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DUST CONTROL HANDBOOK FOR LONGWALL MINING OPERATIONS

Contract J0348000

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FOREWORD

This report was prepared by BCR National Laboratory, Monroeville, PA under USBM Contract No. J0348000. The contract was initiated under the Mining Research Program. It was administered under the technical direction of the Pittsburgh Mining and Safety Research Center with Mr. Robert A. Jankowski acting as Technical Project Officer. Mr. Joseph A. Gilchrist was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period April 1984 to May 1985. This report was submitted by the authors in May 1985.

No patentable inventions resulted from this contract.

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1. INTRODUCTION

The use of the longwall mining method for coal extraction in the United States has steadily increased since its inception in 1960, with 112 systems operable in 1984 (1)*. This increase is attributed mainly to the many advantages longwall mining offers over other mining methods, including higher productivity, improved safety, and a greater recovery of reserves. However, there are obstacles in realizing the full potential of the longwall system; one of the more severe problems is the control of respirable dust to comply with the Federal dust standard of 2 mg/m^3, the maximum average daily concentration of respirable dust to which coal miners can be exposed.

Dust exposures on longwall faces are, in general, significantly higher than in other mining environments. The problem is most severe at operations employing double-drum shearers; many have not been able to consistently comply with the dust standard. Longwall operators, often in cooperation with the U.S. Bureau of Mines (USBM) and the Mine Safety and Health Administration (MSHA), have developed a number of practices and techniques designed to reduce the dust exposure of all longwall face workers. Although significant progress has been achieved, especially in the last five years, the problem of maintaining dust concentrations at acceptable levels continues to impede progress towards realizing the full potential of the longwall mining method.

This manual is directed at those mine-level personnel responsible for selecting, implementing, modifying, and maintaining dust-control systems for longwall mining operations. The handbook summarizes

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*Underscored numbers in parentheses refer to list of references presented at the end of each chapter.

the current state-of-the-art, presents novel and effective control techniques--as well as those techniques proven ineffective, outlines the advantages/disadvantages of available control techniques, specifies essential design and operating parameters, and presents implementation and maintenance guidelines. Manual content primarily addresses control of respirable dust, but it should be remembered that any technique effective in reducing respirable dust should also be effective in the control of float dust.

Several effective dust-control techniques must be utilized in combination, as no single technique can reduce longwall dust concentrations to compliance levels. Techniques used for controlling exposure to respirable dust are typically grouped into the following categories (2):

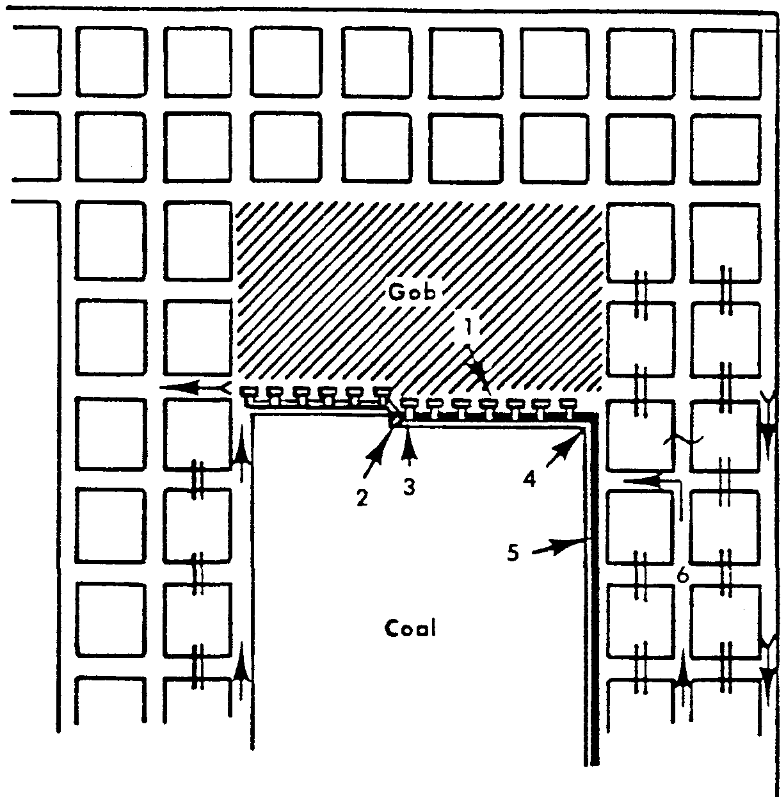
- Reduction of dust generated
- Suppression
- Dilution
- Capture or knockdown
- Extraction
- Avoidance

Each of these categories will be discussed throughout the handbook as various dust-control techniques are described. Chapter 1 will conclude with a brief description of the dust sources typically encountered on a longwall panel and a discussion of factors commonly associated with operations having the least and most difficulty complying with dust standards. Chapters 2 through 4 will describe control techniques proven effective and practical in achieving compliance with the dust standard, while Chapter 5 presents those methods found to be ineffective and/or difficult to implement. Details and results of recent and on-going research studies are discussed in Chapter 6, while Chapter 7 addresses dust-control systems utilized on panels equipped with plows. Chapter 8 describes various personal protective devices available to longwall workers. Information on spray nozzle design and selection, coal cutting and machine design, and appropriate sampling procedures for assessing effectiveness of control techniques is included in Appendices A, B, and C, respectively; Appendix D lists manufacturers and suppliers of novel dust-control systems. References are included at the end of each chapter for those seeking more detailed information, and an index is provided to help locate specific topics.

DUST SOURCES

As shown in Figure 1, a variety of dust sources exist on longwall faces (3). The relative contribution of each to overall airborne dust concentrations may vary from one face to another. Typically, the major source of dust results from the cutting and loading of coal by the shearer. Additional sources of airborne dust which may contribute significantly to the total airborne dust along the face include the conveying of coal by the armored face conveyor; coal-transfer points between the face conveyor, stage loader, and section belt conveyor; use of a crusher in the headgate entry; advancement of roof supports; and the contamination of intake air caused by the transportation of materials and personnel.

During a U.S. Bureau of Mines' survey of six longwall operations (4), five primary dust sources were identified: intake dust, dust generated by coal transport and the stage loader, dust generated during movement of the roof supports, dust generated by the shearer during the cut pass (primarily a result of the drums' cutting action), and dust generated by the shearer during the cleanup pass (loading of cut material and trimming of bottom rock). Table 1 lists the contribution of



Dust Sources:

1. Roof Support Movement
2. Shearer, Cutting of Coal
3. Coal Falling onto Panline
4. Transfer Point/Stage Loader/Crusher
5. Belt
6. Intake Air Contamination

Figure 1. Dust Sources on Longwall Sections

each source to the total respirable dust exposures of the longwall shearer operators. At four of the six operations surveyed, the major source of dust was the shearer during the cut pass. For these four operations, the contribution ranged from 47 to 60 percent of the total respirable dust exposures of the longwall shearer operators. As shown in Table 1, the dust generated by the shearer

TABLE 1. CONTRIBUTION OF PRIMARY DUST SOURCES TO OVERALL DUST LEVELS

Dust Source	Percentage of Total Operator Dust Exposure	
	Range	Average
Intake	1-9	6
Stage loader-coal transport	13-64	33
Support movement	0-31	12
Shearer		
Head-to-tail cut pass	0-60	35
Head-to-tail cleanup pass	15-50	32
Tail-to-head cut pass	0-47	20
Tail-to-head cleanup pass	4-20	10

during the cleanup pass can be a significant factor in overall dust levels, contributing as much as 50 percent to the operators' total exposure. The surveys also indicated that, on the average, dust generated from sources other than the shearer (i.e., intake, stage loader-coal transport, and support movement) accounts for one-half of the total respirable dust exposures of the shearer operators. Although in most instances the shearer is the primary dust source, and the major control efforts should be directed at it, secondary sources--in particular, coal-transport systems and movement of roof supports--should not be overlooked. Depending upon the particular operation, additional controls on the shearer may not have much effect on dust levels at the operator's position, since the source of exposure is not the shearer.

Another study conducted on five longwall faces resulted in the data shown in Table 2 (5). Dust concentrations were measured along the face to determine the contribution of the three major sources to overall face dust levels. The greatest dust production occurred when the shearer cut upwind from tailgate to headgate; dust concentrations resulting from the movement of roof supports and transporting of coal by the face conveyor were typically 20 to 30 percent of those levels produced during cutting and sumping operations.

A common fallacy that exists in the industry today is that high respirable dust exposures are always associated with high-production longwall panels. This belief is contradicted by dust surveys conducted by MSHA on 29 longwall operations during the years 1971-1974 and 1980-1982(6,7). The results of these surveys indicate that no correlation exists between tonnage and respirable dust exposure; rather, the exposure of the designated occupation was more dependent on the effectiveness of the techniques used to control dust than on the amount of coal produced.

TABLE 2. MAJOR LONGWALL DUST SOURCES

Source	Dust Concentration, mg/m³
Roof Supports	0.6-0.8
Face Conveyor	1.1
Shearer	
Tramming (Clean-up pass)	0.9-2.0
Cutting to tailgate	3.0-3.3
Cutting to headgate	3.3-4.4
Sumping at tailgate	3.8
Sumping at headgate	3.1-3.8

BASIC PARAMETERS FOR BETTER DUST CONTROL

In the early 1980's, the U.S. Bureau of Mines conducted extensive dust-measurement surveys at 12 longwall sections utilizing double-drum shearers (4,8); six of the sections are regularly in compliance with the Federal dust standard, while the other six operations were identified as having the most difficulty complying with the standard. The objective of the program was to identify the dust-control techniques proven to be most effective on the "clean" faces, and those factors contributing to high respirable dust levels on the six "dusty" faces.

Table 3 lists the cutting parameters and dust-control procedures employed at the 12 faces. Although the average values for both the "clean"

TABLE 3. COMPOSITE OF SIX "CLEANEST" AND SIX "DUSTIEST" LONGWALL OPERATIONS

	Six Cleanest Faces	Six Dustiest Faces
Cutting height, in.	53-92* (72)**	66-116 (87)
Tram speed, fpm	12-17 (15)	12-20 (15)
Drum speed, rpm	37-45 (41)	28-60 (44)
Average face air velocity, fpm	200-315 (250)	125-650 (390)
Shearer water flow (total), gpm	26-85 (60)	35-100 (60)
Shearer water pressure, psi		
External spray system	75-275 (150)	0-300 (135)
Drum spray system	30-300 (115)	15-100 (60)
Production, tps	700-2000 (1250)	800-1800 (1300)

*range of values
**average value

and "dusty" operations are similar, it must be emphasized that (1) a variety of control procedures must be implemented in combination to assure compliance, and (2) the control technique must be appropriate for the dust source. Likewise, supplying sufficient quantities or volumes for various dust-control systems (i.e., high water-flow rates for external shearer spray systems) will not necessarily reduce personal dust exposure if that particular system is applied incorrectly (upwind orientation of external sprays). The survey revealed that all six operations consistently in compliance with the dust standard have adopted the following major dust-control techniques:

- A cutting sequence that allows the shearer operator to work most of the time on the intake-air side of the lead drum

- A passive barrier-external water spray system designed to confine the airborne dust produced by the shearer against the face and direct it downwind and away from the operators

- Utilization of large quantities of water, particularly through the drum sprays, to enhance dust knockdown and prevent dust suspension

Other effective control methods identified during the surveys include reduced drum speeds and the movement of supports immediately on the return-air side of the shearer during the tail-to-head cut. In addition, preventive maintenance--especially the regular cleaning and repair of the shearer water spray system and replacement of worn bits--played a key role in successful compliance efforts.

Five major factors were identified that contributed to high dust levels on the six operations having the most difficulty complying with the dust standard:

- o A poorly defined or structured cutting sequence, which positions face workers on the return-air side of the lead cutting drum

- o A poorly designed external water spray system, allowing shearer-generated dust to boil upwind and be carried out into the walkway over the shearer operators

- o Marginal water flow to the cutting drums, permitting high levels of dust to become airborne during cutting and coal transport

- o Minimal controls at the stage loader and crusher, causing immediate contamination of primary intake air

- o Lack of effective control technology for dust generated during support movement

The results of these surveys further emphasize the need to address all sources of longwall dust generation. Even at minimal production levels, with adequate shearer water flow rates and sufficient face airflows, compliance with the dust standard may still be unattainable if any area or source is ignored or overlooked.

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2. BASIC AND EFFECTIVE DUST-CONTROL TECHNIQUES

Although many longwall mining operations utilizing double-drum shearers have difficulty limiting dust exposure of face workers, several operations have been identified that maintain regular compliance with the mandatory dust standard. The U.S. Bureau of Mines conducted a dust-survey program in the early 1980's at six longwall sections having double-drum shearers which were regularly in compliance; the objective of the program was to identify the most effective dust-control techniques currently in use (1). Three major techniques were recognized:

- A passive barrier and/or external water spray system design that confines shearer-generated dust near the face and away from the operators
- A cutting sequence that allows the shearer operators to work on the intake-air side of the lead drum most of the time
- Large quantities of water through the sprays, particularly the drum sprays, to aid in dust knockdown and prevent dust suspension

Mine operators must utilize a combination of several effective dust-control techniques to control respirable dust, as no single technique can reduce shearer dust concentrations to compliance levels. Application of these three particular control techniques will not necessarily guarantee compliance, but should assist in meeting the Federal dust standard.

SYSTEMS TO HOLD SHEARER DUST AGAINST FACE

Shearer operator dust exposure levels are primarily dependent on how rapidly dust from the upwind drum spreads into the walkway. Water sprays mounted on the shearer body can have a great effect on dispersing the shearer-generated dust cloud, with each spray acting like a small fan, moving air and creating strong cross-currents around the shearer. These sprays can make conditions worse by creating turbulence and mixing, which forces the dust cloud away from the face into the operators' breathing zone. A basic approach to this problem is to split the incoming clean air upstream of the shearer, with one split confining the dust cloud to the face and carrying it away from the operators, and a second split of clean air blowing over the operators. Three methods used to effectively confine and hold the dust cloud to the face are:

- Downwind orientation of shearer-mounted water spray nozzles, the fundamental basis of the shearer clearer system
- Installation of conveyor belt screens or passive barriers on the gob-side edge of the shearer body
- Relocation of face-side cooling water sprays to prevent face dust from boiling into the walkway

Shearer Clearer

Poorly designed shearer-mounted spray systems with nozzles directed upwind at the cutting and loading zone of the upwind drum cause the dust to actually be moved away from the face and upstream of the drum; it is then mixed with the incoming clean airstream and carried back across the shearer operators, as shown in Figure 2 (2).

A novel shearer-spray system, called the shearer clearer, was developed by the Bureau of Mines, which takes advantage of the air-moving capabilities of water sprays. The system consists of several downwind-oriented, shearer-mounted

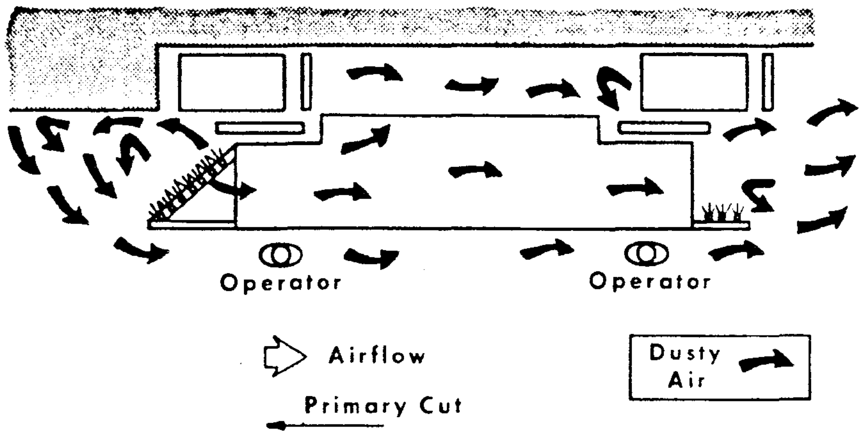

Figure 2. Dust Plume Being Pushed Upstream by a Conventional Water Spray System

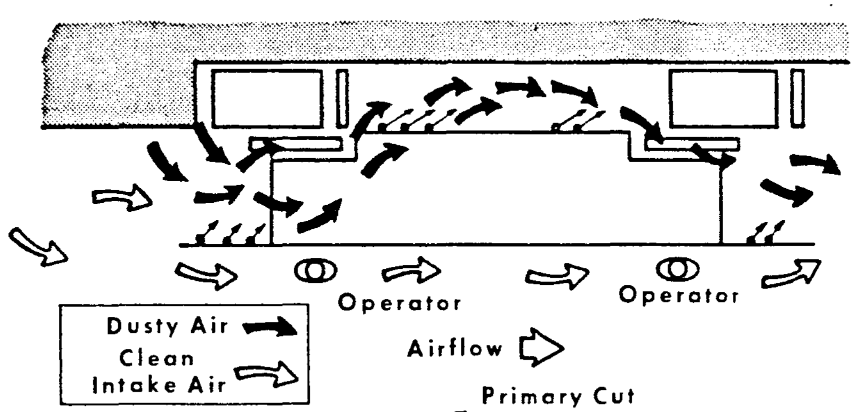

Figure 3. Shearer Clearer Forces Dust-laden Air Towards the Face

sprays and one or more passive barriers to divide the airflow around the shearer into a clean split and a contaminated split, Figure 3. The airsplit is initiated by a splitter arm, equipped with conveyor belting hung from the arm down to the panline, extending from the top gob side corner of the shearer body to approximately 18 inches beyond the cutting edge of the upwind drum. Spray manifolds mounted on the splitter arm control the dust cloud generated by the drum, further enhancing the airsplit. The dust-laden air is drawn over the shearer body and held against the face by two spray manifolds positioned on the face-side of the machine between the drums to prevent a decrease in air velocity. The contaminated face air is then redirected around the downwind drum by a set of sprays located on the downwind splitter arm.

A detailed view of the optimum shearer clearer design, showing recommended locations for water spray nozzles, conveyor-belt screens, and alternative cooling water discharge points, is presented in Figure 4. The figure is accompanied by Table 4, which lists the proper locations and spray discharge angles for the 10 spray nozzles mounted within the seven spray manifolds. Total water usage for the system is approximately 15 gpm which must be maintained at 150 psi.

Underground tests have shown that the shearer clearer will reduce operators' exposure from shearer-generated dust by at least 50 percent when cutting against ventilation and 30 percent with the shearer cutting with ventilation (3). Although a properly installed shearer clearer system will control respirable dust exposures at the operators' positions more effectively than a conventional dust suppression spray system, one must realize that it will not correct for insufficient primary ventilation, replace drum sprays, or reduce operators' exposure to respirable dust from sources other than the shearer (shield movement, transfer points, stage loader/crushers, etc.). In 1981, the installed costs of a shearer clearer

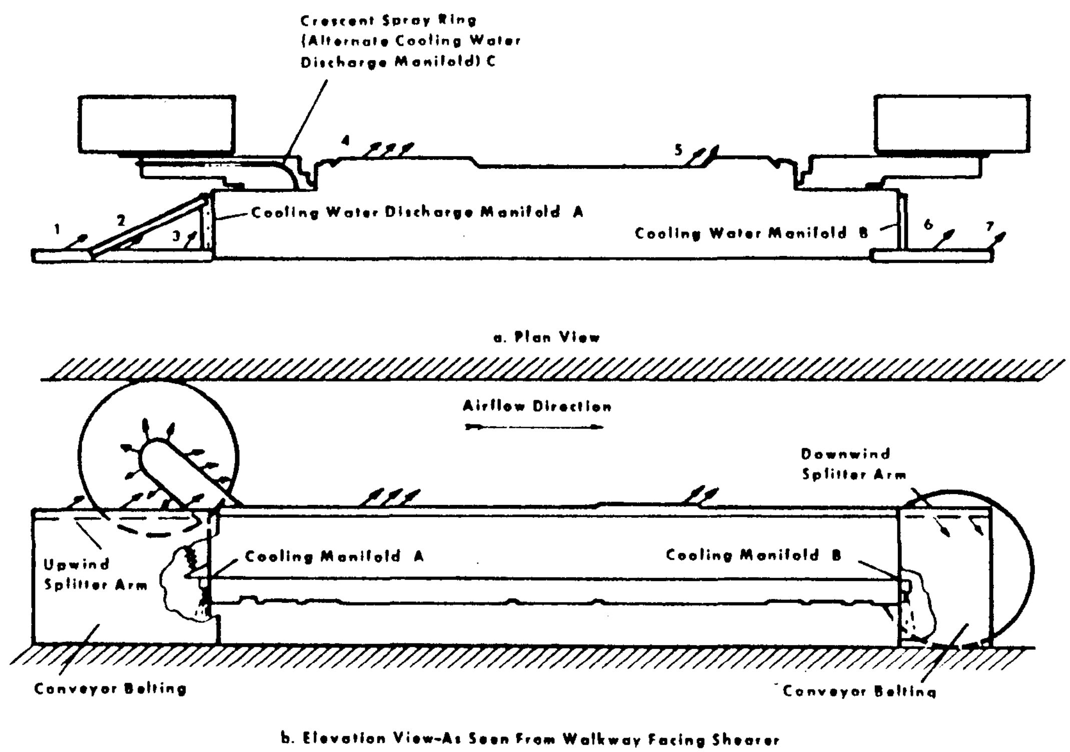

Figure 4. Shearer Clearer System Layout

TABLE 4. SHEARER CLEARER NOZZLE LOCATION GUIDE (2)

Manifold	No. of Nozzles	Location on Shearer	Spray Discharge Angle	
			Outward	Upward
1	1	Nozzle located 8 in. in from outby end of splitter arm	20° toward face	15°
2	1	Midway between manifolds 1 and 3	30° toward face	15°
3	1	Nozzle located 12 in. out from upwind end of shearer	40° toward face	30°
4	3	Outby end of manifold located approximately 12 in. from end of upwind ranging arm	30° toward face	30°
5	2	Inby end of manifold located approximately 40 in. from end of downwind ranging arm	30° toward face	20°
6	1	Nozzle located 8 in. out from downwind end of shearer	25° toward face	15° down
7	1	Nozzle located 6 in. from inby end of downwind splitter arm	25° toward face	15° down

Notes: a. System total: 7 manifolds with 10 nozzles, approximately 15 gpm at 150 psi.

b. Refer to Figure 4 for manifold and nozzle locations.

system were estimated at $15,000 to $20,000, with maintenance and operational costs determined to be slightly greater than those for a conventional spray system (4).

Passive Barriers

Conveyor belt screens, placed on the gob side of the shearer body or mounted from splitter arms extending from either end of the machine (Figure 5) can reduce the amount of dust which spreads out into the walkway; in addition, belting may be installed between the shearer underframe and the panline to prevent conveyor dust from boiling out into the walkway (5).

The size of conveyor belt screens installed on the shearer body is dependent upon seam height, machine design and operator acceptance. A typical barrier design is shown in Figure 6. The barriers should be mounted along the gob side edge of the shearer, and extended along the full length of the

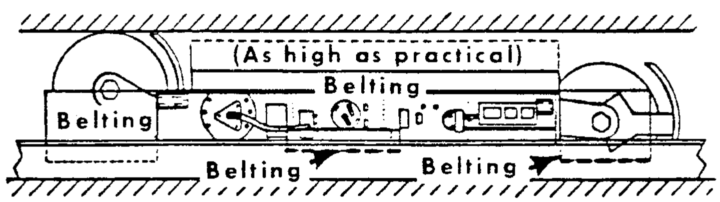

Figure 5. Suggested Locations for Belting on a Shearer

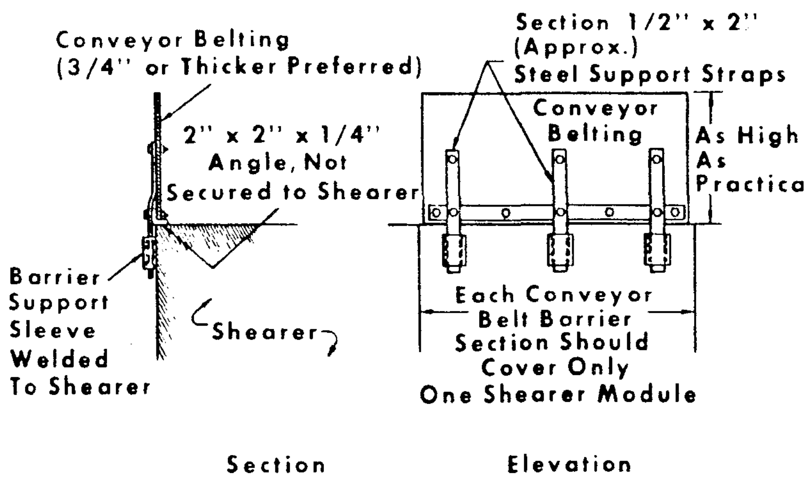

Figure 6. Typical Passive Barrier System Design

upwind splitter arm (if one exists) and along as much of the shearer body as practical (2). The height of the barriers will depend upon the clearance over the shearer. The belting on the shearer body should extend upward as close to the bottom of the roof support canopy as practical, while allowing for low clearance areas and providing the operator adequate visibility of the cutting drum.

One company developed an extendable splitter arm to control the dust which moves out away from the face and into the walkway (6). A spraybar was mounted on a sliding channel which could be extended in front of the existing headgate-side splitter arm for about three feet and then retracted when cutting out at the headgate. The extended part is well in front of the headgate drum and capable of catching the dust boil-out. A cross-section of the extendable splitter arm is shown in Figure 7. A square tube is the main support of the splitter arm and holds the main

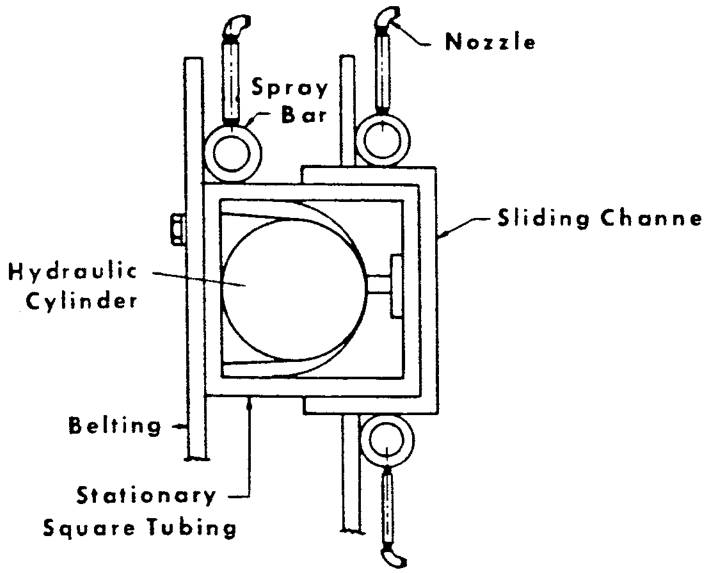

Figure 7. Extendable Splitter-arm Spray Bar

spraybar; a second square tube slides on the outside of the main support and has additional spraybars and belting mounted to it. The hydraulic cylinder used to extend/retract the channel is mounted inside the main support tube for protection. The water sprays are mounted on hoses and located just above the top edge of the belting to help create an airflow over the front of the shearer, thus directing the dust away from the operators.

Actual shearer-belting configurations should be tailored to the particular machine. Operators should ensure that the belting configuration is compatible with the external spray system in directing the dust-laden air away from the operators (7). Improper location and orientation of passive barriers can result in greater dust concentrations at the shearer-operator positions. The most effective orientation used to maintain an adequate air split around the shearer is one that parallels the face. An example of a detrimental passive barrier design is shown in Figure 8.

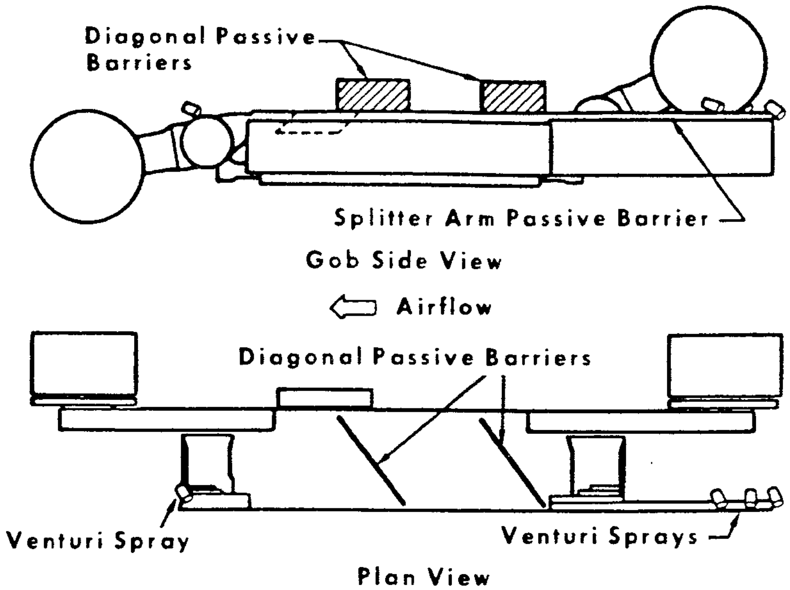

Figure 8. Detrimental Diagonal Passive Barrier Design

Underground smoke tests and dust monitoring showed that the two diagonal passive barriers mounted on top of the shearer directed dust from the face side of the shearer into the walkway and over the operators. Removal of these barriers actually reduced operator dust levels by 30 percent for both tail-to-head and head-to-tail passes (8).

Relocation of Machine Cooling Water Sprays

Shearer cooling water is often discharged through spray nozzles which may create adverse airflow patterns around the shearer, thereby increasing walkway dust levels. These sprays are frequently oriented against the primary airflow or directly into the face, causing dust to be carried back into the walkway, as shown in Figure 9 (9).

Two recommended alternative locations for discharging cooling water are "panline sprays" and

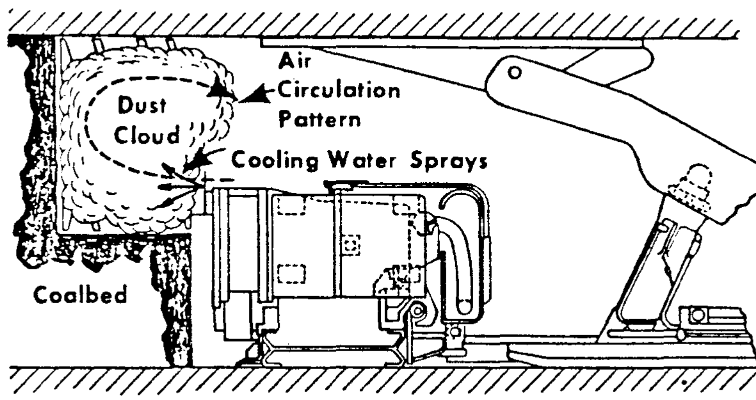

Figure 9. Common Effect of Cooling Sprays on Dust-cloud Dispersion

a "crescent spray manifold." Both locations are shown in Figure 10. The panline spray manifolds can be mounted on both ends of the shearer, aimed down onto the panline. This minimizes the adverse turbulence effect caused by face-side sprays and can result in respirable dust reductions of up to 35 percent at the shearer operator's location (10). Moreover, the additional water directed at the panline will reduce dust from that source. The manifolds should be located in close proximity to the panline, with high-capacity flat fan sprays used for full coverage of the panline.

A second alternative location for cooling water discharge is the crescent spray manifold, typically wrapped around both ranging arms. The manifold can be welded (preferred method) or bolted to the ranging arm, and should be designed to accept recessed spray nozzles; the nozzles should provide a flat-fan spray pattern, and be aimed at the drum and appropriately spaced to provide uniform wetting of the entire cutting zone.

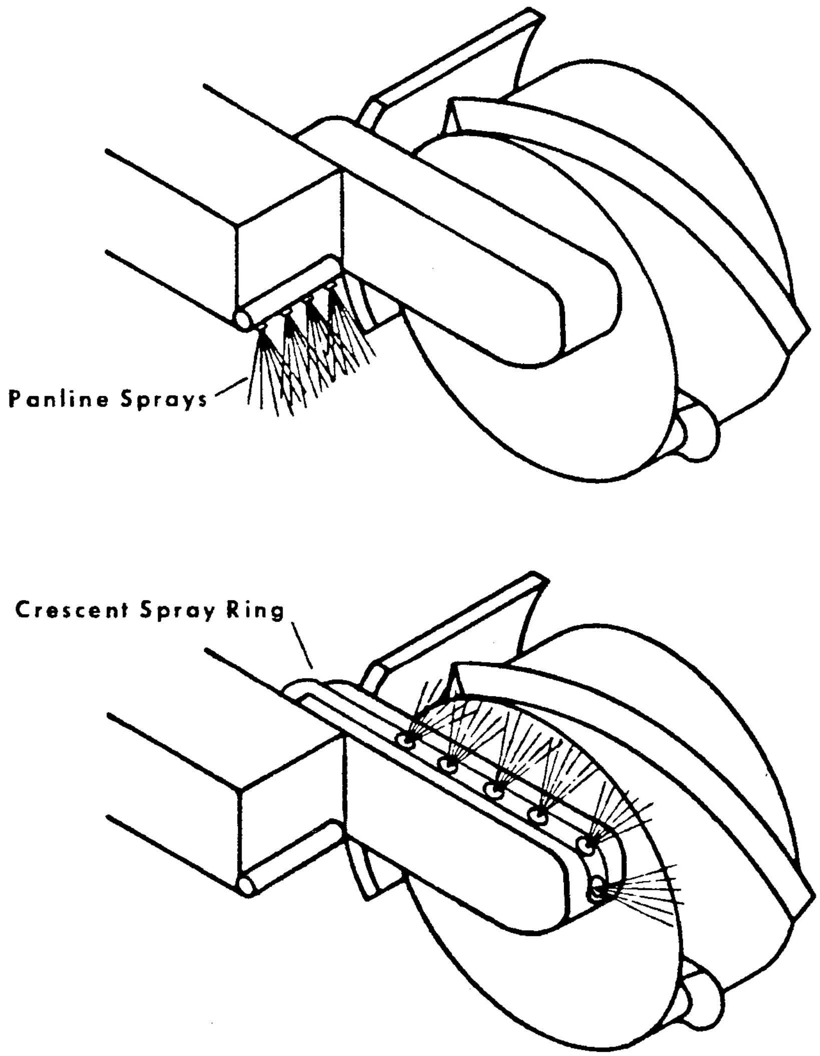

Figure 10. Alternate Cooling Water Spray Locations

Sprays not oriented toward the face, but rather vertically upwards toward the roof and/or upwind, can create adverse air currents around the drum and actually increase the dust exposures of the shearer operators. An advantage of the crescent spray manifolds over the panline sprays is that it allows the operators to visually confirm adequate cooling water flow.

