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Respirable Dust Sources and Controls on Continuous Auger Mining Sections

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BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cfm	cubic foot per minute	min	minute
fpm	foot per minute	pct	percent
ft	foot	s	second
in	inch		

RESPIRABLE DUST SOURCES AND CONTROLS ON CONTINUOUS AUGER MINING SECTIONS

By J. Drew Potts,[1] Robert A. Jankowski,[2] and George Niewiadomski[3]

ABSTRACT

The U.S. Bureau of Mines identified respirable dust sources and controls on four continuous auger mining sections, two with relatively low dust levels and two with high levels. Factors adversely affecting dust levels included auger equipment design, continuous haulage, and low seam height. Dust controls included ventilation practices and spray systems.

Maximizing airflow seemed to reduce dust levels most. Air leakage and shock loss can be reduced by constructing stoppings with brushed-on mortar containing fiberglass and by keeping areas between curtains and ribs free from obstructions and storing equipment not essential for face activities in outby crosscuts. Curtain configuration, setback distance, and installation can also affect dust levels. Use of both blowing and exhausting curtains is the most effective configuration. Setbacks from the face should not exceed 15 ft. Installing brattice curtains at least 5.5 ft from ribs, when entries are 26 ft wide, minimizes velocity head. Installing curtains tightly against the mine roof and floor helps maintain a forward airflow movement in the center of the mine heading; curtain overlap can create a tighter seal. The wet-auger spray system also effectively controls dust, provided the mine is already exercising good ventilation practices.

[1]Mining engineer, Pittsburgh Research Center, U.S. Bureau of Mines, Pittsburgh, PA.
[2]Supervisory physical scientist, Pittsburgh Research Center.
[3]Mining engineer, U.S. Mine Safety and Health Administration, Arlington, VA.

INTRODUCTION

Federal dust standards have been mandated to reduce the incidence and progression of coal miners' pneumoconiosis. Data collected by the U.S. Mine Safety and Health Administration (MSHA) show that auger mining operations continue to experience dust control problems, which affects their ability to comply with these standards on a continuous basis. Many auger operations require miners (jacksetters and helpers) to work inby the mining machine operator in areas of high dust. Return-side jacksetters and helpers work in return air, and MSHA has identified these workers as being in "designated occupations." Mine operators must take bimonthly samples at the locations of these designated occupations to establish compliance with the applicable respirable dust standard.

Many auger mining operations have a history of compliance problems, while others maintain compliance on a more continuous basis. This difference in compliance histories led researchers at MSHA and the Bureau of Mines to believe that a gap in control technology existed. At the request of MSHA, the Bureau undertook a fact-finding study with two objectives: first, to identify the factors affecting the respirable dust levels on continuous auger sections, and second, to identify the mining practices that reduce respirable dust levels. This study conformed with the Bureau's goal to create a healthier underground work environment. The Bureau conducted four underground surveys and an extensive review of previous research. This report presents the findings of the study in order to reduce the technology gap that appears to exist between auger mines with high respirable dust levels and auger mines with low levels.

ACKNOWLEDGMENTS

The authors thank Tom Mal, mining engineering technician, Pittsburgh Research Center, for his recommendations concerning data collection and interpretation. The assistance of the mining companies that participated in this study is also greatly appreciated.

SAMPLING PROCEDURES

The Bureau conducted the respirable dust surveys with gravimetric samplers, a real-time aerosol monitor (RAM), and a recording vane anemometer. The gravimetric measurements of respirable dust represent production time only. The shift-average dust levels were not measured. The RAM measures respirable dust in relative units and was used to measure fluctuations in respirable dust at each mine.

The dust-surveying equipment was used at various positions throughout the mining section. Two gravimetric samplers and the recording vane anemometer were placed in intake air. Two gravimetric samplers and the RAM were placed at the miner operator's position. Gravimetric samplers were also used at the intake and return jacksetter positions and in the return airway.

