

HEALTH AND SAFETY ISSUES RELATED TO EXTENDED LONGWALLS

Edward D. Thimons, Robert A. Jankowski, and Gerald L. Finfinger

Pittsburgh Research Center
U.S. Bureau of Mines
Pittsburgh, PA

ABSTRACT

Longwall mining has always been associated with high productivity and increased resource recovery. To optimize these benefits, there has been a trend in the industry to increase the size of longwall coal panels. These extended longwall panels, sometimes referred to as "super longwalls", offer some major benefits in terms of fewer panel moves, less entry development, and increased resource recovery. However, the use of extended longwalls does change the mining environment and this may positively or negatively impact health and safety concerns. For example, fewer panel moves could reduce injury rates since more accidents occur during moves than during actual longwall mining. Also, the frequency of accidents in longwall mining is lower than in continuous mining. Since extended longwalls reduce the amount of continuous miner development, accident rates should be lower. On the other hand, extended panels could introduce concerns in the areas of dust, methane, ground control, ventilation, and fire and escape. In this paper we will take a look

at these issues and what some current extended longwall operations are doing in terms of operating changes to address them.

INTRODUCTION

The underground coal mining industry has undergone a number of significant changes over the past century one of which has been the introduction of the longwall mining system. The first longwalling operations were small advancing faces radiating from a central point and were mined by manual labor (1). Production rates on these early longwalls were low by today's standards with maximum production being about 750 tons per day. Highly mechanized longwall mining in the U.S. was first tried in a Bureau of Mines sponsored study in 1954 at the Stotesbury Mine near Beckley, WV (2). Early longwall mining in the U.S. was not an immediate success with production rates averaging only about 530 tons per shift. However, longwall technology developed rapidly and in 1990, 96 longwalls were operating in this country. The average

longwall currently produces over 1,200,000 tons per year and longwall mining accounts for about 38 pct of underground coal production. In 1990, more than 30 longwall faces claimed to be capable of producing in excess of 6,000 tons of raw coal per shift, up from 7 faces in 1987 (3). Efforts are underway to further increase longwall productivity. One approach being used is to increase the size of longwall panels (Table 1) (4). These larger panels tend to be more productive for a number of reasons:

Table 1. Data For All Longwalls.

YEAR	NUMBER OF LONGWALLS	AVERAGE WIDTH, FT	MAXIMUM LENGTH, FT	PRODUCTION FROM LONGWALLS PERCENT
1973	55	461	N/A*	4
1974	72	460	N/A	3
1975	70	465	N/A	4
1976	72	482	6200	5
1977	80	484	6200	6
1978	91	487	7000	7
1979	111	491	7000	18
1980	100	495	7000	14
1981	112	525	N/A	14
1982	112	527	N/A	15
1983	118	541	8000	16
1984	112	541	8000	17
1985	118	605	8000	18
1986	109	656	9400	22
1987	102	630	10000	25
1988	92	658	10000	32
1989	95	649	N/A	36
1990	96	707	13000	38

* N/A - Information not available

- * An increased recovery of coal reserves results because longer panels mean fewer submains and wider panels mean fewer gateroads within a given reserve.
- * The reduction in the number of submains and gateroads means that fewer continuous miners may be needed and it is easier for continuous miner development to stay ahead of longwall panel mining. One mine reported that the equivalent of 1.5 to 2 continuous miners were needed

to stay ahead of longwall mining on their extended longwall panels where as 3 to 4 continuous miners were needed to stay ahead of longwall mining on their previous conventional size panels.

- * Construction costs are reduced because of the elimination of gate intersections. Fewer overcasts and belt drive installations are needed.
- * The use of longwall mining equipment is maximized because the number of longwall panel moves is reduced. Panel moves require both more supervisory personnel and miners than when mining is taking place. This increases personnel costs at a time when no coal is being mined.

Another reason that productivity has the potential to be higher on extended longwalls is that more reliable, heavy-duty equipment is required to insure that it will last through the panels. Therefore, mines are purchasing beefed-up tailgate transition pans, conveyor drives, and face conveyor components. Heavier duty shearers and shearers of a modular design are being employed in some cases. One mine using an extended longwall specifies that all longwall face conveyor components must be guaranteed for six million tons of raw coal before rebuild. Therefore, some, maybe even most, of the productivity gains on extended longwalls result from the use of more reliable equipment on the face. One mine estimated that their shift production levels increased about 12 pct from going to an extended longwall. Other mines using extended panels agree that the larger panels and associated heavier equipment do result in higher productivity.

