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Assessment of Experimental Longwall Recovery Rooms for Increasing Productivity and Expediting Equipment Removal Operations

By Eric R. Bauer, Jeffrey M. Listak, and Mike Berdine

BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

ft	foot	in	inch
ft^2	square foot	psi	pound per square inch
ft/d	foot per day	st	short ton
h	hour		

ASSESSMENT OF EXPERIMENTAL LONGWALL RECOVERY ROOMS FOR INCREASING PRODUCTIVITY AND EXPEDITING EQUIPMENT REMOVAL OPERATIONS

By Eric R. Bauer,[1] Jeffrey M. Listak,[1] and Mike Berdine[2]

ABSTRACT

The U.S. Bureau of Mines, in cooperation with a southwestern Pennsylvania coal mining company, BethEnergy Inc., Mine No. 60, Eighty-Four, PA, recently assessed the feasibility of using predriven recovery rooms (open entry recovery) when longwall mining to increase the productivity of the coal extraction process. Two recovery entries, one 200 ft long and another 600 ft long, were supplementally supported with bolts, channels, and wire mesh, and either fly ash-cement piers or fiber cribs, then mined into by the longwall face. The recovery entries showed little deterioration as the supports provided adequate resistance to the front abutment loading. Compared with conventional recovery methods, the fullface recovery room allowed for panel extraction to be completed nearly 17 days faster and to reduce face equipment move time by 1-1/2 days. The potential productivity increase accompanying recovery rooms is greater than the cost of supporting a fullface recovery room. The fullface recovery room provided over 18 additional production days and the opportunity to mine nearly 68,400 st of coal per year per panel mined.

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INTRODUCTION

Moving the equipment of a longwall face from one panel to the next is a critical efficiency issue to any longwall operation. Currently, 20 days is the average move time for U.S. longwall operations, while move times as long as 30 days are no exception (*1*).[3] Coal-to-coal move times of 2 to 5 days (*2*) and 8 days (*3*) have been reported. These reduced move times are a result of face width and panel length (distance of move), experience of mine personnel (shortcuts learned, etc.), and the amount of equipment installed on the new face prior to startup of the actual move.

Conventional methods of longwall equipment recovery involve preparations for equipment removal a considerable distance (usually 50+ ft) from the actual recovery point. The mine roof is supported by installing bolts and wire mesh along the longwall face at the end of panel advance. These preparations, needed to eliminate the hazard of roof falls and face sloughing during equipment recovery, slow the advance rate, impeding production. Additional supports are needed when the longwall face reaches the recovery point, which is simply a predetermined position where the longwall stops mining. I-beams, bolts, cribbing, and, if roof conditions are extremely poor, polyurethane injection is utilized to stabilize the mine roof. The space available for equipment recovery is restricted making removal of equipment cumbersome.

Past efforts to reduce move time have concentrated on recovery equipment designs, worker training, and planning of the entire recovery system. Davis (*4*) described how specialized transport vehicles have streamlined the moves from one face to another. Evans (*5*) reported that training is an integral part of longwall moves. McKay (*6*) reported that the efficient planning of equipment and method of recovery, will highly impact the speed and cost of face installation or transfer. Palfy (*7*) reported on a successful trial of a 12-ft-wide, 100-ft-long recovery entry. Comprehensive discussions of conventional longwall face recovery operations are given by Tucker (*2*), Monks, Hodgkinson, and Ferris (*3*), Oitto, Wisecarver, and Sikes (*8*), Mack and Stovash (*9*), and Ketron (*1*).

An alternative recovery method, is to predrive an entry the width of the panel for salvage operations. The entry is supported ahead of time to control the front abutment loading created by the approaching face. This would minimize production delays on approach to the recovery point and delays caused by recovery operations. In addition, the recovery entry provides a larger area to maneuver recovery equipment. This U.S. Bureau of Mines study addresses the open entry recovery method, an idea that is rather new to current U.S. longwall mining practices. The objective of this research is to provide the mining industry with an improved method of longwall equipment recovery that would reduce move time and increase panel extraction rates. The study was conducted with the cooperation of, and at, an underground coal mine in southwestern Pennsylvania. Two experimental recovery rooms were supported with bolts, channels, wire mesh, and either fly ash-cement piers or fiber cribs, to prevent roof failure. Instrumentation was installed to monitor the effects of the front abutment on the predriven entry and supplemental supports. Laboratory material property tests of the coal and supplemental supports were conducted to supplement the in-mine study.

This report presents the results of the laboratory material property testing, an analysis of field measurements, and an assessment of recovery room stability.

ACKNOWLEDGMENTS

The authors express their appreciation to the personnel of BethEnergy Inc., Mine No. 60, for their cooperation and assistance in this study.

RECOVERY ROOM CONCEPT

One way of increasing the production of a longwall is to improve the equipment recovery operation. By providing a pre-supported entry the width of the panel, production losses associated with pre-move preparation and equipment recovery can be reduced. This is what a longwall recovery room is designed to accomplish.

CONVENTIONAL RECOVERY METHODS

Typical conventional methods of equipment recovery are shown in figure 1. Several recovery butts are driven into the panel from the gate roads or submains during development, through which the face equipment is removed. The face is stopped when it intersects the recovery butts and is aligned with the desired headgate and tailgate crosscuts. At this point the conveyor drives and shearer are removed. The roof between the shields and

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

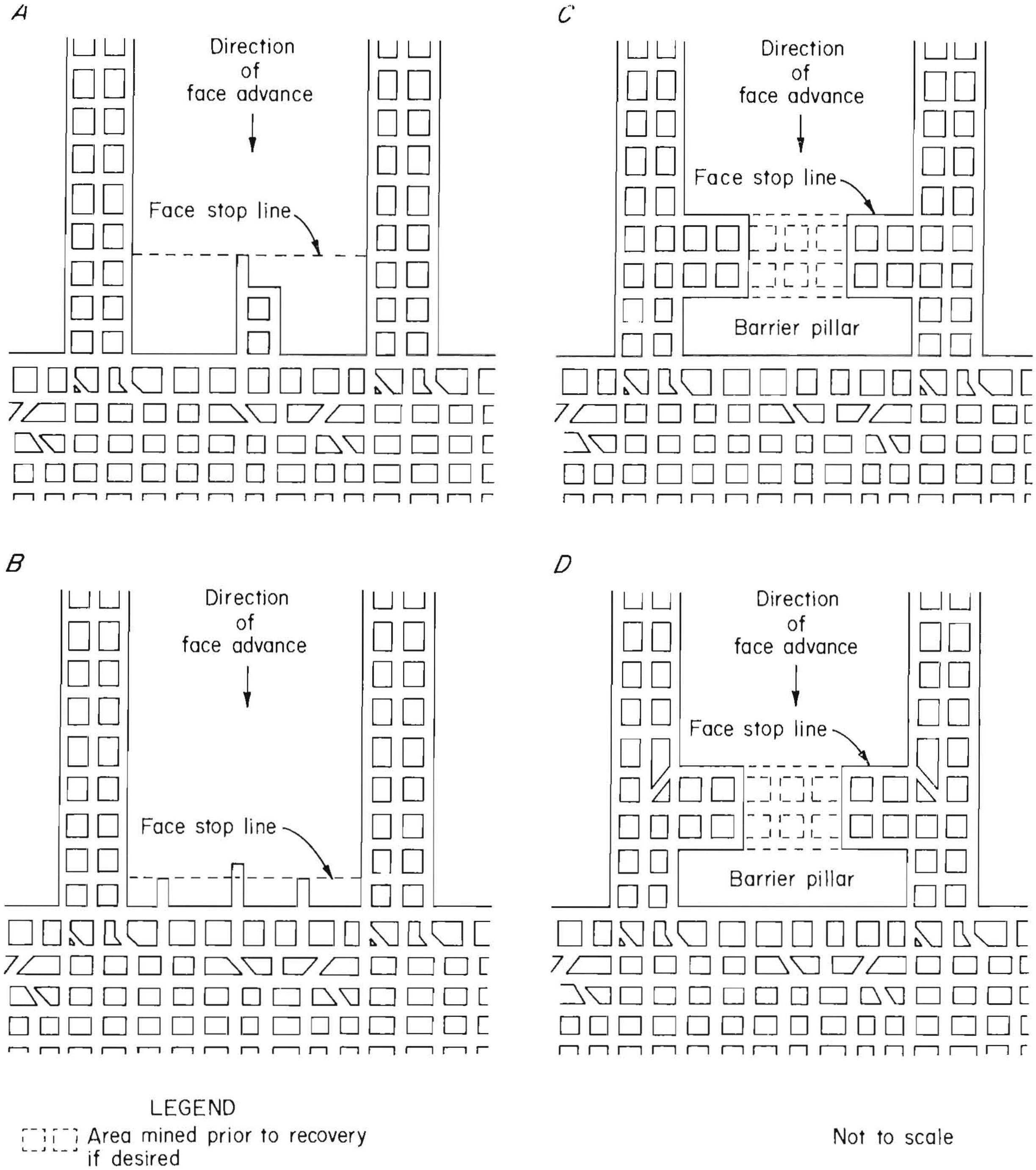

Figure 1.–**Conventional longwall equipment recovery methods.** *A*, **Barrier pillar access;** *B*, **stall (butt) access;** *C*, **chute access;** *D*, **angled chute access.**

face is bolted, simultaneously with removal of the armored face conveyor. Removal of the remaining face equipment (powered supports) is then completed. The result of employing this method of face equipment removal is that face advance is slowed by the pre-move roof support preparations. In addition, equipment removal is delayed because of space limitations and by the bolting process.

