

Practical Ways to Reduce Exposure to Coal Dust in Longwall Mining— A Toolbox



U.S. Department of Labor
Mine Safety and Health Administration

1999

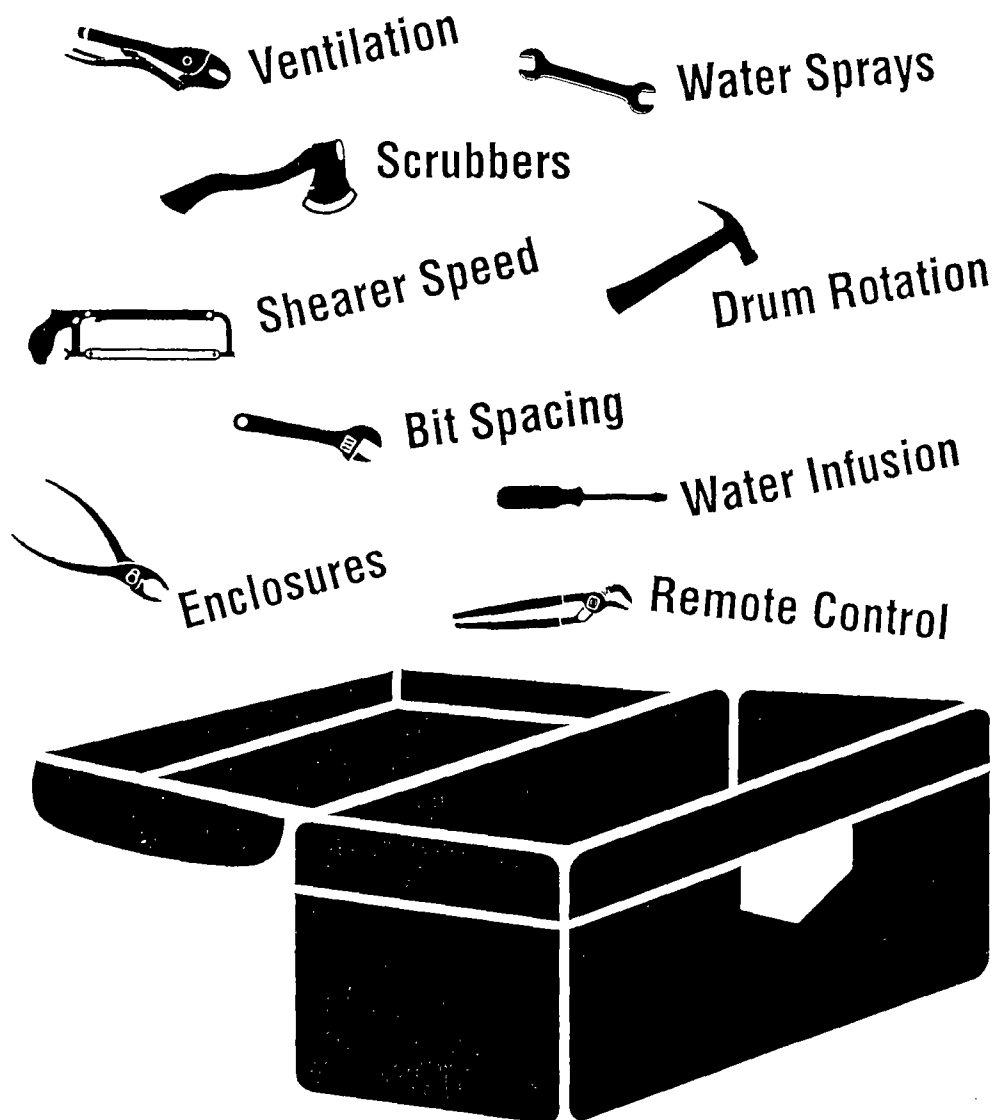


TABLE OF CONTENTS

INTRODUCTION

The Problem 1

THE TOOLBOX

Improved Ventilation 5
 Face Air Quantity and Velocity5
 Gob Curtains 7
 Cut-Out Curtains 8
 Air-Splitting Barriers 9

Optimized Water Delivery 10

Effective Water Spray Systems11
 Internal Shearer Drum Sprays11
 External Shearer Body Sprays..... .13
 Roof Support Water Sprays..15
 Crusher/Stageloader Sprays.....16
 Water Spray Types and
 Applications 17

Improved Cutting Parameters20

 Modified Cutting Sequence.....20
 Slow Speed Deep Cutting22

Other Dust Control Measures23

 Roadway Dust Control 23
 Wetting Agents 23
 Foam Application 24
 Water Infusion..... 24

Spot Scrubber Systems 24

Limiting Production 25

Remote Control Devices 26

Bit Wear 26

Additional Dust Controls Before
Initial Roof Fall 27

High Pressure Drum
Water Sprays 27

On-Shift Examinations of
Dust Control Pramameters 28

Respiratory Protection 28

Appendix A:
Longwall Dust Control Checklist 29

Appendix B:
Additional Reading 33

The Problem

The Mine Safety and Health Administration (MSHA) and the National Institute for Occupational Safety and Health (NIOSH) have been active in respirable coal mine dust control research since the Federal Coal Mine Health and Safety Act was passed in 1969. Until the late 70s, this research centered on the development of dust control technologies to reduce miners' exposure to respirable dust in mines using conventional continuous mining methods. As a result of efforts by the mining industry, MSHA, and NIOSH, significant progress has been achieved in lowering the respirable coal mine dust levels in these mines from over 5 mg/m³ in 1969 to less than 2 mg/m³ today.

However, this impressive achievement has not been duplicated in mines using longwall mining systems for coal extraction, which have more difficulty in complying with the current 2mg/m³ Federal dust standard. This is partly due to the large increase in tons of coal produced each shift, resulting from improved longwall equipment, increased availability of the technology, larger longwall panels, and automation.

This handbook discusses various effective **engineering controls** that can help lower the levels

of respirable dust in the mine atmosphere in the active workings of each mine. Engineering controls include methods that minimize the level of airborne dust in the mine atmosphere by either reducing dust generation or by suppression, dilution, or capturing and containing the dust.

Unlike engineering controls, **administrative controls** or “**work practices**” are designed to minimize the exposure of individual workers by positioning them in the work area in such a way as to limit the time they are exposed to a particular dust source. These types of controls fall short of meeting the intent of the Act, and should not be used in lieu of engineering controls. Work practices can be effective in protecting some individuals only if followed properly and consistently, and if the environmental exposure remains constant and predictable. Of course, this is not characteristic of coal mining in general. Furthermore, the potential for frequent change of location can make it very difficult to identify sources of dust exposure.

If administrative-type controls are used, the required bimonthly samples should be collected from the environment of the designated occupation work position. That is, the sampling unit must remain with the occupation the entire shift and not with individual miners working in that occupation or location, even if miners rotate in and out of that position during the shift.