IMPROVED CUTTING SEQUENCE DESIGNS AND OPERATING PROCEDURES

The operational sequence on longwalls may be adjusted to reduce dust exposures of face workers through improved procedures for cutting the face and moving supports. These procedures are designed to keep personnel on the upwind side of the dust-generating source(s) and/or remove them from high dust concentration zones, when concentration gradients exist.

Undirectional Cutting Sequence

A primary method of controlling dust exposures on double-drum shearer longwall faces is through modification of the cutting sequence. Currently, 75 percent of operating sections use a unidirectional, or half-face, cutting sequence in which the shearer cuts coal in only one direction, as opposed to a bidirectional, or full-face, cutting sequence in which full cuts are taken in both directions. Typically, the lead drum takes a full cut in the raised position during the main cutting pass with the trailing drum cutting bottom coal; a minimal amount of coal is loaded during the return cleanup pass.

The actual effect of unidirectional cutting on production has not been well established. However, one advantage of the unidirectional cutting sequence is that only one shearer turn is required at the face ends, Figure 11, while three turns are necessary when cutting in both directions, Figure 12. Hence, the unidirectional cutting sequence is

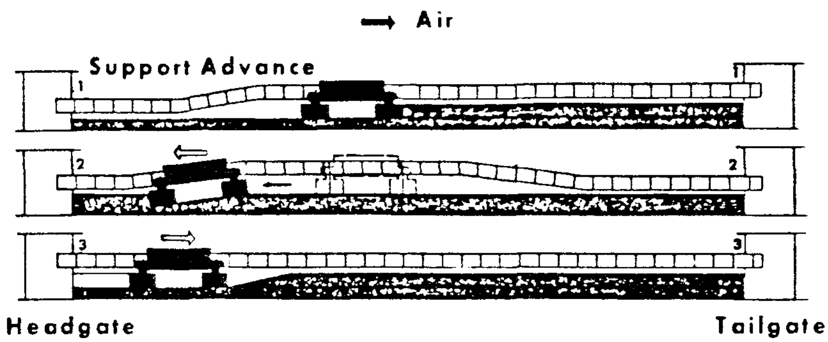

Figure 11. Unidirectional or Half-face Cutting Sequence

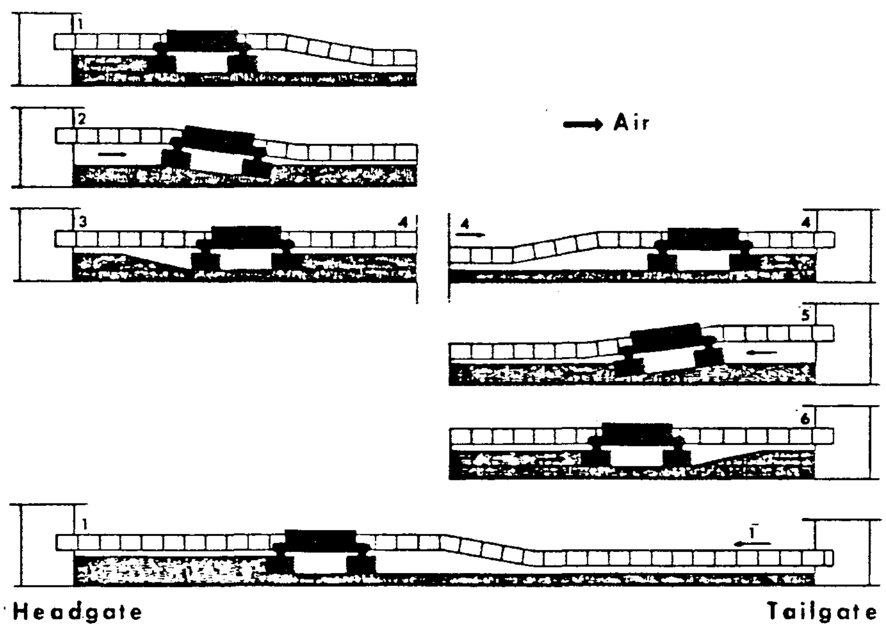

Figure 12. Bidirectional or Full-face Cutting Sequence

normally not less productive than the bidirectional method and, particularly in narrower faces 400-500 feet long, the unidirectional method actually shows improved productivity (11). In addition, the more complicated full-face conveyor snaking procedure is avoided and the cleanup pass helps in maintaining a straight faceline and better working conditions.

Modified cutting sequences alter the dust profile around the shearer by placing the primary dust-producing drum on the return-air side of both shearer operators. On faces where the main cutting pass is taken upwind from tail-to-head, both operators must remain at their controls and are, therefore, positioned on the return-air side of the lead drum. An alternative method to reduce shearer operators' dust exposures is to take the primary cut downwind from head-to-tail with the operators positioned upwind of the lead cutting drum (12). Figure 13 compares the instantaneous dust profiles around the shearer cutting from head-to-tail and from tail-to-head, and also shows

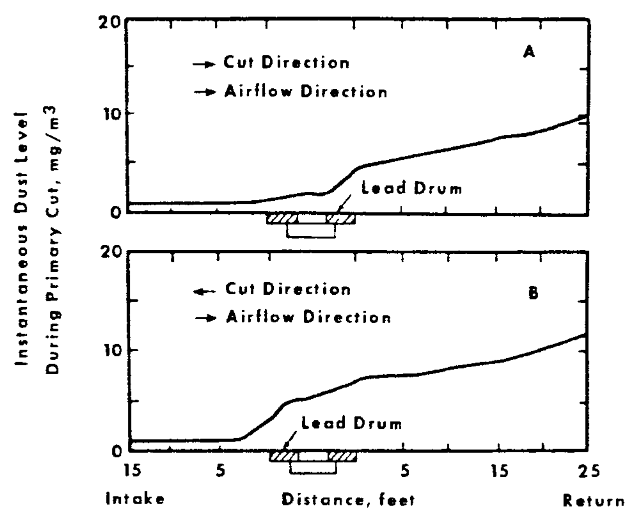

Figure 13. Instantaneous Dust Levels when the Shearer Cuts with (A) or against (B) the Airflow Direction

the large gradient in dust concentrations that can exist between the intake and return air side of the lead drum (1). Dust surveys conducted by the USBM on 14 longwall faces showed that the average shearer operator's exposure when cutting tail-to-head was 44 percent greater than when cutting head-to-tail. A possible disadvantage of head-to-tail cutting is that blockage may occur beneath the machine underframe as the material cut by the lead (tailgate) drum is loaded onto the face conveyor. This would primarily depend on the breaking characteristics of the coal and shearer design.

Further reductions in operator dust exposures can be achieved on the head-to-tail cutting sequence by "free-wheeling" the trailing drum during the head-to-tail pass. During a typical head-to-tail cut, the lead (tailgate) drum takes a full cut while the trailing (headgate) drum cuts bottom coal. However, in this mode of operation, the dust generated by the trailing drum can spread into the walkway, as shown in Figure 14, and increase the dust exposure of both operators. A modified unidirectional cutting sequence is shown in Figure 15 (13). In this sequence, the lead drum cuts full width during the head-to-tail pass while the trailing drum is "free-wheeling" or cutting a minimum volume of coal. For the return tail-to-head pass, the trailing drum cuts the remaining bottom coal, thereby enabling both operators to remain on the intake-air side of the primary dust-generating source except when cutting out at the headgate. In addition to reducing operator dust exposures, this cutting sequence also saves wear on the conveyor and helps to eliminate overloads. On the other hand, the designed capacity of the double-drum shearer is not utilized fully; both ends of the shearer are very unbalanced in loading with the tailgate drum responsible for loading much of the material while the headgate drum is almost constantly in a "free-wheeling" position (14).

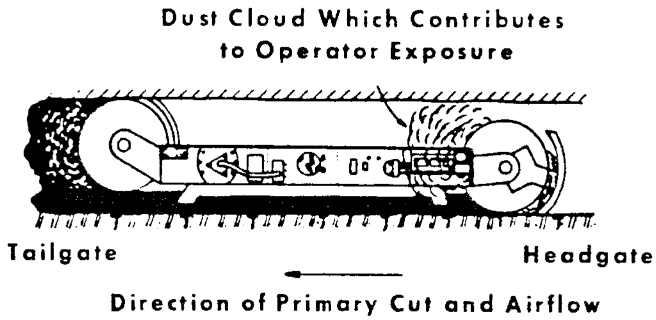

Figure 14. Typical Unidirectional Cutting Sequence with Headgate Drum Cutting Bottom Coal

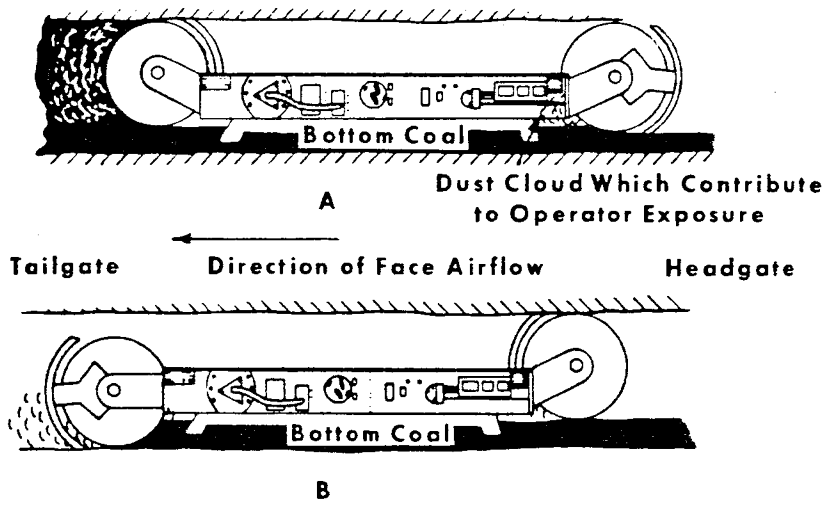

Figure 15. Modified Unidirectional Cutting Sequence with "Free Wheeling" Headgate Drum

Enhanced Bidirectional Cutting

As previously mentioned, the shearer operator's dust exposure is generally dependent on his position relative to the lead drum. When cutting against the airflow while employing a bidirectional cutting sequence, both shearer operators are exposed to high dust levels generated by the lead drum. Figure 16 shows a unique application of machine design and utilization to enhance dust control on bidirectional longwall faces (10,15).

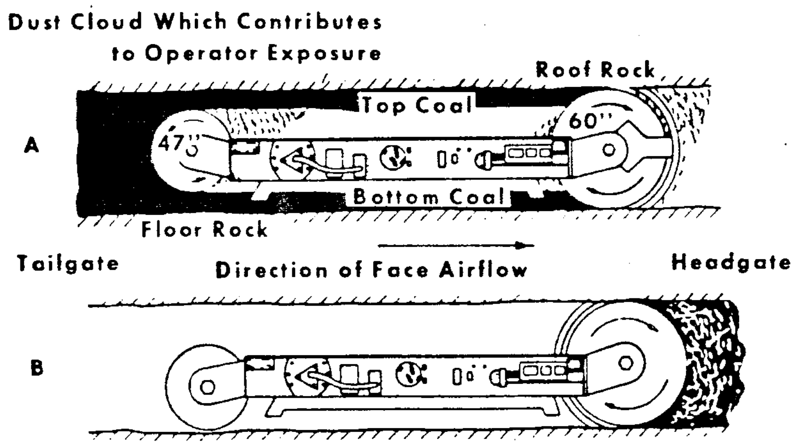

Figure 16. Enhanced Bidirectional Cutting Sequence Using Drums of Unequal Sizes

In this design, the shearer is equipped with two drums of unequal size. The diameter of the intake-air side or tailgate drum (i.e., homotropal ventilation) is 47 inches and the drum on the return-air or headgate side is 60 inches. During the downwind tailgate-to-headgate cut, the leading large drum cuts the entire seam with the small drum "free-wheeling". Because the smaller upwind drum cuts no coal, and the large drum is located on the return-air side of both operators, the dust levels are relatively low. For the upwind headgate-to-tailgate cut, the smaller drum leads and cuts the middle of the seam while the trailing larger drum trims the roof and floor coal. Both the shearer operators and the support movers are on the downwind side of the small drum during this phase of the cutting sequence. However, the dust concentrations produced by this drum are reduced because:

- Low drum speed and smaller drum diameter result in lower bit speeds, producing less dust.

- The small-diameter drum cuts the middle portion of the seam, avoiding higher dust levels caused by cutting roof or floor rock.

- The absence of a cowl may reduce coal recirculation within the drum, thus decreasing dust generation.

There are certain practical constraints on the maximum and minimum sizes of the drums (8). To avoid problems with material recirculation, the peripheral speed of the large drum should be limited to 600 fpm; this, in turn, results in a maximum drum diameter of 76 inches for the large drum when applying a minimum rotational speed of 30 rpm. The minimum diameter of the small drum ranges from 46 to 54 inches, depending on the hub size of the shearer ranging arm. By replacing a standard set of 60-inch drums on a homotropal face (i.e., airflow directed from tail-to-head) of 7-foot seam height with large/small drums of 76 and 50 inches, respectively, the amount of coal cut upwind of the shearer operators during the tail-to-head pass is reduced 66 percent. For the head-to-tail pass, the use of large/small drums reduces the amount of coal extracted by the upwind drum by 17 percent. This technique may be more applicable to thinner seams in which the full seam height can be cut by the larger downwind drum; in thicker and/or undulating seams, this method may not be practical as it cannot easily accomodate seam-horizon variations. Experience to date has shown that the mechanical reliability of the shearer is not adversely affected by the use of unequal sized cutting drums.

Support Movement Practices

For purposes of dust control, cutting sequence and support movement practices are designed to minimize the amount of time jacksetters work downwind from the shearer as well as to maintain dust exposures of the shearer operators as low as possible. One such practice employed to reduce face workers' exposure involves support advance on the downwind side of the shearer, thus keeping the shearer operators in uncontaminated air (16). When the pass cycle against the airflow is used as a cleanup pass, the dust levels generated by the shearer are typically low; hence, the dust exposure levels of the jacksetters working downwind of the shearer will remain relatively low as long as no significant amount of rock is cut during the cleanup pass. When the primary cut is taken against the airflow, a properly designed external shearer water spray system can adequately confine shearer-generated dust against the face for approximately 40 feet downwind from the shearer, Figure 17, thereby providing an acceptable environment for jacksetters working immediately downwind.

Sometimes, it is not feasible to move the supports on the downwind side of the shearer during the cleanup pass, as roof conditions may require support advance immediately after the shearer takes the primary cut. Therefore, supports are moved on the intake-air side of the shearer as it cuts in the head-to-tail direction (downwind), exposing the shearer operators to any dust generated by the support movement. Under these circumstances, some mine operators have

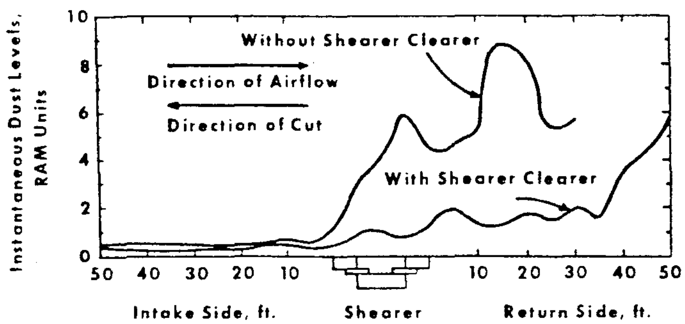

Figure 17. Use of Shearer Clearer Spray System to Reduce Dust Exposures of Roof Support Workers Downwind

found that support-generated dust can be effectively diluted by increasing the distance between support-advance and the shearer from 20 feet to at least 50 feet, Figure 18. Hence, the dust is diluted and diffused by the face airflow before reaching the shearer operators. Increasing face airflow velocity up to 400 fpm, but no greater than 500 fpm, should also enhance support dust dilution while preventing dust entrainment. Additional information regarding the control of support-generated dust, including the use of remote control for support advance and novel support spray arrangements, is presented in Chapters 4 and 6.

WATER SUPPLY, QUANTITY AND PRESSURE

The application of water is one of the primary means used for dust suppression in coal-mining operations. On longwalls, water is used extensively for dust control under varied applications. Both U.S. and foreign research studies

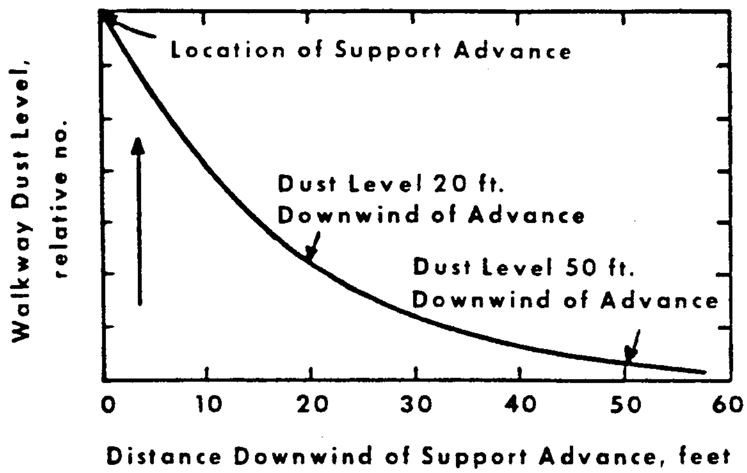

Figure 18. Improved Dilution of Support-generated Dust by Increasing the Distance Between Support Advance and Shearer Located Downwind

indicate that shearer dust generation can be reduced by increasing the quantity and pressure of water supplied through the cutting drums. Greater water quantities and pressures, supplied particularly through drum sprays but also through external shearer-mounted sprays, aid in dust knockdown and help to prevent dust suspension. The effectiveness of such spray systems is largely dependent on the longwall water supply and distribution system.

Water Supply Systems

A well-designed water supply system is necessary to assure water pressure and quantity to the shearer water spray systems. Spray nozzles operating at low pressures and flows often become plugged, thus decreasing the dust-suppression capability of the spray system. Upgrading a water supply system generally involves minimal expense and requires one or more of the following improvements (17):

o Increased pump capacity for additional flow and pressure.

o Increased line sizes to decrease pressure losses.

o Installation of a "non-clogging" filtration system to improve water quality and reduce maintenance downtime.

An example of an upgraded longwall water supply system is shown in Figure 19. Based on

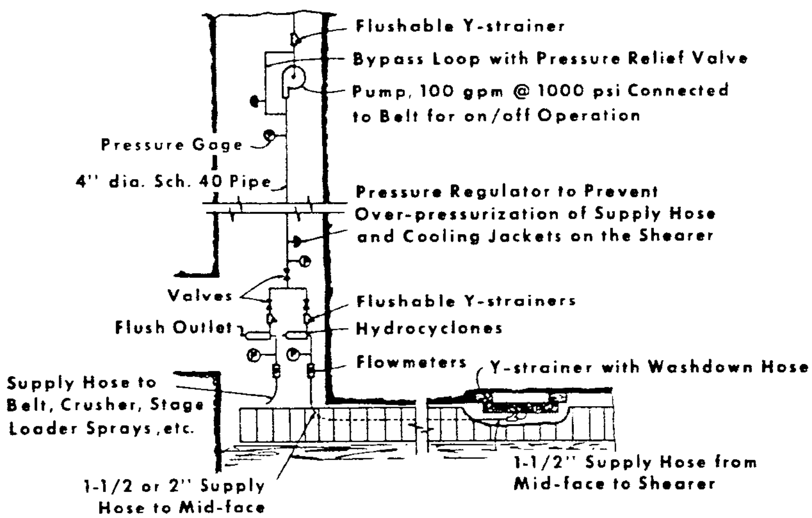

Figure 19. Upgraded Longwall Water Supply System

studies conducted to determine water supply needs on longwalls, the following recommendations are appropriate (7):

o Section booster pumps - Booster pumps are typically sited at the base of the panel and may be 4,000 feet or more from the face when a new panel begins. To provide an adequate quantity of water and to compensate for pressure losses in the piping to the face, these pumps should be rated at approximately 100 gpm at 1,000 psi. The pumps should be protected with an upstream Y-strainer capable of removing large particulates. The periodic operation of the spray systems should be accommodated by either an automatic flow switch, which will start or stop the pump at predetermined flows, or with pressure-relief valves and a bypass loop equipped with a timed shut off.

- Piping to the Face - Piping from the booster pumps to the face should preferably be 3 or 4 inches in diameter. Two-inch diameter pipe will result in line losses of about 320 psi through 4,000 feet, but pressure losses are negligible when larger diameter pipes are used.

- Trailing Hoses - Cable-handler design may, in some cases, limit trailing-hose diameter. However, nearly all will accommodate 1-1/2-inch diameter hose, and its use is encouraged. Pressure loss through 600 feet of 1-1/2-inch hose at 75 gpm is approximately 190 psi, whereas losses through 1-1/4-inch hose at the same flow rate would be 440 psi. On most faces, pressure losses may be further reduced by running 2-inch hose to the center of the face and using 1-1/2-inch hose from that point.

- Valves and Couplings - Valves should be full bore at the machine intake with quick-action lever control. They should also be well protected. No couplings should break the trailing hose to the machine except at the face midpoint. Swivel couplings might be used at the machine intake to permit the hose to twist. The end portion of the hose might be attached to the machine with a clamp and spring arrangement to provide strain relief for the coupling.

- o Filtration - A Y-strainer and hydrocylone filter installed at the end of the section water supply pipe are recommended. The Y-strainer and pipe fittings should be installed so that at least a three-foot length of straight or slightly curved pipe exists between the strainer and hydrocyclone; this will prevent turbulence at the hydrocyclone inlet. The system should be located in an accessible location for easy maintenance, and the Y-strainer and hydrocyclone flushed weekly under pressure (more frequently if necessary). An additional Y-strainer with 60-mesh screen can be installed on the shearer. The machine washdown hose can be coupled to the flushing outlet of the strainer to insure routine cleaning.

- o Gauges - Pressure and flow gauges are useful for monitoring and controlling the water supply. Flow and pressure gauges should be installed at the end of the section supply pipe. Connectors should be full bore, and the meters may be left in the line permanently. A pressure gauge should also be installed at the shearer intake. The system is useful in apportioning water between the different spray systems on the face; e.g., headgate sprays and shearer sprays.

- o Piping on the Machine - As previously mentioned, the intake valve should be the quick-action lever type and well protected. It may be interlocked to the machine motors so that the machine cannot be operated without previously turning on the sprays. This will prevent external blockage of the sprays, which may result from dry cutting. Water is often fed to a distribution manifold on the machine where it is apportioned to the machine's various water circuits. A pressure reducer may be installed downstream from the block on the line to the cooling circuits if line pressure exceeds manufacturer's specifications for these circuits. For protection, all piping should be internal to the machine body. Pipe diameters must be at least 1/2-inch; 3/4-inch is preferred.

Several studies have shown that the dust generated by the shearer can be reduced by increasing the quantity and pressure of water supplied to the shearer. In two separate studies (18,19), water flow to the shearer was increased by approximately 50 percent (40 to 62 gpm in the first case, 45 to 65 gpm in the second case). In both instances, dust levels at the shearer were reduced 40 percent. A third study emphasized the particular importance of providing sufficient water flows to the cutting drums (20). Total shearer water flow for each of two longwall sections was over 100 gpm. However, the drum flows of 60 gpm for the one section as compared to only 20 gpm for the other caused significant differences in dust levels as shown in Figure 20. Average dust concentrations at the shearer midpoints were 3.4 mg/m^3 for the "high-flow" drums as compared to 8.7 mg/m^3 for the "low-flow" drums.

The British National Coal Board conducted tests to evaluate the performance of high-pressure internal spray systems (21). A single-drum shearer was used to assess the effect of increasing the spray pressure at a constant flow of 30 gpm. The

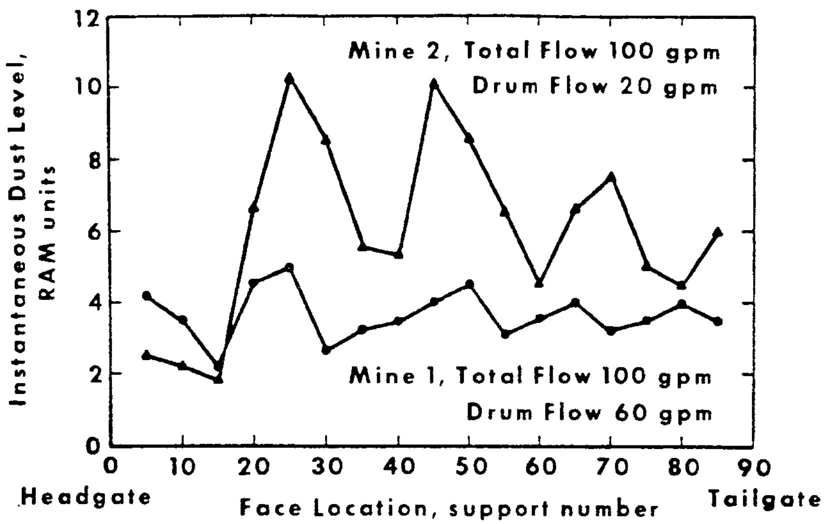

Figure 20. Effect of Increased Drum Water Flow on Longwall Dust Levels

shearer cut in the direction of face airflow, and the drum was equipped with a cowl. Twenty-eight 0.1-inch jet sprays were used for the low-pressure (30 psi) tests and twenty-eight 0.04-inch jet sprays for the high-pressure (1,204 psi) tests. The high-pressure sprays were found to be significantly more effective in reducing dust concentrations than the low-pressure sprays. This was attributed to one or both of the following conditions: (1) better penetration of the spray water into the primary breakage zone, and (2) atomization of the spray water into fast-moving fine droplets for increased dust capture.

Recently, studies were conducted in the U.S. to assess the effect on dust levels of proportioning the water flows to the drums and increasing the water flow rate (22). Tests were conducted in the Pittsburgh No. 8 seam, with the cut taken from head-to-tail with the airflow. When water was shifted from the downwind drum to the upwind drum, both the dust exposure of the downwind drum operator and total dust levels in the return were reduced. The switch from a low flow on the upwind drum and a high flow on the downwind drum to the reverse situation resulted in a 63-percent reduction in the dust exposure and a 32-percent reduction in the total dust generation. When the total flow to the drums, with the flow equally distributed between the drums, was increased from 34 to 56 gpm, the total dust generation decreased from 21.8 mg/m^3 to 11.6 mg/m^3; however, the dust exposure of the downwind drum operator increased from approximately 1.3 mg/m^3 to 4.5 mg/m^3. This increase was believed to be a result of the higher flow rate (and spray pressure) pushing the dust from the face into the walkway and over the operator. A more thorough discussion of drum-water proportioning, and the results of this particular study, are included in Chapter 4.

The point at which increased water flow and pressure no longer produce a corresponding reduction in dust levels has yet to be well-established. The amount of water used is often limited by practical considerations and local mining conditions, such as the effect of additional water on the mine floor and belt conveyors, and the increased moisture content in mined coal.

<u>Shearer Drum Water Distribution Systems</u>

Longwall shearers are routinely equipped with internal spray systems (i.e., wethead or drum-mounted sprays) because water can be introduced easily through the drum, and internal systems are more efficient than external systems in terms of the amount of dust suppressed per gallon of water. There are two basic water distribution systems for cutting drums:

- <u>Bit or Pick Face Flushing</u> - Nozzles are typically located in the bit blocks or special blocks, either immediately in front of or behind the bits; spray water impinges on and flushes the cutting surface of the bit and then forms a fine mist around the bit tip, thus wetting the coal prior to, during, and after the cutting process. Typical spray nozzle locations are shown in Figure 21.

- Cutting Zone Flushing - Also known as cavity-filling systems, cutting zone flushing utilizes spray nozzles installed in a pipe manifold or special blocks mounted on the hub of the drum between the scrolls, or along the edge of the scrolls. Spray water is directed radially from the drum, saturating the airstream flowing around and past the drum with water droplets. These droplets impinge on the dust particles liberated into the airstream during cutting, thereby promoting agglomeration and fallout.

When selecting a drum water distribution system, the following should be considered (7):

- Nozzle maintenance requirements are likely to be higher on bit-flushing systems because (1) a larger number of nozzles (e.g., one per bit) are used as compared to a cutting zone flushing system which may only require a total of ten nozzles mounted on each drum, and (2) the nozzles used on bit-flushing systems are likely to have smaller orifices, increasing the frequency of plugging.

- Water-supply channels are easier to fabricate for cutting zone flushing systems.

- Nozzles mounted behind the bits have been shown to reduce the probability of frictionally induced ignitions of methane.

- Sprays directed at the bits may reduce bit wear.

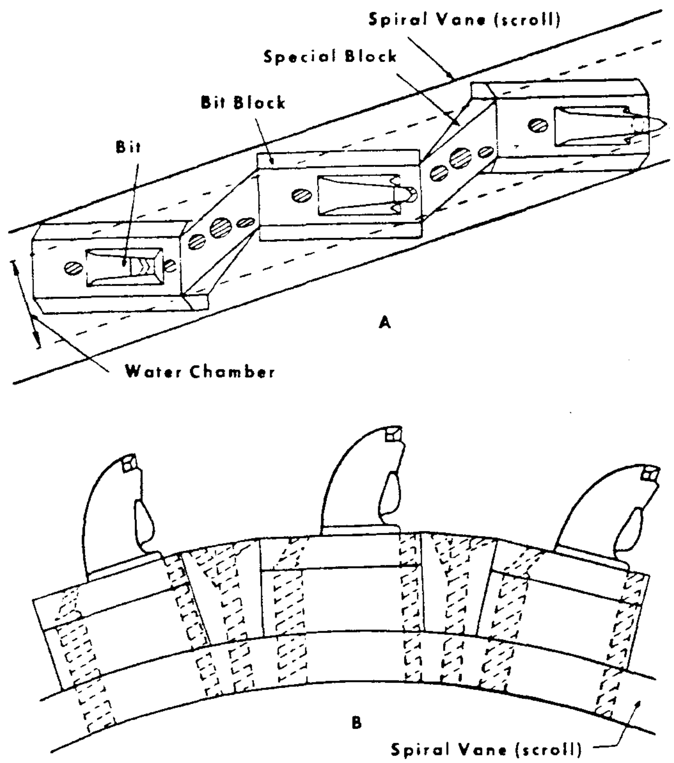

Figure 21. Various Bit Flushing Spray Nozzle Locations

- The British have indicated that pick face flushing systems can be improved through the use of stainless steel spray bodies, threadless spray outlets, hollow or solid cone outlet patterns rather than pure jets, and by reducing orifice size to 1/16 inch (23).

Extensive field tests were conducted in the mid 1970s to evaluate the effectiveness of front-pick, back-pick, and cutting-zone flushing systems (24). The back-pick and cutting-zone flushing systems performed comparably, and both were more effective than the front-pick flushing system; all three systems were found to be significantly more effective than an external spray system. Moreover, the quantity and pressure of water used was determined to be the most important factor in suppressing respirable dust; all three systems were considerably more effective with increased water flow and pressure.

Studies conducted by the French resulted in similar findings (22). In their tests, a cavity-filling system performed about as well as a pick-face flushing system with a water flow rate of 24-29 gpm on a single-drum shearer. Using either system, the dust levels increased when the flow was reduced to 21-24 gpm in combination with a spray pressure reduction. However, at the reduced flow rate, the pick-face flushing system appeared to perform somewhat better than the cavity-filling system.

The Germans conducted tests on a double-drum shearer to assess the effect of changes in the number of spray nozzles per drum (25). Total spray flow rates were kept constant for the three following nozzle configurations (per drum):

- 30 vane nozzles (one per pick)
  16 end ring nozzles
  orifice diameter = 0.047 inch

- 18 vane nozzles
  12 end ring nozzles
  orifice diameter = 0.059 inch

- 12 vane nozzles
  5 end ring nozzles
  orifice diameter = 0.079 inch

The dust concentration downwind of the shearer increased as the number of nozzles was reduced. It should be noted that the water flow to the drums (13 gpm per drum) was very low for U.S. standards.

A recent development in point-of-impact dust suppression is a water-through-the-bit cutting system developed in the U.S. and England. Water is flushed in the area where the dust is created by spraying water directly through the bit. A single water passageway through the bit, in conjunction with a needle mounted in the block and inserted through a seal located in the bottom of the bit, directs water to the point where the bit strikes the coal (Figure 22). This system was originally developed to cool the coal/rock area behind the bit, and prevent methane ignitions during cutting.

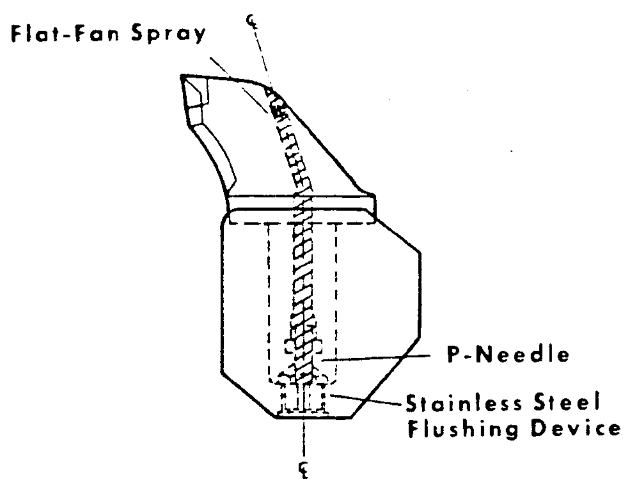

Figure 22. Water-through-the-bit Cutting Tool

Tests were conducted (26) at two longwall mining sections with very diverse geological and mining conditions to compare the dust-suppression capabilities of the three most commonly used drum water spray systems: pick-point flushing, cavity filling, and water-through-the-bit. The pick-point flushing system with solid stream (jet) type spray nozzles was the most effective in suppressing respirable dust near the shearer operators' positions (Figure 23). The pick-point system with cone-type sprays was only 70% as effective and the through-the-bit system with flat-fan sprays was 60% as effective. The cavity-filling system was only 47% as effective as the pick-point jet-spray system at reducing shearer operators' respirable dust exposures. Downwind concentrations were essentially the same for all spray systems tested.

One consideration when selecting a drum-water spray system is cost. The pick-point flushing and the through-the-bit systems are more expensive to install than the cavity-filling system, but the dust-control benefits of the pick-point system outweigh the added costs. The operating costs of the pick-point and cavity-filling systems are about equal.

