Chapter 36

RESEARCH BY NIOSH FOR CONTROLLING RESPIRABLE DUST AND METHANE GAS ON CONTINUOUS MINER FACES

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ABSTRACT

The importance of controlling respirable dust and methane gas levels in underground coal mining cannot be underestimated. While respirable dust can significantly affect the occupational health of underground coal miners, methane gas accumulations pose significant safety concerns for these same workers. Water sprays and machine mounted dust scrubbers offer effective control of respirable dust exposures and methane gas accumulations. Water must not only be applied carefully to avoid dust rollback to the machine operator but must create sufficient turbulence to remove dead zones that could contain high concentrations of methane gas. While the flooded-bed dust scrubber has been generally responsible for decreased worker exposures to respirable dusts, this device has proved effective in controlling methane levels at the face. This paper reviews practical applications of water sprays and dust scrubbers to control respirable dust and methane gas on continuous miner faces.

KEYWORDS

Coal mining, water sprays, coal dust, silica dust, engineering controls

INTRODUCTION

The United States Federal Coal Mine Health and Safety Act of 1969 limits personal exposure to respirable dust to 2.0 mg/m^3. This limit is measured gravimetrically as an 8-hour time weighted average concentration of the respirable coal dust (NIOSH, 1995). If the respirable dust sample contains more than 5 percent silica by weight, the respirable dust standard is reduced according to the formula 10 / (percent silica). Compliance with either the 2.0 mg/m^3 respirable dust standard or reduced dust standard maintain silica percentages at or below 100 Fg/m^3. Because the continuous miner operator is on or near the continuous mining machine, this person is frequently exposed to the greatest levels of respirable dust. According to data supplied by the Federal Mine Safety and Health Administration (MSHA), over 3100 samples were collected at the continuous mining machine operator in 1998. Nearly 60 percent of the occupational samples contained more than 5 percent respirable silica dust while forty percent of these contained silica concentrations in excess of 100 μg/m^3.

NIOSH RESEARCH TO CONTROL RESPIRABLE DUST EXPOSURES

Water sprays remain the most widely used technology for limiting exposures to respirable dust. Water sprays control dust exposure by suppressing airborne dust, inducing airflow to drive dust clouds away from personnel, and preventing generation of airborne dust (Goodman and Jankowski, 1998). Much research by NIOSH and its predecessor, the U.S. Bureau of Mines, dealt with balancing these attributes to provide effective control of respirable coal and silica dusts.

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 created large quantities of dust rollback.

To control rollback, sprays were situated atop and beneath the cutting drum (Figure 1). The sprays operated at a pressure of approximately 690 kPa (100 psi) and a flow rate of 3.6 lpm (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 roughly 48 kPa (7 psi) and a higher flow rate of 18.9 lpm (5 gpm) per spray (Foster-Miller, 1986). Dust rollback decreased 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. In-mine evaluations of these boom sprays showed that miner operator dust exposures were reduced 40 percent compared to the factory-issued spray system.

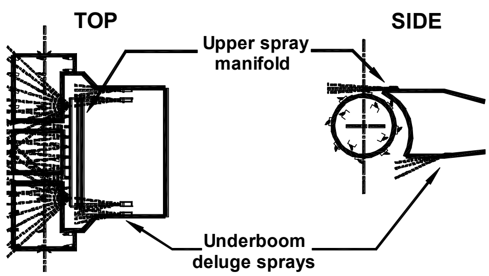

Figure 1. Water sprays to control dust rollback

Additional sprays were installed to improve dust control in the underboom area. Two hollow cone sprays were positioned on the rear corner of the shovel on the side opposite from the ventilation curtain. These sprays were used with exhaust ventilation only. Each spray operated at 1,206 kPa (175 psi) with a flow rate of 8.5 lpm (2.3 gpm). Due to the high spray pressure and flow rate, these sprays induced significant airflow beneath the cutting boom. This not only swept the underboom area dust into the return airway, but also improved suppression of this dust.