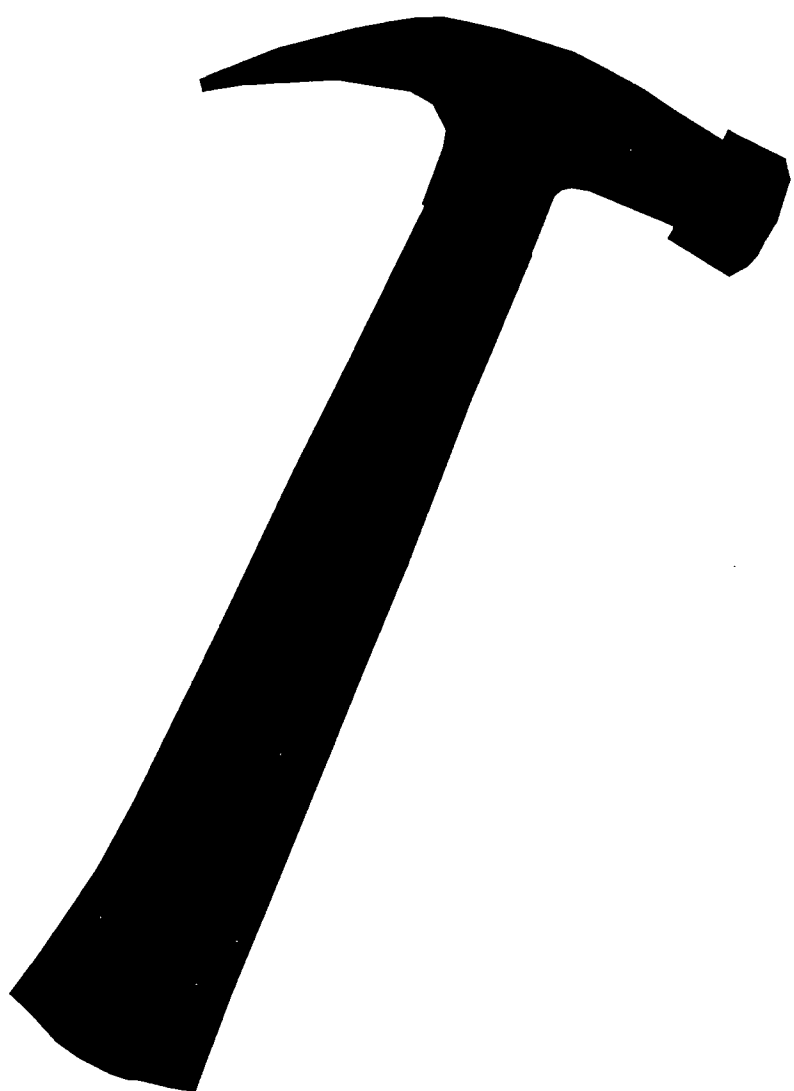
Although the Mine Act requires mine operators to make available approved respirators for miners whenever they are exposed to concentrations of respirable dust in excess of permissible levels, it specifically prohibits their use as a substitute for engineering control measures in the active workings.

Studies have shown that high dust exposures on longwall mining operations are mainly due to:

- Inadequate air volume and velocity;
- Insufficient water quantity and pressure;
- Poorly designed external water spray systems;
- Lack of dust control at the stageloader and crusher;
- Dust generated during support movement;
- Cutting sequences that position face workers downwind of the cutting machine.

This Toolbox addresses each of these problems in turn, and describes currently available methods to control dust generation and reduce dust exposure by the proper application of air and water and by modifying the cutting sequence.

The control measures and practices covered are now being used on many longwall operations, and reflect prudent industrial hygiene practices and MSHA experience. A list of additional reading on these techniques is included in Appendix B.



|

The Toolbox

IMPROVED VENTILATION

Ventilation is the primary way to control dust on longwall operations. Adequate amounts of air must be provided to dilute and carry the airborne respirable dust down the face and away from the operators. In addition, devices such as gob curtains, cut-out curtains, and air-splitting barriers can reduce the amount of dust at the operators' work station.

Face Air Quantity and Velocity

Respirable dust exposure is related to both face airflow and mining rate. MSHA studies have shown that maintaining the designated occupation (DO) at or below 2.0 mg/m³ during the shift requires approximately 5 to 20 cubic feet per minute (cfm) of air along the longwall face per ton of material mined.

Use the following equation to determine the air quantity per ton of material mined:

$$R = \frac{C \times Q}{S \times T}$$

Where:

R = Airflow-to-tons ratio, cfm/ton

C = Actual DO dust concentration, mg/m³

Q = Face airflow, cfm

S = Applicable dust standard, mg/m³

T = Production, tons

To determine the required airflow, you need to first assume an “R” value that will maintain the DO within the applicable standard, i.e., 2 mg/m³. For example, if you assume an “R” equal to 10 cfm/ton and 3,000 tons are produced during a shift, the required airflow along the face would be 30,000 cfm.

The typical open area between the shields and face for a 6 foot coal seam is approximately 60 square feet [(mining height – 1) X 12]. To determine the face air velocity in feet per minute (fpm), divide the recommended face air quantity by the square footage to be ventilated. In the example above, with the recommended minimum face air quantity of 30,000 cfm, the face air velocity will be approximately 500 fpm.

