Ventilation System Design for a Thin–Seam Mining Panel

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ABSTRACT

The extraction of coal from thin-seams is an important component of the future of coal mining in the commonwealth of Virginia. For thin-seam mining systems to be successful they must be able to provide production comparable to the current production methods in thicker seams. This necessitates the extensive use of remote mining technology. Regardless of The level of automation of the remote systems, efficient ventilation remains of paramount importance.

This paper investigates several thin-seam mine panel schemes and possible variations in the ventilation systems. The primary approach made, however, is one of a pair of parallel panels mined simultaneously. A pair of face belts feed coal onto a common district belt. Ventilation is affected by means of a flow-through system. A cut of air is made to ventilate the mining machine and face. The face air being returned to the exhaust stream from the district. Problems associated with face ventilation in an extended remote cut are addressed and possible solutions presented. At the district level, ventilation considerations are addressed concerning the use of bleeder and bleederless schemes. Some special mention is made related to the potential application of backfilling the thin-seam entries following mining.

KEYWORDS

Coal, Thin-seam, Ventilation, and Panel Layout.

INTRODUCTION

In 1990 the production of coal in Virginia peaked at a little over 46.5 million tons (41.5×10^6 tonnes). Since that time a uniform decline has been stemmed through legislative action providing a tax credit to companies for continuing to mine coal in the state. Recognizing the remaining coal resource in the thinner seams, there is an enhanced credit available for mining coal in seams less than 36 inches (0.91m) thick. While there has been some activity, on the part of the mining companies, in seams slight thinner than this, there appears to a technological and risk based limit in seams less than about 30 inches (0.76 m) thick. The Virginia Center for Coal and Energy Research undertook a study to assess the historic attempts at thin-seam mining and the technical improvements that are now available, which may increase the viability of exploiting this coal using remote control mining and haulage equipment. This paper addresses some of the issues surrounding the design of a ventilation system for the working areas of a suggested plan to make economic utilization of an important resource in the future of coal mining in Virginia.

Ventilation in a thin-seam coal mine follows the same rules and principles as ventilation in thick seam coal mining. The main difference is the design of the method to extract the coal. In this case we are suggesting an automated coal winning system that can be run and maintained by miners in the development sections. The mining height in these mines will be in the area of 30 inches, and the height of the development entries is around 6 feet (2 m).

When designing a ventilation system for a thin-seam mine conventional modeling software can be applied. The main difference is that shock losses that are incurred when the air enters the smaller production stalls from the larger development entries must be accounted for. Other than that it is an exercise in design and modeling.

PANEL LAYOUT

This new mining layout was designed taking into account ventilation, development cost, haulage, equipment maneuverability, materials transportation, and recovery. In this new layout large blocks of coal are developed, similar to longwall panels; see Figure 1. The dimensions of these blocks are 1100 feet (335 m) wide by at least 5000 feet (1500 m) in length. In this design the longer the panel, the higher the recovery that is obtained.

This layout frames in each block with two entries on each side. Three entries are located between every other two adjacent panels, with an entry in the middle that is used for main haulage. This haulage entry is shared between the two panels. All development entries are assumed six feet in height and twenty feet in width.

Three parallel entries run along the shorter ends of the panel blocks. The first entry on the outby side of the panel contains tracks for transportation of supplies. This entry serves as the intake airway. The second entry on the outby side of the panel serves as the main haulage entry, and maintained as a neutral airway.

The three entries on the inby side of the panel serve as ventilation main return entries. These entries receive air from the blocks and maintain the ventilation of the other mined out panels in the mine. These entries are important for connecting the ventilation circuit of the mine as a whole.

The outermost entries on the sides of the panels serve as returns for contaminated air. The outer two central entries serve as main intakes, while the center entry is designated as a neutral haulage entry.