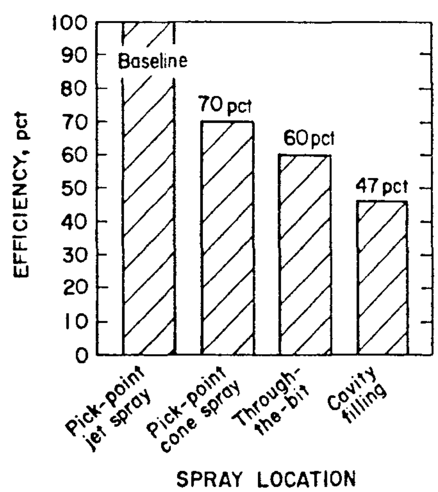

Figure 23. Dust Suppression Capabilities of the Three Common Drum Water Spray Systems

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3. ADDITIONAL NECESSARY CONTROLS

Although the three control methods discussed in Chapter 2 -- downwind-oriented external spray system, proper cutting sequence, and use of large quantities of water -- have been proven to be effective in the control of respirable dust on longwall faces, the application of other techniques is often required to bring a section into compliance. Adequate face ventilation remains an essential means for diluting and removing respirable dust on longwall mining operations. A more recent development in the control of airborne dust involves the use of lower shearer drum rotational speeds to achieve deeper coal cutting (i.e., increased bit penetration).

VENTILATION

The primary function of any mine ventilation system is to dilute liberated methane to safe concentrations. However, as with other mining systems, ventilation is also the principal method used to control dust on longwalls. In the design of a longwall ventilation system, the engineer must maintain sufficient air quantity and velocity along the face, not only to dilute methane, but provide adequate dust control.

Air Quantity and Velocity

Face air velocities of 350 to 450 fpm appear to be most appropriate for longwall dust control (1). This would be equivalent to an average intake air quantity of 20,000 cfm for a five-foot coal seam or 30,000 cfm for a seven-foot seam. Air velocities of this magnitude help to control dust in three ways:

- o Higher air velocities provide greater air quantities for better dilution of intake dust (Figure 24) and dust generated during support movement.

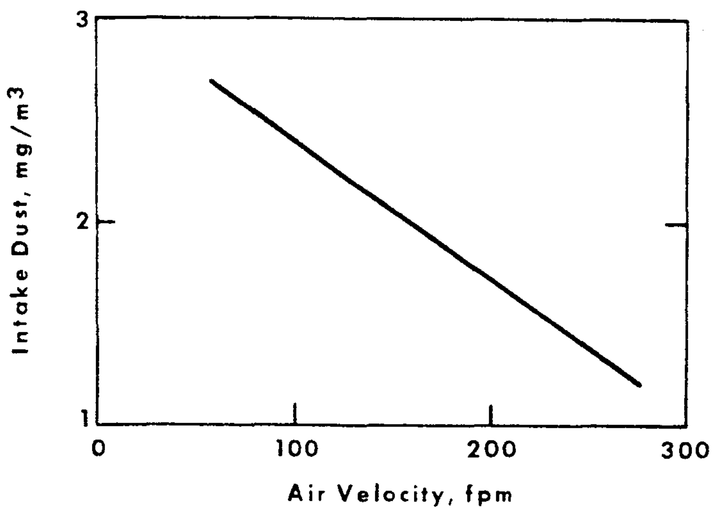

Figure 24. Effect of Increased Face Air Velocity on Intake Dust Concentrations

- o Higher velocities over the shearer help to confine dust to the face area, thus lowering walkway contamination (Figure 25).
- o Higher velocities improve diffusion of dust from stagnant areas in the headgate and along the support line.

Up to a specific velocity, an increase in air velocity across the face will result in lower dust concentrations. Based on a 1978 MSHA survey of 38 longwall operations equipped with single- or double-drum shearers, the shearer operator's respirable dust exposure is minimized when the average face air velocity is approximately 450-500 fpm (2). However, as shown in Figure 26, increases in air velocity beyond this level have the same adverse effect on dust concentrations as lower air velocities. This is a result of the

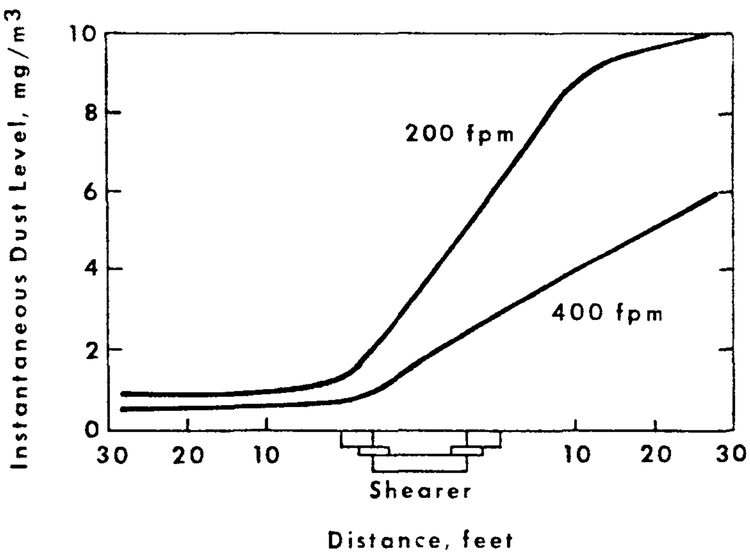

Figure 25. Effect of Increased Face Air Velocity on Shearer Dust Level Profile

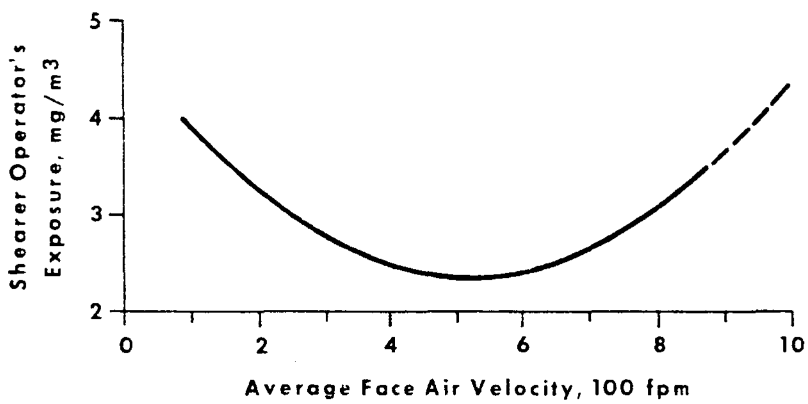

Figure 26. Shearer Operator's Respirable Dust Exposure in Relation to Face Air Velocity

dust entrainment effect (i.e., settled dust being picked up and carried by the airstream) being greater than the dilution effect.

According to a German study (3), the optimum velocity range may be increased to 700-900 fpm when the moisture content of the dust particles is higher than normal. For example, when the moisture content in the dust particles is 5 to 8 percent, the air velocity can be increased to 900 fpm without causing significant re-entrainment (Figure 27). The same velocity along a face where the moisture content of the dust is only 3 to 4 percent may result in a four-fold increase in dust concentrations.

A study was conducted on a West Virginia longwall in 1983, to determine at which point further increases in face air velocity no longer produce substantial decreases in dust concentrations (4). The results of the study are summarized in Table 5. Face airflow velocities were varied over three ranges: high (400-410) medium

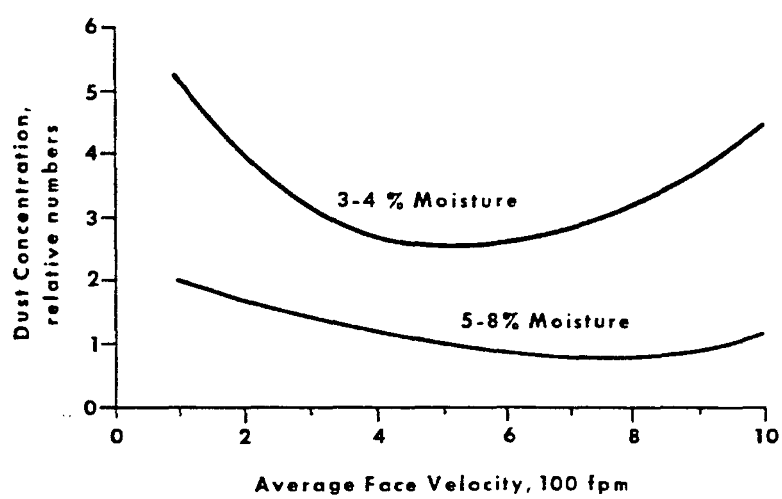

Figure 27. Respirable Dust Concentration vs. Average Face Air Velocity

TABLE 5. SHEARER OPERATOR DUST CONCENTRATIONS FOR SELECTED AIR VELOCITY AND WATER PRESSURE/FLOW CONDITIONS

Face Airflow Velocity	Shearer Water Pressure: Low 40-55 gpm 50-150 psi	Medium 60-68 gpm 180-240 psi	High 70-82 gpm 250-320 psi
	Dust Concentration/ Percent Reduction from Baseline		
Low 250-300 fpm	17.54/ Baseline	7.86/ 55.2%	6.84/ 61.0%
Medium 350-370 fpm	8.67/ 50.6%	4.03/ 77.0%	3.53/ 79.9%
High 400-410 fpm	4.99/ 71.6%	3.77/ 78.5%	2.97/ 83.1%

(350-370 fpm), and low (250-300 fpm). Similarly, water pressure and flow levels to the shearer were also varied over three ranges as shown in Table 5. The low range of each factor (i.e., velocity 250-300 fpm, water pressure at 50-150 psi, and water flow rates of 40-55 gpm) was used as the "baseline" condition, against which the other airflow/water pressure/water flow combinations were compared. The greatest improvement (83.1 percent dust reduction) was achieved when all factors were increased to the "high" levels. However, an improvement nearly as substantial (77.0 percent reduction) was realized by increasing the factors to only the "medium" levels. Those levels of air velocity and water pressure and flow at which further increases do not result in additional significant dust reductions will vary from mine-to-mine; at this particular mine, increasing these three factors to only "medium" levels provided optimum dust reductions, while maintaining reasonable use of ventilating air and quantities of water.

Past surveys of U.S. longwall faces indicate that many operations could benefit from higher face air velocities. In other words, better dust control could result by using air quantities greater than those required to handle the methane. The 1978 survey cited earlier revealed that the average air velocity measured at the mid-point of the face on 7 single- and 31 double-drum shearer operations was 310 fpm and 285 fpm, respectively. A study of 1981 longwall operations (5) showed that only 15 percent (6 of 40 faces) of double-drum operations and 30 percent (3 of 10 faces) of single-drum operations maintained mid-point air velocities greater than 400 fpm.

Maintaining Face Airflow

Proper ventilation of a longwall panel involves more than just supplying the required volume of air to the headgate entry; maintaining that airflow along the entire length of the face is just as critical. This has been greatly enhanced by the increased use of shield-type roof supports. These supports provide a tighter seal between the face and gob areas than chock supports, reducing air leakage and preventing dust created by gob falls from entering the face area. In addition, a higher air velocity is maintained along the face because of the reduced area (as compared to chocks) under the shields. Other ventilation techniques used to achieve better dust control, including homotropal ventilation, auxiliary intake entries, and headgate gob and cut-out curtains, are discussed in Chapter 4.

Necessary Precautions When Using Belt Air to Ventilate the Face

Mining law prohibits the use of air coursed through the belt conveyor entry to ventilate active working places. However, some mine operators have received approval from MSHA to use belt air in the ventilation of longwall faces. In these instances, the belt entry was needed to provide the face with additional airflow required to reduce excessively high methane and/or dust concentrations. Also, the use of the belt conveyor entry as an intake is often required on those panels in which two-entry development systems are employed. When these situations occur, several precautions must be taken to minimize the contribution of the belt conveyor to the dust exposures of face workers.

Air velocity in the belt entry should be as low as possible to minimize the relative velocity between it and the flow of coal moving in the opposite direction. High air velocities can entrain dust from the material on the conveyor, and carry it up to the face. The amount of dust created during conveyance can be reduced by adequately wetting the coal at the face, and rewetting it at transfer points and at selected intervals along the conveyor. When tandem belts are used, care should be taken to minimize the free-fall distance of the material at the transfer point. Where excessive falls are unavoidable, chutes may be used. Also, hoods can be used to prevent the ventilating air from agitating dust; however, some amount of airflow must be provided through the hood to prevent methane accumulations. The use of sprays directed at the underside of the belt and belt scrapers are also effective in reducing the amount of dust generated during the conveyance process. More specific information on the control of dust generated in the belt-haulage entry will be presented in the section "Dust Control in the Headgate Entry" contained in Chapter 4.

DEEP CUTTING

Studies conducted in Great Britain and the U.S. have shown that deep cutting with lower shearer drum rotational speeds can significantly reduce dust generation during coal cutting without adversely affecting production. Thus, the use of low drum speeds to achieve deeper cutting is becoming more common in the U.S.

Reducing drum speed is one of only a few changes a longwall operator can make to increase output, reduce respirable dust, and decrease power consumption (4). Deep cutting, in the sense of increased bit penetration rather than a wider web, is a function of drum speed, machine advance rate, and pick spacing and gage length; the rotational speed of the drum is reduced (typically to 30-40 rpm) and the depth of cut increased by using large bits with wider spacing of the bit lines. Larger fragments of coal are removed, resulting in less exposed coal surface area and, therefore, a reduction in airborne respirable dust. In addition, the slower rotational speed minimizes the fanning action of the cutterhead, thus reducing recirculation and regrinding of the cut coal and minimizing the amount of coal fines liberated into the airstream.

Several British studies have shown that the use of fewer, but larger, bits can improve cutting efficiency and reduce respirable dust generation (6,7). In two separate studies, drums were fitted with only 8 and 12 bits, respectively; the bits measured two inches wide at the tip. Respirable dust levels were reduced by 25-32 percent, even though the spray water used during one of the studies was reduced 25 percent as compared to a conventional drum. Lower dust levels were attributed, in part, to increases in the amount of large coal fragments greater than two inches and reductions in the amount of fines less than one-half inch. An additional benefit realized in one of the studies was a 40-percent reduction in bit-replacement costs.

Recent U.S. field tests have further substantiated the beneficial impact of slow-speed deep cutting (8,9). For these tests, the depth of cut was altered from a minimum of 1.7 inches to a maximum of 5.3 inches by varying drum speed and pick spacing while keeping the advance rate of the shearer constant. A 60-percent reduction in dust generation was achieved by reducing the drum speed from 70 to 35 rpm and, consequently, increasing bit penetration from 1.7 to 3.4 inches (Figure 28). In other words, at 35 rpm nearly four times the amount of coal could have been mined at this particular face before exceeding the compliance level as compared to 70 rpm. Achieving increased bit penetration by reducing the number of bits per line was not as effective in reducing dust levels as that obtained with lower drum speeds. Dust levels were reduced by only 20 percent when bit penetration was doubled by removing alternate vane bits (i.e., one bit per line vs. two bits per line). Additional analyses showed that deep cutting can result in reduced shearer power consumption. Figure 29 shows how average power consumption decreased as drum speed decreased and bit penetration increased. The peak level followed the same pattern, but at approximately 1.25 times nominal full load. There was a 20-percent decrease in shearer power consumption as the drum speed was reduced from 70 to 35 rpm. This allows a slightly higher haulage speed, which should provide an increased rate of production.

An ancillary advantage of increased cut depth is improved product washability because of fewer fines. Depending on the kind of washing or preparation used, slow-speed deep cutting will either cut costs or improve coal preparation efficiency. Principal preparation areas where improvement and/or economic savings may be achieved include fugitive dust control, dewatering fines, replacement of separating media, and tailings disposal.

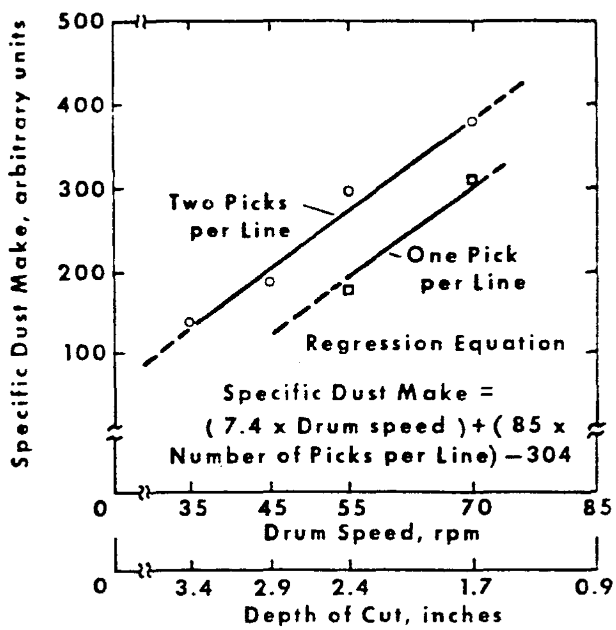

Figure 28. Dust Make as a Function of Drum Speed and Number of Bits per Line

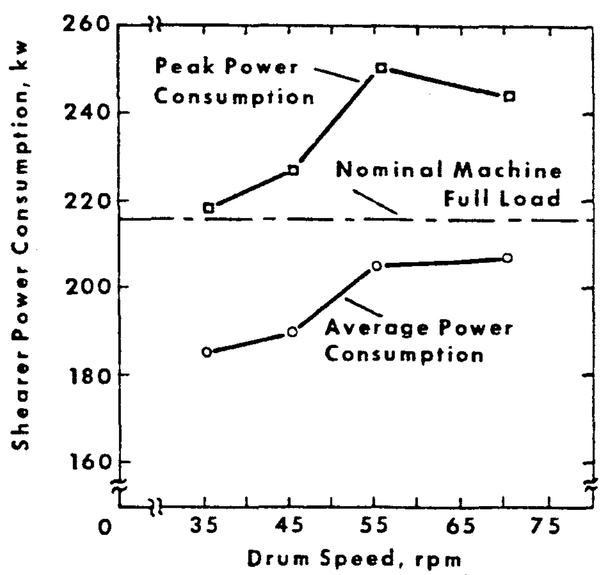

Figure 29. Power Consumption as a Function of Drum Speed at Two Bits per Line

There are some problem areas associated with slow-speed deep cutting. The principal engineering impacts are increased loads on all power and load transmission elements, from the bit to the shearer gearhead. Specifically, bits and bit blocks of sufficient dimensions (particularly bit length) and mechanical strength must be designed to absorb higher torque loads. Low drum speeds may also have detrimental effects on roof and floor conditions. The use of widely-spaced cutting lines to achieve high bit penetration can result in cores of uncut material remaining in the roof or floor. Consequently, roof control problems may occur because of reduced contact between the support canopy and roof, and floor coring could hamper face conveyor advances.

All the major longwall shearer manufacturers offer high-powered machines (450hp) that will operate with drum speeds of 30-40 rpm, and most supply machines with low drum speed settings in the high 20s to low 30s. For the most part, smaller machines tend to be available only with 45-rpm or higher drum speeds. According to the manufacturers, the major constraint in attaining the lowest feasible drum speeds is the amount of torque that can be carried by the ranging-arm gear train. The overriding consensus was that 25 rpm might represent the lowest feasible speed for the modern 400-500 hp machines.

The retrofit costs of a deep-cutting system can vary greatly. A new set of gears will cost approximately $10,000, including new bearings. If the mine, however, requires ultra low speed cutting, then a more sophisticated ranging arm equipped with a double-epicyclic gearbox may be required. The cost of this type ranging arm generally varies from $200,000 to $250,000 per set. In most cases, acceptable low speeds will be attainable by changing the gear ratio; however, if a low speed is selected, the shearer manufacturer should be contacted to determine if this may affect the warranty.

The cost of a drum designed for deep cutting is about the same as a conventional drum ($15,000). The increased cost of bit boxes, etc. on the cutting drum is essentially offset by the reduced number of bits on the drum. The life of a drum generally ranges from three months to one year, depending upon the hardness of the material being cut. Deep-cutting drums with long-reach point attack bits have a reduced working life. The leverage action of the bit on the bit box places high loads on the head of the bit box; this is the primary reason for damage to this type drum.

Bit life can be a major factor in the operating cost of a longwall. For soft cutting (i.e., mainly coal), the forward-attack, long-reach bits should experience longer life because of the reduction in specific energy for slow-speed cutting. For hard cutting conditions, the slow-speed drum is likely to have greater bit costs, as bit life is more dependent on the loss of the carbide tips rather than bit wear. The following information may be helpful in determining the operating cost of a longwall face:

- 3" radial bit - $7/bit
- 5" point attack bit - $11/bit
- Bit operating cost = $0.05 - $0.06/ton
- Drum operating cost = $0.10/ton

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4. OPTIONAL SUPPLEMENTARY CONTROLS

Operators often implement additional control techniques to help combat respirable dust on longwall operations. However, the application of several methods discussed in this chapter are very site-specific, and, therefore, cannot be successfully applied at every longwall installation. Nevertheless, operating experience and past research studies have shown that each of these techniques has been effective in reducing personal dust exposure on one or more longwall operations.

DUST CONTROL IN THE HEADGATE ENTRY

A very important, but often ignored, aspect of an overall longwall dust-control system is the control of intake-air contamination originating from the headgate stage loader, crusher, and coal-transfer points. Intake-air contamination on longwall panels utilizing conventional antitropal (head-to-tail) ventilation has contributed as much as 73 percent to the total respirable dust concentration measured at the shearer (1). By ignoring secondary dust sources such as these, controls implemented by the operator to reduce shearer generated dust may essentially be nullified. Better dust control in the headgate area may be achieved by (1) using ventilation curtains to minimize air leakage into the gob and reduce shearer operators' dust exposure when cutting out at the headgate, (2) enclosing the stage loader and crusher, (3) utilizing water sprays and/or scrubber on the stage loader/crusher, (4) replacing the conventional face conveyor-stage loader transfer point with a roller curve or side-discharge apparatus, and (5) using water sprays, belt-wiping devices, and check curtains on the panel belt conveyor.

Ventilation Curtains

Brattice curtains can be used in the following ways to improve longwall ventilation and dust control:

- A "gob" curtain mounted along the headgate shield line between the first shield and the adjacent coal rib can minimize short-circuiting of primary face ventilation into the gob (2)

- A "wing or cut-out" curtain mounted between the stage loader and coal rib can prevent the ventilation air from blowing across the shearer drum as it cuts into the headgate entry (3)

Air leakage is greatest in the headgate area because there is often a large gap between the first shield and adjacent rib, and the gob behind the first few shields remains open because the headgate entry is supported with roof bolts. This loss of air prevents maximum utilization of the air available to ventilate the face; in addition, dust generated during gob falls may be entrained by this airflow and carried back into the face area. A gob curtain (Figure 30), installed from the roof to the floor between the first support and the adjacent rib in the headgate entry, forces the ventilation airflow to make the 90 degree turn and stay on the face side of the supports, maintaining a sufficient face air quantity.

Air-velocity data collected during a two-week period on a longwall face showed the improvement in face airflow achieved by the use of a gob curtain (4). The average face air velocity with the curtain installed was 35 percent greater than that without the curtain, with the most significant improvement seen in the first 25 to 30 supports, Figure 31. The increase in air volume helps reduce face dust concentrations through dilution. The installation of a gob curtain is a simple,

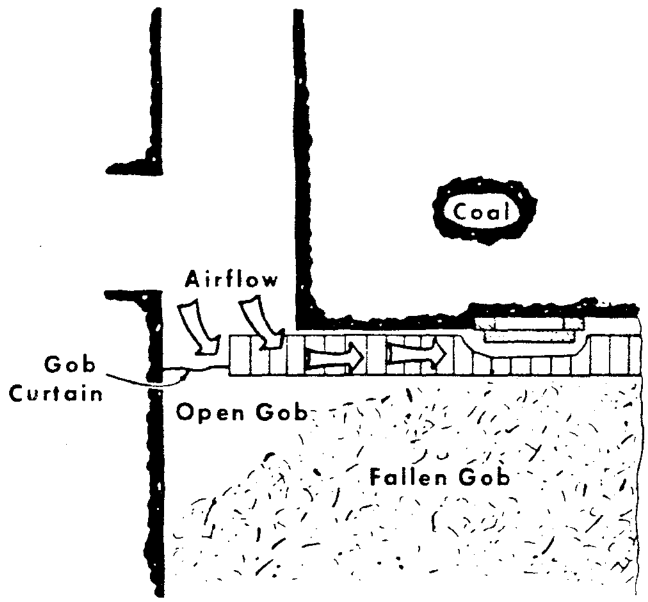

Figure 30. Gob Curtain Forces More Air Along Longwall Face

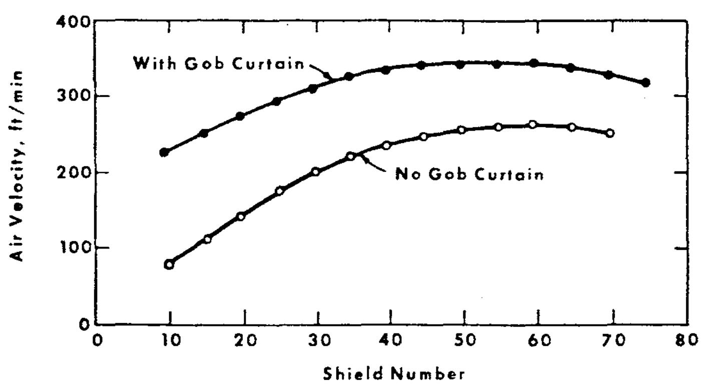

Figure 31. Improvement in Airflow Obtained with the Use of a Gob Curtain

cost-effective ventilation-control technique which should be routinely practiced on all longwalls.

On many longwall operations, misapplication of the primary ventilation airflow may actually contribute to increased dust exposure. In particular, the shearer operators are often exposed to very high concentrations as the headgate drum cuts into the headgate entry. The drum is exposed to the primary airstream, with the high-velocity air passing through and over the rotating drum, picking up large quantities of dust which are carried out into the walkway and over the shearer operators, Figure 32A. An effective method employed by some longwall operations to alleviate this problem is the installation of a wing or cut-out curtain between the panel-side rib and stage loader, to shield the headgate drum from the airstream as it cuts out into the headgate entry, Figure 32B. The curtain is typically located four to six feet back from the corner of the face to provide maximum shielding without interfering with the drum; consequently, the airflow is redirected to flow out and around the drum. The curtain is only in place during the cut-out operation, and is generally advanced every other pass. Dust concentrations monitored at the shearer operator positions indicated that the curtain can reduce their exposures by 50 to 60 percent (Figure 33) during the headgate cut-out and cleanup phase of the mining cycle.

A unique application of longwall ventilation curtains is shown in Figure 34 and involves the combined use of three separate curtains: a gob curtain, a 36-foot long stage loader curtain located along the off-panel side of the stage loader, and a sliding wing curtain extending from the panel-side rib to the stage loader curtain (5). During most of the cutting sequence, the gob curtain is in place and the wing curtain retracted against the panel-side rib. As the shearer approaches the headgate for the cut-out, the gob curtain is removed and the wing curtain pulled

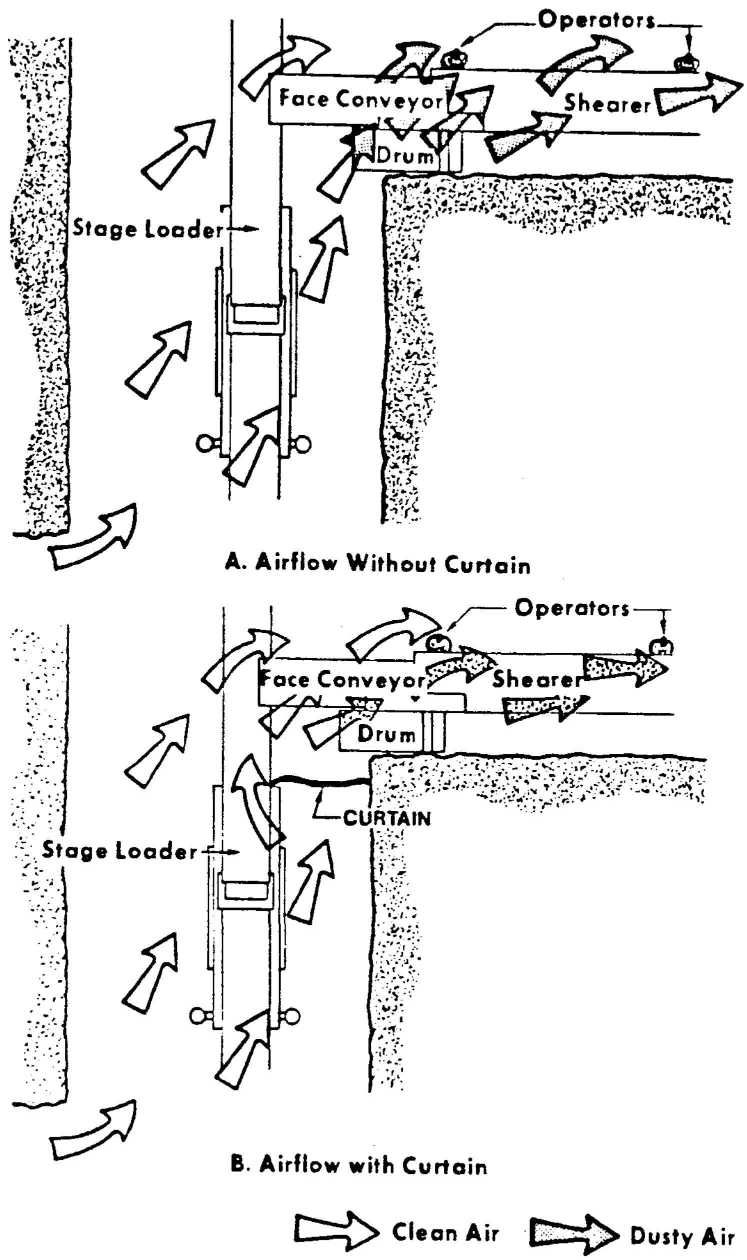

Figure 32. Effect of Curtains on Dust when Cutting Out the Headgate

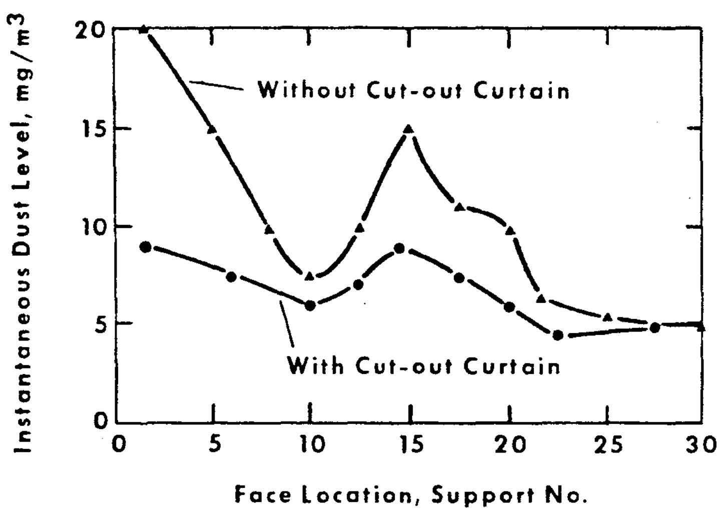

Figure 33. Effect of Cut-out Curtain on Dust Levels Measured at the Shearer Midpoint

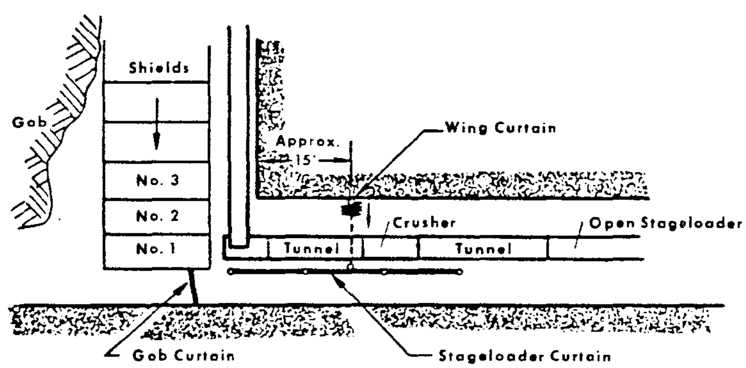

Figure 34. Unique Wing Curtain/Gob Curtain/Stage Loader Curtain System for Headgate Cut-out Dust Control

tight across the stage loader; this purposely short-circuits some of the airflow into the gob and blocks most of the air from passing over the headgate drum. Dust reductions up to 55 percent have been achieved at the shearer operator's position when using this system. This curtain arrangement should not be used on sections with high methane liberation rates.

Headgate Stage Loader and Crusher

Control of dust generated at the stage loader is often overlooked, but warrants great attention. This dust remains airborne across the entire face and can have a significant impact on the full-shift dust exposure of all face personnel. The major source of dust in the headgate entry is the stage loader/crusher.

A basic approach to this problem is the use of water sprays mounted along the stage loader. Several sprays (typically full-cone patterns) are mounted in spraybars which usually span the width of the conveyor to ensure uniform spray coverage of the coal stream. Recommended spraybar locations include the area just inby the crusher and at the stage loader-belt conveyor transfer point. Additional sprays may be located along the stage loader for the direct purpose of controlling airborne dust.

The dust-capture efficiency of these sprays may be enhanced by enclosing the stage loader, either with steel plate or strips of conveyor belting, Figure 35. The enclosure also isolates the conveyed material from the airstream, thus reducing dust entrainment. During underground trials with a fully covered stageloader and additional water spray manifolds, improvements at the headgate operator and at support 20 were 80 percent and 45 percent, respectively (6).

