Controlling respirable dust in underground coal mines in the United States

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ABSTRACT: As mining operations in the United States (US) have become more productive, controlling the dust exposure of mine workers has become more challenging. In response, US mining operations are applying basic controls at elevated levels and are looking to emerging control technologies in an effort to better control airborne respirable dust levels.

The Pittsburgh Research Laboratory (PRL) of the National Institute for Occupational Safety and Health (NIOSH) conducts research to develop and/or improve control technologies that reduce the respirable dust exposure of workers in underground coal mines. The goals of this research involve optimizing the use of water sprays and ventilating air, as well as, evaluating emerging control technologies. An overview of dust controls typically utilized in underground US coal mines will be provided. An update on ongoing PRL research efforts that are evaluating new control technologies will also be presented.

1 INTRODUCTION

Since 1973, a respirable dust standard of 2.0 mg/m^3 over an 8-hour shift has been enforced in underground coal mining by the Mine Safety and Health Administration (MSHA). However, if silica in the collected sample exceeds 5%, a reduced dust standard is established by dividing 10 by the percent silica. For example, if the sample contains 10% silica, a reduced dust standard of 1 mg/m^3 (10/10% silica) is enforced. Periodic sampling is conducted by MSHA and the mine operators to measure compliance with the applicable dust standard. Currently, MSHA samples each mechanized mining unit (MMU) four times per year, while the operator is required to collect samples on a bimonthly basis.

Underground coal mining accounts for 33% of the coal production in the United States. Of this, 51% of the production is produced by longwall mines (EIA 2006). Approximately 45 longwalls are in operation at a given time. Average longwall production as reported by mine operators during compliance dust sampling in 2006 was 4,800 tons (5,300 short tons) per shift (Niewiadomski 2007). This production has been achieved through improved machine reliability and improved operating practices. Average longwall panel size in 2002 was 287 m (940 ft) wide and nearly 3050 m (10,000 ft) long (Rider and Colinet 2007). These improvements in longwalls challenge dust control efforts. In 2006, 16% and 14% of compliance samples exceeded the applicable dust standard for the tailgate shearer operators and jacksetters, respectively.

In addition to improvements and changes being realized on US longwalls, continuous mining operations have also seen dramatic changes. Average production on the approximately 780 continuous miner sections during compliance sampling reached 690 tons (760 short tons) per shift in 2006

(Niewiadomski 2007). The vast majority of continuous miners are now operating with flooded bed scrubbers and taking extended cuts that are greater than 6 m (20 ft). An increase in the number of mines utilizing supersections (sections with two continuous miners) has also occurred. However, utilization of super sections has increased the potential for roof bolter operators to work downwind of a continuous miner, resulting in increased dust exposure. A negative change that has occurred has been an increase in the quantity of rock that is being cut as seam conditions deteriorate. Cutting of this rock has the potential to add significant quantities of silica dust to the mine environment, resulting in 51% of mines operating on reduced dust standards. In 2005, 11% of continuous miner operator and 12% of roof bolter operator samples exceeded their applicable dust standard.

Since the initiation of the x-ray surveillance program in the US coal mining industry in 1970, the prevalence of Coal Workers' Pneumoconiosis (CWP) in the workforce has been declining. For mine workers with 25 or more years of experience, the prevalence rate of CWP has dropped from 28.2 % in 1973 to 3.3 % in 1999 (NIOSH 2003). However, recent x-ray surveillance data have uncovered cases of rapidly progressing CWP and also revealed an upturn in the prevalence rate (CDC 2006).

As a result of changes that have been occurring in the underground coal industry in the US, the continued overexposure of workers to respirable dust, and recent x-ray findings, the need to improve existing dust control technology and develop new control methods remains a major focus for NIOSH and the US mining industry.

2 LONGWALL MINING DUST CONTROL

Ventilating air and water sprays are the primary controls used for protecting workers from overexposure to respirable dust. Ventilation provides reduced dust levels through dilution of generated dust and through transporting dust away before it can migrate to the breathing zones of miners. As a result, efforts must be made to maximize the quantity and quality of ventilating air that reaches the face. This is achieved by ensuring that dust levels in the intake air steam are low, that stoppings and curtains are tight, and that as much of the intake air is directed down the face as possible. Outby dust sources can be controlled by wetting roadways, minimizing outby dust-producing activities (unloading supplies, removing stoppings), and ensuring that sufficient coal wetting occurs before being transported out the belt entry. In recent surveys of US longwalls, the average face airflow was found to be 3.4 m/sec (665 fpm) with an estimated average air quantity of 31.6 m^3/sec (67,000 cfm). This air quantity represents a 65% increase in airflow from 10 years ago (Rider and Colinet 2007).