Average panel widths and lengths are increasing yearly (Table 1) (4). In 1980, the average panel width of the operating longwall faces in the U.S. was 495 ft. In 1990, the average width of the 96 operating longwall faces was 707 ft, an increase of 43 pct. In 1980, only 24 longwall panels exceeded 5,000 ft in length with the longest being 7,000 ft long. In 1990, 50 longwall faces exceeded 5,000 ft in length; 6 of these exceeded 10,000 ft in length, with the longest of these being 13,000 ft. Indications are that this trend will continue as long as productivity gains can be achieved. Therefore, it is important to be aware of the health and safety considerations accompanying the use of extended longwalls and the more reliable equipment associated with them. The implementation of larger panels does not necessarily present a degraded health and safety environment for miners. In fact, it may even offer some safety advantages. However, it does introduce changes in the mining situation which may require different approaches to maintain a safe and healthy work environment. The following looks at some of the key health and safety issues that the Bureau of Mines believes can be impacted by the use of extended longwall panels. It is important to note that this discussion is generic in nature, and that every mine will be affected differently by the use of extended longwalls depending upon factors such as the gas content of the coal seam, the geologic conditions, the roof conditions, the physical properties of the coal, the age of the mine, the degree of automation, and other mine conditions.

It must also be pointed out that a direct health and safety comparison cannot always be made between an extended panel and a

conventional size panel. In some cases the extended panel must be compared to two or three conventional panels, whose total size equals the size of the extended panel. For example, with respect to spontaneous combustion concerns, it could be argued that the perimeter of an extended panel gob is much larger than the perimeter of a conventional panel. Therefore, the extended panel is more likely to have a spontaneous combustion occurrence since they generally occur around gob perimeters in spontaneous combustion prone mines. For a true comparison, the total perimeter of the extended panel gob must be compared to the sum of the perimeters of the two or more conventional panel gobs that would occupy the same space.

DUST CONTROL

As more coal is mined, more dust is generated (fig. 1). Dust generation is primarily a function of coal production rate.

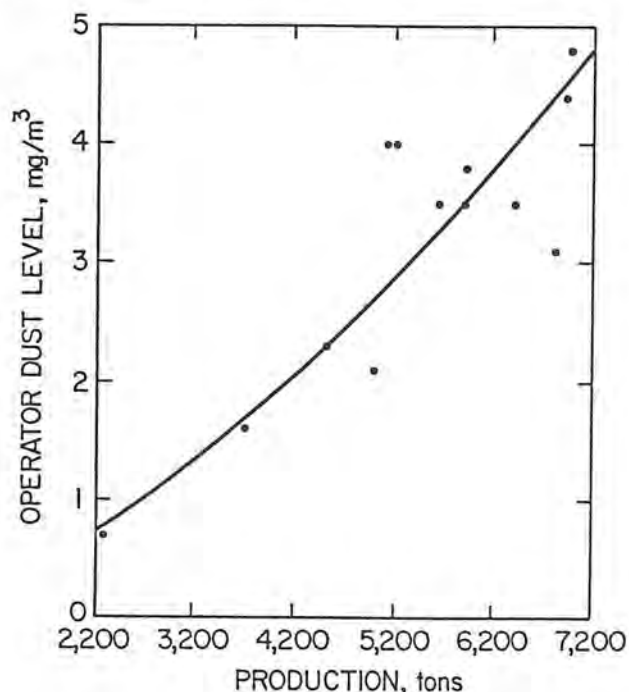


Figure 1. Dust generation as a function of coal production per shift.