The production stalls are cut parallel to each other in a herring bone pattern. This establishes production cuts 500 feet (150 m) long that are roughly 13 feet (4 m) in width and 30 inches (0.76 m) in height, with support pillars between each cut. The width of these support pillars is highly dependent on the degree of fragmentation of the country rock, coal strength, depth of overburden, and strength of backfill, if used. An average value for a pillar width at 1000-feet of overburden with moderately intact rock, strong coal, and a 30 inch mining height would be 11 feet (3.4 m) wide with no backfill, and 5.9 feet (1.8 m) wide with a 1000-psi (6.9 MPa) strength backfill. (Donovan, 1998)

The herring bone pattern was selected for length of cut and maneuverability of equipment. Production cuts angle at 45° and are accessible with continuous haulage units. This allows the haulage units to remain in one continuous string, instead of having to be disassembled and put back together each time a production cut is completed.

Haulage in this system is accomplished using a series of conveyors. First the stall conveyor train off loads onto a secondary stall conveyor in the respective panel entry. The coal then travels down this conveyor and is delivered to the section belt conveyor. The section belt carries coal from both panels of the block to the mine main conveyor system.

When backfill is utilized there is a pumping station at the end of each panel's secondary haulage entry. This pumping station pumps backfill material to fill into the mined out stalls, and preserve the integrity of the ventilation system. By filling in these mined out stalls, leakage pathways are sealed off, requiring the air to travel in the pathways that have been designated as the ventilation network.

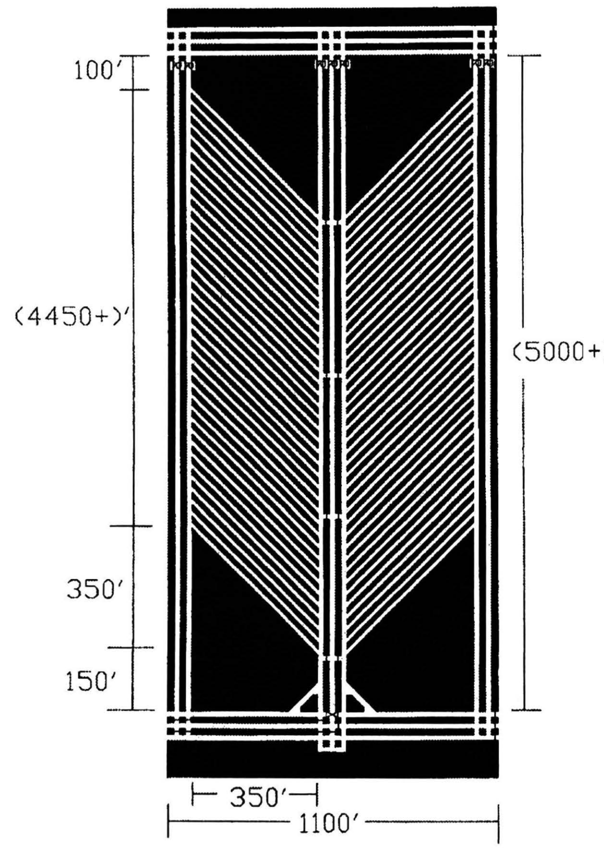

Figure 1. General Block Layout with dimensions (Holman, McPherson, Loomis 1999).

METHOD OF MINING

First the miner and the stall conveyor train units are coupled and attached to a special guide rail on the secondary conveyor train. Mining is ready to begin. The miner begins cutting production stalls at 45° to the respective main intake entry. The continuous miner advances forward cutting coal, to form the production stalls, until it emerges in the return entry. As the coal is cut, it is gathered by the miner and loaded on the continuous haulage unit. The coal is transported down the length of the stall and is off loaded onto the secondary stall conveyor train.

Since the continuous haulage unit rolls along a guide rail that is attached to the secondary stall conveyor train, it can continuously follow the miner without losing contact with the primary stall conveyor. This allows for constant mining on the advance.

The coal then travels down the secondary conveyor until it is transferred to the section belt conveyor. The section belt conveyor delivers the coal mined from both panels of each active block to the mine main conveyor system for delivery the surface.