AUGER DUST SOURCES

The Bureau identified three main factors that adversely affect respirable dust levels on continuous auger mining sections: auger equipment design, continuous haulage, and low seam height.

EQUIPMENT DESIGN

The Mark 20 and 21 mining machines, manufactured by Fairchild, International, are the most frequently used continuous auger miners. Their simple designs and low operating costs make them popular choices for low-coal mining. However, their unique method of advance and cutting can cause dust control problems.

The Mark 20 mining machine advances across the active face, using steel winching cables attached to jacks. Jacksetters wedge the anchor jacks between the roof and floor of the mine. They are required to work 5 to 10 feet inby the miner operator on the intake and return sides of the mining machine (fig. 1). The Mark 21 mining machine advances by automated jacks; however, helpers are still needed inby the mining machine operator to shovel coal and set timbers. Thus, return-side jacksetters and helpers must work in the mining machine's return air.

The auger mining machine's method of advance can also create a very jagged rib configuration (fig. 1). A jagged rib causes significant area expansion and contraction head losses on air coursed between the ribs and curtains.

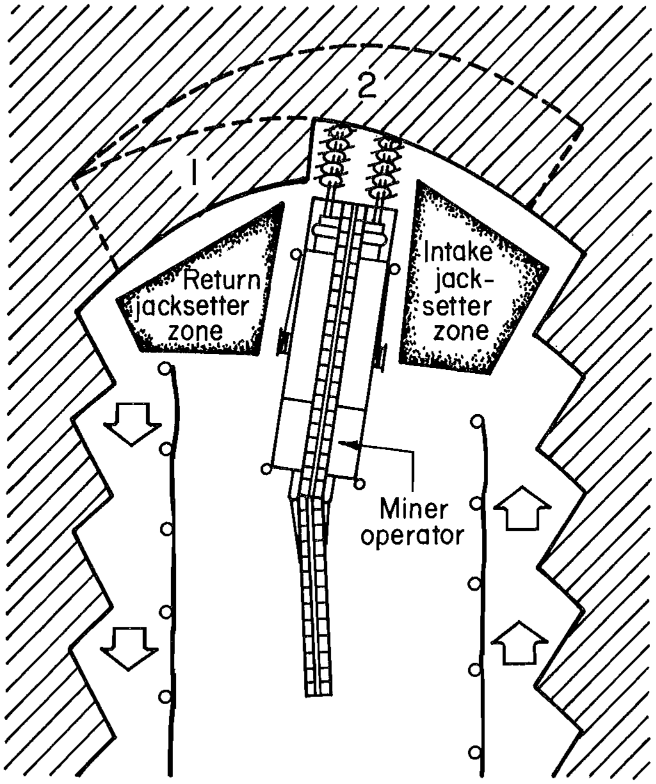

Figure 1.—Face worker positions and jagged rib configuration.

CONTINUOUS HAULAGE

The Mark 20 and 21 mining machines use continuous haulage to transport coal from the face to the main haulage line. Continuous haulage can reduce the efficiency of the ventilation network by restricting airflow in two ways. First, it creates the need for longer brattice lines because the curtains cannot be hung across the bridge conveyor; brattice lines of 100 ft are common. Second, the restricted maneuverability of the bridge conveyor limits the mine to a three-entry development plan. Both of these conditions increase the pressure head requirement of the main fan by restricting airflow.

Another problem with continuous haulage *(1)*[4] results from the inability to turn all crosscuts from intake to return air. At times, the mining machine must hole into the intake airway. This occurs when the mining machine turns a crosscut from the belt entry to the intake entry. During this cut, intake air forces the dust that is being generated at the face over the face workers. Continuous haulage can also be a source of intake dust. Coal dust becomes entrained in the airstream because of particle bounce created by conveyor vibration. However, continuous haulage did not appear to be a significant intake dust source at any of the four mines surveyed for this study.