Extensive underground testing of these sprays was conducted with the operator located on the mining machine. Dust reductions of 60 percent at the continuous miner operator's location were noted. Subsequent analyses showed that these shovel sprays also were quite effective in controlling respirable silica dust produced by the continuous miner. In fact, silica dust was virtually eliminated at the miner operator's location (Figure 2).

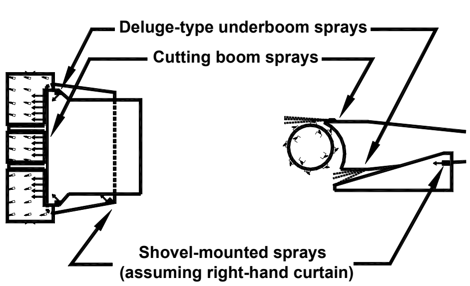

Figure 2. Shovel mounted sprays control underboom dust

Half the respirable silica generated in underground coal mining has a size between 1.0 and 3.5 microns. Due to the relatively small size of these particles, their capture is difficult with larger water droplets produced by conventional water sprays. Higher pressure sprays can generate the smaller water droplet sizes and increased spray velocities required to capture smaller-sized particles.

High pressure sprays operating at 17,250 kPa (2,500 psi) were installed under the cutting boom and directed toward the face. Dust levels were reduced nearly 60 percent with the most dramatic dust reductions occurring in the size range below 2.9 microns. In fact, the reduction more than doubled for 1.8 micron particles with the addition of high pressure sprays (Jayaraman and Jankowski, 1988).

Past work showed that flooded-bed scrubbers effectively controlled occupational dust exposures when used with either blowing or exhausting face ventilation schemes. As of 1997, approximately 60 percent of the operating continuous mining machines used a flooded-bed dust scrubber to control occupational dust levels. MSHA typically requires air quantities measured at the curtain mouth to be equal to or slightly greater than the rated capacity of the dust scrubber (Schultz and Fields, 1999). Excessive air flow at the mouth of a blowing curtain is thought to overpower the scrubber and blow dust by the scrubber inlets. However, excessive air flow at the mouth of an exhausting curtain does not appear to significantly affect dust capture (Colinet and Jankowski, 1996).

Increased emphasis on controlling occupational dust exposures led to increases in face airflow and scrubber airflow. Although physical constraints limit scrubber performance, scrubber airflow was increased by reducing the density of the scrubber filter. However, this reduction suggested lower dust collection efficiencies and thus increased occupational exposures to respirable coal and silica dusts. Recent work investigated silica collection efficiencies of filters containing 10, 15, 20, and 30 layers of stainless steel meshing (Colinet and Jankowski, 2000). The 20-layer scrubber filter is the most common filter in use in the U.S. mining industry. Also investigated was a filter panel containing a non-woven synthetic fiber and one containing an array of nylon brushes. Multiple scrubber duct velocities of 11.1 and 17.8 m/s were tested.

Over the range of velocities tested, respirable silica collection efficiencies ranged from 69 percent to 84 percent for the standard 20-layer scrubber filter. Efficiencies for the denser 30-layer and synthetic fiber filters varied from 91 to 95 percent. The 10-layer filter panel had the lowest collection efficiencies ranging from 58 percent to 76 percent. All filter panels showed improved silica collection at higher scrubber velocities (Figure 3).

Dust scrubbers are very effective when the dust is contained beneath the cutting head. Movement of the continuous mining machine at the face sometimes can cause this dust to escape from under the cutting head. Placing water sprays on the left and right sides of the cutting head induces additional airflow in these areas. This increases containment of the dust cloud under the cutting head and can improve the capture of this dust by the scrubber. This, in turn, reduces both dust rollback and dust exposure for the machine operator.

