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UTILIZATION OF BELT AIR TO VENTILATE WORKING SECTIONS IN UNDERGROUND COAL MINES

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Abstract

This paper describes the basic requirements for the utilization of belt air to ventilate working sections at remote locations in relation to the main fans. It highlights the risks involved, potential problems, and the provisions that must be followed by mine operators for the safe use of belt air.

The paper also presents a brief review of the current regulations, conveyor belting tests, atmospheric monitoring system requirements, and the experience gained by mine operators to utilize the belt entries to ventilate remote working sections or areas where mechanized equipment is being installed or removed.

The paper concludes with a set of recommendations with respect to the utilization of belt air and the composition of belt material in underground coal mines.

Introduction

Utilization of belt air to ventilate working sections is a technique that allows mine operators to use the belt entry to course the fresh air to ventilate working sections provided that certain conditions are met. First and foremost is that the belt entry be equipped with an Atmospheric Monitoring System (AMS) to provide an early warning of fire. Others include training of miners to respond to AMS alarms and the need to monitor the primary escapeways for carbon monoxide and/or smoke. This technique is being used by a number of underground coal mines in the United States to overcome adverse ground conditions or coal seams with high methane emissions. The Skyline Mine near Hunting- ton, Utah and Jim Walter Resources' No 4 Mine are two of the mines that have incorporated this technique to their regular ventilation designs. Prior to 2004, the technique was allowed only through a Petition for Modifications (PFM). The Rule of 2004 suspended this requirement and allowed the mine operators to add additional intake air to the belt entry through an approved point-feed regulator.

This paper presents a brief review of the current regulations on belt air course, belt testing and the AMS requirements, the experience gained by the mining industry, and the remaining risks to be addressed to safely use the belt air for ventilating working sections.

Review of Current Regulations

The Federal Mine Safety and Health Act of 1977 stated that: "In any coal mine opened after operative date of this title, the entries used as intake and return air courses shall be separated from the belt haulage entries, and each operator of such mine shall limit the velocity of the air coursed through the belt haulage entries to the amount necessary to provide an adequate supply of oxygen in such entries, and to ensure that the air therein shall contain less than 1 volume percent of methane, and such air shall not be used to ventilate active working places." (Sec. 301(y)(1)) However, mine operators were allowed to request a petition for modification to utilize the belt air to ventilate working sections. Approximately 90 petitions were granted between 1975 and 2003.

The Rule of 2004 lifts the PFM requirement and allows mine operators to use the belt air to ventilate working sections or an area where mechanized mining equipment is being installed or removed provided that the following conditions are met (30 CFR §75:350(b)):

- The belt entry must be equipped with an Atmospheric Monitoring System
- All miners must be trained annually in the basic operating principles of an AMS including the actions required in the event of activation of any CO alert or alarm system
- The average concentration of respirable dust in the belt air course must be maintained at or below 1 mg/m^3
- The primary escapeways must be monitored for carbon monoxide or smoke
- The areas ventilated with belt air must be developed with three or more entries
- In areas of the mine developed after the Rule, no more than 50 % of the total intake air delivered to the workings can be supplied from the belt air course.

This practice is currently being applied by several underground coal mine operators especially by those with specific requirements where the use of belt air can reduce the overall mine hazards.

Under Section 11 of the Mine Improvement and New Emergency Response Act of 2006 (MINER ACT) a Technical Study Panel was created (Sec. 514) to provide independent scientific and engineering review and recommendations with respect to the utilization of belt air and the composition of fire retardant properties of belt materials in underground coal mines. The Panel, after reviewing numerous reports, attending three public hearings, and visiting two underground coal mines where belt air is utilized identified a few potential problems that should be addressed before utilizing the belt air to ventilate working sections. Both authors were members of this Panel.

Utilization of Belt Air to Ventilate Working Sections

In U.S. underground coal mines, mined coal is transported mainly by means of conveyor belts, many of these belts are installed and operated in isolated entries called belt entries since 1969. By law, these entries are separated from other entries by means of stoppings, doors and overcasts. They are ventilated with intake air in sufficient quantities as to maintain methane and respirable dust concentrations below their allowable limits. This air cannot be used in working sections where mechanized equipment is being installed or removed, except when the belt entry is equipped with safeguards as indicated by 30 CFR §75.350 (b).

