometry of the simulated underground workings had to be modified for the testing. Figure 12 shows those portions of the simulated workings that were narrowed to an 18-ft width. This was accomplished by constructing 2-ft-wide false ribs with 2- by 4-in lumber covered with lightweight black cloth. A 40-in-high false roof was added by stretching black cloth over wires running across the narrowed entries and crosscuts. Also, because of a claim by 4M that the miniminer system could utilize rib posting as part of roof support systems, wooden posts were erected in a portion of the modified room-and-pillar workings. The posting reduced the

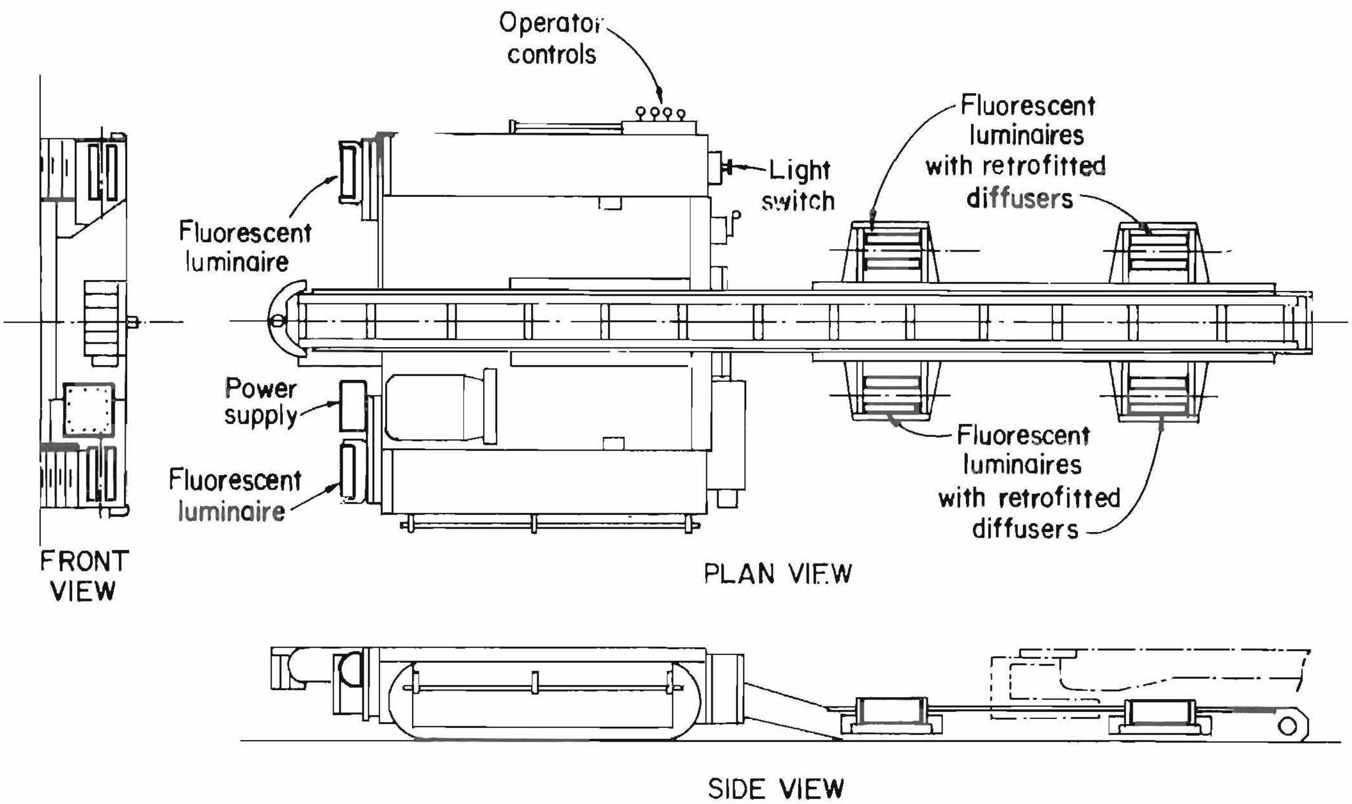


FIGURE 10. - Mobile bridge carrier illumination system.

effective entry width to 14 ft and was used to test the ability of the mining system to maneuver in such a narrow span. Figure 13 shows a cross-sectional view of the modified simulated workings with the false rib, roof, and posting in place.

Prior to the actual maneuverability evaluation, 4 hour meters and 20 hydraulic pressure taps were installed on the mining equipment. Two of the hour meters were installed on the miniminer: one to record the total time the miner was energized and one to record the operating time of the cutting head. Another hour meter was installed on the mobile-bridge carrier and the fourth meter was installed on the crossover dump. These meters recorded the total times that the units were energized. All the hour meters recorded elapsed time to the nearest 0.1 h.

Hydraulic pressure taps were installed at selected points within the mining system's hydraulic circuits for the purpose of simplifying the diagnosis of malfunctions. Twelve taps were installed on the miner, four were installed on the mobile bridge carrier, and four were installed on the crossover dump. Appendix B describes the locations of the hydraulic taps.

The hydraulic taps were installed by drilling and tapping into fittings or connecting to "tees" placed in the hydraulic lines. A precision 0- to 2,000-psig pressure gage outfitted with a special probe was used to take the hydraulic pressure readings. A reading was made by inserting the probe into a tap, which allowed pressure to be transferred to the gage with a minimal loss of fluid. Prior to taking any pressure readings, the hydraulic oil tanks of the motorized units were filled to capacity. The measured hydraulic pressure values are given in appendix B.

In an area outside the simulated room-and-pillar workings of the EMTA, baseline

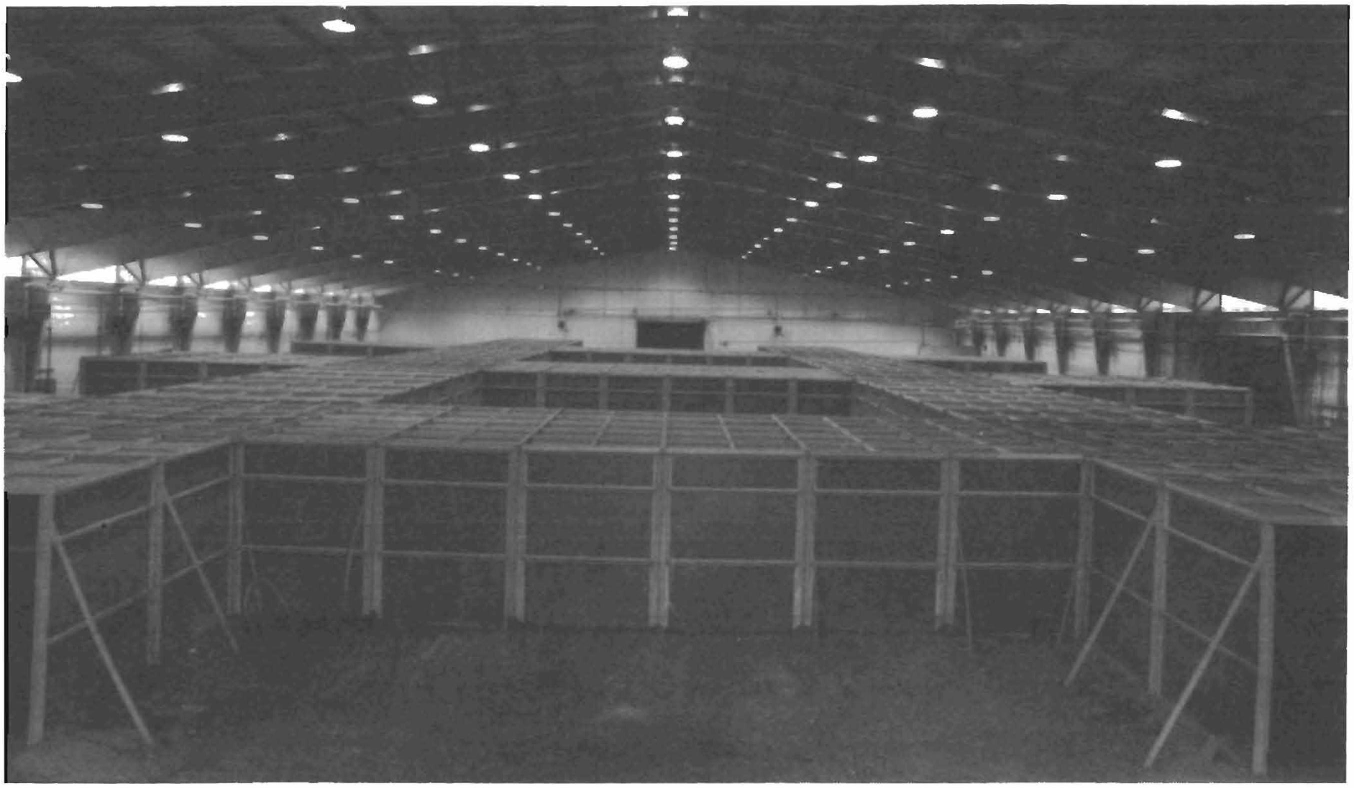


FIGURE 11. - Interior view of the Equipment Maneuverability Trials Area.

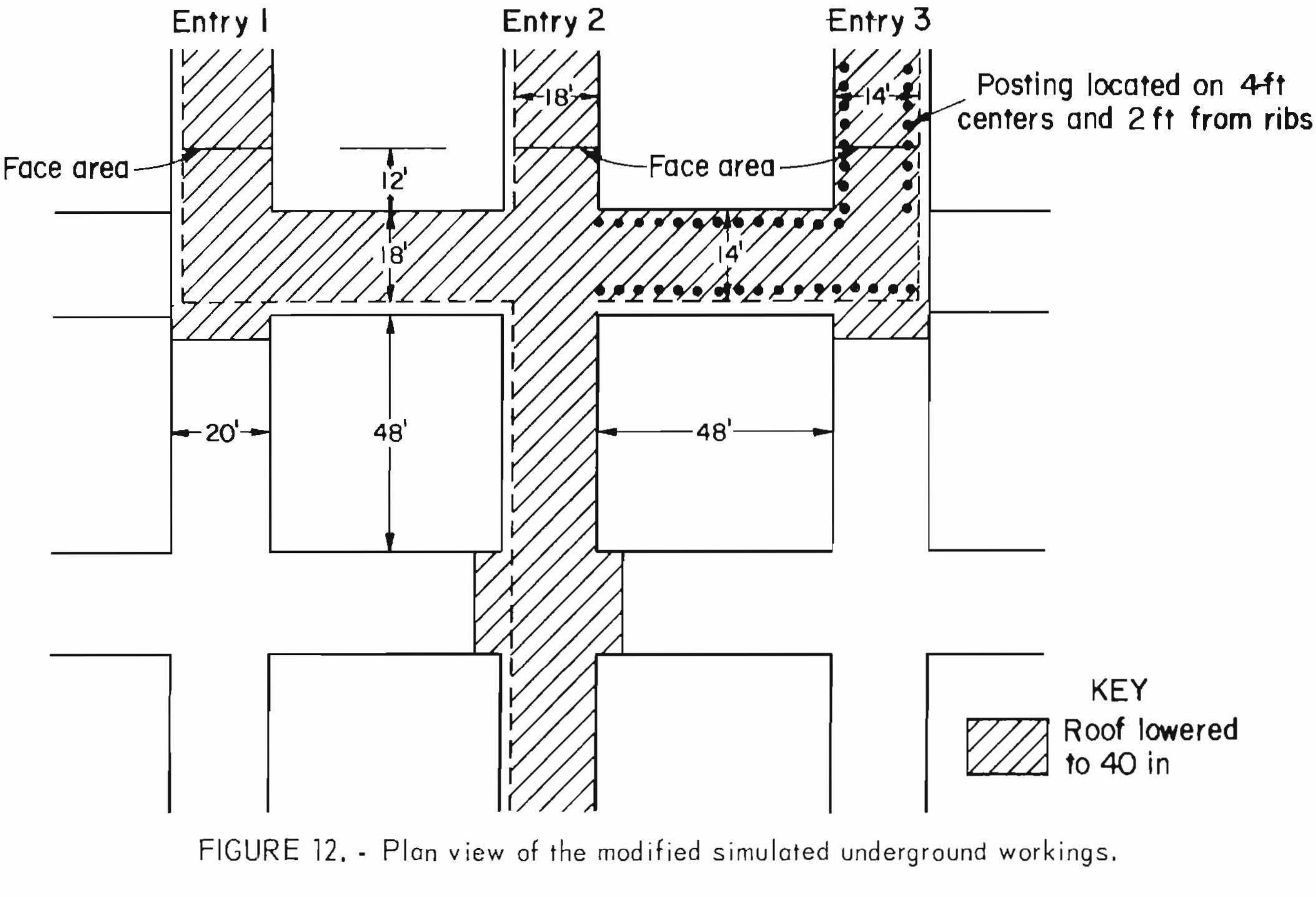


FIGURE 12. - Plan view of the modified simulated underground workings.

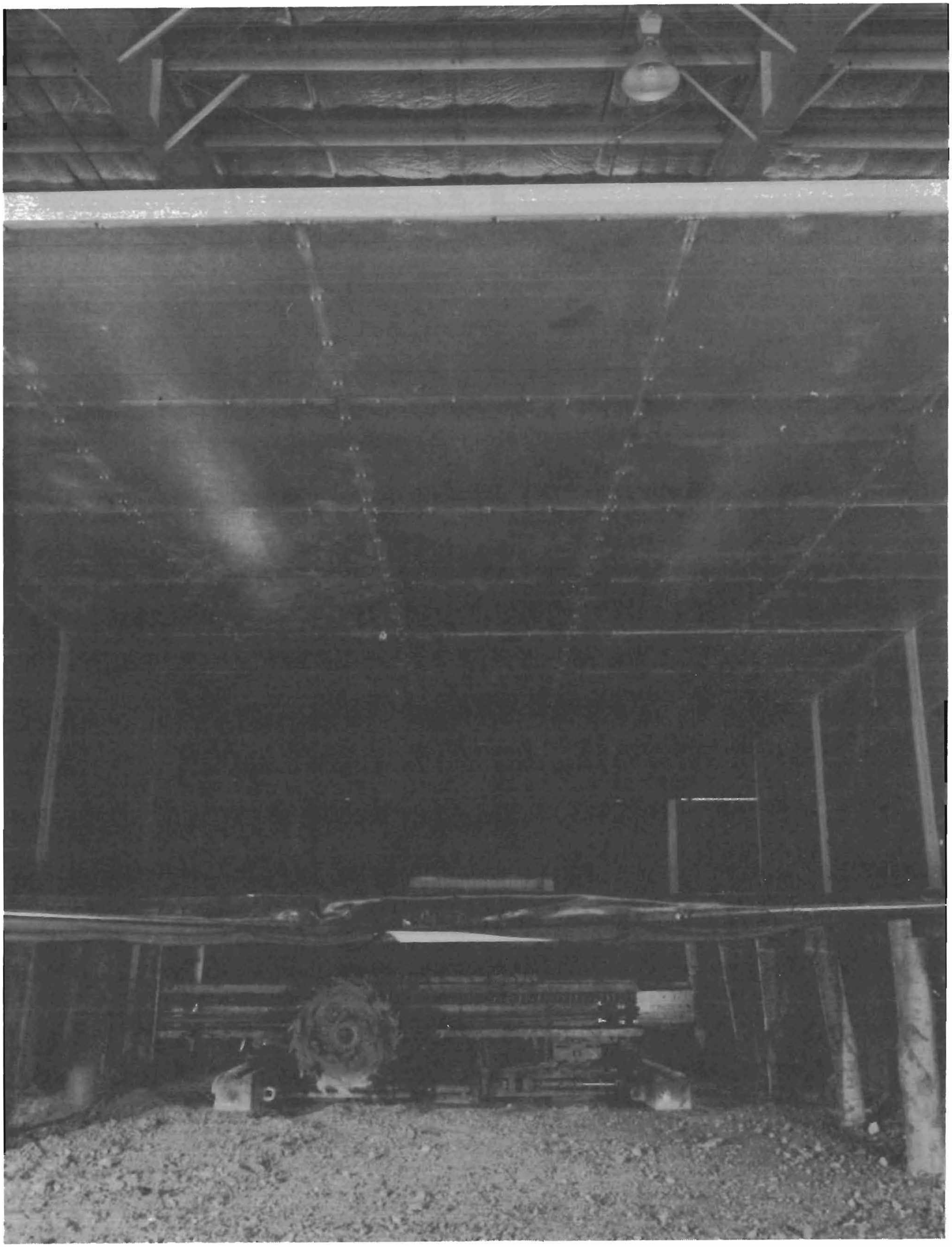


FIGURE 13. - Cross-sectional view of the modified simulated underground workings.

measurements were made of the various cutting, tramming, and material transport functions. These measurements were made primarily to serve as a reference with which the test data could be compared for a gross judgment of acceptability. Tramming rates were determined as each uncoupled unit was trammed for a distance of 50 ft on the compacted clay floor. Subsystem velocity values for the conveyor systems, the gathering augers, etc., were calculated as an average of three trials. The baseline measurements are presented in table 1, and were consistent with the specifications supplied by the manufacturer (appendix A).

MANEUVERABILITY EVALUATION

The maneuverability evaluation established the following positive factors for the miniminer system: the mining system is highly maneuverable, the miniminer can be readily positioned to cut 90° breakthroughs, the mining system can be trammed through entries and crosscuts at an average rate of 14 fpm and the design of the miniminer system should allow both extraordinary ability and flexibility in the area of roof support. The major negative factor uncovered during this portion of the surface evaluation was that the mobile bridge carrier operator is placed in both an inefficient and sometimes hazardous position when tramming.

The miniminer system was installed in the modified simulated room-and-pillar workings of the EMTA so that it could be

TABLE 1. - Baseline measurements

Miniminer:	
Tram rate forward, fpm:	
High...........................	32
Low............................	9
Tram rate reverse, fpm:	
High...........................	31
Low............................	9
Chain conveyor rate..........fpm..	138
Auger rate...................rpm..	198
Head feed, left to right.......s..	139
Head feed, right to left.......s..	140
Head raise time................s..	16
Cutterhead rate..............rpm..	75
Mobile bridge carrier:	
Tram rate forward............fpm..	32
Tram rate reverse............fpm..	28
Chain conveyor rate..........fpm..	150
Crossover dump:	
Chain conveyor rate..........fpm..	158
Advance rate for panline.....s/c..	20

maneuvered into the configurations shown in figures 14 through 17. The outby end of the panline was allowed to extend out of the building, through an available garage door, so that the mining system could be retreated intact into entry 2.

Subsequent to the installation of the miniminer system in EMTA, training of the equipment operators commenced. Immediately, the practical utility of the surface test facility was proven when severe problems were encountered in trying to maneuver the mining system inby, toward the face area of entries 1 and 3. Referring back to figures 14, 15, and 17, the ~~problem was that when the powered articu-~~ lation point between the double outby bridges was trammed from the retreated position into the vicinity of the crosscut of entry 2, the outby dolly would derail from the panline. At first, it was suspected that this condition was due to the inexperience of the mobile bridge carrier operator, who controls the positions of the bridges and the angle of articulation between them. However, when repeated methodical attempts produced no successes, the fault was correctly placed on the equipment. The apparent cause of the problem was that the dolly lacked sufficient mass against which to react the considerable forces developed at the powered articulation point. Figure 18 shows the powered articulation point, which is controlled from a lever at the mobile bridge carrier operator's position. Figure 19 shows the outby dolly on the brink of disengaging from the panline.

At this point, the manufacturer was informed of the problem and was asked

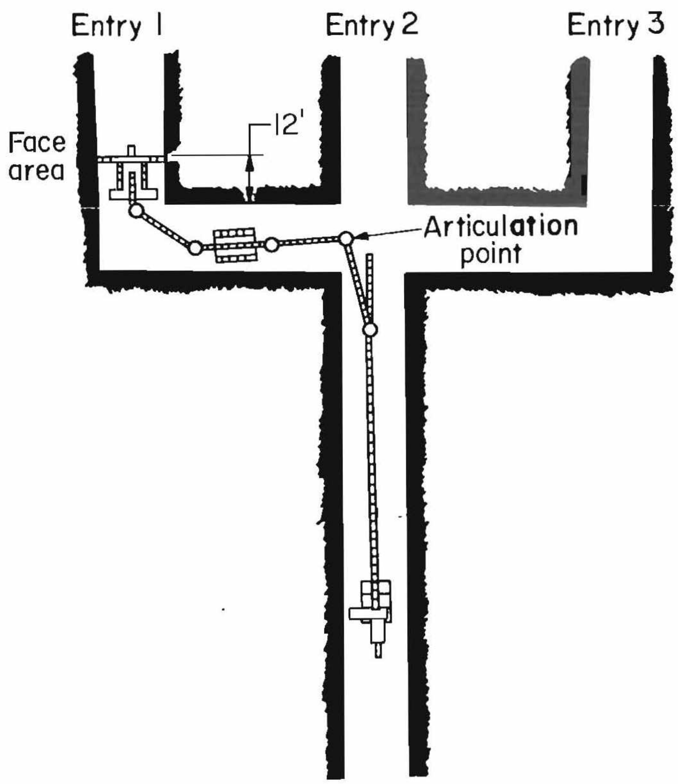


FIGURE 14. - Miniminer system at face area of entry 1.

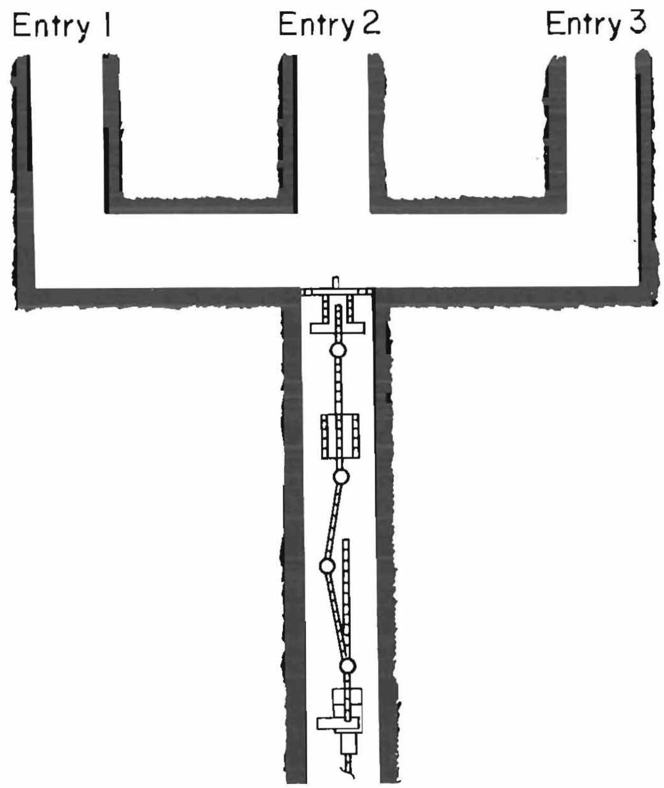


FIGURE 15. - Miniminer system at retreated location of entry 2.

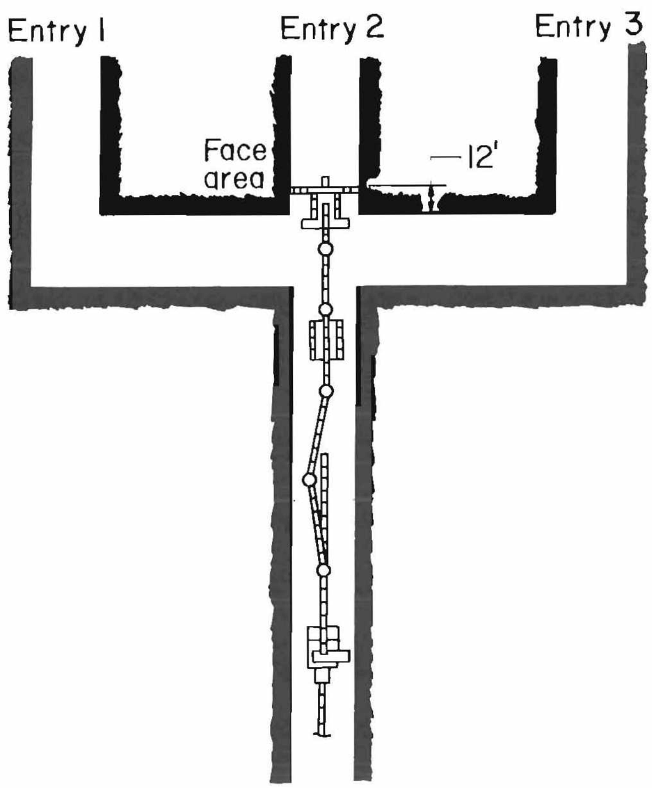


FIGURE 16. - Miniminer system at face area of entry 2.

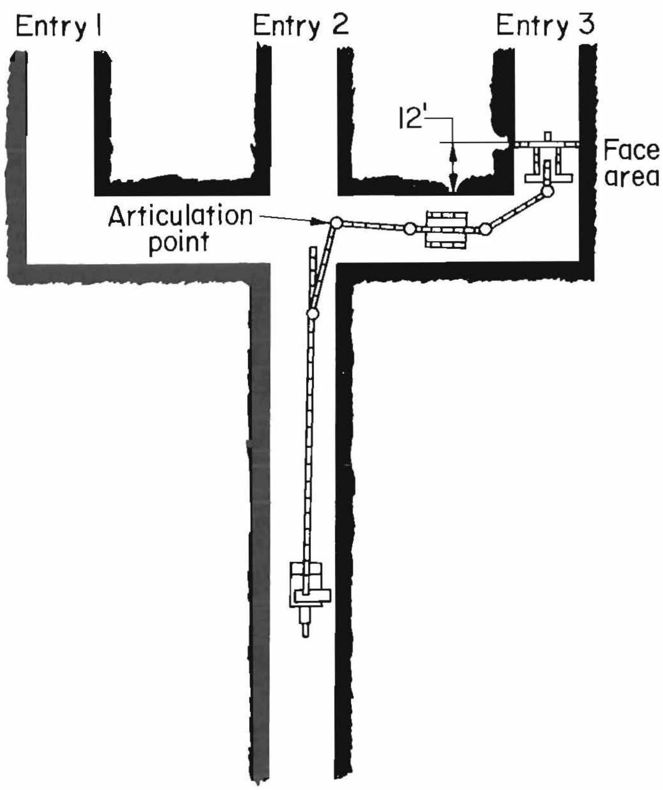


FIGURE 17. - Miniminer system at face area of entry 3.

FIGURE 18. - View of powered articulation point.

FIGURE 19. - View of panline dolly.

to come to Bruceton (PA) to observe a firsthand demonstration. (The manufacturer was also shown a problem with the gathering augers at this time. This is detailed in the "Cutting Evaluation" section.)

Subsequent to the demonstration, 4M reacted quickly and rectified the problem by supplying a new set of bridges, which were exchanged for the old design. The new bridges were approximately 50 pct lighter, due primarily to the elimination of mechanisms for adjusting the tensions in the conveyor chains. The lower weight served to lower the forces necessary to articulate the double bridges and hence the forces reacted onto the panline dolly. The new bridges were slightly angled at their midpoints, which lowered their center of gravity. Though no difficulties were encountered with the forward bridge between the miner and bridge carrier, it was also replaced with a lightened version at that time.