The installation of a water-powered scrubber immediately outby the stage loader/crusher can also be effective in controlling crusher-generated dust (7,8). The scrubber consists of a

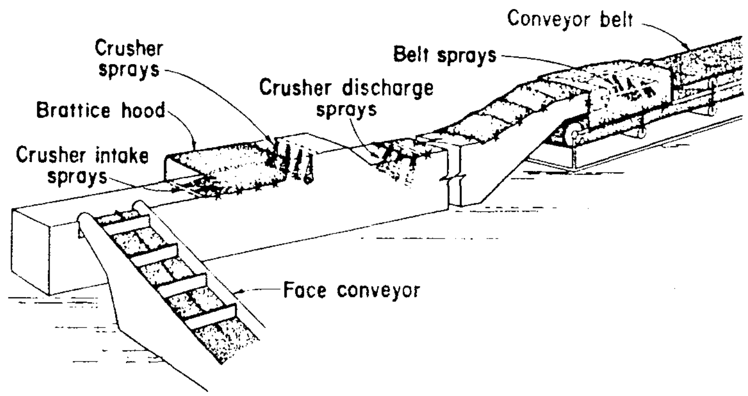

Figure 35. Enclosed Stageloader-Water Spray Arrangement

rectangular duct with conventional water spray nozzles located at the inby end and a water droplet eliminator at the outby end. It contains no moving parts and can be installed in a single shift; a transition duct is used to attach the scrubber intake to the crusher discharge. Dust-laden air is drawn from the crusher and through the scrubber where it is cleaned by water sprays and discharged through the water droplet eliminator. The resulting dust/water slurry is dumped onto the coal as it passes underneath the scrubber; the additional wetting helps to reduce the dust generated by coal transport and transfer on the belt conveyor. The following scrubber operational and installation guidelines are recommended:

- Spray water pressures of 400-500 psi
- Spray water flow rates of 1 gpm for every 250 cfm of air moved

- o Air velocities through the scrubber of 1000-1400 fpm
- o Position the scrubber as close to the crusher as possible to maximize its effectiveness
- o Install a brattice hood and water sprays directed at the crusher intake if dust "boil out" occurs
- o Use smooth transitions to adapt the scrubber intake to the stage loader to minimize pressure drops
- o Install water filtration system to minimize nozzle plugging

An underground dust-sampling survey was conducted to evaluate a stage loader dust-control system consisting of a water-powered scrubber, a crusher intake hood, and water sprays directed at the crusher intake. The scrubber was supplied with 9 gpm of water at 500 psi for an airflow of 2,000 cfm through the unit. A dust reduction of 75 percent was realized at the headgate operator's work position, with a 50-percent reduction observed in the intake dust levels along the face. The approximate cost of this type scrubber is $1/cfm of air moved, with operational and maintenance costs minimal.

Belt Conveyor and Transfer Points

Dust generated during the transport of coal by belt conveyors can be entrained by the ventilating airflow, increasing the dust exposure of all longwall personnel. If the coal is wetted adequately at the face, the amount of dust created during conveyance and at transfer points will be decreased; however, the moisture may evaporate and rewetting may be necessary at intervals along the belt (9).

Belt scraping/wiping systems are sometimes necessary to remove material which adheres to the belt and is subject to crushing at the head and tail rollers. Belt scrapers, installed on the return side of the belt near the drive, are effective for cleaning the load-bearing side of the belt. Various designs are available, including spring-loaded, counter-weighted units which hold a scraper or plow tight against the belt and motor-driven wire brushes which rotate in opposition to belt travel. Fine dust may also adhere to the non-load bearing side of the belt. A recommended technique for cleaning this side of the belt is to construct a belt wiper with inexpensive, foam-backed carpeting, Figure 36. Two strips of carpeting, approximately six feet long, are cut to a width six inches less than the width of the belt, placed one on top of the other, and folded in the middle. A pipe, drilled with several holes along its length and connected to a water supply hose, is inserted through the fold with the carpeting clamped below it. The carpeting is suspended slightly above the non-load bearing side so that it wipes and slightly moistens the belt. Care must be taken to establish the minimum amount of water required, as excessive amounts can cause slippage problems.

An alternative method is to install low-quantity, wide-angle flat fan sprays above the non-load bearing side of the belt. Once again, water quantities should be limited, with the appropriate spray flow rates determined from the length and width of the belt. For example, a flow of 0.08 gpm was found to be adequate for a 1300-foot long, 36-inch wide belt. In an evaluation of various dust-suppression spray nozzle locations at a belt-to-belt transfer point, a single spray located above the non-load bearing side of the outby belt reduced airborne respirable and float dust by more than 90 percent, compared with dry operation (10). The spray operated at 0.33 gpm and was used

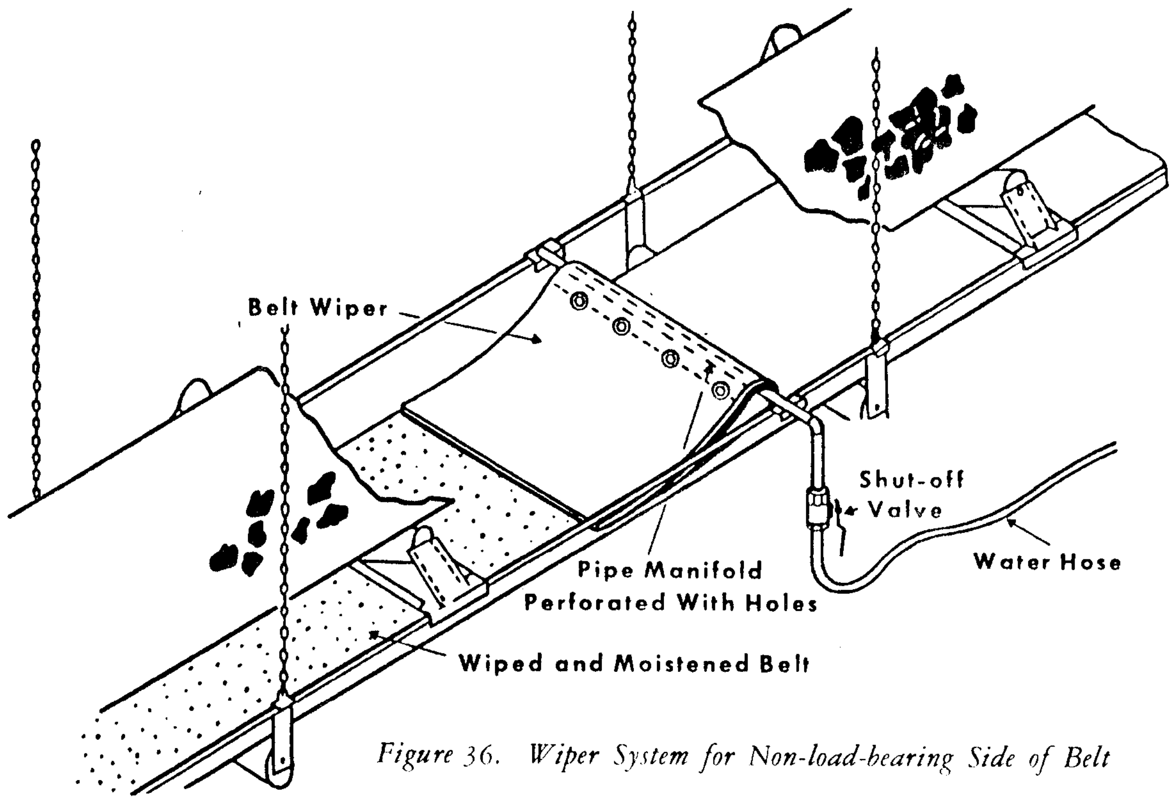

Figure 36. Wiper System for Non-load-bearing Side of Belt

in conjunction with a section of carpet measuring two feet.

Another source of dust in the headgate entry is the face conveyor to stage loader transfer point. The free fall of coal from the discharge of the armored-chain face conveyor onto the stage loader exposes the material to the primary ventilating airstream where dust particles can be entrained and carried along the face. Moreover, the impact of the falling material onto the stage loader results in secondary fragmentation and additional dust generation. Two alternate methods of transfer between face conveyor and entry transport that can reduce dust generation in this area are the roller curve and side discharge systems, Figure 37 (11). The roller curve is used to

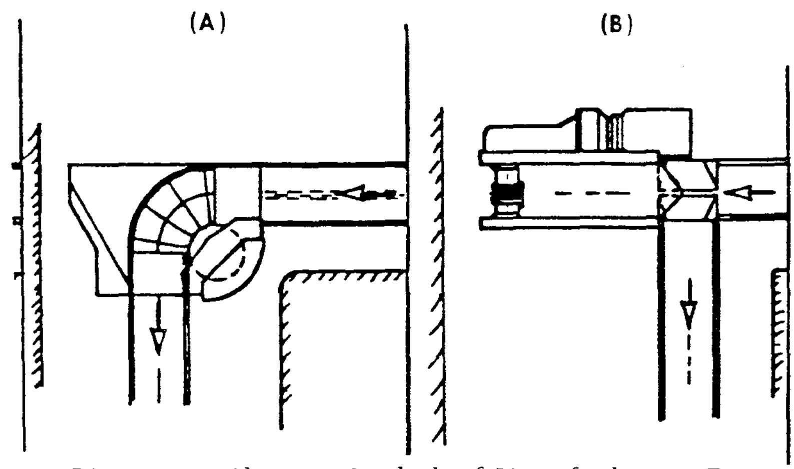

Figure 37. Alternate Methods of Transfer between Face Conveyor and Entry Transport: (A) Roller Curve and (B) Side Discharge

integrate the face and entry haulage system to transfer the coal from the face conveyor to the panel belt (12). The face conveyor chain makes a 90 degree turn on the roller curve at the headgate end, thus eliminating the transfer point, and coal is fed onto the panel belt at a point about 30 feet from the headgate. One manufacturer provides a roller curve consisting of two discs mounted on roller bearings and shielded by a steel plate. Two sheaves or rollers provide guidance and support for the tips of the face-conveyor flights at the intersection of face and entry. At any one time, a minimum of four flights are engaged on the curve. The entry conveyor portion of the roller curve system overlaps a special belt tailpiece, which is secured, advanced, and adjusted by a simple hydraulic anchorage and tramming unit. Other advantages of the roller curve are that coal recirculation or "carryback" is reduced as the coal falls more freely from the flights after being transported around the curve, and the shearer is able to come to the end of the face when cutting out without interference from stage-loading equipment.

The second method used to combat dust generation at the face conveyor to stage loader transfer point is the use of side discharge. This technique is used in conjunction with conventional face conveying and stage-loading equipment. The coal is not dumped over the face conveyor chain sprockets, but is deflected before it reaches the sprockets and loaded onto the stage loader, which is inserted below the face conveyor drive frame. Dust generation is reduced as the free-fall distance of the coal is lessened, and the amount of coal fragmentation is decreased.

The transfer point between the stage loader and panel belt conveyor must be properly ventilated to eliminate ventilation deadspots (i.e., stagnant airflow) which can cause significant dust-concentration gradients in this vicinity. As the stage loader advances and approaches the chain pillar where the belt check curtain is installed (Figure 38), ventilation at the transfer point may approach zero. Hence, the check curtain should be moved to the next outby pillar and some intake air allowed to pass through the second outby crosscut. Excessive air velocity in this area should be avoided to reduce dust entrainment. One way to achieve this is to keep the immediate vicinity of

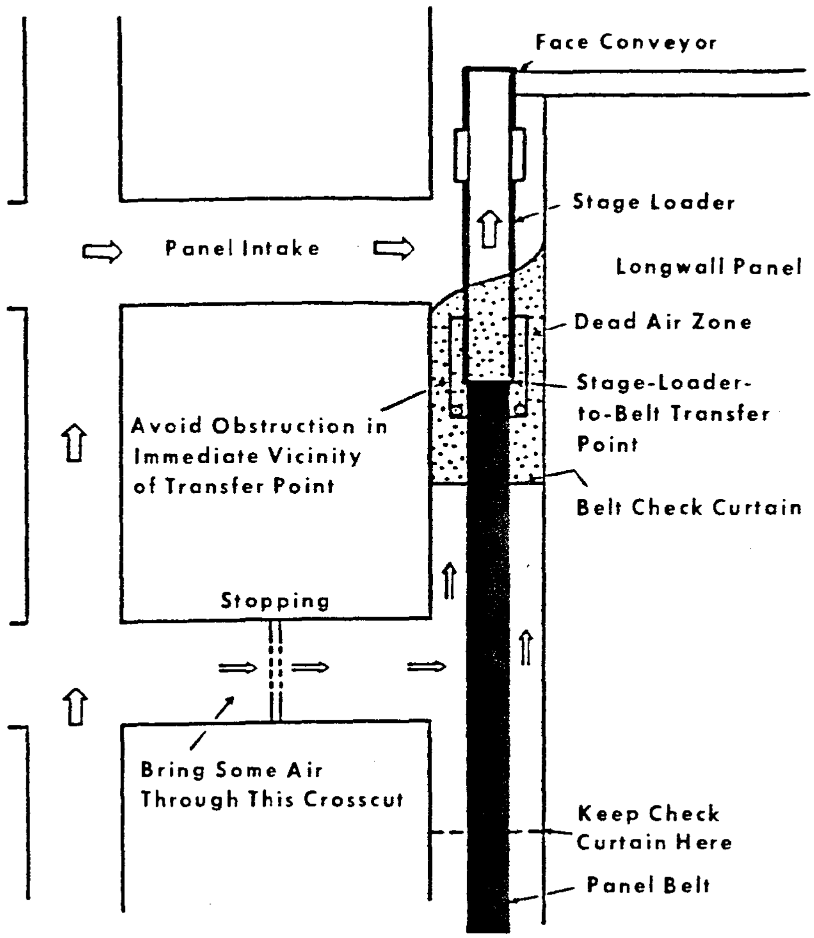

Figure 38. Ventilation of the Stage Loader-to-panel Belt Conveyor Transfer Point

the transfer point free from obstructions which can reduce the cross-sectional area of the entry, and, therefore, accelerate airflow over the transfer point.

WATER PROPORTIONING

The dust exposure of the shearer operators is more dependent on their position relative to the upwind drum than the amount of coal and rock cut by the drum. On many operations, the downwind drum can be disregarded as a dust source contributing to the operators' dust exposures. When cutting with the airflow, the upwind drum cuts the bottom coal and floor rock and is the main contributor to the operators' dust exposures; when cutting against the airflow, the lead drum is upwind and taking a full cut, exposing the operators to very high dust concentrations.

As discussed in Chapter 2, increasing the water flow to the drums usually reduces airborne dust levels produced by the shearer. However, some operations may not be able to tolerate an increase in water flow because of the problems that may result with the floor, especially clay floors. Also, the excess water in the coal will reduce its run-of-mine Btu value and may cause problems in the coal-transport system (conveyor belt slippage) and in the coal preparation plant. For these operations, supplying larger quantities of water to only the upwind drum can have a significant impact on the amount of water used per ton of coal mined while reducing operator dust exposure (13). For example, a longwall currently operating with a shearer water flow rate of 40 gpm would have to increase this rate by 50 percent to obtain a desired flow of 60 gpm (30 gpm to each drum). The same results (i.e., gallons per ton of coal mined by the upwind drum) can be achieved by using a 60/40 proportioning system, thereby supplying 30 gpm to the upwind drum and maintaining

20 gpm at the downwind drum, while only increasing total water flow by 25 percent (40 gpm to 50 gpm).

A Bureau of Mines' study was conducted to assess the effect on operator exposure of proportioning the water flows to the drums (14). The dust exposure of the downwind drum operator and total dust make at the tailgate were measured with the shearer cutting downwind for two separate water flow conditions: (1) total flow of 34 gpm with 10 gpm supplied to one drum and 24 gpm to the other drum, and (2) total flow of 48 gpm with 12 gpm supplied to one drum and 36 gpm to the other drum. When water was shifted from the downwind drum to the upwind drum, both the operator dust exposure and total dust make were reduced. The switch from a low flow on the upwind drum (10 or 12 gpm) and a high flow on the downwind drum (24 or 36 gpm) to the reverse situation resulted in an average 63-percent reduction in the operator dust exposure and a 32-percent reduction in total dust make. When comparing drum-water proportioning systems to those with the flow equally distributed between the drums, the following was evident:

- Total dust make was always lower for any proportioning system when compared to equivalent flows.

- Operator dust exposure was the highest with low flow on the upwind drum and high flow on the downwind drum

- For a total flow of 34 gpm, the dust exposure was slightly less (1.3 mg/m^3 vs. 1.7 mg/m^3) for an equivalent-flow system than for a proportioning system with high flow on the upwind drum and low flow on the downwind drum

- For a total flow of 48 gpm, the dust exposure was 52 percent greater (3.8 mg/m^3 vs. 2.5 mg/m^3) for an equivalent-flow system than for a proportioning system with high flow on the upwind drum and low flow on the downwind drum

- For equivalent-flow systems, the operator dust exposure increased as the total flow was increased from 34 gpm to 48 gpm to 56 gpm, even though total dust generation decreased. This was partially attributed to the high flow rates and spray pressures at the downwind drum pushing the dust from the face into the walkway and over the operator. In addition, the operator frequently moved downwind from the controls to observe the cutting action of the downwind drum; if he were to stay at his controls, exposure to dust from the downwind drum is unlikely, provided there is sufficient ventilation and an effective external spray system.

Additional tests are planned to determine the effect on dust "boilover" of increasing the water flow rate while keeping the spray pressure constant. These tests may indicate that respirable dust levels can be further reduced by redistributing the water to the upwind drum when the sprays on this drum are changed (i.e., larger orifice size) to keep the pressure low.

LONGWALL AUTOMATION - REMOTE CONTROL

Longwall automation, specifically the remote control of shearers and roof supports, can have a significant impact on reducing the dust exposures of face personnel. Although not yet widely adopted on U.S. longwalls, longwall automation possesses the advantage of placing the operator on the clean upwind side of equipment operation.

Shearer Remote Control

Most manufacturers now offer either radio or umbilical (hard wire) remote control for use with their shearers. Although the equipment for radio remote control is available, its use in the U.S. has been limited by its relative complexity and low reliability. Its greatest potential application may be in high coal where face spalls (i.e., coal and rock rolling off the face and into the walkway) can result in serious injury to the shearer operators. Umbilical remote controls are easy to retrofit to modern shearers, and, therefore, more commonly used in the U.S. than radio remote. With some improvements in mine ruggedness, but without expensive modifications to the shearer or the need for an inefficient cutting cycle, umbilical remote control will generally provide simple, reliable operation.

Remote control enables the shearer operators to control the machine from positions along the face less contaminated than their normal control stations. A USBM contractor evaluated the use of remote control to reduce operator dust exposures in which dust concentrations were measured at the conventional shearer operators' positions and at a location 20 feet upwind of the normal control stations (15). The average exposures for the conventional and remote locations are shown in Figure 39. The headgate-drum operator's exposure was reduced 68 percent when he was moved 20 feet upwind of his normal control position. There was no significant difference in the dust exposure of the tailgate-drum operator when he was moved from his normal control station to a position 20 feet upwind (which actually placed him at the headgate-drum operator's normal control station). This was attributed to an inefficient external spray system which created adverse airflow patterns and dust gradients in the vicinity of the headgate-drum control station. With a properly oriented spray system, dust levels at the headgate-drum control

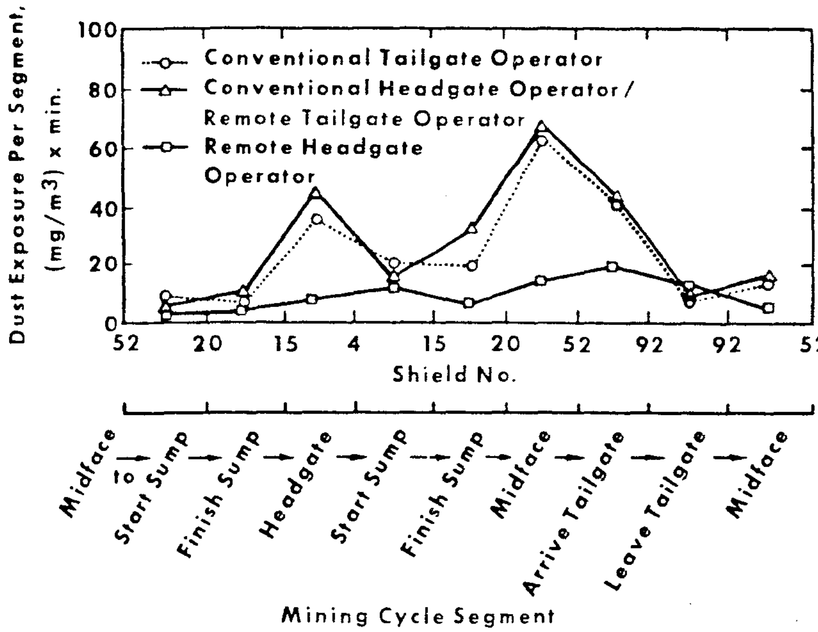

Figure 39. Average Dust Exposures for Conventional and Remote Shearer Operator Positions

station should be lower than those at the tailgate-drum operator's normal control station.

Roof Support Automation

The amount of dust generated during the process of lowering, advancing, and raising the roof supports can be significant. Consequently, the dust exposures of the roof-support operators, or jacksetters, will not only be affected by their location relative to the shearer, but also to the support being advanced. The desired direction of support advancement is downwind, allowing the ventilating air to carry support-generated dust away from the jacksetter when adjacent support-control is used. However, the jacksetter is still generally exposed to a certain amount of dust dispersed upwind of the support. The use of remote-control systems for roof supports allows the jacksetter to remain upwind of support movement and the shearer during upwind unidirectional and bidirectional cutting sequences.

Most remote systems manufactured today are controlled hydraulically or electro-hydraulically, and permit remote-initiated, automatic, sequential support advancements (9). Supports are typically automated in groups or batches; for example, a 500-foot face may be equipped with 10 batches of 10 supports each. Following an actuation operation, the supports within a batch are sequentially advanced in the desired direction. The advancing sequence may be initiated from a support adjacent to the end of the batch being moved or from a remote upwind batch location, Figure 40. For a

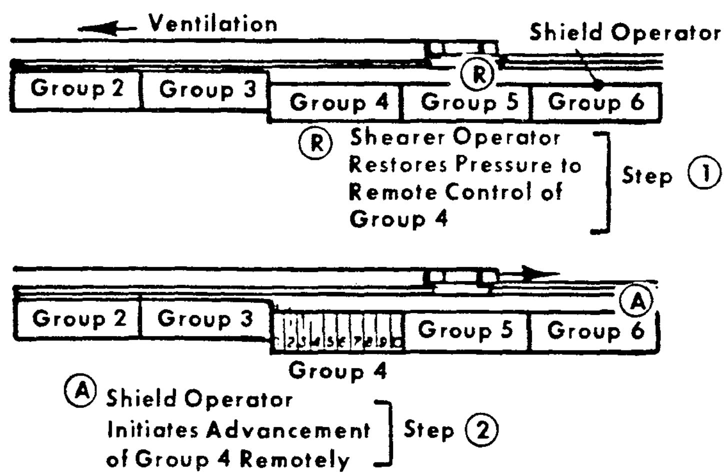

Figure 40. Remote Control of Batched Supports

typical remote system, the automatic movement of the supports begins when the shearer operator passes a support and activates the group-initiating valve. The jacksetter then activates the group-automatic-selector valve. After the first shield reaches full setting pressure, the second shield releases, advances, and sets. This sequence continues through the full batch. Safety features commonly incorporated into most remote systems include the following (16):

- Each shield must reach full pressure against the roof before the next shield can move

- Supports cannot be advanced unless both adjacent supports are set

- Each support is equipped with an audible warning that informs face personnel that it is the next unit to be moved

- Emergency stops are provided on each support to terminate the automatic sequence, if necessary

Although several automated roof-support systems are currently in use in the U.K. and Australia, their use in the U.S. has been limited to only a very few faces.

HOMOTROPAL VENTILATION/AUXILIARY INTAKES

On many longwall faces, intake contamination from the headgate stage loader and crusher can create a significant dust control problem. In addition, when the air is coursed in the conventional head-to-tail direction, the direction of coal transport opposes that of the airflow. As a result, the relative velocity between the airflow and the moving coal is usually high enough to cause dust entrainment from the conveyor, especially when the coal is dry. On those faces where these dust sources are a significant problem, and conventional headgate dust-control methods are proven ineffective, the option of coursing the air from the tailgate to the headgate so that it flows in the same direction as the transported coal (i.e., homotropal ventilation) should be considered, Figure 41. An auxiliary intake must also be maintained at the headgate end to provide sufficient air to both dilute dust in the headgate area and provide a positive airflow towards the face to

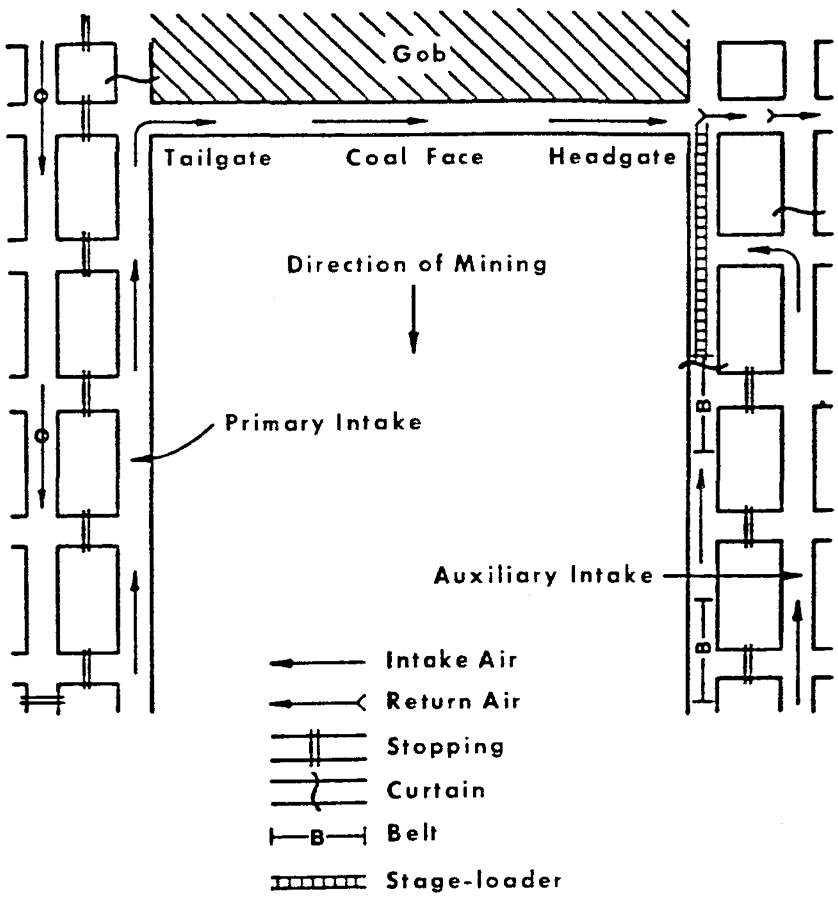

Figure 41. Longwall Panel Layout for Tailgate-to-Headgate (Homotropal) Ventilation

prevent contaminated face air from entering the headgate.

Test results (17) have shown that homotropal ventilation can lower instantaneous intake dust concentrations along the face by approximately 1 mg/m^3, Figure 42. Of course, the reduction in

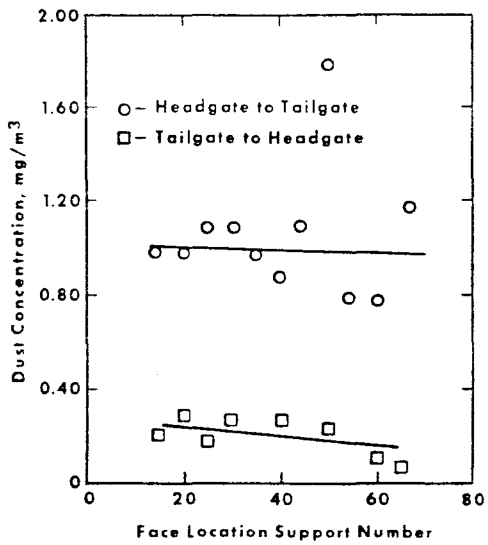

Figure 42. Effect of Homotropal Ventilation on Intake Dust Levels

the eight-hour, full-shift gravimetric concentration will be less, depending on the operating time of the shearer during the shift. Assuming a shearer cutting time of four hours per shift, a reduction in instantaneous dust levels of 1 mg/m^3 would reduce the full-shift concentration by approximately 0.5 mg/m^3. This would be beneficial to those operations which are marginally out of compliance.

A major disadvantage of the homotropal ventilation system is the necessity of maintaining the tailgate entry as the primary intake. Under poor roof conditions, this may not be economical. Roof falls in the tailgate, resulting from the roof pressure associated with extracted adjacent panels, can be minimized by correctly sizing the chain pillars. Pillars adjacent to the active gob should be designed to "yield" before the tailgate roof breaks. In addition to regular roof-bolt support, the tailgate entries should be supported by two rows of cribsets. Homotropal ventilation is also very difficult to implement on established panels, considering the amount of time and work involved in installing a new ventilation system, re-orienting shearer external spray systems, changing the adjacent hydraulic control of roof supports, and retraining face personnel to operate a new sequence of tasks. Its use should only be considered for future panels, following a comprehensive analysis of its effect on all aspects of mining operations.

Many mines are using the tailgate entry adjacent to the longwall panel as an auxiliary intake in conjunction with a conventional head-to-tail ventilation system. This provides the tailgate worker and jacksetters in the tailgate vicinity with intake air, reducing their exposure to the respirable dust generated along the face. An additional advantage of this practice is that another intake escapeway is available to face personnel, and, if well maintained, the entry may be used as an additional supply road. The quantity of tailgate air is small, typically about 5,000 cfm.

USE OF A WATER-POWERED SCRUBBER AND BRATTICE PARTITION TO REDUCE TAILGATE WORKERS' DUST EXPOSURE

Miners required to work at the tailgate are constantly exposed to the dust generated along the face. One approach that has been used to clean the air in the vicinity of the workers' location is the use of a water-powered scrubber installed on one of the tailgate shields. The cleaned air is maintained as a clean split by exhausting it into a bratticed-off space at the working area.

Because of its simplicity and size, the jet spray air mover (JSAM), Figure 43, is most frequently used for this application (7). It has no moving parts, and is operated by water at low flow rates (<10 gpm) and fairly high pressures (250-500 psig). It can clean quantities of air ranging from 2,000 to 3,000 cfm. The size of the unit, 4 x 2 x 1 ft, allows it to be easily installed on a shield support.

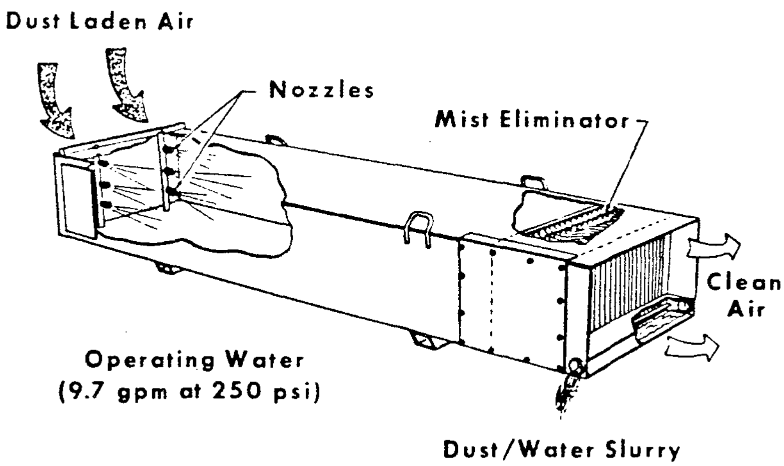

Figure 43. Water-powered Scrubber

Laboratory testing of the scrubber-partition installation indicated an 84-percent efficiency with 2,500 cfm behind the curtain (18). The system was installed on a longwall where a tailgate worker was required to stay at the tailgate for the entire shift to make methane checks every 20 minutes. The underground layout of the partition and scrubber is shown in Figure 44. In this particular arrangement, the scrubber exhaust was

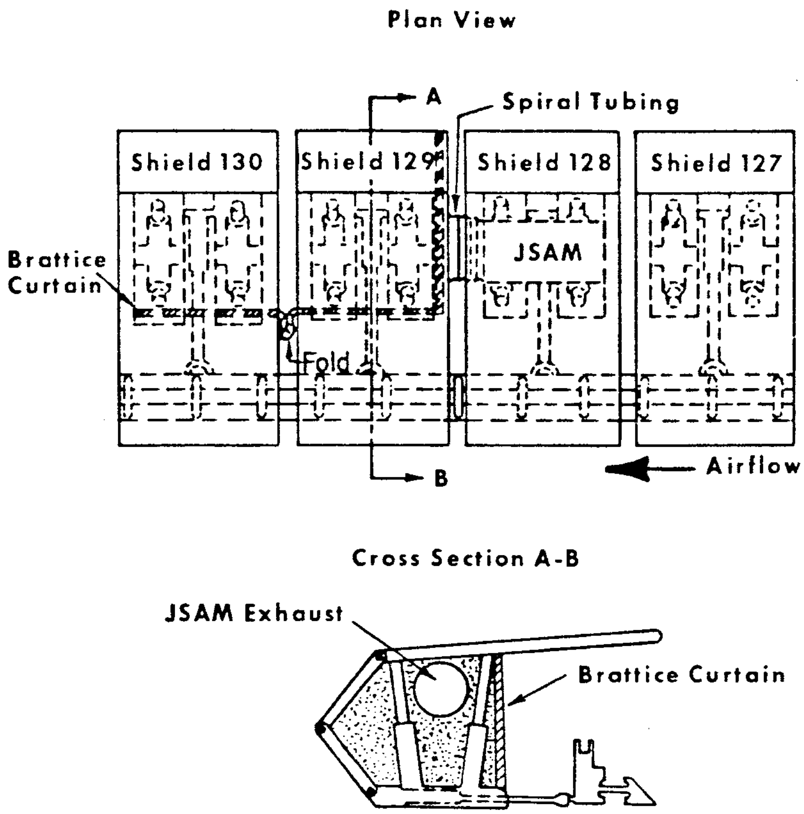

Figure 44. Tailgate Scrubber and Brattice Partition Layout

connected to the partition by spiral tubing to allow movement between shields. The partition was extended along the width of two shields, approximately 10 feet. Dust sampling behind the partition and in the walkway showed a 34-percent reduction in respirable dust behind the partition with the scrubber operating at 250 psig and 7.0 gpm, producing 2,140 cfm of cleaned air. With the scrubber operating at 450 psig and 8.3 gpm (2,700 cfm cleaned air), the dust reduction increased to 42 percent. Both the laboratory and underground studies indicated that increasing the airflow through the scrubber, by increasing the water quantity and pressure, will increase the system's effectiveness and result in greater dust reductions. A dust reduction of 50 percent would be expected with the scrubber operating at 500 psig. To maintain the desired water quantity and pressure at the scrubber, the size of the supply line from mid-face to the scrubber might have to be increased. For example, the supply line for the underground tests was 1/2-inch in diameter; the use of a 3/4-inch hose could have reduced frictional losses by about 100 psig. However, care must be taken not to exceed scrubber pressures of 500 psig and water quantities of 10 gpm so that the scrubber exhaust air is not saturated with excessive water mist.