When a production stall is finished, the miner and stall conveyor train are backed out of the stall and down the entry, towards the intake end. The miner is now positioned to start the next stall. While the miner advances, mining the new production stall, the previously mined production stall can be backfilled, if backfill is being employed. This process is repeated until all of the planned production stalls in that panel are mined out. The equipment is then moved to a new block, which has been prepared during the mining of the previous one, and the block and panel mining process begins again.

BACKFILLING

There are many reasons that backfilling has been incorporated into this design. The most important reason is for ground control. By placing backfill into the mined out stalls, structural integrity of the pillars is greatly increased. The fill material becomes compacted and exerts a confining force on the remaining coal pillars, increasing their strength. This increase in strength allows the pillars to have a smaller width. Having smaller pillars can provide for higher recoveries and higher profit margins for the mine.

Another reason for back filling is ventilation control. With this mining layout, as it is planned, backfill will be needed to fully close off the mined out stalls. This limits the area that the air can flow through and keeps ventilation air velocities at acceptable levels. The backfill also serves to seal off mined out sections so that the methane concentrations will remain above the explosive range, and will be isolated from any possible ignition sources.

Another reason to backfill falls directly under the economic considerations of this plan, disposal of solid wastes. If solid wastes can be mixed into the fill material and pumped underground in a manner that does not threaten the environment, there is the potential for generating additional revenue. Even if waste that will bring in revenue cannot be found, there is always mine waste to dispose of, and money can be saved by disposing of the mine's own waste.

VENTILATION CONFIGURATIONS

Given the selected mining system, numerous ventilation configurations could be suggested and evaluated. Depending on the overall configuration, the variety of schemes that can be devised will have an effect on the overall operation of the mine. A few of the possible configurations will be addressed here, along with comments on the impact to the mining system design. These possible systems are categorized into bleederless and bleeder ventilation schemes.

Regardless of the scheme use to control the ventilation on a panel and block scale, control of the airflow at the cutting face will be unaffected. Delivery of air to the continuous miner deep within the stall will be accomplished using a forcing fan and duct system. An airflow of approximately 4000 cubic feet per minute (1.9 m^3/s) will provide a velocity exceeding 100 feet per minute (0.5 m/s) returning down the active stall. Using a smooth duct 12 inches (0.3 m) in diameter, this will require a total pressure of approximately 10 inches water gauge (2.5 kPa). The air returning from the active stall will be directed to the panel return, away from the operations personnel. This configuration is illustrated in Figure 2.

Bleederless Ventilation Schemes

In the bleederless ventilation system the mined stall will either be sealed with plugs or backfilled completely. In this sense there will not be the need to make special provisions to control the methane emissions by direct ventilation control.

Rather, separate splits of air will be used to ventilate the back drifts, the front drifts, and the section belt entries. The basic configuration calls for the section belt entry to be, ostensibly, neutral; hence, there should be no leakage from that entry towards the either of the front entries. This general scheme is illustrated in Figure 3.

There will, necessarily, be a slight pressure drop from the front to the back entries of each panel. This pressure drop is required to ensure that any leakage from the isolated stalls be towards the back entries and the main returns.