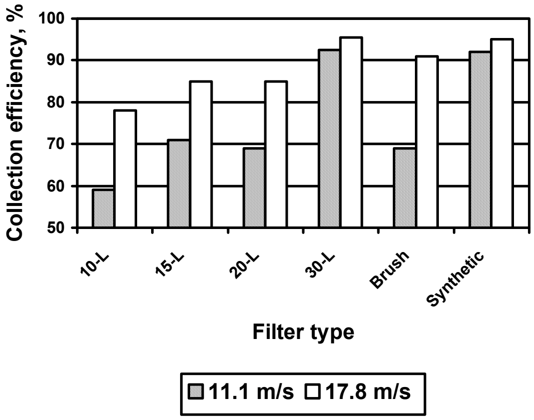

Figure 3. Silica collection efficiencies for various filters

These sprays were tested at an underground operation. One manifold, each containing two flat fan sprays, was mounted on each side of the continuous miner, near the scrubber inlets. Each spray delivered 6.1 lpm (1.61 gpm). Dust levels were measured at the left and right rear corners of the continuous miner and at the remote miner operator location, with and without the additional side sprays in operation (Goodman, 2000).

Respirable dust exposures decreased 20% for the mining machine operator. Similar reductions were seen at the left and right rear corner sampling locations. It is likely that the decreases in dust concentrations arose from a combination of improved suppression and improved capture by the dust scrubber (Figure 4).

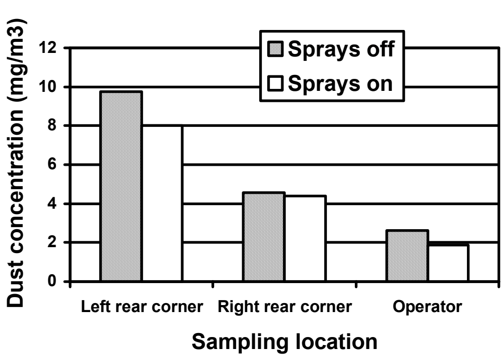

Figure 4. Effects of additional sprays on measured dust levels

NIOSH RESEARCH TO CONTROL METHANE GAS

Federal regulations require that methane levels in the face area be maintained below one percent. Methane readings obtained with a hand held methane monitor are usually taken as close to the face as practical although they cannot be taken closer than 0.3 m (12 in) from the roof, face, ribs, and floor. Machine-mounted methane monitors are used to continuously monitor methane levels on the mining machine. Whenever methane readings are one percent or higher mining must stop until concentrations are reduced below one percent.

Methane gas released at or near the mining face is controlled by providing sufficient intake air to the face to maintain methane levels below one percent. Although air delivered to the end of the tubing or curtain must be directed to the face, most of this intake air never reaches the face. Generally, the quantity of air reaching the face decreases as tubing or curtain setback distance increases. Although water sprays and scrubbers are designed primarily for dust control, research has shown that they can also be used to reduce methane levels by increasing the amount of intake air that reaches the face.

Exhaust face ventilation systems are generally preferred over blowing face ventilation systems for dust control because the dust is removed from the face area before it passes over the machine operator's location (Shultz and Fields, 1999). However, for a given setback distance, airflow quantities reaching the face with exhaust ventilation are often less, and face methane concentrations higher.

Water sprays systems can be designed for use with exhaust ventilation to maintain and improve face airflow at longer setback distances (Foster-Miller, 1985). The nozzles in the spray system are oriented to move air from the intake to return side of the entry. Each of the spray nozzles acts as a small fan and the system is referred to as a spray fan system. Tests showed that increasing water pressure and flow rate increased the air moved by the sprays. Although typical flow pressure for the spray fan system was at least 689 KPa (100 psi), high water pressure created turbulence that led to dust roll back.

The orientation and location of spray nozzles on the mining machine are also important factors in determining face airflow. Nozzles on the mining machine boom should be directed toward the return side to maintain airflow across the face while nozzles on the intake side of the machine maintain intake airflow to the face. The best design for a particular mining face is the one that provides the greatest air flow quantity with consistent flow patterns (intake to return) at the face. The effects of sprays on face airflow can be compared by using smoke or the discharge from a fire extinguisher to draw face airflow patterns. Test results show that, when compared to a 3-m (10-ft) primary ventilation brattice, the spray fan system consistently provided better face ventilation up to and including a 12-m (40-ft) brattice setback (Volkwein, *et al*., 1985). Use of the spray fan system allowed curtain setback distance to be increased while maintaining the effectiveness of the face ventilation system.

