HEALTH AND SAFETY ISSUES RELATED TO EXTENDED LONGWALLS

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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. Longwall downtime is reduced because the amount of time spent on equipment moves and entry development is shortened. Resource recovery ratios can be increased because fewer coal pillars are left in place due to the elimination of some submains and a reduction in the number of gate entries. This can save millions of tons of coal that would otherwise be left in place. However, the introduction of extended longwalls may introduce a number of potential health and safety related issues which encompass the areas of dust, methane, ground control, ventilation, and fire and escape. In this paper we point out what these issues are, and take a look at 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 encompassing both evolutionary and revolutionary improvements. One of the more major changes has been the introduction of the longwall mining system. The first use of the concept is believed to have been initially tried in Shropshire, England toward the end of the 17th century[1]. The first longwalling operations were small advancing faces radiating from a central point and were mined by manual labor. The face support systems were wood and steel props. 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 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 and three out of four longwalls failing. However, longwall technology developed rapidly and in 1990, 96 longwalls were operating in this country. Average longwall production is currently over 1,200,000 tons per year and 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

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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:

* 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 1.5 to 2 continuous miners were needed to stay ahead of longwall mining on their extended longwall panels where 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.

More reliable equipment is needed on extended longwalls 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 6 million tons of raw coal before rebuild. Therefore, some productivity gains result simply from the use of more reliable equipment on the face. This makes it difficult to accurately estimate productivity gains resulting from the use of extended longwalls alone. However, one mine estimated that their bottom line longwall mining productivity increased about 12 percent solely from going to an extended longwall. Other mines using extended panels, while not willing to make estimates, agree that the larger panels do result in higher bottom line 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 percent. 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 towards longer and wider longwall panels will continue as long as productivity gains can be achieved. Therefore, it is important to be aware of some of the health and safety considerations associated with the use of these extended longwalls. 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.

DUST CONTROL

Extended face longwalls may introduce dust levels higher than those on conventional size longwalls. Additional dust may result from the cutting process itself and from other longwall face sources. Although gains in dust control technology have been made for longwalls during the past few years, they have been far overshadowed by the large increases in coal extraction rates. Presently, over 20 pct of longwall sections in operation are capable of average clean coal extraction rates in excess of 4,000 tons/shift. These extraction rates will continue to increase, as a larger percentage of the industry adopts the extended face design. As an indicator of what we can expect in the future, a recent study by the Bureau of the top six U.S. longwall mining sections showed they average in excess of 4,000 tons/shift of clean coal, with dust exposure levels of 3.8 mg/m^3. Currently, over 38 pct of underground coal extraction comes from longwalls, and this rate is continually increasing. As more coal is mined, more dust is generated (figure 1). Thus, increased dependency on extended face longwall technology will likely mean that more dust will be produced. Any additional increase in longwall coal production, without new dust control technology, will result in increased levels of dust exposure.

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 [illegible].5 pct increase in production can be achieved with bi-directional cutting when face length is extended from [illegible] to [illegible] ft (figure 2). Uni-directional cutting showed a slight decrease in production. However, bi-directional cutting increases the face workers exposure to respirable dust since the machine is cutting a larger portion of the time. Combating dust from extended face longwalls will require control technologies that both suppress dust at the source and capture dust in the air. Dust avoidance 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.

A recent Bureau survey of high production longwall shearer faces showed the primary source of respirable dust was still the cutting action of the shearer[8]. Techniques 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 in eastern Kentucky include the addition of water-powered scrubbers on the shearer, and the use of a combination foam/surfactant. A western 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 and significant amounts of respirable dust still become airborne.

Dust generation from roof support advance, stage loader/crusher operations, and face sloughage may contribute up to half of a longwall worker's dust exposure. Wider faces will tend to slow face advance which will allow immediate roof quality to deteriorate and separate over time. 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 longwall is attempting to use foam, applied to the top of the canopies. The success of this approach is currently being determined. Higher levels of production will require rapid and constant coal transport. 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 high production, extended longwall face in Pennsylvania involves the addition of a high-pressure, water-powered scrubber on the crusher. A second longwall 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. Several mines are utilizing belt air, in an effort to improve ventilation quantities on extended longwall faces. Improved 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. Slower face advance allows more time for the face to take weight, which may induce more dust from face sloughage, a problem area that has not yet been addressed by dust control research.