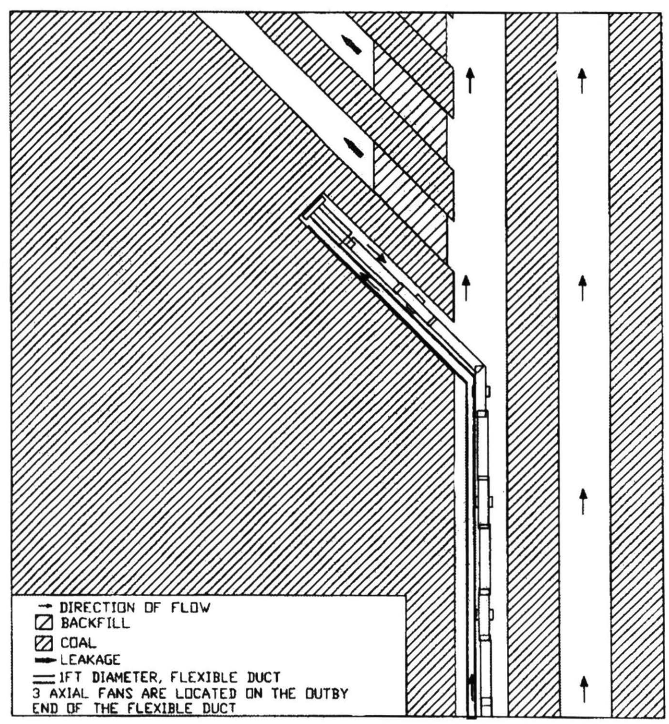

Figure 2. General Illustration of Face Ventilation (Holman, McPherson, and Loomis 1999).

Under normal operating conditions airflow in the back drifts will progress past the sealed stalls picking up what leakage may be present. This air will enter the main returns at the inby end of the active block. Airflow in the front entries will ventilate the mining equipment and personnel of either panel, as well as a split taken to ventilate the remote face, continuous miner, and stall conveyor train. Air used for this purpose will pass over the active working equipment towards the main returns at the inby end of the block. Under conditions supporting a neutral belt entry, it is expected that leakage will be from the front entries to the section belt entry. The air flowing across the section belt will be routed to the main returns.

At the time of break through, and until the open stall can be effectively sealed, a portion of the air flowing in the front entries will flow through that opening towards the back drifts. Control of the assurance that the airflow will be in that direction provides further necessity that the back drifts be at a slightly lower pressure than those at the front.

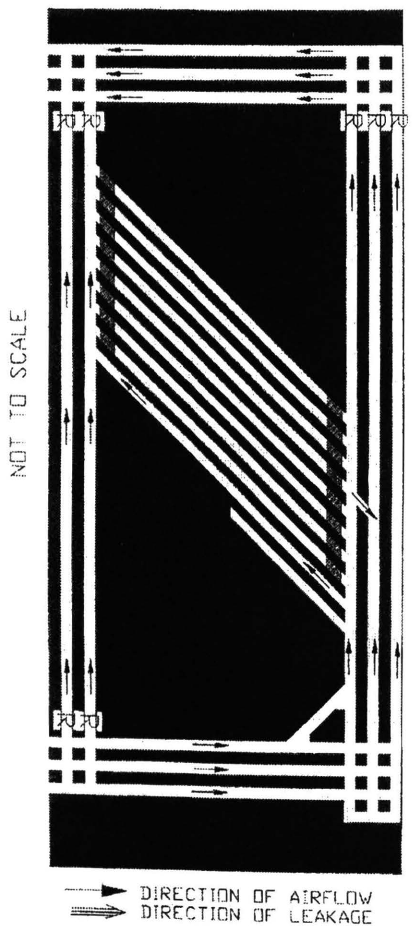

Figure 3. Generalized bleederless system for proposed thin-seam panel.

Bleeder Ventilation Schemes

The use of bleeder type ventilation schemes allows for the control of airflow through the extracted area of mining sections. In the configuration suggested here for thin–seam extraction a bleeder system would be used if there was no attempt made to seal the stalls that have been previously mined. In such a case, it would be necessary to limit airflow through the stalls inby the one under currently being mined. Since there would be air movement in this zone the control of the emitted methane becomes an issue. It is most desirable that this methane enriched air not mix directly with the general mine return, until such a time that the confluence becomes inevitable.

A bleeder type ventilation system applied to this thin–seam mining configuration might be similar to that illustrated in Figure 4. This figure is shown in semi-schematic. That is, the mains are shown a as three entries, an intake, a belt, and a return, when in fact several airways may be configured in parallel to serve these individual functions. In this design, the entries inby the active section serve as the bleeder system. Brattice type stoppings are employed to limit the airflow through the mined out stalls inby the current stall. The exception being the first stall immediately inby, which is used as the general section return. In this system the outer pairs of entries, on either side of the block, serve a dual purpose. In one sense, they are panel returns outby the current ventilation stall. In the other, they are bleeder entries inby the current ventilation stall.