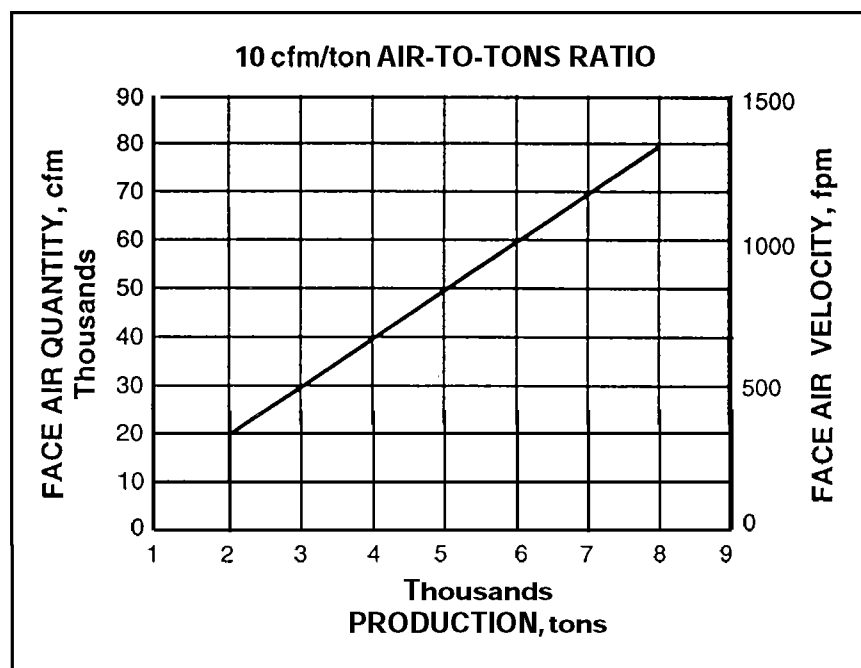


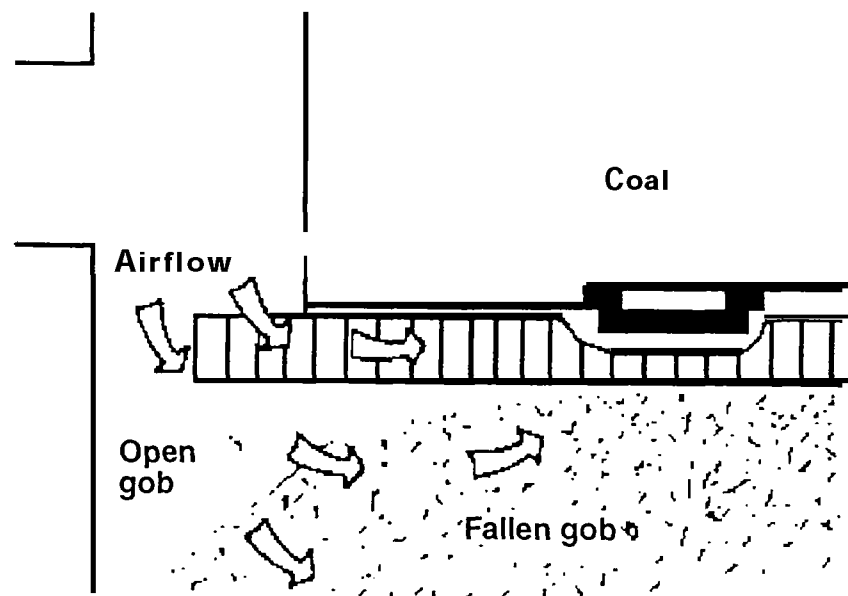
Figure 1. Face air quantity and velocity versus production for a 2.0 mg/m³ dust exposure

Higher production levels will require higher air quantity and velocity. The increased velocities will help confine dust to the face area, lowering walkway contamination.

Gob Curtains

Loss of air into the gob in the headgate area can reduce the air available to ventilate the face (see Figure 2). Also, this dust-laden gob air may reenter the face area, compounding the dust problem at longwall sections. A simple and inexpensive technique to prevent this is to install a

Figure 2. Air loss at headgate



curtain along the support line at the headgate end of the face (see Figure 3). The need for the curtain depends on the tightness of the gob and the section ventilation. A gob curtain would be especially useful in maintaining face air flow prior to obtaining a tightly caved gob.

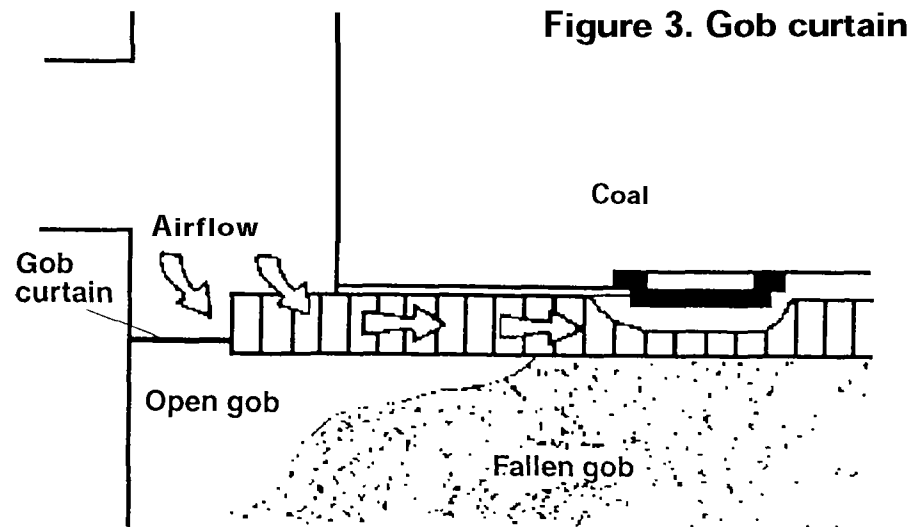
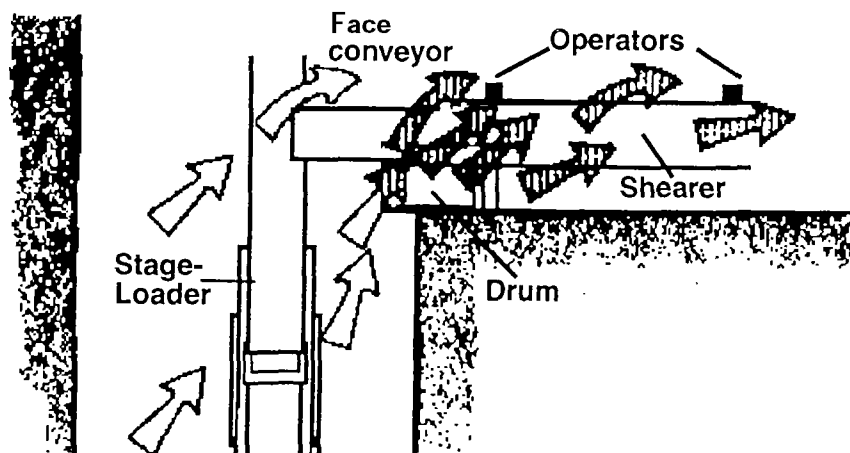


Figure 3. Gob curtain

Cut-Out Curtains

Cut-out curtains are used to increase the air velocity across the shearer operator and reduce dust rollback over the operator during cutting out at the headgate (Figure 4). A brattice cloth curtain is suspended from the roof between the rib and the stageloader (Figure 5). The curtain is usually located 4 to 6 feet back from the corner of the face so it doesn't interfere with the drum. The curtain is used only during the actual cut-

Figure 4. Dust rollback



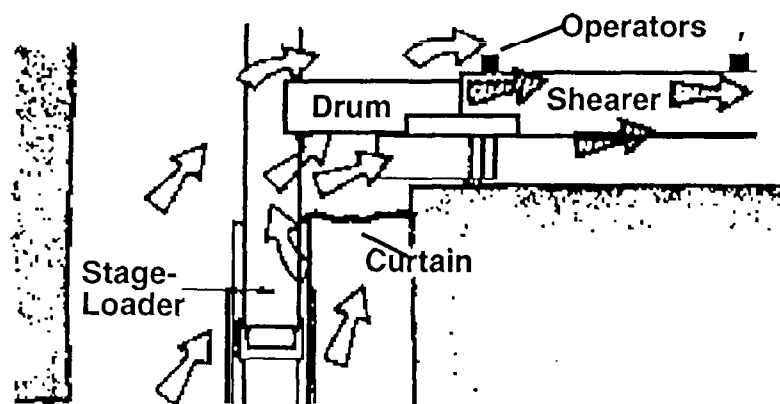


Figure 5. Cut-out curtain

out operation and is usually advanced every other pass. Use of this curtain has been found to reduce operators' dust exposure by 50 to 60 per cent during this phase of the longwall process.