As clean intake air is brought onto the face, the potential exists for this air to be contaminated by dust generated at the crusher/stageloader. In response, water sprays should be placed on both sides of the crusher and at the stageloader-to-section belt transfer (Jayaraman et al., 1992). The objective of these sprays is to wet the coal product and prevent respirable dust from becoming airborne. Consequently, water quantity is more critical than water pressure, so larger orifice, full-cone sprays operating at water pressures below 414 kPa (60 psi) are recommended. Also, the entire crusher/stageloader unit should be completely enclosed to prevent dust that is generated within the unit from escaping into the ventilating air. Mines have successfully utilized steel plating, conveyor belting, expanding foam, and line brattice to seal these units. Belting can also be hung at the inlet to the crusher and brattice can be used to enclose the transfer point from the stageloader-to-section belt. Figure 1 shows two enclosed stageloaders and conveyor belting hung at the crusher inlet.

In order to maximize the quantity of intake air that reaches the face, a gob curtain can be hung in the headgate entry (Jankowski et al. 1993). This is simply a section of line brattice that is hung between the rib and first shield in the headgate entry to turn intake air down the face. Several longwalls have expanded on this technique by extending brattice behind the shield legs on

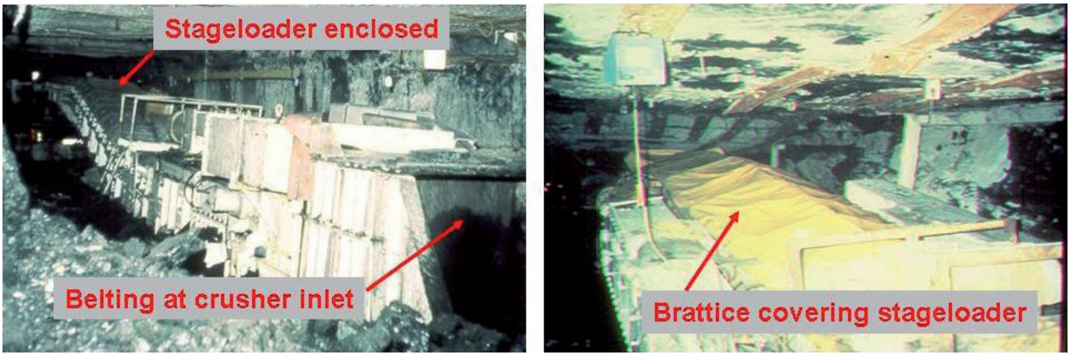

Figure 1. Enclosed stageloaders and crusher.

the first 5-10 shields to further improve the seal around the headgate and turn as much air down the face as possible.

Water spray application is the other primary control being used to substantially reduce the dust exposure of longwall face workers. The first attempt to control dust generation from the shearer occurs as the shearer bits cut the coal. All shearers in the US are equipped with water sprays in the cutting drums. In general, water spray pressure to the shearer drums should be limited to a maximum of 690 kPa (100 psi) to prevent dust from being blown into the walkway by the sprays. Also, past research has shown that full-cone or jet sprays are the most effective type of spray patterns to use in the shearer drums. These sprays increase wetting without inducing substantial air movement around the drum.

In recent surveys of ten US longwalls, all operations were using directional spray systems on their shearers (Rider and Colinet 2007). The exact type, number, and location of these sprays varied significantly between mines, but all were operating on the principle of splitting the ventilating air as it reaches the headgate side of the shearer and holding the dust-laden air near the face. This air split is facilitated through the use of a "splitter arm," which is a steel arm that extends from the headgate side of the shearer body parallel to the headgate ranging arm. Sprays are mounted on this splitter arm and oriented at an angle to the face in the direction of the airflow coming from the headgate. Additional spray manifolds are located along the body of the shearer to further enhance the movement of the ventilating air along the face. Typically, a section of conveyor belting is also hung from the splitter arm as a physical barrier between the face conveyor and walkway. Figure 2 illustrates a directional spray system operating on a shearer. The physical structure of the splitter arm and water sprays on the arm force the dust-laden portion of the ventilating air toward the face, while the "clean" split of air travels down the walkway. Spray manifolds on the back side of the shearer help to maintain this dust near the face and move the dust cloud past the shearer. Since the sprays in these directional spray systems are attempting to move air, the operating pressure is critical and pressures of at least 1035 kPa (150 psi) should be utilized. Hollow cone sprays and/or venturi sprays are effective in this application.