When the air in the belt entry is used for ventilation, additional intake air is supplied to the entry through a point feed regulator. The quality of air in the entry is monitored by means of CO sensors installed, operated and maintained in a well-structured system. The sensors are spaced every 1,000 feet unless the air velocity drops to less than 50 fpm; in such a case the spacing is reduced to 350 ft. In addition, mine operators are required to monitor the quality of air in the escapeways. Another requirement to protect workers from combustion products is to train them to respond to AMS alert and alarm signals for evacuation in case of emergency. The quantity of air in the belt entry is regulated to no more than 50 percent of the total quantity of air used at the face.

Figure 1 shows the airway arrangement for a three-entry development heading where the belt entry air is used for ventilation. This figure also shows the location of the CO sensors in relation to the point feed regulator and the working areas. Figure 2 shows the entry arrangement for a retreat longwall mining method. In this case the belt air is used to supply additional quantity of fresh air to the face.

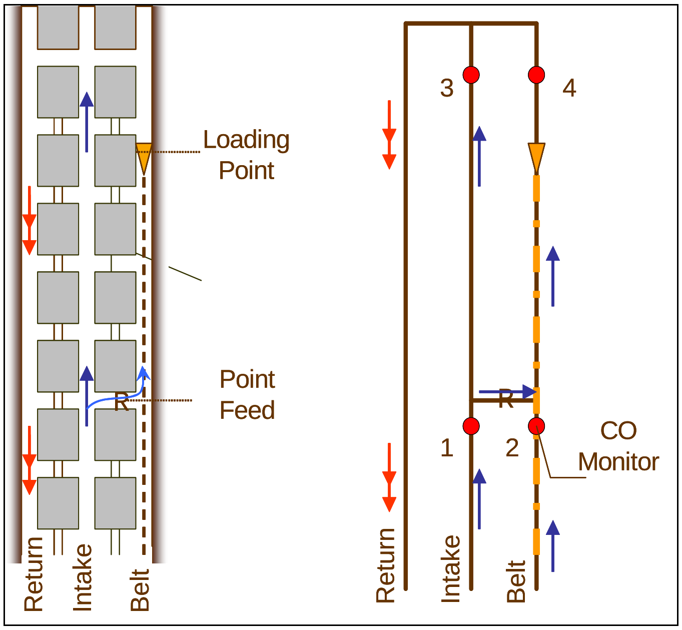

Figure 1. Airway arrangement for a 3-entry heading where belt entry air is used to ventilate a working section.

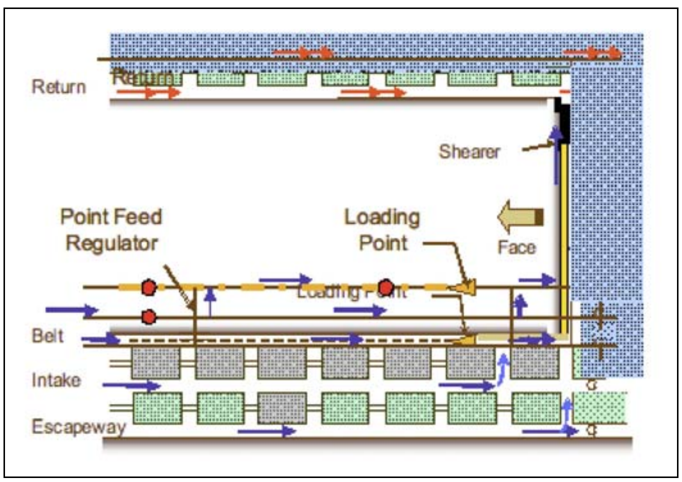

Figure 2. Airway arrangement for a longwall mine where belt entry is used to provide additional air quantity to the face.

Why Use Belt Air

Belt air is used for ventilation for the following reasons:

1. It adds additional quantity of air to a working section or face
2. It avoids flow reversals and dead spots in the belt entry
3. In highly resistive mine sections, the existing vent system may not be able to deliver the required quantity of air unless the fan pressure is increased considerably, or the required air quantity and pressure exceed fan operating capacity
4. For safety reasons. In bump-prone mines where the geologic and rock mechanics problems make it necessary to limit the number of entries developed. This condition and the amount of methane generated in a working section make mining more dangerous without using belt air as the use of belt entry as intake can provide sufficient ventilation to the working section.