Air-Splitting Barriers

Conveyor belt screens placed on the gob side of the body of the shearer and extended to the roof hold the dust to the face area and provide a cleaner air split in the walkway over the shearer operator (Figure 6). Barriers may also be line brattice installed along the face between the walkway and the face conveyor.

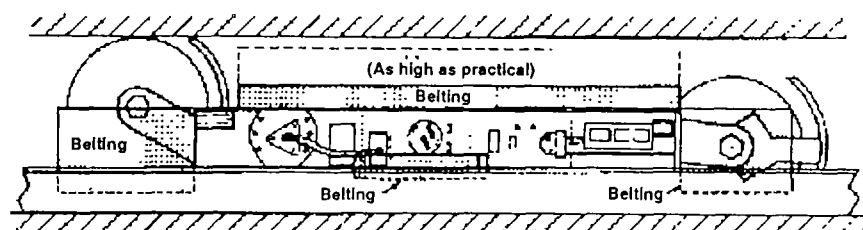


Figure 6. Air-splitting screens

OPTIMIZED WATER DELIVERY

Upgrading the water supply system can contribute to a significant reduction in dust level along the longwall face. This may be accomplished through:

1. Increasing pump capacity for additional flow and pressure;
2. Increasing line sizes to decrease pressure losses and maintenance downtime;
3. Improving water quality by installing a non-clogging filtration system.

An optimum water supply system should include a 3- or 4-inch-diameter supply line with a booster pump capable of supplying 100 gallons per minute (gpm) at 1,000 pounds per square inch (psi). The machine should **be** equipped with an overpressure regulator for cooling jacket water.

The water supply hose from the end of the hard pipe to the shearer should be at least 1½ inch in diameter (a 2-inch-diameter hose is preferable if there is room in the cable tray).

A good water filtration system will improve water quality and is essential for an effective water spray dust control system. A major component of such a system is a commercially available hydrocyclone that will remove less-

than-1/8-inch particulate. Greater than 1/8-inch particulate is removed by a flushable Y-strainer upstream of the hydrocyclone. This system should be installed in tandem with flow meters and pressure gauges at the end of the water supply pipe.

EFFECTIVE WATER SPRAY SYSTEMS

Water delivered through spray nozzles is used to keep newly formed dust from becoming airborne, to direct airflow, and to wet the coal. Since it is very difficult to control dust once it becomes airborne, all measures should be aimed at suppressing it at the source. A properly designed water spray system can reduce respirable dust by 20 to 60 percent.

To effectively control dust, a shearer must be equipped with two types of water spray systems-**internal drum sprays, which suppress** dust before it becomes airborne, and **external machine sprays**, which direct airborne dust away from the shearer operator.

Internal Shearer Drum Sprays

Drum sprays consist of nozzles mounted directly on the cutting drum to deliver water as close as possible to the primary point of dust generation. The most commonly used drum water spray system is pick-point flushing, which

directs water directly to the bit/coal interface (see Figure 7). The system uses nozzles mounted in the bit blocks or in special blocks immediately

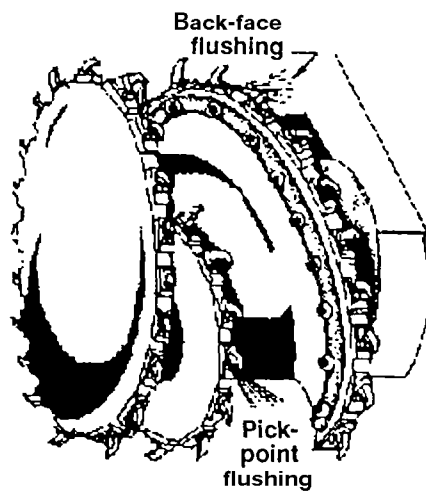


Figure 7. Pick-point flushing

uses spray nozzles mounted behind the bits to direct the water over the rear portion of the bit shaft to cool the bits and the hot streaks left in the rock after the bit passes.

Both pick-point and reverse pick point flushing systems have been shown to be most effective with solid-stream spray nozzle designs (see discussion of nozzle types, p. 17). For optimum effectiveness, a water filtration system should be used to prevent clogging of the spray nozzles.

Increased water quantity improves the dust suppression effectiveness of drum sprays. A minimum water quantity of 35 gallons per minute (gpm) per drum and, depending on the type of bit used, an operating water pressure ranging from 70 to 120 pounds per square inch (psi) is recommended.

in front of the bits. Typically, a drum should be equipped with one spray per bit.

The reverse pick-point flushing system uses spray noz-

External Shearer Body Sprays

On most longwall faces, the primary air upstream from the shearer is relatively clean if proper controls have been applied in the headgate area. If this airflow can be split and the dust cloud generated by the cutting drums confined to the face side of the shearer, the shearer operators can be supplied with a split of clean air. This “shearer-clearer” system consists of several strategically mounted water sprays and one or more passive barriers.

Many external spray configurations are possible, but basic parameters include sprays oriented approximately 30 degrees toward the face, with a minimum nozzle pressure of 150 psi; and an intake splitter arm extending from the headgate side of the machine. Improperly oriented externally-mounted sprays aimed at the head drum

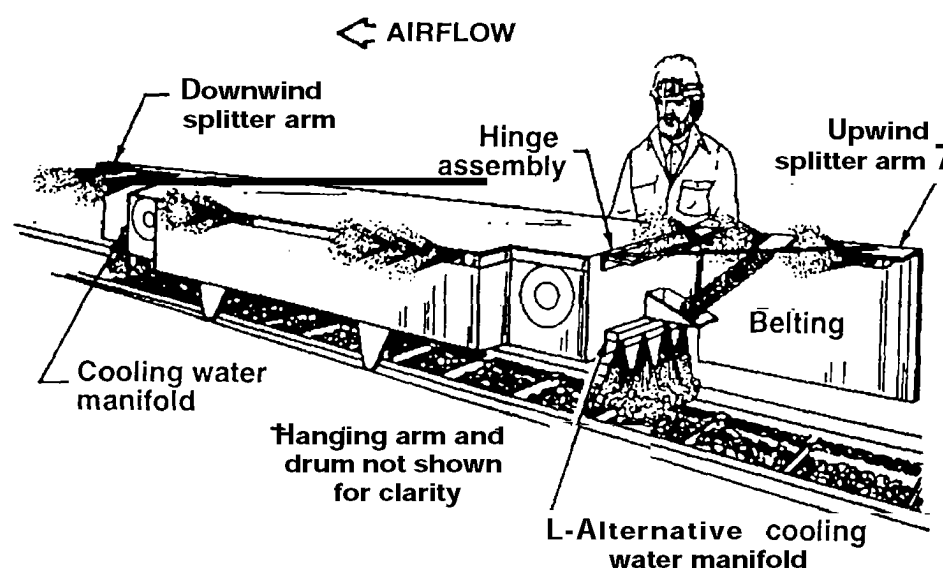


Figure 8. External water spray system

can direct dust from that drum upstream, where it can mix with the primary airstream and be carried back over the shearer operators.