As industry attempts to increase its productivity, output from longwall mining sections is forecasted to increase to 45 pct of all underground coal production. In light of this trend, advancement of dust control technology, especially on extended faces, is a necessity to maintain compliance with the mandated dust standard. If new control technology is not made available, the standard could act as a binding constraint on future output.

METHANE CONTROL

Even though advanced mining technology exists, and larger longwall panels by their nature are more efficient, the productivity gains expected may not be realized in a substantial number of United States coal basins. Many of the areas where extended longwalls are currently being mined, or are planned in the near future, are in gassy coal seams. It is likely that extracting gassy coal at a faster rate from larger panels can, and probably will, add to methane emission problems and could strain a mine's gas drainage and ventilation systems.

It is quite possible that the expected productivity gains from utilizing extended longwalls may not be realized due to the increased methane emissions into the mine. This may present an increased mining safety problem. Research conducted at a mine operating in the lower Kittanning Coalbed in Pennsylvania, revealed that when a more efficient, higher capacity 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. 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 13 pct from 630 ft to 700 ft, increased the total methane emissions by almost 70 pct (figure 3). This level of increased methane emissions could strain existing ventilation systems having an adverse impact on both safety and productivity, and could necessitate expensive remedial and/or methane drainage solutions.

While methane emissions on the larger dimension longwall panels are likely to be higher, the majority of the increased emissions will 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 a method of dealing with the increased emissions. Figure 4 shows that gob gas boreholes on a longwall panel in the Pocahontas No. 3 coalbed captured double the amount of methane than what was carried away by the mine's ventilation system over the life of the panel. However, some operators have found that increasing the amount of ventilation air for the extended longwall panels can in some cases dilute the increased methane levels on both the face and in the gob areas.

GROUND CONTROL

Extended longwalls contain as much as three times as much coal as today's typical panels. They also take about three times as long to mine. As a result, the service lives of the gateroads is extended considerably. It is well known that the longer the 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].

In extended longwalls, gate development must begin earlier relative to face start-up, because the longer gates take longer to mine. More importantly, once the headgate pass is completed, the gate must wait for a considerable period of time while being subject to a side abutment load. These gates will thus require larger protective chain pillars and/or additional artificial support[8].

~~Another problem with longer gate entries will be the difficulty in cleaning up roof falls when they do occur. Access to tailgate entries in particular is usually severely limited once the headgate pass is complete. In some cases it has been necessary to wheelbarrow crib blocks to resupport a hazardous area. Obviously, this would be extremely difficult in a 10,000 ft long tailgate.~~

One problem many people expect 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. However, there are specific geologic conditions that may result in instabilities depending on the behavior of the strata in the gob[8].

Recently, longwall face bumps have been associated with the inability of massive strata to break upon coal extraction in a timely fashion. It appears as though this massive roof strata spanned over the current 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. It is widely believed that broader panels 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 by small increments may only increase the length of unsupported strata, escalating 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. This problem is enhanced on extended longwall installations since the face width is longer and more difficult to manage.

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 more than 30 percent over the past 20 years (figure 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 helps in maintaining a straight face alignment. At least one extended longwall mine has found it necessary to do additional roof supporting in the headgate and tailgate entries, especially in the area within 150 feet of the face. In several instances, roof falls in this area have closed off the tailgate escapeway.

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 significantly 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 large 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 return entries to maintain their original shape is also critical. This minimizes resistance in the long returns. If, after doing the above, the overall mine ventilation system is still not of adequate capacity and configuration to provide enough pressure at the neck of the gate entries, then several approaches can be tried.

* The air carrying capacity of the entries may have to be increased. This can be done by increasing the number of entries, increasing the size of the entries, or using 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 (figure 6). Both the headgate and tailgate entries are used as intakes, with all 125,000 cfm of ventilation air exiting out of the 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.

A second mine now using extended longwalls originally increased the number of entries to 5 or 6 from the 4 they were using on their conventional size panels. They felt this was needed to handle the additional ventilation capacity. However, the introduction of increased mine fan capacity and additional exhaust shafts allowed them to go to a 4 entry system. They drill a single 150,000 cfm exhaust shaft 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, explosions, and escapeways. These issues are not unique to the larger panels, but are somewhat magnified by the longer distances involved.