Extended longwalls could result in increased dust levels for two reasons, both resulting from production increases. First, as stated earlier, extended longwall operators tend to use more reliable, heavy-duty face equipment, which generally results in higher productivity. Second, because of operational considerations, extended face longwalls will favor the use of the bi-directional cutting sequence. Productive mining time of bi-directional vs. uni-directional cutting faces improves significantly with wider faces. As an example, simulation studies have shown a 9.5 pct increase in production can be achieved with bi-directional cutting when face length is extended from 500 to 1,000 ft (fig. 2). Uni-directional cutting showed a slight decrease in production (5). However, bi-directional cutting increases the face workers exposure to respirable dust since the machine is cutting a larger portion of the time. Dust avoidance

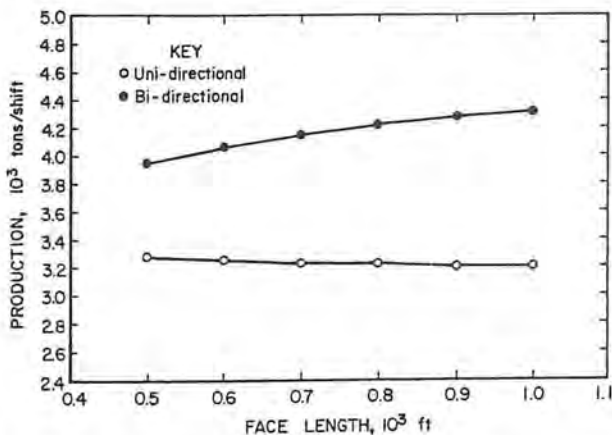


Figure 2. Impact of face length on coal production for uni-directional and bi-directional cutting.

procedures, commonly employed to reduce dust exposure on uni-directional faces, may well have limited success since the bi-directional cutting sequence will place face workers downwind of dust sources during all phases of the mining cycle. During the

downwind cutting pass, the shearer operator(s) will be downwind of support advance; during the upwind cutting pass, the support movers will be downwind of the shearer.

The primary source of respirable dust on longwall faces is still the cutting action of the shearer (6). Techniques that several mines have implemented for the control of shearer-generated dust on extended longwall faces have included high drum water flow rates, deep cutting, radio-remote control, and high pressure drum spray systems. Novel approaches which are being tried at one high production, extended longwall face include the addition of water-powered scrubbers on the shearer, and the use of a combination foam/surfactant. A second extended longwall mine is currently experimenting with a compressed-air/foam generation system built into the cutting drums. Although these attempts have been quite successful, additional operating costs are associated with their implementation.

Dust generation from roof support advance and stage loader/crusher operations may contribute up to half of a longwall worker's dust exposure. Wider faces will tend to slow face advance which can allow immediate roof quality to deteriorate. Poor quality roof is responsible for debris on support canopies and results in more dust during support advance. Several mines with extended longwall faces have installed water sprays on the support canopies in an effort to wet the accumulated debris. One Western extended longwall operator is attempting to use foam, applied to the top of the canopies. The success of this approach is currently being determined. If extended panels and the

associated better equipment do increase productivity, then more rapid and constant coal transport will be needed. The stageloader/crusher system will be handling more coal and thus producing more dust. Coal transport on the face conveyor may lead to potential dust problems. A novel approach being tried at one extended longwall face in Pennsylvania involves the addition of a high-pressure, water-powered scrubber on the crusher. An extended longwall mine in Kentucky has installed a scrubber in the support-line, at the headgate, in an effort to catch crusher dust as it enters the face. Some mines are increasing face air volumes and, in some cases, utilizing belt air, in an effort to improve ventilation on extended longwall faces. Increased ventilation quantities will help to remove and dilute face dust levels; however, additional attention may be needed to control dust levels along these high capacity beltlines.

METHANE CONTROL

If extended longwall panels do prove to be more productive, some of these potential productivity gains could be limited in the more gassy coal seams. It is likely that extracting gassy coal at a faster rate from larger panels could add to methane emission problems. Additional ventilation capacity or more gob gas drainage boreholes might be needed. Research conducted at a mine operating in the lower Kittanning Coalbed in Pennsylvania, revealed that when a more efficient, higher capacity conventional size longwall was installed, the time to mine a panel was reduced from 261 days to 191 days. Total methane production from the gob gas vent hole on the new panel (same size) increased only 13 pct over the

life of the panel. However, the daily production increased by 56 pct from 2.5 MMcfd to 3.9 MMcfd. It appears that while the total volume of gas available to flow was only slightly increased, the higher extraction rate exposed that volume of gas to the mine in a shorter time, therefore, increasing the daily exposure volume. If extended panels do result in higher production rates due to better equipment and bi-directional cutting, then methane emission rates may be higher.