WATER INFUSION

Water infusion is a dust-control technique involving the injection of water, under pressure, into an area of coal prior to extraction. This increases the moisture content of a seam before mining, and, therefore, reduces the dust levels during mining. Infusion holes are drilled in advance of the coal face. They are sealed with retrievable, inflatable packers or by grouting a pipe into the hole. Water is applied under pressure through the seals to the end portion of the hole where it flows through the slips and cleavage planes present in the coal seam.

Water infusion of longwall faces to suppress dust is a common practice in Europe. Belgium has utilized water-infusion techniques for over 20 years. In the northern coal fields of France, which covers 89 percent of the coal produced, the basic dust-control technique is water infusion. German mining regulations require water infusion of all faces where possible, and over 50 percent of their longwalls are infused. The two water-infusion methods practiced on advancing longwall panels in Europe are face infusion and infusion from advanced gate roads. For face infusion, the holes are either drilled to a depth approximately 20 inches past the daily face advance (shallow-hole infusion) or to a depth of about 40 feet for several days of mining (deep-hole infusion). In both cases, the holes are spaced along the face 1-1/2 to 2 times the depth of the hole. Approximately 15-80 gallons of water are pumped into each hole at pressures generally less than 200 psig. Dust reductions typically range between 50 and 70 percent. Infusion from advanced gate roads is used to a lesser degree in Europe. Successful trials (i.e., dust reductions of 35-50 percent) have been achieved by infusing water at pressures up to 600 psig into deep holes (65-260 feet) for 10 hours or longer.

Use in the U.S. has generally been limited to a few plow operations in the Pocahontas No. 3 seam and various test programs. Since retreat longwall systems are used almost exclusively in this country, infusion from the existing gate entries is more desirable than face infusion which limits production. A detailed description of this procedure and the equipment used is presented later in this section. Studies have shown that under appropriate conditions infusion of a coalbed may result in significant respirable and total airborne dust reductions. Table 6 summarizes results of these trials (19, 20, 21, 22). A more

TABLE 6. SUMMARY OF AMERICAN LONGWALL INFUSION TRIALS

Seam	Hole Depth (feet)	Water Pressure (psi)	Flow Rate (gpm)	Conclusions
Eagle	200	400 maximum	12	Observed reduction in visible dust. Improved visibility at face and transfer points. No measurements taken
York Canyon	N/A	N/A	N/A	Water short-circuited through large fractures
Pocahontas No. 3	80-220	1500-2200	15	Reduced respirable dust 40 to 79 percent
	42-300	650-1000	10	Reduced respirable dust 50 percent
	270	600	6-10	Reduced respirable dust 43 to 68 percent
Lower Sunnyside	300	315-600	13-27	Reduced respirable dust 47 to 64 percent
Upper Freeport	160-280	180-225	10	Reduced respirable dust up to 38 percent

detailed account of one of these case studies will be presented later in this section.

Suitability of the Coalbed

The viability of infusion as a dust-control technique depends primarily on the seam geologic conditions. Hard coals with virtually no fracture systems are unsuitable for infusion because they are impermeable. Infusion of blocky coals with widely spaced cleats will not produce satisfactory results since most of the coal's surface area will be unwetted, resulting in greater dust generation from the newly fractured surfaces produced by cutting. The presence of clay veins, dikes, extensive faulting, etc., may result in zones with low resistance to water flow and cause short circuiting rather than a wide, even distribution of water. Surface properties of the coal itself affect its wettability, and hence, its resistance to water flow through cleat structures. Finally, infusion can potentially be detrimental to roof and bottom conditions; however, the USBM has reported that this has not been a major problem in American tests to date.

Friable coals are generally most suited for infusion because of their greater fracture densities. Even with these coals, some new surfaces are formed during coal cutting, resulting in some dust generation. An in-mine test of coal permeability and infusion-flow characteristics is recommended prior to undertaking any major water-infusion project. An estimate of seam infusibility can be determined without investing much time and money by drilling a series of short 3-inch holes to a depth of about 50 feet in the rib side of the proposed panel and attempting to infuse the hole, as described in the following section. If seam characteristics prevent water infusion at reasonable pressures and flow rates, other more effective dust-control techniques should be investigated.

Infusion Techniques and Equipment

The water-infusion process involves three distinct operations: (1) hole drilling, (2) hole packing, and (3) water infusion. Longwall panels can be infused from one or both sides of the panel as shown in Figure 45.

Infusion holes require a drilling capability for 3-inch diameter holes approximately 25 feet beyond the centerline of the panel width. Hole spacing may vary due to mechanical properties of the coal seam, but holes are usually spaced at distances equal to the radius of the infusion zone (1/2 the panel width). Several commercial portable electric-hydraulic drills are capable of this task. Also, an air-powered drill may be suitable under certain circumstances (coal is friable enough and no deformation of the hole at the rib). The hole is then packed approximately 50 feet from the inby end.

The Bureau of Mines has developed an alternative infusion hole-sealing method (packer) for long holes (65-260 feet), which is less costly and labor-intensive and more reliable than the reusable hydraulic packers commonly used in Europe. The packer can be assembled in any mine machine shop from commercially available materials. This packer consists of 10 mil polyurethane plastic sheathing with the edges glued together to form a tube 1/2 inch larger in diameter than the infusion hole, placed around a 1-inch PVC pipe. The tube is protected and sealed at both ends by a 1-foot long rubber hose banded over the pipe at each end. This tube is filled with a grout mixture of cement, Calseal, and salt at a pressure up to 250 psi and is allowed to set for a period of approximately 24 hours. Pressurizing the cement in the packer does no produce any stresses in the polyurethane tube because it is wider than the hole. Finally, the material cost to construct this packer for a 250-foot long hole is $250, compared to $50,000 to effectively seal the same length of hole with hydraulic packers (including labor).

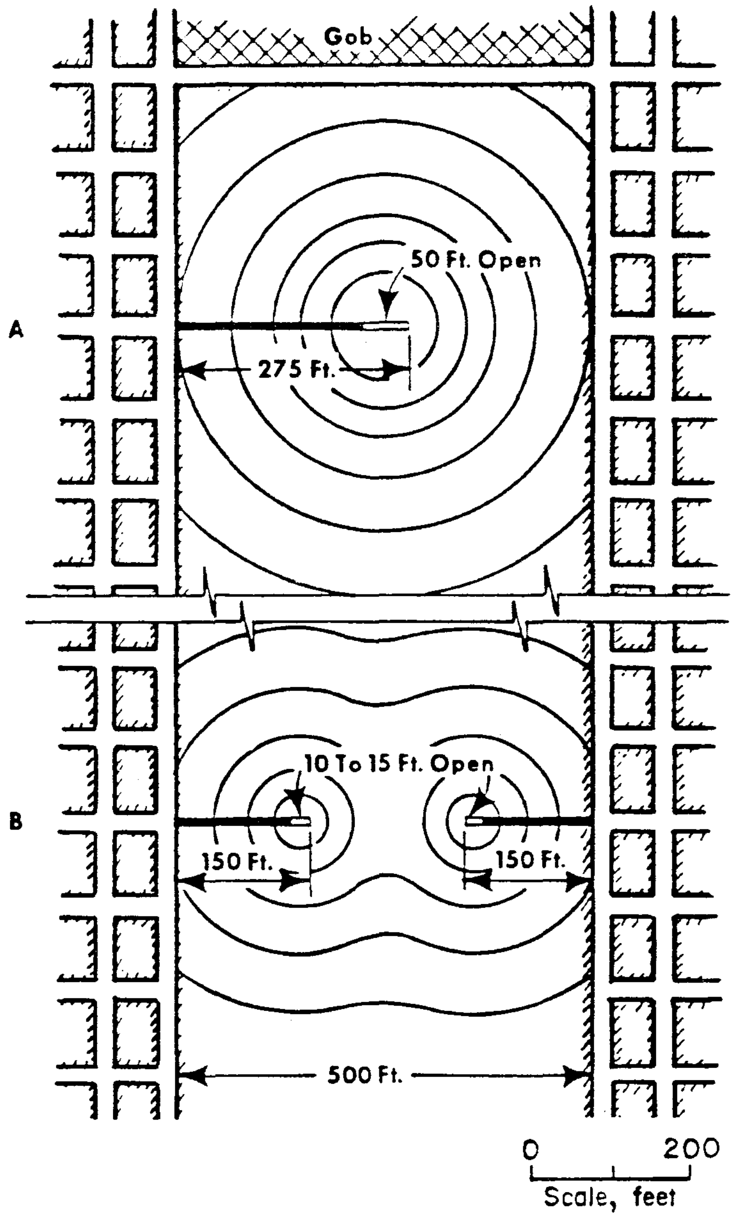

Figure 45. Infusion of a Longwall Panel with One or Two Holes

After the infusion hole is properly drilled and packed, a suitable water pump is used to maximize the amount of water infused into the coal. There are several commercially available water pumps that are suitable for water infusion needs. Optimum water flow and pressure during infusion will vary from mine-to-mine and seam-to-seam. However, the pump should be able to operate continuously for many days at high pressures ranging up to 2,500 psi. This will assure optimum flow rate of 10 gpm or more under most seam conditions.

To project the amount of water the coal will absorb, a 1.0 percent uniform fracture porosity for the coalbed and a cylindrical shaped infusion zone is generally assumed. The estimated water quantity for infusion of one hole can be calculated as shown below:

$$Q = 0.01\pi r^2 h(7.48 \text{ gal/ft}^3)$$

where Q = quantity of water infused, gals
r = 1/2 panel width, ft
h = coal seam thickness, ft
and 0.01 = 1.0 percent of coal volume is void space

To achieve the maximum quantity of water infused in a hole (approach or surpass the estimate), an optimum pressure and flow rate must be established. These rates are established from trial or test infusion holes. Infusibility of coals vary from seam-to-seam, and sometimes in different regions of the same seam. Therefore, the optimum water flow and pressure for a particular coal seam is determined from the infusion experience gained from previous trials. However, initially in the first few holes (trial holes) lower pressures should be tried (usually less than 500 psi) to observe the flow of water into the coal at the lower pressure. If the water flow is lower than a flow rate which can infuse the hole in a reasonable time frame, increase the water pressure in increments to achieve desired flow rates. Caution is advised if pressures approach 2,000 psi since the water can fracture the coal seam and may short circuit, limiting infusion below its full potential. Furthermore, if pressures exceeding 2,000 psi yield slow flow rates, the coal seam is not generally considered suitable for infusion. It is usually recommended that trial holes be tried to determine whether the coal seam is suitable for infusion.

Determination of the completed infusion process of a hole is accomplished by regular inspections of water seepage on both sides of the panel. However, seepage may be difficult to find at the ribs because mining-induced fractures parallel to the rib will prevent water from migrating to the entry. Water may not be observed at all places along the ribs, but may be observed seeping from the panel near the floor. Another sign that the infusion process may be complete is a drop in infusion pressure accompanied by an increase flow rate which usually indicates that the water has reached the ribs or is short-circuiting along the path of least resistance.

Case Study

A total of five, 3-inch diameter holes, on 270-foot centers, were drilled, packed, and infused along the rib side of a 530-foot wide longwall plow panel in the Pocahontas No. 3 coal seam. Located roughly 18 inches below the roof and above a mid-seam parting, infusion holes were drilled to a depth of 270 feet using portable electric hydraulic rotary drills. As each hole was completed, a premixed batch of grout was pumped in and packed to a depth of 220 feet at pressures of 125-150 psi. Grout composition consisted of water, Calseal, cement, salt, and CFR2. Simultaneous infusion of several holes was possible using a pump with a rated maximum capacity of 50 gpm flow rate at 2,000 psi connected to a 50-hp motor.

As past research had indicated, the Pocahontas No. 3 seam proved to be an excellent seam for water infusion. The first infused hole encountered by the retreating longwall face received 79,054 gallons of water, the computed theoretical volume. The mine selected to infuse the remaining four holes beyond their calculated theoretical volume to ensure that the coal block was completely saturated. Water was pumped into each hole until: (1) accumulations of water on the floor interfered with mining, (2) short circuiting of water occurred, or (3) the face reached the hole. Hole No. 2 had received only 2,300 gallons of water when the packer failed, resulting in short-circuiting of water. Holes No. 3, 4, and 5 each accepted 175,306, 120,140, and 107,049 gallons, respectively.

Table 7 lists the results of gravimetric sampling for the pre-infused and infused sampling periods. Concentrations reflect the average over three shifts for each of the six sampling stations. Note that no 8-hour, full-shift sampling, similar to compliance sampling, was performed.

TABLE 7. PRE-INFUSED VS. INFUSED GRAVIMETRIC SAMPLING DATA

Sampling Station	Dust Concentration mg/m^3* Pre-Infused	Dust Concentration mg/m^3* Infused	Percent Reduction
Section Intake	0.2	0.1	50
Beltway	0.2	0.1	50
Support 2	1.1	0.5	55
Support 15	2.1	1.2	43
Midface	3.9	1.3	67
Support 97	3.1	1.0	68

*Concentrations are not calculated MRE equivalents

Dust reduction values were computed and represent the percent difference in dust levels at each sampling station as a result of the implementation of water infusion.

Through a comparison between baseline, pre-infused, and infused dust data, it was apparent that a successful application of water infusion was achieved. Dust reductions along the face varied between a minimum of 43 percent to a maximum of 68 percent, with the most significant reductions measured at midface and support 97. It is evident that water infusion had increased the moisture content of the coal and overlying strata which resulted in significant dust reductions at several face sources. Although dust levels were reduced by 43 percent at support 15, they were the lowest reductions measured along the face. This can be attributed to the operation of a crusher mounted on the face conveyor and upwind of support 15. This suggests that additional controls were needed at the crusher to counter dust generation. A 54 percent decrease in respirable dust levels at support 2 indicated that water infusion had significantly decreased dust generated in the vicinity of the stage loader. Although primary intake and beltway air had little impact on dust levels, the data were included to indicate the possible association between water infusion and intake sources of dust.

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5. CONTROL METHODS PROVEN INEFFECTIVE OR DIFFICULT TO IMPLEMENT

The application of certain dust-control methods should be discouraged, as studies have proven them to be ineffective; in some cases, implementation of these methods have actually increased personal dust exposure. This includes the use of face curtains installed along the walkway and the application of foam from nozzles mounted on the shearer body. Other methods have been discarded because of space limitations and the difficulty experienced in operating and maintaining the necessary equipment. This has been the major drawback to the use of dust-collector systems on longwall faces, such as machine-mounted and spot scrubbers.

FACE CURTAINS

Also known as walkway curtains, face curtains are intermittently spaced along the face and suspended from roof supports perpendicular to the airflow in an attempt to keep shearer-generated dust near the face. Laboratory tests were conducted in a longwall gallery using a variety of curtain lengths, orientations, and spacings (1). Results showed that all curtain configurations caused eddying of the airflow into the walkway and subsequent increases in walkway contamination levels. A walkway curtain installed on a support near the headgate end of the panel (i.e., about the fifth shield) has been found to be effective in reducing shearer-operator dust exposures during the headgate cut-out.

DUST COLLECTORS

A mechanical dust collector or scrubber typically consists of an air mover to direct the dust-laden air into the scrubber, a dust-removal system to separate the dust particles from the airstream, and a demister unit to remove the water from the airstream. Water-powered units, simpler in design and operation, utilize high-pressure water sprays mounted in an opening or duct to induce airflow and clean the dust-laden air. To date, dust collectors have only been installed on longwall shearers for research purposes. Various problems have been encountered, including: (1) inadequate vertical clearance, (2) a tendency for clogging of the intake and discharge ducts, (3) a low-collection efficiency caused by inadequate fan capacity (a result of space limitations, and, therefore, undersized fans), and (4) improper placement of the inlet duct to capture the unconfined dust cloud. Other problems associated with mechanical dust-collector systems are the high noise levels of the fan and increased maintenance time, including replacement of the filter panel in the flooded-bed scrubber.

The following will describe some of the problems experienced during past attempts at installing, operating, and maintaining various dust-collection devices on longwall shearers, including machine-mounted mechanical scrubbers, spot scrubbers, water-powered extraction (ventilated) cowls, and, to a certain extent, hollow-shaft ventilators. One dust-collection device which has shown promise during preliminary testing in England and the U.S. is the water-powered extraction (ventilated) drum. A description of this device and corresponding test results are presented in Chapter 6.

Machine-Mounted Scrubbers

Machine-mounted scrubbers have been tested on longwall shearers with little success. Most attempts to retrofit existing shearers with scrubber systems have ended in failure (2). The most common problems encountered include the following:

- The dust cloud produced by the cutting action of the shearer is relatively unconfined and exposed to a high-velocity airstream. Appropriate air-inlet locations and airflow capacities to effectively capture the cloud are difficult to attain.

- Air inlets must be close to the cutterhead vicinity; but, in such locations, they are subject to damage or blockage with cut material. Discharge ducts may also be vulnerable to blockage.

- Very limited space is available for ducting on the machine or for housing the fan or scrubber unit. When installed, the system may pose significant constraints on operation.

The two scrubber systems shown in Figure 46 were tested underground with some success (2,3). The one system utilized a 5,000 cfm minicyclone scrubber retrofitted on an Eickhoff EDW 340L shearer. The machine's underframe was enclosed to provide internal ducting. The other system was installed on a Sagem DTS 300 shearer and consisted of a wetted-fan dust collector and an air duct placed on top of the upwind shearer arm. Measured dust reductions for both systems ranged from 50 to 60 percent.

Spot Scrubbers

Spot scrubbers are simply water-powered dust capture tubes mounted on the shearer body. They consist of open-ended tubes containing high pressure water sprays to entrain air and capture dust particles. Studies conducted in England and the United States have shown that these devices can achieve high dust-capture efficiencies (4,5). The results of one laboratory study to evaluate a spot-scrubber unit, measuring 25 in. high x 24 in.

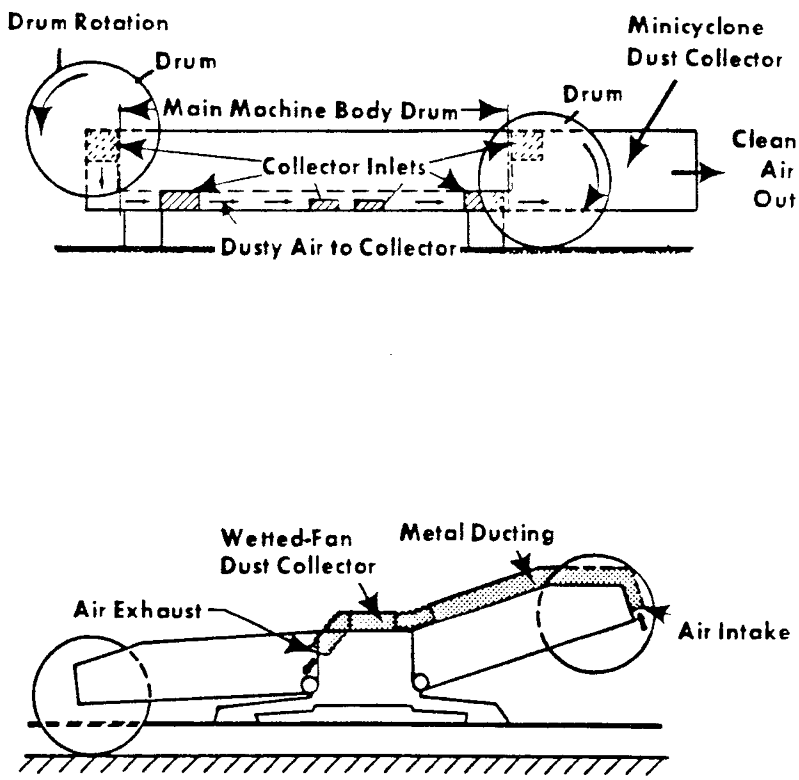

Figure 46. Dust Collectors Incorporated on Shearers

wide x 6 in. deep and containing four water sprays, are summarized below:

- o Airflow through the scrubber was dependent upon water flow and pressure. Scrubber capacities exceeding 3,000 cfm are possible using small orifice nozzles (not less than 1/16 inch) at high pressures (> 500 psi) or larger orifice nozzles at pressures less than 500 psi.

- o Dust-removal efficiency was dependent upon water pressure. Results showed that scrubber performance increased linearly as the pressure was increased from 150 to 900 psi. However, when the data were normalized for water consumption, the dust-removal efficiency of the scrubber remained fairly constant at pressures greater than 700 psi.

- o The best location for the spot scrubber was determined to be immediately behind the lead drum cowl. Dust-capture efficiencies of over 80 percent were achieved when the scrubber capacity exceeded 15 percent (i.e., 3,000 cfm for typical U.S. longwall faces) of the primary face airlfow.

In addition to the relatively inexpensiveness and simplicity of the basic spot scrubber, other advantages include low noise, safe operation in methane environments because of no fans or motors, and minimal maintenance due to no moving parts. However, the main factors which have restricted their use underground are (1) water must be supplied to the scrubbers at high pressures (>500 psi) not commonly found on U.S. longwall faces, and (2) the airflow entrained by the units are quite low relative to typical face air quantities.

Ventilated Cowls

The ventilated, or water-powered extraction, cowl utilizes high-pressure water sprays mounted within the cowl to entrain and scrub contaminated air; the clean air is exhausted through the back of the cowl and toward the floor. An MRDE-designed cowl extraction system (4), shown in Figure 47, employs a cowl constructed of two

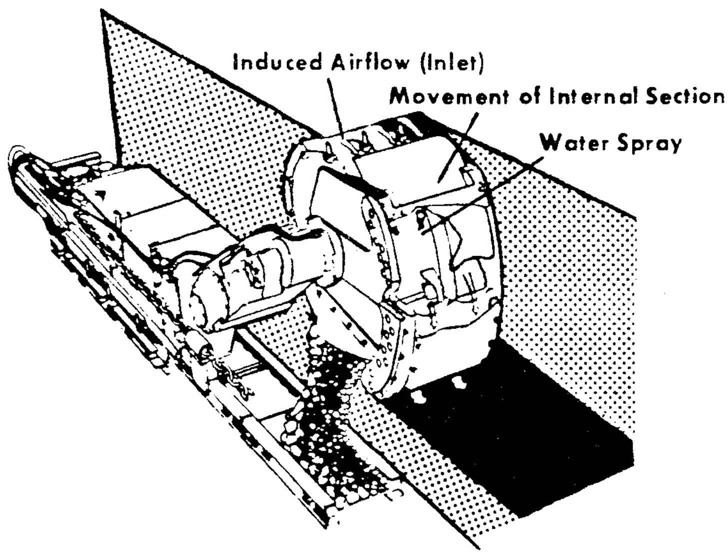

Figure 47. Ventilated Cowl

separate components: an outer shell, open at the top and bottom, which fits over a three-sided inner shell free to move vertically relative to the outer shell; the inner shell rides on the floor to increase confinement. A set of four sprays mounted on the one end of the cowl induces airflow through the cowl. When the cutting direction is reversed, the cowl is turned over and the inner shell slides relative to the outer shell, thus opening the dust extractor at the top. Concurrently, a duplicate set of four sprays mounted on the other end of the cowl is activated. This is accomplished with an automatic reversing valve, located in the center of the cowl blade, which allows water to reach only the upper set of water sprays.

Typical water flow rates for ventilated cowl systems range between 5 and 6 gpm at approximately 1,500 psi with induced airflows between 1,500 and 2,000 cfm. Dust-capture efficiencies increase with increased confinement of the dust in the cutting area. Unfortunately, capture efficiencies have been less than expected, largely because the trailing drum is unprotected from the primary face airflow, making the unconfined dust cloud very difficult to capture. Dust confinement becomes an even greater problem for cowl units operating in higher seams.

Hollow-Shaft Ventilator

The hollow-shaft ventilator has been used on some shearers to help ventilate the face-side cutting zone of the shearer drum. Its primary application is to induce a flow of fresh air into the back of the drum to dilute high methane concentrations. The possibility of using these devices to enhance the existing dust-suppression system, while maintaining the volume of air necessary for proper methane dilution, has also been investigated (6,7).

A hollow-shaft ventilator consists of a water spray mounted in an opening through the drum shaft. A typical installation would include a drum shaft with a 3-5/8-inch diameter axial hole with a conical plate fitted on the face side of the drum. High-pressure water (500-1500 psi) is fed in from the gob side of the shearer through a nozzle to produce a spray that induces airflow through a gap around the conical plate. The British have conducted extensive studies to establish the effects of ventilator water-flow rates and water-to-air ratios on respirable dust levels. These studies revealed that, although the introduction of low levels (210 cfm) of ventilation into the cutting zone did not increase dust levels, there was a considerable increase in shearer dust dispersion (in some instances, fourfold) when high air quantities (530 cfm) were induced through the ventilator, even with drum sprays in operation (8). It was determined that by significantly increasing the amount of water through the ventilator, while only incurring a slight increase in the quantity of air induced by the spray, substantial dust reductions could be achieved. Dust measurements taken at the tailgate end of two faces showed an average reduction of 47 percent when the water quantity through the hollow-shaft ventilator was doubled (from 3.0 to 6.5 gpm at one face; 4.5 to 10.0 gpm at another face). However, the British have recommended that, because of the problems encountered in maintaining adequate water flow and pressure to these devices, the hollow-shaft ventilator should be used solely as a ventilation aid in diluting methane concentrations; in those instances in which there is no reduction in the required airflow as a result of directing additional water through the shaft, as high a water-to-air ratio as practical should be used to aid dust suppression.

EXTERNAL FOAM APPLICATION

External foam spray systems consist of several foam generators or spray nozzles mounted on the shearer. The generators are supplied with foam mixture through a valve bank located on the shearer body; the location and number of generators are determined by the primary dust-generation zones on the face and the area each individual generator can reach. Separate hoses, contained in the cable-handling system located in the spillplate cable trough, transport the foam concentrate and water to the valve bank. A typical water-to-foam ratio is 80:1; for example, 20 gpm water and 0.25 gpm foam.

Although the use of external foam spray systems has been found in some cases to be effective in reducing face dust levels (9), numerous operational difficulties have prohibited their acceptance as a practical dust-control technique on longwall operations, including:

- High maintenance requirements
- Foam generators can be susceptible to frequent damage
- Foam is difficult to project to the underside of the drums where much dust is generated
- Spray widths are often too narrow for adequate foam coverage
- Excessive spray volumes can be detrimental to soft mine floors
- System efficiency diminishes in higher seams
- High cost of some foaming agents

WETTING AGENTS

The use of wetting agents or surfactants has been debated by mine operators for many years. Clearly, a wetting agent will reduce the surface tension of water by as much as 50 percent and increase the wetting power of water. This reduction in surface tension results in a decrease in the contact angle, Figure 48. However, exactly how the reduction in surface tension results in better dust control is unclear and highly debated. Some believe that wetting agents can reduce airborne dust by reducing the size of the water spray droplet and allowing the water droplet to wet airborne dust particles it would otherwise repel. Once wetted, the dust particles cannot remain airborne. Others feel that wetting agents have no effect on airborne dust but help to keep respirable dust from becoming airborne. Although the use of wetting agents has been proven to be effective in reducing dust levels on some mining operations, their application on longwalls has not resulted in significant dust reductions.

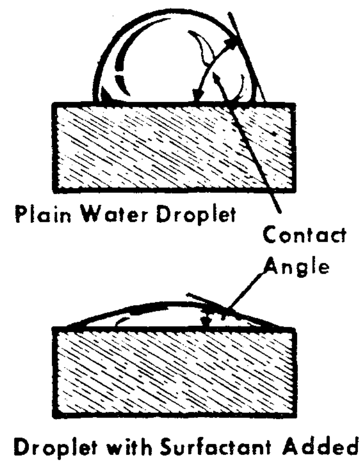

Figure 48. Contact Angle of a Water Droplet

CRESCENT SPRAY MANIFOLDS ON RANGING ARMS

The use of a crescent spray manifold installed around the shearer ranging arm(s) was previously discussed in Chapter 2 as an alternate location for cooling water discharge. This location was determined to be more suitable for the discharge of cooling water, as conventional discharge sprays caused the dust to be pushed from the face into the walkway and over the machine operators. The specific application of crescent sprays to reduce operator dust exposure has not been well-documented. Recent laboratory and underground studies (10, 11) indicate that these sprays have little effect on dust levels at the shearer and downwind.

A crescent spray manifold consists of several spray nozzles mounted in a pipe manifold wrapped around the shearer ranging arm; the nozzles should be oriented downwind, wherever possible, and aimed into the cutting drum and properly spaced to uniformly wet the cutting zone (best accomplished with "flat fan" sprays). Recommended nozzle discharge orientations are presented in Figure 49. It is recommended that the manifold be welded to the ranging arm, although bolting is usually acceptable, and designed to house recessed nozzles to minimize damage. Laboratory tests have shown that a crescent-spray manifold on the upwind drum creates turbulence, and increases the dust exposure of the downwind shearer operator when cutting with the ventilation. With the shearer cutting against ventilation, the upwind crescent-arm sprays had essentially no impact on walkway contamination levels. These tests also showed that the crescent spray manifold could be used on the downwind ranging arm (in both cutting directions) without adversely affecting contamination levels in the walkway.

Underground tests have shown that dust levels measured at the shearer are slightly higher with the crescent-arm sprays operating. The increase in dust concentration was partially attributed to incorrect spray-type (hollow cone instead of flat fan) and orientation (perpendicular to the face rather than downwind). Although crescent-arm sprays can be a viable alternative to conventional cooling water discharge locations, their use

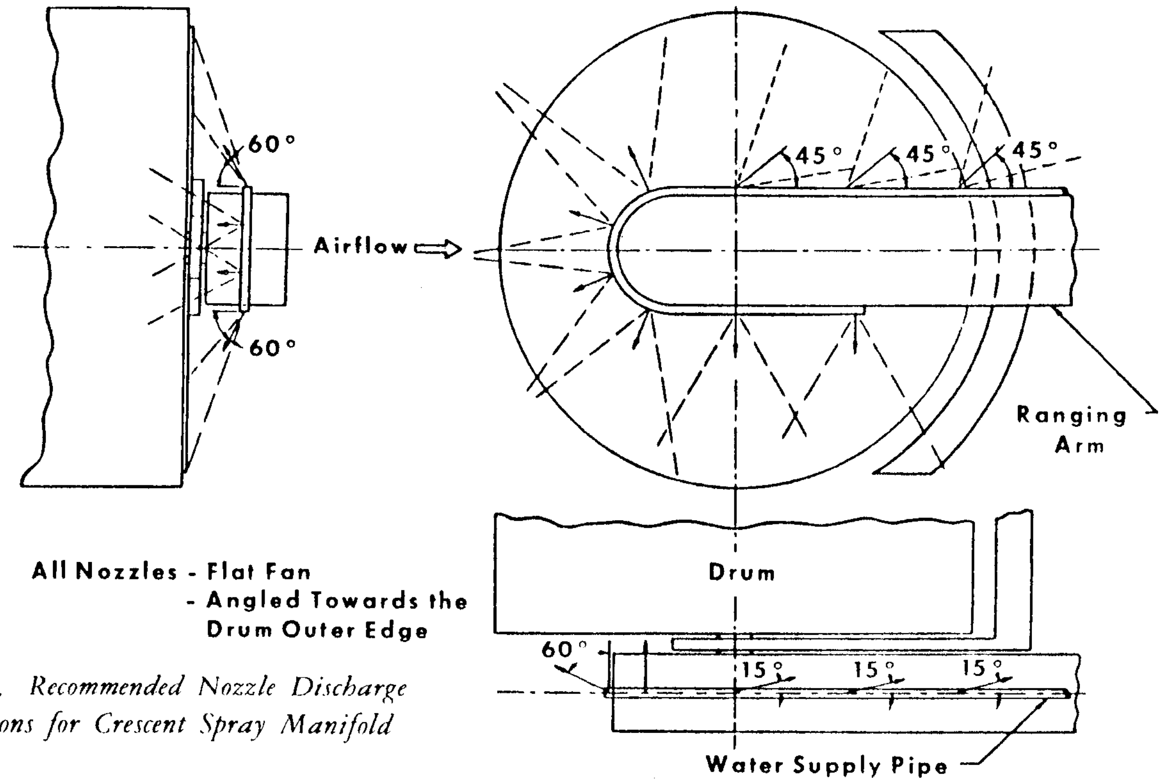

Figure 49. Recommended Nozzle Discharge Orientations for Crescent Spray Manifold

should not be viewed as a principal means of dust control.

CONVENTIONAL SUPPORT SPRAYS

On a few shearer operations, water sprays have been mounted at regular intervals (i.e., every fifth or tenth support) on the support canopies over the face conveyor, directed at the face and with the airflow. Their purpose is to humidify the face area to knock down and suppress the dust generated during support movement. They have proven to be difficult to maintain, and face personnel, especially support movers, are frequently wetted by the resulting spray mist; consequently, the sprays are used sparingly and any required maintenance is often overlooked. In addition, the accumulation of the spray water can be very detrimental to bottom conditions. This has also been the major problem experienced with the use of sprays mounted on the back and/or sides of the support to keep dust from entering into the walkway.

AIR SPRAYS

Recent studies have been conducted to determine the effectiveness of air sprays mounted on roof supports for dust control on longwall faces (12). It was thought that by spraying compressed air through air diffusion nozzles along the face, the dust cloud could be better confined toward the face with increased dilution of dust concentrations at the shearer operator positions. The study was conducted on a simulated 100-foot long, 6-foot high longwall face using a tracer gas to simulate respirable dust. Two diesel-powered compressors were used to provide 2,100 scfm of compressed air to a total of 80 nozzles installed in the model; two banks of two sprays each were mounted on each support unit--one on the canopy and the other near the walkway. The nozzles were capable of delivering 27 scfm at 60 psi. Face airflow, at velocities varying between 200 and 550 fpm, was provided by an exhaust fan located at the "tailgate" end.

The air-spray system produced dust reductions between 30 and 75 percent. However, the improvement in dust levels was determined to be a result of the total amount of air present on the face, rather than to the operation of the air sprays themselves. As the total face air quantity increased, dust levels declined. In other words, if the amount of air delivered through the nozzles was added to the primary ventilating airflow at the "headgate" end of the model and directed down the face, the same reductions in dust levels could be achieved. Therefore, the application of an air-spray system underground would be impractical, considering the added expense involved in installing, operating, and maintaining such a system when similar dust reductions can be attained by simply increasing face ventilation.