LOW SEAM HEIGHT

The Mark 20 and 21 mining machines are about 24 in high. The average seam thickness of the four mines surveyed was 35 in. Thus, clearance between the top of the mining machine and the mine roof averaged less than 1 ft. Limited clearance, as well as the auger mining machine's method of cutting, creates a unique respirable dust problem for the miner operator and intake jacksetter.

Limited clearance causes a portion of intake air to circulate toward the rear of the mining machine instead of across the face. This air becomes laden with dust that boils out from the leading auger head when the mining machine is cutting toward the intake blowing curtain (fig. 2). The respirable dust exposures of the miner operator and intake jacksetter increase significantly during these cuts. The Bureau measured this condition at mine D. Figure 3 shows the relative respirable dust exposure levels of mine D's mining machine operator during a sampling period from 11:16 to 11:25 a.m. A RAM was used to measure the average dust levels during each minute of the sampling period. From 11:16 to 11:20 a.m., the mining machine was cutting toward the return curtain and the average dust exposure level of the miner operator was 2.79 RAM units. From 11:21 to 11:25 a.m., the mining machine was cutting toward the intake curtain and the average dust exposure level of the miner operator was 8.33 RAM units; the dust exposure level of the miner operator tripled when the mining machine cut toward the intake blowing curtain. Potential solutions to this situation are discussed in the section entitled "Spray Systems."

[4]Italic numbers in parentheses refer to items in the list of references at the end of this report.

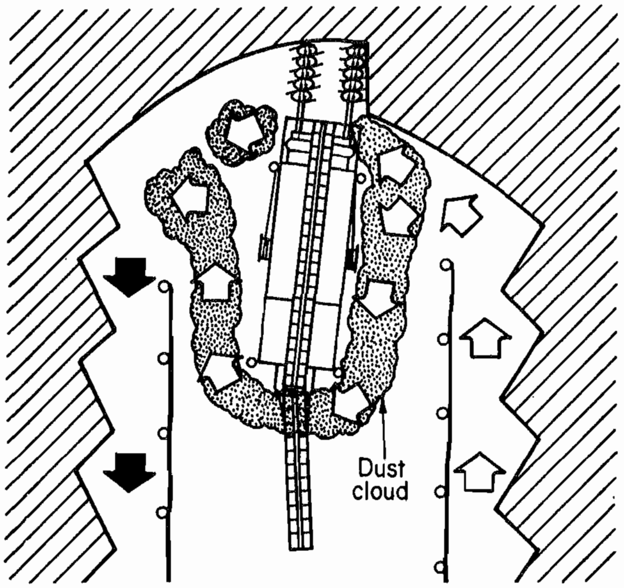

Figure 2.—Air and dust courses when miner cuts toward blowing curtain.

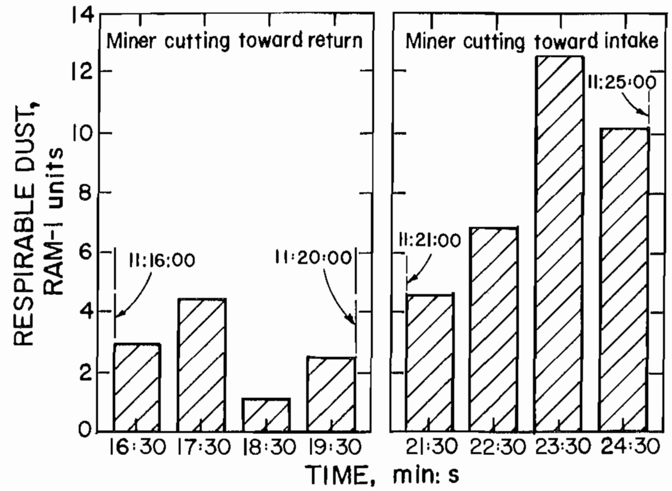

Figure 3.—Respirable dust exposures of miner operator (mine D).

EXISTING CONTROLS

The Bureau identified two main components of respirable dust control on continuous auger mining sections: good ventilation practices and the wet-auger spray system.