This dual nature leads to a precarious balance between the movement of air being moved through the ventilation stall and through the barricaded stalls inby. The most desirous condition being that there is a slight tendency for the airflow to be towards the bleeder end of the panel, rather than towards the main airways end.

The application of a bleeder system also places the overall design of the main ventilation in the U-tube configuration. In that mode, the main entries will have intake, return, and belt air moving in parallel flow, with the associated problems of leakage between the sides of the system. This configuration may lead to excessive development costs related to the additional entries necessary to support the limited flow associated with the bleeders. Furthermore, the necessity of intake and return air crossing in the mains leads to a particularly complex arrangement of overcasts and stoppings in the region of the center entries of the active block.

VENTILATION MODELING

The main difference between the ventilation of this mining system and other currently used systems is the ventilation of the panel layout. For this reason the material presented here will focus its attention on the measures used to ventilate the panel. The overall ventilation of the mine being carried out in a similar manner as would be designed in a typical underground coal mine.

The software that was employed to model this ventilation system was VnetPC® for Windows version 1.0a, developed by Mine Ventilation Services, Inc. The first step in the modeling process was to design a schematic to represent the entries in the panel layout. In the creation of this schematic many of the parallel entries, which move air in the same direction, were treated as if they were one branch of the schematic. This can be seen in the dual entries that frame in the outermost edges of the block. The mined out stalls were also treated in a similar fashion utilizing an airway resistance consistent with the multiple parallel entries. Cross-cuts between parallel, but dissimilar, airways were treated also treated as equivalent resistances.

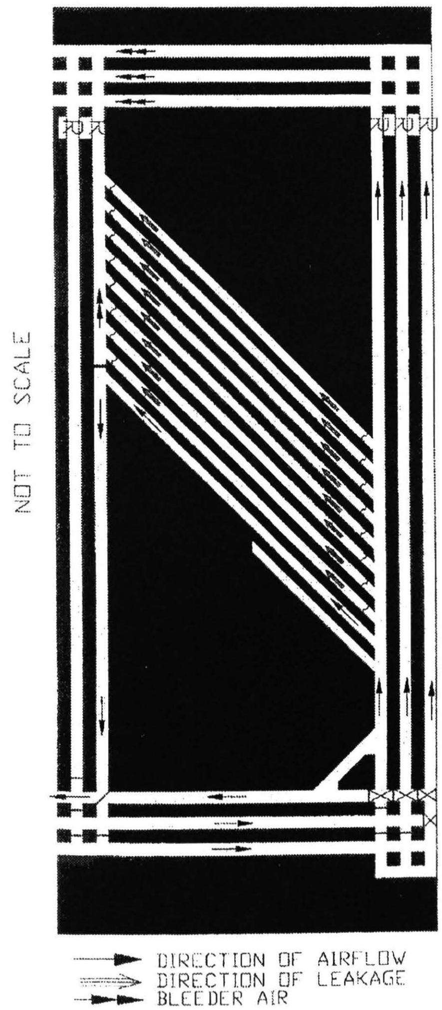

Figure 4. Generalized bleeder system for proposed thin-seam panel.

An example of the basic network shown in Figure 5. For the purpose of flexibility the fan has been modeled of a fixed quantity type. The airways to the left of those associated with the block are necessary to complete the model, but otherwise have no significant effect and are therefore assigned no resistance. In addition, the airways inby the active block have been modeled to allow for air to flow deeper into the mine. The resistances of these branches, on the right hand side, have been assigned at a nominal value that is consistent with the intended purpose. The model, developed in this fashion, allows for the investigation of the airflow through the active working block and panels while nominally recognizing the presence of the remainder of the mine workings.

Due to the nature of the mining process, the model was constructed to handle the increasing number of parallel production stalls. Three stages of the model were constructed to evaluated airflow as mining progresses on the retreat. The first stage has only two production stalls cut, one each panel of the block.