Using the belt entry for ventilation reduces the effective resistance of a section by increasing the number of airways. For the same fan pressure, this results in an increase in the total flow rate at a slight decrease in fan pressure. But, the most import fact is that it makes more air available to ventilate a working section given the same number of airways driven. This is the main reason for striving to use the belt air for ventilation.

Another benefit that can be derived from using the belt air for ventilation is the elimination of dead spots along the belt entry. When the belt entry is regulated from two directions, a condition required for a neutral entry, the likelihood for having dead spots and flow reversals in the belt entry is quite high. Dead spots can allow methane to accumulate to dangerous levels, thus, representing a safety hazard to mine workers.

In mines with smaller cross-sectional areas, providing each section with the required quantity might be a challenge. The problem is even greater when such workings are located at remote places and belt entries physically isolated from other entries by means of numerous stoppings and doors. These structures are sources of leakage that allow the fresh air to short-circuit to surface without being used at the workings. Under such conditions the required quantity of air at the workings can only be supplied by developing new entries (reducing the mine resistance), or by increasing the fan pressure. However, higher fan pressure implies higher leakage rate, thus decreasing the efficiency of the ventilation system.

Another reason for using the belt air for ventilation is to enhance safety in mines where the coal is mined under adverse conditions. In the history of belt air, at least two valid cases have been documented: (1) deep cover, bump-prone coal mines in the western U.S. and (2) deep cover and highly gassy mines in the eastern U.S.

In the western states, longwall mines are operated under deep overburden. The immediate roof is often of poor quality resulting in early rib and roof falls. The problem is magnified when longwall panels are developed using three or more entry gate roads. Decreasing the number of entries may reduce the intersection failures (weak spots) substantially. Using the belt entry for ventilation allows the mine operator to reduce the mine hazard by decreasing the number of coal bumps in the working sections (Kenzy, 2007). In the eastern states, the coal is extracted from highly gassy coal seems where, even after systematic methane drainage, the methane is still too high for mining operations. It is not uncommon for those mines to have airflow quantities ranging between 50,000 and 80,000 cfm in the last open cross-cut and over 120,000 cfm at the return regulator of a longwall panel. To supply such large quantities of air over long distance, the mine operator is practically compelled to utilize all available air courses to direct the air to the working areas (McNider, 2007).

Figure 3 shows two cases of face ventilation. Figure 3a illustrates a case where the belt air is used to supplement the intake air in a heading. The flow directions are well established and will not change unless the stoppings are severely damaged. Figure 3b shows a case of flow reversals in belt entries. Flow reversals and dead spots are created when the belt entries are regulated from more than one direction.

Utilization of Belt Air in US Underground Mines

The Federal Coal Mine Health and Safety Act of 1969, Section 303(y)(1), prohibited the use of belt air to ventilate working sections. However, the Act did not suspend this practice completely. Mines opened after the Act had to petition and obtain the approval to use the belt air. Island Creek Coal Company of Virginia was the first to submit a Petition for Modification of the Act. The petition was granted contingent to the installation of a CO monitoring system in the mine in 1975. The system proved to be a desirable safeguard to protect workers from fires. Since then the number of mines using belt air increased rapidly. By 1989, approximately 60 petitions had been granted all required the installation of CO monitors. In 1988, MSHA made three changes to this requirement to enhance safety: (1) reduced the sensor spacing from 2,000 to 1,000 ft, (2) eliminated the upper velocity restriction of 300 fpm, and (3) required the mine operators to use improved belt materials as soon as the materials become available.

