CHAPTER 4.—CONTROLLING RESPIRABLE DUST ON CONTINUOUS MINING OPERATIONS

By Jeffrey M. Listak[1]

This chapter discusses proven methods and engineering controls to minimize respirable dust concentrations on continuous mining operations. The highest respirable dust concentrations on continuous mining sections are generated from two sources: the continuous miner and the roof bolter. Also, continuous miner and roof bolter operators are often exposed to elevated silica levels as a result of cutting or drilling into rock.

The occupation on a mechanized mining unit with the highest dust exposure, based on results of respirable dust samples collected by MSHA, is classified as the designated occupation (DO) by MSHA. In addition to being sampled by MSHA, each DO is also sampled bimonthly by the mine operator. The samples are then submitted to MSHA for analysis to determine compliance with the applicable dust standard. MSHA lowers the dust standard below 2 mg/m^3 if the silica content of the sample exceeds 5% by weight in dust samples. For operations on reduced dust standards, MSHA inspector samples from 2004–2008 show that 20% of miner operator samples and 10% of bolter operator samples exceeded their applicable reduced dust standard [MSHA 2009].

In this chapter, controls for continuous miners and roof bolters are discussed in detail. Controls for other related sources of dust, such as intake air, are also described.

CONTINUOUS MINER DUST CONTROL

The greatest source of respirable dust at continuous mining operations is the continuous mining machine. At most continuous mining operations, the DO is the continuous miner operator. Dust generated by the continuous miner has the potential to expose the miner operator and anyone working downwind of the active mining.

As with any dust source, air and water are used to dilute, suppress, redirect, or capture dust. Ventilating air to a continuous mining section, whether blowing or exhausting, is the primary means of protecting workers from overexposure to respirable dust. Proper application of water spray systems, ventilation, and mechanical equipment (scrubbers) provides the best overall means of respirable dust control. Maintenance of scrubbers, water sprays, and bits are basic to any effective dust control strategy and must be routinely practiced. Suppression of dust is the most effective means of dust control. Suppression is achieved by the direct application of water, usually at the point of attack, to wet the coal before and as it is broken to prevent dust from becoming airborne. Once dust is airborne, other methods of control must be applied to dilute it, direct it away from workers, or remove it from the work environment. Redirection of dust is achieved by water sprays that move dust-laden air in a direction away from the operator and into the return entry or behind the return curtain. Capture of dust is achieved either by water sprays that impact with the dust in the air to remove it or by mechanical means (e.g., fan-powered dust collectors). Ventilating air dilutes and directs dust away from workers. Either blowing or

[1]Mining engineer, Office of Mine Safety and Health Research, National Institute for Occupational Safety and Health, Pittsburgh, PA.

exhausting ventilation is used on continuous mining sections. Advantages and disadvantages of each method will be described.

Water Spray Systems

There are several types of water sprays available for use on continuous miners to control dust. Spray nozzle type, location, pattern, flow, and pressure are all factors to consider when designing a spray system. The type of spray used at a particular location depends on the desired application. For example, for suppression of dust, high flow at low pressure close to the source is most effective. For airborne dust capture, smaller high-velocity droplets are required to impact with dust and remove it from the air. For redirection, higher pressure is required. Figure 4-1 shows the sprays most commonly used for controlling dust. A description of the spray patterns used and their applications is also provided.

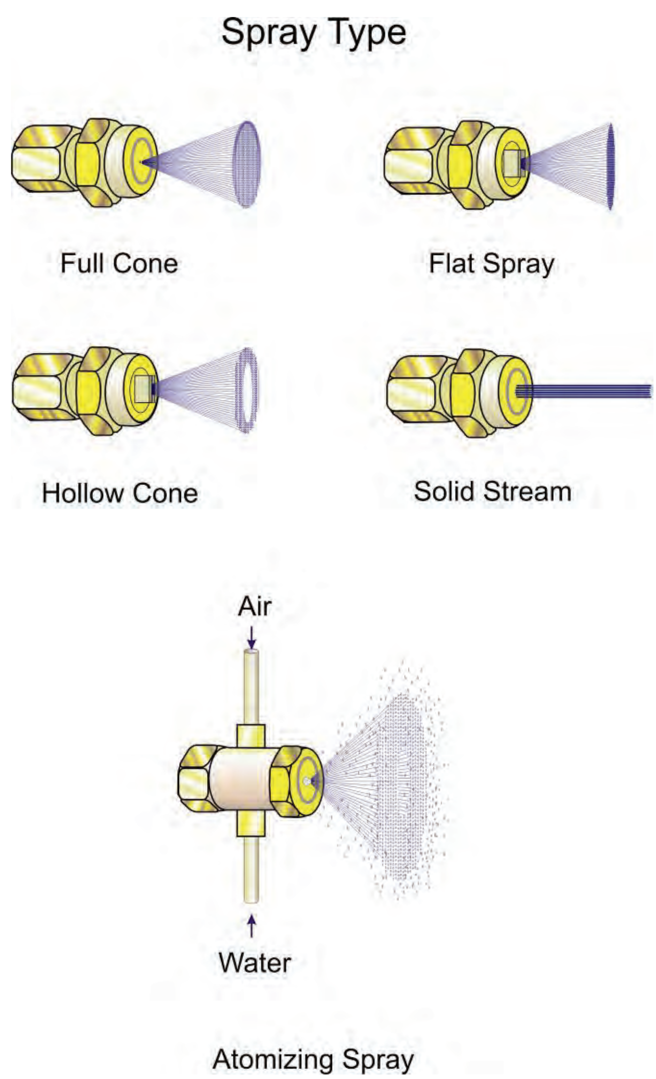

Figure 4-1.—Spray types used for dust control in mining.

- **Hollow-cone.** Hollow-cone sprays use a circular, outer-ring spray pattern in three different designs: whirl chamber, deflected, and spiral sprays. These sprays produce small to medium droplet sizes. Hollow-cone sprays are the best choice for most practical mining applications because they have larger-orifice nozzles and are less likely to clog [Kissell 2003]. Standard water spray systems from the manufacturer typically locate hollow-cone sprays on the boom directly behind the cutter head, on the underside of the boom, and along the sides of the cutter head. They are particularly effective for dust knockdown, as well as redirecting dust away from the worker.

- **Full-cone.** Full-cone sprays use a solid cone-shaped spray pattern with a round impact area that provides high velocity over a distance. They produce medium to large droplet sizes over a wide range of pressures and flows. They are normally used when the sprays need to be located farther away from the dust source or when a uniform wetting pattern is desired, such as scrubber filters or belt transfer points. Full-cone sprays are also useful to wet the throat area of the miner's conveyor to suppress dust during transfer to shuttle cars.

- **Solid-stream.** A straight, solid, uniform stream of water at high flow and low pressure is the goal of solid-stream sprays. They provide uniformity of wetting of the material to be cut. They are designed to be used close to the source to deluge the area before cutting or loading. The objective of solid-stream sprays is dust suppression.

- **Flat-fan.** The flat-fan spray pattern comes in three different designs: tapered, even, and deflected-type sprays. Flat-fan sprays produce small to medium droplet sizes over a wide range of flows and spray angles and are normally located in narrow, enclosed spaces. Locating flat-fan sprays along the side of the cutter head helps to contain dust under the boom, allowing for capture by the scrubber inlets. Flat-fan sprays are effective for dust containment.

- **Air-atomizing.** Air-atomizing spray patterns are available in two different designs: hydraulic and air-assisted. Hydraulic nozzles produce fine-mist droplet sizes and have low volume capacities. Air-assisted nozzles produce the smallest droplets of all sprays, but are the most expensive and complex to install because they require compressed air.

Figure 4-2 shows the airborne capture performance of the different spray nozzles at different operating pressures and compares the relative effectiveness of each spray type. Although air-atomizing nozzles produce the best airborne dust capture, their use in mines is impractical due to high maintenance requirements (i.e., they are prone to clogging) and the need to supply compressed air to each nozzle.