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6. STATUS OF CURRENT RESEARCH ACTIVITIES

Mine operators and researchers in the United States and abroad continue to explore and evaluate promising techniques aimed at controlling respirable dust on longwall operations. Areas of current investigation include reverse drum rotation, the application of foam through the drum, wetting the immediate roof to abate support-generated dust, and the ventilated or dust-extraction drum.

REVERSE DRUM ROTATION

The amount of dust generated and liberated while coal is loaded onto the face conveyor can significantly add to the dust exposure of the shearer operators. Recent studies (1) indicate that loading efficiency can be improved and dust exposures reduced when the direction of drum rotation is reversed (i.e., lead drum cuts from floor-to-roof rather than roof-to-floor). With reverse rotation, the ranging arms do not interfere with the loading process to the same extent as that which occurs with conventional rotation. For the lead drum, the amount of time the coal remains in the drum and the distance the coal travels within the drum are also reduced. As a result, coal recirculation and breakage is reduced as the capacity of the drum is increased and loading becomes less obstructed.

Tests were conducted on a longwall section in Alabama to compare shearer-operator dust exposures for conventional and reversed drum rotation. The use of reverse drum rotation resulted in substantial reductions in operator exposure when cutting in the direction of ventilating airflow. Dust measurements taken at the shearer mid-point between the operators were very similar to levels measured 20 feet upwind of the leading drum when using reverse rotation. With conventional rotation, the average dust level at the shearer was approximately four times greater than the intake dust concentration. Figure 50 compares the shearer-operator dust levels for cutting with both rotation directions. Downwind dust levels were similar for both directions of rotation. Also, rotation direction did not have any impact on dust levels for the tail-to-head cleanup pass.

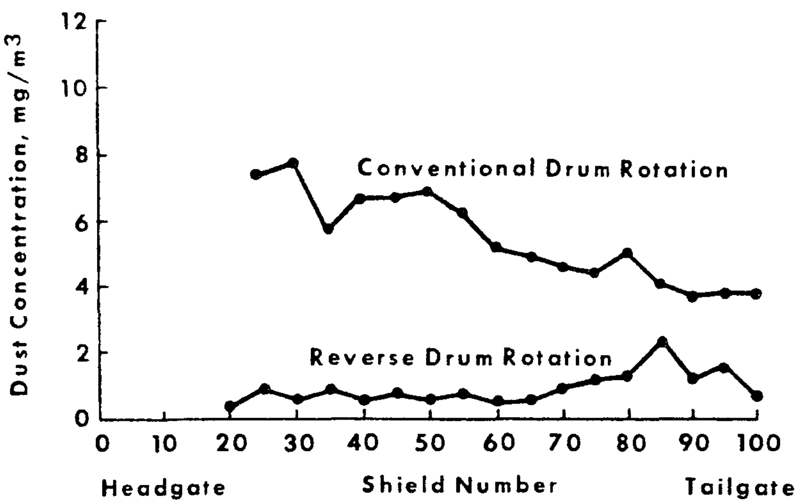

Figure 50. Effect of Reversed Drum Rotation on Shearer Operator Dust Levels

It must be emphasized that these results are based on a limited number of tests conducted at one mine. As is the case with many dust-control techniques, the effective application of reversed rotation is site-specific, and, therefore, the results obtained from this particular coal face should not necessarily be expected on another. The data obtained during this study did indicate that the reduction in operator dust levels achieved with reversed drum rotation was primarily a result of the improved loading ability of the trailing drum. However, this can partially be attributed to the fact that, for the conventional rotation condition, the trailing drum had to handle a greater volume of coal because the leading drum was not equipped with a cowl. This obviously hindered the loading performance of the trailing drum when conventional rotation was used.

FOAM

The use of compressed-air foam can be effective in suppressing and controlling respirable dust generated during the cutting and transport of coal on double-drum shearer faces. Foam controls dust by increasing the surface contact area, mixing with the coal and physically preventing dust from becoming airborne. Hence, the optimum location for foam injection is at the point where the dust is generated, before the dust becomes airborne. This is best accomplished by passing the foam through nozzles located in the cutter drum.

To be effective, the foam should have a good wetting capability and a moderate expansion factor. The stability of the foam is also critical. It should not be so stable as to be uncollapsible, resulting in a large buildup in the face area, but it should not collapse at such a fast rate that it is ineffective in controlling dust.

A recent study conducted on a West Virginia longwall installation in 1983 reduced dust levels at the shearer-operator position by 56 percent when compared to the water spray system installed on the shearer (2,3). Figure 51 shows the plotted values of shearer-generated dust for the water spray and foam systems. In addition, the foam system used 50 percent less water, while reducing intake dust concentrations by approximately 30 percent. The major portion of foam was directed through the shearer drums, with a minor amount of foam sprayed through nozzles located on the shearer body and directed toward the headgate-side drum. Flushing the foam through nozzles evenly spaced along the scrolls of the drums was determined to be preferable to pick-face foaming. The fewer outlets (twelve 11/32-inch nozzles on the

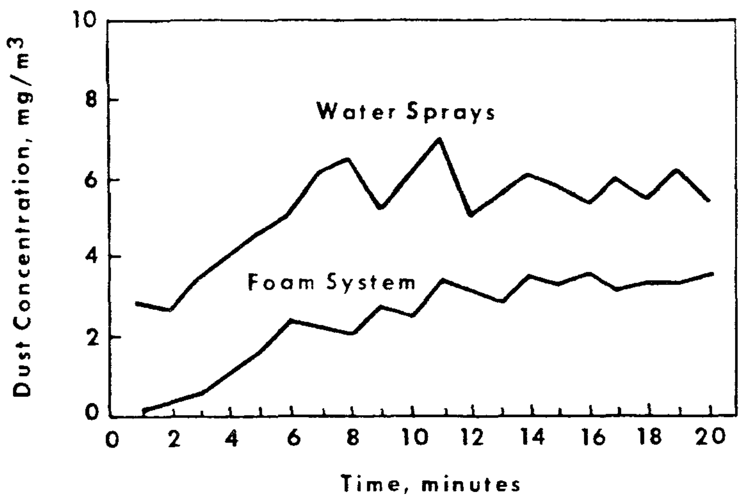

Figure 51. Plot of Shearer Generated Dust

headgate drum; eight 7/32-inch nozzles on the tailgate drum) provide a higher discharge pressure of the foam and also reduce the occurrence of nozzle blockage.

A schematic of the foam system layout is shown in Figure 52. The system consisted of a rotary-screw air compressor capable of delivering 103 cfm at 125 psi, a metering pump used to inject the foaming agent into the water line at a rate of 10.5 gph, a foam block mounted on the shearer beneath the cover plate in which the compressed air was mixed with the foaming agent and water, and appropriate airlines and water hoses. A minimum of 3/4-inch diameter line should be used within the shearer to flush an adequate quantity of foam through the drums.

There are certain limitations associated with foam systems of this type which might affect its applicability or reduce its effectiveness, including:

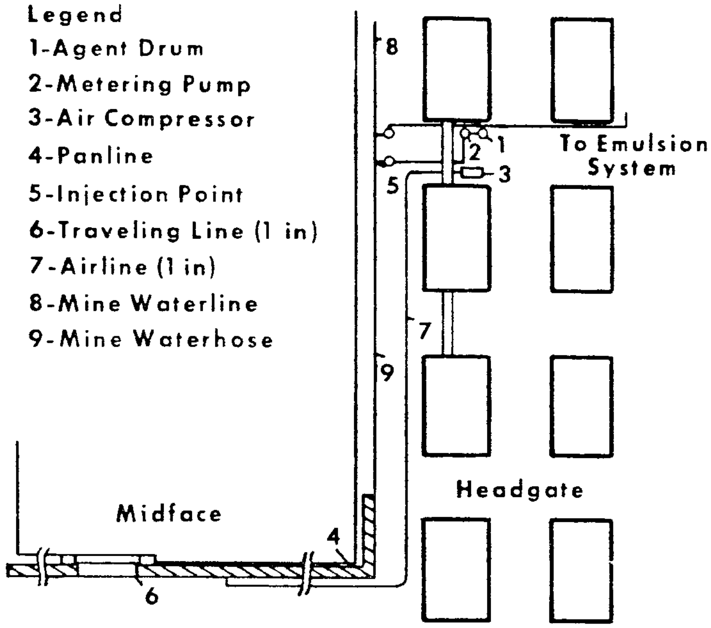

Figure 52. Schematic of Foam System Layout

- An additional hose (airline) needs to be inserted in the cable and hose-handling system. In cases where an open trough exists, the addition of the airline is quite easy. However, in instances where a Bretby-type cable-handler is used, it may not be possible to introduce the airline.

- There was apparently more difficulty in removing the blunt cutter bits from the drum. The shank of the bit was comparatively drier than when the water spray system was used.

- There were complaints of minor skin irritation caused by the mixture of the foaming agent and water.

- Acceptance of the foam system was also constrained by the cost of the foaming agent. The operating cost of the foam system based on the cost of chemical at $12.15/gallon, 400:1 water to chemical ratio, 250 minutes effective shift time, and 1,200 tons of raw coal per shift was about $0.25 per ton.

WETTING ROOF TO REDUCE SUPPORT DUST

Water application on the immediate roof may also help reduce support-generated dust. The residual moisture on the roof should suppress some of the dust created during the crushing and grinding process of lowering, advancing, and resetting the roof supports. Sufficient wetting of the immediate roof with water from the shearer can be accomplished in three ways (4):

- o Maintain adequate water pressure at the drum sprays to wet the roof while the face is being cut
- o During the cleanup pass on unidirectional operations, the lead drum--typically not cutting much material--can be free-wheeled near the roof, allowing the water sprays to wet the roof
- o Spray the roof using one or several water sprays mounted on top of the shearer body, directing the water downwind and at an upward angle of approximately 45 degrees

One objective of a current USBM contract is to conduct underground tests to compare dust levels generated when supports are advanced under "dry" and "wet" roof conditions.

VENTILATED DRUM

The ventilated or dust-extraction drum is a promising device developed by England's National Coal Board, Mining Research and Development Establishment (NCB-MRDE). The drum utilizes water sprays in tubes mounted through the drum to collect dust-laden air from the face side of the cutting zone, scrub the dust, and discharge the clean air and dirty water on the gob side of the drum. Laboratory studies in England and the U.S., and underground tests conducted in British mines with single-drum shearers have shown the extraction drum to have high dust-capture capabilities.

The extraction drum controls ventilation in the immediate cutting zone by inducing air from the face side through extraction tubes mounted in the drum hub. Each tube contains one water spray operated at very high pressures. Both the water and air are discharged against a deflector, or baffle, on the gob side of the drum. The induced airflow draws air inward toward the face, around the drum, and back into the cutting zone. The initial MRDE design, Figures 53 and 54, incorporated nine 4-inch (100 mm) diameter extraction tubes inside the drum hub (5). The system induces an airflow of 3,200 cfm at spray pressures of 1,450 psi and total water flow of 15.5 gpm (for one drum). Testing of the drum in a tracer gas gallery and a simulated coal face was very encouraging; dust concentrations were reduced by 95 percent with the extraction system in use, and by 98 percent when the system was used in combination with wet cutting. Laboratory studies in the U.S. indicate a 75 percent capture efficiency of cutting zone dust for a double-drum shearer cutting in both directions (6).

British underground trials have shown that use of the extraction drum reduces dust levels by over 80 percent (compared to pick-face flushing systems) for single fixed-drum shearers and by 61 percent for a single ranging-drum shearer.

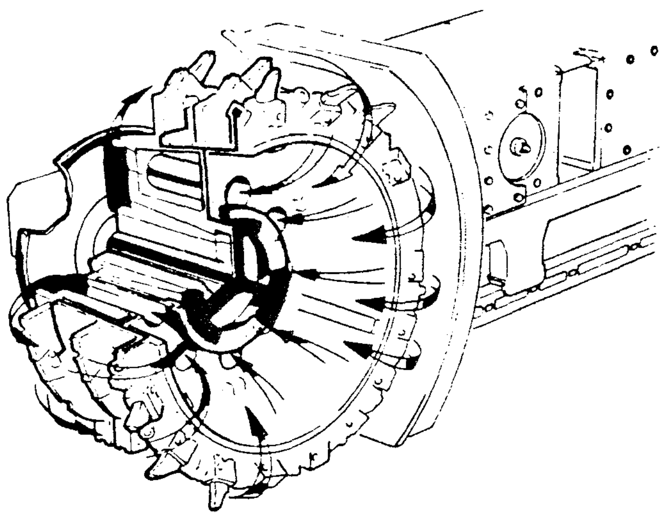

Figure 53. MRDE Ventilated Drum

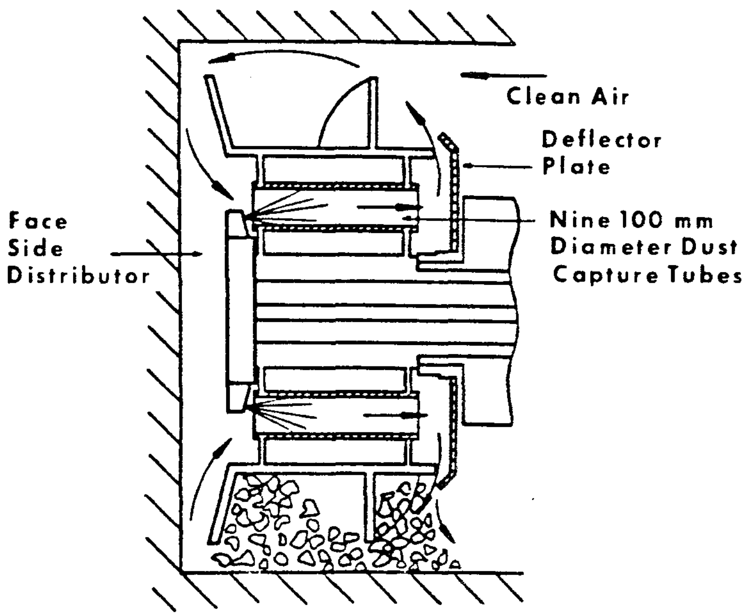

Figure 54. Cross-section of Ventilated Drum

Operational problems have been experienced. Dry cutting increased intake contamination and caused coarse dust particles to be carried into the operator's area. This was resolved by applying water to the bits in addition to use of the extraction drum. Premature failure of the high-pressure seals in the main distribution system was also an early concern. However, seal life was significantly improved by changing both the type of seal and shaft. For most shearers operating in the U.S., the present design only allows the extraction system to be used on drums with diameters greater than 63 inches. The British are currently investigating modified designs to make the extraction system suitable for smaller drums. Evaluation of the system underground on a double-drum shearer operation in the U.S. is anticipated in 1985.

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7. DUST-CONTROL SYSTEMS FOR PLOWS

The popularity of the shearer has led to a gradual decline in the use of plows on U.S. longwall faces. Many of the techniques previously discussed are applicable to plow faces. In particular, the section in Chapter 4 describing dust control in the headgate entry should be consulted, as this is often overlooked on plow operations. Studies have indicated that the dust generated during coal transport and crushing and support movement contributes more to overall dust levels than the plow itself. During one particular dust-sampling program, the intake dust concentration was found to be 63 percent of the total dust concentration measured along the face.

Additional information regarding the application of specific dust-control techniques on plow faces is presented in Chapter 2 (Water Supply, Quantity, and Pressure), Chapter 3 (Face Air Quantity and Velocity), and Chapter 4 (Homotropal Ventilation and Auxiliary Intakes and Water Infusion).

PLOW SPRAY SYSTEMS

Spray systems used to allay dust generated by plows fall into two categories:

- o Systems with sprays mounted along the length of the face
- o Systems with sprays mounted directly on the plow body

For reasons discussed later, plow-mounted sprays have never been very popular, and their use is declining. Thus, sprays along the face is the primary dust-control system used.

Sprays Along the Face

These systems consist of a series of spray nozzles mounted along the conveyor spill plate or on the front tips of the roof canopies and aimed at the face. The system is called "full face" if all the nozzles along the entire face are operated continuously when the plow is operating. When only those nozzles in the vicinity of the plow are operated at any one time, the system is called "sequential." Sequential systems are, in general, preferred over full-face systems because of more efficient use of available water supply; they provide more water, at higher pressure, where it is most needed. Other advantages of the sequential system are that the sprays present less of a nuisance to the men working along the face, and, by using less water, chance of bottom deterioration is reduced and possible negative effects on the coal preparation process are less likely.

Figure 55 shows a schematic of the piping network for a sequential spray system. A hose,

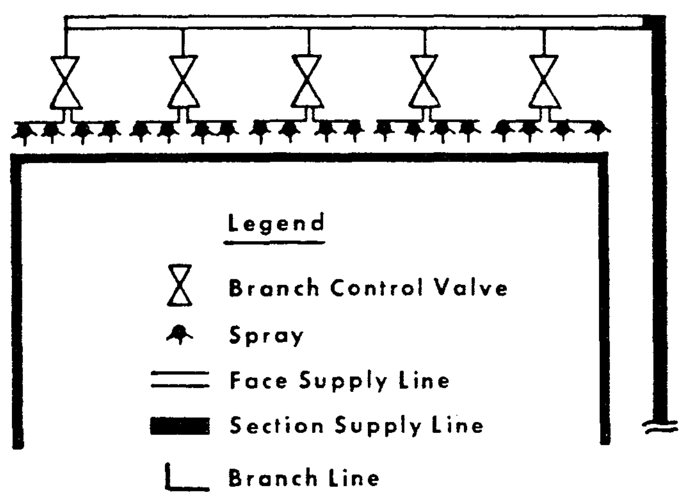

Figure 55. Piping Schematic for Plow Sequential Spray System

connected to the section supply pipe, serves as a trunk line for delivery of water along the face. Portions of the face (typically 50 feet) are sprayed by discrete branches which tap into the trunk line. Operation of each branch is controlled by a valve, as illustrated. The valves, in turn, are actuated by the position of the plow on the face. Typically, the branch immediately in front of and the branch immediately behind the plow are operated at a given time.

A number of control systems have been used to activate the branch control valves. For plows with base plates which slide under the face conveyor, magnetic valves may be used on the branch lines; these are activated by the passing of the plow. Such a system must account for direction and speed of plow travel. One commonly applied system, which is applicable for plows with and without base plates, uses solenoid valves at the branch lines in conjunction with a plow-position monitor. The position of the plow is determined by an analogue nut, driven by a threaded shaft coupled to the plow drive. The position of the nut on the shaft is proportional to the position of the plow. The nut, in turn, actuates the appropriate solenoid valves which open the water line to those branches in the plow vicinity. Regardless of the type control system employed, coordination between the valves and position of the plow must be maintained for the system to remain effective.

The following should be considered when establishing the spray configuration for a sequential system:

- Nozzle orientation is primarily dependent on face conditions and air velocity. For face air velocities typically encountered on U.S. plow faces, the nozzles should be oriented 35 to 45 degrees from a line perpendicular to the face in the direction of airflow. Laboratory tests have shown that sprays oriented upwind are not as effective in capture of airborne dust as sprays oriented downwind. German studies have indicated that sprays oriented downwind are often ineffective on faces with high air velocities; the high velocity prevents the spray droplets from reaching the face. Under such conditions, water is either sprayed directly at the face or slightly upwind to ensure that the water droplets reach the face. When using upwind sprays, the nozzles should never be oriented more than 30 degrees upwind from a line perpendicular to the face. At greater angles, the spray will force the airflow into the walkway which could increase the dust exposure of personnel positioned along the face.

- Nozzles and operating pressures should be specified which provide a spray with coarse droplets with sufficient momentum to reach the face and cover the face area. Narrow-angle, full-cone sprays are suggested to fulfill these requirements. In higher seams, two nozzles may be employed at one point to achieve coverage of the entire height of the coal face. Nozzle pressures of about 100 psi are generally adequate, but this will depend on other aspects of system design and local conditions. Operation at excessive pressures should be avoided so that droplets are not so finely atomized that they will not carry to the face. To avoid puddle formation, the sprays should not impinge on the roof canopies or other structures.

- The spacing of nozzles or groups of nozzles should insure complete coverage along the length of the face. Using narrow-angle sprays oriented as discussed above, this distance will usually be 5 feet or less. Face geometry and nozzle spray-angle specifications may be used to make a precise calculation.

Plow Sprays

The use of plow-mounted sprays offered a means to provide greater quantities of water into the cutting zone. However, severe operational problems were encountered with the trailing water hose required to deliver water to the plow body. The application was also limited to plows equipped with a stabilizer arm which rides on the spill-plate structure. These disadvantages far outweighed the marginal reductions in dust.

Specifically, the greatest problems occurred with keeping the trailing hose in the trough. The hose trough, constructed as part of the spill-plate structure, had to be deep enough to allow doubling of the hose as the plow traveled back and forth across the face. However, coal accumulating in the trough, and repeated cuts over part of the face, which cause multiple loops, would result in the hose jumping out of the trough. The trough depth is naturally limited by the seam height. One study suggested that problems were less likely in seams greater than 54 inches, which obviously severely limits the application of plow-mounted sprays.

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8. PERSONAL PROTECTIVE EQUIPMENT

The Federal Coal Mine Health and Safety Act of 1969 mandated that approved respiratory equipment must be made available to personnel when exposed to respirable dust concentrations greater than 2.0 mg/m^3. However, use of this equipment is limited to the interim period between detection of excess dust levels and implementation of control techniques designed to reduce dust concentration to allowable levels. The two principal types of respiratory equipment used on longwall faces are the face mask respirator and air helmet; both utilize a filter to clean the air, before inhalation by the wearer.

FACE MASK RESPIRATORS

The face-mask respirator contains a mask/filtering unit that covers the nose and mouth of the wearer, and is held against the face by a head strap. Two types of respirators are commonly used: (1) replaceable filter respirator, and (2) single-use respirator.

Replaceable Filter Respirators

The replaceable filter respirator consists of a filter-holding unit, typically fabricated from plastic, metal, or hard rubber, that also contains intake and exhaust valves. The filtering efficiency of approved filters is 98 percent or more (1). Soft rubber or cloth is used to form a facepiece around the filter-holding unit that forms a seal against the wearer's face in an attempt to prevent dust-laden air from by-passing the filter. With a reasonably leak-tight facepiece fit, the respirator should remove approximately 95 percent of the respirable dust.

During one respirator evaluation program (2), two models of face-mask respirators were tested on four longwall sections to determine the protection afforded to the wearer when worn in the tailgate area for an entire shift. The dust exposure of the tailgate worker was 80 to 92 percent less when wearing either one of the respirators.

Although the respirator does an excellent job of dust removal when properly fitted, some personal discomforts may arise, including:

- o increased breathing resistance, aggravated by dust loading on filter
- o facial irritation caused by face seal
- o interference with normal voice communication
- o interference with eyeglasses or goggles

Single-Use Respirators

The single-use respirator is a much lighter and simpler design. The entire mask is fabricated from filter material and covers the mouth and nose, similar to a surgical mask. The single-use respirator offers the following advantages when compared to the replaceable-filter respirator (3):

- o lighter and, thus, more comfortable to the wearer
- o provides greater filtering area and, consequently, has lower breathing resistance
- o filter material contacts face and generally is less irritating than rubber or cloth
- o requires no maintenance

However, single-use respirators usually do not form as tight a seal against the wearer's face as replaceable-filter types, allowing more leakage. Also, single-use respirators provide no protection for the filter material, and, as a result, are not as durable as the replaceable filter-type.

AIR HELMET

The air helmet is a redesigned hard hat equipped with a battery-powered fan, filtering system, and face visor, thus providing protection for the head, lungs, and eyes in one unit, Figure 56. Although the air helmet is slightly larger and heavier than conventional hard hats, weighing approximately three pounds, wearer acceptance has been quite favorable.

A small fan is mounted in the rear of the helmet to draw dust-laden air through a filtering system; the resulting cleaned air is directed behind a full-face visor and over the wearer's face. The clear visor is equipped with soft rubber face seals along both sides, so that exhaled air and excess clean air are allowed to exit the helmet at the bottom of the visor. Also, these face seals and additional seals inside the helmet limit contamination from unfiltered air. The fan is externally powered by a rechargeable battery smaller than a conventional cap-lamp battery to be worn on the miner's belt.

The visor can be flipped up when the air helmet is not operated. In the original air helmet design, this resulted in the cap lamp being directed at the roof, since the cap lamp was clipped to a bracket on top of the visor. This rendered the cap lamp useless if the visor was not in place or a self-rescuer had to be worn. A flip bracket was recently developed (4) to allow the cap lamp to remain in its normal position when the visor is raised.

Initial tests with the air helmet in a static chamber resulted in dust reduction efficiencies of nearly 100 percent (5). Additional studies were conducted to test the effect of air velocity and

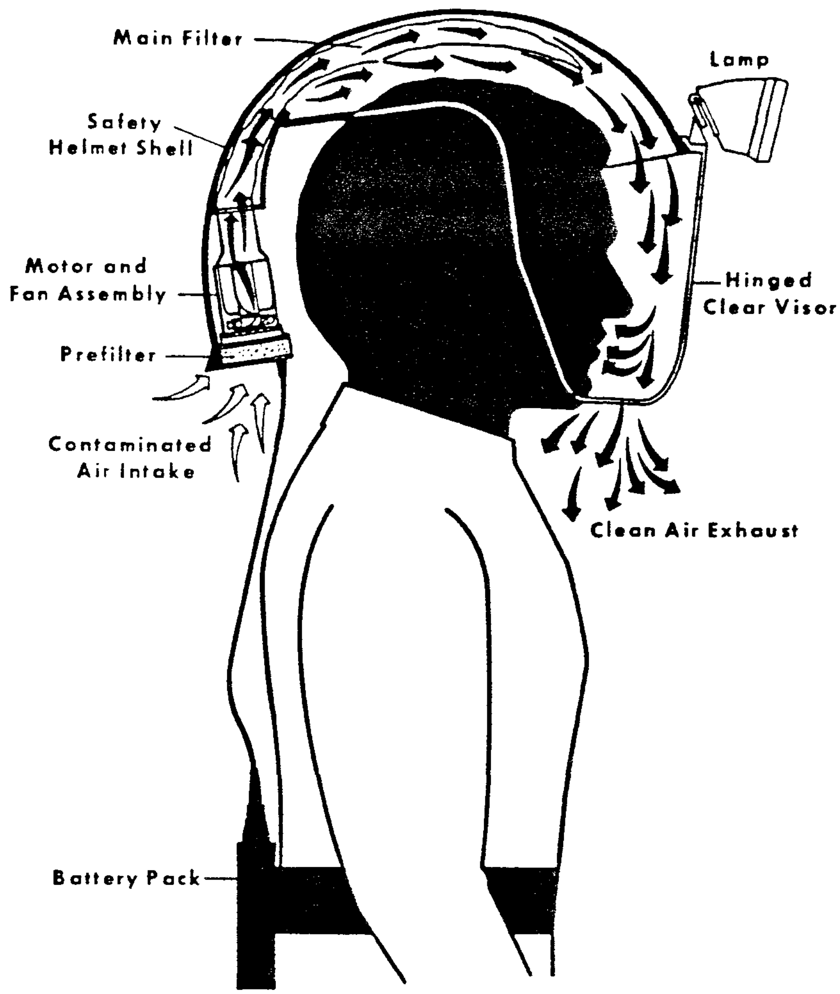

Figure 56. Air Helmet

helmet position in the airflow on the effectiveness of the air helmet (6). Table 8 provides the results of this testing, and shows that air velocity and position can have a major impact on the effectiveness of the helmet.

TABLE 8. DUST REDUCTION AS A FUNCTION OF VELOCITY AND POSITION, PCT

Velocity, fpm	Angle of Helmet to Airflow 0°	45°	90°	135°	Average of 4 Positions
400	99.2	92.8	89.8	93.0	93.7
800	94.2	65.4	65.4	70.0	73.8
1,200	85.9	50.9	49.8	52.1	59.7
1,600	71.5	31.9	40.5	44.8	47.2

Underground tests on four longwall double-drum shearer faces were also conducted. For three of the four mines, the air velocity in the face walkway was less than 400 fpm, and the air helmets reduced respirable dust in the wearer's (shearer operator, jacksetter, and two researchers) breathing zone by an average of 84 percent. At the fourth mine, the air velocity was approximately 1,200 fpm, and, as a result, the air helmet was not as efficient, with an average reduction of 49 percent. It should be noted that the underground sampling includes periods when the face visor was lowered and periods when it was raised, according to normal underground use; this would tend to minimize differences between inside and outside samples, thus reducing the apparent effectiveness of the helmet.

Both the laboratory and underground results show that the air helmet can provide excellent dust reductions, 90 percent or more, on the majority of longwall faces in the United States. For those longwall faces with high air velocities, the effectiveness of the air helmet is reduced, and the face mask respirator would be a more appropriate form of protection.

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APPENDIX A

SPRAY NOZZLE CHARACTERISTICS AND WATER SPRAY SYSTEMS

NOZZLE CHARACTERISTICS

Each nozzle has a specific set of characteristics defined by flow rate, spray angle, spray pattern, droplet size, and droplet velocity. These characteristics are largely determined by nozzle design and the operating pressure. The nozzle design includes the size and geometry of the nozzle orifice, and the design of the whirl chamber which imparts motion to the water before ejection. Increasing or decreasing the operating pressure of a specific nozzle can significantly alter the nozzle characteristics. The physical characteristics of the spray must match the intended application to create an effective and efficient water-spray system.

Flow Rate

The flow rate of a nozzle is primarily determined by nozzle design and operating pressure. The design includes size of the nozzle passages, particularly the orifice. For a given nozzle, an increase in pressure will result in an increase in flow rate. In general, flow rate is proportional to the square root of pressure. This relationship is shown in Figure A-1 for three typical orifice sizes. The water flow at any operating pressure can be estimated if the flow at another operating pressure is known, using the following relationship:

$$GPM_2 = \sqrt{\frac{psi_2}{psi_1}}\ GPM_1$$

where GPM is the unknown flow rate for the pressure psi and GPM is the flow rate at pressure

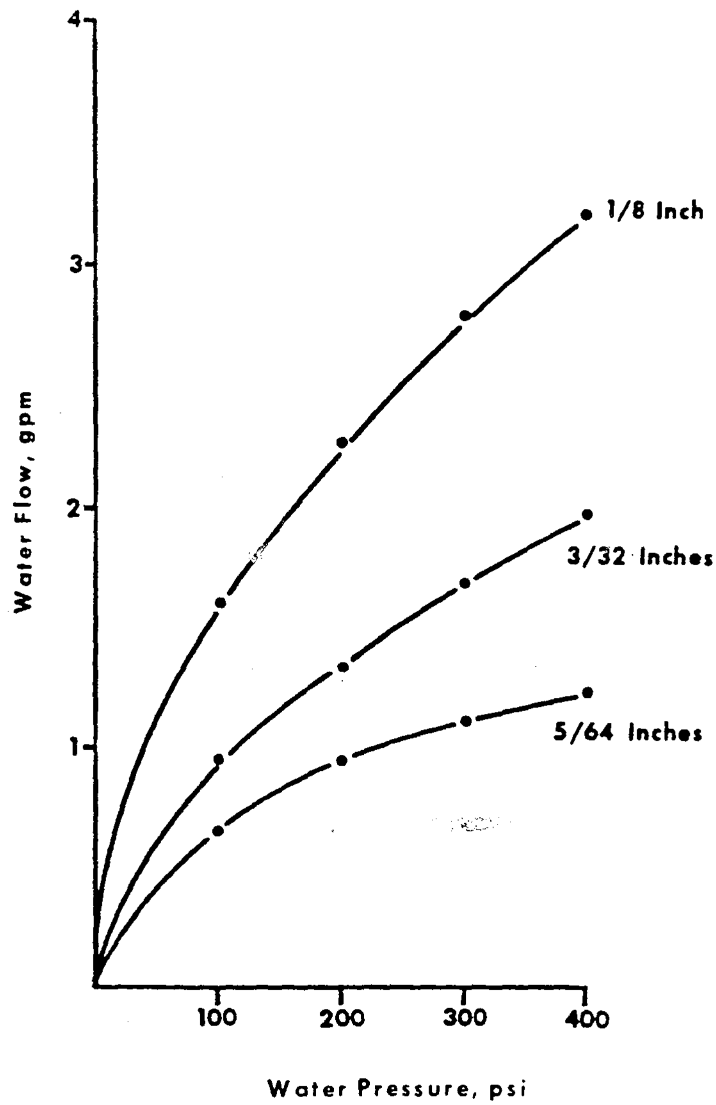


Figure A-1. Water Flow/Pressure of Common Nozzle Orifices

psi_1. This relationship is useful for calculating flow rates for pressures not given on manufacturers' specification sheets or for estimating flows from measured values.

Spray Angle

Knowledge of the spray angle, Figure A-2, is useful in determining the effective coverage of the spray. The spray angle is primarily determined by nozzle design. Designs are available which provide spray angles from 0 degrees (solid stream) to over 150 degrees. For a particular nozzle, the spray angle will vary slightly with changes in pressure; it typically increases at higher pressures.

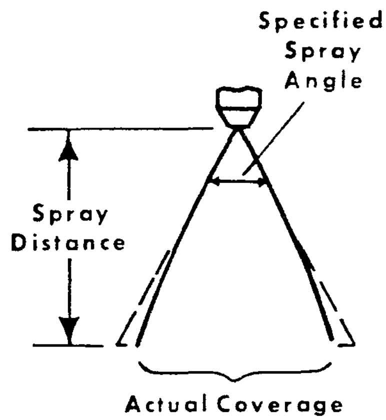


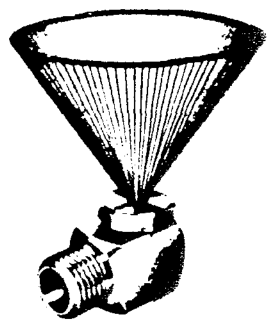
Figure A-2. Spray Angle and Actual Spray Coverage

Spray angles given in manufacturers' specification sheets are typically measured near the nozzle orifice. In practice, the spray will tend to narrow as distance from the nozzle increases, as illustrated in Figure A-2. If knowledge of the precise coverage of a spray is necessary, most manufacturers will provide data on the effective spray angle for a specified distance.