In a study of gas emissions from longwall panels in a moderately gassy area of the Pocahontas No. 3. Coalbed in Virginia, it was found that expanding panel width only 11 pct from 630 ft to 700 ft, while maintaining the same panel length, increased the total methane emissions by almost 70 pct (fig. 3). The vast majority of this additional gas occurred in the gob and was vented out of the gob gas boreholes. The increased emissions resulted from the 11 pct larger panel and from the associated changes in the caving patterns. This level of increased methane emissions could have been an exceptional case,

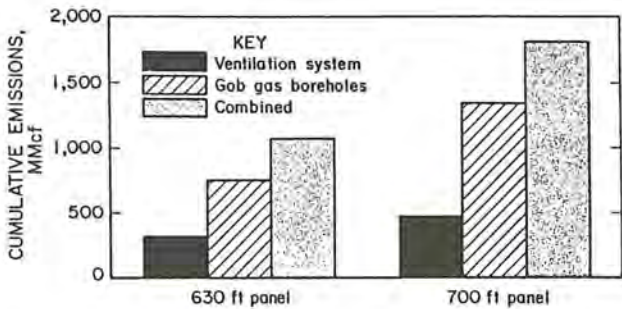


Figure 3. Impact of panel width on methane emissions in a Pocahontas No. 3 coalbed.

but it does imply that larger panels in gassy mines could require more ventilation or improved methane drainage.

While methane emissions on the larger dimension longwall panels will be higher if production rates increase, the majority of the increased emissions will most likely be in the gob areas from superjacent and subjacent strata. The additional methane load can best be handled by installing a larger number of gob gas drainage boreholes. In the experience of some mines it has been necessary to install 8 or 9 gob gas boreholes for each extended longwall panel. While the cost of these boreholes can be significant, they do provide an efficient method of dealing with the increased emissions. Figure 4 shows that gob gas boreholes on an extended longwall panel in the Pocahontas No. 3 coalbed captured double the amount of methane that was carried away by the mine's ventilation system over the life of the panel.

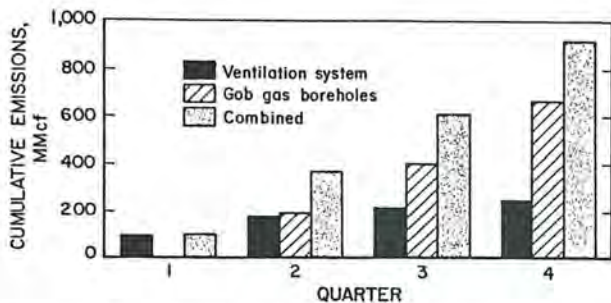


Figure 4. Gas emission patterns on a longwall as a function of time.

GROUND CONTROL

Extended longwalls contain as much as three times as much coal as conventional size panels, and therefore, require significantly more time to mine. As a result, the service lives of the gateroads are extended considerably. Additionally, on extended longwalls, gate development must begin earlier relative to face start-up, because the longer gates take more time to mine. It is well known that the longer a

mine opening needs to remain open, the more likely it is that conditions will deteriorate. This is particularly true for entries like longwall gates that are subject to heavy abutment loads from full-extraction mining (7). These gates may require larger protective chain pillars and/or additional artificial support (8).

One issue with extended longwalls is increased abutment loads due to the additional face width. Analysis suggests that in many instances this should not be a concern. Once a panel reaches a "critical" width, all additional abutment loads are actually carried by the gob. Most extended panels will fit into this category, however, there can be specific geologic conditions that may result in instabilities depending on the behavior of the strata in the gob (9).

Recently, longwall face bumps have been associated with the inability of massive strata to break upon coal extraction in a timely fashion. A limited number of deep longwall mines are subject to these incidences. It appears that this massive roof strata spans over the extraction panel, avoiding failure until the adjacent panel is pulled. The cantilevering of large volumes of roof strata adjacent to active longwall faces exerts tremendous stress on the longwall panel and adjacent gate entry pillars, increasing the potential for coal bumps. How extended panels will be impacted by this phenomena is not clear. It is believed by many that the wider panels on extended longwalls can produce a critical span which will assure the proper caving of the roof strata. Unfortunately, the influence of the strength, thickness, and geometry of the massive roof strata at different overburdens

is poorly understood. Therefore, widening a longwall panel in massive strata may or may not escalate the potential for longwall face bumps (10,11).