Conveyer belting can also be used along the machine body to form a barrier to hold the dust against the face. A shield washdown hose should be part of the external shearer-spray system.

Further improvements in the shearer water spray system may be obtained by relocating the face side cooling water sprays. Figure 9 illustrates the faulty air circulation pattern caused by sprays directed straight at the face. Air induced by the sprays turns around and moves back over the shearer, bringing dust with it into the walkway.

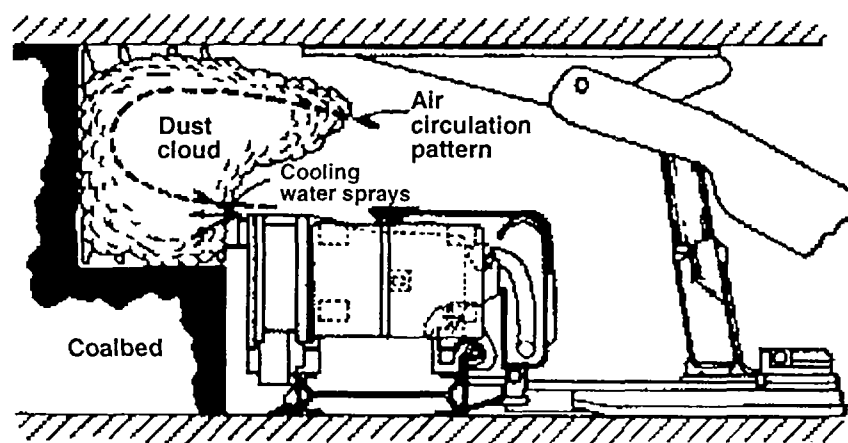


Figure 9. Airflow patterns of standard cooling water sprays

To avoid this problem, water from the cooling sprays should be directed to a manifold at the end of the shearer, spraying straight down onto the panline. In addition to reducing the res-

pirable dust levels at the operators' location caused by adverse air circulation, the additional water being directed onto the panline will reduce dust from that source.

Roof Support Water Sprays

Dust generated when shields are advanced can contribute significantly to dust levels at the longwall face, especially downwind of shield movement. Currently there are a limited number of techniques available to reduce and control this dust, including airflow to dilute the dust concentration once the dust becomes airborne, and water to suppress the dust generated.

The most successful way is to apply water manually, using a washdown hose attached to the shearer. This procedure is conducted during the head-to-tail pass to remove any dust which accumulated during the previous pass. To prevent crushing and recrushing of roof material during the shield-advance cycle, the tops of the supports should be periodically lowered and washed.

In lieu of manual water application, roof support water sprays may be used to control dust generated during support movement. When the shield pressure is released, a valve opens and water is sprayed on top of the shield while it is advanced. When the shield pressure is set, the valve closes and the spray stops.

Crusher/Stageloader Sprays

The dust generated by the breaking action of crusher/stageloader is the single largest source of contamination of intake air. This dust mixes with the primary ventilation airstream and is carried along the entire length of the longwall face, contributing to the full-shift exposure of all face personnel working downwind. To minimize the amount of dust generated, it is important to equip the crusher/stageloader with a properly designed dust suppression system.

There are two primary methods to accomplish this (see Figure 10):

1. Install water sprays at the inlet of the crusher and at various points within the crusher/stageloader;
2. Tightly enclose the unit with steel plate to prevent escape of the dust cloud.

Also, conveyor belting should be placed over the crusher inlet.

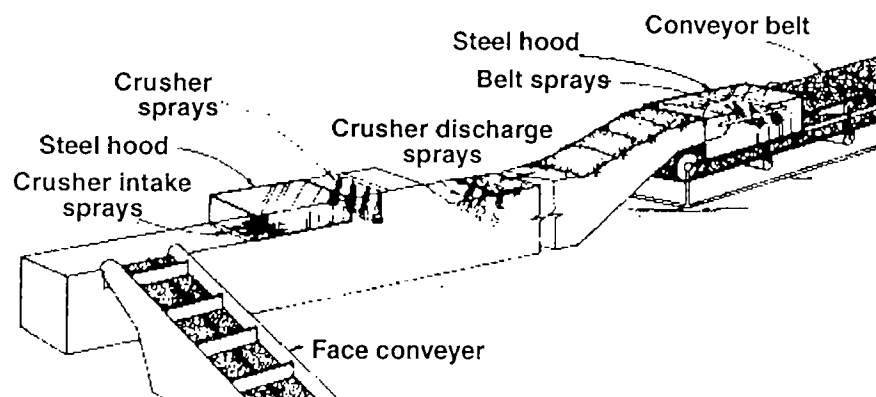


Figure 10. Dust control at crusher/stageloader

The crusher/stageloader enclosure should contain at least three banks of spray bars: one at the enclosure inlet, one over the crusher picks, and one at the crusher outlet. Each spray bar should contain at least three sprays and operate at a minimum pressure of 70 psi. Provisions should be made for easy inspection and maintenance of the spray bars.

Moisture on the coal may evaporate during travel between belt transfer points, which may be several thousand feet apart. Applying approximately 3 gpm, of water at 50 psi to the coal at transfer points will help prevent dust particles from dislodging and becoming airborne during transfer. A bank of at least three sprays should be installed at the stageloader-to-belt transfer point.

Water Spray Types and Applications

Effective dust control also depends on selecting the right water spray nozzle for the right job. Studies have shown that hollow-cone and atomizing water spray nozzles are most effective for suppressing dust. Venturi and hollow-cone nozzles are effective air movers, while full-cone, flat-spray, and solid-stream nozzles are best for coal wetting. The following are examples of the use of different nozzle types:

Hollow cone (HC) - Hollow cone nozzles can be used for external shearer-spray systems, including the shearer-clearer spray system. They