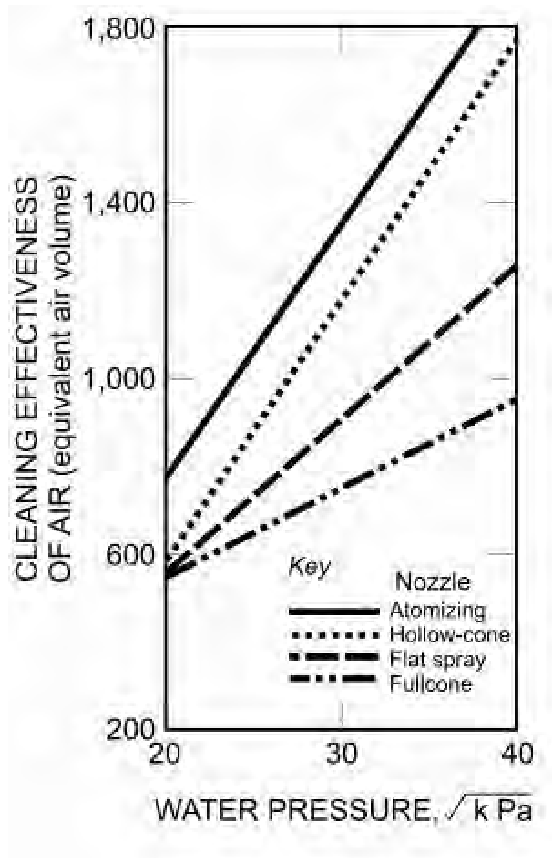

Figure 4-2.—Relative spray effectiveness of four spray nozzles used in mining.

Most continuous miners use a combination of spray types to achieve the best control. Although higher water pressure will raise the effectiveness of water sprays, a marked disadvantage is that it entrains large volumes of air and subsequently dust. This can result in dust rollback. The earliest water sprays on a continuous miner were used for bit lubrication, bit cooling, and dust control. Although these sprays controlled respirable dust exposure to a limited extent, they also created large quantities of turbulence and dust rollback. Dust rollback over the continuous miner infiltrated the operator's position, resulting in dust overexposure. To control rollback, sprays were relocated atop and beneath the cutting drum. The top sprays operated at a pressure of 100 psi and a flow rate of 0.95 gpm per spray. Two large-orifice, deluge-type sprays were mounted on the left and right underside of the boom and directed to spray into the cutting bits. These sprays operated at a low pressure of about 7 psi and a higher flow rate of 5 gpm per spray. Dust rollback was decreased as a result because the spray droplets moved only a short distance before impacting on the cutting bits. The short distance also increased coal surface wetting capabilities while minimizing turbulence (Figure 4-3). In-mine evaluations of these boom sprays show that miner operator dust exposures are reduced by 40% compared to the factory-installed spray system [Schroeder et al. 1986].

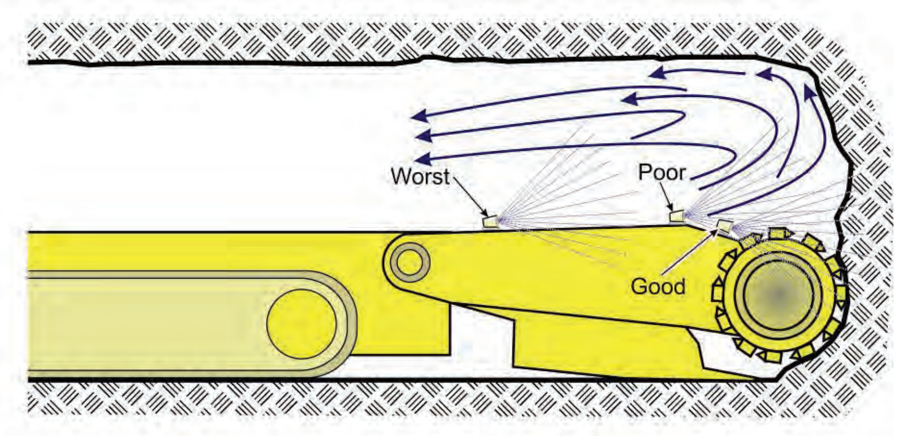

Figure 4-3.—Spray location impact on dust rollback.

High-pressure sprays, installed at the rear corner of the shovel on the side opposite from the exhausting ventilation curtain, can sweep underboom dust toward the curtain. Extensive underground testing showed that the shovel sprays reduced coal dust exposures by 60% at the miner operator's location while virtually eliminating exposures to respirable quartz dust [Schroeder et al. 1986].

The following practices have been shown to reduce dust exposures on continuous mining operations:

- Dust rollback over the miner can be caused by high-pressure (>100 psi), wide-angle cone sprays [Jayaraman et al. 1984]. A typical miner spray does most of its airborne dust collection in the first 12 in. Thus, top and side nozzles should be arranged for "low" reach and no overspray (Figure 4-4, A and B). Past research has shown that flat-fan sprays at a horizontal orientation with high flow and low pressure (<100 psi) across the boom, located as close to the cutter head as possible, provide uniform coal wetting across the cutter head during mining while limiting rollback. Large-orifice, low-pressure deluge throat sprays should be used under the boom on flight conveyors at 5 gpm. Broken material should be wetted as it is gathered and conveyed (Figure 4-4, C) [Schroeder et al. 1986].

- For dust containment at the face, flat-fan sprays, located 1 ft back from the cutter head on both sides of the miner with a vertical spray pattern that is oriented 30° from the miner body, act as blocking sprays and will help contain dust, thus enabling improved dust capture by the scrubber inlets [Goodman 2000]. Laboratory testing has shown that increasing spray nozzle pressure and/or the width of the spray angle will increase the airflow induced by that nozzle, potentially increasing its effectiveness as a blocking spray [Pollock and Organiscak 2007].

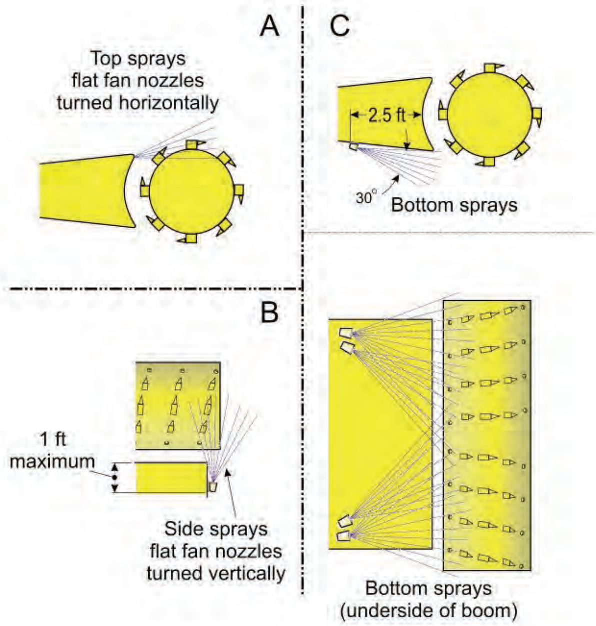

Figure 4-4.—Antirollback spray system for miner.

- High-pressure sprays are recommended for redirecting of dust. High pressure (>150 psi) raises the efficiency per unit of water [Jayaraman and Jankowski 1988] and is effective for air moving (Figure 4-5). However, care must be taken when determining location and direction because high pressure can cause turbulence, leading to rollback.

- A directional spray system design (spray fan) is a water-powered ventilation system originally designed to sweep methane gas toward the return. This system contains several spray manifolds placed on the continuous mining machine to direct fresh intake air to the cutting face, sweep contaminated air across the face, and direct this airflow into the return airway. In practice, the spray fan system is used only with an exhaust face ventilation scheme. The spray fan design has been successful for methane control at the face, but is not as effective for dust control [Goodman et al. 2004].