VENTILATION

Of the four mines surveyed for this study, two (mines A and B) were unable to effectively control respirable dust. The other two mines (C and D) were much more effective at controlling the dust levels. The most obvious differences between the mines with high dust levels and the mines with relatively low levels were the ventilation practices. Important ventilation parameters include airflow (air leakage and shock loss), curtain configuration, curtain setback distance from the face, and curtain installation.

Table 1 shows the characteristics of each mine. In general, mines C and D had more effective ventilation systems for dust control than mines A and B. Mines C and D delivered more air to the section and used the dual-curtain configuration to ventilate the active face. Mines C and D also advanced the curtains concurrently with the mining machine, while maximizing the distance between the curtains and ribs. Mine D practiced a unique and effective ventilation technique: the brattice lines followed the mining machine across the active face, forcing air across it (fig. 4).

Table 2 shows the results of the gravimetric surveys of each mine. Face workers at mines C and D were exposed to much less respirable dust than face workers at mines A and B.

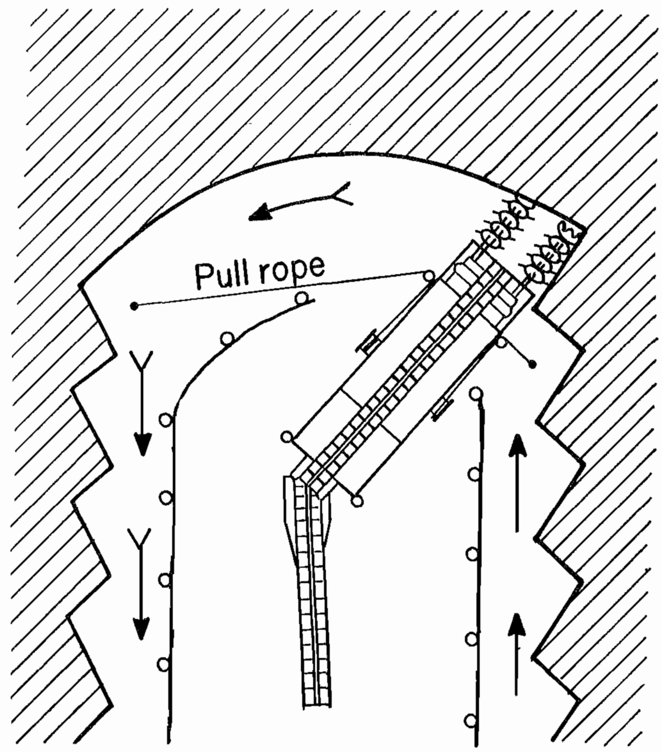

Figure 4.—Brattice lines follow miner across face (mine D).

TABLE 1.—Characteristics of mines surveyed

	Mine A	Mine B	Mine C	Mine D
Mining technique	2-entry advance, 3d retreat.	2-entry advance, 3d retreat.	3-entry	3-entry.
Miner model	Mark 20	Mark 20	Mark 21	Mark 20.
Mining height . . . in	39	27	34	40
Room and crosscut width . . . ft	28	30	26	26.
Stopping construction	Troweled-on mortar	Wood fiber mortar	Troweled-on mortar	Fiberglass fiber mortar.
Roof control	Full timber, spot bolting.	Full timber	Full bolting and timbers.	Full bolting and timbers.
Distance of face from portal . . . ft	4,000	5,000	3,000	1,300
Ventilation:				
Fan capacity . . . cfm	65,000	60,000	69,000	68,000.
Airflow, last open crosscut . . cfm	2,000	3,000	10,000	15,000.
Curtain configuration	Dual curtain	Blowing curtain	Dual curtain	Dual curtain.
Curtain setback:[1]				
Intake . . . ft	18	13	15	11.
Return . . . ft	20	NAp	17	11.
Distance between curtain and ribs . . . ft	3-4	3-4	4-5	5-6.
Spray system	Spray bar	Wet auger	Wet auger	Spray bar.