Past studies have shown that the face alignment can significantly affect the loading gates on longwall faces and make ground control more difficult. The profile of the caving line largely follows the profile of the face position and portions of the face that lag behind will generally see higher loading rates on the supports and coal face. These conditions degrade the stability and control of the face area. The wider faces on extended longwalls could make face alignment more difficult.

Longwall operators have implemented a variety of modifications to their longwall systems to help alleviate potential ground control problems that may arise during mining of the larger dimension panels. To counteract the potential for increased abutment loads during a slower retreat operation, some mines are installing larger shields. Average support capacities have increased significantly over the past 20 years (fig. 5). The higher capacity supports provide an additional protection against increased abutment loads if the retreat of the panel is interrupted or delayed. Some operators are also increasing the number of mining shifts per week on the panels to ensure panel retreat is keeping ahead of the gob loading. One mine using an extended panel, found it necessary to mine seven days a week to keep the increased weight from catching up with them on the face. There has also been an increase in the use of automated shield advance systems, which help in maintaining a straight face alignment. At least one extended longwall mine has found

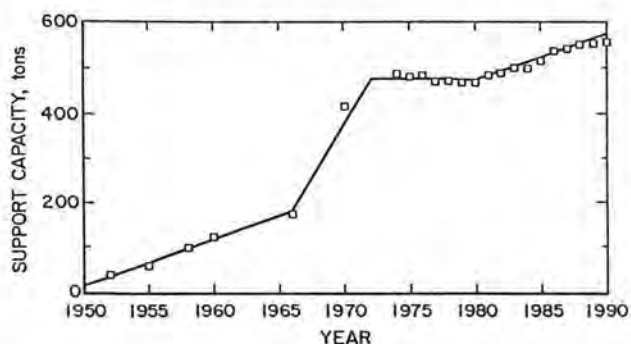


Figure 5. Increasing average support capacities as a function of time.

it necessary to do additional roof supporting in the headgate and tailgate entries, especially in the area within 150 ft of the face. In several instances, roof falls in this area partially closed off the tailgate escapeway and required immediate cleanup.

VENTILATION

Ventilation will play a key role with respect to dust control, methane control, and escapeway planning on extended longwalls. The longer entry lengths and face widths result in higher ventilation pressure drops than are encountered on more conventional size longwall panels. This will be particularly true in low seam coal mines. Higher ventilation pressures are not only needed to adequately ventilate the face during panel mining, but also to provide enough air during the driving of the long gate entries. Careful consideration must be given to designing ventilation systems which overcome the pressure drops associated with extended panels. Limiting air leakage along stopping lines becomes more important on extended panels. Good stopping construction techniques, capable of handling the higher than normal differential pressures, are vital. Reliable mechanical reinforcement of entries to maintain their original shape is

also critical to minimize their airflow resistance. If, after doing the above, the overall mine ventilation system is still not of adequate capacity and configuration to provide enough pressure at the outby end of the gate entries, then several approaches can be tried.

- * The air carrying capacity of the entries may have to be increased by increasing the number of entries, or obtaining a petition for modification and taking the necessary precautions to use the belt entry to carry ventilation air.
- * The fan capacity of the mine can be increased to a level where the needed flow and pressure are delivered to the longwall entries.
- * Additional shafts can be drilled to exhaust air at the backsides of the extended panels.

One mine that went from using conventional size longwalls to extended longwalls, found that they were able to reduce the number of entries from 4 to 3 on the extended panels by introducing exhaust boreholes at the tailgate ends of the panels (fig. 6). Both the headgate and tailgate entries are used as intakes, with all 125,000 cfm of ventilation air exiting out of the 4 ft diameter exhaust ventilation borehole. One borehole is drilled for every two panels. To keep velocities and resistances lower, the belt entries are used as intakes. Panel air is supplied from two separate splits of intake air.

A second mine now using extended longwalls originally increased the number of panel entries from the 4 they were using on their conventional size panels to 5 on one extended panel and 6 on another extended panel.