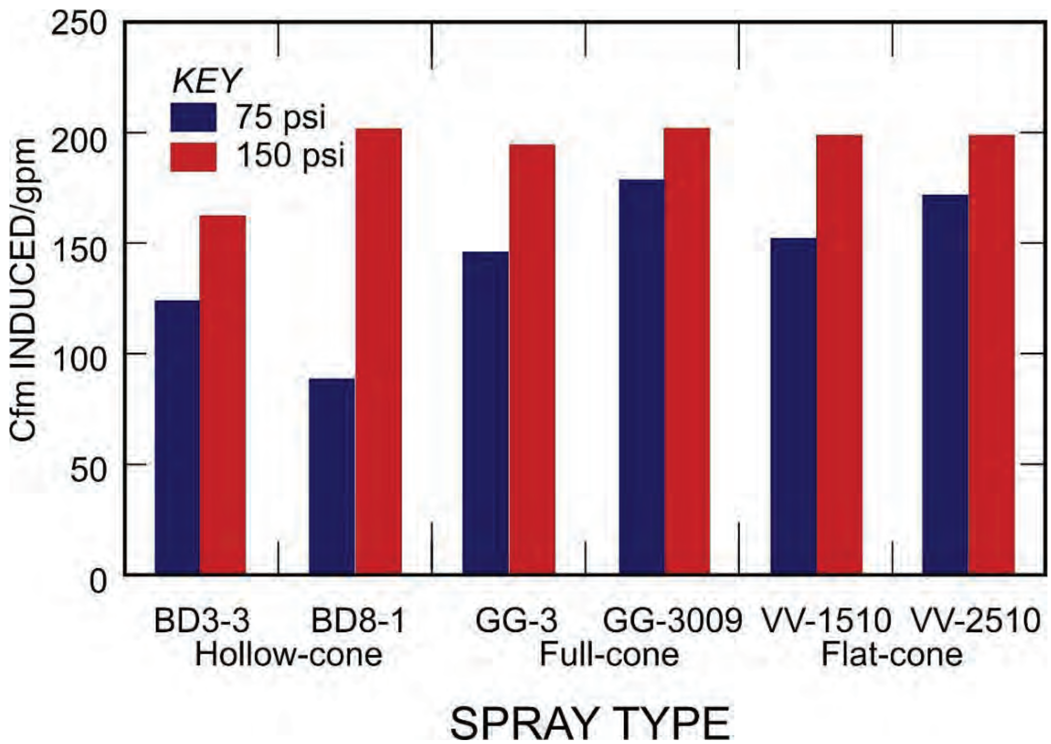

Figure 4-5.—Air-moving effectiveness of different spray types.

- Recently developed wet-head continuous miners have water sprays mounted on the cutter head directly behind the cutter bits. Water sprays in this position cool bits, which reduce frictional ignitions and have the potential for reducing dust generation during cutting. Available spray nozzles are either solid-cone spray patterns with a 1-mm orifice and flow of 0.4 gpm at 100 psi, or hollow-cone patterns with a flow of 0.2 gpm at 100 psi. However, wet-head technology has not yet consistently demonstrated dust reduction benefits in reported studies. These studies have shown variation in dust reductions under its current configuration [Strebig 1975; Goodman et al. 2006]. One benefit that has been reported by mining machine operators is increased visibility at the cutter head when the wet head is used. This may lead to better control of the cutting head and have a beneficial impact on required maintenance (reduced bit changes) and subsequent dust generation.

- Good water filtration greatly aids in spray system effectiveness. Dirt and rust particles in the water line can cause frequent clogging of spray nozzles. A simple, nonclogging water filtration system is available and should be used to replace conventional spray filters [Divers 1976].

- Operators should examine, clean, and/or replace sprays if necessary before each cut.

- A cut sequence should be adopted so that cut-throughs are made from intake to returns when practical to prevent return air from blowing back over the operator [Fields et al. 1991].

- Handheld remote control of the continuous miner has made it possible for operators to stay outby the miner while operating the machine. However, operator positioning is crucial depending on the ventilation scheme being used. Correct positioning will be discussed later in the “Face Ventilation” section.

- Remote control also enables mines to advance farther than the traditional 20-ft cut, if approved by MSHA. However, deep-cut mining requires that additional ventilation and dust control measures be incorporated. The machine-mounted scrubber is a critical component for deep-cut mining [Schultz and Fields 1999].

Flooded-Bed Scrubbers

Remotely controlled continuous miners allow the operator to remain under supported roof while the miner can advance to cut depths up to 40 ft, if approved by MSHA. Extended cuts reduce the number of face changes required of the miner, which can lead to higher production. Therefore, most U.S. continuous mining operations are taking deep or extended cuts. However, remote control operation does not allow the operator to advance the ventilation curtain to dilute the face of dust and methane. As a result, deep-cut mining has benefited from the installation of fan-powered, flooded-bed scrubbers on miners. Scrubber inlets mounted close to the cutter head help move air toward the face and capture dust near the face.

Flooded-bed scrubbers capture dust-laden air from the cutting face, carry this air through ductwork on the miner, and pass the air through a filter panel that is wetted with water sprays (Figure 4-6). As dust particles impact and travel through the filter panel, they mix with water droplets and are removed from the airstream by a mist eliminator. The cleaned air is discharged from the scrubber back into the mine environment. The density and type of media used in the filter panel influence the dust collection efficiency and air-moving capacity of the scrubber. Optimum flooded-bed scrubber performance is achieved when all of the dust-laden air at the cutting face is drawn into the scrubber and a high percentage (>90%) of the respirable dust is removed from this air [NIOSH 1997].

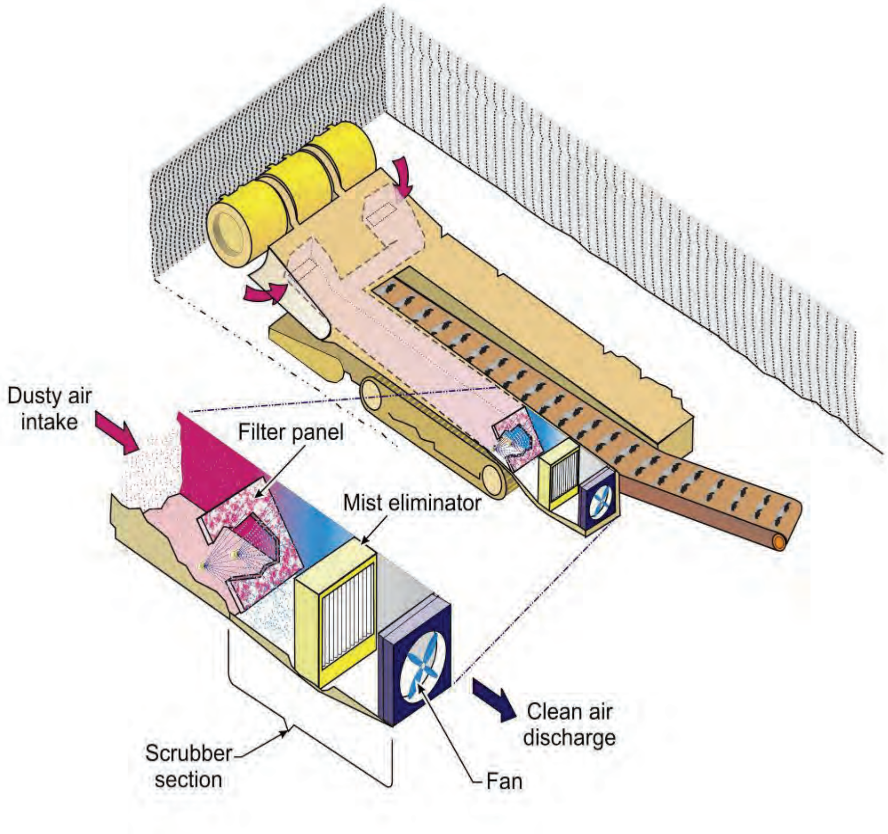

Figure 4-6.—Components and design of a flooded-bed scrubber.