NAp Not applicable.
[1]Average distance from end of ventilation curtain to face.

TABLE 2.—Results of gravimetric dust surveys,[1] concentrations in milligrams per cubic meter

Mine	Intake	Intake jacksetter or helper	Miner operator	Return jacksetter or helper	Return
A	0.88	29.1	29.8	49.1	28.6
B	.75	2.89	11.6	57.7	NAp
C	.09	1.26	1.26	8.42	8.25
D	.08	.09	3.46	9.91	10.3

NAp Not applicable
[1]Measurements represent production time only; they are not shift-average samples. Concentrations shown are 3-day averages.

Airflow

Maintaining adequate airflow to the section is a critical element of effective face ventilation. Delivering more air to the active face will dilute the generated dust more effectively. Increasing the air quantity will also result in higher air velocities, and more air will penetrate across the restricted auger face. A comparison between mines A and C demonstrates the importance of this parameter.

The most striking difference between mines A and C (table 1) was airflow. Mine C had good airflow, with over 10,000 cfm measured just outby the intake brattice line. Mine A had poor airflow, with less than 2,000 cfm measured at the same position. Mine C's miner operator was exposed to 95 pct less respirable dust than mine A's miner operator (table 2). Mine C's intake helper was exposed to 95 pct less dust than mine A's intake jacksetter. Mine C's return helper was exposed to 80 pct less dust than mine A's return jacksetter. These results clearly demonstrate the benefits of good airflow for dust control. The mine operator can maximize airflow by eliminating sources of air leakage and shock loss.

Air Leakage

Mines A and C used dry stacked concrete blocks and troweled-on mortar to construct stoppings. However, the Bureau has shown *(2)* that brushed-on mortar containing fiberglass additives reduces air leakage between entries. Fiberglass additives increase the adhesiveness and strength of the mortar. Brushing fills cracks and joints more effectively and creates a tighter seal against air leakage. Only one coat of 1/8-in-thick mortar is necessary for pressure differentials of less than 5 in water gauge. Improved stoppings reduce air leakage by 50 pct at low pressure (<2 in water gauge), 65 pct at medium pressure (2 to 5 in water gauge), and 94 pct at high pressure (>5 in water gauge). Reduced leakage improves the efficiency of the ventilation network, allowing more air to reach the active section.

Shock Losses

Reducing shock loss increases the efficiency of the ventilation network. Keeping the entries and areas between the curtains and ribs free from obstructions is essential for efficient ventilation.

Mine D parked the bolting machine between the blowing curtain and rib at least once during the study. Mine D allowed 5.5 ft between the blowing curtain and rib and had a seam thickness of 3.3 ft. The bolting machine was 5 ft wide and 2 ft high and occupied about 55 pct of the cross-sectional area between the blowing curtain and rib. The bolting machine created a significant obstruction shock loss and increased air leakage.

The Bureau estimated the effect of this obstruction on face ventilation in a full-scale mock auger mine heading, equipped with a full-scale mock auger miner and bridge conveyor. The bolting machine obstruction and the conditions observed at mine D (table 1) were simulated in the heading. Before the mock bolting machine was placed in the aircourse, a 50-pct leakage of air along the blowing curtain line was built into the face ventilation system. Leakage is frequently over 50 pct *(3)*, even with a well-maintained brattice line. Parking the mock bolting machine between the blowing curtain and rib resulted in a 32-pct increase in air leakage along the blowing curtain line. Thus, less air was able to penetrate to the face. On an actual auger mine section, this condition would result in less effective dust dilution and higher dust exposure levels for all face workers.

Parking the bolting machine in the last open crosscut would significantly improve the effectiveness of the face ventilation system at mine D. The bolting machine would occupy only 10 pct of the cross-sectional area of the last open crosscut, and it would still be convenient to face operations in this location. However, all scoops, mantrips, and other large equipment not essential to face operations should be stored in outby crosscuts.