Larger panels place extra demands on ventilation and haulage systems and significantly increase the amount of combustible materials, especially those required for continuous haulage, such as wood cribs and posts as well as conveyor belting. This may create an increased risk of fire and every effort should be made to improve the fire resistance of these materials. Automated fire warning systems, which detect the products of combustion, such as carbon monoxide (CO) or smoke, are even more 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, 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.

The extensive gobs resulting from extended longwalls may pose some unique concerns in terms of fire detection and suppression in the gobs. Timely detection of fires in gobs will require more comprehensive monitoring to reduce detection times. The detection and suppression of spontaneous combustion fires in the gobs is already a problem on conventional longwall sections. It could be an even more difficult task on extended longwalls because of the large gob volumes involved. Various inerting and inhibiting schemes are currently being investigated, but significant additional work is needed.

Some people in the industry believe that extended longwalls will require improvements on both fixed and mobile fire suppression equipment along with improved face communication systems to speed up warnings to face workers. Conversely, two extended longwall operators pointed out that they did not make any changes in their fire suppression systems because of the increased panel sizes. Additionally, they did not find it necessary to make any changes in their face communication systems.

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. This may or may not be true. The total length of the escape route must be considered. If escape shafts are located close to the panels, escapeway distances can be kept to acceptable levels. It is the overall escape route distance, the path of the escape route, and the integrity of the escape route that are the critical factors. Careful ventilation planning of escape routes and the use of reliable doors and stoppings are important. The use of fire and explosion proof stoppings and doors greatly helps guarantee escapeway isolation. 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. 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.

SAFETY ADVANTAGES OF EXTENDED LONGWALLS

While extended longwalls do raise some health and safety issues, they are not without 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. Several mines reported an increase in back injuries along with injuries due to hands, arms, and feet being crushed. 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.

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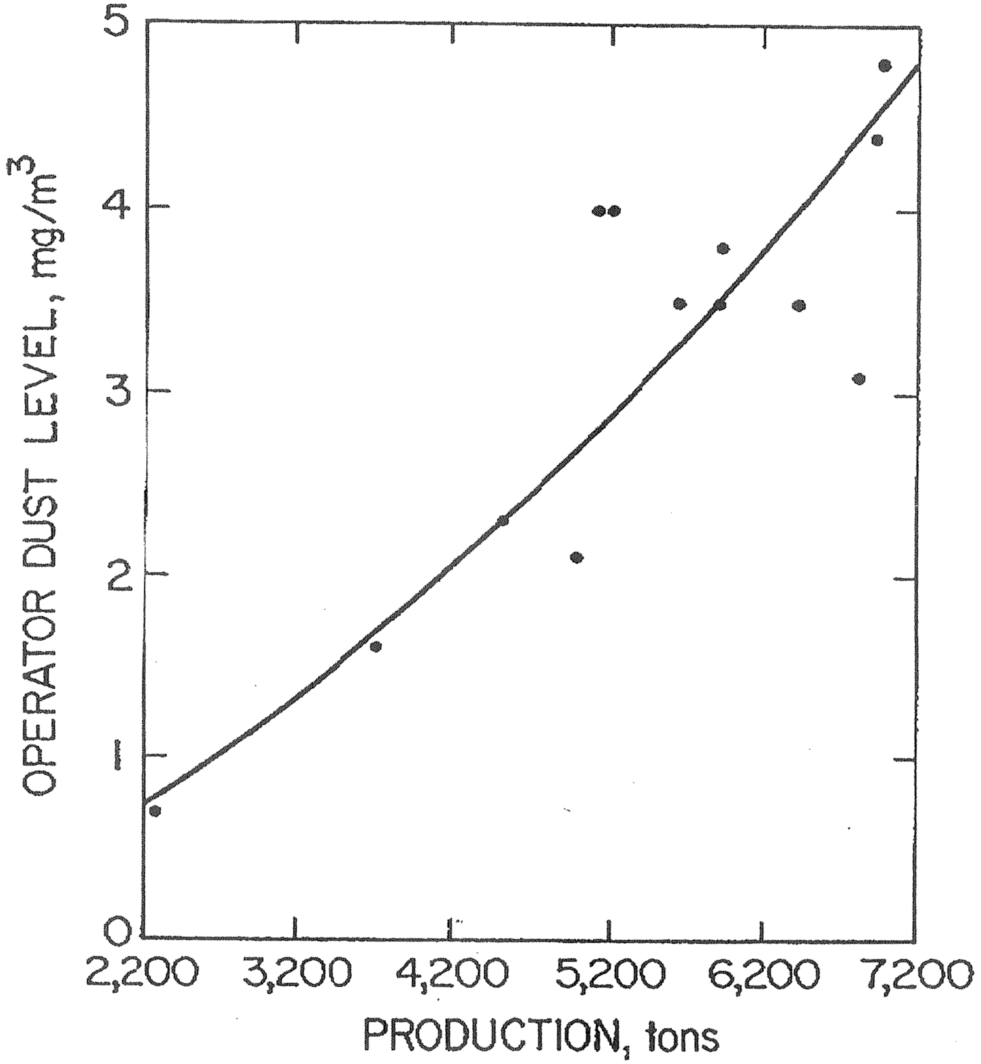
Table 1