The following practices have been shown to improve the efficiency of the scrubber:

- **Scrubber maintenance.** Scrubbers lose as much as one-third of their airflow after just one cut [Schultz and Fields 1999]. The most common cause of efficiency loss is filter panel clogging. Pitot tubes should be used to obtain air velocity readings as a measure of scrubber performance. When the dust is excessive, cleaning of the filter panel (Figure 4-7), the demister (Figure 4-8), and the scrubber ductwork is required more often. Also, the spray nozzles in the ductwork should be checked to ensure they are completely wetting the entire filter panel and not just the center.

Figure 4-7.—Cleaning scrubber filter panel with water spray.

Figure 4-8.—Cleaning the demister with a water nozzle.

One major manufacturer recommends the following cleaning schedule for a flooded-bed dust collector:

(1) *Twice each shift:* Clean filter with water.

(2) *Once each shift:* Replace filter with cleaned filter. Back-flush dirty filter with water and allow to dry. When dry, shake remaining dirt from filter before reusing.

(3) *Daily:* Wash inlets and ductwork with water.

(4) *Weekly:* Wash venturi, sump, and demister module.

This recommended maintenance schedule is for general operation. However, field investigations have shown that in some instances more frequent filter cleaning is necessary. In some mines, filters should be cleaned with water at least after each place change. In addition, inlets and ductwork may require more frequent cleaning. The operator's approved mine ventilation plan will specify the specific maintenance schedule to be followed.

- **Airflow measurement.** MSHA requires a minimum airflow of 3,000 cfm to ventilate the active face (30 CFR[2] 75.325). However, when scrubbers are used, MSHA typically recommends that the face airflow be at or slightly above the airflow capacity of the scrubber. Consequently, MSHA periodically requires pitot tube traverse measurements of airflow through the scrubber. This scrubber airflow will then be considered when MSHA sets the minimum face airflow that is required. MSHA recommends that this face airflow be available and measured with the scrubber turned off. In practice, most operations are supplying quantities above the statutory minimum of 3,000 cfm in an effort to better control respirable dust and methane.
- **Filter panel thickness.** The thickness of the filter panel controls the filter collection efficiency. Of the 10-, 20-, and 30-layered panels available, the 30-layer panel is the most efficient (>90%) in capturing respirable-sized dust [NIOSH 1997] (Figure 4-9). However, it should be noted that the thicker filter panels will increase pressure drop and reduce the quantity of airflow through the scrubber. Ensure that the filter sprays are working properly and provide complete coverage of the filter media. The filter spray is typically a low-pressure (<50 psi), full-cone nozzle spray.

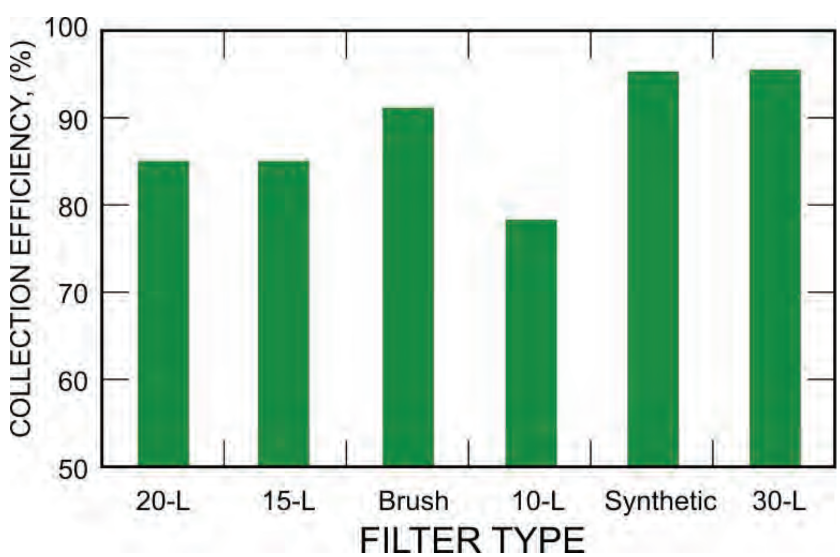

Figure 4-9.—Dust collection efficiency of scrubber filter panels.

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[2]Code of Federal Regulations. See CFR in references.

- **Dust capture factors.** Overall performance of a flooded-bed scrubber depends on the collection efficiency of the filter panel and the capture efficiency, which is the amount of ventilating air drawn into the unit [Colinet and Jankowski 2000]. The machine design factors that impact capture efficiency are the scrubber air quantity and the location of the inlets. The air quantity should always be as large as possible and the inlets as far forward and close to the cutting drum as practical. Increasing filter density improves silica collection but also reduces the quantity of air that is drawn through the scrubber [Jayaraman et al. 1992]. In addition, the scrubber should continue to operate for 10–12 sec after coal cutting ends to allow the scrubber to capture dust remaining in the face.

- **Use of surfactants.** Surfactants have the potential to increase the wettability of dust by reducing the surface tension of the water and improving the capture of dust particles. In one trial, the use of surfactants in the scrubber sprays at a concentration of 0.013% by weight showed dust reductions as high as 31% [Hirschi et al. 2002].

- **Redirected scrubber discharge.** Face ventilation on sections with low mean entry air velocity can be augmented by redirecting scrubber discharge toward the face. However, the application of redirected scrubber air depends on the amount of methane being liberated at the face. A preliminary NIOSH study showed that redirecting a portion of the scrubber discharge toward the face is successful at reducing dust levels in the face entry. NIOSH also completed a brief study of scrubber redirection at an eastern mine that showed this method reduced dust exposures of the shuttle car operators by over 50%. Its impact on miner operator exposures was somewhat less, showing the need for maintaining proper balance between the redirected scrubber flow and face ventilation flow.

Bit Type and Wear

Bit type and bit wear can adversely affect respirable dust concentrations. Routine inspection of bits and replacement of dull, broken, or missing bits improve cutting efficiency and help minimize dust generation. Also, a study showed that bits designed with large carbide inserts and smooth transitions between the carbide and steel shank typically produce less dust [Organiscak et al. 1996] (see Figure 4-10). Lab studies on conical cutting bits have shown that significantly worn bits without their carbide tips produce much more dust [Organiscak et al. 1996].

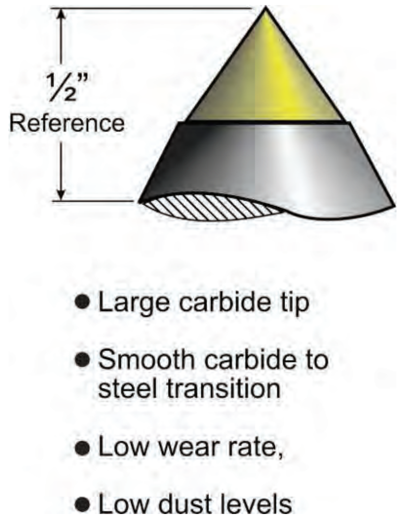

Figure 4-10.—Proper bit design can lower dust generation.

Modified Cutting Method

If roof rock must be cut, it is often beneficial to cut the coal beneath the rock first and then back the miner up to cut the remaining rock. This method of cutting leaves the rock in place until it can be cut out to a free, unconfined space, which creates less respirable dust (especially silica dust) [Jayaraman et al. 1988]. Figure 4-11 shows the modified cutting cycle.