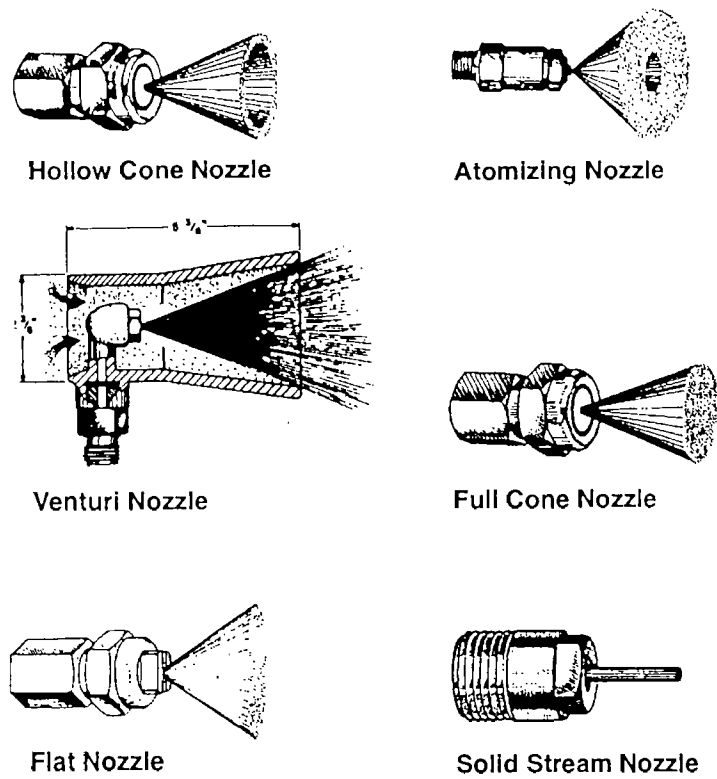


Figure 11. Types of nozzles

can also be used at the mouth of the crusher, within the crusher, at the crusher discharge, at the stageloader-to-belt transfer point, and at other outby transfer points. HC nozzles produce a circular spray pattern with droplets concentrated around the perimeter of a hollow center. The droplets are small with a wide spray angle.

Atomizing (AT) - Studies show that atomizing nozzles are best for dust scrubbing, although they are susceptible to damage and foul easily in the mine environment. AT nozzles use hydraulic pressure or compressed air to produce very small (fog-like) water droplets. The spray pattern is usually full-cone; however, hollow-cone and flat-spray patterns are also available.

Venturi (VE) - The VE nozzle is a conventional hollow-cone or full-cone nozzle or an atomizing nozzle mounted in a “venturi shroud.” The air is drawn through the venturi to combine with the water jet, reducing the size of the droplets. The shape of the shroud determines the pattern of the spray. The droplet characteristics can vary, since any nozzle can be placed in the venturi shroud.

Full-Cone (FC) - Full cone nozzles produce a uniform distribution of droplets over a circular or square area. Compared to other nozzles, the FC produces large droplets with high velocities. FC nozzles can be used to wet coal before belt transfer points and with belt wipers to remove coal particles from the nonconveying side of the conveyor belt.

Flat Spray (FS) - Flat spray nozzles produce a narrow, rectangular spray pattern of very large droplets with very high velocities. Spray angles up to 110 degrees are available. FS nozzles can be used to wet coal before belt transfer points and with belt wipers to remove coal particles from the conveying side of the conveyor belt.

Solid Stream (SS) - Essentially a flat-spray nozzle with a circular spray pattern and a spray angle of 0 degrees, the SS nozzle has the highest velocity and impact per square inch. SS nozzles are often used for shearer-drum spray systems, including the pick-point flushing system.

IMPROVED CUTTING PARAMETERS

Any face personnel required to work adjacent to or on the return side of the shearer will be exposed to the large quantity dust produced by the cutting action of the shearer drums. However, modifications in cutting sequence and machine design can be used to reduce the amount of dust produced as well as the respirable dust exposure of most longwall face workers.

Modified Cutting Sequence

Double-drum, ranging-arm shearers are designed to mine the full longwall face in either or both directions. However, when mining in both directions, the shield setters must work downwind of the shearer during half of the mining cycle unless automated shields are used. Modifying the mining cycle to cut in only one direction can reduce this exposure to the shield setters. By cutting the main cut only with the leading drum, which is the primary source of dust generation, both shearer operators will be on the upwind-air-side of the shearer.

Two unidirectional cutting sequences are possible: head to tail and tail to head.

1. Main cut from head to tail.

Dust generated upwind from the shearer operators can be reduced by “freewheeling” the trail-

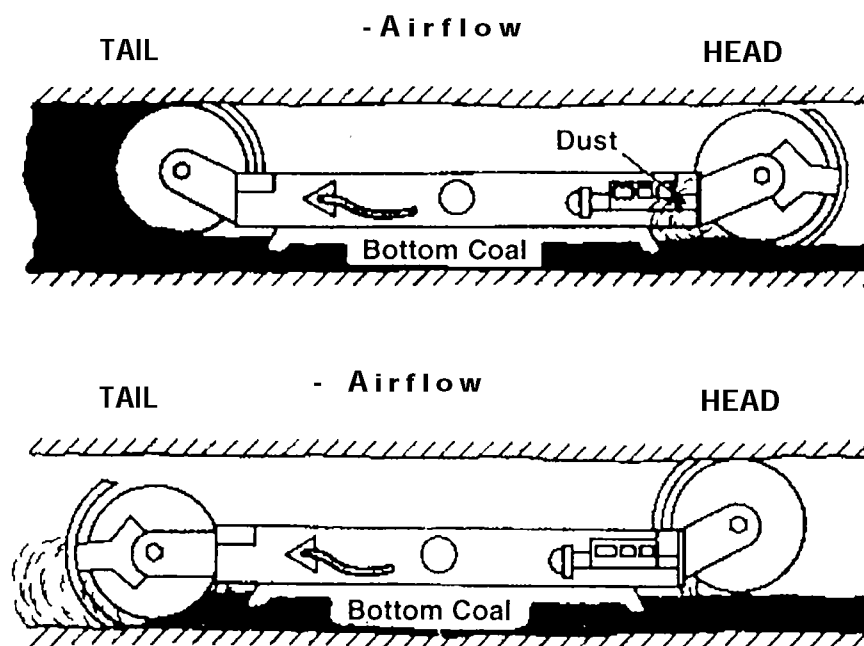


Figure 12. Main cut from head to tail

ing drum (head drum), cutting minimal coal with it. The tail drum can then mine the bottom coal during the tail-to-head clean-up pass (see Figure 12). Although the shield setters will be on the return-air side of the shearer while advancing the shields and pushing over the panline, they will be exposed to less dust from the clean-up cut than from the main cut.

2. Main cut from tail to head.

When the main cut is mined from tail to head and the clean-up cut is mined from head to tail, one shearer operator, shield setters, or other miners can move upwind of the shearer (or leave the face altogether) on the main cut. Only one shearer operator needs to remain on the face to operate the shearer and, if the shearer is

equipped with a radio remote control (see page 26), the operator can be positioned upwind of the head drum. The shields are advanced and the face conveyor is pushed on the clean-up cut. While this sequence places the shield setters on the upwind side of the shearer and eliminates exposure to any dust generated by the shearer, it exposes both shearer operators to the dust generated by shield movement.

Slow Speed Deep Cutting

Deep cutting with slow speed drums can substantially reduce the amount of dust generated during coal cutting. As deep cutting removes larger coal fragments, less coal surface is exposed. The lower rotating speed of the drums reduces the fanning action of the cutterheads and thus reduces the amount of dust that becomes airborne. Shearer power consumption is also significantly lower with slow speed deep cutting.

OTHER DUST CONTROL MEASURES

While improved ventilation, optimized water delivery, and modified cutting practices are the key elements of a longwall dust control system, there are other measures available that should be considered when designing a dust control strategy.