The second stage has two open production cuts with two more schematic branches modeling the leakage of air through the sealed production stalls. The third, and final stage, models the worst case scenario, an open stall and two equivalent parallel resistance branches in each panel. This represents the situation following the mining of the final stalls in the active block.

Figure 5 illustrates a typical model of the airflow within the suggested ventilation layout. In this model the airflow in the center, section belt, entry of the block is controlled at the outby end so that this entry remains at a negative pressure with respect to the panel access, front, entries. Both of these, on the left and right, have regulators at the inby ends to control the volume of flow through the panel accesses.

The panel exhaust, back, airways, on the outer left and right of the block, are equipped with regulators at both the outby and inby ends; at either end of the herringbone panels. The outby regulator ensures a limited quantity of fresh air flow into these entries and assures that the flow is toward these returns from the panel accesses. The inby regulators control the quantity of flow through the mined out panel stalls. Prudent control between the regulators on the intake and the return sides of the panels will ensure that the airflow through the closed off stalls is maintained at a controlled level.

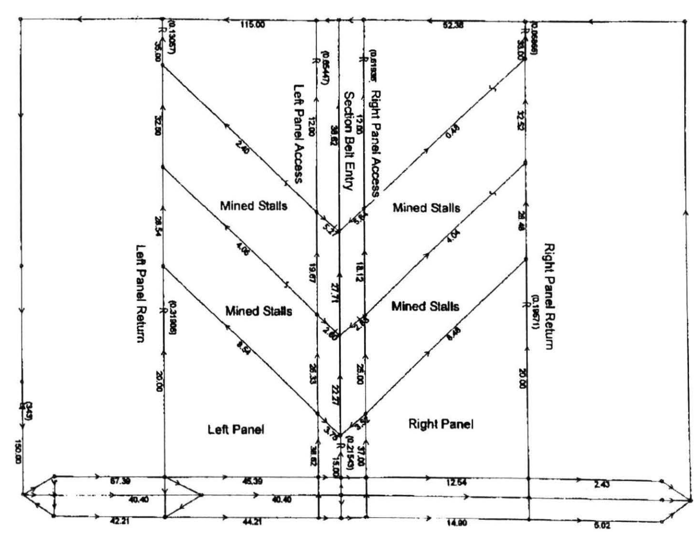

Figure 5. Ventilation model layout of suggested ventilation system.

SUGGESTED THIN-SEAM VENTILATION SYSTEM

The general review of the ventilation system for this mining layout suggests the configuration illustrated in Figure 6. This system is a basic flow–through application that makes allowance for the ventilation of the active stall. Fresh air enters the active section at the outby end and in all three entries. This air flows past the active working stall, on either side of the section belt entry. The airflow in the working entries is controlled by regulators at the inby end of the block. The air passes through these regulators directly into the mine return airway.