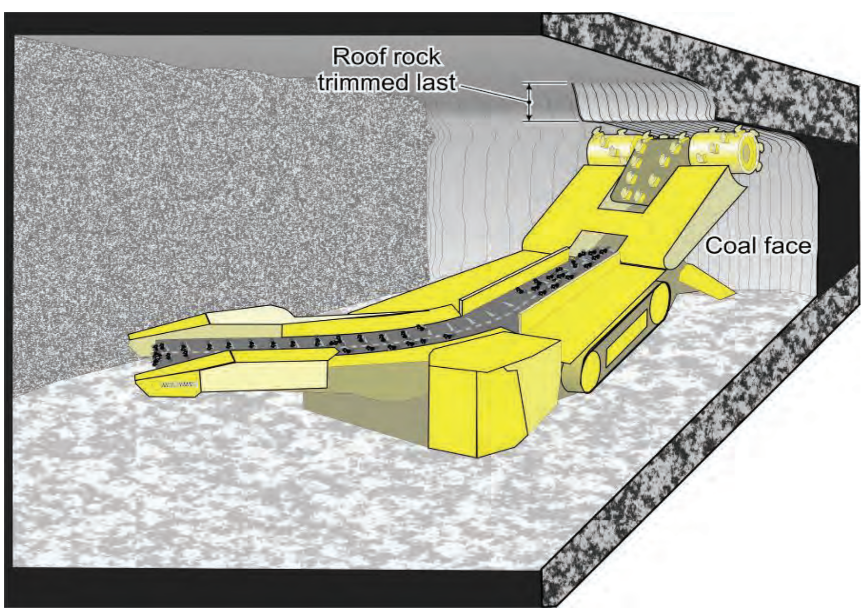

Figure 4-11.—Modified cutting cycle can lower dust generation.

FACE VENTILATION

The velocity and quantity of face ventilating air are important factors for controlling respirable dust exposure of the continuous miner operator. A good ventilation plan consists of sufficient mean entry air velocity to confine dust near the face and/or direct it toward the return entry with high enough quantity for diluting generated respirable dust. The two ventilation schemes most widely used for underground coal mining are blowing and exhausting. There are advantages and disadvantages to both systems as they relate to face worker dust exposure.

Blowing Face Ventilation

When blowing ventilation is used, intake air is delivered to the face of the working entry by blowing it from behind line brattice or tubing. The clean air is blown toward the face and sweeps the dust-laden air toward the return entries. This system allows the continuous miner operator to be positioned in the clean discharge air at the end of the blowing curtain or tubing. Although this method effectively sweeps dust and methane from the face, it also positions mobile equipment operators (e.g., shuttle car operators) and roof bolter operators working downwind in return air. Continuous miner operator movement is restricted due to the need to be positioned in the discharge air at the end of the curtain or tubing.

The following best practices will reduce dust exposure on blowing ventilation sections:

- The operator should be positioned in the mouth of the blowing line curtain with intake air sweeping from behind. The operator should not proceed past the end of the line curtain. If the operator must be on the return side of the curtain, some of the intake air should be bled over the line brattice to provide fresh air to the operator (see Figure 4-12). Good communication with shuttle car operators is essential because visibility can be a problem depending on where the continuous miner operator is standing.

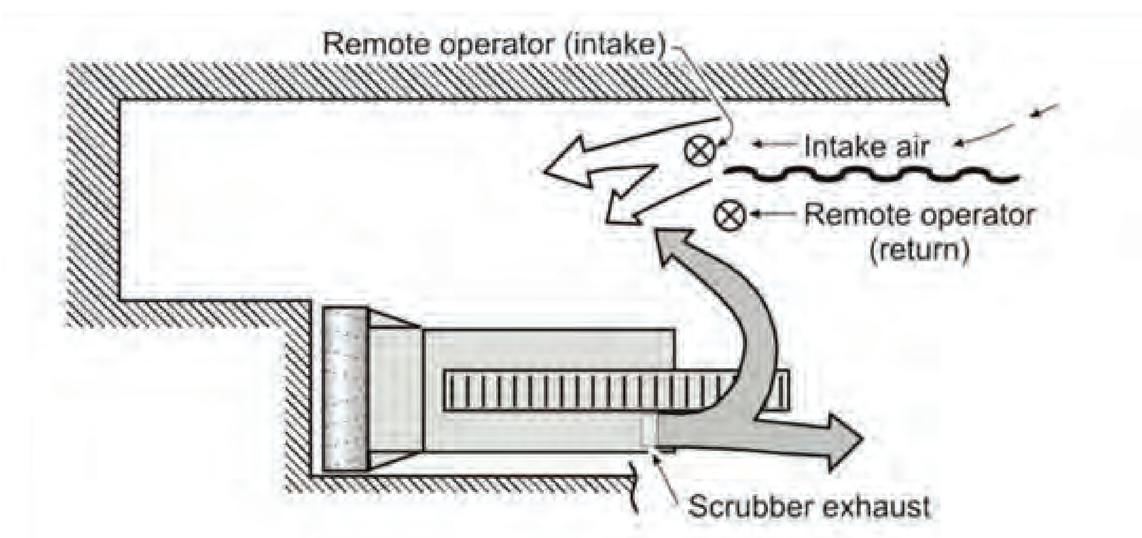

Figure 4-12.—Schematic of a blowing ventilation system.

- According to MSHA, when it is necessary for the operator to move from the clean air position (end of the curtain), the operator should allow the dust-laden air to clear the entry and stop the scrubber before moving.

- According to MSHA, when aligning the continuous miner to square a face, the operator should position the machine and then return to the end of the curtain before coal cutting resumes. This reduces the potential for injury.

- Brattice discharge velocities exceeding 800 fpm have better penetration to the face and thus better dilution of dust and methane. When brattice discharge velocities are less than 400 fpm, there is little difference in performance between blowing and exhausting ventilation [Luxner 1969].

- Scrubber discharge must be on the opposite side of the line brattice to allow scrubber exhaust to discharge directly into return air.

- The air quantity provided by the line curtain should be limited to 1,000 cfm over the scrubber capacity. Air quantities exceeding 1,000 cfm over the scrubber capacity can overpower the scrubber and push dust-laden air past the scrubber inlets [Schultz and Fields 1999]. Therefore, MSHA typically requires that the airflow entering a cut be equal to or exceed the scrubber airflow by no more than 1,000 cfm and must be measured with the scrubber off.

- Excess air velocity may be reduced by flaring out the line curtain at the end to lower the velocity of the air emerging from behind it or by pulling the line curtain back slightly to prevent overpowering the scrubber [Schultz and Fields 1999].

- Experiments have shown that erecting a short line curtain during the slab cut shields the operator from the air jet emerging from a blowing duct [Jayaraman and Jankowski 1988].

Exhausting Face Ventilation

When exhausting ventilation is used, intake air is delivered to the face in the working entry. The clean air sweeps the face, and the dust-laden air is then drawn behind the return curtain or through the exhaust tubing to the return entries. This system will keep mobile equipment in fresh air and affords the continuous miner operator more freedom of movement than a blowing ventilation system. In addition, exhausting ventilation allows more visibility around the loading area so that shuttle car operators can easily determine where the continuous miner operator is located when entering the face area.

The following best practices will reduce dust exposure on exhausting ventilation sections:

- Figure 4-13 shows a schematic of an exhaust ventilation system. Exhausting airflow allows for more flexibility than blowing, giving the operator more options to avoid dusty air. However, MSHA maintains that position A (opposite side of curtain) is preferred. As always, good communication between the continuous miner operator and shuttle car operators is essential for safe positioning.