Some relatively minor problems were still encountered with the new bridges in regard to the outby dolly disengaging from the panline. However, the new bridges vastly improved the situation experienced with the older, heavier bridges, and allowed the powered articulation point to be routinely trammed past the intersection of entry 2. The new bridges were used in the rest of the surface evaluation. Figure 20 shows a view of one of the lightened bridges.

FACE-CHANGE TIME TRIALS

During this phase of the testing, the miniminer system was found capable of being trammed through entries and crosscuts at an average rate of 14 fpm. No apparent difficulties were observed when

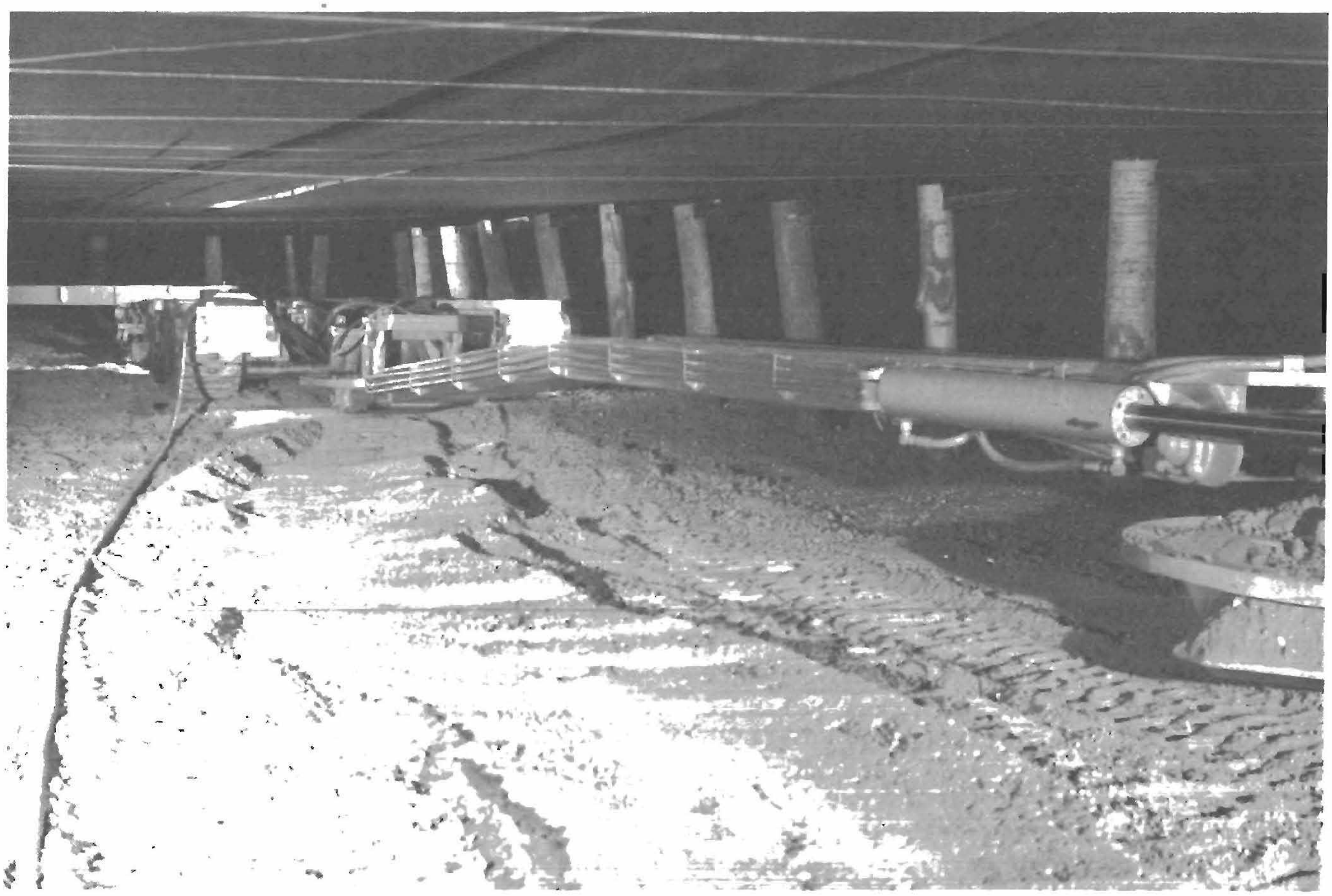


FIGURE 20. - View of lightened bridge conveyor.

tramming through entries reduced to an effective width of 14 ft by rib posting. Operational delays were primarily due to the front and panline dollies becoming untracked.

Place-change time trials were conducted in the modified areas of the simulated room-and-pillar workings to establish an average tramming rate for the mining system being moved from "face-to-face." A learning curve for a "working section crew" maneuvering the miniminer system was also established.

Referring to figures 14 through 17, a "tram cycle" was defined as tramming the connected miniminer system from the face area of entry 1 to the retreated position in entry 2; from the retreated position in entry 2 to the face area of entry 2; from the face area of entry 2 back to the retreated position in entry 2; from the retreated position in entry 2 to the face area of entry 3; from the face area of entry 3 to the retreated position in entry 2; and finally, from the retreated position in entry 2 back to the face area of entry 1. The face area in each entry was designated by a line drawn 12 ft inby the crosscut, which was the maximum extension of the miniminer system into entries 1 and 3. As mentioned previously, the dimensions of the entries and crosscuts were 18 ft wide and 40 in high. Also, rib posting in the crosscut between entries 2 and 3 reduced the effective span to 14 ft.

Time study data were collected for 10 tram cycles. An observer stationed in entry 2 recorded the starting and stopping times during each segment of a tram cycle. (A tram segment is where the equipment was trammed from entry 1 (face) to 2 (retreat), from 2 (retreat) to entry 2 (face), etc.) The observer also recorded the times associated with all delays. Two types of delays were observed: those caused primarily by operator error, defined as operational delays; and those caused by component failure, defined as component delays. The operational delays usually involved the inby or outby dolly becoming untracked and were considered part of the normal data. Delays caused by equipment failure were recorded in regard to duration and cause, but were excluded from the data bank and the subsequent analysis.

The same six-person crew was used during all of the place-change time trials. The functions of the personnel were as follows: miniminer operator, miniminer cable handler, mobile bridge carrier operator, mobile bridge carrier cable handler, crossover dump operator, and mechanic-utility person. The mechanic-utility person was allowed to help correct problems that caused operational delays. The observer stationed in entry 2, however, was not allowed to provide assistance and neither were any other observers of the testing. Commonly used tools such as a 5-ton hydraulic jack, a pry bar, and a crescent wrench were kept on hand in entry 2.

Although initial attempts were made using fewer people, successful tramming of the miniminer system required the following six workers: miniminer operator, miniminer cable handler, mobile bridge carrier operator, mobile bridge carrier cable handler, crossover dump operator, and a section mechanic-utility person. Note that this list does not include a supervisory person (section foreman) and roof bolters. The "section crew" contrasts with the following personnel specified by the manufacturer: section foreman, miniminer operator, two roof bolters, mobile bridge carrier operator, and utility-cleanup person. The crossover dump operator was required because the semiautomatic mechanism for advancing the panline never functioned properly. The cable handlers were necessary when the mining system was being retreated out of a face area. The section mechanic-utility person was required as a "second set of eyes" for the mobile bridge carrier operator whenever the panline dolly was out of the operator's line-of-sight.

The section crew wore knee pads and cap-lamp-equipped hard hats for all of the face-change time trials. The only interior lighting within the test site during the time trials came from the crew's cap lamps and the miniminer's illumination system. Figure 21 is a photograph of the mining system being trammed in the test site; it was staged after the maneuverability evaluation was completed.

The data recorded during the face-change time trials are presented in tables 2 and 3. The average tramming velocity throughout the time trials was 14 fpm. It was calculated by totaling the distance that the miniminer system was trammed during the 10 cycles and dividing by the total time spent in tramming. The highest average velocity for an individual tram segment was 28 fpm, while the slowest was 9 fpm. Combining the minimum times recorded for each tram segment yields a total minimum time of 23 min to traverse the 506-ft-long course involved in a face-change cycle. Conversely, the total of the longest tram segments was 44 min. These times correspond to average velocities of 22 fpm and 11 fpm.

At the 90-pct-confidence level, there was no statistically significant difference between the mean time value calculated for the mining system being trammed

TABLE 2. - Data from face-change time trials

Trial	1981 date of trial	Tram segment						
		1-2R	2R-2	2-2R	2R-3	3-2R	2R-1	Total
		TIME, min						
1........	06/21	[1]10.2	2.9	[1]3.2	6.8	6.7	7.9	37.7
2........	06/25	7.0	[1]3.0	2.8	7.6	[1]10.6	7.8	[1]38.8
3........	06/25	6.4	1.9	2.0	7.4	7.1	[1]9.3	34.1
4........	07/ 1	9.4	2.0	[2]1.1	6.6	9.1	7.8	36.0
5........	07/ 1	8.8	1.7	1.5	[1]7.6	6.7	6.5	32.8
6........	07/ 1	6.2	2.1	1.8	5.8	7.2	[2]5.5	28.6
7........	07/ 1	6.6	2.0	2.2	5.9	8.3	8.2	33.2
8........	07/ 7	5.9	1.6	2.1	6.9	7.7	6.0	30.2
9........	07/ 7	[2]4.9	[2]1.2	1.8	5.8	[2]5.6	6.2	[2]25.5
10........	07/ 8	5.6	1.3	1.5	[2]4.8	7.2	5.7	26.1
Mean....	NAp	7.1	2.0	2.0	6.5	7.6	7.1	32.3
		VELOCITY, fpm						
Mean......	NAp	14	15	15	15	13	14	14
Minimum...	NAp	10	10	9	13	9	11	NAp
Maximum...	NAp	20	25	28	20	17	18	NAp

NAp Not applicable. [1]Maximum. [2]Minimum.

TABLE 3. - Operational delays per time trial

Trial	Velocity, fpm	Time lost, min	From untracked dollies	
			Front	Panline
1....	12	22.7	1	2
2....	12	4.1	0	0
3....	13	16.0	0	2
4....	12	13.3	1	1
5....	14	14.7	0	4
6....	16	7.0	1	0
7....	14	2.7	0	0
8....	15	3.3	0	0
9....	18	0	0	0
10....	17	0	0	0
Mean	14	8.4	NAp	NAp

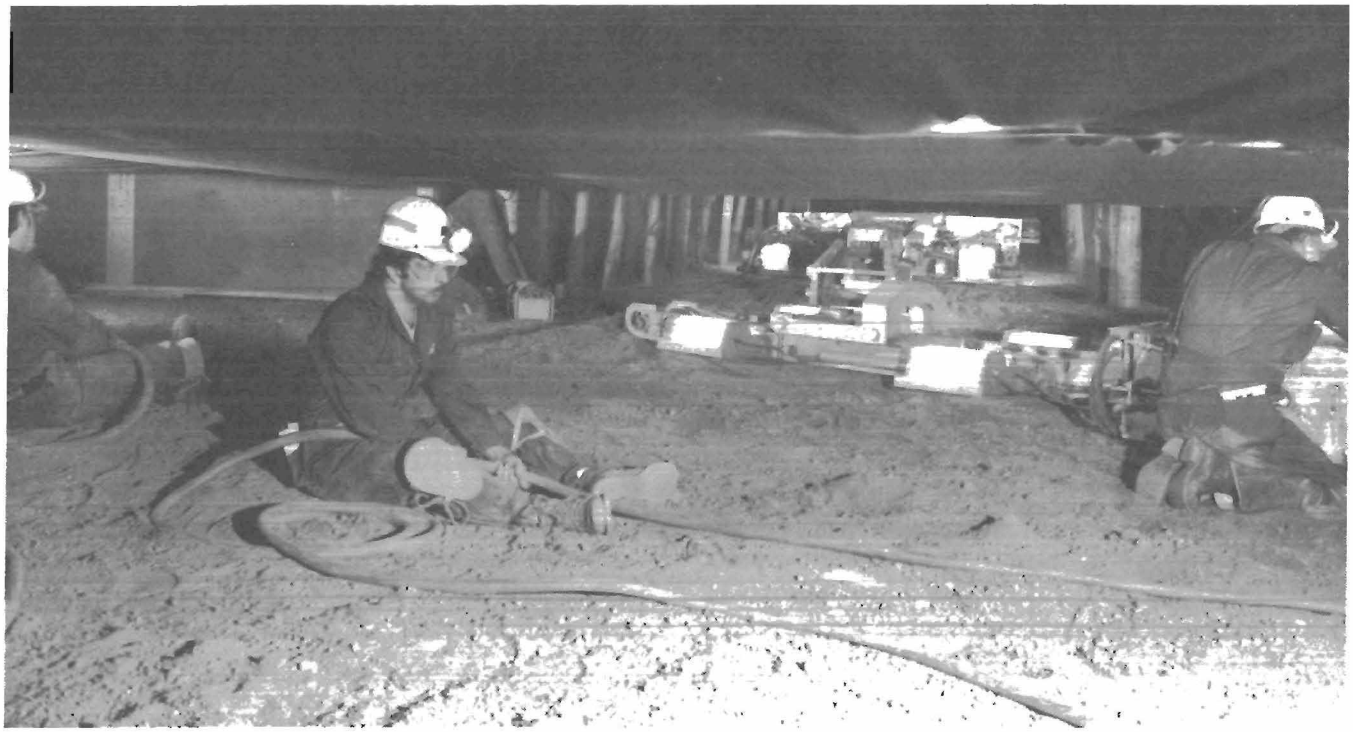


FIGURE 21. - View of miniminer system being trammed.

from entry 2 (retreat) to entry 1 (face) and the mean time value calculated for the place-change segment entry 2 (retreat) to entry 3 (face). This also holds true for the mean time values calculated for place-change segments entry 1 (face) to entry 2 (retreat) and entry 3 (face) to entry 2 (retreat). In other words, the miniminer system seemed capable of being trammed through an entry posted to an effective width of 14 ft as readily as being trammed through an 18-ft wide entry. The statistical calculations are given in appendix C.

In total, the inby and outby dollies became unattached 12 times during the 10 face-change time cycles. When the outby dolly became unattached, which happened nine times, it took approximately 4 min to retrack it. When the inby dolly became unattached, it took approximately 8 min to correct the situation. (Additional details are given in appendix D.)

Figure 22 presents a graph of the recorded time values plotted against the trial number progression. Both the total time per face-change cycle and the sequence of total times for operational delays are graphed. As expected, both plots show the learning curves experienced by the test personnel as they discovered the fine points of maneuvering the miniminer system. Using the method of least squares, linear regression curves were calculated for both plots and are also shown. Both of the time versus trial-number functions, T1 and T2, show very high, negative, linear correlations, r_1 and r_2, that serve to bolster the adage that "practice makes perfect."

FACE-CHANGE TIME TRIALS DISCUSSION

The simulated pillars used in the face-change trials were located on 68-ft centers and are not considered typical of a low-seam coal mining plan where the miniminer system is likely to be used. Assuming that typical low-seam pillars would be square and located on 54-ft centers (50 pct extraction ratio), one dolly would untrack and cause a 5-min operational delay; tramming velocities would range to the extremes recorded in the testing, 9 to 28 fpm; and face areas

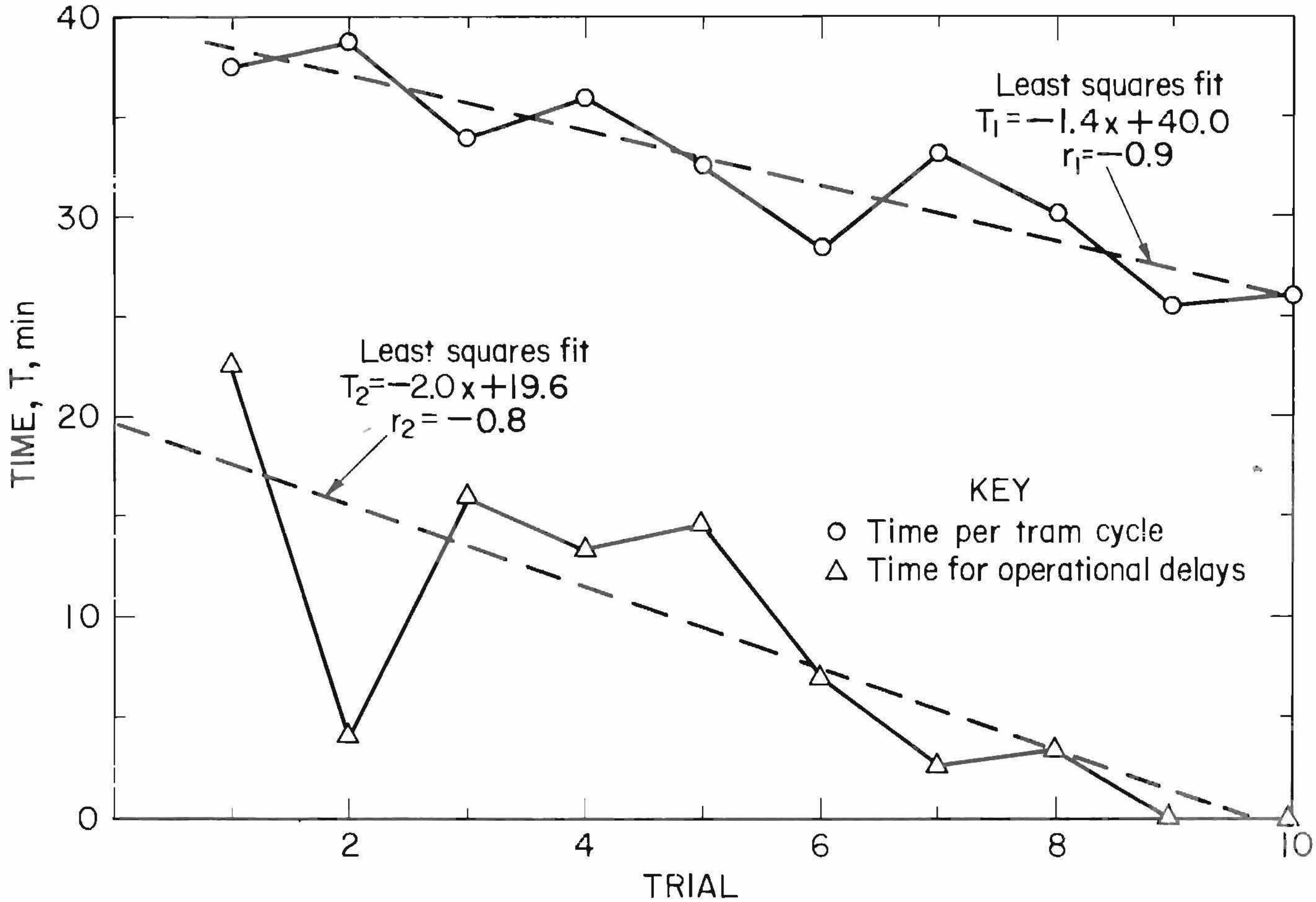


FIGURE 22. - Plots of time values versus trial progression.

would be located 12 ft inby the last open crosscuts, the miniminer system could be expected to be trammed from face to adjacent face in 16 to 8 min. Further assuming that the equipment operators are experienced and no operational delays occur, as with face-change cycles 9 and 10, the face-change times would range from 11 to 3 min. All these times are respectable, even for individual pieces of equipment. When considering that the miniminer system consists of connected pieces of equipment and that the values consider tramming through 14-ft-wide posted entries, the times verge on being exceptional.

POSITIONING ABILITY

It was determined that the miniminer system, while connected to its continuous haulage system, is easily capable of turning 90° crosscuts while confined within 18-ft-wide entries. Figures 23, 24, and 25 are photographs taken while both the miniminer and camera were situated in the "face area" of entry 2. The setup is illustrated in figure 26. Starting with the longitudinal axis of the miner coincident with the longitudinal axis of the entry (fig. 23), the miniminer was maneuvered 90° clockwise (fig. 24), and then 180° counterclockwise to the position shown in figure 25. This entire maneuver was executed in approximately 3 min. The miniminer system was judged capable of turning 90° crosscuts at any location within the modified simulated underground workings.

POSITIONING ABILITY DISCUSSION

The ability of the miniminer system to turn true 90° crosscuts is very advantageous to roof support. Ninety degree crosscuts reduce the effective roof spans

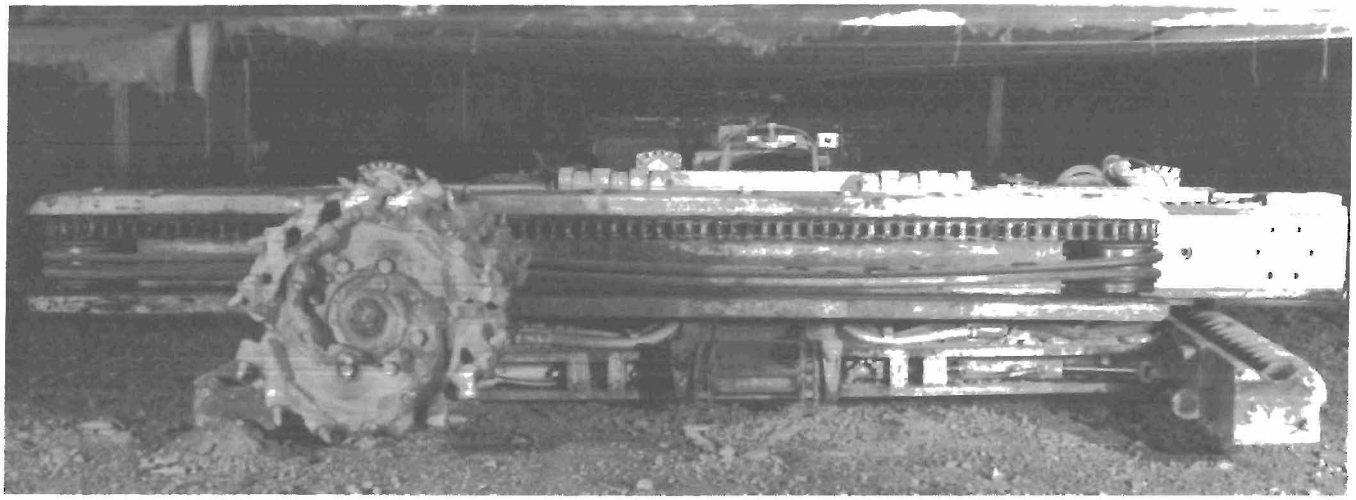


FIGURE 23. - View of miniminer coincident with longitudinal axis of entry 2.

FIGURE 24. - View of miniminer turned 90° clockwise.

FIGURE 25. - View of miniminer turned 90° counterclockwise.

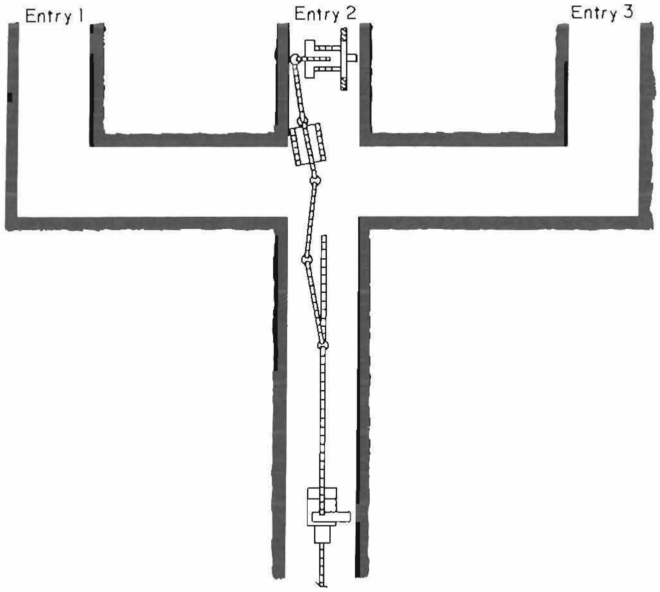


FIGURE 26. - Setup for positioning testing.

at intersections, reducing the bending stresses to which the roof strata are subjected.

HUMAN FACTORS EVALUATION

During this phase of testing, a significant safety hazard was identified for the operator of the mobile bridge carrier during tramming. The operator of the miniminer, on the other hand, was found to be relatively safe and lightly occupied when maneuvering the machine. Several additional minor hazards were also identified.

The human factors evaluation of the miniminer system was primarily concerned with the identification of significant potential safety hazards to workers engaged in tramming the mining system. The procedure used was to videotape the miniminer operator, the bridge carrier operator, and the two cable handlers during the execution of a tram cycle. Each tape was then reviewed for safety hazards and was also retained as a permanent record.

The miniminer and bridge carrier operators and the cable handlers were found to be exposed to the same varieties of safety hazards as are section workers of any other continuous miner with a connected haulage system. As in other such systems, articulation points, of which the miniminer system has five, are potential "pinch points" to the workers. In contrast with other continuous haulage systems, however, the reduced widths and lengths of the miniminer, the bridge carrier, and the bridge conveyors leave much more free space in the entries. This could contribute to a comparatively safer work section for the miniminer system in regard to workers being exposed to pinch points or being squeezed by the machinery.

Though not mentioned in the manufacturer's literature on suggested typical working section crews, trailing cable handlers were required for both the miner and the bridge carrier when the mining system was being trammed. Though lightly taxed when the miniminer system was being trammed inby, the cable handlers were busy and very necessary when the system was being trammed outby. Not surprisingly, these cable handlers were subjected to the electrical shock and tripping hazards associated with the job.

Due very much to the controls being on a 20-ft-long umbilical cord extending from the miner, the miniminer operator was found to be relatively safe and lightly occupied during the tramming operation. In fact, after the operator gained experience, position change was required only after the miner was trammed approximately 35 ft in a given direction.