OPEN ENTRY RECOVERY METHODS

In contrast, idealized open entry recovery rooms are shown in figure 2. The fullface entry, if effectively supported, can be mined into by the longwall with minimal pre-move production losses. The equipment is removed through the nearest crosscut and from both the headgate

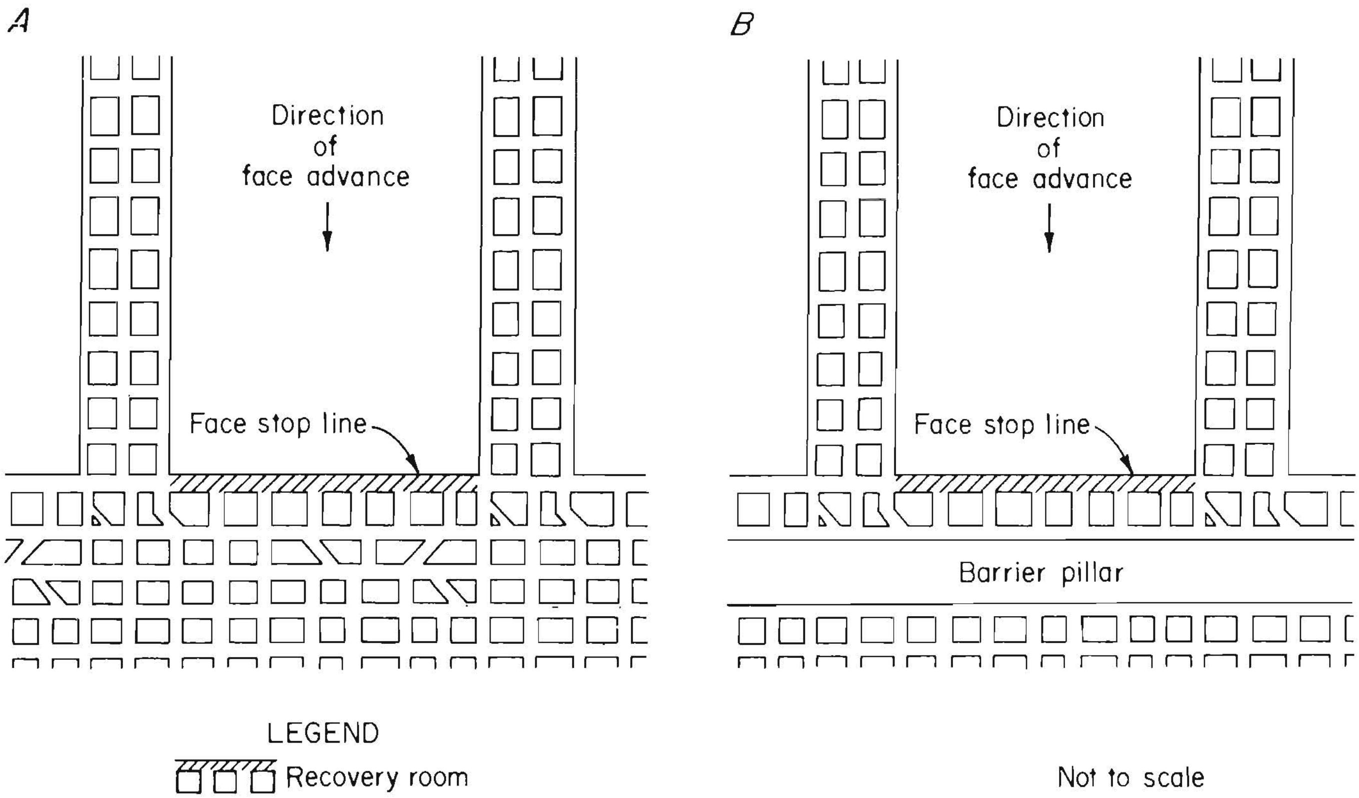

Figure 2.–Idealized open entry recovery rooms. *A*, **Shallow seam design;** *B*, **deep seam design.**

and tailgate. This reduces face removal downtime caused by space restrictions and the face bolting operations that are no longer needed. This method is applicable to retreating longwalls only, which dominate the U.S. longwall mining industry.

SUPPORT REQUIREMENTS

A variety of supports can be employed to stabilize the recovery room. Bolts, posts, cribs, reuseable or retrievable supports, cement piers, etc., could all be suitable recovery room supports. At present, it is not possible to give the exact type and amount of supports required to insure recovery room stability. This is because many variables are involved in the selection of supports. These include the geometry of the panel, mining height, geologic conditions, coal seam, immediate roof strata, recovery entry dimensions, support type and configuration, overburden, front abutment loading, and face support capacity. Thus, the support requirements presented here are solely a reflection of the results obtained during the recovery room trials detailed later in this report.

During development the recovery entry is supported as per Mine Safety and Health Administration (MSHA) approved roof control plan. This initial support is comprised of a specified bolting pattern, bolt, plate, etc. This is followed by installation of wire mesh, high-strength longer bolts (super bolts), and channels. The meshing and bolting are designed to eliminate blocks of roof from falling between the bolts and to insure that an adequate roof beam is established. If the roof bolts function as designed and an adequate roof beam is created, the front abutment will transfer to the support pillars, resulting in greater stability of the recovery entry. The spacing of the high-strength bolts is arbitrary, but a minimum 4-ft spacing is recommended. In some cases, at shallower depths of cover, bolting may be sufficient to maintain entry stability. Since over 5-1/2 in of convergence was measured during the fullface trial, even with crib-type supports in place, bolting alone is not recommended.

Crib-type supports are placed in the recovery entry to minimize roof-to-floor convergence resulting from front abutment loading. Their design is governed by the variables previously listed and by several other requirements that are equally important. One requirement is that the supports be strong enough to withstand the front abutment, yet be easily cut by the shearer. It is suggested that the compressive strength of the supports be no more than two to four times the strength of the coal. Next, the supports must be of a material that is compatible with the cleaning process at the preparation plant. Another factor which must be considered is the cost of the supports, including the labor required for installation. A yielding capability must also be designed into the supports. This is easily accomplished by placing 6 to 12 in of wood between the top of the support and the mine roof. Finally, the dimensions of the supports must be considered in respect to the dimensions of the recovery room. They must be placed such that a quantity of them can be cut out to provide enough area to maneuver the recovery equipment.

Generally, a starting point is to select and design supports that provide support equal to the removed coal. Support resistance is simply a term used to describe the amount of roof support required. Using the compressive strength of the coal as the desired support resistance, the number of supports needed is found by comparing the compressive strength of the coal to the compressive strength of the supports. It is believed that this will provide an overdesign of the supports because the contribution of the installed roof bolts is not considered, and unfortunately, is not easily determined. The support resistance can then be modified based on actual performance in the recovery rooms.

MINE LOCATION AND GEOLOGY

BethEnergy Mine No. 60 in Eighty-Four, Washington County, PA (fig. 3), is within the Appalachian Plateau Province of southwestern PA. Structural relief in the area does not exceed 350 ft and dips are generally less than 4°. Mining takes place in the Pittsburgh Coalbed, which lies stratigraphically within the Pennsylvania age coal bearing strata of the Monongahela Group. The main seam averages 6 ft, with 1 ft of gray fireclay binder and 1.5 ft of top coal (fig. 4). Since the thickness of these members varies widely throughout the mine, the extraction height ranges from 7 to 9 ft.

The immediate roof consists of approximately 4 ft of gray shale, overlain by thin members of coal and carbonaceous shale. Upper stratigraphic members are primarily gray sandy shales (*10*). Overburden at the mine ranges from 350 to 700 ft; 450 to 550 ft at the study sites. The floor rock was a sandy shale, and although some floor heave did occur, it was not a problem. Also, geologic features (e.g., clay veins, kettlebottoms, jointing, etc.) posed no problems in the study sites.

The two recovery room trials were conducted on the same longwall panel, 4A (fig. 5). The first was a 200-ft entry (face width reduction from 800 to 600 ft) located 1,000 ft from the planned recovery point. The second site, located at the end of the panel, was the entire width of the remaining face (600 ft).

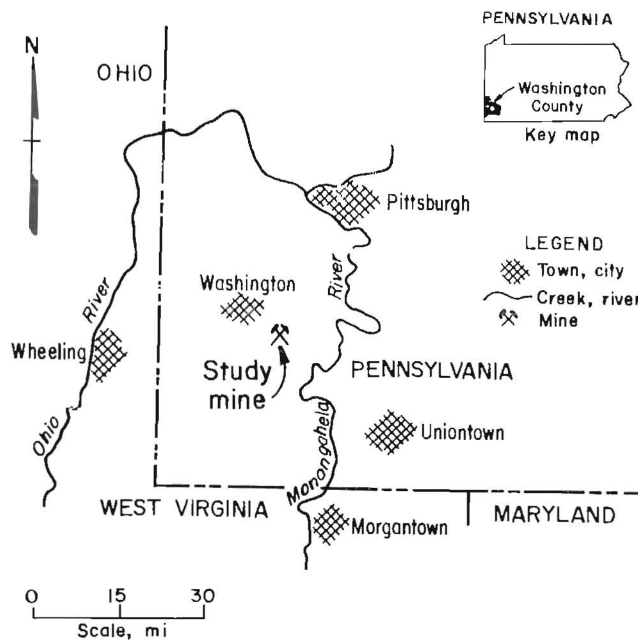

Figure 3.–Location of study mine.