Timbers stored between the ribs and brattice curtains create another obstruction shock loss. Most of the mines visited during this study had room to store timbers between the blowing curtain and the exhausting curtain. This area is convenient to face operations, and locating the timbers in neutral air eliminates a source of shock loss. Face workers should also keep the areas between the curtains and ribs free from roof and rib fall material. Eliminating these shock losses assures the mine operator that more air will reach the face without increasing the main fan's power consumption.

Curtain Configuration

Most continuous auger operations use the dual-curtain configuration to ventilate the active face, using both a blowing curtain and an exhausting curtain to direct air to and from the face. The two curtains are essential for effective auger mine face ventilation.

The American Conference of Governmental Industrial Hygienists (ACGIH), Committee on Industrial Ventilation *(4)*, has shown that air blown from an opening retains its directional effect over a much greater distance than air exhausted through the same-size opening (fig. 5). This characteristic of blowing ventilation can be used by the auger mine operator to more effectively force air across the restricted face.

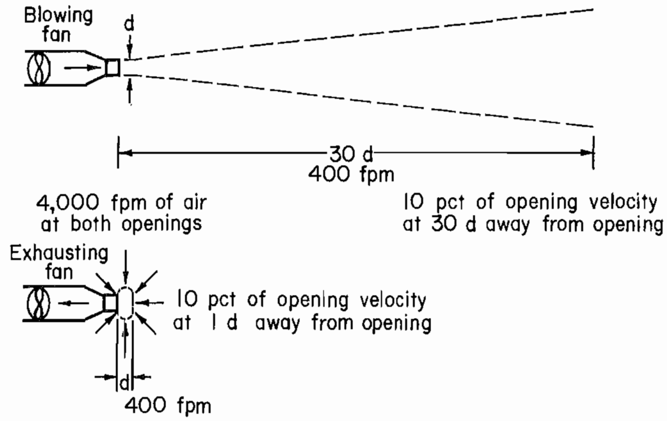

Figure 5.—Directional effect of blowing and exhausting ventilation (d = diameter).

The exhausting curtain can keep the air in the auger mine heading moving toward the face, providing for better dilution of generated dust in the return jacksetter's zone. This is only true, however, if the airflow quantity behind the exhausting curtain is greater than that behind the intake curtain. Maintaining a tight exhausting curtain seal helps to ensure a proper intake-return airflow balance.

Curtain Setbacks

Data collected from a recent tracer gas study by Foster-Miller, Inc. *(1)*, show the importance of maintaining proper curtain setback distances from the face. In general, the face workers should keep the intake and return curtains as close to the face as possible. The dust exposures of the intake and return jacksetters are critical because of their proximity to the dust source.

Foster-Miller constructed a testing gallery designed to simulate an auger mine heading for the curtain setback study. It was 82 ft long, 18 ft wide, and 3 ft high. The gallery was equipped with a full-scale model of a Mark 20 mining machine and bridge conveyor. It was ventilated with a dual-curtain configuration, and 1,000 cfm of air was maintained at the mouth of the return curtain throughout the testing. Tracer gas was released from a pipe manifold at the leading auger head to simulate respirable dust generation. Tracer gas concentrations were monitored in the intake and return jacksetter zones. The test variables included mining machine cutting direction and curtain setbacks from the face. The cutting direction variable included cutting toward the return curtain and toward the intake curtain.

Figure 6 shows how dual-curtain setbacks of 15, 20, 25, and 30 ft affected the tracer gas levels at the intake and return jacksetter zones. Moving the curtains from 15 ft to 20 ft away from the face produced the largest degradation in face ventilation. The 15-ft setback was 65 pct more effective than the 20-ft setback in controlling tracer gas at the intake jacksetter zone. The 15-ft setback was 40 pct more effective at the return jacksetter zone. Moving the curtains from 20 ft to 25 ft away from the face continued to produce significant degradations in face ventilation. It is critical for mines to keep the blowing and exhausting curtains no more than 15 ft from the face.