The primary potential safety hazard identified involves the bridge carrier operator. Also, it appeared too much was expected of this operator because he or she must watch for safety hazards while crawling beside the machine when tramming. The major concern is that when the mining system is turning right (in the convention of the time trials, going from the retreated position of entry 2 to the face area of entry 3), the operator is forced next to a rib of the entry from which the turn is being executed. This situation is shown in figure 27. Here the operator is exposed to a potential crushing hazard that could be caused by a rib roll or inadvertent activation of the

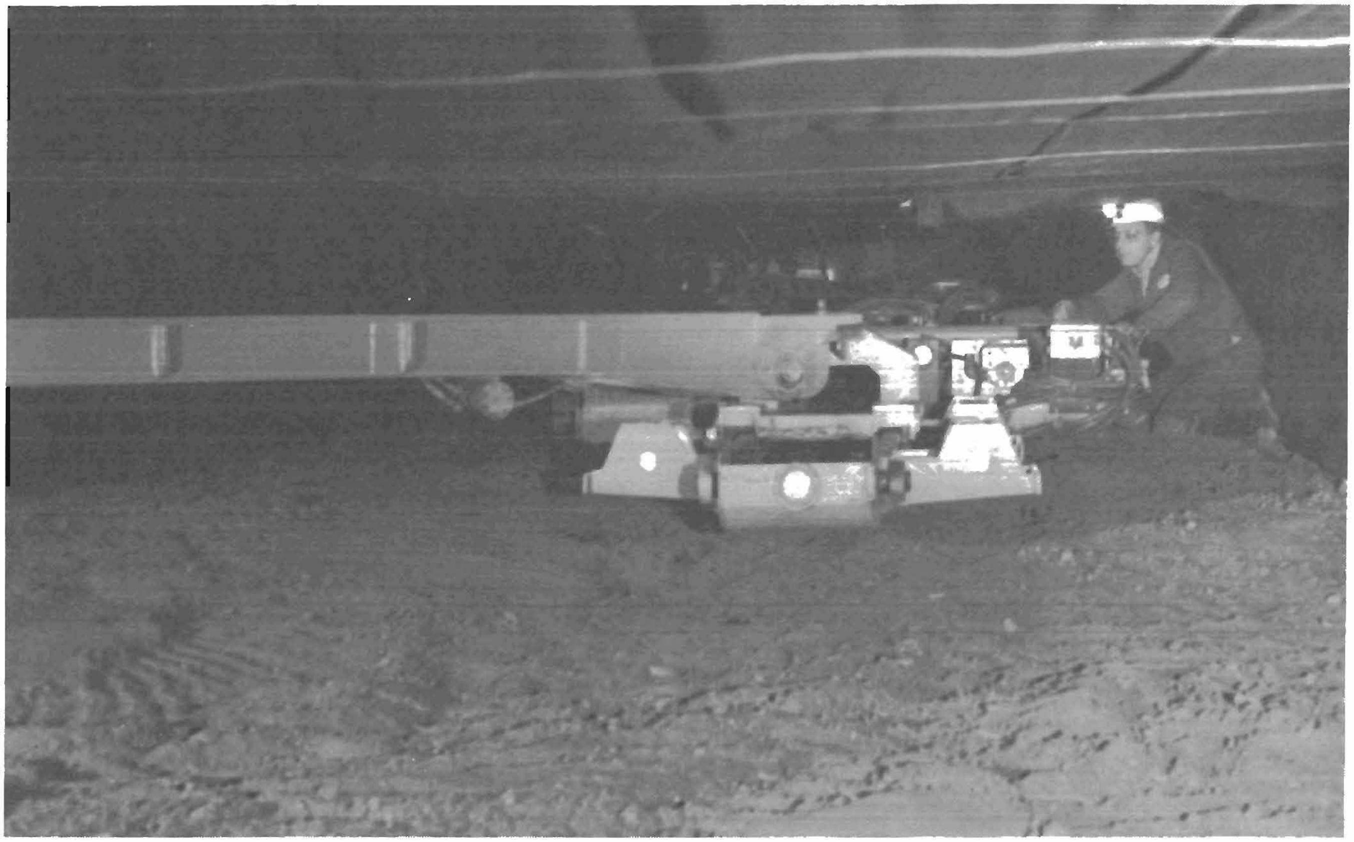


FIGURE 27. - Position of the mobile bridge carrier operator during execution of a right-hand turn.

tram controls. Additionally, the operating position is very awkward and inefficient, especially since the operator must periodically (approximately every 10 s) observe the events happening both to the rear and forward of the machine. This observation is quite difficult to accomplish given the fact that the operator must crawl along with the machine and its controls. Also, as will be detailed shortly, the bridge carrier operator is expected to initiate the advance or retreat of the panline. This only compounds his or her already overly-busy routine.

The recommended solution to the above problems is for the bridge carrier to be operated remotely, from controls placed on an umbilical cord, in the same manner as was done with the miner's controls. Additional positive reasons for doing this follow.

HUMAN FACTOR RELATED CONSIDERATIONS DISCUSSION

The manufacturer obviously used a great deal of effort in coming up with a complicated, electromechanical system for semiautomatically initiating the advance or retreat of the panline when the mining system is being trammed. The system relies on two sets of magnetic switches located on a panline section adjacent to the inby end section of the panline. These switches are hard-wired to solenoid valves that actuate complex hydraulic circuits for advancing or retreating the panline. The switches are intended to be triggered by a set of magnets located on the bottom side of the wheeled panline dolly. When the magnets pass over the inby magnetic switch, the panline is to be automatically advanced one panline section length, 8 ft. When the magnets pass over the outby magnetic switch, the panline is to be retreated the length of one panline section.

Although the above seems a very good idea, the electrical and hydraulic switching circuitry never functioned properly throughout the maneuverability evaluation. This necessitated that the advance or retreat of the panline be done manually by a crossover dump operator. Even assuming that the electrical and hydraulic switching circuit would work perfectly, there still exists a major problem with the system: the already overly-busy bridge carrier operator is expected to be able to position the panline dolly over the correct magnetic switch to initiate the inby or outby motion of the panline. Unfortunately, the operator cannot even see the dolly after the bridge carrier has turned through a crosscut. During the maneuverability evaluation, the mechanic-utility person was used as an extra set of eyes when the mining system was turning a crosscut. He informed the bridge carrier operator on the status of the panline dolly and offered advice on what tramming motion or what actuation of the articulation ram would prevent the dolly from untracking.

Two remedies are suggested for the problem described: The manual advance-retreat controls of the crossover dump be extended up the panline to where an observer (section mechanic, foreman, etc.) could initiate panline motion; or, the umbilical cord for the recommended relocation of the bridge carrier's controls be made long enough to enable the operator to see the panline dolly.

COMPATIBILITY OF MINIMINER SYSTEM WITH ROOF SUPPORT CONSIDERATIONS

During the maneuverability evaluation, consideration was given as to what roof support elements and/or systems are compatible with the miniminer system's design. It was determined that the mining system should allow both extraordinary ability and flexibility in the general area of roof support. Its compatibility with a broad range of roof support hardware, techniques, and practices should give the miniminer system significant roof control advantages over other existing low-coal mining machines and mining systems.

As mentioned previously, the miniminer system can be maneuvered rather easily through 18-ft-wide entries where the effective roof span has been narrowed to 14 ft by rib posting. For these dimensions, elementary stress calculations show that posting could reduce the maximum bending and shearing stresses experienced by roof strata by up to 23 pct and 13 pct, respectively. Because it appeared likely that the mining system could be maneuvered through entries, but not necessarily intersections, where rib posting would have been placed closer than 14 ft apart, such support could further reduce the stresses experienced by the mine roof.

Although a very old means of roof support, posting or timbering offers several advantages over more modern roof support hardware: timbers are relatively inexpensive; no special equipment is needed for installation; the axially loaded or unloaded nature of a post can be simply determined by tapping on the member; and reliable visual and aural signals are usually given prior to compressive failure. Posting, in general, and rib posting, in particular, are considered excellent means of roof support for use with the miniminer system. This statement is given further emphasis when considering, as will be detailed, that the design of the miniminer system should allow the final placement of rib posting close to the working face.

With the exception of the gathering augers and the cutting head slide-bar feed mechanism, the miniminer measures 10 ft across when mining. Also, by design, the miner is situated in the center of the entry when mining. These factors produce 4-ft-wide open areas on both sides of the miner, between the machine and the ribs. The open areas start approximately 4 ft back from the most inby extension of the cutting head and extend for approximately 10 ft along the remaining length of the miner. These areas are ideally suited for the placement of temporary roof supports or rib posting initially used as temporary support, but left behind permanently.

When the miniminer is cutting coal, the forward bridge conveyor, approximately 14 ft back from the face, runs from the miner's tail boom back to the bridge carrier. Both the miner and the 12-in-wide bridge conveyor are normally situated in the center of the entry. This situation leaves open areas between the ribs and the sides of the bridge conveyor that are approximately 8 ft in width and from 10 to 14 ft in length (the length depends upon the location of the dolly on the cantilevered receiving section of the bridge carrier). These areas are suited to allow roof bolting to take place simultaneously with the extraction and haulage of coal. Thus, "truly continous mining" is a definite possibility for the miniminer system. (It is assumed that sufficient space exists to utilize standard ventilation equipment and techniques.) Although no self-propelled roof bolters are presently available with dimensions that would allow their use in the open areas, 4M has completed the design of such a bolter.

A quick search of available bolting equipment produced a small, manually propelled, hydraulically powered, roof drill-bolter, manufactured in Great Britain, that would easily fit in the open areas between the miner, the ribs, and the bridge carrier. This roof drill-bolter could provide the miniminer system with the present-day capability of truly continuous mining. Figure 28 is a staged photograph showing the open areas both to the sides and behind the miner. Here, roof bolting personnel and the miniminer operator are shown, along with some temporary supports and "mockup fabrications" of the British roof drill-bolter and the bolters control modules.

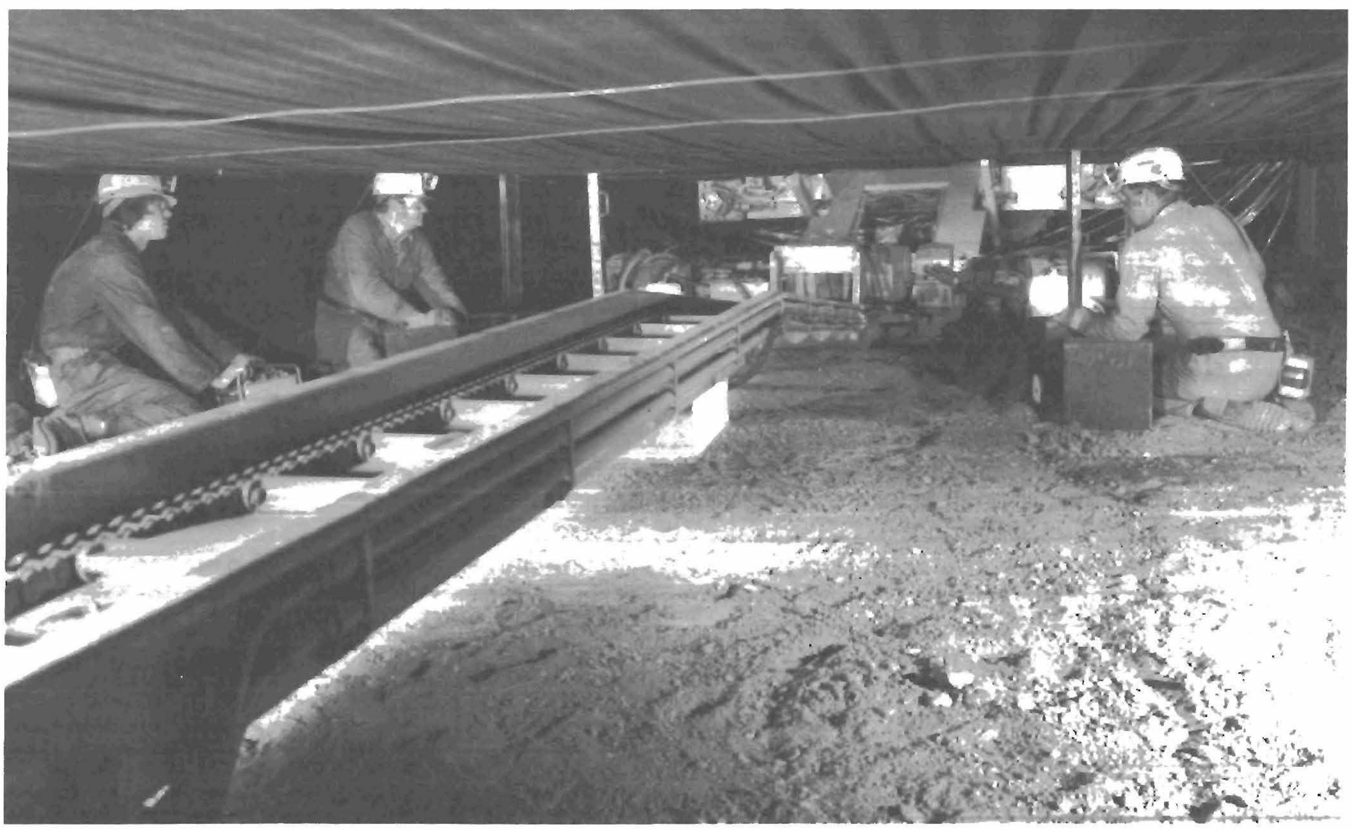


FIGURE 28. - View of open areas behind miniminer allowing for roof bolting.

OTHER CONSIDERATIONS

Two major and several minor downtime periods were experienced during the maneuverability evaluation. The major downtime periods were caused by failures of grease-filled ram cylinders used to adjust the track tension of the miner and the failure of the miner's left-side tram motor. Additional details on equipment failure and modifications during this portion of the surface evaluation are presented in appendix E.

SUMMARY OF RESULTS FOR MANEUVERABILITY EVALUATION

The results of the maneuverability evaluation were primarily positive. The mining system is extremely maneuverable. This, coupled with its low profile, could allow the miniminer system to be used where geometric or other (economic) considerations exclude other mining equipment. Such would be the case in coal seams that would cause longer continuous miners and haulage equipment to pitch from end to end and strike the roof and/or floor. It would also be the case where geology causes coal seams to thin sporadically and continuous miners with less maneuverability would have to cut high percentages of rock.

It was established that experienced operators can tram the mining system from face to face at an average rate of approximately 14 fpm. For pillar sizes commonly used in low-coal mining situations, the miniminer system is capable of being moved from face to adjoining face in 4 to 11 min.

The miniminer system should allow great flexibility in the general area of roof support. The mining system has the capabilities to (1) cut true 90° crosscuts that minimize the effective roof spans at intersections, (2) allow placement of timbers or temporary supports within 5 ft of the face, and (3) maneuver through entries where the effective roof spans have been reduced by rib posting. Moreover, the miniminer system appears uniquely capable of allowing the installation of roof bolts within 15 ft of the working face. This holds true for both planned bolting machines and existing, but manually propelled, portable hydraulic bolters. Coupled with its continuous haulage system, the mining system could thus be capable of truly continuous mining.

On the negative side, a primary safety concern was identified for the bridge carrier operator when the mining system is making a right turn. In this situation, the operator is left exposed to a potential crushing hazard brought on by his or her proximity to a rib of the entry from which the turn is being executed. Other, more minor negative findings were that (1) pinch points exist at the articulation points along the continuous haulage system, (2) the automatic initiation of the advance or retreat of the panline does not function properly in its present form, and (3) an observer was required to watch and convey information to the bridge carrier operator on the status of the panline dolly whenever the operator was out of the line-of-sight of the dolly.

As explained earlier, several of the negative factors could be corrected by placing the mobile bridge carrier operator controls on an umbilical cord.

CUTTING EVALUATION

The data collected during the cutting evaluation established the following positive factors for the miniminer system: the miniminer was capable of precision cutting and was rather easily controlled by the miner operator; the measured dust and noise generation levels were low; the miniminer was capable of cutting on an oblique angle to the face, as would be done in pillar mining; and the measured spillage along the haulage system was rather low.

The major following negative factors were uncovered: the observed cutting rates were low, and averaged 0.4 tpm; the observed coal loading rates were low, and ranged from 0.4 to 1.2 tpm; the reliability of the overall system was found to be low, with the equipment being in an "available status" on a 52-pct basis; the gathering augers would often unlock from their operating position during loading; and the haulage system appeared underpowered and would often jam under load.

Some, but not all, of the negative findings were at least partially influenced by the physical properties of the artificial coal used in the testing. Also, some negative findings were deemed the result of the mining system being in the preproduction prototype stage and could be corrected by the manufacturer through moderate effort.

PREPARATION FOR THE CUTTING EVALUATION

The cutting evaluation was conducted in the Cutting Trials Area (CTA), Building 152, and required a block of simulated coal devoted to the project. Figure 29 shows an interior view of the CTA with the coal block in place. The block was 30 ft wide by 40 ft long by 50 in high and was cast during the time that the preparation for the maneuverability evaluation was taking place. As shown, the simulated coal block was situated in the center of the CTA, adjacent to a larger block of the same material.

The composition of the simulated coal was specified to be the same as that used by the U.S. Department of Energy (DOE) in previously performed testing of longwall shearers. This was done in hopes of being able to correlate the data from the miniminer system testing with some of the previously obtained data. The composition of the simulated coal was as follows, in parts per volume: 1.5- to 2-in lump bituminous coal, 10; fly ash, 8; cement, 1; and water, 1.5. The simulated coal block also had a 2-in-thick roof cap that was composed of 6 parts per volume of fly ash, 1 part per volume of cement, and 1 part per volume of water. A closeup view of the simulated coal mixture is shown in figure 30.

Specimens of the simulated coal mixture were tested and showed the following average physical properties: density of 107 pcf, compressive strength of 898 psi, and shear strength of 132 psi.

A Hardgrove grindability index (HGI) was determined for two specimens taken from the coal block. For one sample prepared by crushing several 3-in chunks of the material, an HGI of 62 was obtained. For the other sample, which was prepared by sieving a sample between 590- and 1,190-µm screens, an HGI of 73 was obtained. As a means for comparison, HGI values of from 38 to 109 are listed for 28 random samples of Eastern U.S. coal.[4] Thus, the HGI values of 62 and 73 obtained for the test simulated coal mixture should be considered about average in grindability.

PRELIMINARY CUTTING TRIALS

As was detailed in the "Maneuverability Evaluation" section, 4M was asked to visit the Bruceton test facilities to witness the major problem experienced in trying to tram the powered articulation point through the intersection of entry 2 in EMTA. During this same general time period, preliminary cutting trials were conducted in the CTA. The primary purpose for conducting cutting trials at this time was to determine if any gross equipment problems existed with the miniminer cutting coal. Thus, the manufacturer could be made aware of such problems and be able to implement corrections in time to be included in the surface testing.

[4]American Institute of Mining, Metallurgical, and Petroleum Engineers. Coal Preparation, 1968, pp. 56-57.

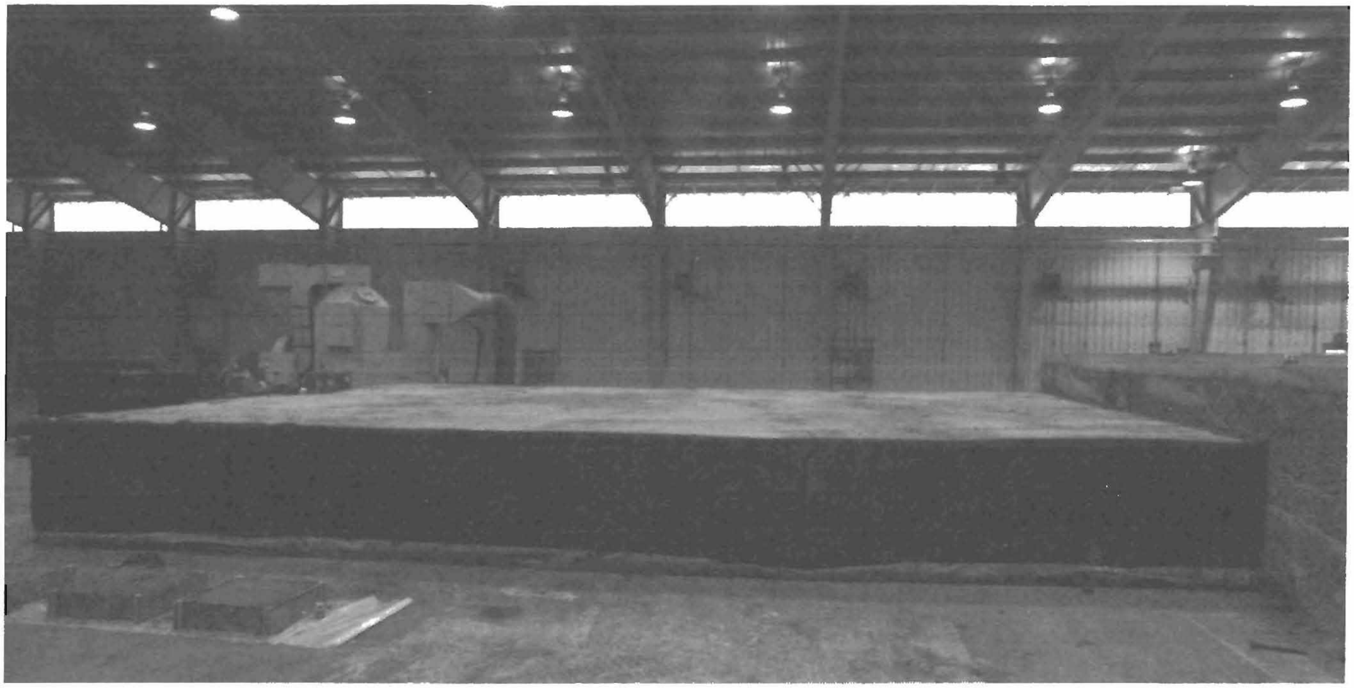


FIGURE 29. - Interior view of Cutting Trials Area with simulated coal block in place.

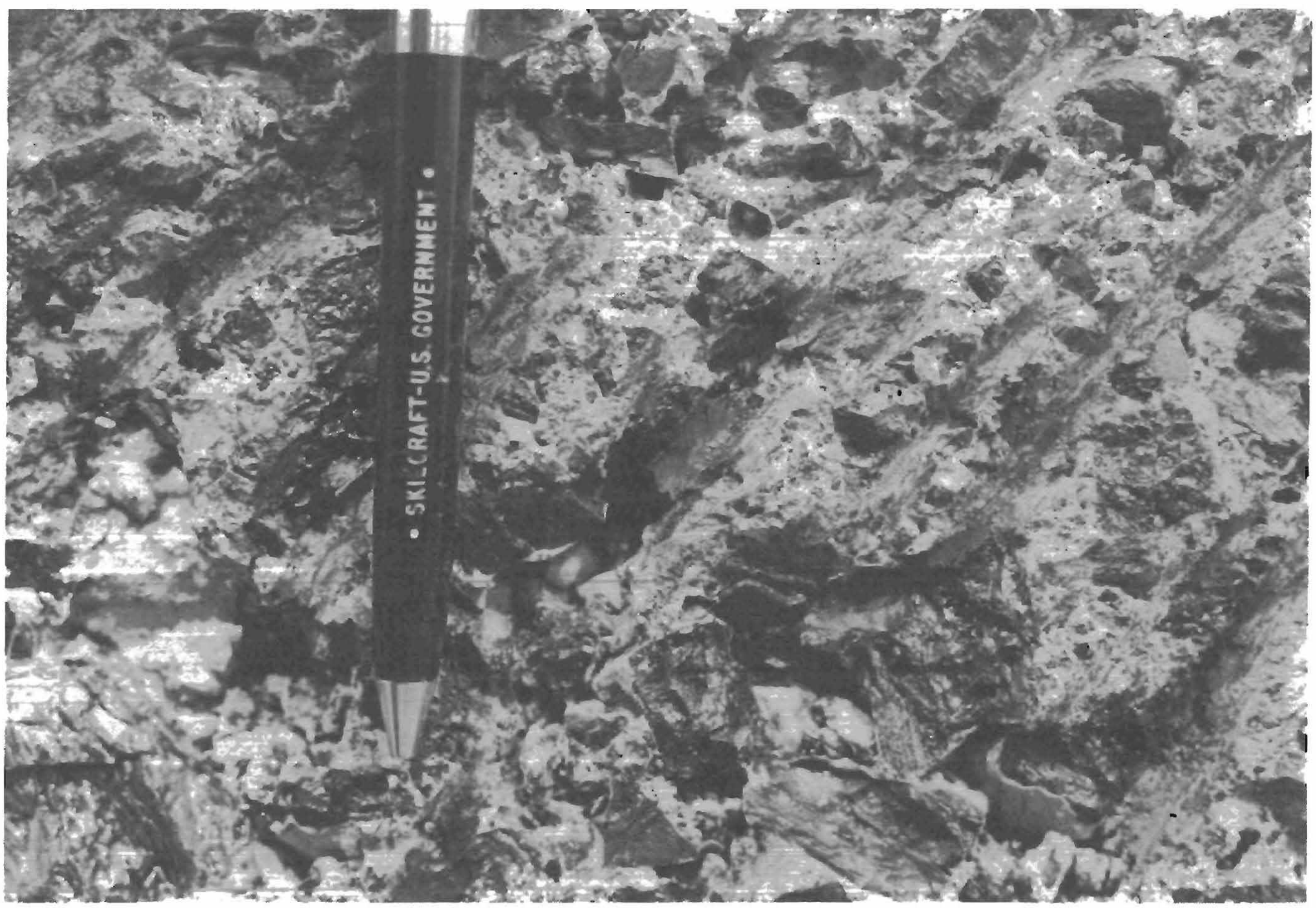


FIGURE 30. - Closeup view of simulated coal mixture.

Figure 31 shows the equipment configuration during the preliminary cutting trials. As shown, only the miniminer and the forward bridge conveyor were moved to the CTA for the cutting trials; the rest of the mining system remained in the EMTA. During the four lifts that were taken at this time, cut simulated coal was loaded from the bridge conveyor into a scoop car. The miner's water sprays were turned on during this cutting.

The following determinations resulted from the preliminary cutting trials: the miniminer could successfully cut the simulated coal material; the miniminer remained relatively stable during cutting and did not require the activation of its stab jacks; the measured cutting rate was low; the gathering augers were apparently incapable of keeping up with the output of the cutting head; and an unexpected problem existed with conveying the artificial material.

The first sump of the miniminer's cutting head into the coal block showed that the machine was quite capable of cutting the simulated coal mixture. No problems were observed with any of the cutting components including the head, the slide bar feed mechanism, and the head elevation assembly. It was also evident that the miniminer's stab jacks would not be needed during the cutting tests. Although both the cutting head and the feed bar mechanism oscillated as the head approached the maximum lateral extensions, the body of the miniminer remained stationary in front of the face. Also, the oscillations did not adversely affect the cutting operation. (The stab jacks were designed to bear against the mine roof and add additional bearing force to stabilize the miner during cutting.)

A combined cutting and loading rate of 0.4 tpm of artificial coal was observed during the preliminary cutting trials.

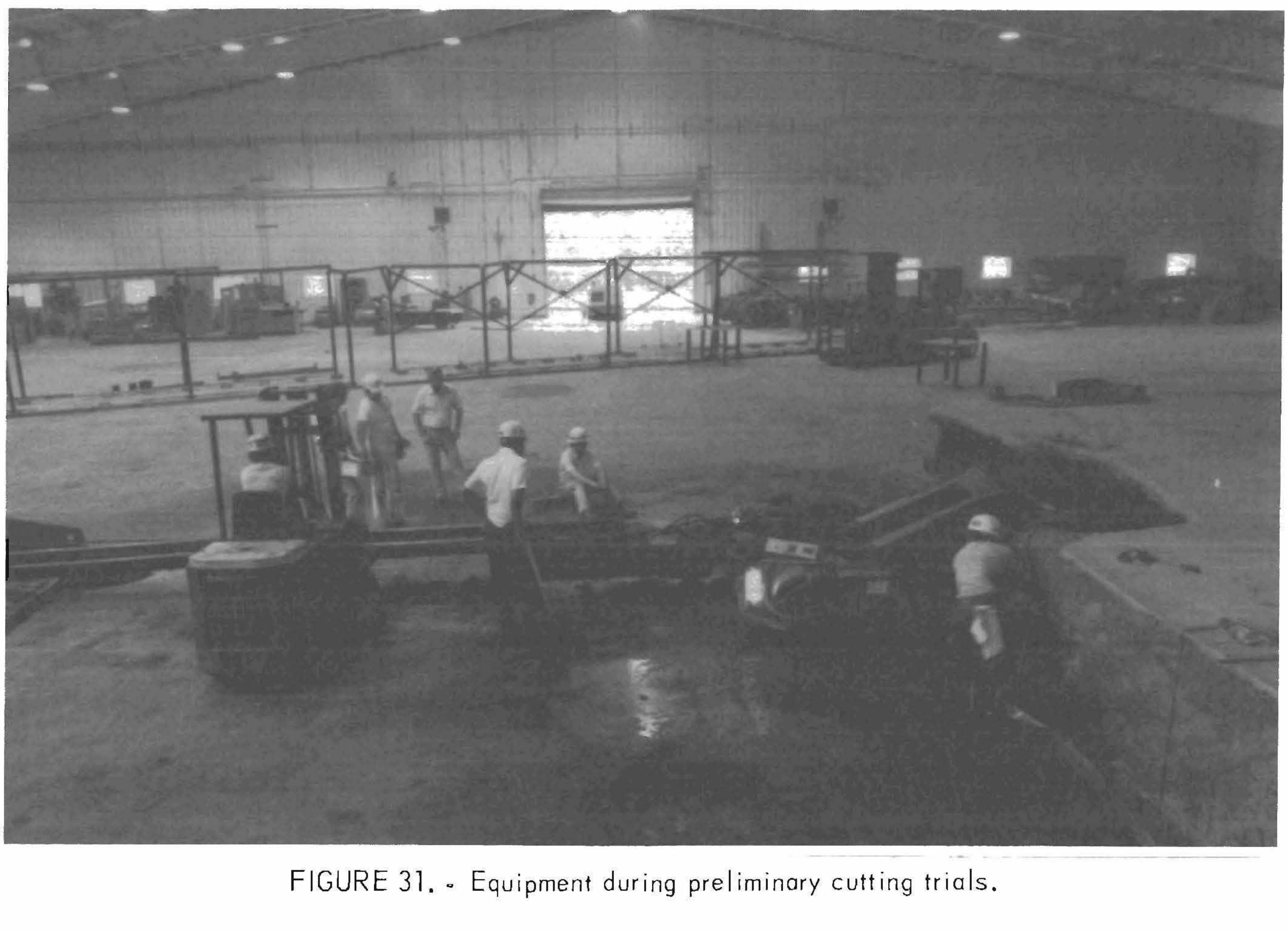


FIGURE 31. - Equipment during preliminary cutting trials.