Total of 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



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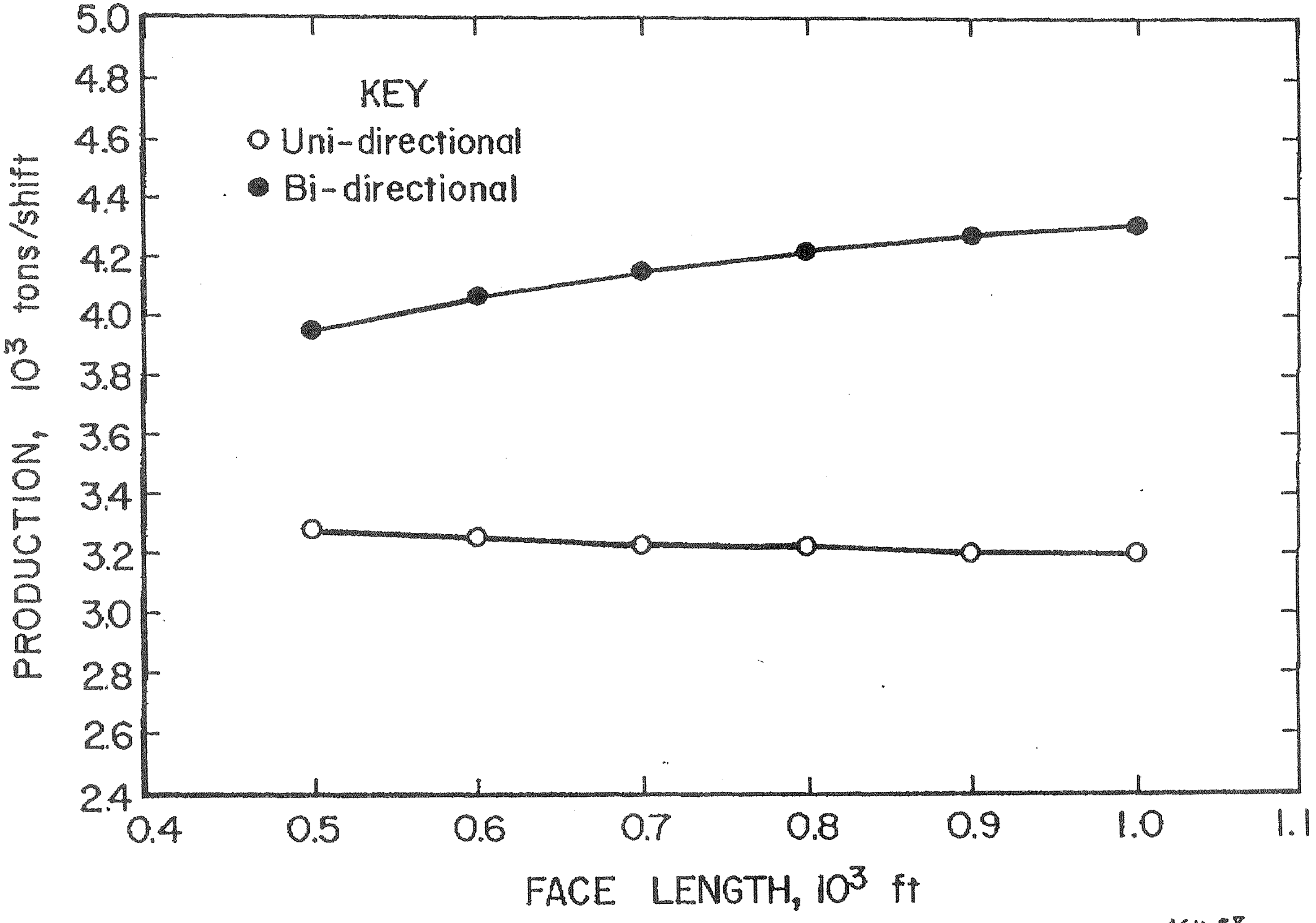
904