Curtain Installation

The important elements of curtain installation include maximizing the distance between the curtains and ribs, and maintaining tight curtain seals.

Maximizing the distance between the ribs and curtains reduces the resistance to airflow. Mines A and B could have significantly increased this distance. Mine C allowed 4.5 ft between the ribs and brattice curtains, and drove 26-ft-wide entries. Mine D allowed 5.5 ft between the ribs and brattice curtains, and also drove 26-ft-wide entries. Mines A and B allowed only 3.5 ft between the ribs and brattice curtains, and drove 28- and 30-ft-wide entries, respectively. Mines A and B could increase the distance between the curtains and ribs by at least 2 ft. Increasing this distance decreases the velocity head loss and allows more air to reach the face.

Maintaining tight curtain seals helps keep the air in the center of the mine heading moving toward the face. A few simple techniques *(5)* will assure tight brattice seals.

Mines A and B hung the curtains from timbers. Mines C and D predominantly used timbers; however, they also occasionally hung the curtains from bolt plates. Using the mine's natural air pressure to force the curtains against the timbers will improve the curtain seals. Setting the timbers between the exhausting curtain and rib forces the exhausting curtain against the timbers. Conversely, placing the blowing curtain between the timbers and rib forces the blowing curtain against the timbers.

Curtain overlap at the roof and floor of the mine can also be used to improve the curtain seal. Placing rocks, timbers, or lumps of coal on the curtain at the floor reduces gaps. If the roof is soft, attaching the curtain to the roof between the timbers with nails reduces curtain sag. If the roof is hard, additional timbers may be necessary to reduce sag.

SPRAY SYSTEMS

The Bureau observed two different auger miner water spray systems during the study. Mines A and D used an externally attached spray bar to wet the face. Mines B and C used "through-the-drum" sprays. The through-the-drum spray system uses a transfer mechanism to pass water from the mining machine body to sprays located on the shells of the hollow auger cutting drums. The mining industry commonly refers to the through-the-drum spray system as the "wet-auger spray system." A 1975 study *(6)* showed that the wet-auger system was 60 pct more effective than the spray-bar system in reducing the respirable dust generated from each ton of coal mined.

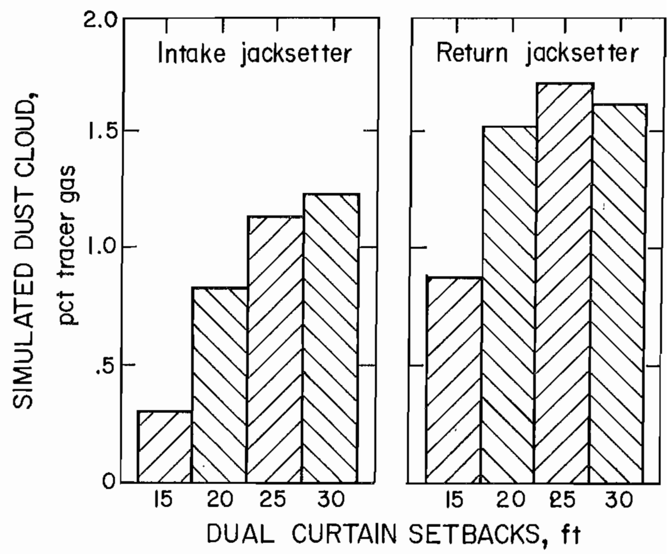

Figure 6.—Effect of various curtain setbacks on tracer gas levels in jacksetter zones.

However, a comparison between mines B and D (table 1) shows the limitation of the wet-auger spray system. Mine B neglected good ventilation practices and was unable to effectively control respirable dust with the wet-auger spray system, whereas mine D used an external spray-bar system and was still able to control dust with good ventilation practices. Mine D's intake jacksetter was exposed to 97 pct less respirable dust than mine B's intake jacksetter. Mine D's return jacksetter was exposed to 83 pct less dust than mine B's return jacksetter. These results show that the wet-auger spray system is not a substitute for good ventilation practices.