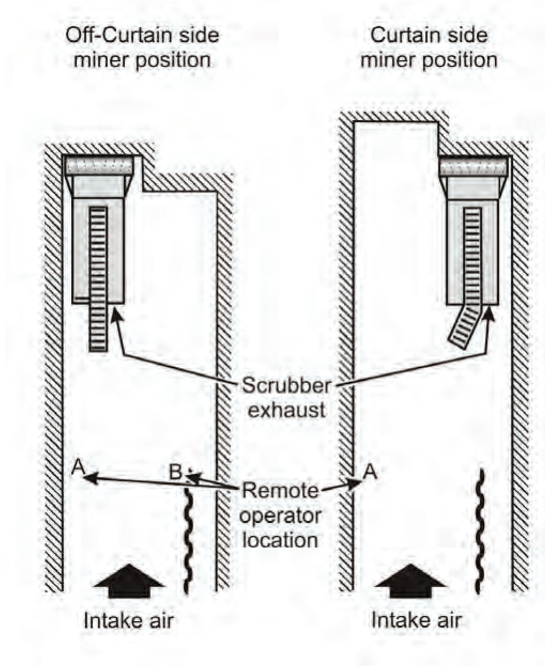

Figure 4-13.—Schematic of an exhaust ventilation system.

- An advantage of exhausting ventilation is that shuttle car operators are always positioned in fresh air.

- Air quantity reaching the inby end of the line curtain should be equal to or slightly greater than the scrubber capacity to guard against recirculation of air.

- MSHA regulations state that mean entry air velocity must be at least 60 ft/min when using exhaust ventilation systems.

- The end of the exhaust curtain or tubing must be kept within 10 ft of the face when not using a scrubber to ensure that air reaches and effectively sweeps the face.

- The operator should not proceed inby the end of the line curtain since this will expose the operator to dust-laden return air. If operator dust levels are too high, the first thing to check is whether the operator is standing parallel to or outby the end of the line curtain [Kissell and Goodman 2003].

- Scrubber exhaust must be on the same side of the entry as the line curtain to allow scrubber exhaust to discharge directly into return air [Colinet and Jankowski 1996].

DUST CONTROL FOR ROOF BOLTERS

Most roof bolting machines are equipped with MSHA-approved dry dust collection systems to remove dust during drilling. Roof bolter operators can be overexposed to dust from the drilling process, cleaning the dust collector, poor dust collector maintenance, or working downwind of the continuous mining machine. The largest source of operator dust exposure can occur from working downwind of the continuous miner. If the dry dust collector is properly maintained and if the bolter is not working downwind of the continuous miner, very little dust should be measured in the roof bolter's work environment [USBM 1984].

Three major bolter problem areas are (1) filter problems (leaks or plugging), (2) accumulation of dust in the collection system, and (3) low airflow at the bit due to hose, fitting, and relief valve leaks.

The following best practices can help reduce dust exposure to the bolter operator:

- **Maintaining the dust collector system.** Hoses and gaskets should be checked for leaks. Smoke tubes can be used to show where leaks occur. Checks should also be made for loose hose connections and damaged compartment door gaskets. Vacuum pressure at the drill head should be checked daily by using an approved pressure gauge to maintain manufacturer's vacuum specifications for proper airflow listed on the approval plate.

- **Cleaning the dust box.** Frequent cleaning of the main dust compartment is necessary to ensure proper operation of the dust collection system. The operator should maintain an upwind position when removing dust from the dust box to reduce exposure. If a rake is used to pull dust from the main compartment, care should be taken so that a dust cloud is not created and dust does not contaminate clothing. When emptying dust boxes on a dual-boom roof bolter, the return-side operator should empty the collector box first and then take a position on the intake side of the entry until the other box is emptied. Again, when performing this function, an upwind position is crucial to minimize dust exposure, and use of a respirator is recommended. Similarly, cleaning should take place in a well-ventilated entry so that liberated dust is quickly removed from the operator's breathing zone. The procedure for handling of drill cuttings is detailed in the operator's manual for most roof bolting machines.

- **Using dust collector bags.** Dust collector bags can be used with dry dust collectors to greatly reduce dust exposures when cleaning the dust box. A retrofit kit installed in the collector box enables installation of the bags (Figure 4-14) for those machines equipped with precleaner cyclones. The use of dust collector bags to contain dust in the main compartment allows workers to easily remove the dust from the main compartment and deposit it against the rib. Exposure during cleaning is reduced, the cuttings are located out of the entry traffic, and the canister filter can remain in operation for a much longer time period because of reduced dust loading [NIOSH 2007].

Figure 4-14.—Dust collector box with collector bag installed.

- **Removing and replacing the canister filter.** In past practice, canister filters were removed and impacted against a surface to dislodge caked dust from the filter media. The filter was reinserted into the collector box. Unfortunately, this practice can create a dust cloud that contaminates the breathing zone of the roof bolter operators. Cleaning the filter in this manner also creates the potential for contaminating the collector's downstream discharge components (vacuum pump and muffler) with respirable dust (Figure 4-15). When these downstream components become contaminated, respirable dust is discharged back into the mine environment in the collector's exhaust. To rectify this hazardous condition, the downstream components must be removed and cleaned as described in the next section. Although the cleaning and reuse of canister filters is still occurring, NIOSH, MSHA, and bolter manufacturers recommend that contaminated filters be replaced to minimize worker dust exposures. Replacement of filter canisters should be completed in well-ventilated entries.

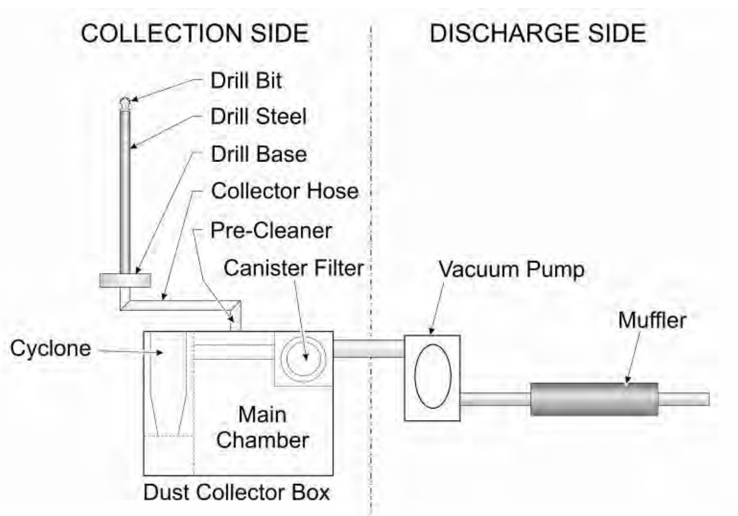

Figure 4-15.—Schematic of roof bolter dust collector components.

- **Cleaning the discharge side of the collector.** If the discharge side of the collector system becomes contaminated due to collector filter damage and/or leaks, all components downstream of the collector box must be removed and flushed with water. Surveys have shown that removing and cleaning contaminated components downstream of the canister filter results in major improvements in dust and silica levels emitted from the collector's discharge [Thaxton 1984].

- **Installing a sock on precleaners.** Some roof bolting machines are equipped with dust collector precleaners, which are cyclones collectors designed to remove larger cuttings from the airstream before reaching the collector box. These cuttings are routinely dumped after each hole is drilled and may contain some respirable dust. When the precleaner door is actuated, the dust falls an unconfined distance from the precleaner's discharge chute to the mine floor. Some dust can be entrained into the ventilating air as it falls to the mine floor. This entrained dust can be minimized by attaching a "sock" made from brattice or rubber belting as an extension to the chute to minimize the distance the dust falls unconfined.

- **Using "dust hog" bits.** Dust hog bits have a collection port in the bit body and are more effective at capturing drill dust than shank bits, where the collection port is in the drill steel. In one study, shank bits allowed from 3 to 10 times more dust to escape from the drill hole collar than "dust hog" bits [USBM 1985]. Shank-type bits should be avoided where possible, and dull bits should be replaced immediately.

- **Positioning to avoid working downwind of the continuous miner.** Regardless of the type of ventilation being used, the cutting sequence must be designed to limit the amount of time the bolter works downwind of the continuous miner. Properly sequenced cuts with double-split ventilation can eliminate the need to work downwind of dust concentrations created by the continuous miner. However, double-split ventilation is often used on super sections (i.e., two miners and two bolters in each split). If super sections are in use, then proper cut sequencing in each split is required to minimize the hazard of working downwind of the miner.