FIG 1



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867

FIG 2

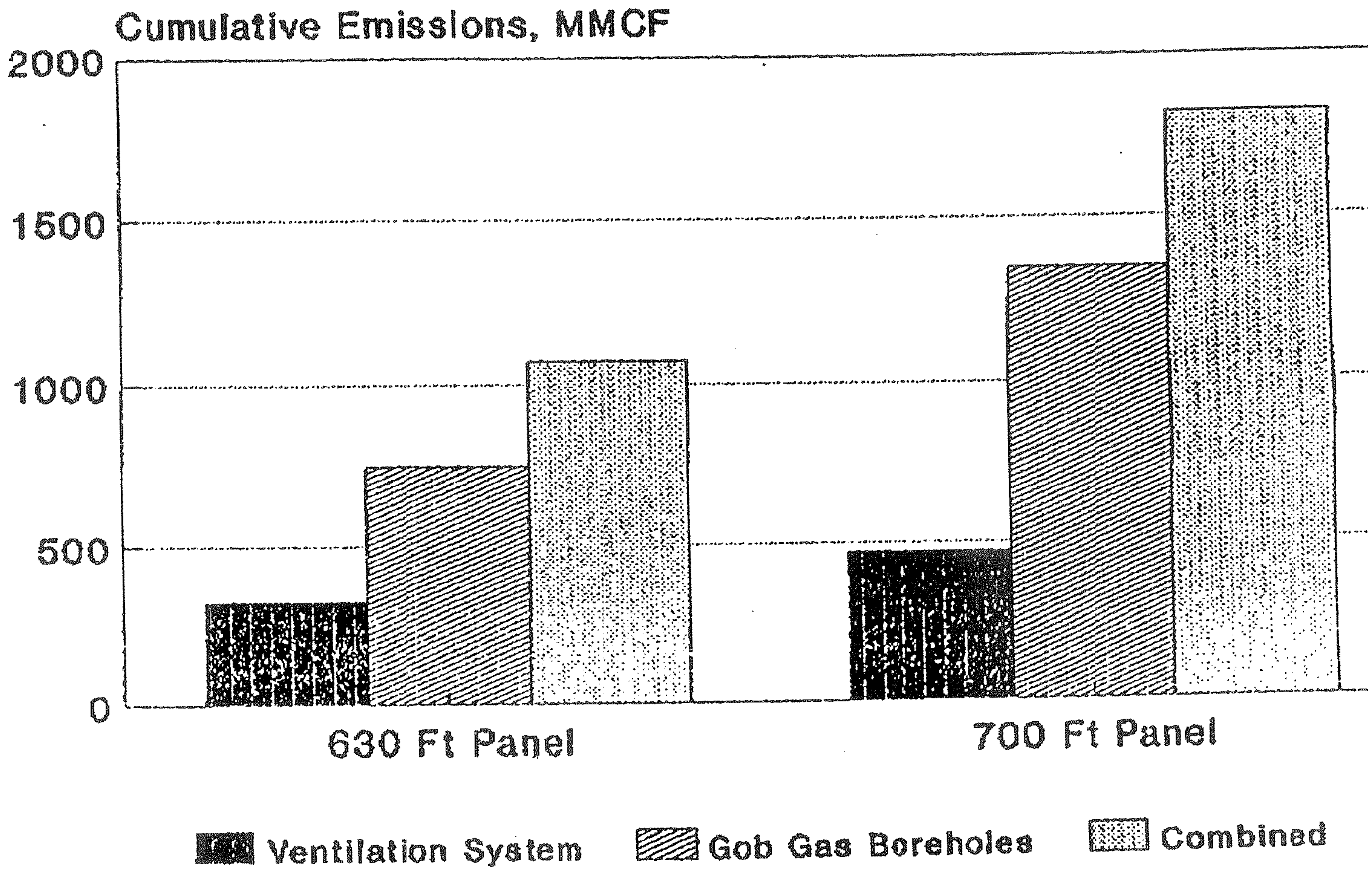