Blowing face ventilation systems are usually preferred over exhausting face ventilation systems for methane control because, for a given curtain or tubing setback distance, the former provides more air to the mining face (Luxner, 1969). Scrubbers are used with most blowing systems to reduce the amount of dust that passes over the operator's work location. Dust control and ventilation plans approved by MSHA typically permit blowing curtain ventilation flows to exceed the rated capacity of the dust scrubber by no more than 0.50 m^3/sec (1,000 cfm). This additional face airflow helps control face methane levels.

Early studies indicated that water spray systems used with a dust scrubber and blowing ventilation had little effect on face methane levels (Gillies, 1982). Spray systems used with scrubbers usually were directed toward the face and were not intended, as with the spray fan system, to direct air from the intake to return side of the face. Test results showed that the scrubber maintained the intake airflow reaching the face as curtain setback distance increased from 7.5 m to 15 m (25 ft to 50 ft) (Ingersoll Rand Research, 1984).

Releasing smoke near the face showed how face airflow patterns changed and indicated that, with the scrubber operating, intake airflow was present on the curtain side of the entry (Figure 5). Intake air velocities, measured at the end of the blowing curtain, increased with the scrubber operating. These increases were greater at the higher scrubber flows and lower intake flows. Face methane levels decreased with increasing scrubber flow, even when scrubber flow was greater than intake flow (Figure 6) (Taylor *et al*., 1996a).

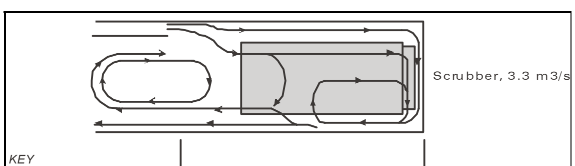

Figure 5. Face airflow patterns with and without scrubber

Using a scrubber with exhaust ventilation also reduced face methane levels. The methane levels were lower with blowing than exhausting due to the higher velocities created by the blowing system (Taylor, *et al*., 1996b). However, for both types of face ventilation the methane concentrations decreased as scrubber flow increased. When using a dust scrubber, the mouth of the exhaust curtain must be positioned outby the exhaust of the scrubber. With the curtain mouth inby the scrubber exhaust, air recirculation to the face increases and, more importantly, intake air reaching the face is reduced.

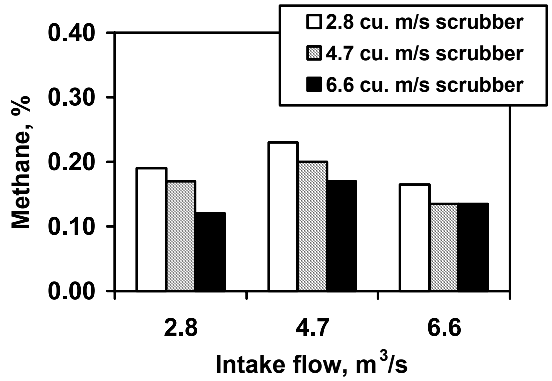

Figure 6. Face methane levels with varying intake and scrubber flows

SUMMARY

Water sprays remain the most widely used method for controlling respirable dust exposures. NIOSH research has evaluated sprays to reduce dust rollback from the cutting head, high pressure sprays to control exposures to respirable silica dust, and sprays to improve performance of a flooded-bed dust scrubber. The dust capture properties of various wetted screens used in the dust scrubber have been evaluated.

Face methane concentrations at the cutting face have been reduced using water sprays and flooded-bed scrubbers. NIOSH research has shown that water sprays can be used to maintain and improve face airflow at longer setback distances with exhaust face ventilation systems. This work has also shown that dust scrubbers increase intake airflow with either blowing or exhausting face ventilation systems. Higher face ventilation flows are needed to control face methane concentrations.

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