Spray Pattern

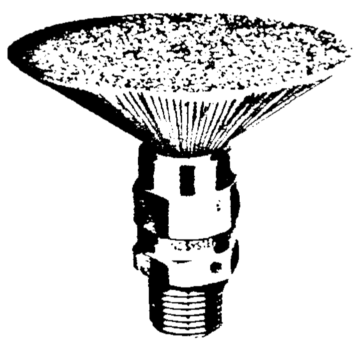
There are three basic spray patterns: hollow cone, full cone, and flat. These patterns are illustrated in Figure A-3, along with general comments on basic characteristics. A specific spray pattern is created by the nozzle design, particularly the whirl chamber. Nozzles are generally characterized by the type of spray pattern

COMMENTS



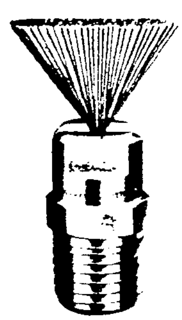
A. Hollow Cone

Generally, spray droplets are smaller and spray angle is wider relative to other types of nozzles. Useful where dust is widely dispersed. Frequently used at transfer points and as external sprays on longwall shearers.



B. Full Cone

Typically, droplets are higher in velocity than other sprays. Useful to provide a high-velocity spray where the nozzle is located distant from the area where dust suppression is desired. Frequently applied at the cutting face as drum sprays.



C. Flat

Figure A-3. Common Spray Patterns

Droplets are generally very large compared to other sprays and are delivered at high velocity. Frequently used in crescent-shaped ranging-arm and panline spray manifolds.

created, and will be discussed in greater detail in the section, TYPES OF NOZZLES.

Droplet Size

Droplet size is a function of the nozzle design and operating pressure. Each nozzle, operating at a specific pressure, creates a specific droplet size distribution. This means that each nozzle creates a number of particles in several different size ranges. Thus, it is common to refer to an average or medium volume diameter which is a size where half of the total volume is made up of particles smaller than the medium, and half are larger.

In general, wide-angle, hollow-cone, low-capacity nozzles operating at higher pressures produce smaller spray particles. Spray particles become larger as nozzle capacity increases, spray angle becomes narrower, and pressure decreases, Table A-1. The largest particles are obtained with narrow-angle, full-cone, high-capacity nozzles spraying at the lowest pressure. Spray manufacturers can generally supply droplet size information for specific nozzles.

Droplet Velocity

Droplet velocity is also determined by nozzle design and operating pressure. Narrow-angle, low-capacity nozzles have the highest velocity droplets. Droplet velocity of all sprays will increase with increased pressure. The velocity of the spray will decrease with increasing distance from the nozzle. The velocity of any particle at a given distance from the nozzle will depend on the initial droplet velocity, droplet size, and direction of the spray (gravitational effects).

TYPES OF NOZZLES

There are five types of nozzles commonly used for dust control in coal mining: full cone, hollow cone, flat spray, solid stream, venturi spray, and

TABLE A-1. MINIMUM PRESSURE REQUIRED TO OBTAIN GIVEN DROPLET SIZE FOR GIVEN NOZZLE

Type of Nozzle	Orifice in.	Flow Rate @ 40 psi, gpm	Droplet Size Range, Microns					
			10-40	50-100	200-400	500-1000	1000-2000	2000-5000
Atomizing	.020	1.0	500	40				
Hollow cone	.094	0.60			30	10		
	.125	1.0			50			
	.156	1.6			90	10		
	.312	8.0				70	10	
	.562	16.0					25	10
Full cone	.062	0.57				65	5	
	.109	1.9					40	5
Flat	.021	0.067			10			
	.052	0.40				10		
	.109	2.0					12	
	.188	6.0						10

atomizing. The basic characteristics of each nozzle type are described as follows:

Full-Cone Nozzle

The full-cone nozzle is characterized by a uniform distribution of droplets over a circular area. Compared to other types of nozzles, the full-cone nozzle produces large droplets with a high velocity. Various spray angles and flow rates are available. Nozzles are also available which produce either a circular or square spray pattern.

Hollow-Cone Nozzle

The hollow-cone nozzle is characterized by a circular spray pattern with the spray droplets concentrated around the perimeter and a hollow center. Compared to other types, spray droplets are smaller and the spray angle is wider.

Flat Spray Nozzle

The flat spray nozzle is characterized by a narrow rectangular spray pattern. Spray angles are available up to 110 degrees. The droplets are generally very large and droplet velocity is very high.

Solid Stream Nozzle

The solid stream nozzle is essentially a flat spray nozzle, characterized by a circular spray pattern and a spray angle of 0 degrees. Compared to other nozzles, the solid stream spray has the highest velocity efficiency and impact per square inch.

Venturi Spray

The venturi spray, Figure A-4, is simply a conventional nozzle mounted in a small venturi shroud. The air entrained by the spray is accelerated through the venturi section, further atomizing the spray droplets. The pattern of the spray is determined by the shape of the venturi shroud and may be rectangular or circular. The droplet size can vary since any nozzle can be placed in the venturi shroud.

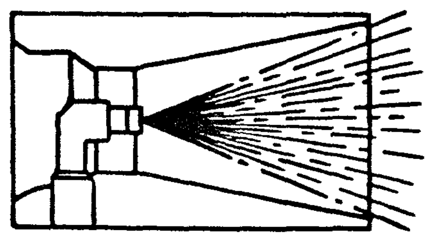


Figure A-4. Venturi Nozzle

Atomizing Nozzle

Atomizing nozzles use hydraulic pressure alone, or compressed air, to produce a fine mist of very small spray particles. A fog-like mist can easily be produced using an atomizing nozzle. The spray pattern is usually a full cone, but hollow-cone and flat atomizing nozzles are available.

WATER SPRAYS AS AIR MOVERS

Through momentum transfer between spray droplets and the surrounding air, water sprays are capable of moving considerable quantities of air. This capacity can be used to deliver air to underventilated areas and to direct air currents. Dust control is primarily benefited by preventing undesirable dispersion or movement of the dust cloud to personnel stations. Both venturi and conventional sprays are employed in air-moving applications.

Standard Spray Nozzles

Standard spray nozzles, without the use of a venturi shroud, can entrain or move significant quantities of air. The best example of this is in the development of the shearer-clearer system. The development of any water spray system should include a determination of the impact of air currents created by the water sprays.

Laboratory studies (2) were conducted to determine the air-moving efficiency of various types of spray nozzles. The results of these studies showed that:

- o Low-capacity nozzles producing small droplets entrain air more efficiently than larger nozzles producing large droplets.
- o Hollow-cone nozzles are slightly more efficient air movers than full-cone nozzles.
- o In an unrestricted area, spray angles of 70 to 90 degrees offer the highest air-moving efficiencies.
- o Hollow cone nozzles move a comparable volume of air as an equivalent venturi spray.

Venturi Sprays

A water-powered venturi spray consists of a spray nozzle centrally mounted to spray through an enclosure of circular or rectangular cross-section. As water is sprayed through the enclosure, a significant amount of air is carried along externally to the spray pattern.

Figure A-5 illustrates the air-pumping capacity of a venturi spray which is a variation of the shrouded spray that has been used in Great Britain. A full-cone spray nozzle, with an orifice diameter of approximately 3/32 inch and water

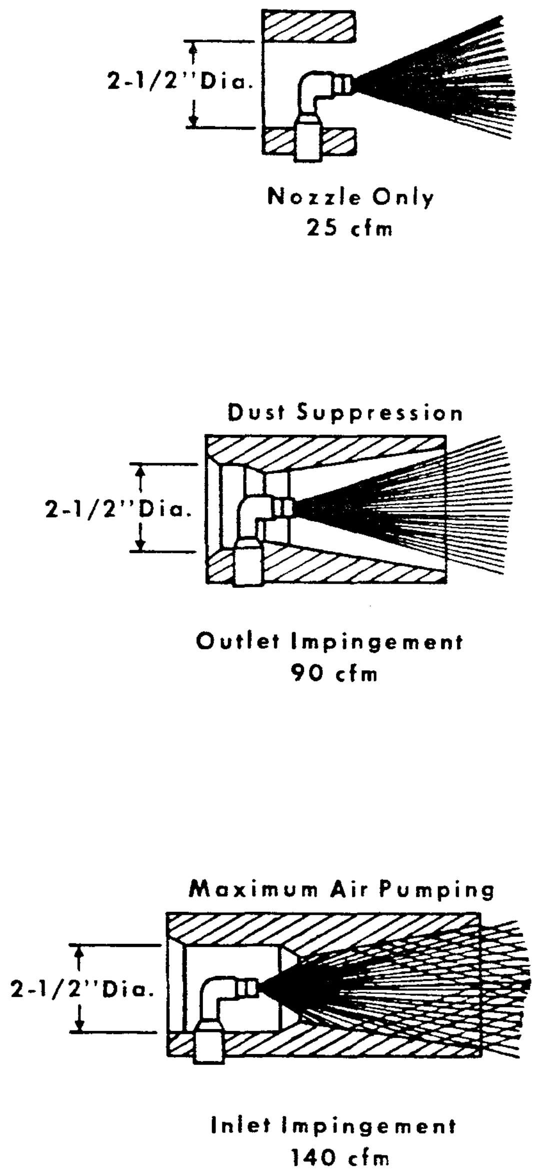


Figure A-5. Venturi Configuration Effect on Spray Air-moving Capacity supplied at a pressure of 100 psi, will pump 25 cfm of air through a 2.5-inch diameter inlet. After adding a venturi section to the same inlet section, the nozzle will pump 90 cfm of air with outlet impingement and 140 cfm with inlet impingement, Figure A-5.

As shown by the graphs in Figure A-6, the amount of air pumped through the venturi increases with greater water pressure and flow rate. It also increases with a wider angle spray. These three elements must be adjusted to meet the needs of each mining situation. For example, wet mining conditions might dictate that less water be used. In that case, a nozzle with a small orifice diameter and a greater spray angle (of 80 or 90 degrees) might be selected. Water pressure could be increased by using a booster pump on the panel. One company reports that a venturi system consisting of three spray nozzles pumped 340 cfm of atomized water and air through its venturi section, while an additional 4,500 cfm of air was simultaneously carried outside the venturi and directed by the spray pattern (7).

USE OF WATER SPRAYS FOR DUST SUPPRESSION

Next to ventilation, the use of water sprays is the most common method of dust control in mines. Measured dust reductions from sprays have ranged from 20 to 60 percent; 30 percent is believed to be typical (3). They are also very cost-effective, since they are inexpensive to install and use.

Water sprays suppress respirable dust in two distinct ways: impaction and airborne capture. In impaction, water wets the coal surfaces and prevents dust from becoming airborne. During airborne capture, the water droplets collide with and hold the dust particles, enabling them to settle from the airstream. It is easier and more effective to suppress dust by wetting coal surfaces. Once dust becomes airborne, control is much more

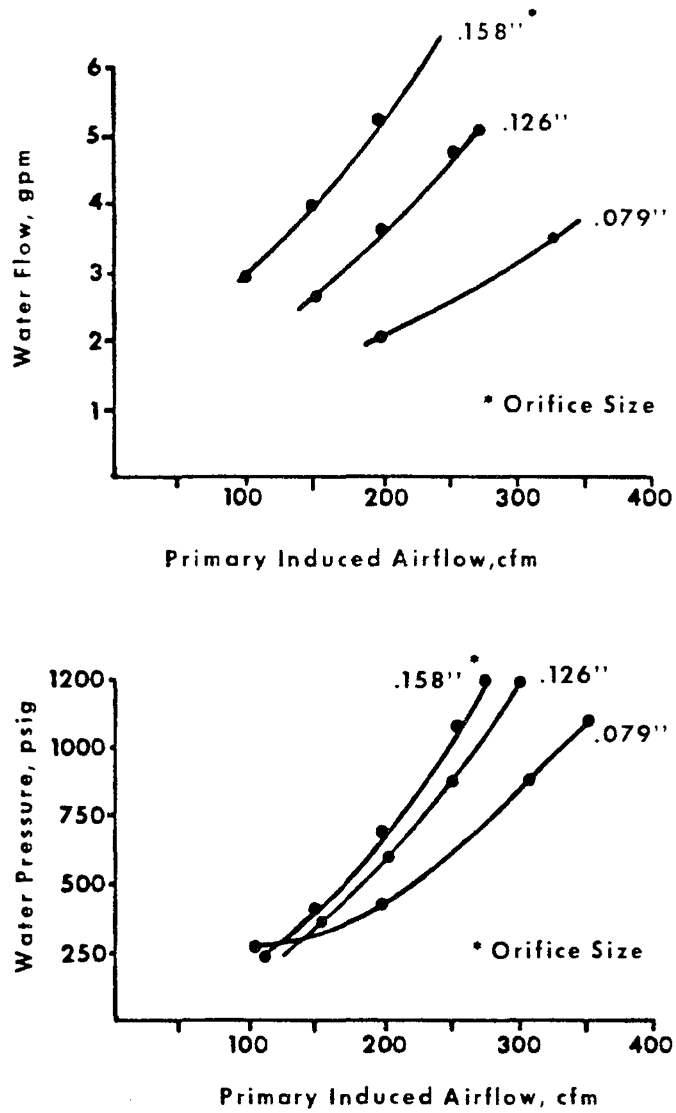


Figure A-6. Induced Airflow as a Function of Water Flow and Pressure for Venturi Sprays difficult, although properly designed systems can be effective in removing airborne dust.

Effect of Nozzle Characteristics on Dust Suppression

In the selection of nozzles, it is useful to keep in mind the following observations that relate the effects of various types of nozzles and nozzle characteristics to dust-suppression systems:

- For a given nozzle, an increase in operating pressure will

  - increase flow rate
  - decrease droplet size
  - increase droplet velocity

- Increase in pressure, up to a point, will increase the spray angle; at high pressure the spray will tend to draw in and the spray angle becomes narrower because of induced airflow

- Given the same pressure and nozzle type, an increase in flow rate will result in larger droplets

- Generally, smaller droplets are associated with wider spray angles

- Droplet velocity and carry depend on pressure and droplet size; an increase in pressure will increase droplet velocity and decrease droplet size. However, a larger droplet may retain its size with less evaporation and with less momentum loss through impaction with dust particles

- Compared to larger droplets, smaller droplets have a reduced distance of projection and incur a rapid decrease in relative velocity between droplets and dust particles due to air resistance

- Interference between sprays mounted side-by-side causes no loss in airborne capture unless the nozzles are less than 6 inches apart

Laboratory studies (4, 10) have been conducted to rank the airborne capture ability of six different types of water spray nozzles. The test procedure involved releasing a quantity of dust into a large, closed chamber. Water sprays were turned on inside the chamber and their effectiveness was evaluated from the rate at which the dust was removed. Each nozzle was tested at various water pressures.

The results are presented in Figure A-7. In general, the results show that airborne capture is increased by decreasing droplet size. The atomizing and hollow-cone nozzles, which produce smaller droplets, were much more effective than the full-cone, flat, or venturi spray nozzles. Smaller droplets can also be obtained by increasing pressure. Thus, for each nozzle an increase in pressure resulted in an increase in airborne capture. However, dust-removal ability increases directly with the square root of water pressure, so large pressure increases are required to obtain an equivalent improvement in dust capture.

Dust Suppression Guidelines

The following guidelines defining spray characteristics for optimal systems are provided to assist in the selection of nozzles for a particular application (1, 2, 3, 11):

- Coal-wetting efficiency (in terms of areal coverage of the droplets per given volume of water) for impaction is maximized if the spray nozzles deliver high-

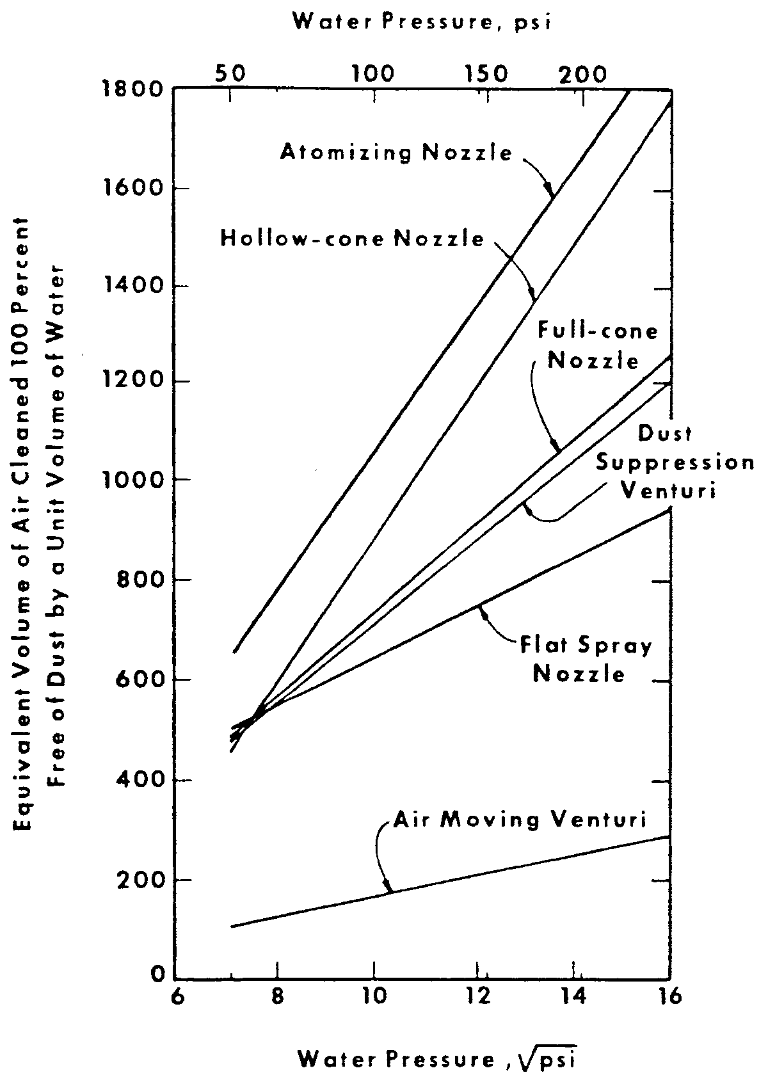


Figure A-7. Airborne Capture Performance of Six Types of Spray Nozzles velocity droplets approximately 500 microns in diameter. Increases or decreases in mean droplet size reduce efficiency. For example, if the average droplet size of a spray is 40 percent less than this optimum size, the coverage per volume of water is reduced by about 25 percent.

- Down to a certain minimum size, smaller diameter spray droplets are more effective for the capture of airborne respirable dust. Droplets of extremely small diameter, however, are not very effective; they are slowed very quickly by friction (drag). Studies have shown that droplets approximately 200 microns in diameter are most effective for capture of airborne dust particles. This size applies to a wide range of droplet velocities.

- Droplets traveling at high velocities are more effective in capturing airborne dust particles than those traveling at low velocities. Droplet velocities can be maximized through selection of appropriate nozzles and/or by increasing nozzle operating pressure. However, as noted previously, droplet size for a given nozzle decreases with increasing pressure. Care should be taken to assure that pressure is not increased to the point that droplets are so small they are quickly slowed and rendered useless by drag effects.

- Both processes, coal wetting and airborne capture, are enhanced by increasing the concentration of spray droplets, i.e., the spray flow rate.

- Airborne dust capture efficiencies are also affected by local airflow patterns and air entrained by the water sprays. The effects of airflow must be examined with respect to the specific application.

Spray System Design Considerations

The performance of sprays in field applications is influenced by many parameters, and determination of their precise effect can be complex. Hence, even though concrete criteria exist for optimization of the coal-wetting and airborne-capture processes, as detailed in the previous section, firm standards for spray configurations and operating parameters are not currently available for many field applications. In light of the absence of "cookbook" specifications for some applications, a discussion of the primary considerations for design of spray configurations is appropriate. These include:

- Definition of dust sources for a particular spray application.
- Determination of the dust-abatement process (coal wetting or airborne knockdown) most appropriate for the sources defined above.
- Definition of practical constraints on the system.
- Establishment of a spray geometry consistent with the areas of dust, suitable nozzle locations, and physical characteristics of the spray defined above.
- Determination of the effect of local airflow and air entrained by the spray.

Definition of dust sources include determination of the dust generating processes and the specific areas where the dust from these processes is liberated. Zones of spray coverage can be established accordingly. The relative significance of various dust sources also must be established if more than one is present. This enables efficient allocation of available water supply. Often, important dust sources are not immediately obvious. For example, studies have shown that dust dislodged from the non-load-bearing side of the belt at transfer points is much more significant than dust generated by the falling coal or agitation (3).

Determination of the most appropriate dust-abatement process enables specification of nozzles that provide a spray with appropriate droplet size, velocity, and other characteristics in accordance with the discussion of the previous section. This may be difficult in some cases, particularly on cutterhead applications where both wetting and airborne capture are likely to occur.

Practical constraints frequently place limitations on spray-system design. One common limitation is the quantity of water that can be sprayed without damaging the mine bottom. This will vary, of course, from one mine to another. In addition, increased water quantities may be permissible with some spray configurations because the water will be loaded out with the coal. A second constraint on many spray systems is that the available water supply may limit nozzle pressures and system water quantities. The areas for dust suppression and application of sprays should be ranked so that the available water supply may be used most effectively. Other factors such as the effect of sprays on personnel, problems in supplying wet coal to the preparation plant, physical damage of the nozzles, etc., may also have to be considered when designing spray systems.

In the physical design phase, manufacturers' specifications on nozzle patterns, spray angles, droplet sizes and velocity, etc., are used to select appropriate nozzles which are located and oriented in accordance with the requisites established above.

Finally, local airflow patterns and the air entrained by the spray can affect system design. A high airflow, counter to the direction of the spray, may slow droplets and reduce their dust-collection efficiency. Air entrained by the spray nozzles also affects the distribution of the dust cloud and the airborne-dust capture efficiency of the spray itself. The effect of these factors should be reviewed for each application.

WATER SUPPLY

The basis for any well-engineered water spray system is the water supply system. The supply system should be designed to provide adequate flow and pressure to the nozzles.

Water used in coal mines is generally obtained from rivers, creeks, wells, reservoirs, or city water supplies. A recent USBM-sponsored study revealed that 80 percent of the mines surveyed use a fresh water or municipal supply, while the remainder recycle some amount of mine water for reuse (6). The water is often pumped into surface storage tanks and then fed into the mine's water distribution system. When gravity head alone is not sufficient to develop the water pressure required, booster pumps are installed to provide adequate pressure and quantity of water at the face.

The face water-supply system should be designed early in the planning stages of an underground operation. Water pipes and hoses should be selected to meet the greatest demand of the water-spray system. The size of piping should be large enough to provide at least 80 gpm for longwall sections. Often, greater quantities are desirable.

The nomograph shown in Figure A-8 (5) provides a simplified, diagrammetic method of determining the piping diameter necessary to provide adequate water flow to the spray nozzles used for dust suppression. The graph applies to pressure

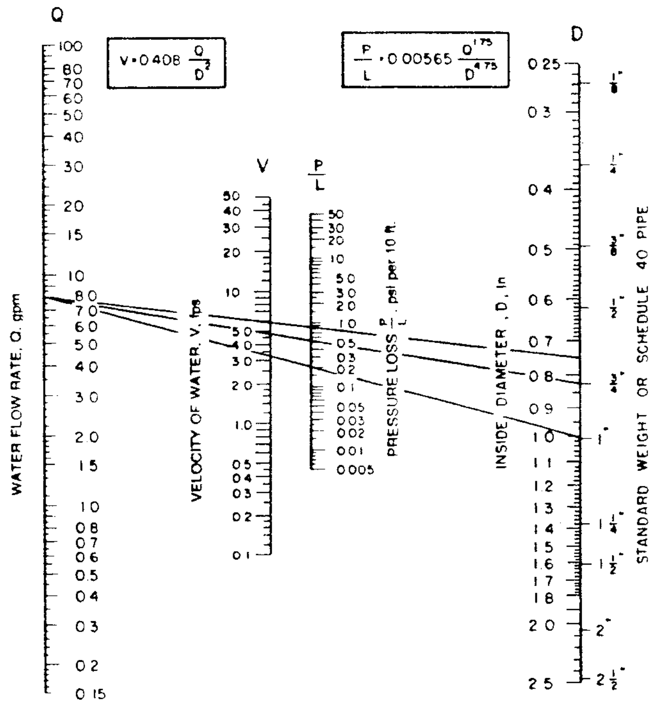


Figure A-8. Nomograph for Determining Pressure Loss and Velocity for Turbulent Flow (R 2100) loss under turbulent flow conditions, which normally occurs in underground water lines. Using the nomograph, the minimum size of a water-supply line can be determined for a given set of water-flow and pressure requirements.

For example, assume that a set of nozzles requires 8 gpm delivered at 75 psi for effective dust suppression, and the spray site is 1200 feet (maximum) from the main supply line. The pressure at the tapping point of the main line is 100 psi at a flow rate of 8 gpm.

To determine the pressure drop for a given flow rate and hose size using the nomograph, draw a line from the desired flow rate to a selected pipe size. (Note the top line of Figure A-8.) Read the pressure loss per 10 feet of pipe where this line crosses the pressure loss line. If the pressure loss is excessive, select a second pipe size and recalculate the pressure loss.

In the example, a 1-inch ID hose would result in a pressure loss of 0.2 psi per 10 feet; for the 1200-foot length, the total pressure loss would be 24 psi (0.2 x 120), which would result in 76 psi at the nozzles. Hence, a 1-inch hose would be the minimum for this application. Any smaller-sized hose would result in a nozzle pressure of less than 75 psi and a flow rate less than the specified 8 gpm.

By selecting a 1.25-inch pipe instead of 1-inch, the pressure loss per 10 feet is reduced from 0.2 to 0.04 psi per 10 feet, providing greater pressure at the nozzles.

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APPENDIX B

COAL CUTTING AND MACHINE DESIGN

Most airborne respirable dust is created during the coal-cutting and loading operation. A fundamental principle in the cutting of a brittle material such as coal is that more fine material and, hence, more respirable dust, is generated as the specific energy spent in the cutting process increases. Thus, the development of efficient cutting machines (in terms of energy consumed per ton of material) is desirable from the viewpoints of operating costs and dust production.

Existing mining machines, with the exception of longwall plows, use a rotary element to drive the cutting bits. However, cutting in this way is inefficient. The dust make at the bottom and top of the cut is assumed to be large because bits are taking only a shallow bite at these points, Figure B-1. When the cutter head has advanced 60 percent of the total distance it will advance during the period that the bit is in the coal, only 10 percent of the volume of coal that will be extracted has been removed because of the "crescent-shaped" nature of the cut. The bit-spacing to depth-of-cut ratio (a critical parameter in cutter-head design) varies continuously throughout the cycle. Finally, the optimum angle of attack to the bedding planes, 45 degrees, is met at only one point during the cutting cycle.

CUTTING PARAMETERS

Despite the inherent inefficiencies in rotary cutting, dust levels can be reduced through selection of proper cutting parameters including depth-of-cut, cutting speed, bit spacing, type of bit, and improved loading.

Unfortunately, extensive modifications of existing machines may be required for application of some of the improved coal-cutting concepts to

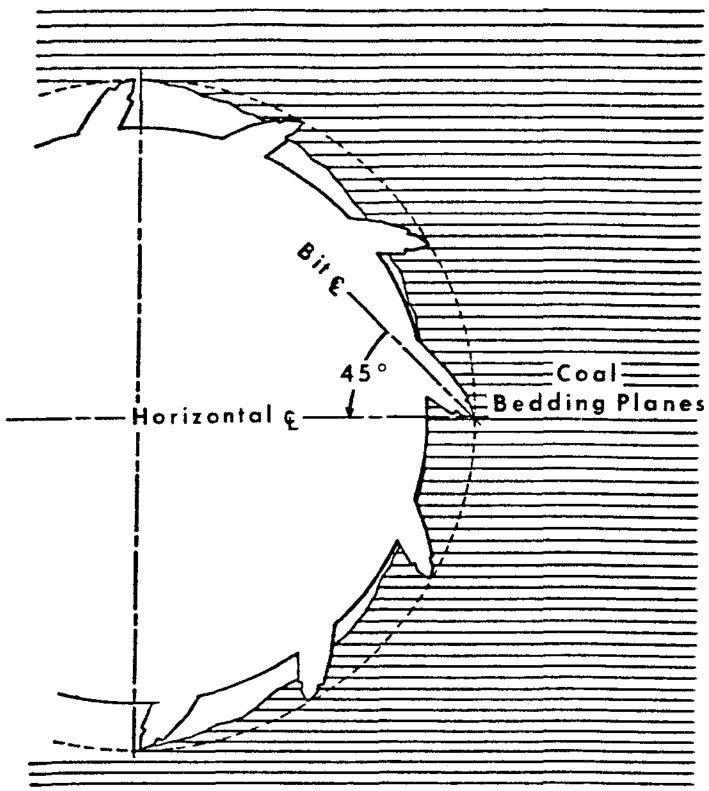

Figure B-1. Bit Path at the Coal Face for Rotary Cutting Drums be discussed; in some cases, retrofit installations may not be possible. However, operators should be aware that machine manufacturers are beginning to make some options available on new machines. In addition, improved cutting is possible with existing machines in some cases, through minor modifications. Two things all operators can do to improve cutting efficiency and reduce dust is to replace worn bits and bit blocks promptly, and to insure that machine operators are cutting efficiently to the full capabilities of their machines.

Depth of Cut

The depth of cut is defined simply as the maximum penetration of a single bit. It has been proven that shallow cuts are very inefficient and produce large amounts of fine coal, and, therefore, a high quantity of dust, Figure B-2. Thus, the depth of cut should be maximized. On a shearer drum, the depth of cut is defined by the following relationship:

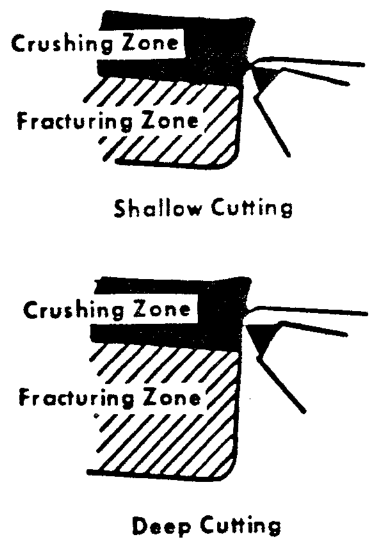

Figure B-2. Effect of Deep Cutting on Dust Production

$$D = \frac{S \times 12}{R \times N}$$

where: D = Maximum depth of cut (inches/revolution)

S = Shearer haulage speed (feet/minute)

R = Rotational speed of the drum (revolutions/minute)

N = Number of bits on each line of attack

In practical terms, the depth of cut can be increased by:

- o Reducing drum rotational speed while maintaining machine-haulage speed
- o Increasing machine-haulage speed
- o Use of fewer bits per line of attack on the drum
- o Use of wider spacing of the bit lines and a reduction in total number of bits (typically larger bits are employed to withstand higher forces on each bit)

Deep cutting is a relative term and must be better defined to provide operators a proper perspective for their own operations. One article (8) defines deep cutting in one or more of the following ways:

- o Cutting with an average pick penetration distance greater than that used in the past
- o Cutting with a pick penetration greater than the longwall operator would have used if the advantages of deep and slow cutting were not considered
- o Cutting with a well-designed shearer drum below 40 rpm

Although these definitions are somewhat arbitrary, the point is that any move toward deeper cutting will benefit the mine operator.

The benefits of deep cutting include a reduction in airborne respirable dust and specific energy consumption, and an increase in production rate. A field study (7) documented a 60 percent reduction in dust levels when the depth of cut was doubled from 1.7 to 3.4 inches by reducing the drum speed from 70 to 35 rpm. Removal of every other vane bit resulted in a 20 percent reduction. Not all reductions have been this spectacular, but less dust is generated and less becomes airborne because of the reduced fanning action from a slower drum. By increasing the depth of cut, the average power required to achieve a given production rate is reduced. Finally, production rate will increase directly with increases in the shearer haulage speed (up to the limit of the conveyor speed).

However, deep cutting at slower drum speeds does present some potential pitfalls that the operator must be aware of. The cutting torque required increases as the depth of cut increases. Thus, there are increased loads on the bits and shearer drum drive transmission. Although energy requirements per ton of coal produced are reduced, the forces on the individual bits are increased. These higher forces require bits with greater mechanical strength. Increased loads on the bit blocks, gearboxes, and ranging arms must also be anticipated and provided for. Increased haulage power must be provided since the haulage effort required increases roughly in proportion with bit penetration. Finally, when fewer bits are used, drive train components will feel greater torque variations, and, if suitable equipment is not used, increased vibration will decrease machine reliability. The loss of bits with slow-speed ranging arms and low-bit density drums results in large transient forces on the drive train which may result in premature failure of the ranging arm.

Cutting characteristics of the particular coal and present machine capabilities place a practical limit on the depth of cut. Considerable work has been done on the development of new deep-cutting shearers since higher torques, in addition to other factors discussed, limit the depth of cut obtainable with present shearers. To accommodate deep cutting and wider bit spacing, new shearer designs include:

- o Use of fewer but larger bits (in Britain, the average drum has 30 bits)
- o Stronger drum construction (wider vanes and stronger bits and bit blocks)
- o Higher machine-haulage speed
- o Slow-speed gearheads (e.g., a drum speed as low as 22.5 rpm is utilized in one British mine where the coal is very soft) or dual-speed gearboxes
- o Stronger machine under-frame construction

Manufacturers now offer shearers that will operate with drum speeds of 30-40 rpm. Some manufacturers offer drum speeds in the high 20's to low 30's, which represent the lower limit of drum speeds currently offered and warranted in the U.S. Care should be exercised in selecting a low-speed gearbox to ensure that choking of the drum does not occur.

At the present time, some longwall shearers are equipped with two-speed gear boxes to change the drum speed in seams of varying conditions. A high speed is used for hard cutting and a low speed is used for easy cutting. For a ranging-arm shearer, the high speed can be used for cutting the top of the seam while the low speed can be used to cut the bottom, where an additional free face makes cutting easier. The low speed is also used in loading operations when the machine is cleaning up.

Bit Spacing

Bit spacing is mainly limited by the properties of the material to be cut and the depth of cut to be taken. Efficient breakout is generally considered to occur at a bit-spacing to depth-of-cut ratio of 2-3:1. The effect of a good space-to-depth ratio is shown in Figure B-3.