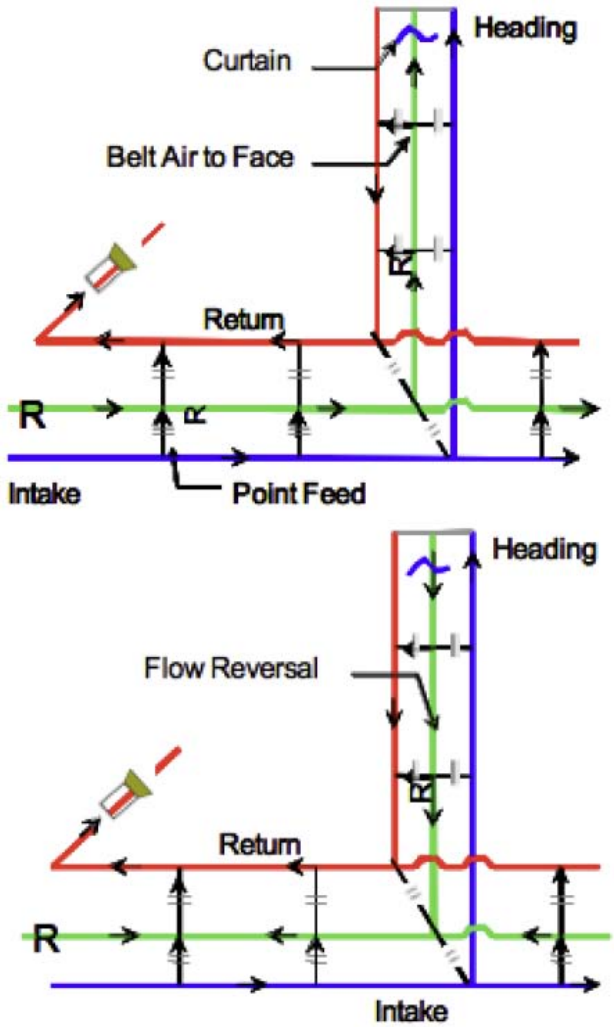

Figure 3. Face ventilation schematics where belt entry is on neutral (top) and when it is used to ventilate faces (bottom).

In 2003, a survey conducted by MSHA indicated that the number of mines with AMS installations increased to 146 (20.6 % of active mines). Out of this, 137 mines were using AMS to comply with regulations on the use of belt air. In 2004, after five public hearings the rule making for using the belt air for ventilation was finalized and the PFM process suspended (Francart, 2005).

Conveyor Belt Flammability Tests

Currently, conveyor belts used in underground coal mines are only required to pass the '2G' flammability test (30CFR§18.65). The test is conducted by MSHA at its Approval and Certification Center of Trialdelphia, WV. The test is performed in a 21-in cubic cabinet equipped with a belt sample holder, a Bunsen burner, and a fan of variable speed. Four 6-in long, 1/2-in wide belt samples are tested in this facility. For a test, a sample is positioned horizontally in the cabinet with its transverse axis inclined at 45 degrees. During a test the flame is applied to one end of the sample for 1 min in still air. At the end of this period the burner is removed and the fan switched on to provide an air current of 300 fpm. The duration of the sample flame and afterglow is monitored for 3 min. The belt passes the test if 4 samples of the same belt do not exhibit either duration of flame exceeding an average of 1 min or duration of afterglow exceeding an average of 3 min (Lazzara, 2007).

This test is not perfect to determine fire resistant belts. Factors such as belt thickness, belt material composition, and fire propagation at different air flow rates are not considered in the evaluation. Based on the small scale of the test facility and result obtained, it is difficult to predict the behavior of belt materials under more realistic conditions. MSHA studies have shown that in spite of using "fire resistant" belts, belt fires have persisted. Between 1970 and 1988, 22 % of reported fires occurred in belt entries (Stephan, 1989).

In early 1980s, the U. S. Bureau of Mines conducted a series of large scale tests in a man-made tunnel at its Lake Lynn Lab in Pittsburgh, PA. Twenty one synthetic rubber and PVC belt samples were tested, all but two of these passed the 2G test. The tests showed that most of these samples developed a flashover phenomenon and sustained burning for significant lengths, particularly at air velocities of about 300 fpm. For a pre-established evaluation criterion only 6 samples passed the test. This showed the inadequacy of the 2G Test to determine fire resistant belts.

Based on the results of the large scale tests, the Belt Evaluation laboratory Test (BELT) was developed. This test is conducted in a 5.5-ft long by 1.5-ft square ventilation tunnel, equipped with a burner and a fan. During a test, the front end of a 5-ft long by 9-in wide sample is ignited. After 5 min the burner is removed and the belt allowed to burn until the fire is out. A belt passes the test if in three separate trials there remains a portion of the 5 ft sample that is undamaged across its width. This facility was used to replicate the results of large scale tests. Based on these results, MSHA initiated the rule making to replace the 2G Test for belting with BELT. The proposal was first submitted for hearing and approval on Dec 24, 1992, discussed in public meetings, closed and reopened in several occasions and finally withdrawn on June 15, 2002. The main reason for withdrawing the proposal was that the accident and injury data since the initiation of the rule making process reflected a decline in the number of belt fires. This decline was erroneously attributed to improvements in belt monitoring and maintenance. Therefore, there was no need for any rulemaking.