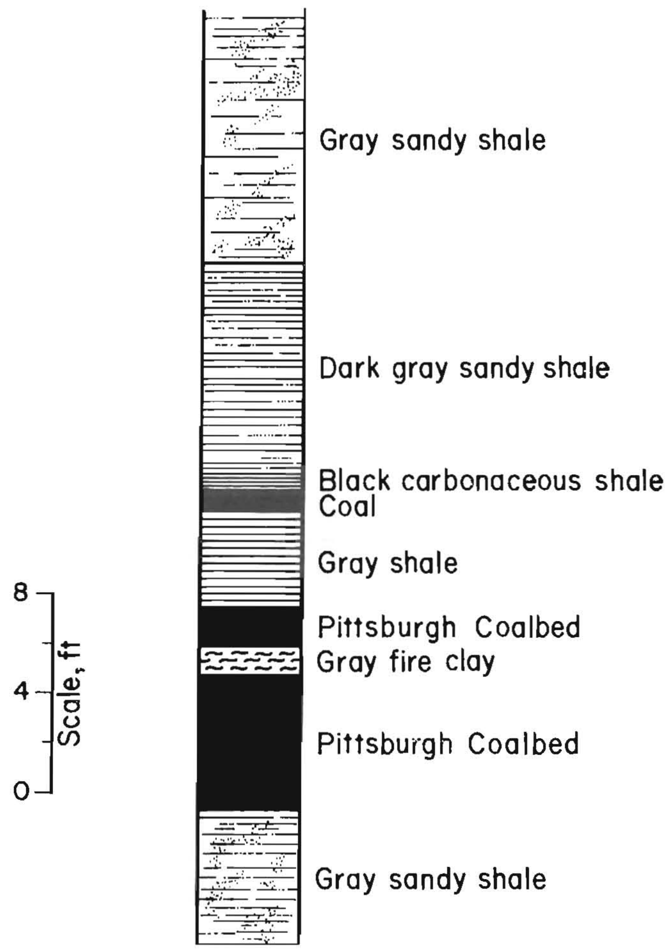

Figure 4.–Generalized stratigraphic column for study mine (*10*).

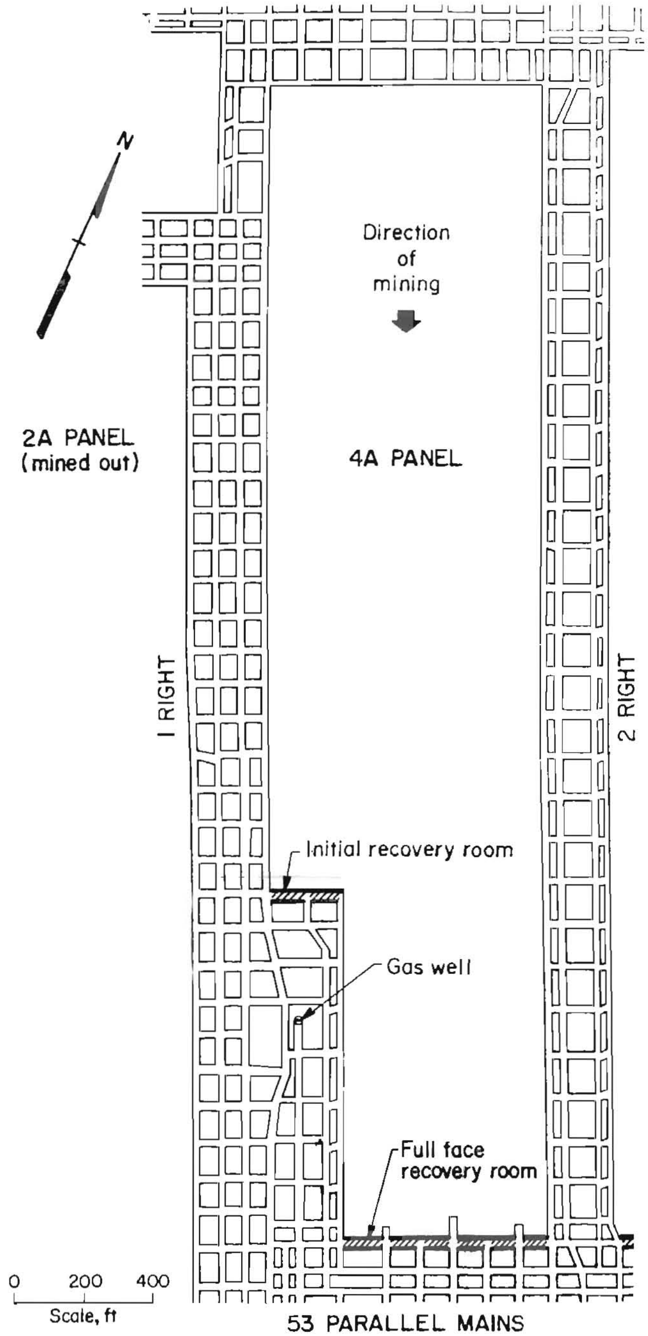

Figure 5.–Location of initial and fullface recovery rooms.

COST AND PRODUCTION ANALYSIS

CONVENTIONAL LONGWALL RECOVERY COSTS

The estimated cost of preparing a face for conventional recovery operations at this mine is $35,100. This includes the cost of materials and labor to install wire mesh above the supports and two rows of bolts and channels at the end of the panel. The appendix includes a line item cost report for conventional recovery operations and the two recovery rooms. Both this cost and those for the recovery rooms were prepared by mine personnel involved with directing the recovery support operations. Even though this is less than the cost of preparing a recovery room, the production losses associated with conventional recovery methods outweigh the cost advantage.

RECOVERY ROOM SUPPORT COSTS

The estimated cost of implementing the initial and panel 4A fullface recovery rooms was $103,400 and $136,500, respectively. These estimates include the cost of materials and labor to initially, and supplementally, support the recovery rooms. Table 1 summarizes the support costs and shows that as the support requirements are adjusted based on results of each test, the cost of supporting the recovery rooms has been reduced.

Table 1.–Support costs for conventional recovery and recovery rooms

Type of recovery method	Total cost[1]	Cost per ft of face
Conventional	[2]$35,100	$58.50
Initial recovery room ..	103,400	517.00
Panel 4A fullface	136,500	227.50

[1]To the nearest $100.
[2]Average for the last 5 conventional face moves.

TIME AND PRODUCTION ADVANTAGES

Several advantages were gained by employing a predriven recovery room rather than conventional longwall recovery methods. First, productivity was maintained to the end of the panel when using the predriven recovery room, while considerable production delays occur when preparing a face for conventional recovery operations. At this mine, for the eight most recently extracted panels, the average normal face advance was 26.5 ft/d. Normal face advance were those periods where no major delays, such as equipment failures or face and gate road stability problems, occurred that seriously slowed production. To determine the affect of face preparation during conventional recovery on production, the final month of face advance for the same panels was calculated, and found to average only 14.0 ft/d, or 53% of the average normal face advance of 26.5 ft/d. This 47% reduction in face advance equates to approximately 47,700 st of lost coal production for each panel mined per year. With no pre-move preparation delays, the final month advance for panel 4A averaged 30.9 ft/d, a production increase of nearly 121%. Thus, the panel was extracted nearly 17 days faster.

Also, actual face equipment recovery time was less when using the recovery room, allowing for quicker start-up of the subsequent panel. Face-to-face transfer was accomplished in 31 calendar days following the fullface recovery room trial as compared with an average of 32.4 calendar days for conventional recovery operations (last five face moves). Although the move time savings were small, savings in future recovery rooms are expected to be more significant.

Table 2 summarizes the preliminary advantages predriven recovery rooms provided. In the fullface trial, over 18 additional days of production and the opportunity to mine nearly 68,400 st of additional coal per year per panel mined can be realized. At current metallurgical coal prices of $27 to $34/st (*11*), additional revenues of $1.8 to $2.3 million are possible.

Table 2.–Time and production advantages of fullface recovery room

Savings due to quicker–	Time, days	Production, st	Additional revenues[1]
Panel extraction ..	17	64,400	$1.7-2.1
Face move	1	4,000	.1- .2
Total	18	68,400	1.8-2.3

[1]Million U.S. dollars.

LABORATORY STRENGTH TESTING

An integral part of this study was the determination of coal and supplemental support strength properties.[4] These properties were needed to calculate stress changes accompanying front abutment loading and to evaluate support performance and recovery room stability.