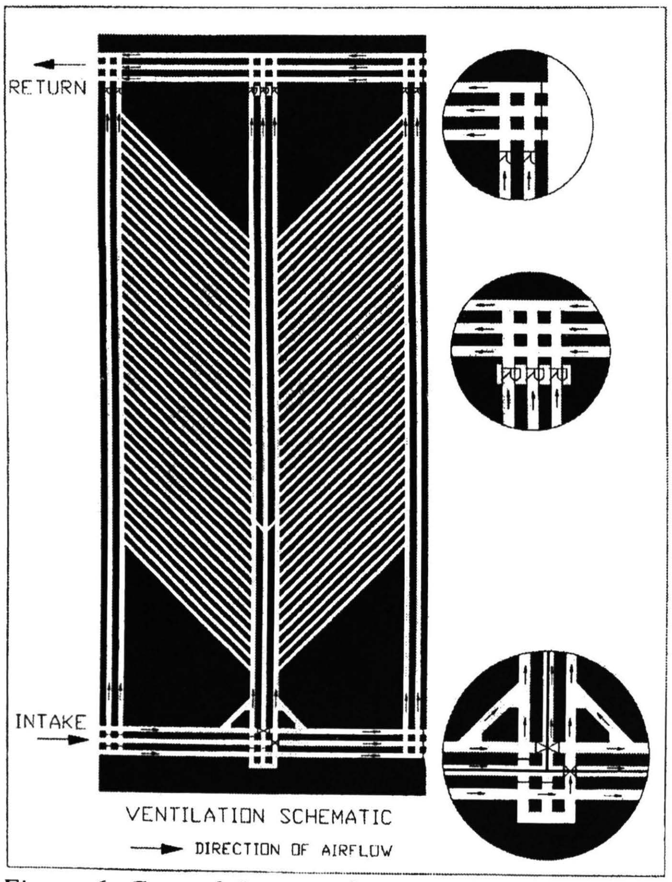

Figure 6. General Layout of suggested ventilation system (Holman, McPherson, and Loomis 1999).

Ventilation of the active stall, on either side of the block main entries, will be affected using a ventilation duct–fan combination affixed to the stall conveyor train, see Figure 2. This system will operate in a forcing configuration. Sufficient airflow past the stall will be necessary to ensure that recirculation does not occur. The air flowing out of the stall will then be directed out of the section.

Further control of the airflow in and through the section will be maintained by backfilling the previously mined stalls with plugs approximately forty feet deep. In this configuration the number of open entries for flow–through ventilation is similar to that of a longwall panel, and significantly less than a room and pillar section. Use of the plugged stalls provides better control of the ventilation, less leakage, and improved environmental conditions in those areas where mine personnel will work and travel.

A plug with a depth of about 40 feet (12 m) will be used at both ends of the mined out stalls to isolate the volume within. With time the air trapped between the plugs will have suppressed oxygen levels resulting from oxidation processes and increasing methane concentrations. This is intended to provide an excessively methane rich environment, inhibiting the likelihood of the mixture being within an explosive range, and isolation from possible sources of ignition. The forty-foot plugs will permit very little leakage. Furthermore, the block regulators will be set so that the central main entries are slightly pressurized to the outer entries. This will provide additional insurance the no emission from the sealed stalls to the conveyor entries will occur.

CONCLUSIONS

The coal mining industry in Virginia is reaching a critical point in its life cycle. Without an effort to exploit the thinner seams there is little expectation that this industry will continue to be a significant source of revenue for southwest Virginia. This paper has briefly investigated one of several technological problems associated with making use of a significant resource, which remains in that region.

A majority of the technical concerns associated with the deployment of thin-seam mining systems are currently being investigated and appear to have a high level of readiness. This is, however, not an entirely technical problem (Loomis, Holman, and McPherson 1998). There are numerous other factors that must all be included to ensure that coal mining remains a force in the economy of Virginia. These other, non-technical, factors center on the willingness of the various participants to undertake the necessary risk.

In the situation of an aging workforce, young, technically trained, workers must see that there is a future for them in the coal mines of there home counties. Without this vision it is likely that the future labor force will move away, removing the most vital resource in the coal mining industry.

The coal mining companies must be willing undertake a certain degree of risk to continue mining in geographic regions that are known to them. Faced with declining returns, many companies are likely to move on to richer fields. However, through prudent cooperation these companies may be willing to try mining methods aimed at extending the maximum extraction from the existing resources.

The land holding companies and coal owners are in a situation of desiring to see the best utilization of their property. This means safely and efficiently extracting the coal. In turn, the extraction generates wealth for the mining communities and promotes the quality of life for the miners, the residents, and their families.

Returning to the technical aspects of thin-seam mining, the equipment manufacturers must be willing to take a risk in the development of the necessary machines. To do this, they need to see the likelihood of a return on that investment.

The railroads and port authorities must be active participants. These agencies generate revenue from coal transportation and carry the economic benefits of mining out of the coal producing regions. Finally, the end users, power plants and coking facilities need to express their desire to continue to consume coal that they have come to rely on, mined in southwest Virginia

All of the parties that have an interest in the continuation of coal mining in southwest Virginia will need to work together to bring this to fruition. The technical and non-technical problems do not appear insurmountable, but must be tackled from all sides.

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