Roadway Dust Control

This source of background dust is generally low, but sometimes can affect workers when construction, supply haulage, and roadway grading or cleanup activities are being conducted in the section intake air entries during the production shift. If haulage activities must take place during a production shift, the haulage roadways must be kept damp. Since water is likely to evaporate in the ventilation air, a hygroscopic salt or effective dust allaying agent should be used.

Wetting Agents

Wetting agents (surfactants) are chemical water additives that reduce the surface tension of water and make it easier for the water droplet to wet a dust particle. Because such agents require a relatively long reaction time, their effectiveness in reducing dust generation during coal cutting is minimal. However, when applied at

the face, they will reduce dust generation at outby transfer points.

Foam Application

Foam application at the point where dust is generated will suppress dust close to its source and prevent it from becoming airborne. The use of a properly designed foam application system can reduce exposures and lower water consumption. Tests have shown that foam is more effective when applied directly at the point of dust generation, through the shearer drum sprays rather than through external sprays.

Water Infusion

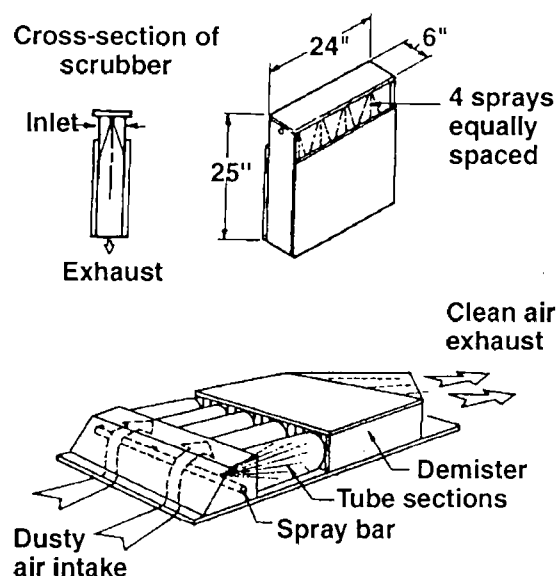
Water infusion increases the moisture content of the coal, reducing dust generation during mining. Longwall panels are infused by drilling horizontal holes from the development entries to the center of the panel. Water is then pumped through the prepared hole into the coal seam. The effectiveness of water infusion depends on the infused time and the amount of water the coal seam accepts (its infusability), which depends on cleat density (cleat spacing) and cleat size (crack diameter). If needed, the holes also can serve to de-gas the panel.

Spot Scrubber Systems

Spot scrubbers are installed on the crusher/stageloader or along the face to remove the dust

from a confined area. Because of their limited airflow capacity, spot scrubbers are limited to spot cleaning of a specific dust source. Confining the dust source through the use of barriers also helps to improve the dust collection and removal efficiency of the spot scrubber. Figure 13

Figure 13. Spot scrubbers



illustrates two designs: one consisting of a basic rectangular box incorporating four sprays, the other using a demister to remove the water from the cleaned

airstream for installation on the crusher/stage-loader.

Limiting Production

At times, production must be limited to maintain dust concentrations below the applicable standard when adverse mining conditions are encountered. These conditions may include mining before the initial roof fall, a roof fall at the tail, or an irregular face due to rock or roof conditions, resulting in a reduced face airflow. An estimate of production rates during adverse con-

ditions can be determined by proportioning production to the reduced airflow.

Remote Control Devices

Remote control devices enable shearer operators to control shearer functions from locations that are less dusty than their normal control stations. The two types are remote control units currently available are a wireless radio and an umbilical (hard wire) type. With either type, the head-drum operator can control the shearer from a distance up to 20 feet on the intake-air side (upwind) of the shearer. Because remote control devices do not reduce the amount of dust in the mine atmosphere, they should be considered administrative rather than environmental controls.

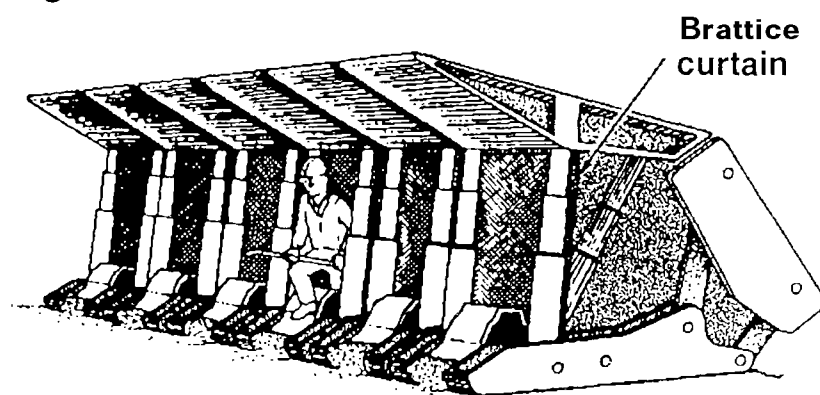
Bit Wear

Regular bit replacement is an essential part of any dust control program. A sharp bit acts as a wedge to split the coal, while a worn bit merely crushes the coal at the point of contact, increasing coal fines and dust. Studies of the effect of bit wear on dust generation found that dust concentrations increased considerably after a 7 percent bit wear loss and that bits should be changed at that point. Since bit wear is affected by machine operating parameters such as depth of cut, spray position, drum speed, and rock properties, it is important to check the condition of bits frequently and replace any that are worn.

Additional Dust Controls Before Initial Roof Fall

Using line brattice along the walkway and/or belting behind the shields can maintain adequate ventilation along the longwall face to dilute and carry away dust prior to the initial roof fall (see Figure 14). Line brattice and/or belting is suspended along the shields either in front (face side) of the rear legs if a 4-leg support system is used, or on the gob side of the legs of a 2-leg support system. In some support designs the canopy ends one foot from the base, resulting in a sizeable open area through which ventilation air can escape. The barrier curtain should extend to the base of the support to minimize air leakage into the gob.

Figure 14



High-Pressure Water Drum Sprays

High-pressure water drum sprays consisting of an inward-facing spray system and operated at 800 to 1200 psi can reduce dust generation, confine the dust to the face area, and reduce res-

pirable dust levels at and downwind of the shearer operators. Sprays are located in each bit block and are oriented 15 and 30 degrees toward the face. A water flow rate of 30 gpm per drum is desired.

On-Shift Examination of Dust Control Parameters

Regular on-shift checks of dust control parameters are required by 30 CFR 75.362(a)(2). These checks will ensure that the provisions of the operator's approved dust control plan are being followed. On-shift examinations involve both visual observations and measurements of control parameters stipulated in the plan.

Respiratory Protection

Respiratory protection should be provided and worn by workers when entering an area where they may be exposed to dust levels in excess of the applicable standard, or while controls are being installed. However, current regulations prohibit the use of respirators as a substitute for environmental controls. Such devices are intended to be used only as an interim control measure until adequate engineering controls are installed. For a respiratory program to be effective, respirators must be properly selected, fit tested, maintained, and worn, according to ANSI Standard Z88.2-1969, "American National Standards Practices for Respiratory Protection."