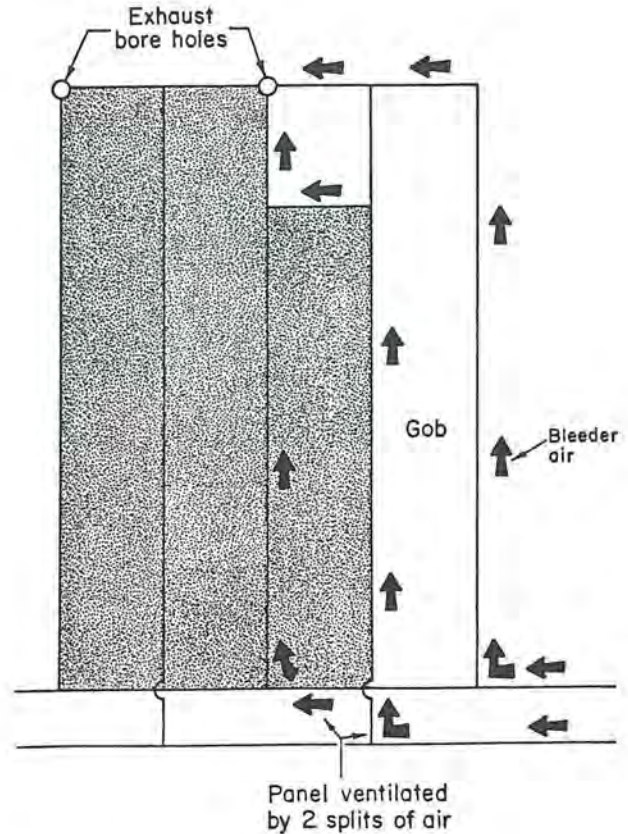


Figure 6. One mine's approach to ventilating extended panels.

They felt this was needed to handle the additional ventilation needs. However, the introduction of increased mine fan capacity and additional exhaust shafts allowed them to go back to 4 entry systems. They drill an exhaust shaft capable of handling 150,000 cfm at the backside of a series of panels. This shaft handles all of the bleeder entry air and a portion of the exhaust air from each panel as it is mined.

FIRE AND ESCAPE

The use of extended longwalls raises a number of issues related to mine fires and escapeways. These issues are not unique to the larger panels, but can be somewhat magnified by the size of the panels.

In the limited number of mines prone to spontaneous combustion, the extensive gobs resulting from extended longwalls may pose some unique concerns in terms of fire detection and suppression. The detection and suppression of spontaneous combustion fires in the gobs is already a problem on a few conventional longwall sections. If these same mines had extended longwalls, it could be an even more difficult task because of the somewhat slower face advance rates, and the higher ventilation pressures required. Spontaneous combustion fires in gobs generally occur along the perimeters of the gobs where ventilation air provides the needed oxygen and in the caved area just behind the face because air escapes into the gob in this area. The gob area just behind the face will be ventilated for longer periods because face advance will be slower. The higher ventilation pressures required to supply air on extended longwalls may force air further into the gob, thus increasing the potential for spontaneous combustion to occur.

Some people in the industry believe that extended longwalls will require improvements on both fixed and mobile fire suppression equipment. Because of the longer distances involved on extended panels, available water hoses and foam generator equipment will have to be more mobile or more readily available.

Extended longwalls obviously result in longer escape routes off of the panels. It could be argued that this has a negative impact on mine escape since escapeway distances are longer. The critical factor is how long it takes for a miner to get outby the fire. If the increased panel lengths cause miners to have to travel a further distance to get outby of a fire, then the

extended panels will impact safe escape.

A recent Bureau fault tree analysis showed that the most critical factor in escaping a mine fire was how quickly miners were notified of a fire and attempted to get outby the fire. Therefore, automated fire warning systems, which detect the products of combustion, such as carbon monoxide (CO) or smoke, are critical on extended longwalls. Early warning of a fire is imperative for successful escape. At least two mines now using extended panels have CO monitors at 1,000 ft spacings along their belts. In one mine the belt is used as an intake, necessitating the use of monitors by law, while in the other mine the belt is a neutral entry. The CO monitors in the neutral beltway will probably be slower to detect a fire, but they still provide an added degree of safety.