This value was calculated for the second lift taken, where 8 tons of material was cut and loaded out in 22 min. The weight of the artificial coal was calculated by measuring the face area to determine the volume of removed material, then multiplying by the known, average density of the artificial coal.

No formal measurements were made at this time to determine the loading rate for the dual gathering augers. However, both the test personnel and the manufacturer observed that the cutting head produced cut coal at a rate faster than the augers were able to gather and deliver the material to the miner's central conveyor. Based on this observation, the manufacturer decided that larger capacity augers were needed and set about to design and fabricate them. Descriptions of both the new and old augers and measurements of their respective loading rates follow.

A problem that would re-surface during the formal cutting tests was discovered during the preliminary cutting trials. The miner conveyor and the bridge conveyor jammed approximately eight times during the cutting of the four lifts. In trying to determine the cause(s) of the jamming, several small pieces of cast metal were discovered in the coal that had been conveyed. The metal pieces apparently came from the artificial coal block and were blamed for the jamming. During later testing, it became apparent that the jamming of conveyors was caused by the physical properties of the artificial coal material and not by metal pieces. The root of the problem was apparently the fly ash component of the mixture, as it did not grind down as readily as genuine coal and caused increased friction.

The conveyors jammed very frequently during the cutting evaluation. This situation was usually remedied by having laborers insert pry bars on either side of the double chain and pry against an adjacent pivot bracket. This activity is shown in figure 32. In those cases where the situation could not be corrected by prying, a chain hook was attached to the conveyor chain and was pulled with a front-end loader.

DUST GENERATION[5]

The first area investigated during the formal cutting evaluation was dust generation. An average dust concentration value of 2 mg/m^3 was determined for the miniminer cutting the simulated coal mixture without the aid of water sprays.[6] This value was recorded when the miniminer was producing cut material at a very low average rate of 0.2 tpm, owing to operational problems stemming mainly from the conveyors jamming. No valid dust measurements were made with the miner cutting with the water sprays on.

The primary goal in this testing was to obtain measurements of the miniminer's dust generation while cutting the artificial coal in an environment that simulated the ventilation experienced at an underground, working face.

Figure 33 shows the test site during the dust generation testing. A wooden framework was constructed of 2- by 4-in lumber; it was 16 ft deep by 20 ft wide by 50 in high. After being lined with thick, translucent plastic, the framework was butted against the artificial coal block and functioned as an entry would in confining airflow across the face. A portable wooden box with an open end was also constructed with dimensions of 19 in wide, 48 in high, and 96 in long. The box functioned as ventilation brattice and also contained the dust measuring instruments. As shown in figure 34, the brattice box was situated on the left side of the miner, next to the "rib" created by the framework. A large,

[5]Testing conducted by A. B. Cecala, mining engineer, A. Covelli, physical science technician, C. W. Urban, mining engineer technician, and J. C. Volkwein, physical scientist, Pittsburgh Research Center, Pittsburgh, PA.

[6]Because a correlation factor presently does not exist, the relationship of this value to genuine coal will not be known until underground testing is conducted.

FIGURE 32. - Jammed conveyor being freed.

portable, wet scrubber unit was used to induce airflow across the artificial coal face and was attached to the brattice box by 20-in diam flexible tubing. This setup simulated an exhaust ventilation system using face brattice. Airflow was adjusted to approximately 4,500 cfm across the face, which insured that the air velocity was at least 60 fpm across surfaces within the simulated "entry."

Instrumentation located within the brattice box consisted of real-time aerosol monitors (RAM's) and an eight-stage cascade impactor. The RAM's were connected to a strip chart recorder and gave continuous readouts of the measured dust concentrations. The cascade impactor measured the size distributions of the dust particles and was read after a total of approximately 30 min of cutting time. The instrument readouts and ancillary devices are shown in figure 35.

It was initially planned to measure both "dry" and "wet" dust generation; however, this proved impossible. Owing to numerous shutdowns caused by jamming of the conveyors and unlocking of the gathering augers, only the dry condition was measured. Also owing to the shutdowns, the dry measurements were made during short cutting segments of approximately 1-min duration.

The average overall dust concentration measured by the RAM units was 2 mg/m^3 for the dry cutting condition. When considering the face as being composed of four sections and measuring the dust

FIGURE 33. - Test site during dust generation testing.

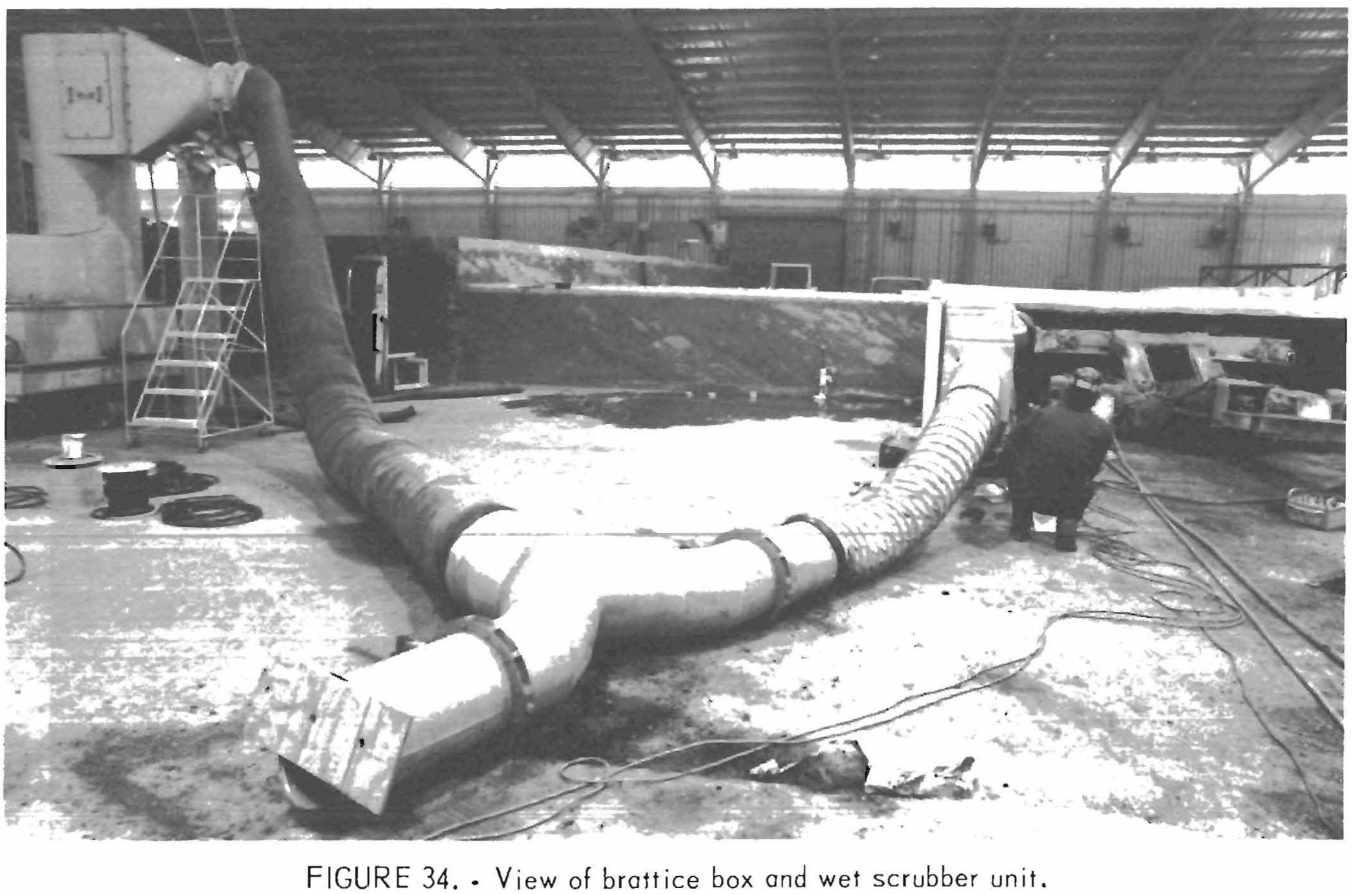


FIGURE 34. - View of brattice box and wet scrubber unit.

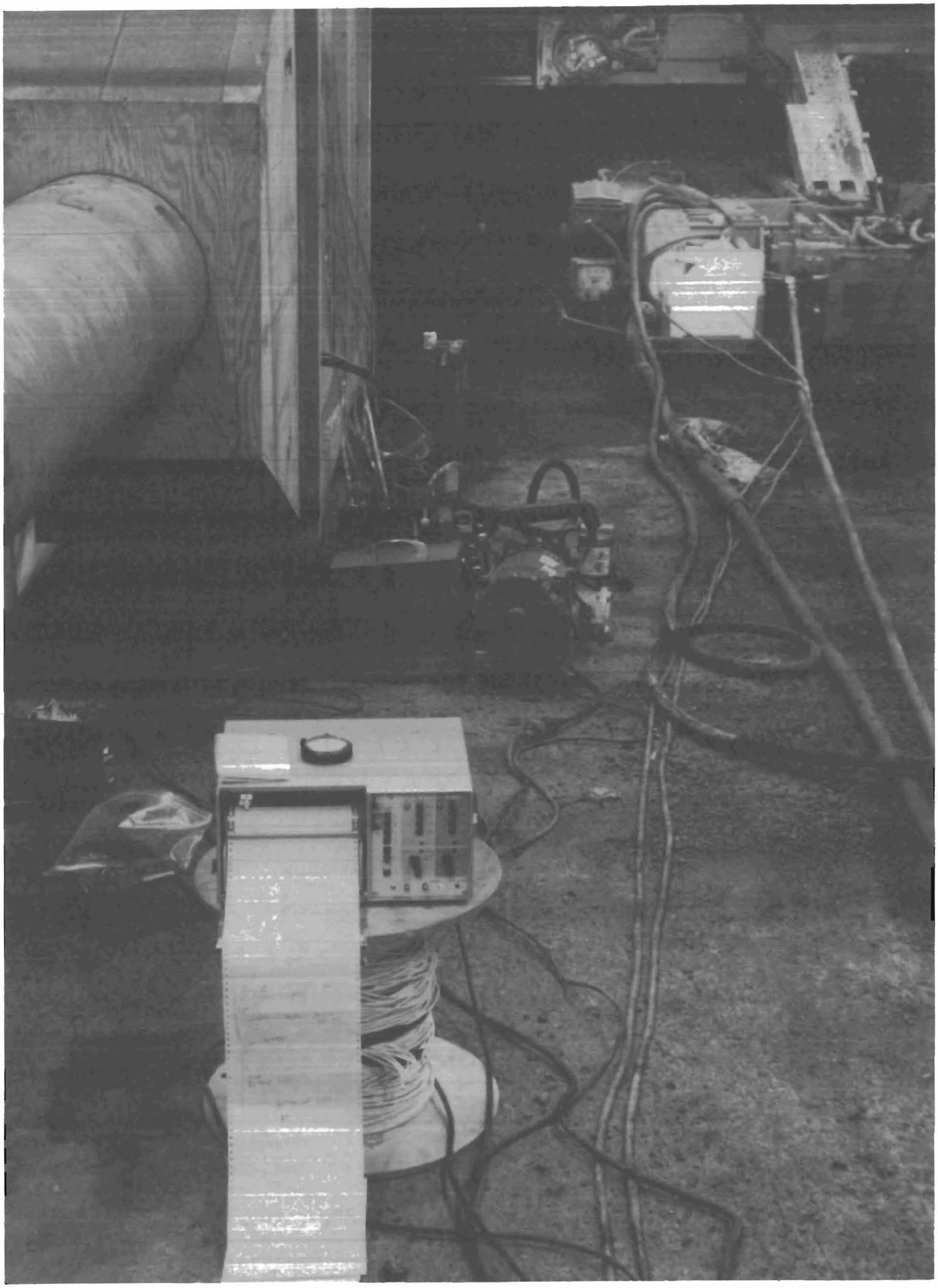


FIGURE 35. - View of readouts for dust instrumentation.

concentrations for each section individually, the results were as presented in figure 36. As shown, the dust concentrations were higher, by an approximate 58 pct margin, when the upper versus the lower sections of the face were being cut. This may have been due to the cut coal hitting the floor and causing additional dust. Also, there was a small increase in the dust concentrations when considering the left side of the face as opposed to the right. No explanation for this phenomenon is given at this time.

The above results indicate that the dust generated by the miniminer during cutting was minimal. This is especially so when considering that the artificial coal was being cut dry. However, the low dust generation came as no surprise as the cutting rate during the dust generation was low, averaging 0.2 tpm. Higher cutting rates should cause a corresponding increase in the resulting dust generation.

The data gathered by the cascade impactor showed the particle size distribution of the artificial coal to be similar to that of actual coal. There was a good polydispersal of dust particles, with the medium aerodynamic diameter being 5 μm, and with a geometric standard deviation of 2.5.

In summary, low levels of respirable dust were measured for the miniminer cutting dry artificial coal at an average rate of 0.2 tpm. Even assuming higher cutting rates accompanied by higher dust concentrations, it is expected that good face ventilation practices and well-placed water sprays will provide adequate dust control.

2.9 mg/m^3	2.7 mg/m^3
1.9 mg/m^3	1.1 mg/m^3

FIGURE 36. - Measured dust generation for individual quadrants of the face.

NOISE GENERATION[7]

The noise levels generated by the miniminer system should cause no extraordinary problems in complying with current Federal regulations regarding noise exposure for the operators of the miner and bridge carrier during a normal 8-h shift. A primary reason for this finding is that the miner operator can be positioned away from the location of the miner, as the controls extend from the machine via a 20-ft-long umbilical cord. If forced to operate from positions in relatively close proximity to the miniminer, the operator would, as expected, be exposed to significantly higher noise levels.

The acoustic evalution was conducted in three parts: sound power measurements, diagnostic measurements, and measurements made while cutting the artificial coal. All measurements were taken at predetermined locations around the mining equipment using a one-third octave band spectrum analyzer. All measurements except diagnostic measurements were recorded on magnetic tape to allow subsequent laboratory analysis.

During the sound power measurements, the miniminer (without the haulage system) was situated within the CTA away from the walls and other large objects. This minimized the effects of reflected sound waves. A near-field, two-surface method was used, which permits the sound power of large machinery to be determined by taking measurements relatively close to the hardware. The locations where measurements were made are indicated in figure 37. During this testing, the miniminer was operated with all functions activated, but with the cutting head spinning in air.

[7]Testing conducted by L. Marraccini, supervisory physicist, G. Durkt, industrial hygienist, and F. Delle Valle, engineering technician, MSHA Pittsburgh Health Technology Center, Pittsburgh, PA.

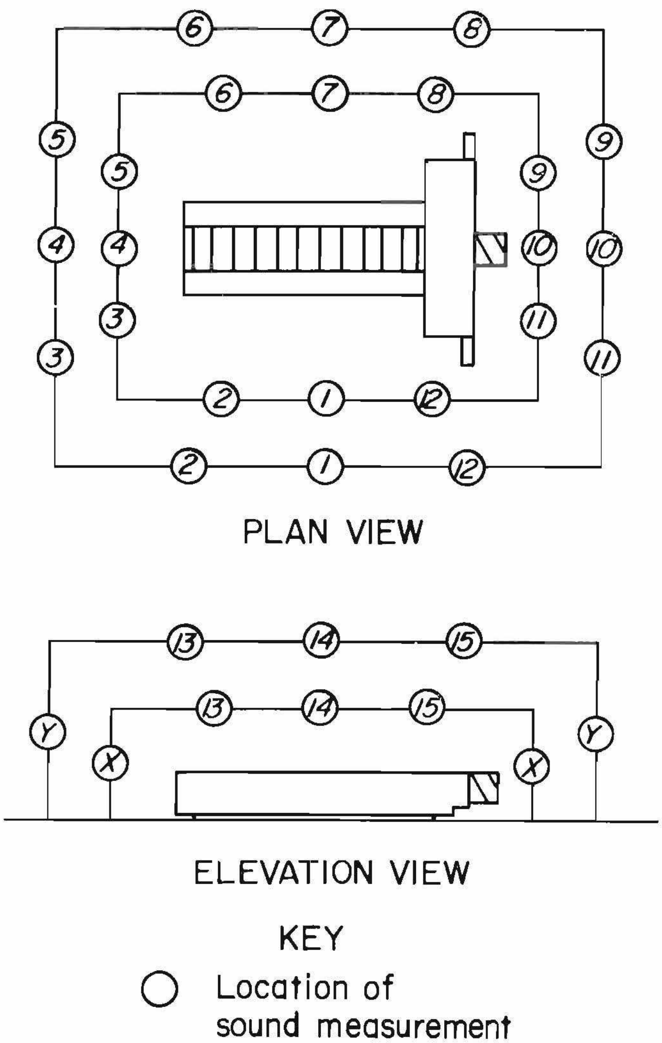


FIGURE 37. - Locations of measurements for sound power levels.

Results of the sound power measurements are presented in table 4 and figure 38. For reference purposes, table 4 and figure 38 also show previously gathered data for another auger-type miner. As shown, the sound power values for the miniminer ranged from a minimum of 79 dB re 10^{-12} W at 32 Hz to a maximum of 105 dB re 10^{-12} W at 1,000 Hz.

Sound power measurements determine the total sound energy radiated by a source per unit time and could be used to calculate expected sound levels generated by the miniminer for given locations and site geometries. Such calculations are beyond the scope of this report and are not provided.

TABLE 4. - Sound power values[1] for miniminer, two-box method, decibels

Frequency, Hz	4M miniminer	Wilcox Mark 20[2]
32........	79	82
63........	85	100
125.......	93	106
250.......	98	108
500.......	101	105
1,000.....	106	106
2,000.....	100	103
4,000.....	97	98
8,000.....	90	91
A.........	108	110
C.........	108	113

[1] Sound power values referenced to 10^{-12} W.
[2] Acoustically modified by MSHA, Pittsburgh (PA) Health Technology Center.

Additional information that resulted from the sound power measurements is shown in figures 39 and 40. This information concerns the sound pressure levels and frequencies to which the miner operator and bridge carrier operator would be subjected.

For the diagnostic testing, sound level measurements were made at various locations around the complete mining system as the various operating functions were systematically activated. The testing also included measurements made with all of the mining system's functions in operation. Figure 41 shows the orientation of the mining system during this testing.

The third part of the acoustic evaluation determined noise levels while the miniminer system was cutting and transporting artificial coal. This area was not covered as thoroughly as was desired because of the previously mentioned problem of conveyor jamming. The same techniques that were used in the diagnostic testing were also used in this testing.

Table 5 and figures 42 and 43 present the results obtained from the second and third phases of the acoustic evaluation. Referring to figure 42, the

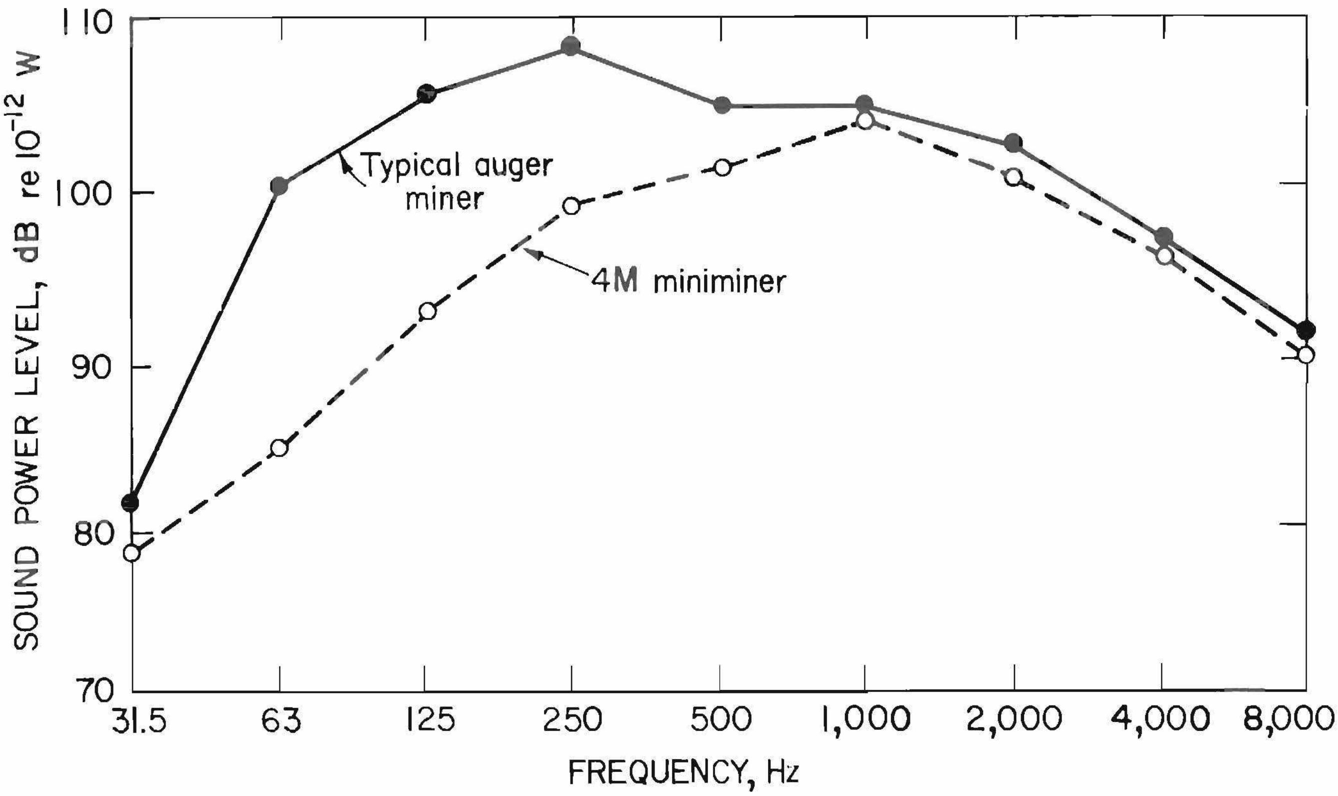


FIGURE 38. - Sound power measurement for miniminer and another auger miner.

TABLE 5. - Sound pressure levels at various locations around miniminer system

Measurement position	Cutting head, auger feed		Auger feed, miner conveyor, 1st bridge		2d, 3d, and 4th bridge		Cutting head, auger feed, miner conveyor 1st bridge		Entire miner and conveyor systems operating		General cut and load with all systems operating	
	dBA	dBC	dBA	dBC	dBA	dBC	dBA	dBC	dBA	dBC	dBA	dBC
Operator position	79	70	83	84	84	85	84	85	84	85	88	89
Conveyor operator	78	79	82	83	89	90	82	83	88	89	87	89
1........	86	86	87	87	88	88	88	88	87	88	91	91
2........	93	92	95	95	95	95	95	95	94	94	94	95
3........	88	88	90	90	91	92	91	91	91	91	92	92
4........	88	88	88	88	91	91	88	89	89	90	89	90

assumed operator position for the miner and also the operator position for the mobile bridge carrier were not subjected to A-weighted sound levels above 90 dB. Thus, the miniminer system, as tested, should be able to comply with MSHA regulations for noise exposure when operated continuously for an 8-h period. This is no small feat and meets, or surpasses, most other existing mining equipment in regard to noise generation. At locations inby the assumed position of the miniminer operator, A-weighted sound levels did rise above 90 dB, with a maximum level of 94.2 dB occurring adjacent to the left-side motor. At this worst case location, 4.5 h of noise exposure per shift would be permitted.

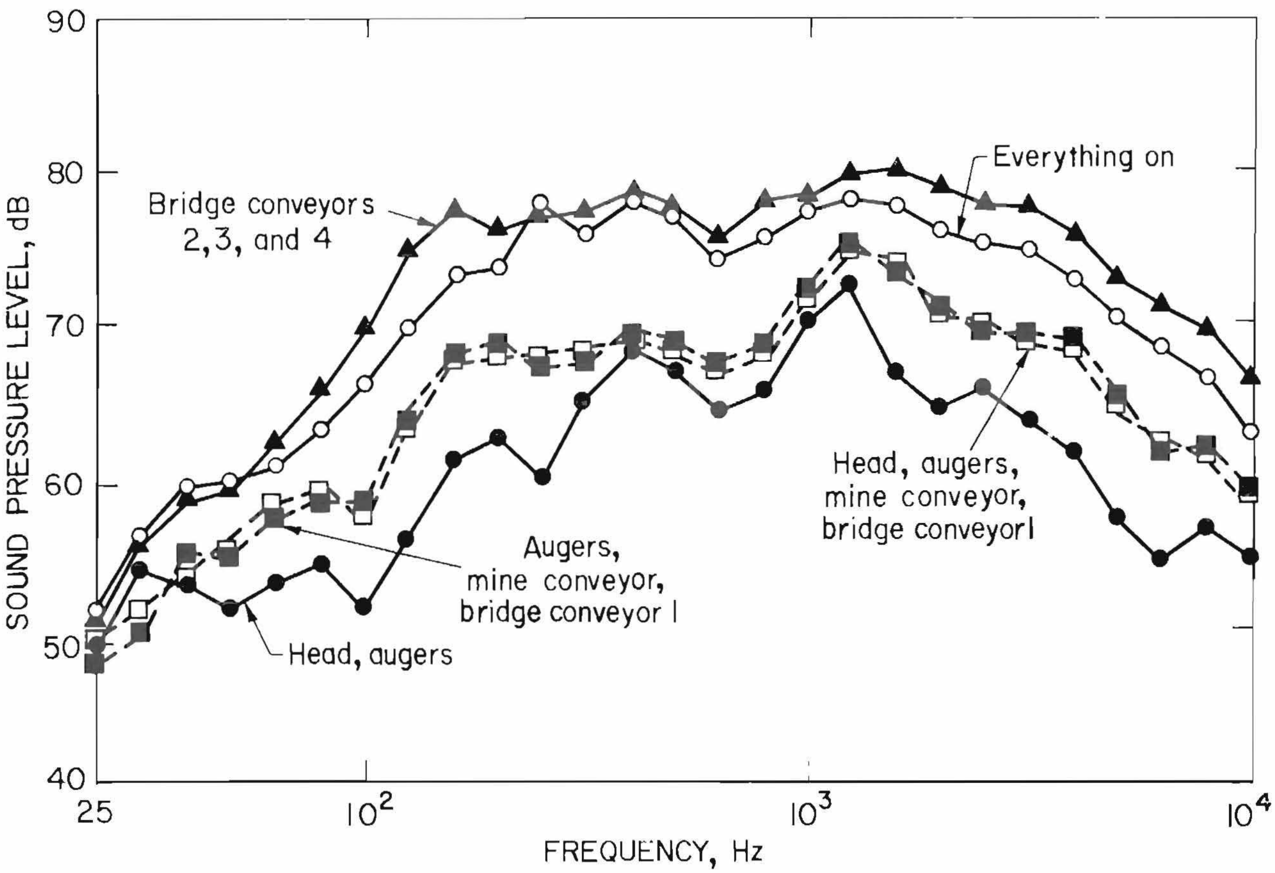


FIGURE 39. - Noise spectrum for miniminer operator.