To assist in protecting the tailgate side shearer operator, companies have started using spray manifolds mounted at the tailgate end of the shearer. Typically, these sprays are located directly above the panline and oriented parallel to the tailgate ranging arm. The water spray pattern and induced airflow help move dust-laden air past the tailgate side operator before the dust reaches the walkway. Figure 3 illustrates a manifold of these sprays mounted on the shearer body. Hollow cone sprays operated at pressures at or above 1035 kPa (150 psi) would be effective air movers in this application.

Measurement of water usage on US longwall operations shows that an average of 495 lpm (130 gpm) is being supplied to the shearer, with an additional 285 lpm (75 gpm) being added with stageloader/crusher sprays (Rider and Colinet 2007). One operator reported using 850 lpm (225 gpm) on their shearer (Dezeuuw 2007).

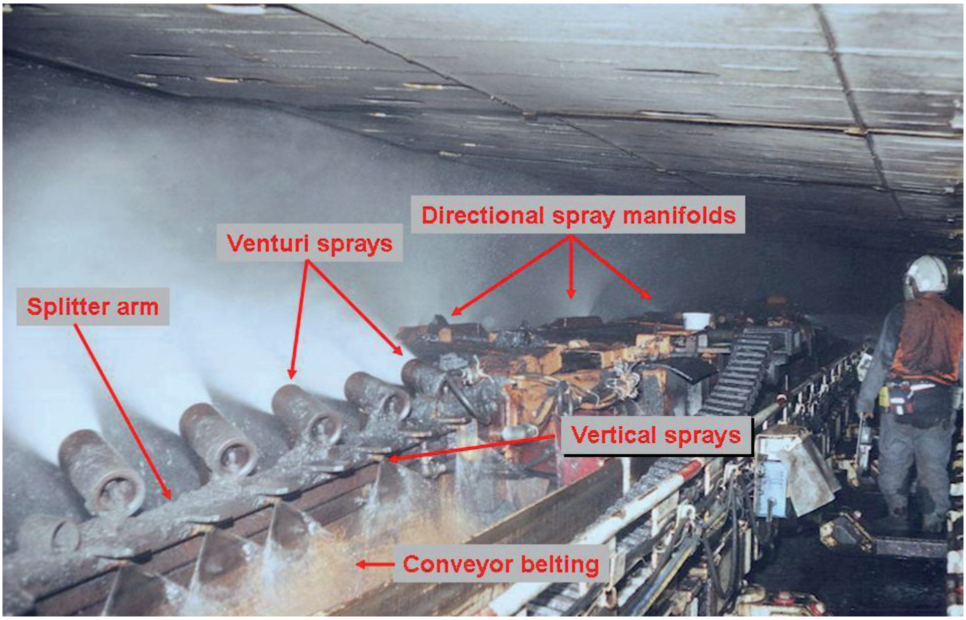

Figure 2. Headgate side splitter arm and directional sprays on shearer.

Figure 3. Spray manifold on tailgate end of shearer.

3 CONTINUOUS MINER DUST CONTROL

Ventilation for continuous mining operations in the US is supplied either through exhaust or blowing ventilation systems. For the exhaust system, fresh air is brought to the face in the working entry and line brattice or tubing is installed within the entry to create an air separation. Dust-laden air is then drawn from the face through the tubing or behind the curtain. This method of ventilation is typically the most effective from a dust control viewpoint since it keeps the main working entry and the continuous miner and shuttle car operators exposed to fresh air.

For blowing ventilation, the clean air is brought to the face through tubing or behind brattice and discharged toward the face. Dust-laden air is then carried out of the face through the entry. This type of ventilation typically penetrates deeper toward the face and is more effective for methane control. Ideally, the miner operator can position himself at the discharge of the brattice/tubing and work in fresh air. However, the shuttle car operators are positioned in the dust-laden return air.

Most operations in the US are taking extended cuts of more than 6m (20 ft) in depth and use continuous miners equipped with fan-powered, flooded-bed scrubbers. These scrubbers assist in moving air toward the face and in capturing airborne dust generated by the miner cutter heads. They typically pull dust-laden air through one to three inlets on the miner boom and pass the air through a filter panel being wetted with water sprays. The dust mixes with the water droplets and is removed from the airstream when the droplets are captured by a demister located behind the filter panel. Over 90% of respirable dust can be removed by a scrubber. The cleaned air is then discharged from the back of the miner and directed toward the return. It is critical that sufficient water is applied to the entire filter panel area to extend the effectiveness and performance of the scrubber. Typically, full-cone sprays operated at 415 kPa (60 psi) are used to wet the scrubber filter. Periodic removal and cleaning of the filter is also necessary to maintain optimum performance of these dust collectors.