Test specimens of the coal and supplemental supports were tested by Bureau personnel for uniaxial compressive strength, Young's modulus and Poisson's ratio. The mean compressive strength of the coal was 1,303 psi. Young's modulus and Poisson's ratio were 0.72×10^6 psi and 0.27, respectively. This compressive strength is slightly higher than the 700 to 1,020 psi reported for the Pittsburgh Seam (*12-15*). For comparison, the best estimate for the compressive strength of most coals is in the range of 700 to 7,000 psi (*16-19*), with some estimates as low as 300 psi and as high as 11,000 psi.

Strength properties of the supplemental supports were also determined. For the fly ash-cement piers in the initial recovery room, the mean uniaxial compressive strength was 2,230 psi, Young's modulus was 0.70×10^6 psi, and Poisson's ratio was 0.21. Compressive strength was 6,956 psi and Young's modulus was 2.97×10^6 psi for the steel-fiber-reinforced concrete cribs used in the fullface recovery room. Poisson's ratio was not determined for the fiber crib blocks. Table 3 lists the results of the laboratory testing.

Table 3.–Results of laboratory strength testing

Medium	Uniaxial compressive strength, psi[1]	Young's modulus, psi	Poisson's ratio
Coal	1,300 (360)	0.72×10^6	0.27
Fly ash-cement . .	2,230 (300)	$.70 \times 10^6$	.21
Fiber crib	6,960 (400)	2.97×10^6	ND

ND Not determined.
[1]Standard deviation in parentheses.

FIELD STUDIES

INITIAL RECOVERY ROOM

Figure 5 shows the 4A longwall panel and the location of the recovery room test sites. The initial site was selected because of a gas well located just outby the site. The face had to avoid mining through this well, creating an ideal area for testing the recovery room concept. The face was reduced from 800 to 600 ft resulting in a 200-ft recovery room.

Supports

Initial supports were 6-ft, 3/4-in-diam, full column resin bolts on 4-ft centers installed during gate road development. The recovery entry was supplementally supported with 12-ft, 1-in-diam, resin super bolts, wire mesh, and 4 by 6-ft fly ash-cement piers. To provide a support resistance of 800 psi, 49 piers were placed in a 2 row arrangement.

A private contractor constructed the piers from a fly ash-cement material. The construction involved assembling 2-ft-high aluminum forms, lining the forms with burlap bags, then pumping the fly ash-cement into the bags (fig. 6). After the cement hardened, the process was repeated until the roof was reached. Bags made from mine brattice (plastic coated burlap) were pumped full of fly ash-cement, to fill any gaps between the piers and roof. For comparison, figure 7 shows a completed fly ash-cement pier next to a conventional wood crib.

As evidenced by the stability of the recovery room, the supports worked as planned. The bolts, channels, and wire mesh enabled the roof to act as a continuous beam while the fly ash-cement piers limited entry convergence. This allowed the front abutment to transfer from the panel to the support pillars without affecting recovery room stability.

The fly ash-cement piers were a good design because their strength characteristics were similar to the coal. The installation to obtain an 800-psi support resistance allowed the piers to yield and fracture, yet still provide adequate support to limit entry convergence (fig. 8). In addition, they were easily cut by the shearer and created no problems at the cleaning plant.

The major drawback that kept mine officials from using these piers on a fullface recovery room was the high cost of installation. At over $75,000 for just 49 piers in a 200-ft recovery room, the cost for supporting a fullface recovery room was prohibitive.

Instrumentation and Results

Vibrating wire stressmeters (VWS) were installed in the longwall panel, piers, and support pillars to measure the front abutment loading. Figure 9 shows the exact locations of the 29 stressmeters installed. The lead wires were strung to a central location for safety and to simplify data collection (fig. 10).

The results of the initial recovery room trial were excellent. The longwall mined into the recovery room cutting out the first row of piers with little or no delays (fig. 11). The stability of both the roof and piers was sufficient to allow for removal of the face equipment. In this case,

[4]Laboratory tests conducted as per American Society for Testing and Materials (ASTM) standards: C39-86, C42-84a, C192-81, C469-87, C470-87, D2938-86, D3148-86, and D4543-85.

Figure 6.–First stage of constructing fly ash-cement piers.

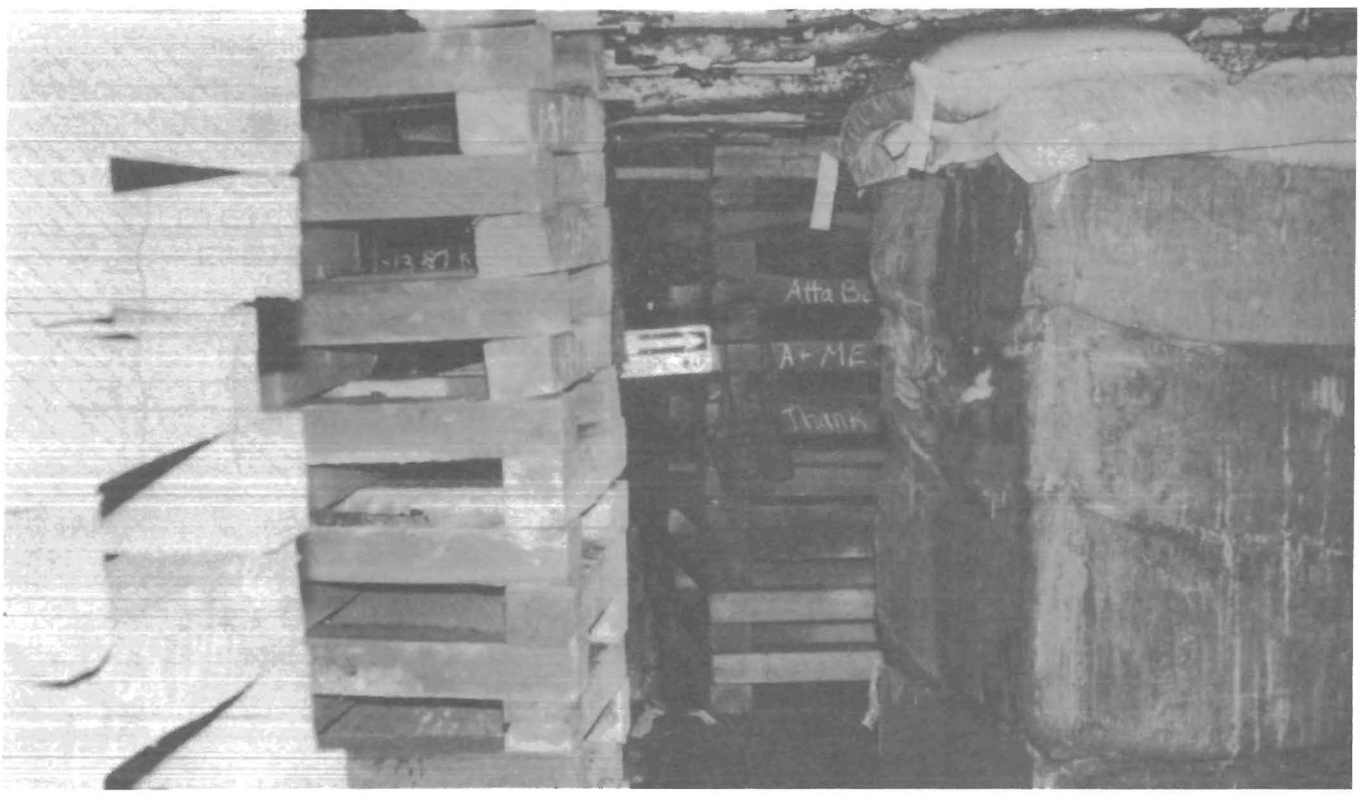

Figure 7.–Completed fly ash-cement pier and conventional wood crib.

Figure 8.–Example of piers crushed by front abutment in initial recovery room.