Additionally, several other considerations can improve the chances of escape from extended panels. Careful ventilation planning of escape routes and the use of reliable doors and stoppings are important. Innovative designs of ventilation systems can improve the potential for safe egress during a mine fire. For example, having the panel ventilated by two pressure balanced intake airways, each from a separate split of air, increases the chance for escape through clean air. The closer to the escape shaft that the separate splits of air originate, the better. It is important that such a ventilation system be properly designed or flow may stagnate across the face or in the bleeders. As pointed out in the ventilation discussion, one extended longwall mine is bringing two separate splits of intake air to the face through both the headgate and tailgate

entries and exhausting all of the panel air out of a shaft at the back of the panel. This method improves the escapeway integrity since it becomes more difficult for contaminant-laden air to pervade both escape entries. Provision should be made for miners to ride out of the panel in the event of a fire, rather than having them walk. This not only speeds up escape time, but reduces the possibility that miners will have to travel through smoke.

FEWER PANEL MOVES MEAN FEWER ACCIDENTS

While extended longwalls may raise some health and safety issues, they are not without potential advantages in this area also. By reducing the number of longwall moves, there is a corresponding decrease in the number of longwall related accidents. In discussions with several longwall operators, there was general agreement that the frequency of accidents is much higher during longwall moves than during actual mining of a panel. There are several likely reasons for this increase in accidents. A major reason is that significantly more non-routine work is done during longwall moves. Also, larger crews are required to move a longwall, than to operate one. As many as 30 personnel may be involved in a longwall move as opposed to about 7 or 8 to mine coal on a longwall face. Many of the people involved in a longwall move may not be as well trained and experienced in underground safety practices as are the daily longwall crews. Additionally, many mines bring extra management personnel underground to assist in longwall moves. They also may not have as much experience as the individuals who supervise the daily longwall operations. Finally, during longwall moves

there is a significant amount of support equipment in the area, which introduces an additional hazard. Additional diesel support equipment may increase the number of nuisance alarms on CO monitoring systems which defeats the benefit of the warning systems. Several mines reported an increase in back injuries along with injuries to hands, arms, and feet during longwall moves. These are injuries typically associated with the moving of large equipment such as occurs in a longwall move. Therefore, minimizing the number of longwall moves by going to extended panels could have a beneficial safety advantage.

ACCIDENT RATES WITH CONTINUOUS MINERS HIGHER THAN WITH LONGWALLS

The use of extended panels reduces the amount of continuous miner development because fewer submains and gateroads are needed. As noted earlier, one mine reported that going to extended panels reduced the number of continuous miners needed to stay ahead of panel development to the equivalent of 1.5 to 2 on their extended panels from 3 to 4 on their conventional size panels. Table 2 shows that accident rates are considerably higher for continuous miners than for longwalls both in terms of accidents per 200,000 manhours and per million tons of coal mined. Data for years 1988 and 1989 show that accident rates with continuous miners were almost three times higher than with longwalls on a per manhour basis and more than two and a half times higher on a per ton basis. Therefore, if the use of extended panels can decrease the amount of continuous miner development, accident rates should be lower in mines using extended panels.

Table 2. Longwall vs Continuous Miner Accident Rates.

Mining Method	Year	Per 200,000 manhours	Per 1,000,000 tons
Longwall	1988	6.12	10.11
	1989	4.94	9.43
Continuous Miner	1988	16.09	28.57
	1989	14.94	25.00

SUMMARY

Many of the health and safety issues associated with extended panels are related to increased production rates. The increased production may result less from the use of larger panels than from the use of more reliable, heavy-duty equipment designed to last through the larger panels. Additionally, care must be taken in comparing health and safety concerns on extended panels to more conventional size panels. In many cases, to obtain a true comparison, the extended panel has to be compared to the two or three conventional size panels that would occupy the same area as the extended panel. There are, however, potential health and safety concerns in the areas of dust, methane, ground control, ventilation, and fire and escape associated strictly with the use of larger panels. It is essential to be aware of these potential concerns if extended panels are to be operated in a safe, healthy, and efficient manner. Several current extended longwall operators have made changes in their operating procedures to address these concerns. On the other hand, there are potential safety advantages to using extended panels. Fewer panel moves and less continuous miner development should translate into lower accident rates.

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Alex Bacho
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