Both the wet-auger system and the spray-bar system were designed to prevent dust from becoming entrained in the airstream. The Bureau is now studying an "auger clearer" spray system that used directional sprays to promote airflow across the face. The auger clearer spray system was designed to confine the dust cloud to the face while moving it toward the return. This may remedy the air restriction problem caused by limited clearance between the mining machine and mine roof. The Bureau is also investigating the potential use of a high-pressure wet-auger spray system. An increase in spray pressure increases the effective surface area of the spray by reducing the mean water droplet size. An increase in water surface area should increase the dust knockdown potential of the spray.

CONCLUSIONS AND RECOMMENDATIONS

The Bureau study found that factors adversely affecting respirable dust levels included equipment design, continuous haulage, and low seam height.

The auger mining machine's method of advance places workers directly in return air. It also creates a jagged rib configuration, which results in reduced ventilation effectiveness because of significant area expansion and contraction losses.

Continuous haulage limits the mine to a three-entry development plan and requires longer runs of brattice curtain. Both of these conditions increase the ventilation head requirement of the main fan. Continuous haulage also creates the inability to turn all crosscuts from intake to return air. This condition results in high dust exposures for all face workers when the mining machine must poke through to the intake airway.

Low seams restrict air movement across the face, resulting in higher dust exposure levels for all face workers because of increased dust rollback.

The mine operator can do a number of things to control or minimize respirable dust exposures. Dust controls include good ventilation practices and the wet-auger water spray system. Important ventilation parameters include airflow (air leakage and shock loss), curtain configuration, curtain setback, and curtain installation.

Airflow can be maximized by eliminating sources of air leakage and shock loss. Constructing stoppings with brushed-on mortar containing fiberglass additives reduces air leakage between the entries. Eliminating sources of shock loss improves the efficiency of the ventilation network. Storing the bolting machine and other equipment essential to face operations in the last open crosscut, instead of between the curtains and ribs, controls one source of shock losses. Mantrips and other equipment not used at the face should be stored in outby crosscuts. Face personnel can also reduce shock losses by removing timbers, roof bolts, and roof and rib fall material from the areas between the curtains and ribs.

The dual-curtain configuration is the most effective curtain arrangement. It forces air across the face, while keeping the air in the center of the heading moving toward the face.

A Bureau-funded contract study that used a tracer gas to simulate dust generation showed that curtain setbacks should not exceed 15 ft. The efficiency of curtains in controlling dust decreases dramatically when they are moved from 15 ft to 20 ft from the face.

The important elements of brattice installation include maximizing the distance between the curtains and ribs, and maintaining tight curtain seals. Face workers should keep the brattice curtains at least 5.5 ft from the ribs when the entries are at least 26 ft wide. Tight curtain seals will keep the air in the center of the heading moving toward the face. A few simple techniques will assure tight brattice curtain seals. It is important to use the mine's air pressure to force the curtains against the timbers: the blowing curtain should be installed on the inside of the timbers, and the exhausting curtain on the outside of the timbers. Curtain overlap should be maintained at the roof and floor of the mine. Placing lumps of coal, rock, or timbers on the curtain overlap at the floor will improve the curtain seal. If the roof is soft, attaching the curtain to the roof between the timbers with nails will reduce curtain sag. If the roof is hard, additional posts may be necessary to reduce curtain sag.

The wet-auger spray system is another effective means of dust control. A previous study showed that the wet-auger system was 60 pct more effective than a spray-bar system at reducing the respirable dust generated from each ton of coal mined. However, the wet-auger spray system is not a substitute for good ventilation practices.

The Bureau is conducting research to evaluate additional auger mining dust control techniques. Project areas include an auger clearer spray system and a high-pressure wet-auger spray system. Future Bureau publications will report on these projects.

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