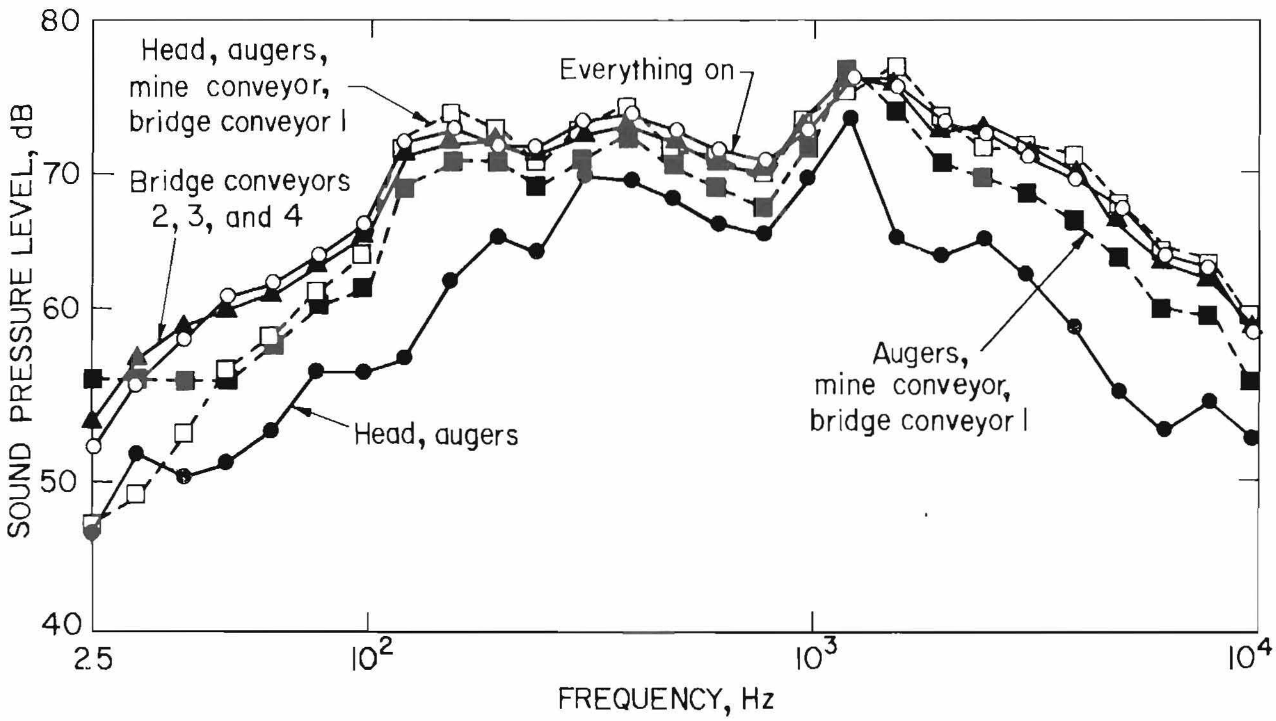


FIGURE 40. - Noise spectrum for mobile bridge carrier operator.

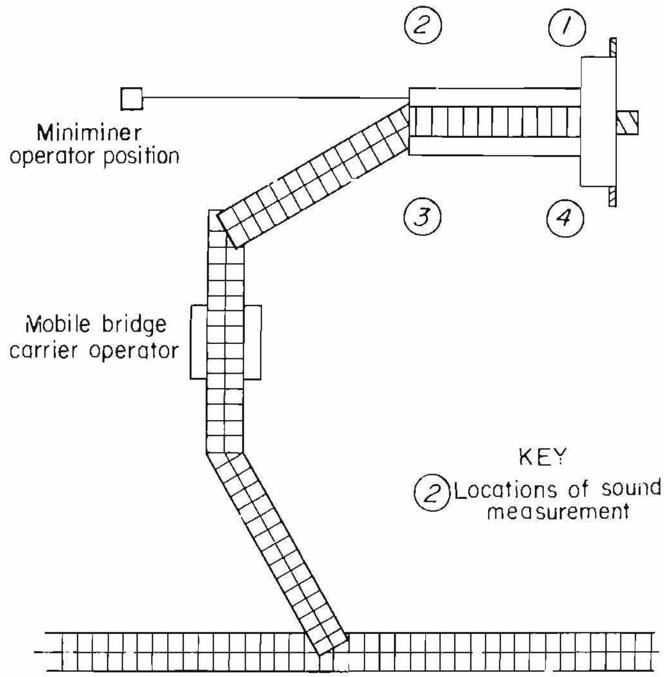


FIGURE 41. - Orientation of miniminer system during diagnostic testing.

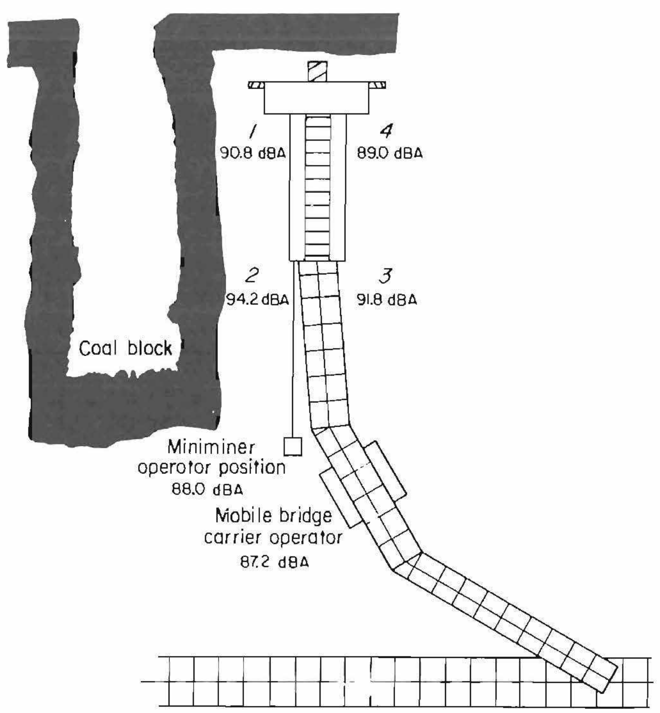


FIGURE 42. - Noise levels at selected locations around miniminer system during cutting.

TESTING PROCEDURE DISCUSSION

Experience from the preliminary cutting tests and also the dust and noise generation testing showed that the mining system could be expected to mine and haul the artificial coal mixture for approximately 1 min before a problem occurred. Usually, a conveyor would jam and would require considerable effort to free it. Because this routine was both very frustrating and could have considerable negative impact on the overall cutting evaluation, an experiment was performed to determine if the fault lay with the conveyors or the artificial coal mixture. Several tons of run-of-mine (ROM) coal was placed in front of the gathering augers. This ROM coal was then gathered by the miner, fed through the system, discharged from the crossover dump, collected, and again placed in front of the augers. This was kept up for approximately 35 min, during which time only three interruptions occurred: pieces of slate jammed the gathering augers twice and the rear bridge conveyor jammed once. Because of these rather positive results, the decisions were made that ROM coal would be used, when possible, in testing the haulage system; and in future tests involving the cutting of the artificial coal mixture, the haulage system would be disconnected at the rear of the miner and the material be fed onto an electrical belt conveyor for disposal.

OPEN-ENDED AND ANGLED CUTTING TESTS

The miniminer should be able to perform pillar-extraction mining for the following two reasons: (1) excessive spillage was not produced when the cutting head was not laterally confined by a rib and (2) the cutting head could cut on an oblique angle to the face. These considerations are the primary differences in mechanics between the miniminer being used for pillar extraction as opposed to development mining.

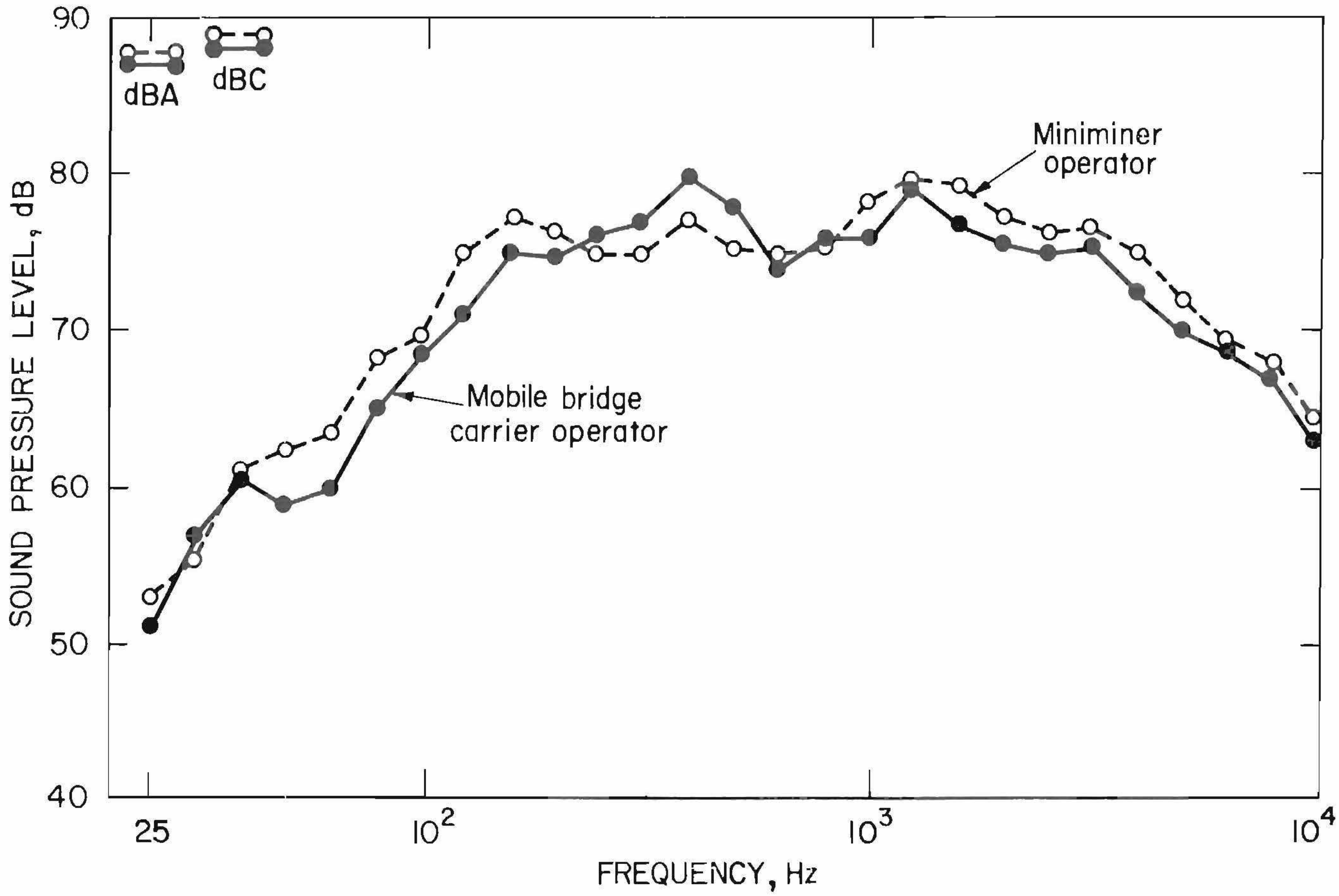


FIGURE 43. - Noise spectrum for miniminer and mobile bridge carrier operators during cutting.

Figure 44 shows the position of the miniminer for the open-ended cutting test. Here, the miner was positioned so that the cutting head would protrude past the right-hand side of the coal block when at its rightmost extension. This situation could occur in pillar mining and would present cleanup problems if the cut coal were thrown an excessive distance by the clockwise-rotating cutting head. As is shown in figure 45, a photograph taken at the end of the lift, the material thrown past the coal block edge was considerable in volume. However, the cuttings pile was so close to the gathering augers that no cleanup problem was deemed to exist.

Figure 46 shows the setup used to judge the ability of the cutting head to cut on an oblique angle to the face. This situation would occur if the miniminer system were used in pillar mining where either the "pocket-and-fender," the "open-end," or similar methods were employed. A total of four cuts was made. On the last cut, the operator was intentionally able to round the corner of the "pillar" by continuously adjusting the miner's tracks. No problems were uncovered with the cutting head mining on an oblique angle to the face.

DISCUSSION ON RESULTS OF ANGLED CUTTING TESTS

The magnitude of the oblique angle that the miniminer can cut is limited by the fact that the gathering augers must be extended at right angles to the longitudinal axis of the miner. This necessitates that any angled cutting be done in slices. However, the extreme mobility of the miniminer should allow easy positioning for taking angled cuts in slices. Because the miniminer is easily capable

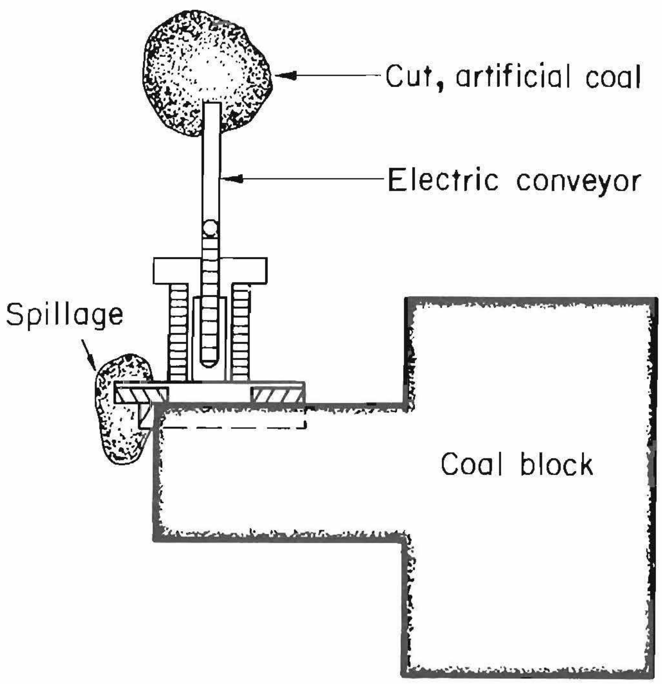


FIGURE 44. - Position of miniminer for open-ended cutting test.

of maneuvering within an 18-ft-wide entry to turn 90° crosscuts, the cutting limitations imposed by the augers should in no way affect the miniminer's potential use in development mining.

CUTTING PATTERN STUDIES

A range of production rates from 0.3 to 0.5 tpm was observed for the miniminer cutting the artificial coal material during tests that looked at the effects of various cutting patterns. However, because of operational and other problems, the observed production rates are not considered particularly accurate in terms of defining the upper production capacity of the miniminer. This fact should be taken into account by individuals evaluating the miniminer system on the basis of this report.

Four lifts of artificial coal were cut in an attempt to determine which patterns of cutting head movement produced the highest average production per lift. Before testing began, promising cutting head patterns were devised for use in this evaluation. One such pattern was suggested by the manufacturer in its literature. The cutting patterns that were tried are illustated in figure 47.

The same miniminer operator was used during the four cuts; he was instructed to cut as fast as possible, without stalling the head. (Previous experience was that the head would stall if the operator attempted to sump in or cut up or down too quickly.) As explained previously, the haulage system was not used and the miner loaded into a scoop car through a 12-ft-long, 1-ft-wide electric conveyor. The carbide tipped cutting bits were examined prior to mining each lift, and were replaced if excessive wear was noticed. An observer recorded times of cutting and/or loading, the direction of the cut, and the times for delays. The volume-removed method was used to calculate the quantity of material that had been cut. When applicable, the amount of loose coal remaining on the floor after the cut was also measured and recorded. Figure 48 shows the situation of the test site during this testing.

A cleanup pass of the cutting head, made after the actual cutting of a lift is completed, appears to be needed. In the one instance where no cleanup pass was made between cuts, the miner was unable to sump totally into the new face because the gathering augers hung-up on the material remaining on the floor. This material consisted of what was left at the boundary location between lifts, and/or cut material that fell in front of the gathering augers. Figure 49 is a photograph of the face area taken after cutting pattern 2, before the cleanup pass was made. As shown, the amount of material left unloaded was large and was as great as 24 in deep adjacent to the face, and approximately 6 in deep outby the face. Figure 50 shows the effective cleanup accomplished by the cutting head and gathering augers. As shown, approximately 10 in of unloaded material remained adjacent to the face. The average time taken for cleanup was approximately 3 min.

FIGURE 45. - Test site at conclusion of open-ended cutting test.

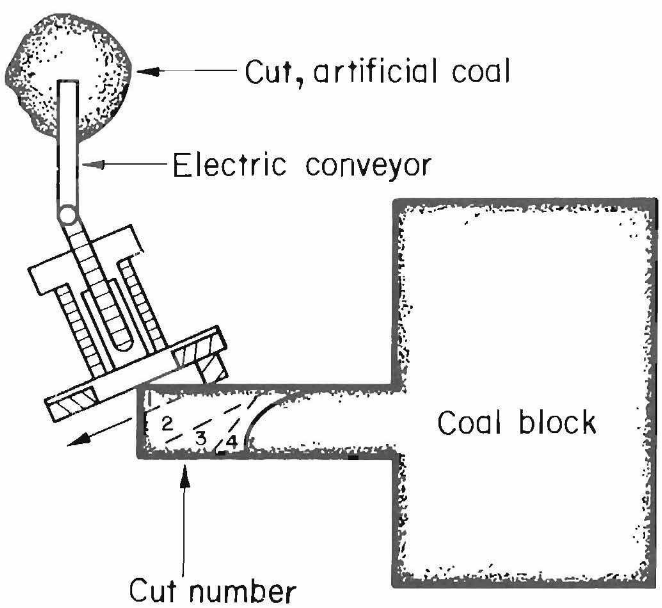


FIGURE 46. - Setup for oblique angle cutting test.

Several operational problems were experienced during the cutting pattern trials. The gathering augers would unlock repeatedly from their operating position during cutting. This was particularly aggravating as an electrical interlock caused both the augers and the cutting head to lose power when the locking mechanism failed. This condition aggravated the testing to the point that the augers were tack welded in the opened, operating position prior to conducting the cutting pattern 3. Another problem encountered was that some of the pieces of artifical coal material would jam the gathering augers. Both of these problems caused the testing to stop until the situations were rectified.

Figure 51 shows the data recorded for the first cutting pattern, which was typical of this testing. Table 6 gives the

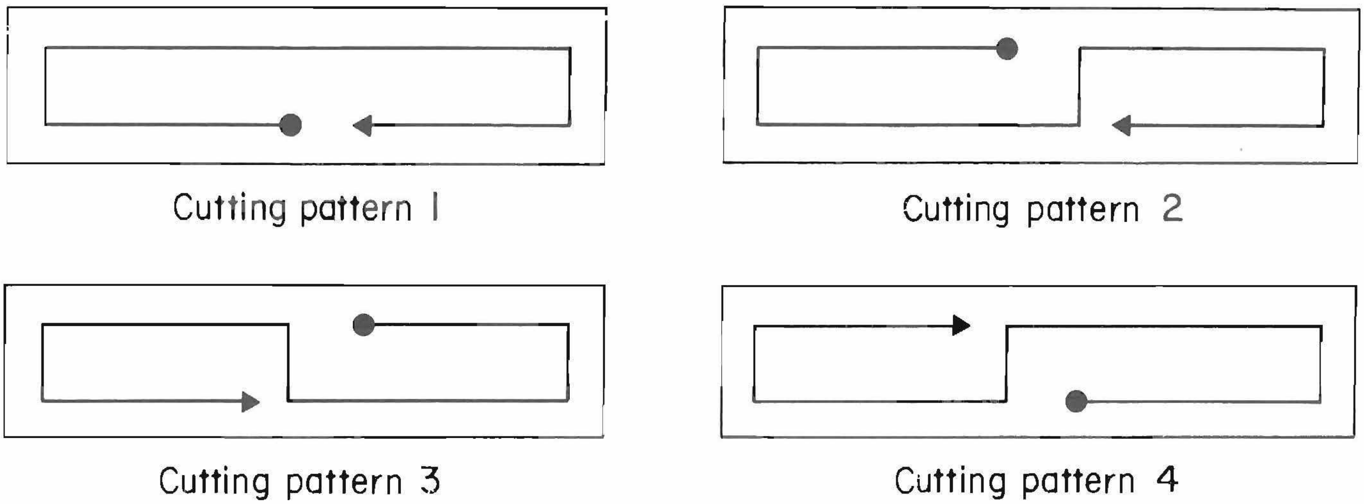


FIGURE 47. - Cutting patterns used in elevation.

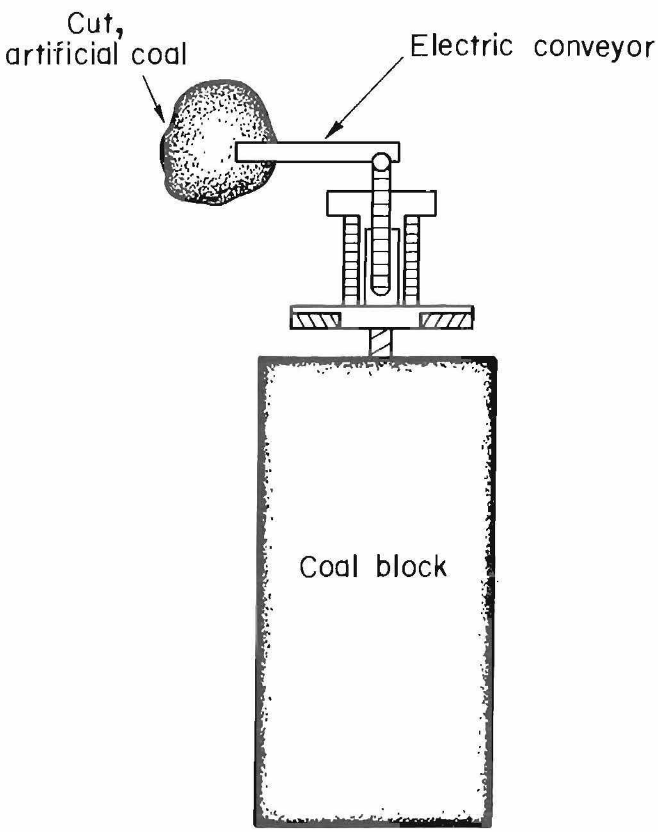


FIGURE 48. - Situation of test site for cutting pattern studies.

summary data for the four patterns. As shown, the production rates varied from 0.3 to 0.5 tpm. If calculated to include the time spent in cleanup, the production rates reduced to a 0.2- to 0.4-tpm range.

TABLE 6. - Summary data for cutting pattern trials

Pattern	Time required, min	Weight of artificial coal cut, tons	Production rate, tpm
1......	15.6	7.3	0.5
2......	18.9	7.4	.4
3......	26.0	8.6	.3
4......	27.2	7.4	.3

DISCUSSION ON RESULTS OF CUTTING PATTERN STUDIES

It is the opinion of the author that the cutting pattern studies did not produce the expected results, much less define the possible range of cutting rates that could be expected of the miniminer in actual production. The cutting pattern studies started with all new cutting bits. As mentioned previously, cutting bits were replaced when the carbide tip appeared excessively worn. However, there was not a sufficient number of new bits available to start each cutting pattern with the head outfitted with brandnew bits.

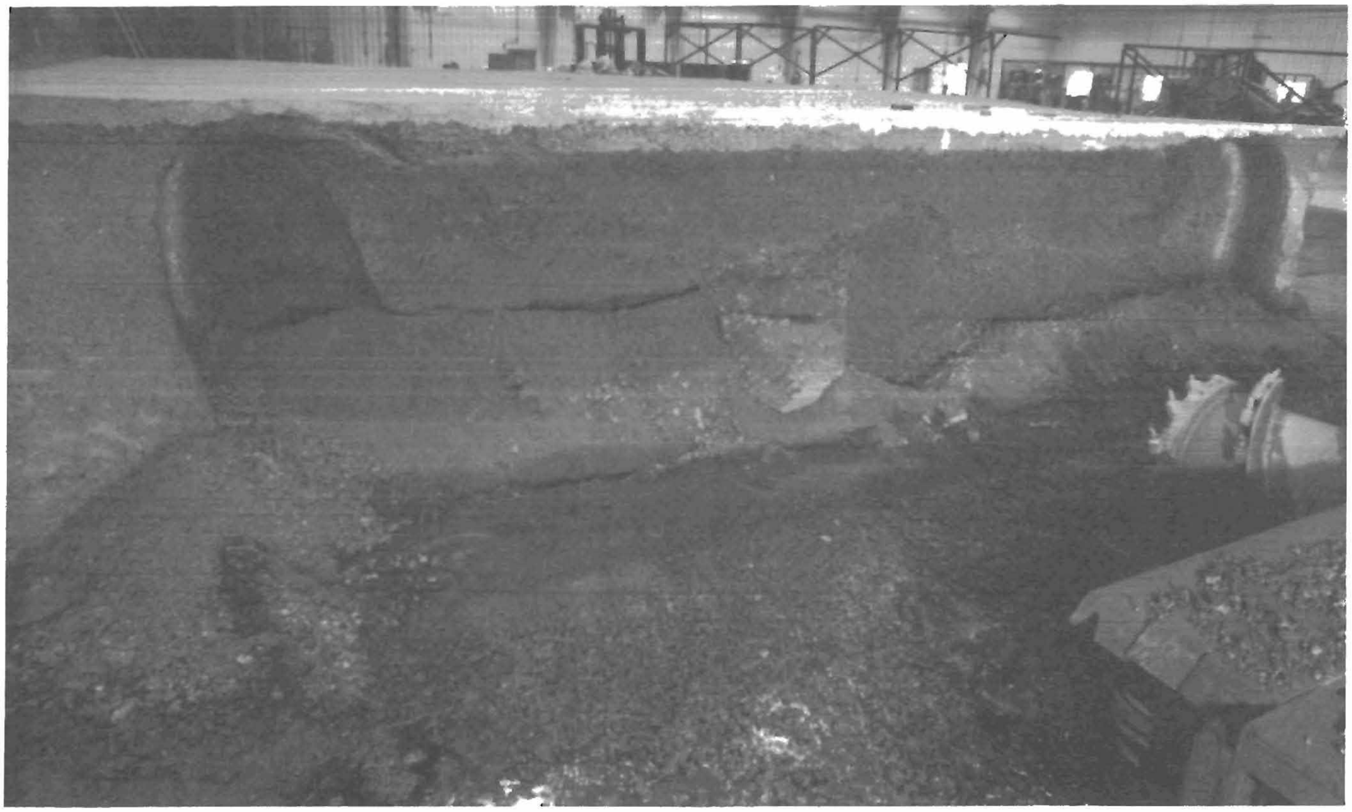


FIGURE 49. - Face before cleanup from pattern 2.