- **Wet drilling/mist drilling.** Although wet drilling can effectively control dust emissions, this option can create difficult working conditions for operators [Kissell and Goodman 2003]. Successful dust control with wet drilling typically requires 2 gpm to be supplied to the drill hole. Water is pumped to the drilling interface through the drill steel, captures dust, and then flows out of the drill hole onto the mine floor. This water can create wet floor problems and an uncomfortable work environment for the bolter operators. Mist drilling attempts to reduce the water application while still maintaining effective dust control. Reduced quantities of water and compressed air are supplied to the drilling interface in an effort to capture dust. Mist drilling typically uses less than 0.5 gpm. Although more desirable from an operations perspective, this method has yet to be shown to be as effective as wet drilling or properly operating dry collection systems [Beck and Goodman 2008].

- **Canopy air curtain.** In addition to dust created by the roof bolter itself, bolter operators can also be exposed to miner-created dust when bolting is required downwind of the continuous miner. NIOSH is currently developing and testing a device to deliver fresh air over the operator's breathing area that would reduce dust exposure while working downwind of the continuous miner [Goodman and Organiscak 2002]. A fan located at the rear of the bolter draws in entry air, filters the air, and supplies it to the area beneath the canopy through tubing and a plenum (Figure 4-16). The plenum is the same shape as the canopy and covers the same area so that protection is provided while the operator is under any portion of the canopy. Laboratory tests have shown that this concept reduced dust levels under the canopy by nearly 60%.

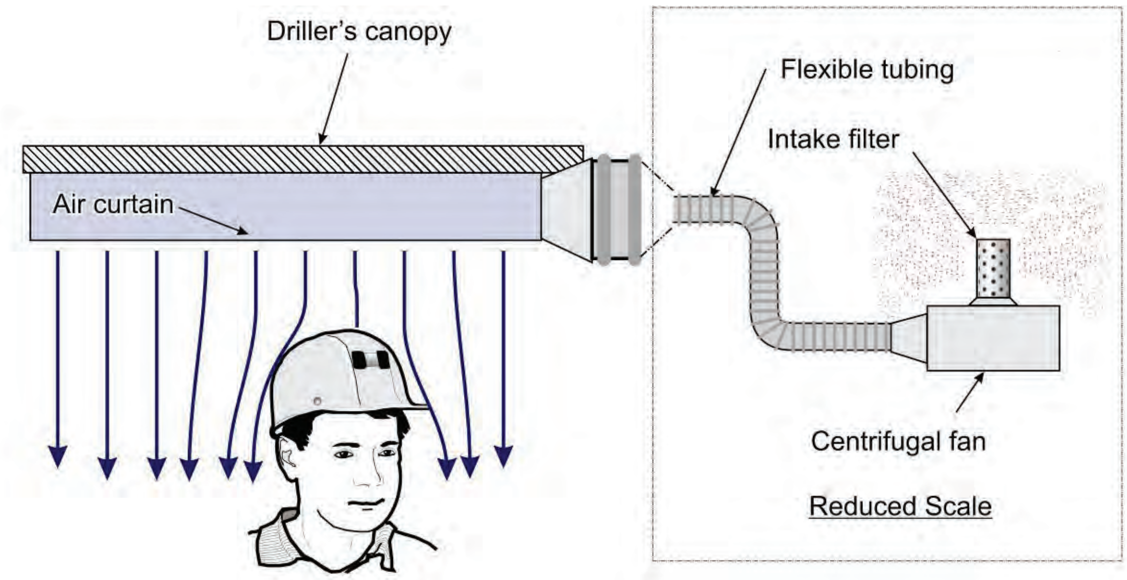

Figure 4-16.—Prototype of canopy curtain.

- **Routing miner-generated dust to the return.** For controlling respirable dust exposure downwind of the continuous miner on sections that ventilate with exhausting auxiliary fans, the simplest and most effective technique is to route the miner-generated dust directly to the return using lightweight, collapsible tubing [Jayaraman et al. 1989]. This allows the dust to reach the return without exposing downwind workers.

- **Working downwind of the bolter.** When downwind of the bolter, as much as 25% of the continuous miner operator's quartz dust exposure can be attributed to dust from the bolting operation. The problem is usually a lack of maintenance on the bolter dust collector [Organiscak et al. 1990].

INTAKE AIRWAYS

The average concentration of respirable dust in intake air must be kept at or below 1 mg/m^3 within 200 ft outby the working face. However, to maintain consistent dust control in the face area, MSHA recommends that intake concentrations be less than 0.5 mg/m^3 [Shultz and Fields 1999]. Maintaining this concentration is not usually difficult, but requires attention from mine operators to address activities that can raise intake air dust levels. Typically, high levels of intake dust are sporadic and brief in nature due to activities in the intake entries that may take place over the course of a working shift. These sporadic activities include:

- Delivery of supplies and/or personnel
- Parking equipment in intake
- Rock dusting
- Scoop activity
- Construction activity

In addition, the belt entry can be used to bring intake air to the working faces and is a potential source of dust generation. If intake dust levels are high, the following steps can be taken to maintain dust levels to a minimum:

- Good housekeeping practices will help keep intake entries free of debris, equipment, and supplies.

- Supply delivery, scoop activity, stopping construction, and rock dusting should be dedicated to nonproduction shifts.

- If haulage activities must take place during a production shift, the haulage roadways should be kept damp at all times. Since water will likely evaporate in the ventilation air, a hygroscopic salt or effective dust-allaying agent should be used [Ondrey et al. 1994]. Keeping dust dampened in the main intake entries will limit dust entrained by activity in these entries.

- Equipment should be parked in crosscuts to keep main airways clear of obstruction.

When belt air is used for face ventilation, dust generated in the belt area should be controlled. Potts and Jankowski [1992] measured the dust level impact of using belt air for face ventilation on continuous miner sections. Controls at the belt head helped maintain low dust levels in the belt entry. Automated sprays were used to suppress dust at the section-to-main transfer point. A belt scraper equipped with sprays controlled dust by cleaning the outside surface of the belt after the coal had been transferred to the main belt. These measures are also discussed in more detail in Chapter 3.

FEEDER-BREAKERS AND SHUTTLE CARS

Dust measurements show that feeder-breaker operations can contribute a significant amount of respirable dust to belt entry air, which emphasizes the need for dust controls at this location [Potts and Jankowski 1992]. Outby areas can be placed on a more stringent dust standard due to the presence of respirable silica dust. A study by Organiscak et al. [1990] showed elevated respirable silica dust concentrations at the feeder-breaker and on the shuttle car. Following are some basic controls for these areas:

- MSHA recommends hollow- or full-cone sprays at the feeder-breaker transfer point to wet and knock down coal and silica dust [Ondrey et al. 1994].
- When shuttle cars unload, dust levels can be decreased by using automated sprays at the mouth of the feeder-breaker that activate during dumping to wet coal before it enters the crusher.
- Throat sprays on the continuous miner will wet coal when entering the conveyor and lessen dust when transferred to and from shuttle cars. Redistributing a small portion of the water available on the continuous mining machine to the chain conveyor may be necessary to ensure that the loaded coal is wet enough to minimize dust reentrainment at the section loading point [Ondrey et al. 1994].
- Shuttle cars should not be in a waiting position beneath check curtains.
- Shuttle car operators should not be located in the direct discharge of the dust collector (scrubber) on the continuous miner.
- When blowing ventilation is used, configure shuttle car runs to minimize the amount of time spent in return air.

REFERENCES

Beck TW, Goodman GVR [2008]. Evaluation of dust exposures associated with mist drilling technology for roof bolters. Min Eng *60*(12):35–39.