Research has shown that the selection of the scrubber filter can have a significant impact on dust collection efficiency. If dust control is a concern, the more efficient filters (30-layer stainless steel or bottle brush filters) can be utilized to maximize dust capture (Colinet and Jankowski 2000).

In addition to the scrubber, all miners are equipped with an external spray system. These sprays are typically located on top of the miner boom behind the cutting drum and oriented toward the bits on the miner cutting drums. These sprays wet the coal as it is being cut and prevent dust from becoming airborne. Research has shown that flat fan sprays that are operated at less than 690 kPa (100 psi) are most effective at reducing dust while preventing rollback (Jayaraman et al. 1984). Rollback occurs when cone type sprays are used at higher pressures. The air-moving action of the cone sprays can force dust back toward the operator, particularly as spray pressures are increased.

In addition to scrubbers and boom sprays, it is important to utilize low-pressure, high-volume sprays under the boom of the miner and in the conveyor throat. These sprays are designed to wet the coal under the boom and prevent dust liberation as the coal is loaded and transported to the shuttle cars. These sprays are typically limited to 415 kPa (60 psi) or less.

NIOSH research has also shown that "blocking sprays" can be mounted on the sides of the miner outby the scrubber inlets to help contain dust near the face. These blocking sprays give the scrubber and external sprays an improved opportunity of capturing this dust. The blocking sprays are also fan sprays that are mounted with a vertical orientation to develop a water barrier along the side of the miner boom. The operating pressure of these sprays can be higher than 690 kPa (100 psi) to increase the impact zone of the sprays.

Within the last few years, the leading continuous miner manufacturer in the US has been offering a miner that is equipped with water sprays in the cutting drums. These "wet head" miners place the spray directly behind the cutting bit and offer improved control of frictional ignition with the potential to reduce dust levels. Figure 4 illustrates the wet head miner and spray nozzle location. NIOSH has evaluated two wet head miners and measured dust reductions at the mine operator ranging from 0.2 to 0.5 mg/m3 (Goodman et al. 2006).

Each miner in these surveys was equipped with approximately 70 sprays on the cutting heads. As designed, the cooling water for these miners was not utilized through the wet head sprays. Consequently, the manufacturer and mine operator wanted to limit the water supplied to the cutting head. Each spray was limited to 1.5 lpm (0.4 gpm) in order to maintain overall water flow to the miner at an acceptable level. The restricted flow to the wet head sprays may have limited the dust reductions to the range observed in these surveys. Additional work with the manufacturer is planned to further explore the dust reduction potential of the wet head design.

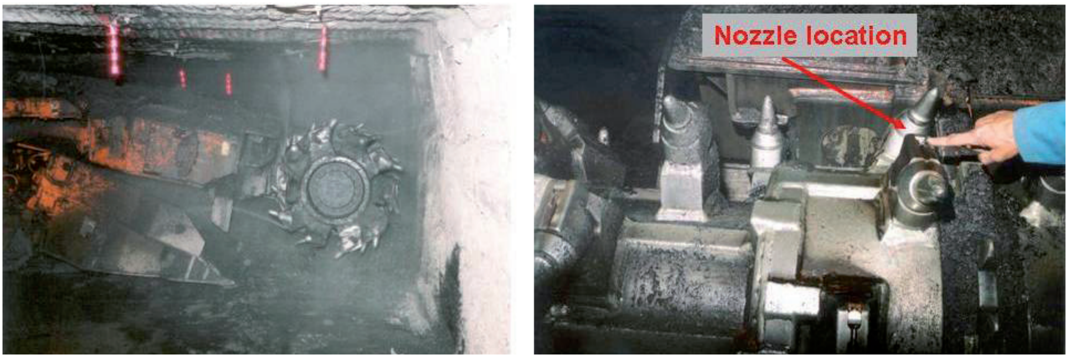

Figure 4. Wet head miner and spray location behind bit.