Figure 3. Methane Production from Two Pane

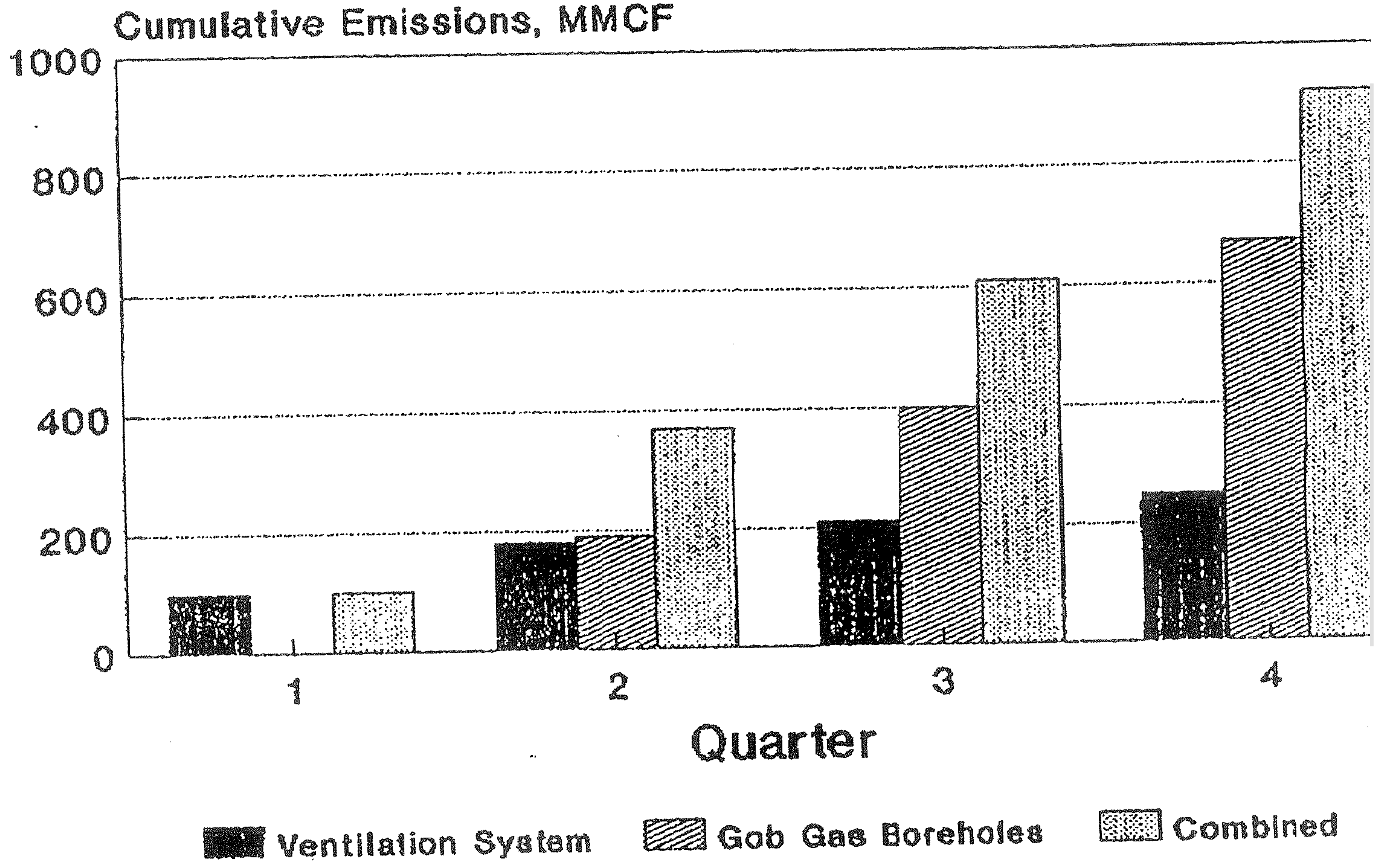

Figure 4 Longwall Methane Production