Atmospheric Monitoring Systems

Mines using belt air for ventilation are required to install and operate an atmospheric monitoring system to predict the onset of belt fires. The system, equipped with CO monitors and audible and visible alarms, should be installed along the belt line and primary escapeways. In addition, the system should be equipped with alarm devices to warn workers on targeted gas concentrations that exceed pre-established levels. For carbon monoxide, the alert and alarm levels are set at 5 ppm and 10 ppm above the background level, respectively. Currently, the AMS is used in several mines to monitor other such as oxygen, methane, carbon dioxide as well as ventilation parameters. The law also requires that the system be operated by specifically trained personnel to interpret the system outputs and respond to alert and alarm signals, and when appropriate, to initiate an emergency evacuation of mine personnel.

In 2004, before the rule of belt air was passed there were 137 mines using AMS to comply with regulations on the use of belt air; currently, this number has increased to 157. The system is used mainly to monitor the following variables: carbon monoxide, methane, oxygen and smoke (Francart, 2007). Major AMS manufacturers are Pyott Boone, Conspec, Rel-tek Corporation and AMR.

Risks and Potential Problems

Conveyor belt systems are subject to problems that can start fire since all the elements of a fire are present in a belt entry. The fuel is represented by transported coal, coal dust and lubricants; the ignition sources are frictional heating and sparks from welding and malfunction of electronic parts; and the oxygen from abundant ventilation air. These are the necessary and sufficient conditions for a fire in a belt entry.

The current MSHA belt testing protocol is inadequate to prevent belt fires. Although all underground coal mines utilize "fire-resistant" belts for quite some time, belt fires persisted. Surveys conducted between 1970 and 1988 have shown that of the 293 reported fires, 65 (22 %) occurred in belt entries. The current 2G test measures the duration of the belt sample flame and afterglow in a test chamber at a constant air velocity (300 fpm), it does not measure the strength of the belt, flame propagation rate and the fumes generated during the burning process; until the recommended BELT standard is implemented, current test remains inadequate in fire protection.

The current MSHA rule does not specify air velocity caps in the belt entry. If the air is moving at less than 50 fpm, due to the location of the monitors in the belt entry, the CO or smoke detection can be missed or delayed considerably, this represents a safety hazard. At velocities greater than 1,000 fpm the problem is physical discomfort created by the dust particles to the mine personnel and the possibility of reentrainment of settled dust. When this air is used for ventilation, it will certainly increase the dust concentration at the face.

The most common source of ignition in belt entries is frictional heating. It occurs if the rollers break, seize or the belt becomes misaligned. There are thousands of rollers per mile in a belt. When a roller breaks and the belt continues to pass over it, the roller can overheat. Frictional heating can also occur if the belt becomes misaligned and rubs against adjacent structures such as steel frames, ribs or floor. Heat generated by friction may be sufficient to ignite grease and accumulated coal dust as well.

Poor maintenance on the belt and belt entry is another important factor that may cause fire in the belt entry. Accumulation of coal and coal dust can act as both fuel and ignition source, and the ribs of a belt entry, if they are not adequately rock dust, may also ignite.

Discussions

AMS Sensors and Fire Detection

The utilization of the belt air for ventilation has proven to be a safe practice of directing additional quantity of air to working sections. In mines that have elected to use belt air, this practice requires the use of fire detection sensors in belt entries and escapeways. The systems, equipped with CO sensors, have been used successfully to detect reportable and non-reportable fires in several mines. However, in spite of technological advances in the monitoring industry, two problems have persisted: (1) type of sensors used to detect fires, and (2) the level of training received by the AMS operators. Although it is known that smoke sensors are more reliable than CO sensors for belt fires, current regulations do not require the use of these sensors in belt entries. Another important factor in detecting belt fires is the AMS operator's training. After reviewing belt fire reports, it was found that in many mines the AMS operators have not had the sufficient training and experience to respond to emergency situations, and they are often distracted as a result of other responsibilities.

2G Belt Flammability Test

The current 2G belt flammability test used by MSHA is inadequate to prevent approved belt from catching fires. This is supported by the fact that many coal mines, in spite of using MSHA approved "fire resistant" belts have continued to experience belt fires. The main reason for this is that the 2G Test is not complete, it only measures whether the belt can ignite; it does not consider other factors such as the flame propagation, smoke density and toxicity, and durability of the belt. The test standards used in other major coal-mining countries are more stringent than that used in the US.