CFR. Code of federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Colinet JF, Jankowski RA [1996]. Dust control considerations for deep-cut faces when using exhaust ventilation and a flooded-bed scrubber. In: Transactions of Society for Mining, Metallurgy, and Exploration, Inc. Vol. 302. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., pp. 104–111.

Colinet JF, Jankowski RA [2000]. Silica collection concerns when using flooded-bed scrubbers. Min Eng *52*(4):49–54.

Divers EF [1976]. Nonclogging water spray system for continuous mining machines: installation and operating guidelines. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, IC 8727. NTIS No. PB 265 934.

Fields KG, Atchison DJ, Haney RA [1991]. Evaluation of dust control for deep cut coal mining systems using a machine mounted dust collector. In: Proceedings of the Third

Symposium on Respirable Dust in the Mineral Industries. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., pp. 349–353.

Goodman GVR [2000]. Using water sprays to improve performance of a flooded-bed dust scrubber. Appl Occup Env Hyg *15*(7):550–560.

Goodman GVR, Organiscak JA [2002]. An evaluation of methods for controlling silica dust exposures on roof bolters. SME preprint 02-163. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.

Goodman GVR, Pollock DE, Beck TW [2004]. A comparison of a directional spray system and a flooded-bed scrubber for controlling respirable dust exposures and face gas concentrations. In: Ganguli R, Bandopadhyay S, eds. Mine ventilation: Proceedings of the 10th U.S./North American Mine Ventilation Symposium (Anchorage, AK, May 16–19, 2004). Leiden, Netherlands: Balkema, pp. 241–248.

Goodman GVR, Beck TW, Pollock DE, Colinet JF, Organiscak JA [2006]. Emerging technologies control respirable dust exposures for continuous mining and roof bolting personnel. In: Mutmansky JM, Ramani RV, eds. Proceedings of the 11th U.S./North American Mine Ventilation Symposium (University Park, PA, June 5–7, 2006). London: Taylor & Francis Group, pp. 211–216.

Hirschi JC, Chugh YP, Saha A, Mohany M [2002]. Evaluating the use of surfactants to enhance dust control efficiency of wet scrubbers for Illinois coal seams. In: De Souza E, ed. Proceedings of the North American/Ninth U.S. Mine Ventilation Symposium (Kingston, Ontario, Canada). Lisse, Netherlands: Balkema, pp. 601–606.

Jayaraman NI, Kissell FN, Schroeder W [1984]. Modify spray heads to reduce dust rollback on miners. Coal Age *89*(6):56–57.

Jayaraman NI, Jankowski RA [1988]. Atomization of water sprays for quartz dust control. Appl Ind Hyg *3*(12):327–331.

Jayaraman NI, McClelland JJ, Jankowski RA [1988]. Reducing quartz dust with flooded-bed scrubber systems on continuous miners. In: Proceedings of the Seventh International Pneumoconiosis Conference (Pittsburgh, PA), pp. 86–93.

Jayaraman NI, Babbitt CA, O'Green J [1989]. Ventilation and dust control techniques for personnel downwind of continuous miner. In: Transactions of Society for Mining, Metallurgy, and Exploration, Inc. Vol. 284. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., pp. 1823–1826.

Jayaraman NI, Colinet JF, Jankowski RA [1992]. Recent Basic research on dust removal for coal mine applications. In: Proceedings of the Fifth International Mine Ventilation Congress (Johannesburg, Republic of South Africa), pp. 395–405.

Kissell FN [2003]. Dust control methods in tunnels and underground mines. In: Kissell FN, ed. Handbook for dust control in mining. Pittsburgh, PA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2003-147, IC 9465, pp. 3–21.

Kissell FN, Goodman GVR [2003]. Continuous miner and roof bolter dust control. In: Kissell FN, ed. Handbook for dust control in mining. Pittsburgh, PA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2003-147, IC 9465, pp. 23–38.

Luxner JV [1969]. Face ventilation in underground bituminous coal mines. Airflow and methane distribution patterns in immediate face area: line brattice. Washington, DC: U.S. Department of the Interior, U.S. Bureau of Mines, RI 7223.

MSHA [2009]. Standardized Information System: Respirable coal mine quartz dust data. Arlington, VA: U.S. Department of Labor, Mine Safety and Health Administration.

NIOSH [1997]. Hazard identification 1: Exposure to silica dust on continuous mining operations using flooded-bed scrubbers. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, HID1, DHHS (NIOSH) Publication No. 97–147.

NIOSH [2007]. Technology news 523: Evaluation of dust collector bags for reducing dust exposure of roof bolter operators. Pittsburgh, PA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2007–119.

Ondrey RS, Haney RA, Tomb TF [1994]. Summary of minimum dust control parameters. In: Proceedings of the Fourth Symposium on Respirable Dust in the Mineral Industries (Pittsburgh, PA, November 8–10, 1994).

Organiscak JA, Page SJ, Jankowski RA [1990]. Sources and characteristics of quartz dust in coal mines. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, IC 9271. NTIS No. PB 91-160911/AS.

Organiscak JA, Khair AW, Ahmad M [1996]. Studies of bit wear and respirable dust generation. In: Transactions of Society for Mining, Metallurgy, and Exploration, Inc. Vol. 298. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc., pp. 1932–1935.

Pollock DE, Organiscak JA [2007]. Airborne dust capture and induced airflow of various spray nozzle designs. Aerosol Sci Technol *41*(7):711–720.

Potts JD, Jankowski RA [1992]. Dust considerations when using belt entry air to ventilate work areas. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines, RI 9426.

Schroeder WE, Babbitt C, Muldoon TL [1986]. Development of optimal water spray systems for dust control in underground mines. Foster-Miller, Inc. U.S. Bureau of Mines contract H0199070. NTIS No. PB 87-141537.

Schultz MJ, Fields KG [1999]. Dust control considerations for deep cut mining sections. SME preprint 99-163. Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc.

Strebig KC [1975]. "Wet-head" tests on miners concluded. Coal Min & Process *12*(4): 78–80, 88.

Thaxton RA [1984]. Maintenance of a roof bolter dust collector as a means to control quartz. In: Proceedings of the Coal Mine Dust Conference (Morgantown, WV, October 8–10, 1984), pp. 137–143.

USBM [1984]. Technology news 198: Better roof bolter dust collector maintenance reduces silica dust levels. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines.

USBM [1985]. Technology news 219: Reducing dust exposure of roof bolter operators. Pittsburgh, PA: U.S. Department of the Interior, Bureau of Mines.

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Best Practices for Dust Control in Coal Mining

By Jay F. Colinet, James P. Rider, Jeffrey M. Listak, John A. Organiscak,
and Anita L. Wolfe

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Office of Mine Safety and Health Research
Pittsburgh, PA • Spokane, WA

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ACRONYMS AND ABBREVIATIONS USED IN THIS REPORT

CWHSP	Coal Workers' Health Surveillance Program
CWP	Coal workers' pneumoconiosis
DO	designated occupation
HVAC	heating, ventilation, and air conditioning
IARC	International Agency for Research on Cancer
ILO	International Labour Office
MSHA	Mine Safety and Health Administration
NIOSH	National Institute for Occupational Safety and Health
PDM	personal dust monitor
pDR	personal DataRAM
PEL	permissible exposure limit
PMF	progressive massive fibrosis
TEOM	tapered-element oscillating microbalance

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cfm	cubic foot per minute
cm	centimeter
fpm	foot per minute
ft	foot
ft/min	foot per minute
gpm	gallon per minute
hr	hour
in	inch
in w.g.	inch water gauge
kPa	kilopascal
lpm	liter per minute
m/sec	meter per second
mg/m^3	milligram per cubic meter
mm	millimeter
mph	miles per hour
$\mu g/m^3$	microgram per cubic meter
psi	pound-force per square inch
sec	second

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