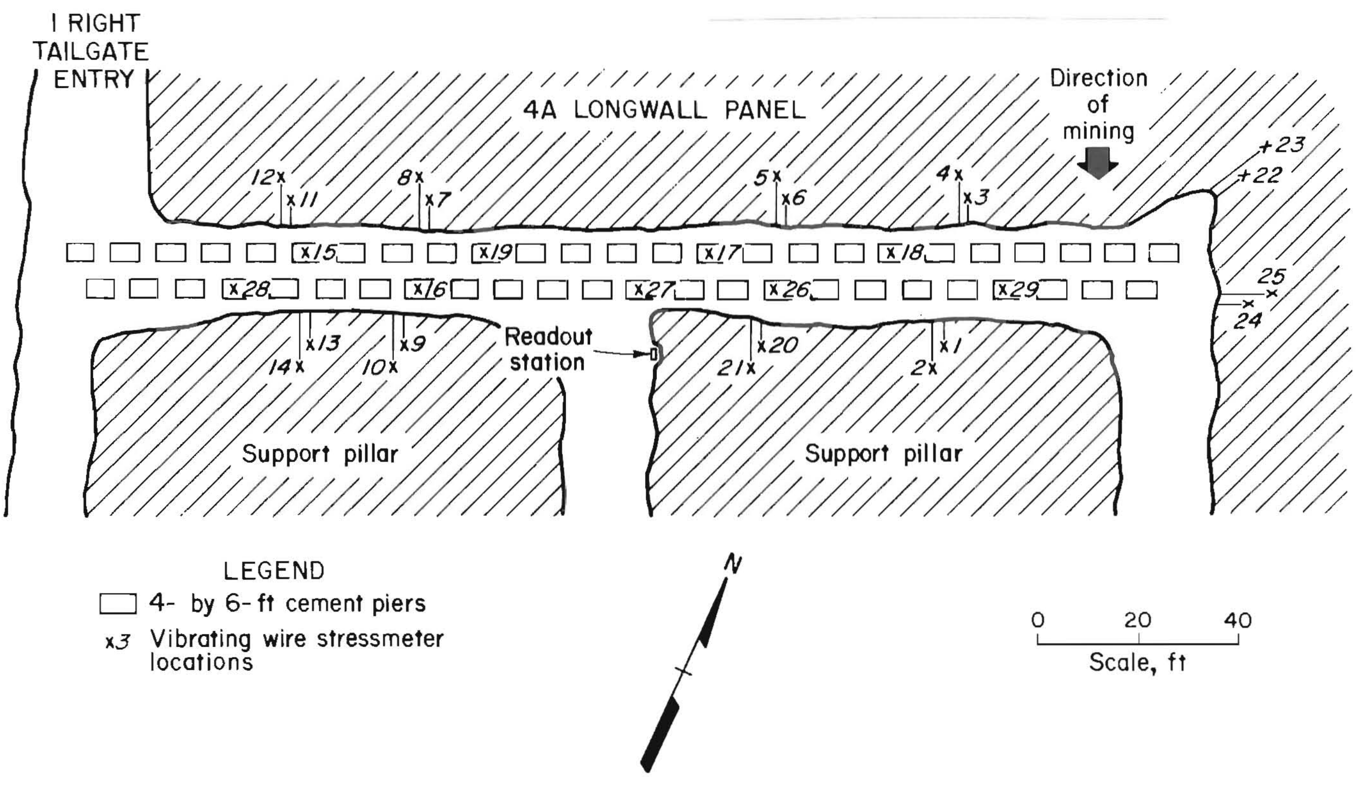

Figure 9.–Location of stressmeters in initial recovery room.

Figure 10.-Centralized readout location.

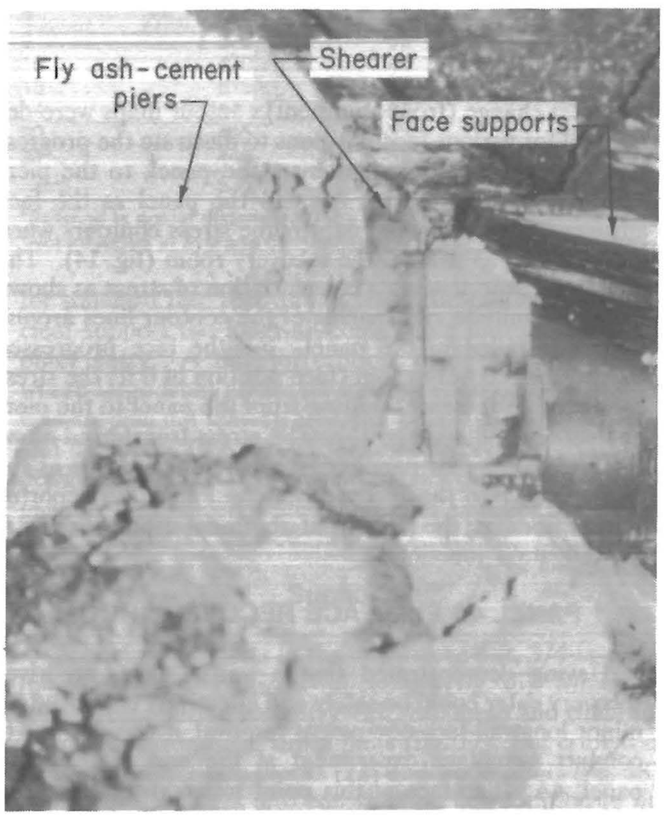

Figure 11.-Longwall shearer cutting fly ash-cement piers.

only the extra armored face conveyor was removed; the remaining face continuing to the end of the panel. The shields were old and not deemed recoverable, thus they were left in place (fig. 12).

The stress measurements provided a varied picture of the front abutment (table 4). Maximum stress change in the panel was 2,700 psi at VWS 22 (see fig. 9 for location of stressmeters). For the support pillars the maximum stress change was 1,110 psi at VWS 1. Finally, in the fly ash-cement piers the maximum stress change was 780 psi at VWS 27.

The arrival of the front abutment was determined by analyzing the stress change data and determining the range of maximum stress changes. For this mine location the first significant stress change (doubling of the previous change), indicating the arrival of the front abutment loading, occurred about 70 ft ahead of the face as seen by the average calculated for the panel and support pillar meters. Variations in the range of stress changes resulted from several factors including failure of the coal as the panel neared the recovery room, yielding design of the piers that delayed stress detection, and stopping the face and measurements an average of 22 ft from the meters in the support pillars.

Figure 13 is a graph of stressmeters 11 through 13, 15, and 28 and illustrates the loading characteristics as the longwall approached, then mined into the recovery room. Increased loading was detected by all the meters from a face position of -70 to -15 ft. At -15 ft the coal in the

Figure 12.–View of initial recovery room after removal of shearer.

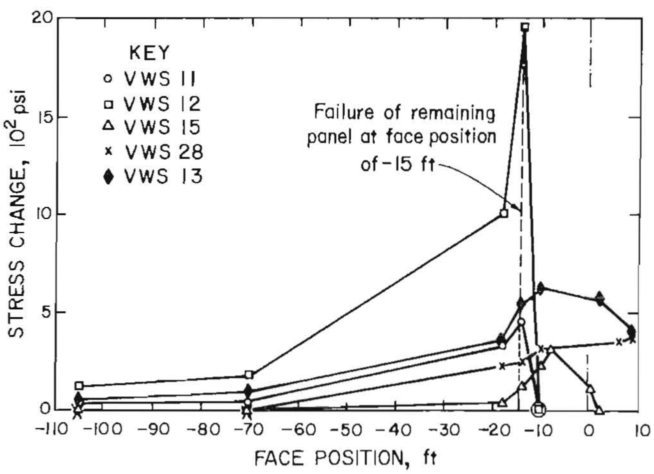

Figure 13.–Stress change versus face position across panel-pier-support pillar system in initial recovery room.

remaining panel failed as indicated by panel meters 11 and 12 going to 0. At this point the remaining meters showed a marked increase in loading as the front abutment transferred from the failed panel to the piers and support pillars. In general, the most significant stress increases occurred from 4 to 16 ft ahead of the face. This is well within the limits proposed by other researchers (*20-21*).

Stress change (front abutment) contour maps were developed for various face positions to illustrate the progression of the front abutment from the panel, to the piers and support pillars, then back to the panel as the face advanced. The first map depicts the stress contours when the face was 23 ft from the recovery room (fig. 14). The panel was experiencing a concentration of stress as shown by the magnitude and spacing of the contour lines around meters installed in the panel. As the face progressed toward the recovery room (face position of 0 ft) the stress continued to increase, shifting from the panel to the piers and support pillars (fig. 15). The stress transferred along the face to the new panel edge on the tailgate side as the face mined into the recovery entry. Peng (*20*) reported similar findings; the peak front abutment usually occurs at the tailgate T-junctions.

PANEL 4A FULLFACE RECOVERY ROOM

Having demonstrated that a partial face, predriven recovery entry could be safely and effectively employed for minor longwall face equipment removal, it was decided to conduct a fullface experiment at the end of the same panel, 4A. The face at this point was 600 ft wide. The outside entry of the 53 parallel submains served as the recovery room (see fig. 5). Although originally prepared

Table 4.–Maximum stress change and face position for stressmeters in initial recovery room (the - sign indicates the face has not reached the recovery room or stressmeter)

VWS	Maximum stress, psi	Face position, ft[1]	Range of maximum stress changes, ft[1]
		PANEL	
3	100	[2]-33	-65 to [2]-33
4	415	-6	-60 to -6
5	485	-6	-95 to -6
6	1,600	-11	-65 to -11
7	1,310	-11	-125 to -11
8	980	-6	-95 to -6
11 ...	460	-9	-38 to -9
12 ...	2,500	-4	-60 to -4
22 ...	2,700	0	-60 to 0
23 ...	1,020	-1	-55 to -1
24 ...	1,455	-7	-56 to -7
25 ...	2,005	-4	-56 to -4
Avg..	1,255	-6	-69 to -6
		PIERS	
15 ...	340	-4	-23 to -4
16 ...	255	-10	-13 to -10
17 ...	40	-5	-21 to -5
18 ...	225	-3	-19 to -3
19 ...	660	-5	-75 to -5
26 ...	735	-9	-56 to -9
27 ...	780	-7	-56 to -7
28 ...	530	-4	-11 to -4
29 ...	395	-4	-56 to -4
Avg..	440	-6	-37 to -6
		SUPPORT PILLARS	
1	1,110	-23	-66 to -23
2	515	-28	-63 to -28
9	575	-33	-66 to -33
10 ...	470	-41	-71 to -41
13 ...	615	-43	-66 to -43
14 ...	145	[2]-98	-98 to [2]-70
20 ...	405	-33	-66 to -33
21 ...	445	-38	-71 to -38
Avg..	535	-34	-71 to -34

[1]Footage is actual distance of face from an individual stressmeter.
[2]Not included in average calculations.

for standard face recovery, it was believed that with sufficient support the longwall could mine into the submains outer entry. A note of caution, in deep operations or where large front abutment loading is expected it may be catastrophic not leaving a barrier pillar between the panel and submains (see fig. 2). The recovery room must be designed to allow for sufficient barrier pillars between the panel and any nearby main entries if extreme front abutment loading is expected.