Sources of Fire

Analyses of fire reports have shown that many belt fires could have been prevented with proper maintenance of the haulage system, i.e. proper maintenance of belt parts and regular clean up of belt entries. Frictional heating is the major source of ignition in belt entries. It occurs when the rollers break or the belt becomes misaligned and allowed to overheat. It also occurs when the belt rubs against accumulations of coal from spillage and coal dust. Only proper belt operation and maintenance can avoid belt fires due to poor house cleaning.

Air Velocity in Belt Entry

The current rule on belt air course ventilation does not specify minimum or maximum air velocities in belt entries. Velocities lower than 50 fpm are allowed in a belt entry provided that the CO sensor spacing is reduced to 350 ft. At 50 fpm the air movement in the entry is barely perceptible, and cannot be even measured accurately. This velocity is not sufficient to ensure an unequivocal detection of combustion products. At the higher end, velocities as high as 1,200 fpm were allowed. Excessive air velocities will reentrain settled dust and transport it to the working sections, thus increasing their dust concentrations.

Belt Entry on Neutral

When the belt air is not used for ventilation, i.e. when the belt entry is regulated at both ends, the regulators and stoppings used to isolate the entry are subject to high pressure differentials. These, due to the dynamic nature of the ventilation system, may create two problems: flow reversal and dead spots in the belt entry, thus affecting its air quality. In gassy mines dead spots can allow methane to accumulate to dangerous levels.

Quality of Stoppings and Air Leakage

In underground coal mines, the extensive use of stoppings, doors and regulators creates pressure imbalances across such control devices in the vent system. These are represented by high leakage flows. As the leakage increases more air quantity is needed to compensate such leakage, which in turn, results in increased fan; more pressure induces more leakage. The leakage quantities can be reduced by improving the quality of the stoppings and other ventilation controls. Research is needed on durable stopping construction materials, improved designs, and most important, the development of environmentally friendly and cost effective stopping sealant materials.

Utilization of Booster Fans

Another alternative to reduce leakage is to utilize booster fans. The main problem with booster fans is the possibility of uncontrolled recirculation in an inadequately designed system. However, with the advent of reliable atmospheric monitoring systems, booster fans can be effectively used to enhance the health and safety conditions in underground coal mines. Research is needed to determine the conditions under which booster fans can be used safely in underground coal mines, especially in deep mines with difficult conditions.

Conclusions and Recommendations

1. The utilization of belt air for ventilation is a mature practice. It is used by more than 157 underground coal mines in the U.S. to direct fresh air to active workings and detect belt fires. The AMS requirement is the most valuable contribution from this technology to fire safety.
2. In mines with adverse mining conditions, belt air is used to enhance safety. In the history of the use of belt air, two valid cases have been documented: (1) deep cover, bump-prove mines in the western U.S. and (2) deep and high methane mines in the eastern U.S.
3. The 2G belt testing standard adopted by MSHA is inadequate for selecting fire-resistant belts for underground coal mines. Factors such as belt durability, flame propagation, smoke density and toxicity are not considered in the evaluation. MSHA should consider replacing it by others such the belt evaluation laboratory test (BELT) developed by the former Bureau of Mines and the drum friction test used in other coal mining countries.
4. A review of belt fire reports has shown that most fires went from small to severe fires because of mismanagement at the AMS control room. The AMS operator should be adequately trained and certified to respond to emergency situations, and with their major job being to monitor the AMS system.
5. Proper maintenance of the haulage system is crucial to belt fire prevention. MSHA should develop safe operation procedures for belt components and check lists for belt entry inspections. The utilization of these and existing standards should be enforced vigorously.
6. The current rule on belt air course ventilation does not specify minimum or maximum air velocities in belt entries. Air velocities as low as 50 fpm and as high as 1,200 fpm are allowed in belt entries. To facilitate the detection of combustion products and reduce the effects of dust entrainment, the air velocity in the belt entry should be restricted to between 100 fpm and 1,000 fpm.

7. The underground mines of the future are likely to be deeper and be required to extract coal under adverse conditions where air leakage becomes a serious problem. It is imperative that MSHA start research on durable stopping materials, improved control designs, and conditions under which booster fans can be used safely in underground coal mines.

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