4 ROOF BOLTER DUST CONTROL

Roof bolter operators are often exposed to respirable silica dust during drilling. This dust can come from drilling into the roof strata or from operating downwind of the continuous miners. Most roof bolters in the US are utilizing a dry vacuum dust collection system that pulls dust through the drill steel back to a dust collector box. The dust is removed from the airstream and deposited in chambers of the collector box or captured by a filter cartridge. When operated and maintained properly, this system can be very effective in capturing and removing dust generated by drilling.

As the collector box fills, it is necessary for the bolter operator to empty the box and clean the filter cartridge. Both of these tasks can expose the bolter operators to elevated levels of silica. One method of minimizing the dust exposure of workers when cleaning the box is through the use of collector bags that contain the dust and reduce loading on the filter cartridge. These bags fill with dust and can be removed without significant dust exposure to the workers. The bag is then discarded without the potential for further contamination. Since the dust loading on the filter cartridge is reduced, the filter does not need to be cleaned or replaced as often. This also reduces the potential for dust getting beyond the seal of the cartridge, where it can be discharged through the muffler back into the mine atmosphere. It should be noted that the dust collector must be fitted with an automated pre-dump that separates larger particles prior to reaching the collector. This minimizes the loading of the collector bag and extends its usable time.

Laboratory and field testing of the collector bags has shown that they reduce dust loading on the filter cartridge by approximately 80 % (Listak and Beck 2007). Figure 5 illustrates the difference in dust deposition within the collector when the bag is utilized. As shown, the collector bag contains the dust and allows the collector to be serviced with less dust exposure.

Figure 5. Dust deposited in the collector box (left) and the collector box with bag utilized (right).

Another recent control that has shown promise is a canopy air curtain. The canopy air curtain is mounted on the underside of the bolter canopy and blows air down over the bolter operator. This air is drawn from the ventilating air in the entry and passes through a filter prior to being blown over the operator. Consequently, a stream of filtered air is passing over the operator, which prevents dust from drilling or dust generated upwind by the miner from reaching the bolter operator.

Laboratory testing has shown a 50% reduction of dust under the air curtain. An underground survey confirms that the air curtain has the potential to reduce operator dust and was well received by the operator (Goodman et al. 2006). Figure 6 illustrates the principle of operation for the canopy air curtain and also shows the air curtain being tested underground. This testing also identified modifications that could be made to the air curtain to improve its effectiveness. NIOSH is currently evaluating a second generation air curtain in the laboratory.

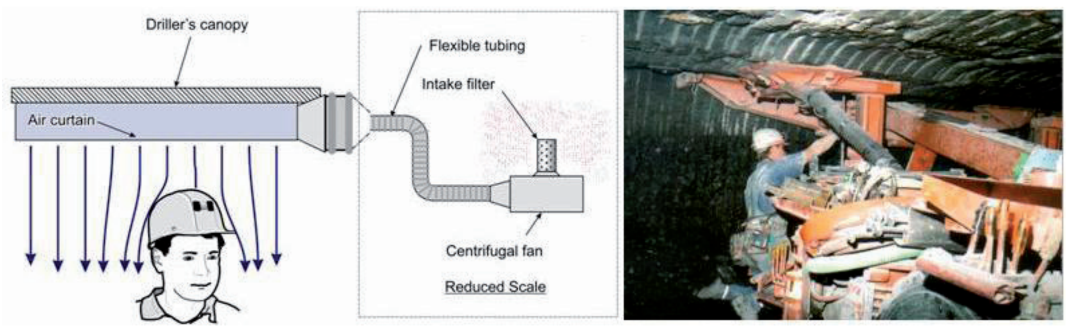

Figure 6. Canopy air curtain being developed for roof bolting machines.

5 DISCUSSION

A number of basic control technologies for longwall and continuous miner operations have been discussed in this paper. Information on several emerging control technologies has also been presented. However, this paper only touched upon a limited number of controls. A more comprehensive summary of dust control principles and technologies is summarized in a NIOSH handbook (Kissell

2003). This handbook provides a concise discussion of multiple control technologies and includes references that can be accessed for greater detail on individual controls.

In order for any and all of these dust controls to realize their maximum potential, it is critical that maintenance of the controls becomes a routine part of operating practices. Management must encourage mine workers to regularly examine the installed dust controls and provide the opportunity for control technologies to be maintained. An effective program for reducing the respirable dust exposure of mine workers must also contain an education and training component along with appropriate control technologies. Workers must be made aware of the potential health risks associated with breathing excess respirable dust. Also, the importance of proper utilization of the dust control technologies must be stressed and supported by mine management. In the US, mine management must post the approved ventilation plan at the mine. This plan includes the types of controls to be used and approved operating levels for these controls.

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