Supports

The initial supports in the entry were 6-ft, 3/4-in-diam, full column resin bolts on 4-ft centers (fig. 16). Mine personnel resupported the entry with wire mesh and channels, 12-ft, 1-in-diam, resin super bolts (fig. 17), and cribs constructed of fiber crib blocks (*22*) and wood fillers (fig. 18). Figure 19 illustrates crib construction and location in the entry. A support resistance of 800 psi was desired in this recovery room also, necessitating erecting nearly 475 cribs in the recovery entry and recovery butts.

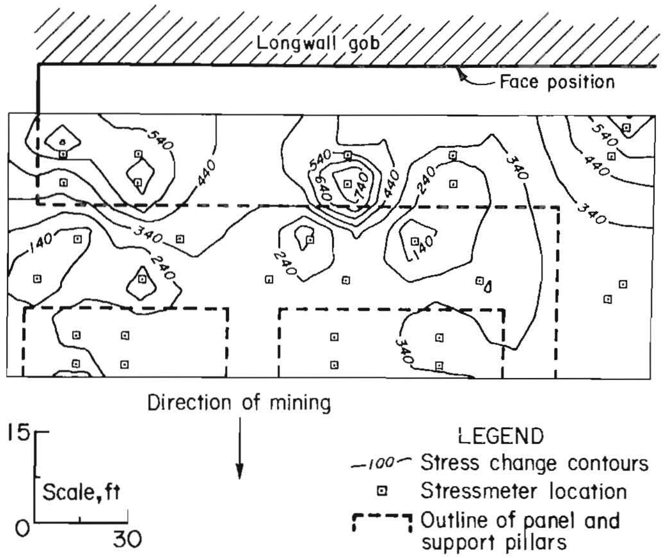

Figure 14.–Stress change contours at face position of -23 ft.

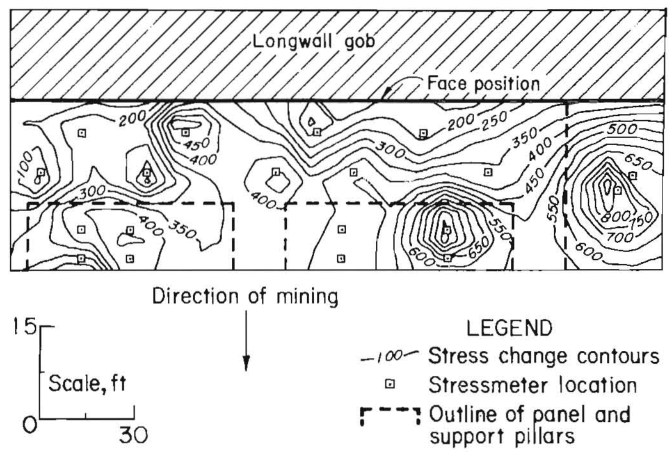

Figure 15.–Stress change contours at face position of 0 ft.

As in the initial test, the supports effectively maintained entry stability. The mine roof acted as a continuous beam, while convergence was minimized. A distinct disadvantage surfaced that eliminated using fiber cribs in future recovery rooms. The shearer had difficulty cutting the fiber crib blocks because they were nearly 5-1/2 times as strong in compression as the coal. Delays in face advance were caused by fiber crib blocks knocked out by the shearer, hanging up or breaking the face conveyor chain, delays that the recovery room concept was designed to eliminate.

Instrumentation and Results

Owing to time constraints and the lack of available instrumentation, only four stressmeters and six extensometer stations were installed. The stressmeters detected

Figure 16.–Typical recovery room prior to supplemental support.

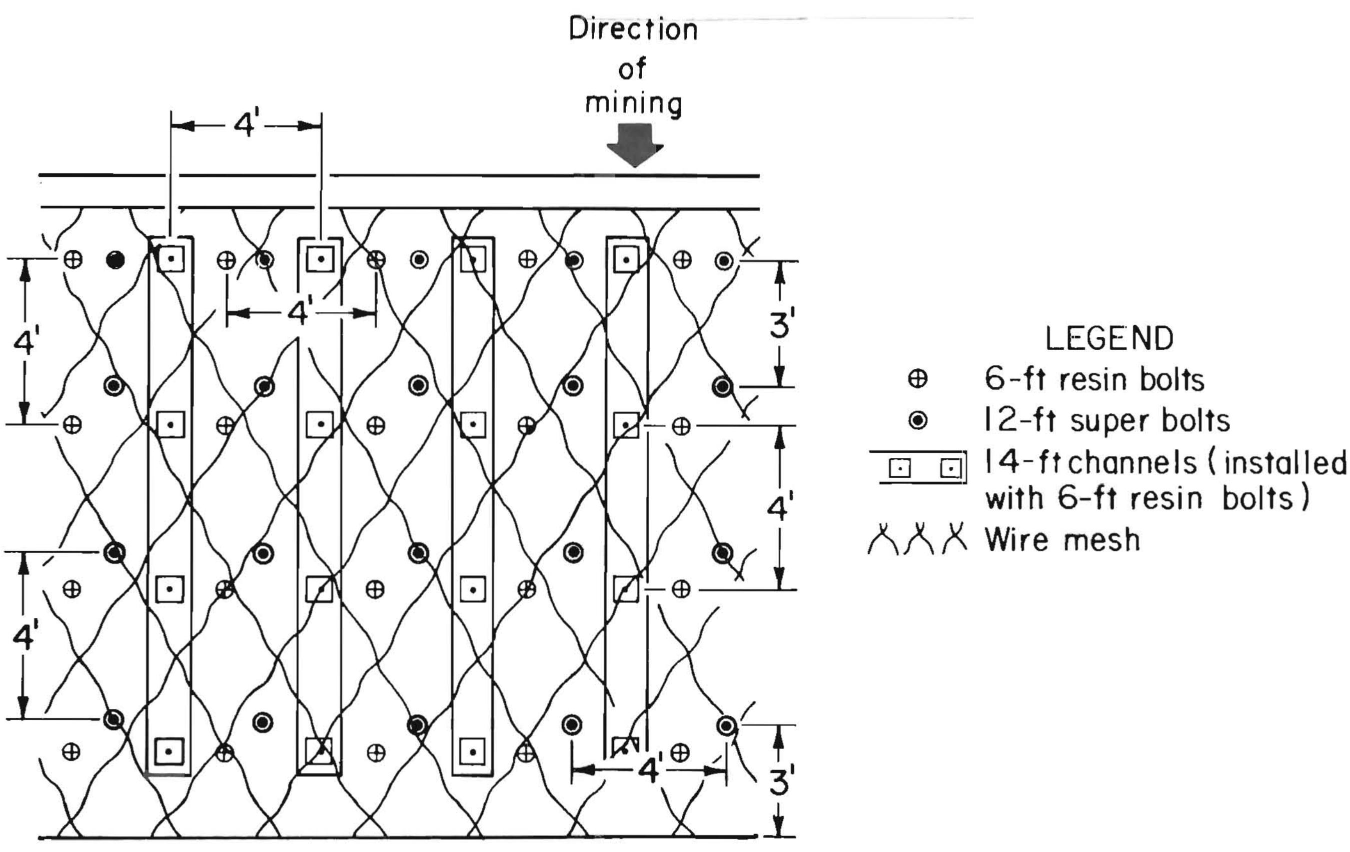

Figure 17.–Support plan for fullface recovery room.

Figure 18.–Installed supports in fullface recovery room.