APPENDIX A:
DUST CONTROL CHECKLIST

This checklist can help you compare your mine’s ventilation plan and the dust control program in place.

CONTROL	PLAN	OBSERVED
Ventilation	_____cfm	_____cfm
Gob Curtain	_____	_____
Belt Air	_____	_____
Cut-Out Curtains	_____	_____
Headgate Enclosure	_____	_____
Sprays on Headgate	_____	_____
Headgate Dust Collector	_____	_____
Crossframe/Side Discharge	_____	_____
Belt at Openings	_____	_____
Electro Hydraulic Shields	_____	_____
Shield Adv. Downwind	_____	_____
Shield Adv. Upwind	_____	_____
Shields Washed Down	_____	_____
Shearer Clearer	_____	_____
Radio Remote Control		_____
Cord Remote Control	_____	_____

**A
D
U
S
T

C
O
N
T
R
O
L

C
H
E
C
K
L
I
S
T**

CONTROL	PLAN	OBSERVED
Drum Spray Pressure	_____ psi	_____psi
Spray Bar Pressure	_____ psi	_____psi
Shearer Body Spray Pressure	_____ psi	_____psi
Booster Pump	_____ rpm	_____ rpm
Drum Speed	_____ rpm	_____ rpm
Air Velocity-Head	_____	_____
Passive Barrier	_____	_____
Wetting Agent	_____	_____
Water Infusion	_____	_____
No One Downwind	_____	_____

APPENDIX B: ADDITIONAL READING

Background

U.S. Bureau of Mines. Longwall Coal Mine Respirable Dust Sources. *Technol. News*, No. 204, July 1984.

Guidebook for Dust Control in Underground Mining, Dec. 1981.

. How the Six Cleanest U.S. Longwalls Stay in Compliance. *Technol. News*, No. 151, July 1982.

Organiscak, J.A., et al. "Dust Control to Improve Quality of Longwall Intake Air." BuMines IC 9114, 1986, 8 pp.

Divers, E. Et al. *Guidelines for Dust Control in Small Underground Coal Mines*. BuMines Handbook, 1987, 32 pp.

Shirey, G.A., et al. *Dust Control Handbook for Longwall Mining Operations*. Contract Final Report #JO348000, BCR National Library, 1985, 223 pp.

Ventilation

Tomb, T.F. et al. *Evaluation of Respirable Dust Control on Longwall Mining Operations*. Trans. SMME., Vol. **288**, **1992**, pp, 1874-1878.

Haney, R.A. et al. *Influence of Airflow and Production on Longwall Dust Control*. Proceedings of the 6th U.S. Mine Ventilation Symposium, 1993, pp. 43-49.

U.S. Bureau of Mines. Reduce Dust on Longwall Faces With a Gob Curtain. *Technol. News*, No. 119, Nov. 1981.

. Ventilation Curtain Reduces Dust from Cutting into Longwall Entry. *Technol. News*, No. 137; March 1982.

. Spring Mounted Screens on Shearer Reduce Operators' Dust Exposure. *Technol. News*, No. 121, Dec. 1981.

. Airflow in Direction of Face Haulage Reduces Intake Dust. *Technol. News*, No. 145, Aug. 1985.

Water Delivery

Divers, E.F. *Nonclogging Water Spray System for Continuous-Mining Machines: Installation and Operating Guidelines*. BuMines IC 8727, 1976, 10 pp.

U.S. Bureau of Mines. Upgrading Longwall Water Supply Systems to Reduce Dust. *Technol. News*, No. 113, Oct. 1981.

. Lowering Dust Exposure by Relocating the Machine Cooling Water Sprays. *Technol. News*, No. 118, Nov. 1981.

. How to Size Components of Water Spray Systems. *Technol. News*, No. 75, Dec. 1979.

. More Water on the Upwind Drum Reduces Exposure of Shearer Operator to Dust. *Technol. News*, No. 155, Sept. 1982.

. Dust Knockdown Performance of Water Spray Nozzles. *Technol. News*, No. 150, July 1982.

. Selecting Water Spray Pressures for Optimum Dust Control. *Technol. News*, No. 244, April 1986.

. Pick-Point Drum Spray System Minimizes Longwall Shearer Operators Respirable Dust Exposure. *Technol. News*, No. 246, April 1986.

. Improved Shearer Clearer for Longwall Dust Control. *Technol. News*, No. 245, April 1986.

. Reducing Longwall Face Workers' Respirable Dust Exposure from Roof Support Movement. *Technol. News*, No. 205, Aug. 1984.

. Improved Stageloader Dust Controls in Longwall Mining Operations. *Technol. News*, No. 224, Aug. 1985.

. Stageloader Dust Control Reduces Longwall Intake Contamination. *Technol. News*, No. 156, Oct. 1982.

Cutting Parameters

U.S. Bureau of Mines. Modified Cutting Sequence Reduces Longwall Shearer Operators' Dust Exposure. *Technol. News*, No. 116, Nov. 1981.

. Reverse Drum Rotation Reduces Longwall Dust and Increases Coal Production. *Technol. News*, No. 284, Aug. 1987.

. Deep Cutting Double Arm Shearer. *Technol. News*, No. 111, Oct. 1981.

Other Measures

U.S. Bureau of Mines. Novel Foam Application Reduces Longwall Dust. *Technol. News*, No. 326, March 1989.

Mukerjee, S.K. and Singh, M.M. "New Techniques for Spraying Dust." *Coal Age*, June 1984, pp. 54-56.

U.S. Bureau of Mines. Water Infusion May Reduce Longwall Worker's Dust Exposure. *Technol. News*, No. 280, June 1987.

. Water Powered Scrubber Reduces Longwall Tailgate Workers' Dust Exposure. *Technol. News*, No. 182, Sept. 1983.

. High Pressure Inward-Facing Drum Sprays Reduce Dust Levels on Longwall Mining Sections.. *Technol. News*, No. 346, Aug. 1989.

Khair, A.W. et al. "Regular bit replacement reduces dust generation." *Coal*, Vol. 98, No. 5, May 1993, p. 67.

Other Measures

U.S. Bureau of Mines. Novel Foam Application Reduces Longwall Dust. *Technol. News*, No. 326, March 1989.

Mukerjee, SK. and Singh, M.M. "New Techniques for Spraying Dust." *Coal Age*, June 1984, pp. 54-56.

U.S. Bureau of Mines. Water Infusion May Reduce Longwall Worker's Dust Exposure. *Technol. News*, No. 280, June 1987.

. Water Powered Scrubber Reduces Longwall Tailgate Workers' Dust Exposure. *Technol. News*, No. 182, Sept. 1983.

. High Pressure Inward-Facing Drum Sprays Reduce Dust Levels on Longwall Mining Sections.. *Technol. News*, No. 346, Aug. 1989.

Khair, A.W. et al. "Regular bit replacement reduces dust generation." *Coal*, Vol. 98, No. 5, May 1993, p. 67.