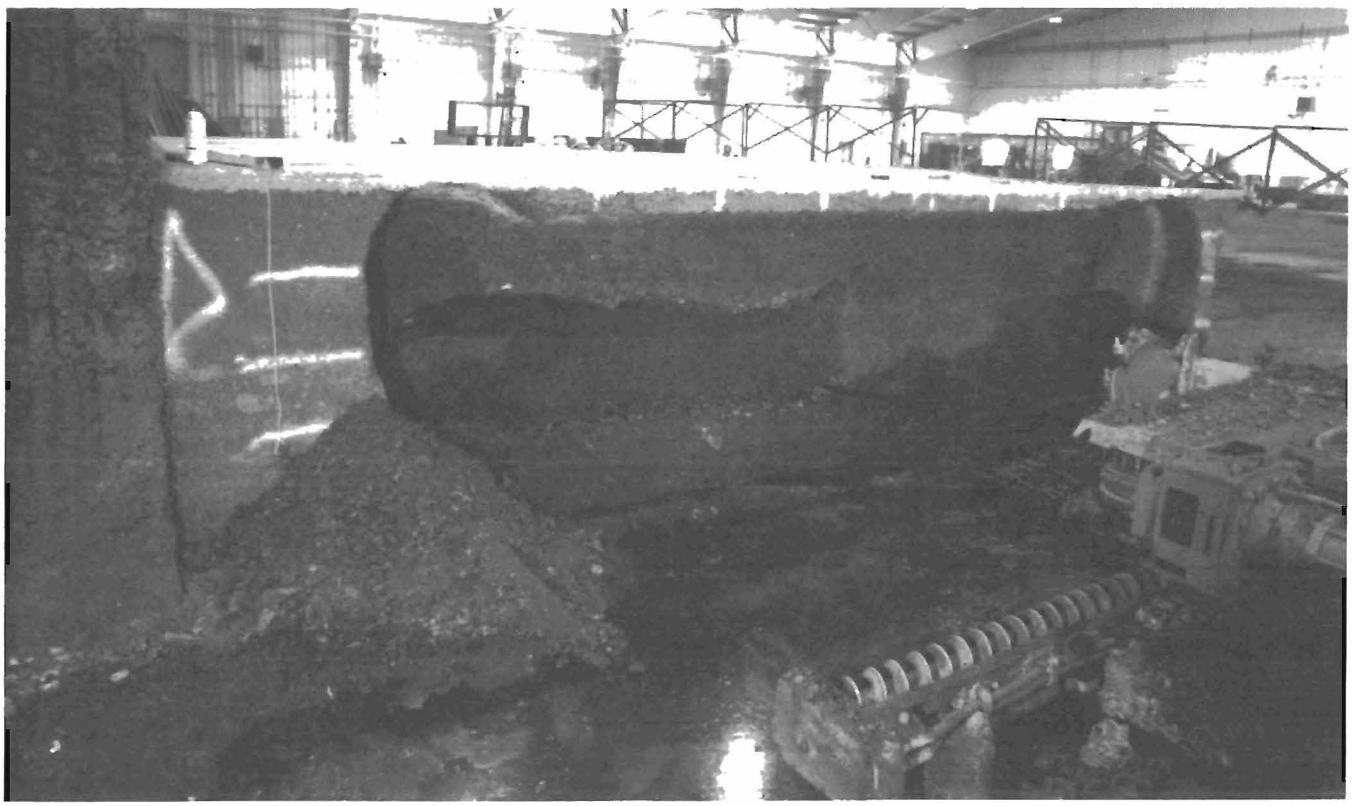
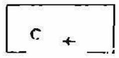


FIGURE 50. - Face after cleanup from pattern 2.

DATE. 08/25/81

PATTERN: 

VOLUME OF CUT: 50 inches high x 18 ft wide x 21.7 inches deep = 136 ft^3

WEIGHT OF CUT ARTIFICIAL COAL: 136 ft^3 x 106 lb/ft^3 x 1 ton/2000 lb = 7.2 ton

Time (hr:min:sec)	Event
2:44:50	Start sump
2:45:01	Stop to lock augers
2:45:22	Continue sump
2:46:30	Stop to unjam conveyor
2:47:15	Continue sump
2:47:22	Cut left
2:51:39	Test delay - empty scoop
3:07:22	Continue cut left
3:08:05	Cut up
3:08:40	Cut right
3:12:07	Stop to tighten seal on oil filter
3:30:34	Cut right
3:30:55	Cut down
3:31:50	Cut left
3:34:40	Stop

TOTAL LOADING TIME = 15.6 Minutes

FIGURE 51. - Typical data for cutting pattern trials.

The artificial coal caused rapid wear of the cutting bits. It was not uncommon for bits that looked entirely satisfactory before a lift was taken to be worn almost completely down after cutting the lift. Because only 10 tons of material constituted a lift, this fact becomes even more significant. The cutting bit situation helps explain the fact that the calculated cutting rates decrease steadily from pattern 1 through pattern 4.

Also, the nature of the artificial coal material certainly affected the observed cutting rates. In discussing the characteristics of the material with the person who designed the original composition for DOE's use, it was learned that the physical property desired for the mixture was the ability to interact with the expansion shell of roof bolts like genuine coal. Thus, cutting properties were only lightly considered. When one considers that bituminous coal occurs in such varieties that the cutting rate of any coal mining machine should most correctly be expressed as a range of values, the observed cutting rates diminish more so in terms of quantitative accuracy.

In an attempt to define the upper boundary of an expected cutting rate for the miniminer, average velocities for the cutting head spinning in free air were determined as it was raised, lowered, and fed from side to side. These values were introduced into the cutting patterns tried and produced a minimum time value. Dividing the weight of the material in a lift by the time value yields an upper boundary for the expected cutting rate of 1.5 tpm. This corresponds with the manufacturer's specified upper range. Obviously, the actual cutting rate of the miniminer in genuine coal will be less than the 1.5 tpm calculated for the cutting head spinning in air. Because of the various factors discussed above, it is the opinion of the author that the actual cutting rate in genuine coal will also range above the maximum rate of 0.5 tpm calculated from the cutting pattern study.

WORST CASE CUTTING

The miniminer was found able to sump into a face with the cutting head extended to the left or right lateral extreme and to make angled cuts with the

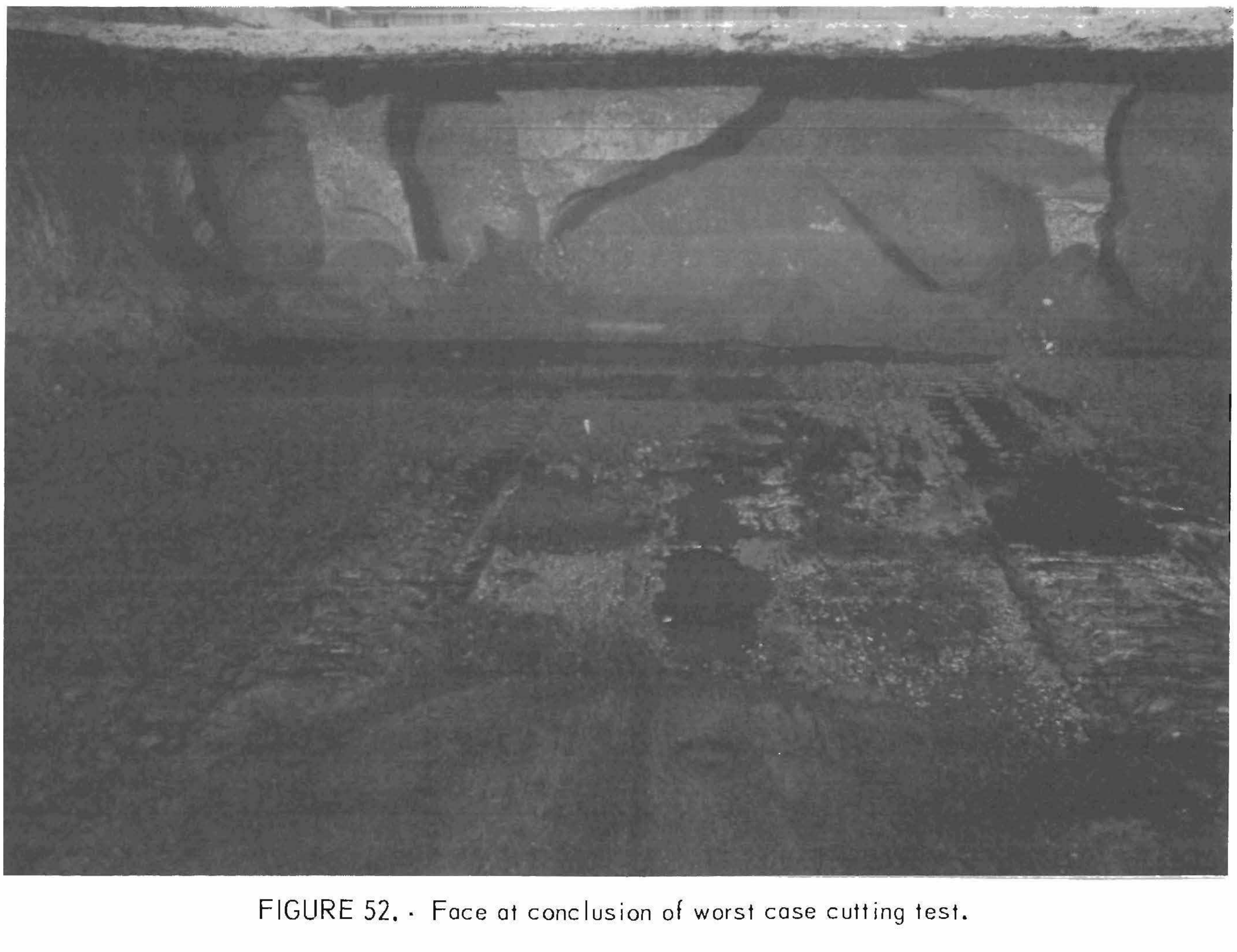


FIGURE 52. - Face at conclusion of worst case cutting test.

cutting head at a right angle to the face. The angle cutting was done by the miner operator using the head feed and head elevation controls simultaneously. Admittedly, these cutting situations would be rarely encountered in normal mining, but were evaluated primarily to determine the limitations of the miner's cutting systems. The operator needed to make adjustments with the crawlers to overcome the tendency of the miner to rotate, but no problems were noted in sumping the miniminer into the face with the cutting head extended to the lateral extremes. Neither were problems observed when making vertically angled cuts. Figure 52 shows the artificial coal face at the conclusion of this testing.

COAL-LOADING TESTS

When equipped with the redesigned 8-in-diam gathering augers, the miniminer was found capable of loading ROM coal at a rate of up to 1.1 tpm. This value was recorded for a short burst of 42 s; loading rates over longer time periods averaged 0.7 tpm.

Four tests were conducted to determine the coal loading capabilities of the miniminer. The first test determined a loading rate for the older, 6-in-diam gathering augers, while tests 2 through 4 evaluated the redesigned 8-in-diam augers. All four tests used the miniminer and the forward bridge conveyor.

For tests 1 through 3, approximately 5 tons of loose ROM coal was placed in front of the miner so that the gathering augers were in full contact with the coal. The miner operator was instructed to tram forward so that the augers would load coal at the maximum rate. After a steady stream of coal was observed being discharged from the tail of the bridge conveyor, the miner was stopped and an empty 55-gal drum was placed under the end of the bridge conveyor. The miner was then restarted. The time required to fill one to several drums was recorded, as was the weight of coal within the drum(s). The loading rates were then calculated from the recorded time and weight values.

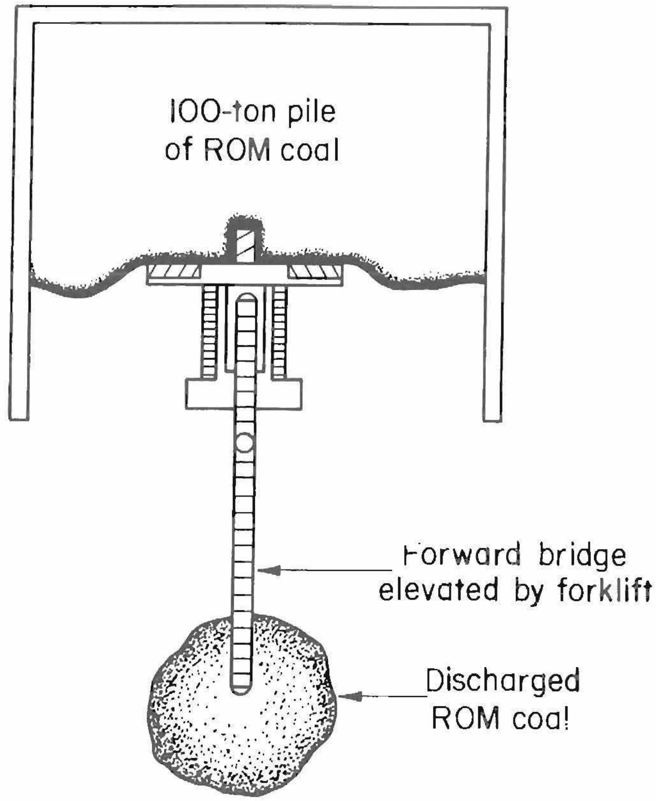


FIGURE 53. - Setup for loading test 4.

The fourth test was conducted using a similar procedure except that the miner was situated on the edge of a large bin of coal and the output from the bridge was dumped continuously on the floor (fig. 53). The transported coal was then collected into drums and weighed.

For test 4, the cutting head was allowed to rotate within the coal pile and transfer coal to the augers. For tests 1 through 3, the cutting head was not allowed to rotate. For all four tests, timing was stopped when a conveyor jammed and was not restarted until the jam was cleared and coal was being steadily discharged from the bridge conveyor.

Table 7 presents the results of the four coal loading tests. As shown, the loading rate determined for the 6-in-diam auger was quite low, at 0.4 tpm. The 8-in-diam augers apparently accomplished the goal of eliminating the miniminer's coal gathering function as the bottleneck in the overall extraction, gathering, and hauling process. The average loading rate of 0.7 tpm recorded for the

8-in-diam augers is 75 pct greater than the average cutting rate of 0.4 tpm determined for the miniminer and is 40 pct greater than the highest recorded cutting rate of 0.5 tpm (table 6).

TABLE 7. - Data from coal-loading tests

Test	Weight of ROM coal loaded, lb	Time of loading, min	Loading rate, tpm
1[1].....	374	0.5	0.4
2......	1,460	1.0	.7
3......	1,510	.7	1.1
4......	13,100	10.5	.6

[1]6-in-diam augers, all others, 8-in-diam augers.

TRACTION TEST

Because continuous miners certainly do not operate on concrete in actual underground mining, a quick test was conducted and a determination made that the miniminer is capable of sumping into a coal face when operating on a bed of mud. Clay was obtained from the Bruceton site and was placed in front of the coal block, extending approximately 15 ft from the face. A front-end loader was used to compact the clay to an approximate depth of 6 in. Water was then added to make the bearing surface for the miner very slippery. The miner operator was instructed to tram the miner to the face,

FIGURE 54. - Face at conclusion of traction test.

sump in, and cut a lift as per normal operating procedure.

It was observed that the extended gathering augers tended to push the mud forward instead of loading it. In effect, the mud shielded the augers and prevented them from gathering. The mud pushed by the augers against the face was of such volume that the miner had to be trammed outby and the mud cleared from both the augers and the base of the face before sumping could be resumed. Once the mud was cleared, no difficulties were observed with the miniminer sumping into the face and cutting the lift. Figure 54 shows the test site at the completion of this test.

RELIABILITY TRIALS

The miniminer system was found in an "available status" on a 52-pct basis during a phase of testing that evaluated the reliability of the mining system. The testing simulated a normal duty cycle for mining equipment being used in underground production, where the cutting, loading, haulage, and tramming functions of the equipment were operated for specified periods of time. The equipment was also deenergized for short periods of time to simulate such occurrences that happen underground during lunch breaks, face changes, and routine maintenance.

FIGURE 55. View of the mining system during reliability trials.

Figure 55 shows the situation of the test site during the reliability trials. As shown, the mining system was partially looped back upon itself so that material was loaded from a large pile of ROM coal in front of the miner, transferred through the haulage system, and discharged from the crossover dump in the general vicinity of the miner. A small skid-loader was used to gather the coal that poured from the crossover dump and replace it on the pile in front of the miner. ROM coal was loaded and transferred through the haulage system in this manner for periods of 20 min. The mining system was then trammed back from the large pile of coal as far as possible, approximately 25 ft, and deenergized.

During the inactive periods, the coal remaining adjacent to the crossover dump was gathered and replaced in the large, original pile. The mining system was then reenergized, trammed back to the pile of ROM coal, and the cycle was reinitiated. Though spinning in free air, the cutting head was activated during the 20-min time periods when coal was being loaded. Water sprays were also activated during the periods as they served the secondary function of cooling the miner's hydraulic fluid by flowing through an oil cooler unit. The sprays were diverted from the coal pile and fed into a sump. This prevented the coal from becoming too wet. Before a day of reliability testing commenced, all the equipment's hydraulic tanks were filled to capacity.

Data that were gathered during this testing consisted of the time spent loading coal and tramming, the cumulative time when the equipment was deenergized, the time spent diagnosing problems, the time spent repairing problems, and also, of course, the natures of the problems.

A total of 428 min of operating time (coal loading, transport, and tramming) were logged during the reliability trials. The time spent repairing problems totaled 400 min, of which 149 min was spent in diagnosing one problem. Looking at availability as the ratio of operating time versus operating time plus repair time, the miniminer system was available 52 pct of the time. If calculated to include the time spent diagnosing problems, the availability of the equipment is reduced to 44 pct.

As should be evident from the percentages given above, many problems were experienced with the miniminer system during the reliability trials. Table 8 is a list of the problems that occurred and the time associated with the repairs. As shown, the gathering augers were the most trouble-prone piece of hardware. The 6-in-diam augers originally installed on the miniminer had a hydraulically activated locking mechanism which was very unreliable.

The new 8-in-diam augers installed on the miner during the reliability trials had a supposedly "improved" mechanical system that locked the augers in the operating position. Unfortunately, the new locking mechanism also did not function properly and tended to release when force was applied to the inby edge of the augers by the coal being loaded. This usually required that the locking mechanisms be manually cleaned of loose coal before relocking could be accomplished. The gathering augers also frequently became jammed with small pieces of coal, slate, and metal. Figure 56 shows some of the objects that caused the jamming. As point of reference, the bolt shown in the figure is of 3/8-in nominal diameter.

It came as no surprise that the problems were experienced with the gathering augers; the augers had been very troublesome throughout the cutting evaluation and the reliability trials served to quantify the problems. Though the problem was an order of magnitude less severe when transporting ROM as opposed to artificial coal, conveyor jamming was a situation that occurred repeatedly throughout the cutting evaluation, and also continued through the reliability evaluation. There was a total of 13 instances during

TABLE 8. - Summary data for reliability trials

Repair event	Number of occurrences	Average time per occurrence, min	Total time per event, min
Clean out auger locking mechanism.....	8	2.7	21.8
Unclog gathering auger................	8	3.6	29.1
Unjam MBC conveyor....................	5	4.2	21.1
Unjam forward bridge conveyor.........	4	2.0	8.1
Unjam articulated bridge conveyors....	2	.8	1.5
Unjam conveyor on crossover dump......	2	6.7	13.5
Put miner conveyor on sprocket........	2	6.5	13.0
Rerail rear dolly.....................	1	3.8	3.8
Lock augers...........................	1	1.1	1.1
Activate boom elevation solenoid......	1	5.5	5.5
Clean out belt conveyor on crossover dump................................	1	112.5	112.5
Unjam belt conveyor on crossover dump.	1	14.5	14.5
Remove bent link from chain on crossover dump...........................	1	5.0	5.0
Replace pump on crossover dump........	1	150.0	150.0
Total............................	38	NAp	400.5

NAp Not applicable.

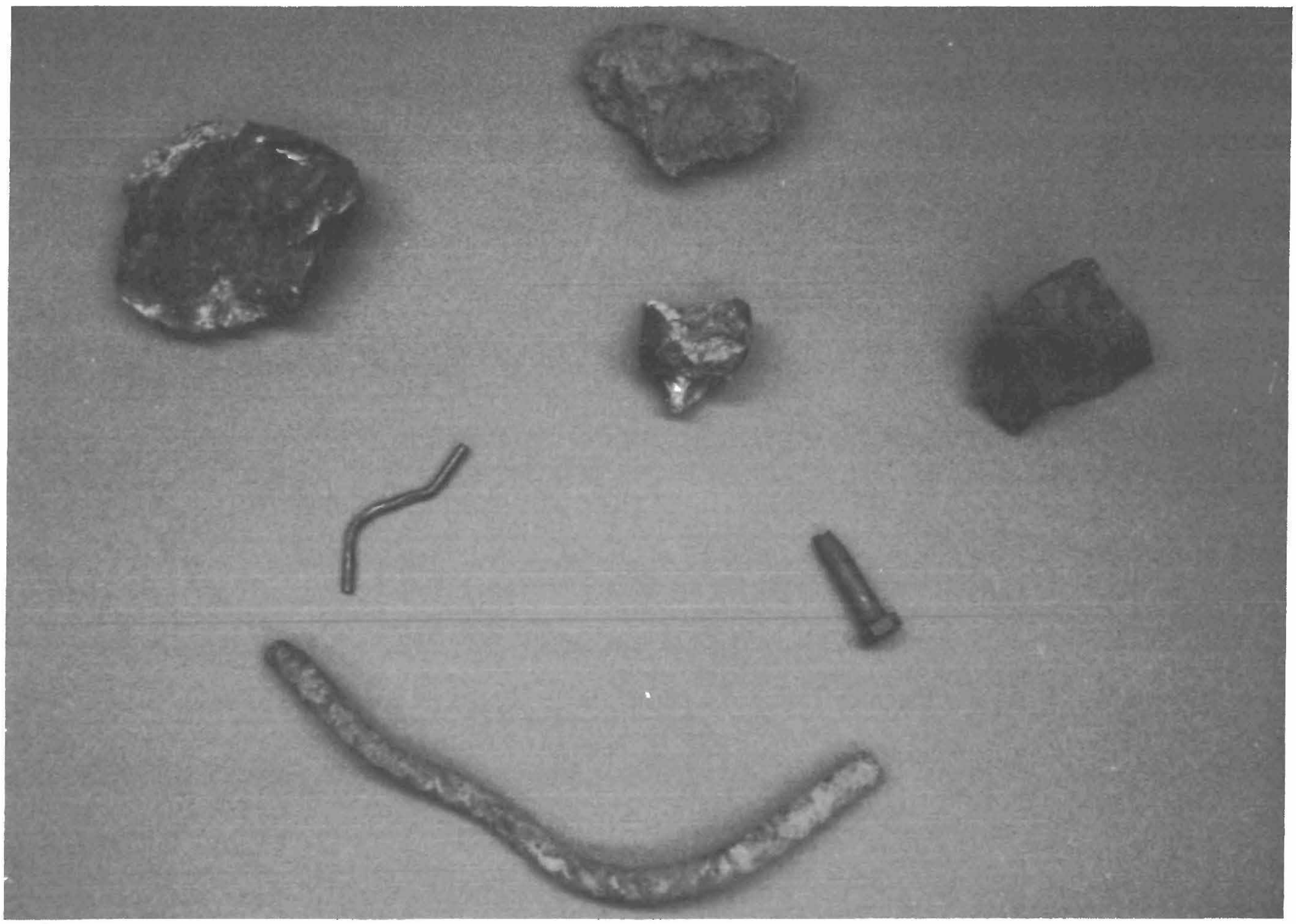


FIGURE 56. - Objects that jammed gathering augers. The bolt is of 3/8-in in nominal diameter.

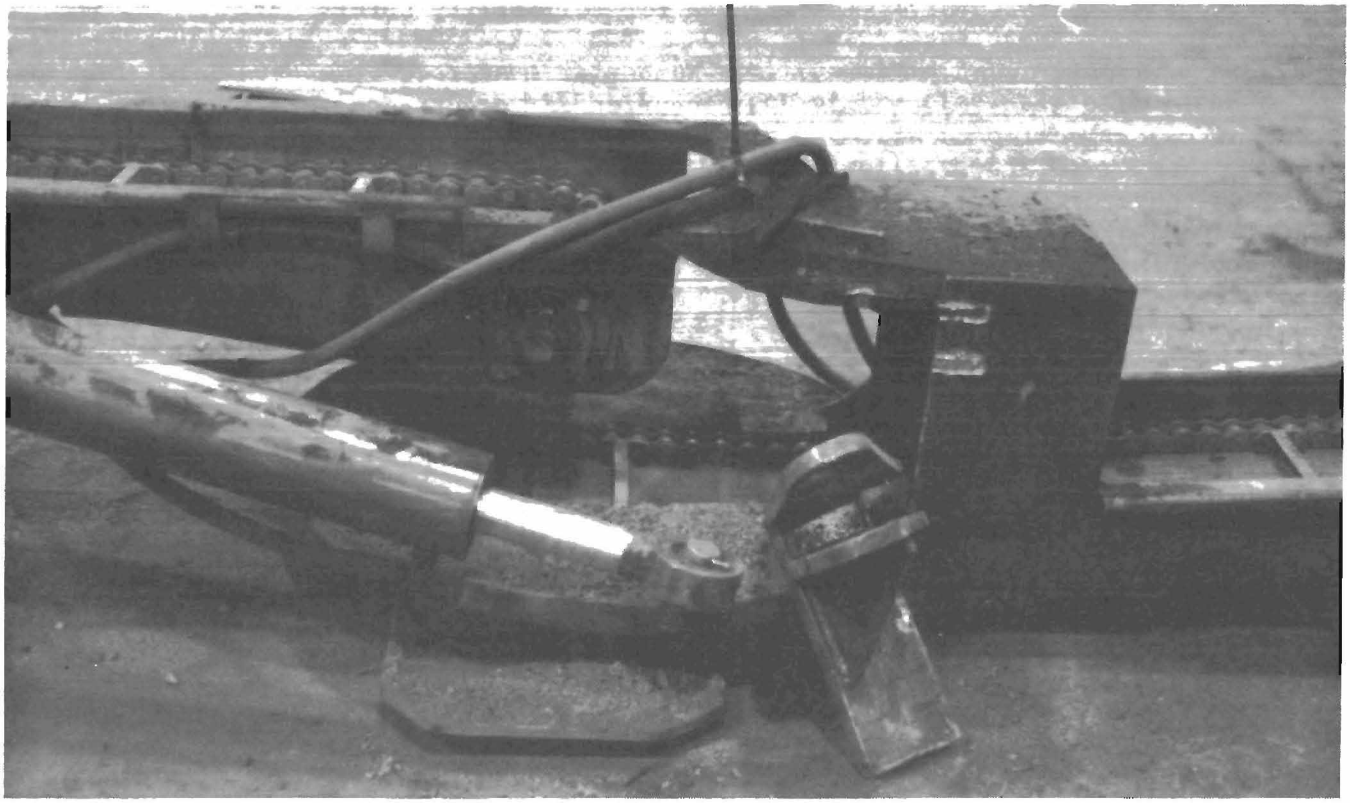


FIGURE 57. - Failed mount for articulation cylinder.