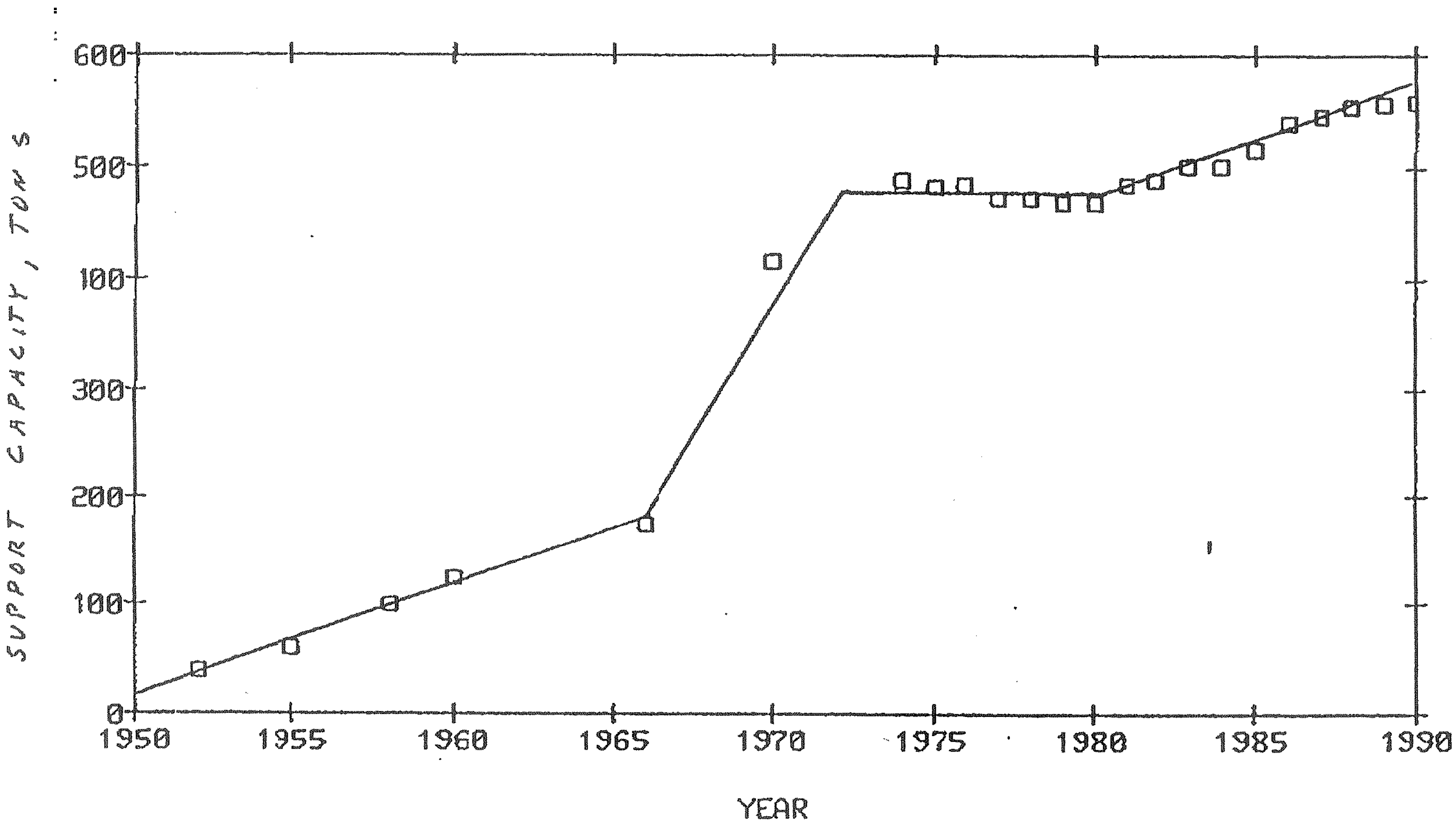

Figure 5
Historical trends in longwall support capacity.