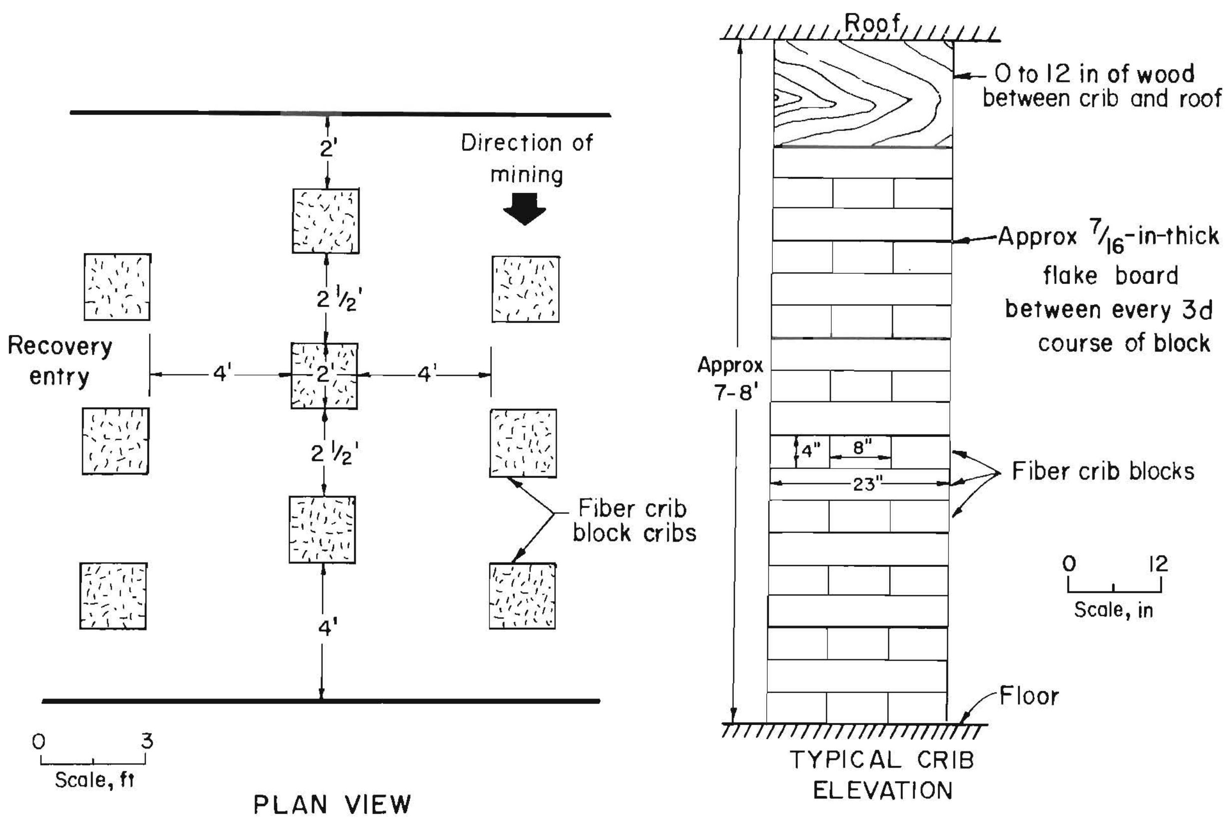

Figure 19.–Fiber crib construction and location in fullface recovery room.

stress changes in cribs near the tailgate side of the recovery entry (fig. 20). The extensometers installed in the intersections detected entry convergence as the face approached the recovery entry (fig. 21).

Once again, the results of the experiment were very encouraging. The face mined into the recovery room and cut out the first couple of rows of cribs (fig. 22) with only minor delays. Entry stability and support performance were sufficient to allow for improved face equipment recovery. Face-to-face transfer was completed in 31 calendar days, or 4% faster than the previous mine average of 32.4 days. The final month's rate of mining was 30.9 ft/d, a 121% increase over face advance during preparation for conventional recovery operations.

The maximum stress change recorded in the cribs was 80 psi and occurred after the face had cut into the recovery room. The absence of substantial stress change resulted from the method of crib construction, specifically the sequence of blocks and wood fillers. First, the sensitivity of the stressmeters was reduced by the presence of the wood fillers. The wood crushed and absorbed much of the front abutment, transferring little to the crib blocks. Also, laboratory testing showed that surface irregularities of the blocks above and below the instrumented block, caused point loading to take place and reduced load detection. Both of these effects increased with the use of multiple layers as was the case in the recovery room. Finally, during construction the instrumented crib blocks were placed in the center of the crib. Since it was possible to wedge tight only the outside edge of the cribs, the center remained loose for a portion of the loading cycle. The center blocks experienced little load as the outside perimeter took the majority of the front abutment. Crushing of the wedges and wood fillers around the perimeter of the cribs verified this conclusion.

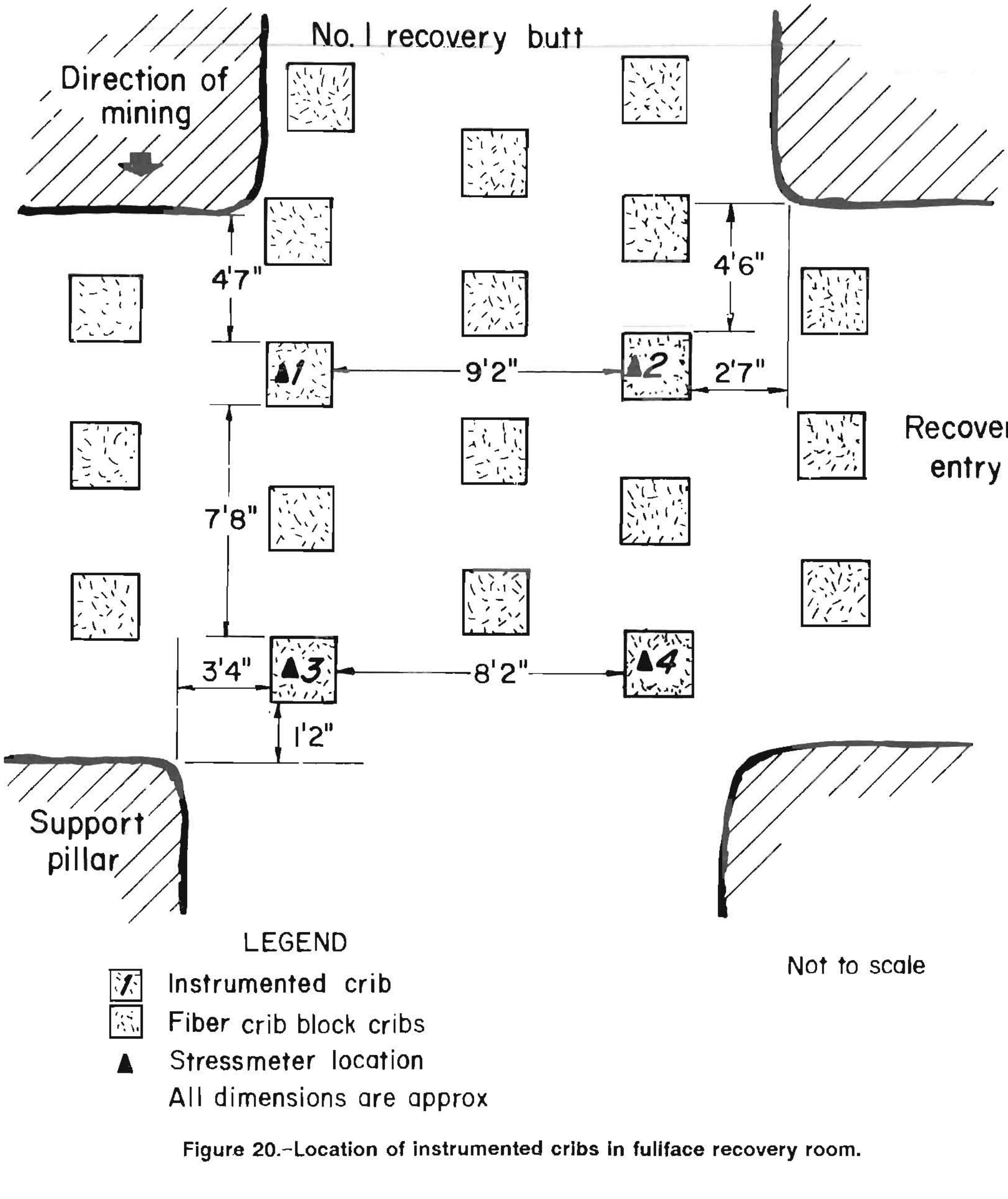

Figure 20.–Location of instrumented cribs in fullface recovery room.