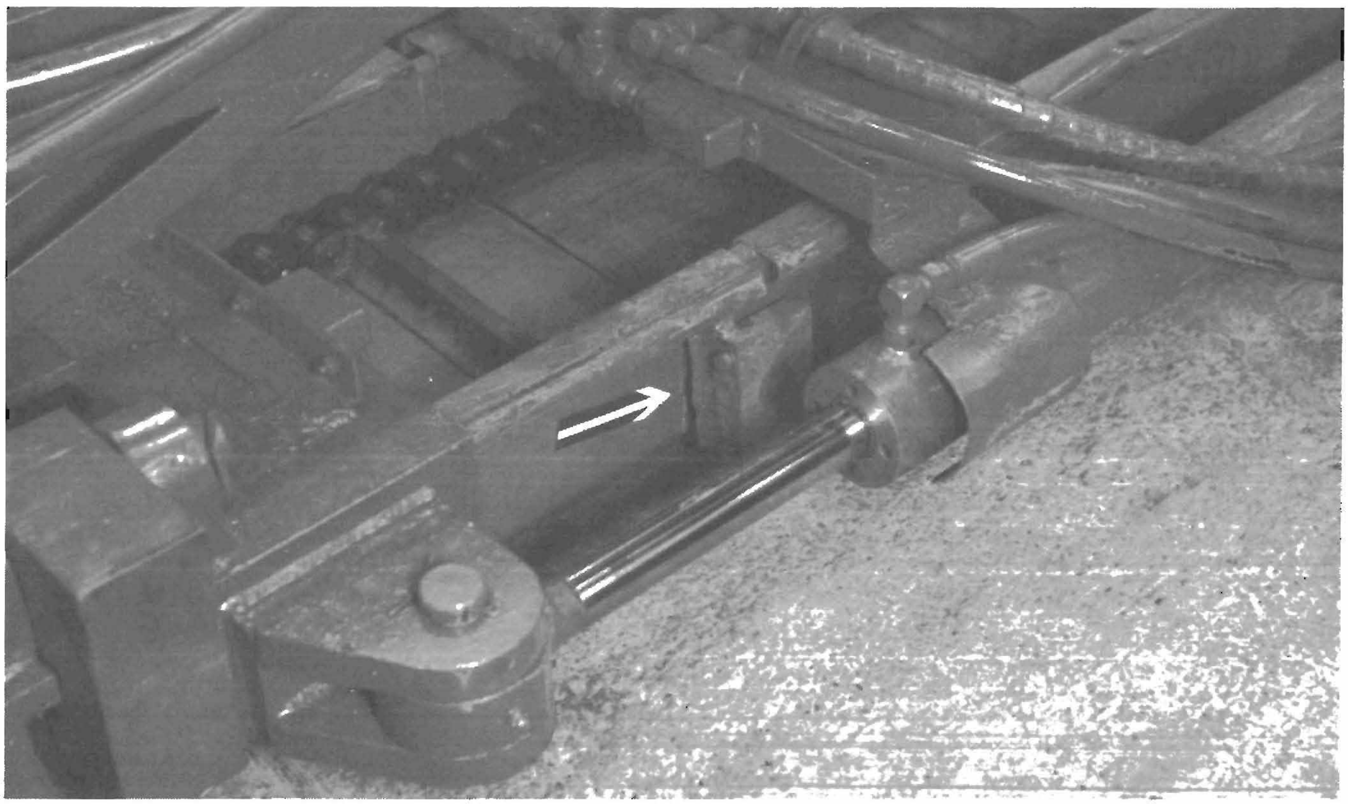


FIGURE 58. - Failed connection between panline sections.

the 7.1 h that the system was operating that the conveyors had to be freed by using pry bars or by pulling on the conveyor chain with a front-end loader.

Several additional problems with the haulage system were identified during the reliability trials. As shown in figure 57, the brackets that mounted the hydraulic ram at the articulation point between the double bridges had become bent and finally failed. Also, many of connector assemblies between the panline sections had failed at this point in the testing. Such failure is shown in figure 58.

Except for one situation, where the total of 149 min of diagnosis time was spent, the mechanical problems during the reliability trials were obvious. Therefore, the equipment status went directly from operation to breakdown to repair. The one situation involving diagnostic time was when a link in the panline's conveyor chain had become bent and would catch on a holddown strip located on the crossover dump. The test personnel felt the diagnostic time for this situation would also have been minimal had the problem reoccurred.

RELIABILITY TRIALS DISCUSSION

The time allocated for the reliability trials was short; it certainly was not long enough to allow extreme confidence in the 52-pct availability figure as an absolute value for the mechanical reliability of the miniminer system. However, the testing did accomplish its intended goal: determining whether or not the mining equipment had any gross problems with its mechanical performance. On this basis it is clear that the equipment does have problems and that the manufacturer needs to make several design changes and also upgrade the selection of commercially available components. As will be detailed in the "Haulage System Operating Parameters" section, the drives for most of the haulage system are apparently underpowered and need to be upgraded. This should greatly reduce or possibly eliminate the many problems experienced owing to the conveyors and augers jamming.

SPILLAGE TRIALS

The miniminer system was found to lose a minimum of 6 pct of the volume of coal transported from the gathering augers through to the discharge of the crossover dump. The spillage trials that established this fact were conducted with the mining system oriented in the same geometry as in the reliability trials. The distance from the gathering augers to the discharge of the crossover dump was approximately 150 ft, and involved six transfer points.

Two spillage tests were actually conducted. The first test had personnel stationed along the haulage system who would continuously scoop up spilled coal from the floor and load it into 55-gal drums. The total amount of coal loaded by the augers during the test was calculated at 5.1 tons by multiplying the time of loading, 14.2 min, by the known loading rate, 0.4 tpm, found from coal loading tests conducted the same day. A total of 12,150 lb of coal was collected, which represented a 21-pct loss. For the second test, the spilled coal was allowed to accumulate where it fell, and was not gathered up until the testing was stopped. In this test, 460 lb of spilled coal was gathered after the mining system had loaded 4.2 tons of coal in 11.6 min. This second test showed a 6-pct loss of coal owing to spillage.

The much more positive results of the second test are easily explained. The coal initially lost accumulated on the floor to the point that the spillage "leaks" were closed off, preventing additional spillage from occurring. This second test is also much more representative of what would occur in underground production use of any continuous haulage system; spillage is significantly reduced and much less manual labor is required.

As expected, the coal spillage occurred primarily at the transfer points. In decreasing order of severity, the spillage locations were as follows: (1) at the transfer point between the miner and the forward bridge conveyor, (2) the transfer point between the mobile bridge carrier and the most inby section of the double, articulated bridges, (3) the transfer point at the location of the panline dolly, and (4) the transfer point at the location of the dolly riding the mobile bridge carrier's receiving section. This order could be expected to change as the geometry of the mining system is changed. However, it is the author's opinion that the overall spillage value of approximately 6 pct should be relatively unchanged regardless of the geometry of the mining system.

It should be noted that the miniminer system, as originally received from the manufacturer, would have fared much worse in regard to spillage than the values presented above. Because a large spillage problem was observed at the transfer point between the miner and forward bridge during the preliminary cutting trials, the manufacturer incorporated much larger receiving sections (fig. 59) on the new, lighter bridges. Also, the test personnel took it upon themselves to relocate the attachment points between discharge and receiving ends of bridges and at dollies so that spillage was minimized.

TABLE 9. - Electrical power characteristics, kilowatts

	Left motor	Right motor
Miniminer function:		
Starting current..........	176	163
No load...................	9	9
Cylinder functions........	20	9
Head feed.................	13	9
Low tram..................	11	15
High tram.................	15	10
Gathering augers..........	13	10
Augers and conveyor.......	13	15
Augers, conveyor, and head	16	20
Augers, conveyor, head, and feed.................	19	20
Average slump.............	30	30
Average cut...............	32	32
Mobile bridge carrier function:[1]		
No load...................	10	
Solenoid functions........	22	
Tram......................	17	
3 conveyors...............	22	
Crossover dump function:[1]		
No load...................	11	
Belt conveyor.............	13	
Chain conveyor............	16	
Both conveyors............	17	

[1]Only 1 motor, neither left nor right.

ELECTRICAL POWER CONSUMPTON

Various electrical power characteristics of the miniminer system were measured and are presented in table 9. As shown, the average electrical power consumed by the miniminer when sumping into the face was 60 kW. Assuming a production rate of 0.4 tpm, the average value obtained from the cutting pattern studies, the miniminer used an average of 2.9 kW·h/t of mined coal. Table 9 also lists similar electrical power information for the various functions of the mobile bridge carrier and the crossover dump. All haulage function data given in the table were measured for the unloaded condition.

Figure 60 presents analog traces of power consumption recorded for the two electrical motors of the miniminer during the cutting of a typical lift. Figures 61 and 62 present similar traces for the mobile bridge carrier and the crossover dump. The latter information was recorded while ROM coal was being run through the haulage system.

The electrical data for the miniminer system were obtained from doughnut-type current transformers placed on the leads to the A and C phases of the electrical motors. Four transformers were used: two for the two motors on the miniminer and one each for the motors on the mobile bridge carrier and the crossover dump. The outputs from the current transformers were fed to watt transducers. In turn, the output of the watt transducers were fed to a strip chart recorder, where permanent records of the power usage of the three machines were made. Figure 63 shows the watt transducers for the miniminer located on the outside of the right-hand electrical panel.

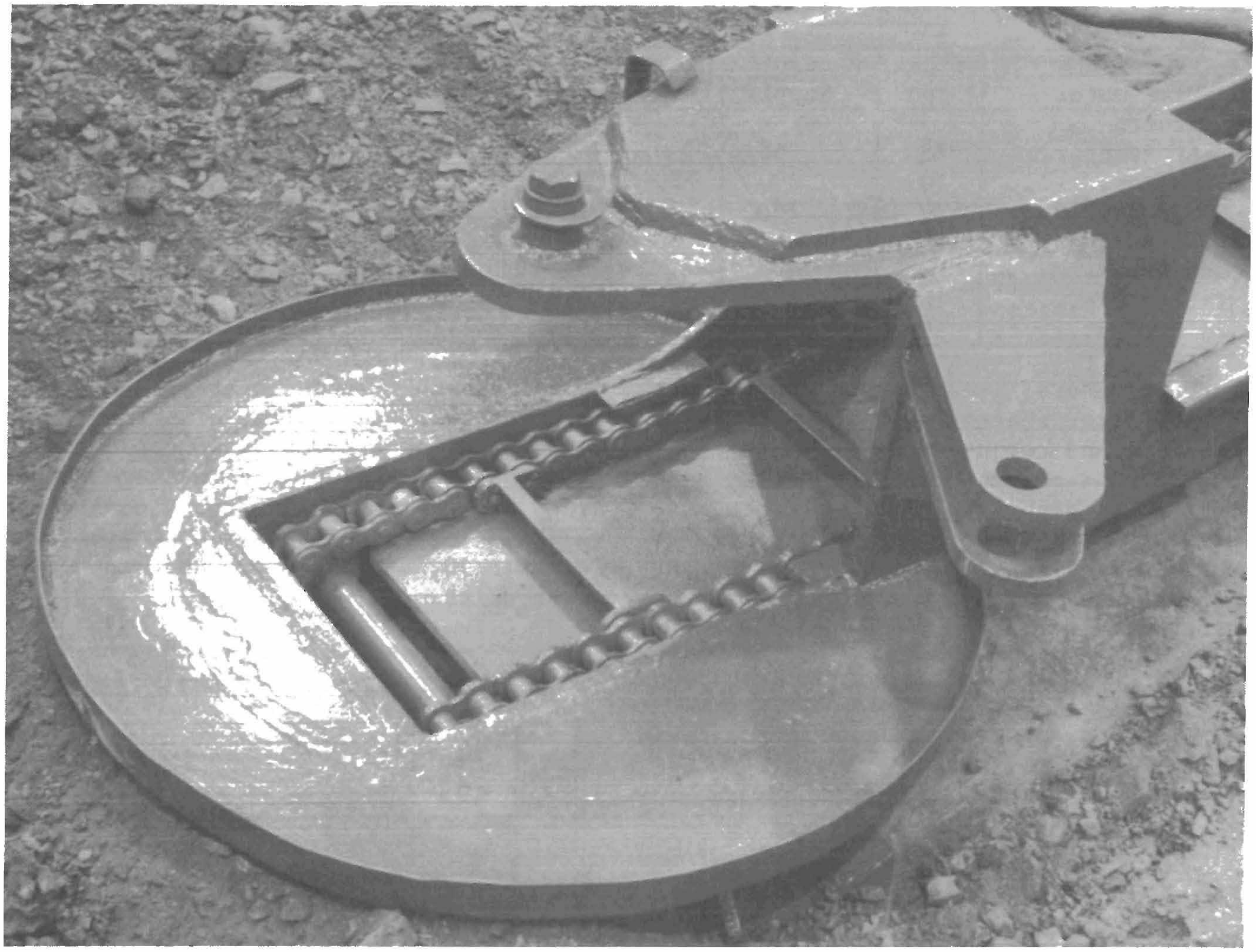


FIGURE 59. - Revised receiving section on conveyor.

The above electrical data are furnished primarily as information only, and no analysis was attempted. The information should be of value as a reference point against which similar information on other mining equipment can be compared.

HAULAGE SYSTEM OPERATING PARAMETERS

As was mentioned previously, the gathering augers and bridge conveyors slowed significantly when carrying a substantial load of coal and were jammed repeatedly by relatively small pieces of coal and slate. This led to the suspicion that one or a combination of the following situations were at fault: the haulage systems were underpowered; and/or unanticipated, large amounts of friction were occurring within the haulage systems, leaving little power for the actual transportation of coal.

A small-scale investigation was initiated as the last active portion of the surface evaluation. It determined, for the various haulage-related circuits, the relative relationships between the potential power available to overcome friction and transport coal versus the power consumed by friction. Besides identifying the problem(s), this information, coupled with the electrical power measurements, should give the manufacturer a more clear-cut route to solving the problem(s).

Table 10 shows the results of the following measurements: hydraulic flow into the haulage drive motors; pressure drops

TABLE 10. - Data on haulage system drives

Circuit and drive motor	Flow, gpm	Hydraulic pressure, psi			Shaft, rpm	Torque, ft•lb	Power, hp	
		Supply	Return	Δp			Shaft	Potential
Miniminer:								
Left auger......	15	55	0	55	206	5-10	0.3	0.5
Conveyor........	10	1,000	750	250	112	35-40	.8	1.4
Forward bridge..	10	750	175	575	121	65-70	1.6	3.2
Mobile bridge carrier:								
1st bridge......	10	1,350	900	450	112	65-70	1.4	2.5
2d bridge.......	10	900	125	125	112	65-70	1.4	4.3

over the motors; revolutions per minute of the motor shafts with the conveyors unloaded; and torque required to turn the motor shafts and move the conveyors, also with the conveyors unloaded. Before measurements were made, all the hydraulic tanks were filled to capacity and each machine was allowed to warm up. The gathered data allowed simple calculations to be made that showed what potential hydraulic power was available to the drive motors and what power was consumed by friction in driving the haulage components at the measured rotational speed values. The calculated values are given in table 10, and are expressed in horsepower units.

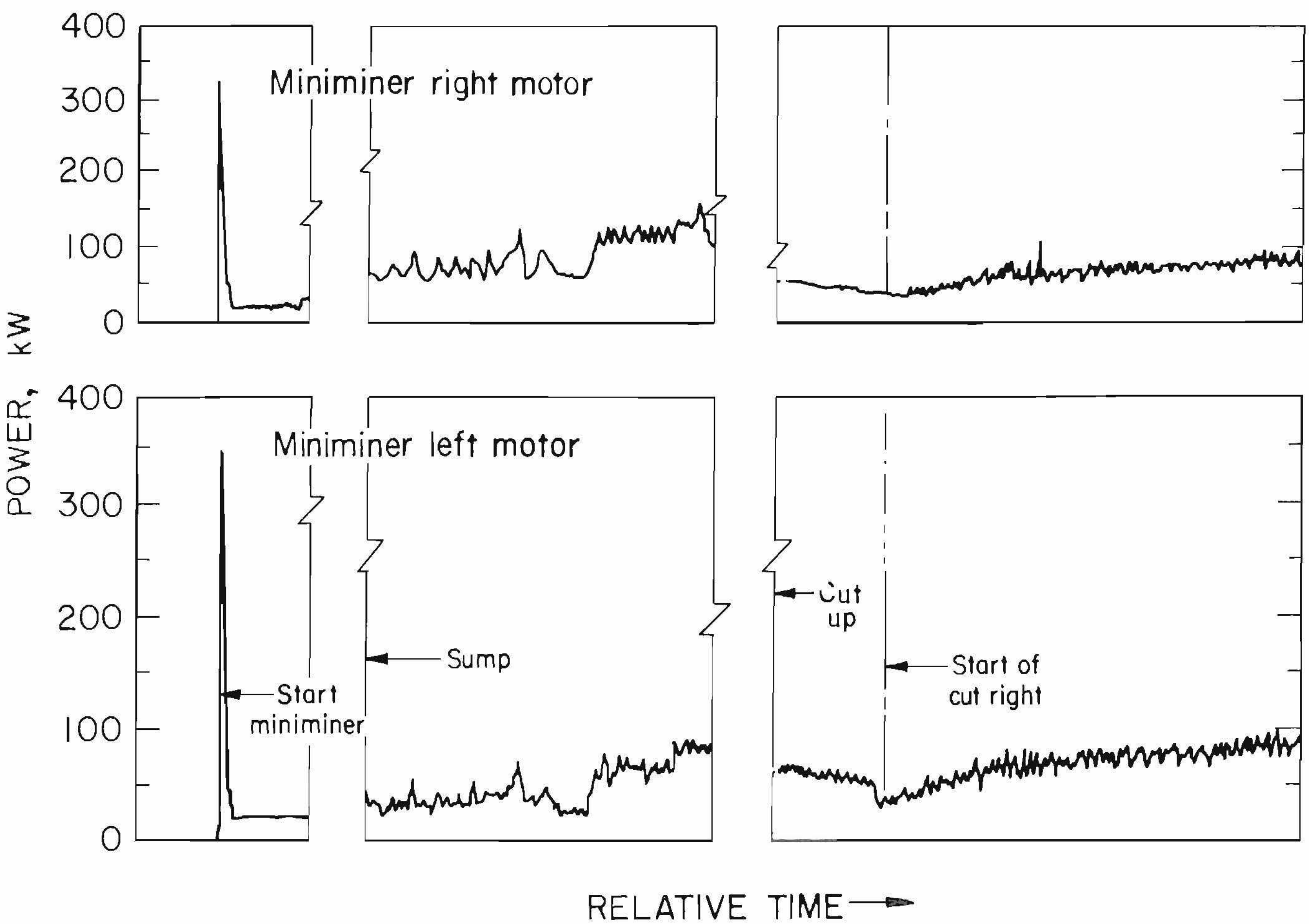


FIGURE 60. - Miniminer power consumption during cutting.

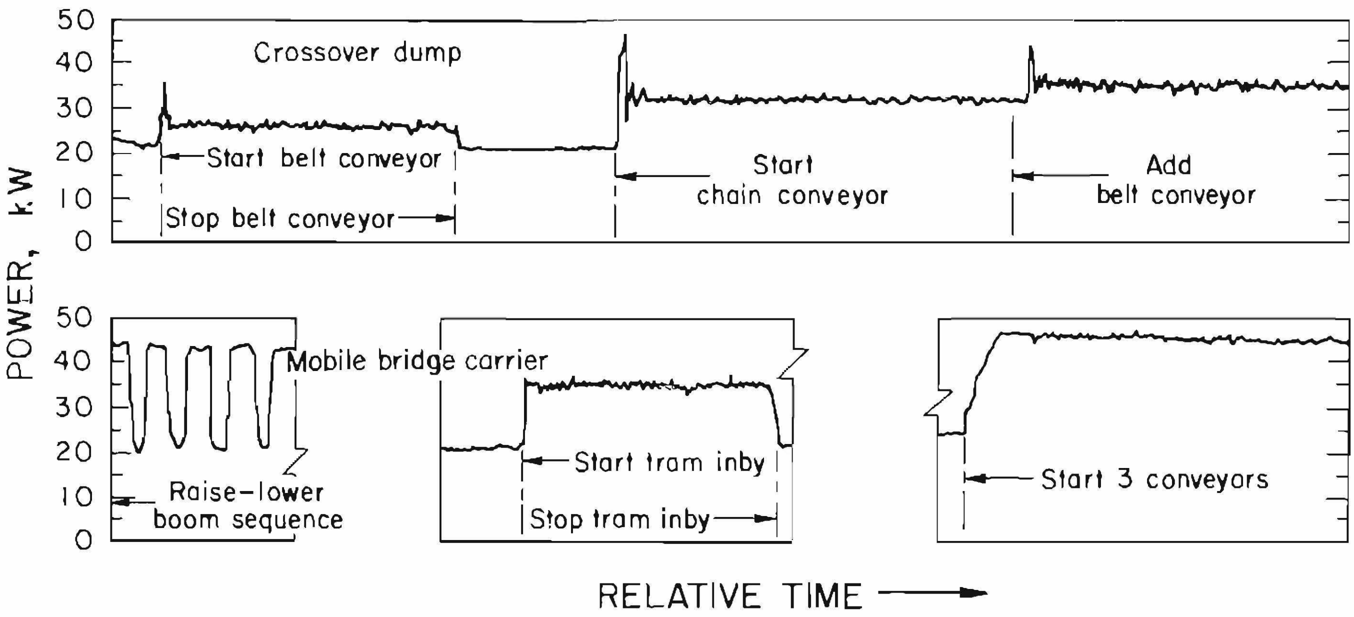


FIGURE 61. - Power consumption of mobile bridge carrier.

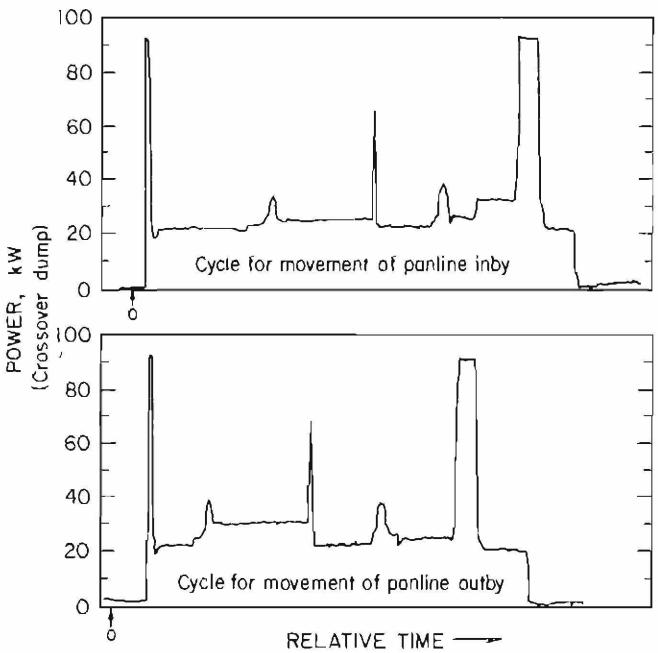


FIGURE 62. - Power consumption for crossover dump.

From discussions with the manufacturer, it was learned that virtually all of the calculated potential hydraulic power values fell significantly below what was assumed would be present when designing the drives for the haulage systems. Additionally, the power-consuming frictions within the conveyor assemblies were measured at much higher values than what the manufacturer assumed during design. Thus, the underpowered nature of the haulage systems apparently stemmed from a combination of the two factors that were investigated. The causes for the drops in measured versus assumed potential hydraulic power values are presently unknown. However, it is the author's opinion that the inability to adjust the conveyor chain tension levels in an infinitely variable manner was the primary cause for the unexpectedly high friction levels.

SUMMARY OF RESULTS FOR CUTTING EVALUATION

No general statement can be made on how the miniminer system fared in the cutting evaluation; both strong positive and strong negative factors were identified for the new mining system.

For both health areas where testing was conducted, dust generation and noise generation, the miniminer system, as tested, appeared capable of complying with current Federal regulations for underground face equipment. The miniminer was very capable of precision cutting, was easily controlled by the miner operator, and, within certain

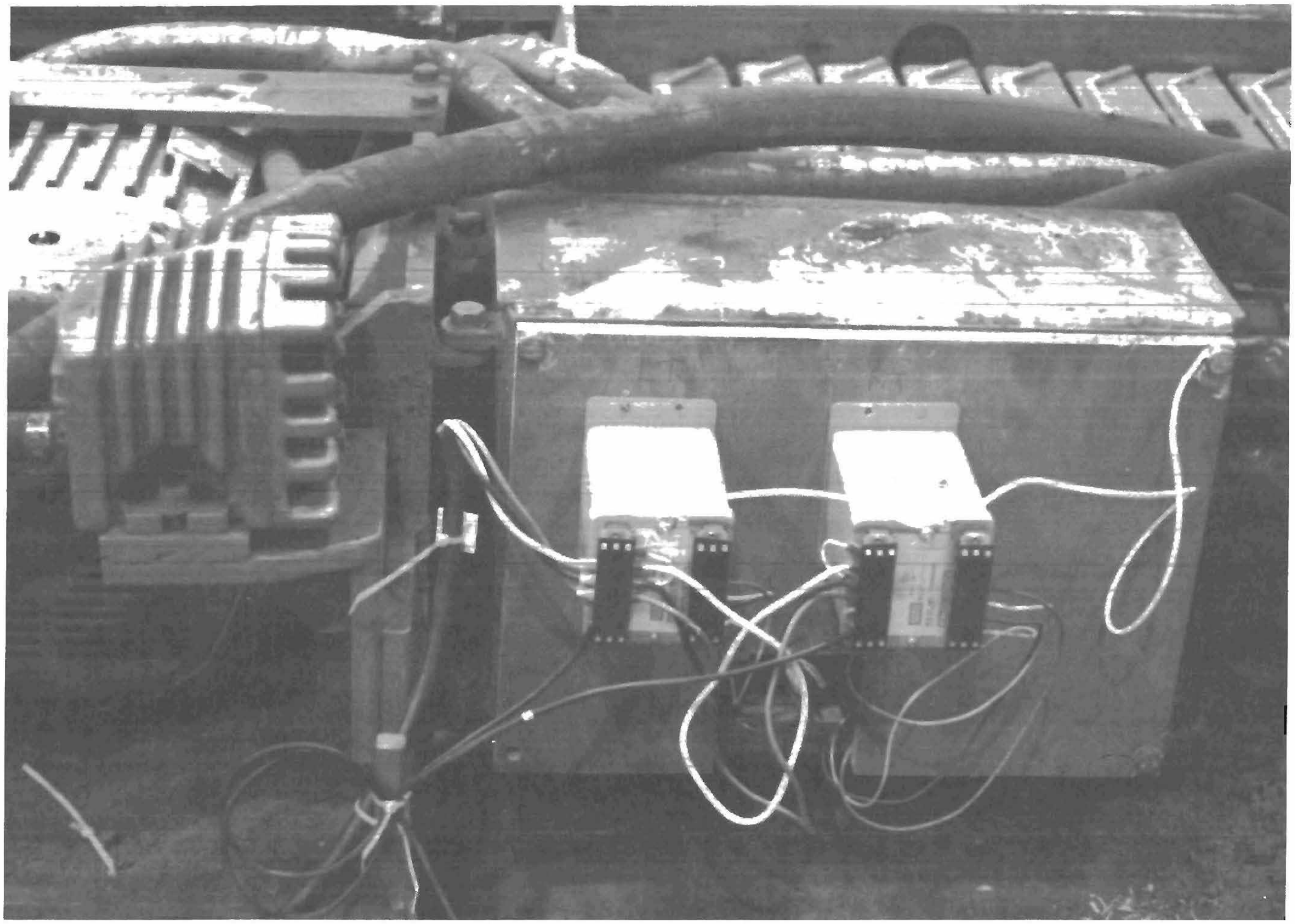


FIGURE 63. -- Electrical power sensors used on miniminer

limitations, was found able to cut on oblique angles to the face. These factors could make the mining system attractive for low-coal pillar mining. Also, the haulage system, as tested, showed relatively little coal spillage.