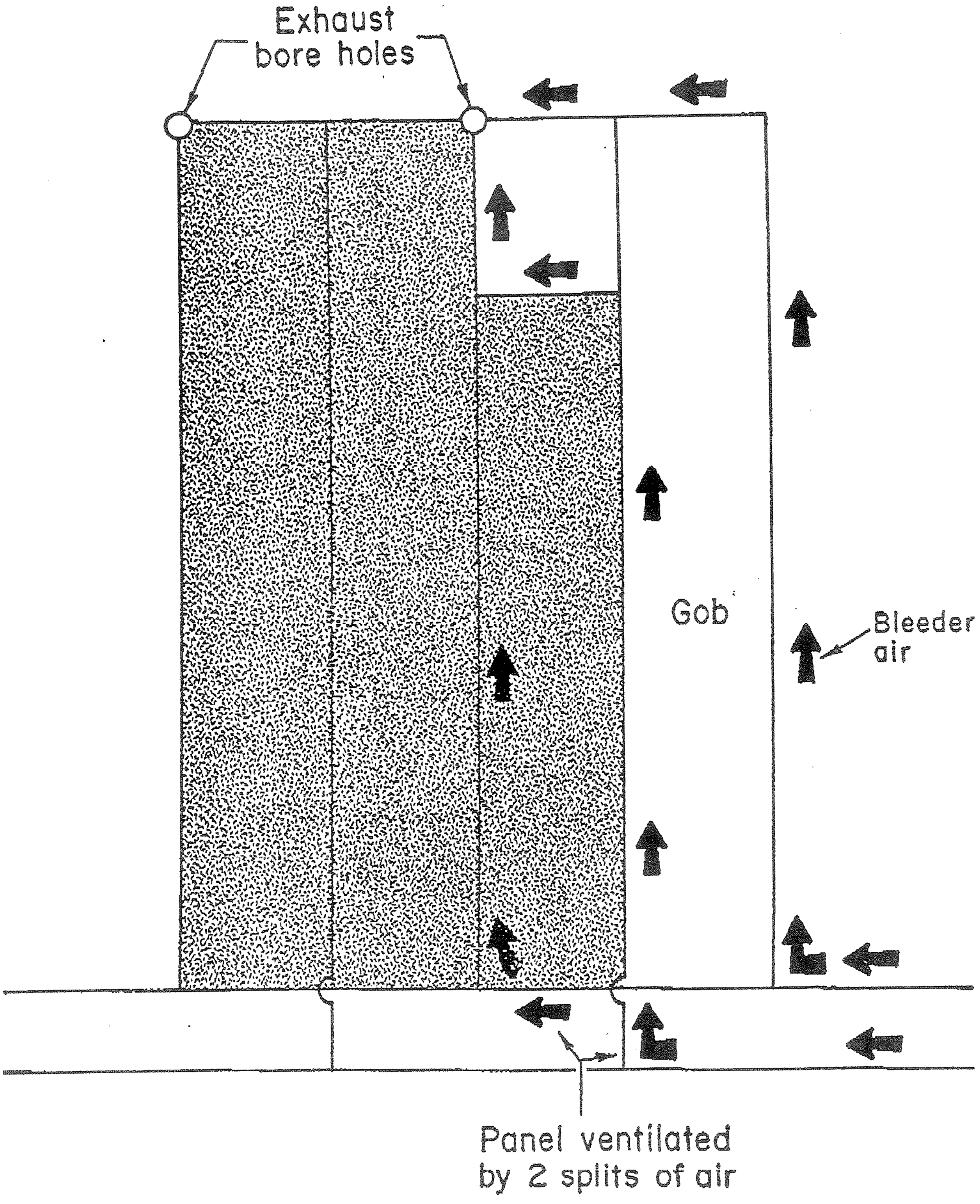
Exhaust bore holes
Gob
Bleeder air
Panel ventilated by 2 splits of air
BR-91-502

FIGURE 6