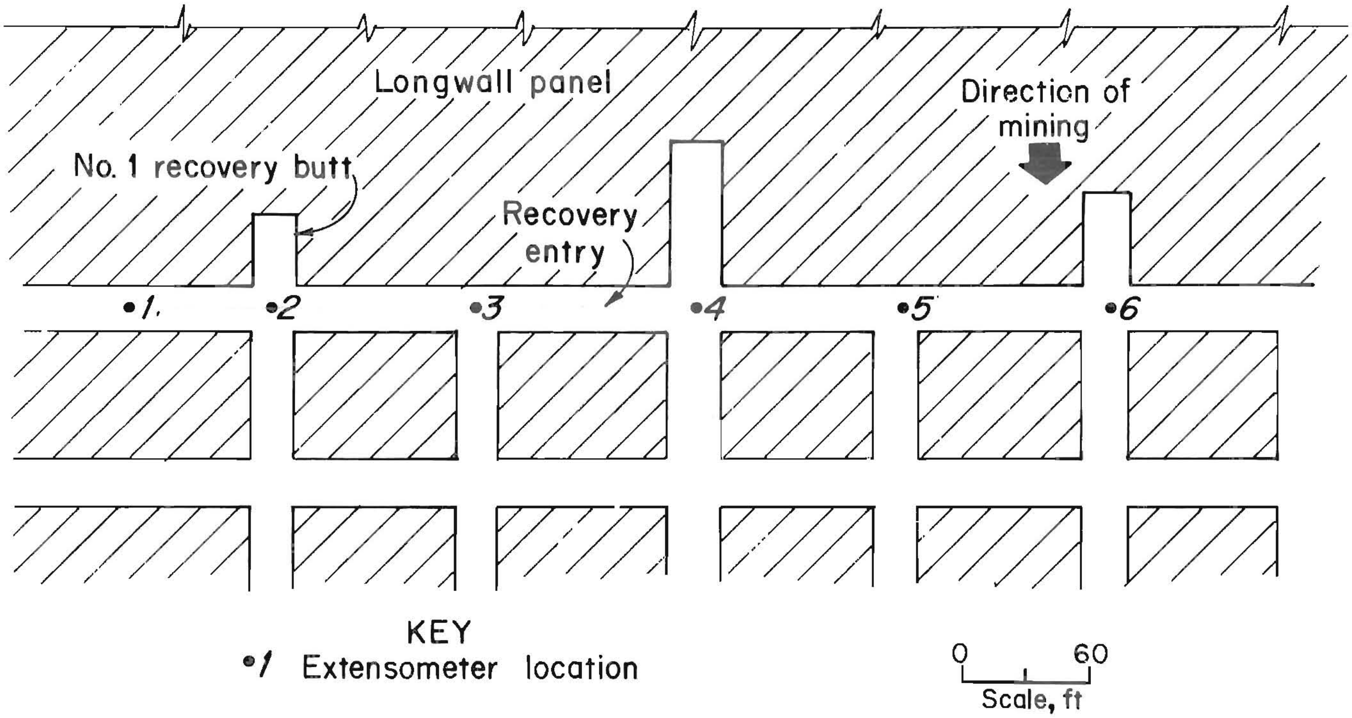

Figure 21.–Location of extensometers in fullface recovery room.

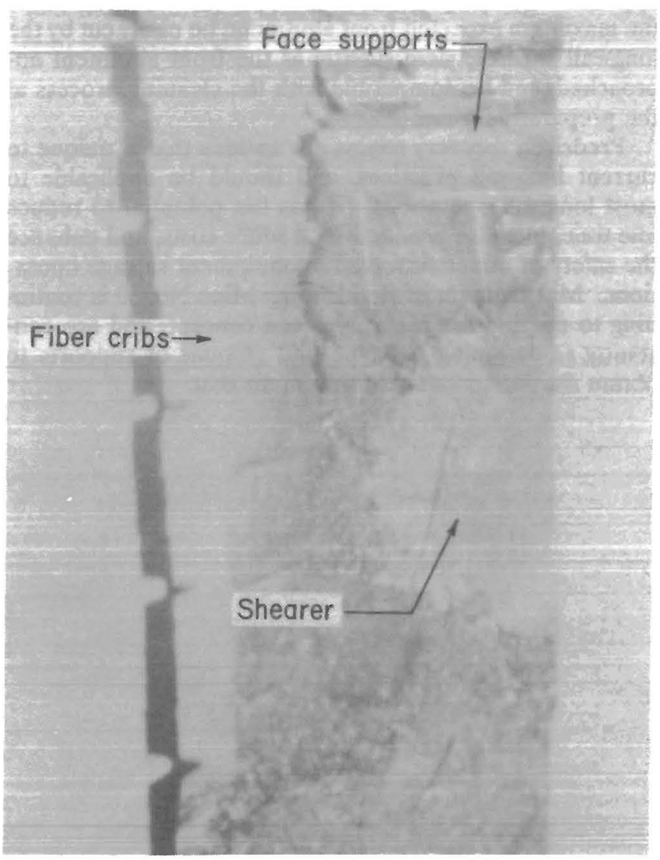

Figure 22.–Longwall shearer cutting fiber cribs.

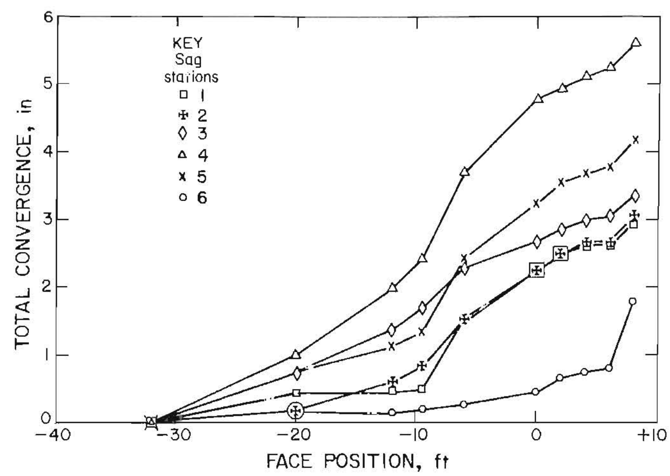

Figure 23.–Entry convergence versus face position in fullface recovery room.

Table 5 lists the convergence measured at each extensometer station. A majority of the convergence occurred within a span of about 18.5 h, starting when the face was 20 ft from the recovery room. Figure 23 is a graph of convergence versus face position. It shows that the rate of convergence was greatest when the face was 0 to 12 ft (shown as -12 to 0 ft in figure 23) away from the recovery entry. Since convergence results from loading, the increased rate of convergence indicates the arrival of the front abutment. This correlates well with what occurred in the initial recovery room trial.

Table 5.-Total convergence in fullface recovery room

Face position, ft[1]	Time	Total convergence by Sag station, in					
		1	2	3	4	5	6
-20	1:16 am	0.44	0.19	0.75	1.00	0.75	0.19
-12	9:00 am	.44	.59	1.38	2.00	1.13	.13
-10	10:15 am	.50	.81	1.69	2.44	1.34	.19
-6	12:00 pm	1.50	1.53	2.31	3.72	2.44	.28
0	2:00 pm	2.25	2.25	2.69	4.81	3.25	.44
2	3:00 pm	2.50	2.50	2.88	4.97	3.56	.66
4	4:00 pm	2.63	2.69	3.00	5.13	3.69	.75
6	5:00 pm	2.63	2.69	3.06	5.25	3.81	.81
8	7:30 pm	2.94	3.06	3.38	5.63	4.19	1.81

[1]Face position is actual distance of face from an individual station.

FUTURE RESEARCH

Planned research will focus on defining the support resistance needed to assure recovery room stability. This includes laboratory and field testing of various supplemental support materials, further refinement of the support resistance principle, and improved instrumentation for monitoring front abutment loading in the panel, supports, and support pillars. In addition, the affect of random shield pressurization on the mechanics of recovery room loading and the contribution of bolt loading to recovery room stability, need to be investigated in-depth since they are two important variables in the design of recovery entry support.

CONCLUSIONS

The use of a predriven longwall recovery room is an effective method for expediting equipment removal and increasing productivity when longwall mining in the Pittsburgh Coalbed. The major advantage to employing a predriven recovery room is the ability to maintain production to the end of the panel. In addition, the recovery room method reduced face-to-face move time by 4% because of the additional area and travelways for equipment removal. In this case, it was estimated that over 18 additional days of production and nearly 68,400 st of coal were gained per panel mined when using predriven recovery rooms instead of conventional recovery methods. The total benefit (additional revenues minus recovery room preparation cost) can be nearly $2.3 million if predriven recovery rooms are used during equipment removal.

Supplemental supports were designed that withstood the peak front abutment and maintained recovery room stability as the longwall mined into the recovery entry. Presently, piers constructed using a fly ash-cement mixture appear to be most promising. This design would withstand the maximum expected front abutment, be easily cut by the longwall shearer, yield slightly as the front abutment approached, and be compatible with the cleaning process at the preparation plant.

Predriven recovery rooms are an idea that is unique to current longwall practices, and should be applicable to most longwall operations. It has the potential to reduce idle time, increase productivity, reduce costs, and enhance the safety of miners involved in equipment salvage operations. Management of BethEnergy Mine No. 60 is continuing to employ the recovery room concept, and are constantly re-designing the type and amount of supports to obtain maximum safety at minimum cost.

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APPENDIX.–COST COMPARISON OF RECOVERY OPERATIONS

A line item cost report for conventional recovery operations and the two recovery rooms are shown below.

Table A-1.–Cost of conventional recovery operations

Cost	Quantity	Total cost
Supports:		
6-ft resin bolts	300	$500
Bolt plates	300	300
Resin glue . . . . ft	300	90
Channels and straps	85	1,700
Wire mesh . . . . . . ft^2	40,000	7,200
Labor: Hours	1,300	25,310
Total preparation cost		35,100

Table A-2.–Cost of initial recovery room (800 to 600 ft face reduction)

Cost	Quantity	Total cost
Supports:		
6-ft resin bolts	200	$330
12-ft resin bolts	100	2,000
Bolt plates	300	300
Resin glue . . . . ft	700	210
Wire mesh . . . . . . ft^2	2,330	420
Fly ash-cement piers	49	75,185
Additional misc	NA	1,675
Labor: Hours	1,200	23,280
Total preparation cost		103,400

NA Not Available.

Table A-3.–Cost of panel 4A fullface recovery room (600 ft)

Cost	Quantity	Total cost
Supports:		
6-ft resin bolts	1,200	$1,980
12-ft resin bolts	300	6,000
Bolt plates	1,500	1,500
Resin glue . . . . ft	3,900	1,170
Channels	150	3,000
Wire mesh . . . . . . ft^2	14,000	2,500
Fiber crib blocks	30,000	75,000
Flake board	420	4,610
Labor: Hours	2,100	40,740
Total preparation cost		136,500

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