Though intentionally designed to cut and convey coal at low rates, the observed rates were considerably lower than expected from the manufacturer's specifications. The average observed cutting rate was 0.4 tpm, while the average observed coal loading rate was 0.7 tpm. Additionally, the preproduction prototype version of the miniminer system that was tested suffered from numerous design and mechanical problems. Foremost among these problems were the following: the availability of the overall mining system during the reliability testing was a meager value of approximately 52 pct; the entire haulage system was considered underpowered, as components would jam repeatedly when transporting artificial or ROM coal; and the locking mechanisms for the gathering augers were found very unreliable, failing repeatedly during the cutting evaluation.

GENERAL RECOMMENDATIONS

Based on the overall results of the surface evaluation of the miniminer system, the following major recommendations are made:

1. The Bureau should not pursue immediate underground testing of the miniminer system. The primary reason for this is that three major concerns were

identified for the mining system tested: the bridge carrier operator could be placed in both precarious and inefficient positions when tramming; the folding gathering augers do not lock in position properly, and can force a person trying to rectify the problem into a hazardous situation; and the conveyors tend to jam repeatedly, requiring potentially injurious labor to unjam them. These negative factors are obviously both safety and productivity concerns.

2. The manufacturer should relocate the operator controls for the mobile bridge carrier on an umibilical cord in the manner done with the controls for the miner. This will remove the operator from the present hazardous situation that occurs when the mining system is being trammed through a right turn. It could also enable the mobile bridge carrier operators to always see the position of the panline dolly, increasing their efficiency.

3. The manufacturer should increase the overall mechanical reliability of the mining system.

4. The manufacturer should identify and solve the problems associated with the jamming of the haulage system when transporting coal and the unreliability of the gathering auger locking mechanisms.

5. The Bureau should gather data on the underground performance of a corrected version of the miniminer system at some future date, in cooperation with the manufacturer.

OVERALL SUMMARY FOR 4M MINIMINER SYSTEM

The surface evaluation found the miniminer system to be a unique, positive concept with considerable future potential for safe, healthful, and possibly economic operation in thin seam mining. The new mining system appears capable of being used with a wide variety of roof support elements and systems and is uniquely capable, when considering current commercially available mining equipment, of allowing the installation of roof bolts behind the miner, within 15 ft of the working face. This attribute should allow the miniminer system be used in a truly continous mining mode, which includes the roof support requirement.

The mining system was found extremely maneuverable, and to such extent that possibilities exist for using it in low-quality coal mining situations presently considered unminable by other existing mining equipment. The miniminer system's extreme maneuverability also makes it possible for an experienced crew to maneuver it through relatively narrow entries at a relatively rapid tram rate. This factor improves its viability for development mining using face-change cycles. Also, the miniminer system appears matched or superior to most other existing mining and coal haulage equipment in the area of noise generation.

The surface testing showed the miniminer system capable of cutting and transporting artificial coal at an approximate rate of 0.4 tpm. This value should be considered anything but absolute, however, as the artifical coal used in the testing was not designed to have cutting characteristics of genuine coal, and its relationship to the cutting characteristics of genuine coal is presently unknown. Also, the frequent jamming of the haulage system components hampered data collection to such an extent that the 0.4 tpm rate is not considered particularly reliable. In the author's opinion, a future, corrected version of the miniminer system should be capable of cutting and transporting coal at maximum rates closer to the 1.0- to 1.5-tpm rate specified by the manufacturer. Of course, production rate is not the only consideration in estimating the economic viability of mining equipment. Capital investments, operating costs, and a host of other considerations that would typically vary from situation to situation are additional factors that mine operators will need to consider when evaluating the miniminer system for use in their coal mines.

Without question, the early version of the miniminer system that was tested had deficiencies that would preclude it from being considered immediately mine-worthy. The haulage system needs to be modified so that it does not labor excessively when carrying coal. The mechanical reliability of the overall mining system needs to be upgraded. The reason that the auger locking mechanisms do not function properly needs to be found and corrected. Also, certain more minor mechanical deficiencies need to be rectified.

The Montgomery Mining Machinery Manufacturing Co. (4M) has been advised of the various positive and negative findings of the surface evaluation. 4M appears satisfied that the surface evaluation was very useful and valid, and has apparently taken action to upgrade the mining system based on the surface testing results. Although none of the changes have been observed or tested, 4M has stated that all the recommended modifications have or will, in the near future, be incorporated into an updated version of the mining system. Also, the identified mechanical deficiencies are receiving similar treatment. It is expected that the upgraded miniminer system and/or its descendents could foster a new era in future thin-seam coal mining.

APPENDIX A.--MINIMINER SYSTEM SPECIFICATIONS

MINIMINER

	ft	in
Length:		
Overall	14	
Of cutting auger	2	3
Of wheelbase	4	6
Over crawlers	6	
Width:		
Over head (gathering head folded)	9	11
Over mainframe	8	10
Of crawler chains	1	
Over gathering head extended	16	
Of cut	18	
Of conveyor pan	1	1
Of conveyor chain	1	
Height:		
Of mainframe	1	8
Over crawler chains	1	6
Of cut, minimum	2	2
Of cut, maximum	4	4
Diameter:		
Of cutting auger	2	
Of gathering scrolls (2)		6

	rpm
Speed:	
Of cutter	78
Of gathering scrolls	200

	fpm
Velocity:	
Of conveyor chain	140
Of crawler chain, maximum	40
Of crawler chain, minimum	10
Of cutting auger feed	10

Head feed power: 2 hydraulically driven planetary gear boxes connected to drive chain.

Cutterhead drive: A piston-type motor mounted on and driving a double-reduction planetary gear box with the cutting element mounted on it.

Crawler drive: 2 piston-type motors mounted on and driving double-reduction planetary gear cases with the crawler chain drive sprockets mounted on them.

Conveyor drive: A low-speed, high-torque hydraulic motor connected via sprockets and chains (a jack shaft with 4:1 reduction) to the conveyor chain drive shaft.

Gathering auger drive: A low-speed, high-torque motor connected via sprocket and chain (2:1 reduction) directly to the end of the auger.

Electric motors: Two 35-hp, 440-V ac, 3-phase, 60-Hz, frame 326TCZ, squirrel cage; explosion tested and certified by MSHA.

Starter: Magnetic contactor with circuit breaker and transformer in an explosion tested and certified (MSHA) enclosure.

Control case: Relays and transformer in an explosion tested and certified (MSHA) enclosure, approved as intrinsically safe.

Remote control console: Approved as intrinsically safe, open-type enclosure with switches mounted on the top cover of console and with console connected to the control case by an umbilical cord.

Headlights: Two 115 V ac, explosion tested, approved, and certified lights mounted on the miniminer mainframe.

Sprays: 6 mist sprays mounted on the mainframe to control dust.

Water pump: Drive motor with starter and a 3-gpm water pump rated at 1,000 psi, mounted on a skid base.

Methane monitor: MSHA approved and certified monitor mounted on miniminer mainframe.

Bridge conveyor hitch: Included as part of the miniminer chain conveyor.

Trailing cable: 500 ft of #2-3 conductor with ground; round, jacketed , MSHA-approved cable.

Cable strain clamps: Supplied for both trailing cable and umbilical cord for the remote control station.

Conveyor chain: 1.5-in pitch, thimble-roller side chains, with flights between strands, and spaced on 12-in centers.

BRIDGE CONVEYOR

	ft	in
Length (center to center)......	20	
Height........................	1	6
Width:		
Over the pan.................	1	4
Of the trough................	1	1
Of the conveyor..............	1	
Depth of pan..................		4
Diameter of receiving plate....	2	

Conveyor chain: 1.5-in pitch, thimble-roller side chains, with flights between strands, and spaced on 12-in center.

Chain conveyor chain: A low-speed, high-torque hydraulic motor connected via sprockets and chains (jack shaft) to the conveyor drive sprocket.

MOBILE BRIDGE CARRIER

	ft	in
Length:		
Overall......................	20	6
Of crawler base..............	4	6
Over crawlers................	6	
Width:		
Overall (mainframe)..........	7	
Of the crawler chains........	1	
Of the conveyor..............	1	2.5
Of the conveyor trough.......	1	1
Of the conveyor chain........	1	
Height:		
Overall......................	1	8
Of the crawlers..............	1	6

	fpm
Velocity:	
Of the conveyors.................	140
Of crawlers......................	40

Crawler drive: 2 piston-type hydraulic motors mounted on and driving double-reduction planetary gear cases with the crawler drive sprockets mounted on them.

Conveyor drive: A low-speed, high-torque hydraulic motor connected via sprockets and chains (a jack shaft with 4:1 reduction) to the conveyor chain drive shaft.

Electric motor: One 35-hp, 440-V ac, 3-phase, 60-Hz, frame 326TCZ, squirrel cage; explosion tested and certified by MSHA.

Starter: Magnetic contactor with circuit breaker and transformer in an explosion tested and certified (MSHA) enclosure.

Trailing cable: 500 ft of #4-3 conductor with ground; round, jacketed, MSHA-approved cable.

ARTICULATED BRIDGE (2 SECTIONS)

	ft	in
Length (center to center, each section).......................	20	
Height........................	1	6
Width:		
Over the pan..................	1	4
Of the trough.................	1	1
Of the conveyor...............	1	
Depth of pan..................		4
Diameter of receiving plate......	2	

Conveyor chain: 1.5-in pitch, thimble-roller side chains, with flights between strands, and spaced on 12-in centers.

Chain conveyor drive (each section): Independent low-speed, high-torque hydraulic motors connected via sprockets and chains (jack shafts) to the conveyor drive sprockets.

Pivot articulation: Front section rides on rear section mounted on a skid base with a cylinder connecting the front and rear sections allowing 45° articulation to either side of the centerline.

PANLINE

	ft
Length:	
Total conveyor	300
Of each section	8
Of tailpieces (2 each)	4

	ft	in
Width:		
Of pan section	1	4
Of conveyor troughs	1	1
Of tailpieces	1	4
Tailpiece takeup	1	2
Depth of trough		4

Conveyor chain: 1.5-in pitch, thimble-roller side chains, with flights between strands, and spaced on 12-in centers.

Conveyor drive: Resides in crossover dump.

Conveyor pan sections	39
Tailpieces	2
16-ft chain sections	41

CROSSOVER DUMP

	ft	in
Length, over mainframe	13	6
Width, over mainframe	5	3
Height	1	8
Diameter of bolt drive pulley		8
Diameter of belt discharge pulley		4

Belt conveyor drive: A low-speed, high-torque piston motor coupled directly to drive pulley.

Chain conveyor belt: A low-speed, high-torque motor coupled directly to the chain drive sprocket.

Base securing screwjacks	4

Electric motor: One 35-hp, 440-V ac, 3-phase, 60-Hz, frame 326TCZ, squirrel cage; explosion tested and certified by MSHA.

Conveyor advancer mechanism: 2 horizontally mounted thrust cylinders with 52-in jack strokes connecting the conveyor advancer mechanism to the mainframe and operating automatically via magnetic switches and cable connections provided

Control case: Magnetic contactor to start motor, circuit breaker for overload protection, transformer and relays for intrinsically safe advancer circuit; all mounted in an explosion tested, approved, and certified enclosure.

Trailing cable: 300 ft of #4-3 conductor with ground; round, jacketed, MSHA-approved cable.

OTHER

Trailing cable: 500 ft of #2/0-3 conductor with ground; round, jacketed, MSHA-approved cable with electrical plugs and receptacles to connect to both the power center and distribution box.

Distribution box: Skid-mounted, fully covered, open-type enclosure with a receptacle to receive the incoming cable and with five circuit breakers to protect the outlets for the miniminer (225 A), the mobile bridge carrier (150 A), the crossover dump (150 A), and for two roof bolters (150 A each).

APPENDIX B.--BASELINE HYDRAULIC MEASUREMENT FOR MINIMINER SYSTEM

MINIMINER

Tap	Location	Function	psig
1......	Between the miner conveyor motor and the bridge conveyor motor.	Miner conveyor off...	135
		Miner conveyor on....	200
2......	Between the miner conveyor pump and the miner conveyor motor.	Miner conveyor on....	400
3......	Cutterhead motor return....................	Cutterhead off.......	100
		Cutterhead on........	100
4......	Between the rihgt and left auger motors......	Augers on............	0
		Augers off...........	0
5......	Cutterhead pump supply......................	Cutterhead on........	105
		Cutterhead off.......	105
6......	Between the cutterhead elevation cylinder and the cutterhead elevation solenoid valve.	Raise head...........	1,600
		Lower head...........	200
7......	Between the left tram pump and the left low tram valve.	Inby left low tram...	1,200
		Outby left low tram..	1,200
		Inby dual low tram...	700
		Outby dual low tram..	350
8......	Between the right tram and auger pump and the right high tram valve.	Auger on.............	575
		Inby right high tram.	1,500
		Outby right high tram	1,500
		Inby dual high tram..	1,100
		Outby dual high tram.	1,100
		Inby dual low tram...	100
9......	Cutterhead motor supply.....................	Cutterhead off.......	190
		Cutterhead on........	850
10......	Between the right tram pump and the right low tram valve.	Inby right low tram..	1,250
		Outby right low tram.	1,250
		Inby dual low tram...	500
		Outby dual low tram..	900
11......	Between the left tram and auger pump and the left high tram valve.	Auger on.............	550
		Inby left high tram..	1,400
		Outby left high tram.	1,550
		Inby dual high tram..	700
		Outby dual high tram.	700
		Inby dual low tram...	5
12......	After the feed and solenoid pump............	Head feet right......	600
		Head feed left.......	600
		Elevate head.........	1,700

MOBILE BRIDGE CARRIER

Tap	Location	Function	psig
1.......	Output right tram pump.......................	Inby right tram......	1,050
		Outby right tram.....	1,050
		Inby dual tram.......	1,000
		Outby dual tram......	850
2.......	Output cylinder pump........................	Boom elevating.......	1,950
		Cylinders raise......	1,950
		Boom elevating.......	
		Cylinders lower......	1,950
		Cantilever elevating.	
		Cyliner raise........	1,950
		Cantilever elevating.	
		Cyliner lower........	1,950
3.......	Output left tram pump.......................	Inby left tram.......	1,050
		Outby left tram......	1,050
		Inby dual tram.......	700
		Outby dual tram......	500
4.......	Between the bridge conveyor pump and the conveyor control valve.	Conveyor off.........	10
		Conveyor on..........	130

CROSSOVER DUMP

Tap	Location	Function	psig
1.......	Between the belt conveyor pump and the belt conveyor motor.	Belt conveyor off....	45
		Belt conveyor on.....	160
2.......	Between the chain conveyor pump and the chain conveyor motor.	Chain conveyor on....	550
		Chain conveyor off...	110
3.......	Between the cylinder pump and the thrust cylinder operating valve.	Inby extend..........	200
		Inby contract........	400
		Outby extend.........	125
		Outby contract.......	500
4.......	Between the advancer pump and the advancer operating valve.	Extend...............	180

APPENDIX C --STATISTICAL COMPARISON OF TRAM RATES FOR POSTED VERSUS NONPOSTED ENTRIES

Compare 2R-3 versus 2R-1:

A_1 2R-3	B_1 2R-1
6.8	7.9
7.6	7.8
7.4	9.3
6.6	7.8
7.6	6.5
5.8	5.5
5.9	8.2
6.9	6.0
5.8	6.2
4.8	5.7
$\bar{X}_A$ = 6.5	$\bar{X}_B$ = 7.1
SS_A = 7.7	SS_B = 14.6

$$t = \frac{\bar{X}_B - \bar{X}_A}{\sqrt{\frac{SS_A + SS_B}{(N_A - 1) + (N_B - 1)}}} \sqrt{\frac{(N_A)(N_B)}{N_A + N_B}}$$

$$t = \frac{7.1 - 6.5}{\sqrt{\frac{7.7 + 14.6}{9 + 9}}} \sqrt{\frac{(10)(10)}{10 + 10}}$$

$$= 1.2$$

$$t_{.10} = 1.7 > 1.2$$

∴ at the 90-pct confidence level there is no statistical difference between $\bar{X}_A$ and $\bar{X}_B$.

Compare 3-2R versus 1-2R:

A_1 3-2R	B_1 1-2R
6.7	10.2
10.6	7.0
7.1	6.4
9.1	9.4
6.7	8.8
7.2	6.2
8.3	6.6
7.7	5.8
5.6	4.9
7.2	5.6
$\bar{X}_A$ = 7.6	$\bar{X}_B$ = 7.1
SS_A = 18.0	SS_B = 28.1

$$t = \frac{7.6 - 7.1}{\sqrt{\frac{18.0 + 28.1}{9 + 9}}} \sqrt{\frac{(10)(10)}{10 + 10}}$$

$$= 0.7$$

$$t_{.10} = 1.7 > 0.7$$

∴ at the 90-pct confidence level there is no statistical difference between $\bar{X}_A$ and $\bar{X}_B$.

NOTE: The above analysis does not take into account that routes 2R-1 and 1-2R are 2 ft longer than 2R-3 and 3-2R. However, correcting the data to a common distance would only cause the calculated values to decrease and would not change the relative relationships.

APPENDIX D.--RETRACKING THE DOLLIES

The vast majority of the operational delays was caused by the inby or panline dollies becoming untracked. The inby dolly would become untracked whenever the horizontal angle between the inby bridge and the cantilevered receiving section of the mobile bridge carrier became less than approximately 100°. On the average, approximately 8 min was required to retrack the inby dolly.

The panline dolly tended to untrack whenever the horizontal angle between it and the panline exceeded approximately 45°. The dolly would also tilt and tend toward becoming untracked if the mobile bridge carrier was moved and an adjustment of the angle of the outby bridge relative to the panline was not made. This angle adjustment was made by the bridge carrier operator through actuation of the hydraulic cylinder located at the articulation point between the double bridges. The angle adjustment was most difficult to make whenever the bridge carrier and operator had trammed through the breakthrough and was out of the line-of-sight of the dolly. Although it may have been possible for the operator to become experienced enough to make the correction unaided, an observer (the section mechanic-utility person) was used to relate the situation of the panline dolly to the bridge carrier operator and indicate the direction and magnitude of required corrections.

Whenever the panline dolly became untracked, it took approximately 4 min to retrack it. When the dolly became uncoupled from the panline, the hydraulic jack was used to raise the outby end of the outby bridge until the dolly cleared the panline. The mobile bridge carrier operator would then use the powered articulation feature to position the dolly over the panline. In those instances when the outby dolly was on the panline but had become untracked, a pry bar was used to move the dolly back into place.

The inby dolly became untracked much less frequently than the panline dolly. The inby dolly was rerailed by elevating the outby end of the forward bridge with a hydraulic jack and maneuvering the inby receiving section of the mobile bridge carrier under the raised dolly. The dolly was then lowered onto the receiving section.

APPENDIX E.--FAILED OR MODIFIED COMPONENTS

Job	Date of problem	Date of repair	Remarks
1. Replaced incorrectly sized breakers in distribution box.	4/15/81	5/ 1/81	Substituted 500-kV·A load center awaiting new breakers.
2. Repaired flexible coupling between mobile bridge carrier conveyor hydraulic actuator and operator control lever.	4/17/81	4/17/81	Welded coupler shut.
3. Repaired pillow block of rear chain sprocket on outby section of articulated bridge.	4/20/81	4/27/81	Acquired new pillow blocks and redesigned mounting.
4. Reinforced the hydraulic cylinder attachment arm at the articulated bridges' swivel point by welding support brackets.	4/21/81	4/21/81	Caused by over-extension of the hydraulic articulation cylinder.
5. Replaced motor starter contacts on miniminer.	4/24/81	4/24/81	Caused by incorrect size breakers at the distribution box.
6. Corrected control problem with crossover dump (COD) panline advance.	5/ 4/81	5/ 4/81	Found chip of paint in hydraulic control actuator.
7. Repaired crank handle on miner hydraulic oil reservoir manual fill pump.	5/ 5/81	5/ 5/81	If the crank handle is positioned pointing downward it will be broken when the gathering augers are retracted.
8. Repaired pinched electrical control wire.	5/ 5/81	5/ 5/81	COD would not advance panline inby.
9. Rewired the COD control wiring	5/ 6/81	5/ 6/81	Electrical control wiring found to be routed incorrectly because of removed motion alarm.
10. Rewired miniminer hour meter circuitry that was shutting off the miniminer power.	5/ 6/81	5/ 6/81	Installed hour meter on miner, which interferred with the methane monitor circuit. Rewired hour meter to correct problem.
11. Raised COD 4 in with crib block.	5/29/81	5/29/81	COD would not advance panline after being set up in EMTA maneuverability trials area.

	Job	Date of problem	Date of repair	Remarks
12.	Added hydraulic oil...........	5/29/81	5/29/81	Miniminer hydraulic system functioned erratically.
13.	Adjusted hydraulic pressure relief valve in tram circuit.	6/ 2/81	6/ 2/81	Miniminer tram functioned erratically.
14.	Replaced left-hand auger swing cylinder.	6/ 3/81	6/ 3/81	Hydraulic cylinder was leaking.
15.	Replaced on-off power control switch on COD.	6/ 5/81	6/ 5/81	Switch failed.
16.	Auger open-close magnetic limit switches were not functioning properly.	Recurring problem		Switches control high-low tram speed and cutterhead activation depending on auger position; excessive clearances between magnetics caused by spilled coal; needs to be redesigned.
17.	Obtained modified conveyor bridges from 4M.	Recurring problem		See note below.

NOTE.--During the initial operator training period in the EMTA, it was observed that turning a 90° crosscut with the miniminer system was extremely difficult. After numerous attempts and failures it became clear that any attempt to slide the pivot point of the sectioned bridges, using the hydraulic articulation cylinder, would cause the rear dolly to jump off the panline. The problem occurred because the dolly resting on the panline was not able to resist the forces of the hydraulic cylinder trying to articulate the bridges. The conveyor bridges and pivot structure were too heavy. 4M was informed and it agreed to supply new conveyor bridges approximately half the weight of the problem bridges. The lighter weight bridges solved the maneuverability problem.

	Job	Date of problem	Date of repair	Remarks
18.	Replaced magnetic limit switches on rear dolly.	6/ 5/81	6/ 5/81	Magnetic switches were broken when rear dolly came off the panline.
19.	Replaced cutterhead drive hydraulic hose during preliminary cutting trials.	6/17/81	6/17/81	The hydraulic hose failed at a coupling when the head jammed during cutting operations. The hose was difficult to replace owing to lack of clearance for tightening coupling.
20.	Replaced drive track tensioning cylinders on miniminer.	6/26/81	6/29/81	Three of four cylinders were found to be defective; back of cylinder had no O-rings.

	Job	Date of problem	Date of repair	Remarks
21.	Repaired miner cable outer jacket.	7/ 1/81	7/ 1/81	Ran over miniminer electrical cable with mobile bridge conveyor.
22.	Replaced left-hand tram motor on miniminer.	7/ 1/81	7/ 1/81	None.
23.	Removed lip from bridge conveyor receiving section.	7/31/81	7/31/81	Lip was restricting movement during maneuverability trials.
24.	Replaced belt-conveyor hydraulic motor on the COD.	8/ 3/81	8/ 4/81	The motor housing split when the belt conveyor stuck. The relief valve pressure was set at specified limits.
25.	Replaced the miniminer right-hand feed and solenoid pump.	8/ 4/81	8/11/81	It was determined that insufficient quantity of hydraulic oil was being delivered when the headfeed slowed and a flow-divider could not be adjusted to supply both the headfeed and the head elevation. The pump was defective.
26.	Added a level bottom section to the inby bridge conveyor chain return trough at the center angled section.	8/13/81	8/13/81	The conveyor chain was binding on the top of the return-trough base.
27.	Lowered the receiving pan of the inby bridge 2 in.	8/13/81	8/13/81	A 2-in addition was added to the bracket connecting the bridge swivel point and the receiving pan to lower the pan. Cut material resting on the receiving pan was being pushed into the miniminer by the bottom of the miner conveyor, creating excessive spillage.
28.	Moved the articulated bridge articulation point back 8 in.	8/14/81	8/14/81	Excessive spillage was occurring at the dump point.
29.	Cut slots in the return trough of the forward articulated bridge.	8/14/81	8/14/81	The conveyor chain was binding on the top of the return trough base.

	Job	Date of problem	Date of repair	Remarks
30.	Installed conveyor guards on the COD conveyor.	8/14/81	8/14/81	6-in-wide strips of conveyor belting were placed on top of the COD cross conveyor to prevent material from falling into the belt rollers.
31.	Installed new 8-in-diam gathering augers on the miner.	9/ 9/81	9/11/81	During preliminary cutting trials, it was observed that the cutterhead could cut coal faster than the 6-in-diam gathering augers could collect it. 4M supplied redesigned 8-in-diam gathering augers which included a redesigned locking mechanism.
32.	Ground drive shaft of 8-in-diam gathering augers.	9/11/81	9/11/81	The augers would not turn and it was discovered that the end bushing was seized to the drive shaft.
33.	Ground clearance area for left auger-drive chain--installed half link into chain.	9/15/81	9/15/81	The drive chain was binding in the housing.
34.	Replaced left gathering auger hydraulic motor.	9/21/81	9/21/81	Erratic chain motion indicated that hydraulic oil was bypassing the motor.
35.	Replace the rear articulated bridge conveyor hydraulic motor.	9/21/81	9/21/81	Do.
36.	Replace the miniminer conveyor hydraulic motor.	9/22/81	9/22/81	Do.
37.	Installed a spacer bar in the cutterbar.	9/22/81	9/23/81	After the new 8-in-diam augers were installed, it was discovered that the lowered cutterhead would not clear the augers. A 2-in space bar was installed in the cutterbar to move the cutterhead forward.
38.	Replaced COD left hydraulic pump.	9/24/81	9/28/81	Pump housing cracked during normal operation.

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