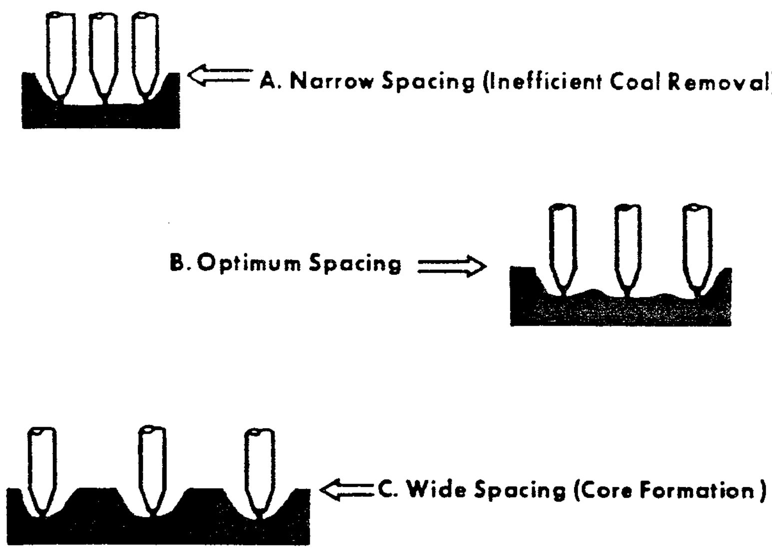

Figure B-3. Effect of Bit Spacing on Coal Cutting

Good breakout should occur not only in front of the bit, but also to either side of it. In addition, if the bit spacing is too narrow, the following bit may tend to jump into grooves cut by the adjacent bits and result in machine instability and excessive vibration.

A proper space-to-depth ratio assures that each bit is taking as deep a cut as possible, with efficient breakout, considering the strength of the bits and the stability of the machine. In many situations, the high bit forces and vibration cannot be tolerated by the machinery. It is possible through experimentation to find the optimum depth-of-cut and space-to-depth ratio for a particular set of conditions.

Bit Speed

Studies have shown that lower bit speeds produce less dust and reduce the amount of dust entrained due to the fanning action of the cutterhead. The linear speed of the drum periphery is important when considering the loading action of the drum and the depth of bit penetration.

Bit speed on a drum is determined by the rotational speed and the diameter of the cutterhead, as follows:

$$S = \pi d \omega$$

Where: S = linear bit speed (ft/min)
d = diameter of the drum at the bit periphery (ft)
ω = rotational speed of the drum (revolution/min)

The use of a lower cutting speed is a practical necessity when cutting to a greater depth. The machine may stall (if traction is sufficient) if a deeper cut is taken with the existing bit speed. If the cutting speed is reduced and the sump or shear rate is held constant, each bit will remove more coal per revolution.

To reduce bit speed, a reduction in rotational speed is usually more practical than a reduction in drum diameter, since drum diameters must be compatible with seam height. Also, in low seams, reduced diameters might restrict height of the vanes which, in turn, might reduce loading efficiency.

A British guideline is to attain a bit speed of less than 600 fpm. Cutting characteristics of the coal and seam height will determine the practicality of attaining this goal. Reduced bit speed would, of course, be an additional advantage of the dual-speed shearer discussed previously.

BIT-LACING PATTERNS

The sequence of bit attack on the face is determined by the bit-lacing patterns. This sequence affects cutting efficiency as well as other cutting aspects.

The "counter-laced" bit pattern is worthy of discussion. The name is derived from the fact that the cutting spirals run counter to the vanes on which the bits are mounted, Figure B-4. Figure B-4 illustrates the pattern of coal breakage and the sequence of bit attack. Advantages of the counter-laced pattern include:

- o Each bit relieves the work of the subsequent tool on the same spiral by creating a free face for the subsequent cut
- o Bit forces are never concentrated on one end of the drum because the second pattern is initiated before the first pattern reaches the face side end of the cut
- o The direction of breakout is the same as the direction of loading across the drum

At least three vanes are required to achieve a counter-laced pattern, and the pattern cannot be installed if an even number of vanes is used.

Bit forces on corner (clearance-kerf) tools may be as much as 10 times greater than those on the vanes. An efficient lacing pattern on these tools is essential. Typically, the tool lines of attack are closer and the number of bits per line is increased toward the corner of the cut to provide a more reasonable level of force per tool. The lacing pattern illustrated in Figure B-5 complements the counter-lacing pattern. Breakout proceeds toward the corner along the sequence, with the cutting relieved by the previous bit. The space available on the drum backplate for bit mounting may limit the number of bits which may be

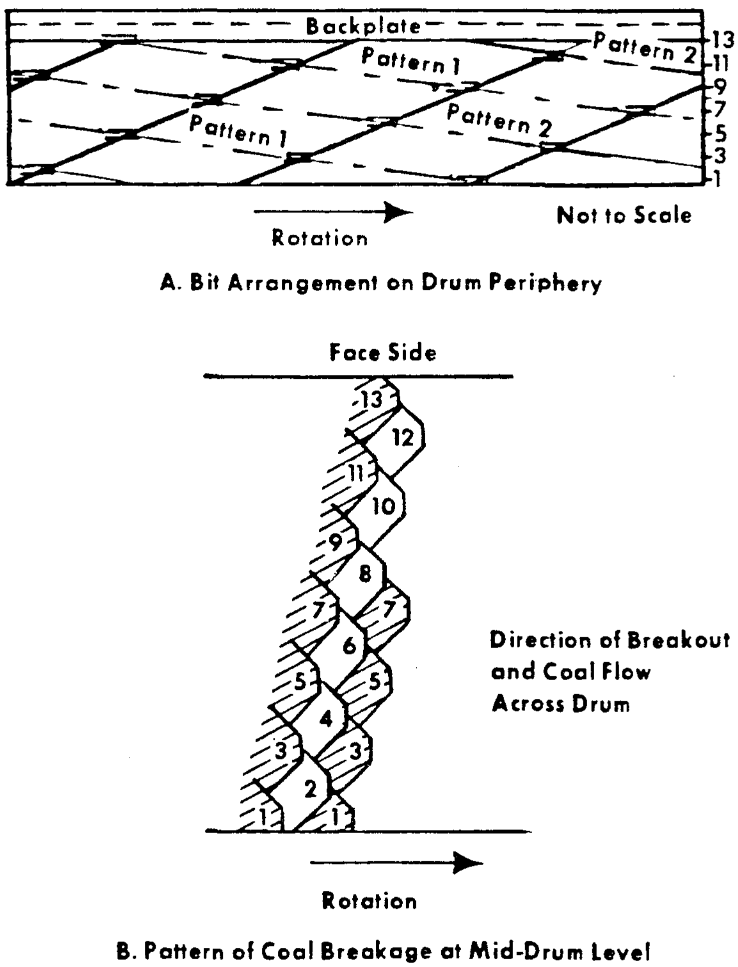

Figure B-4. Counter-laced Bit Arrangement

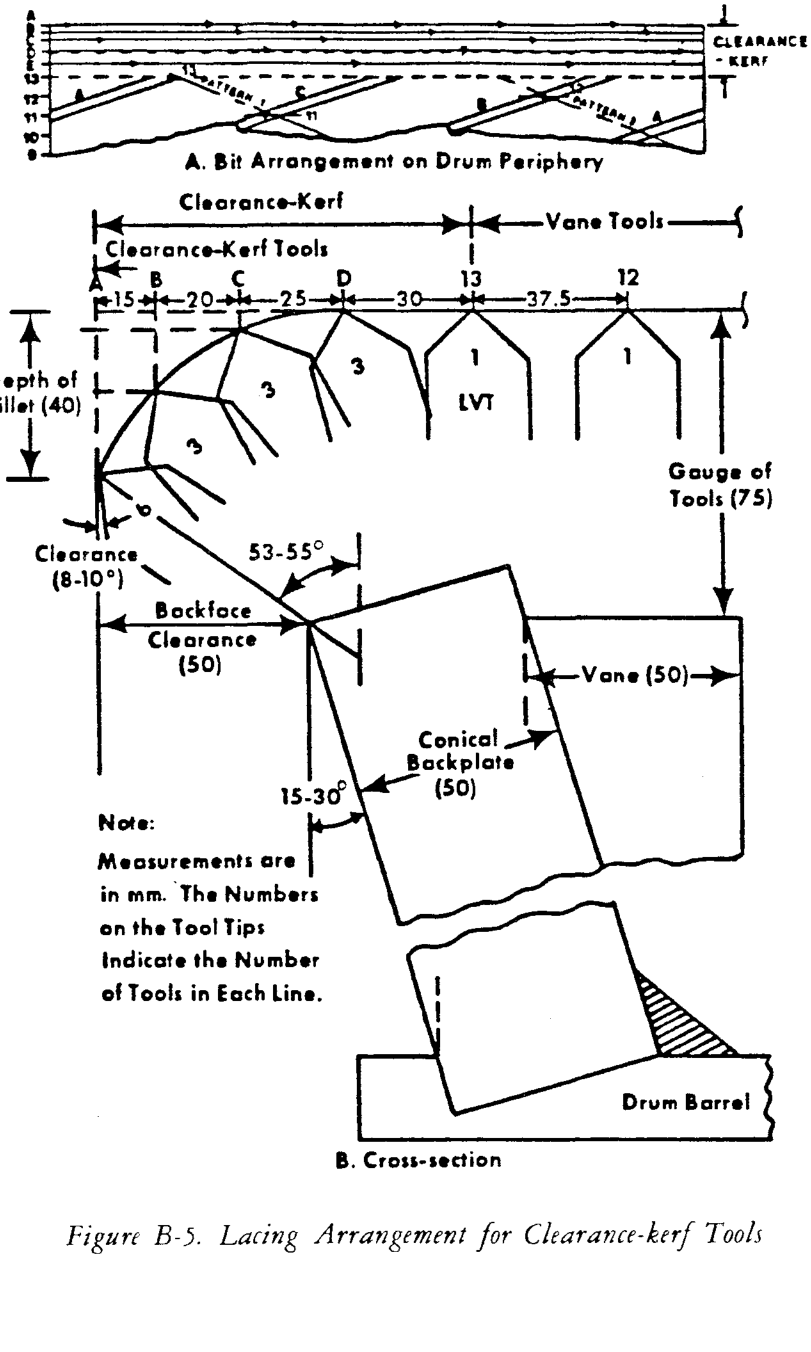

Figure B-5. Lacing Arrangement for Clearance-kerf Tools mounted. In such event, a four-line sequence might be used instead of the five-line sequence shown. Clearance between the side of the last bit and the vertical face line is required to prevent excessive rubbing, as shown in Figure B-5.

Recent field trials (9) have shown that the clearance or backface bits are the single greatest dust source on the longwall face. Thus, the number of clearance bits should be minimized whenever possible.

It was also shown that at narrow web widths (6 inches), the clearance bits generate three times the dust level per unit volume cut compared to full web widths (30 inches). Additional field trials (6) showed that with an increase in web width (from 15 to 21 inches), and a corresponding 40 percent increase in tons of coal mined per pass, there was no increase in downstream dust levels. British tests showed a dust reduction when the web width was increased from 25 to 38 inches. The dust level was 11.3 mg/m^3 at a web width of 25 inches and loading rate of 4 tons/min; a web width of 38 inches and loading rate of 5-1/2 tons/min yielded a dust concentration of 9.4 mg/m^3. Thus, the use of partial sumps in the cutting cycle should be discouraged.

LOADING EFFICIENCY

An essential function of the shearer drum is to load the cut material to the face conveyor. If the loading is inefficient, the coal will tend to recirculate around the drum and will be subject to further breaking, resulting in increased dust production. The shearer advance rate may also be reduced, resulting in decreased production rates. Other aspects of shearer design which affect loading efficiency are vane angle and height, number of vanes, drum rotational speeds, drum diameter, and shearer haulage speeds. Investigative work, including model studies, continues into their precise effects. The British have reported the following observations:

- In most cases, loading efficiency increases as drum rotation speeds decrease. This parameter has a major effect on loading efficiency. Drums with rotational speeds in the range of 20 to 40 rpm are generally efficient.

- Loading efficiency decreases with very low or very high vane angles. Vane angle and rotational speed are related; when rotational speeds are low, a range of vane angles (8 to 30 degrees) is acceptable.

- At high haulage speeds (greater than 20 ft/min), the volume of cut material passing through the drum per unit of time increases; hence, loading efficiency decreases. Consequently, higher rotational speeds--40 to 60 rpm-- might be preferred to maintain the loading rate.

- At low rotational speeds, the number of vanes has very little effect on loading efficiency. However, at high speeds (greater than 60 rpm), the loading efficiency of a drum equipped with three vanes decreases more rapidly than that of a drum of similar geometry with two vanes.

- Increasing the web width increases the volume of coal to be handled by the drum per revolution and requires detailed consideration of all aspects of drum design to maintain a high loading efficiency.

- Loading efficiency problems are more likely with smaller-diameter drums. The problems occur because coal cannot be removed at a high enough rate; the loading aperature is smaller and vane depths are, of necessity, reduced. Drums with more vanes and higher rotational speeds are suggested, but the degree to which these changes should be incorporated depends on the degree of loading problems experienced under the conditions at the particular face. Some typical applications of these parameters to attain efficient loading might be as follows:

Diameter, in.	Drum Speed, rpm	Number of Vanes
36 - 44	60 - 70	3
<36	60 - 80	4

These figures do not apply to in-web shearers.

- o To allow enough volume for coal flow, the minimum recommended distance between adjacent vanes, measured perpendicular to the parallel vane lines, is 8.85 inches
- o Loading efficiency decreases with increases in the distance from the gob-side edge of the loading vanes to the face-side edge of the armored face conveyor (AFC) because coal falls between the drum and the AFC.
- o When criteria for loading and efficient cutting are in conflict, the criterion for efficient cutting should have priority.

BIT DESIGN

In the future, bit design may prove to be a significant factor in the production of dust, but at this time there is no conclusive evidence that any particular bit generates less dust. The bit manufacturers' major concern in bit design is initial cost, ease of replacement, and cost per ton. The manufacturers' solution to optimum cutting is to change bits frequently, and, therefore, maintain sharp, efficient bits. Many feel that after a short time all bits become dull, so the advantages of one bit over another become less significant; and the main consideration should be ease of replacement.

The bit should be designed to provide sufficient clearance both for itself and for the bit block. If not designed properly, the bit and bit block can rub against the coal, resulting in excessive dust.

No agreement has been reached on the "best" type of bit. Some sentiment exists, particularly among the British, that point attack bits (e.g., plumb bob or pencil) should not be used because the tip does not cut clearance for the body of the bit, thus increasing cutting forces. They also have a short effective gage length and are mechanically weak. Laboratory tests with U.S. coals on dust generation from different styles of bits have been inconclusive.

However, from a practical standpoint, mining conditions vary, and no one bit is best for all conditions. Therefore, the conditions in each mine should dictate what bit is best to use.

Regardless of the type of tool employed, initial cost should not be the sole criterion for choice of a particular bit. Bits vary significantly in construction; e.g., strength of the members, method for attaching the carbide tip, and type of carbide. Performance, in terms of wear and breakage under the cutting conditions of the particular application, must be considered in conjunction with cost.

Point-Attack Bits (Round Shank)

Two main types of point-attack bits are the plumb bob and the pencil (or bullet) bit.

The attack angle, Figure B-6, is important for point-attack bits. For the plumb-bob bits, the best practical angle is 45 degrees, which minimizes the bending stresses at the shank of the tool.

The main advantage of the pencil bit is that it costs less than other types of bits.

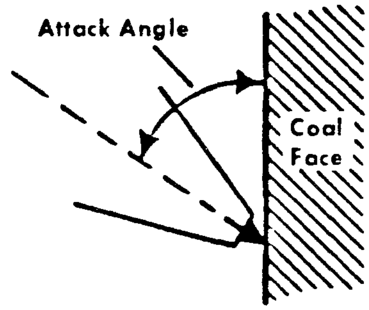

Figure B-6. Attack Angle

Cutter Bit (Rectangular Shank)

The cutter bit is a wedge-shaped tool with a rectangular shank. The British use the cutter bit to a large degree and believe it is much more efficient than the point-attack round shank bit.

The strength of the cutter bit is determined by the wedge, rake, and clearance angles, Figure B-7. As the wedge angle is reduced, support strength for the carbide decreases. As the bit wears, the clearance angle is reduced. When a large wedge angle is needed, it is better to reduce the rake angle and maintain the clearance angle.

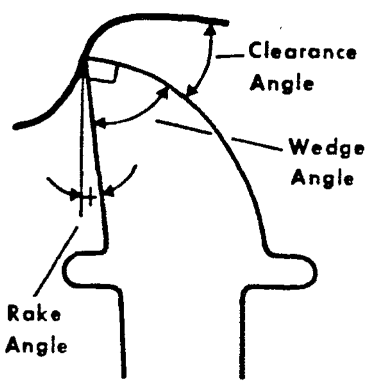

Figure B-7. Cutter Bit

There are conflicting ideas as to what rake and clearance angles are best.

Rake angle values vary from +10 to -10 degrees, and clearance angles from 5 to 30 degrees.

Cutter-type bits with rectangular shanks may be either "radial" or "forward attack" as illustrated in Figure B-8. A primary advantage of the forward-attack tool is that the resultant force is more in line with the bit axis, which reduces the chances of breakage. However, this type bit usually has a five-inch gage length, thus forces are still high. Also, the greater clearance between the bit face and the coal in the direction of cutting has been reported to provide more area for the passage of fragmented coal, reducing cutting forces (11). Point-attack bit blocks require more room in the vane than radial bits; consequently, this reduces the bit density and results in higher loads per bit.

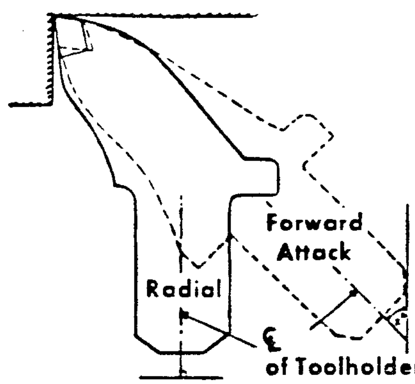

Figure B-8. Radial and Forward Attack Bits

Sharpness and Mounting of Bits

No matter what type bit is used, the prompt replacement of damaged, worn, or missing bits cannot be over-emphasized.

A dull bit rubs against the coal, using an excessive amount of energy. This results in inefficient use of available cutting force, and the machine is unable to penetrate the coal at design rates. This resultant shallow cutting greatly increases dust production.

Not only do dull bits result in higher cutting forces and more dust, but there is an increased likelihood for mechanical damage of bit holders, drums, and gearboxes, and a greater probability for the frictional ignition of methane.

Bit holders mounted on the vanes should not extend too far into the channel between the vanes because this might interfere with passage of the coal and reduce loading efficiency. The configuration illustrated in Figure B-9 is consistent with this requirement, while providing maximum support for the bit holder.

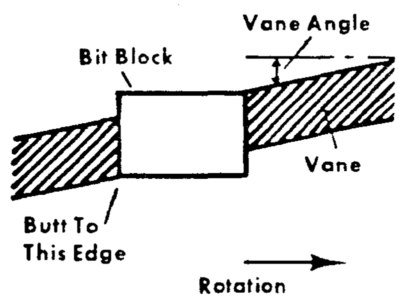

Figure B-9. Bit-block Mounting to Minimize Loading Interference

COWLS

Most longwall shearers are currently equipped with cowls of various designs and construction. This device assists the loading action of the drum, and, especially, helps to confine the dust generated by the drum. In the latter role, it (1) inhibits dispersion of the drum dust cloud to the machine operator's station by isolating the cutting zone from the primary ventilation, and (2) increases the efficiency of spray nozzles in the drum vicinity by trapping the cloud.

For purposes of dust control, the drum should be shrouded from the face airstream to a maximum degree. Practical and operational constraints, however, often limit the degree to which this can be achieved. In many cases, observation of the drum is critical for horizon control, and cowls should not excessively interfere with this requirement. Requirements for turnover of the cowl with directional changes may limit its size in thin seams. Also, good shrouding is more difficult to achieve on ranging machines than on those with fixed drums. Ventilation enters the cutting zone over the top of the cowl blade and between the side of the blade and the face. These gaps should be maintained as small as practical.

The most critical limitation to the shrouding function of cowls is the potential for buildup of methane between the drum and cowl. On most installations, however, this is not a problem.

Some mines employ belting or wire strands on the cowl to increase shrouding. Such devices should not be employed if they increase methane buildup or increase the severity of the other constraints outlined above. When a cowl is added to a machine, excessive increases in the distance between the gob-side edge of the shearer drum and the face-side edge of the face conveyor should be avoided, since this would decrease the loading efficiency of the machine.

MACHINE OPERATION

Numerous design features of shearers affect the amount of fines produced during cutting, the efficiency with which the cut coal is loaded, and the level of entrainment and distribution of the produced dust in the airstream. Improvements in many of these parameters are desirable, not only because of their effect on dust conditions, but also because of concurrent improvements likely in other important mining concerns (e.g., level of production, power costs, bit replacement costs, etc.).

Thus, not only should design to minimize dust be optimized in view of local conditions, but care should be taken to insure that the machine is operated efficiently so that dust is not produced unnecessarily.

When the actual web cut by the machine is less than the width of a drum, higher levels of dust are liberated per volume of material cut.

For the sake of both production and dust levels, a maximum web cut should always be taken. This requires maintenance of a straight face and precise pushover of the face conveyor.

When the cutter bits nip the roof, they produce very significant levels of dust since they are taking shallow cuts in a very dusty material. Care should be taken to avoid this. Also, the free-wheeling drum should not be allowed to contact the roof on the cleanup pass.

The development of sensors for machine guidance to distinguish the coal/rock interface, or the thickness of the coal between the shearer drum and the rock, show potential for reducing the amount of rock cutting. Various sensor configurations are currently being tested, with the ultimate goal of automated machine operation.

A final operating parameter of demonstrated significance is the direction of drum rotation. Drums are divided into right-hand and left-hand drums depending on the direction in which the vane spiral is mounted on the drum shell, and this dictates the direction in which the drum rotates. As drums are normally expected to cut and load coal in both directions across the face, their sense of rotation will be from floor-to-roof in one direction and roof-to-floor in the other.

The common direction of rotation for the lead drum is from roof-to-floor in the direction of cutting. Rotation from floor-to-roof tends to cast the cut coal into the airstream and can increase dust levels. However, loading efficiency is generally improved when the rotation is from floor-to-roof. In this direction, the coal sliding down towards the floor is picked up by the vane as it rotates from the bottom upwards and is transported in the conveying direction. The loading process is, therefore, assisted by this opposed movement between the coal and the vane surface. When the drum rotates from roof-to-floor, the opposite occurs; coal is conveyed through between the drum and the floor at a relative speed (haulage speed vs. vane peripheral speed) and part of the coal is discharged here and some of it remains on the floor. Other benefits of reverse cutting drum rotation can be summarized as follows:

- Improved loading by the leading drum because the interaction between the loading vane and the fractured material is improved

- Improved loading by the trailing drum because the drum is no longer attempting to load coal over the ranging arm but rather through the apperture beneath the cowl arm (Figure B-10)

- Improved cleanup by the leading drum at the face ends resulting in a faster turn-around

- Reduced specific energy for cutting/loading (less secondary degradation of the coal as the coal spends less time in the conveying space of the drum)

- Improved tram speed

- Larger product size, less fines

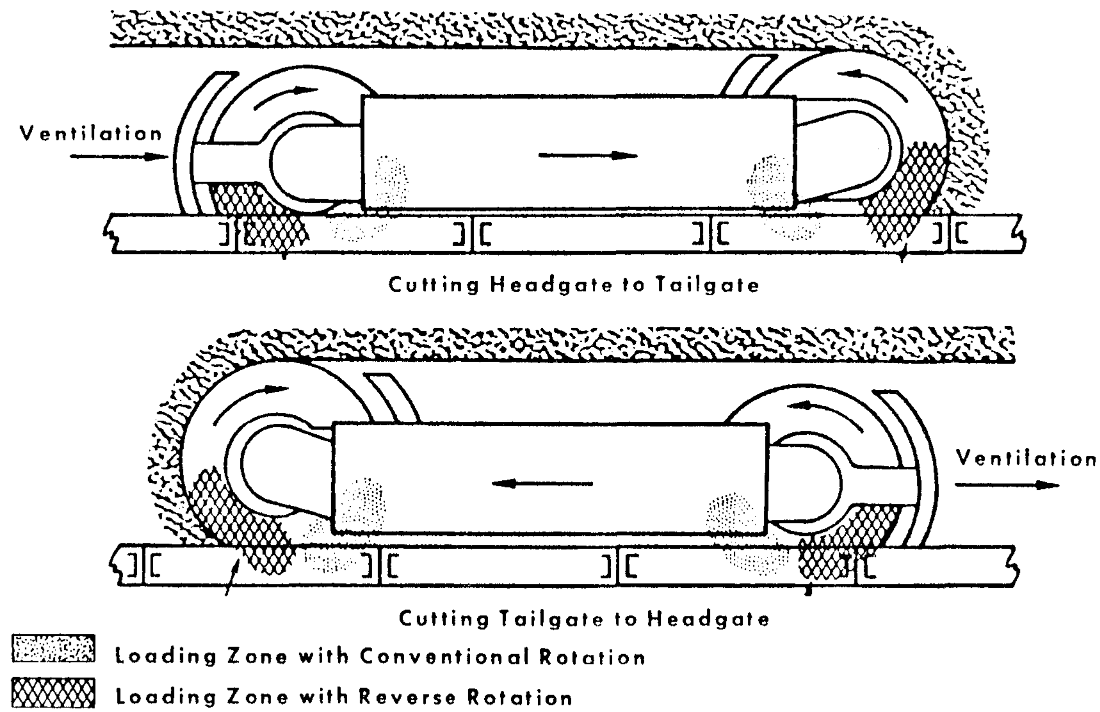

Figure B-10. The Location of Loading Zones when Applying Reverse (Floor to Roof) Rotation of the Cutting Drums

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APPENDIX C

SAMPLING PROCEDURES FOR ASSESSING EFFECTIVENESS OF CONTROL TECHNOLOGIES

There are two types of samplers available to determine dust concentrations: gravimetric samplers and instantaneous monitors. Each type sampler, along with survey methods, will be described to allow the operator to evaluate dust-control techniques.

GRAVIMETRIC SAMPLERS

Gravimetric samplers are routinely used by mine operators to determine compliance with federal dust standards. The samplers, normally worn by mine personnel, are made up of an air pump, filter cassette, and 10 mm cyclone. Typically, the samplers are operated for a full shift and the weight of dust collected is determined after the shift. The dust concentration is determined from the weight of dust and volume of air sampled.

The primary shortcoming of gravimetric samplers is that the sampling time must be long enough to obtain sufficient dust on the filter to provide an accurate weight. If too little dust is collected, then weighing errors can be significant. Typically, 0.2 mg or more of dust should be collected on each filter. During dust surveys, weighing errors can be reduced by using a more accurate balance (weigh to the nearest thousandth of a milligram) or by reusing filters to increase the dust weight.

INSTANTANEOUS SAMPLERS

There are currently three instantaneous dust samplers available to continuously measure dust concentrations. They are the RAM-1 and the Miniram, developed by the GCA Corporation, Bedford, Massachusetts, and the Simslin, developed by the Safety in Mines Research Establishment, Great Britain. These instruments continuously measure the airborne respirable-dust concentration and can provide data over a very short time interval, about one minute. The Miniram is basically a passive sampler (i.e., no air mover) and, as such, offers the advantage of being smaller and lighter than the RAM-1 and Simslin monitors. However, the Miniram is typically not operated with a pump or cyclone, and, therefore, cannot be used for valid sampling according to USBM procedures. The RAM-1 and Simslin monitors are too large to be worn by individuals, but can be placed on machinery or carried for research purposes.

All three instruments rely on a light-scattering technique to measure respirable dust. The intensity of the light scattered by airborne dust particles passing through a light beam is directly related to the surface area of the dust particles, and, therefore, related to the concentration of the dust particles. Measurements of this light intensity can be made over very short time intervals, resulting in a continuous record of the dust levels.

RAM-1 (Real-time Aerosol Monitor)

The RAM-1 uses a 10 mm cyclone to remove the non-respirable dust fraction. The sampler operates at an airflow of 2 liters per minute with a secondary clean-air system (0.2 liters per minute) which allows for continuous flushing of clean, dry air over all critical optical surfaces.

The concentration data are updated three times per second and continually displayed in digital form. The major advantage of the RAM-1 is its read-out flexibility. The instrument is supplied with three selectable concentration ranges (0.2, 20, and 200 mg/m^3).

The RAM-1 weighs 8.9 pounds (4 kg) and has approximate dimensions of 8 x 8 x 8 inches (20 x 20 x 20 cm).

Miniram

The Miniram aerosol monitor behaves very similarly to its predecessor, the RAM-1, and costs about one-third as much. However, it does not require an air pump or size selector to sample the respirable fraction of dust. It depends on ambient air movement to transport the dust through its open-ended sensing chamber. The instrument can also be modified using an adapter (pump) to actively pull the dust-laden air through the sensing chamber.

The Miniram weighs only 1.4 pounds (0.63 kg) with approximate dimensions of 4 x 4 x 2 inches (10 x 10 x 5 cm). It automatically selects a measurement range of either 0.01 to 10 or 0.1 to 100 mg/m^3. Instantaneous measurements are continuously displayed and updated every 10 seconds; a time-weighted average concentration can also be displayed. An analog output is available for continuous data logging or strip-chart recording of the dust readings. There are some limitations and disadvantages associated with the use of this instrument, including:

- o erroneously high readings may occur when water droplets pass through the sensing chamber
- o deposition of dust of the inner walls of the sensing chamber may cause excessive zero drift
- o like the RAM-1, the dust measurements are linearly related to gravimetric measurements obtained with a respirable coal mine dust sampler; however, they do not provide a direct measure of an environment's respirable dust concentration (1).

Simslin Dust Monitor

The Simslin operates by drawing dusty air through a parallel-plate elutriator (to remove non-respirable dust) at a flow rate of 0.625 liters per minute, and then through a light beam and onto a filter which collects the dust. Note that the Simslin must be horizontal when operated to insure proper functioning of the elutriator.

In addition to an instantaneous digital reading which displays the concentration at one-second intervals , the Simslin is capable of displaying average concentrations and storing data into a memory system. A decoder is used to convert the digital information of the memory into a series of analog voltages for a strip-chart recording. The peaks and troughs on the chart correspond to changes in the dust levels produced by changes in mining activity. The changes in activity must be accurately timed to be able to correlate the information on the chart with the activity.

The Simslin weighs 15.6 pounds (7 kg) with dimensions of 16 x 4 x 6 inches (41 x 10 x 15 cm). Its cost is approximately three times that of the RAM-1.

SAMPLING OBJECTIVES AND INSTRUMENTATION

Prior to conducting a respirable dust survey, the survey objectives and sampling strategy must be defined. The sampling instruments and strategy selected by the mine operator must be able to fulfill his objectives.

The two primary purposes for conducting a respirable dust survey are to (1) identify specific dust sources, and (2) evaluate the effectiveness of a control technique. The major sources should be identified before time and money are spent installing controls which do not address the problem areas. Once the primary dust sources are identified, the operator can develop effective control methods to address these areas. A second survey can then be conducted to determine if the new control technique is effective.

Full-shift gravimetric samplers are usually not adequate to determine specific dust sources, and may not be the best approach to determine the effectiveness of a particular control technique. Short-term sampling, however, can be effectively used to determine sources and evaluate techniques. Either gravimetric samplers or instantaneous monitors can be used. If gravimetric samplers are used, multiple (4) samplers should be used at each location to insure accuracy and obtain a valid average dust concentration, since sampling is for short periods of time (typically 20 to 30 minutes). The gravimetric samplers can be placed in a sampling package, Figure C-1, or carried by

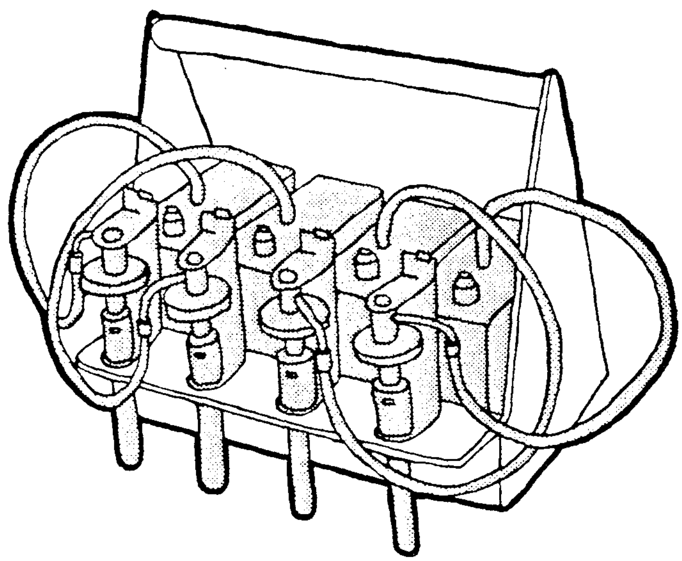

Figure C-1. Hand-held Sampler Package

the survey engineer on a sampling vest, Figure C-2. The sampling pumps are carried in pockets and the cyclone assemblies are attached to the front of the vest.

SAMPLING STRATEGIES

The selection of sampling locations is extremely important because of the large dust

Figure C-2. Sampler Vest

gradients that exist along the longwall face. A change in sampling location during a survey can have a greater effect on the measured dust concentration than the control technique being evaluated.

Two simple and effective sampling strategies, based on short-term sampling, have been developed by the U.S. Bureau of Mines. These strategies can be used to identify dust sources as well as evaluating control techniques. One strategy makes use of gravimetric samplers, while the other uses instantaneous monitors. The sampling strategies are based on the fact that the dust concentration measured at any location is a composite of all dust sources upstream of that location.

Gravimetric Sampling Strategy (3)

Two survey engineers collect gravimetric samples during selected segments of the mining cycle. Multiple samplers should be used at each location. The mining cycle is divided into the head-to-tail pass and the tail-to-head pass. One set of samples is collected on the head-to-tail passes, while a second different set of samples is collected on the tailto-head passes. One person stands at the midpoint of the shearer, while the other remains 15 to 20 feet on the intake air side of the shearer. Both maintain their positions relative to the shearer as it travels along the face. In addition, a sampler package is located in the last open crosscut to measure the section's intake dust concentration, Figure C-3.

For example, assume an operation using a unidirectional tail-to-head cutting pass with support movement on the intake side of the shearer during the head-to-tail cleanup pass. One set of samplers (Figure C-3, Locations B and D) is turned on after the shearer is fully sumped in and begins cutting from tail-to-head. The start time is recorded when the samplers are turned on. As the shearer and survey engineers approach the headgate entry, the instruments are turned off and the stop time is recorded. The filter cassettes or package can now be changed for the head-to-tail cleanup pass. The second set of samplers (Figure C-3, Locations C and E) is used during the head-to-tail pass. This cycle is repeated for each pass, using the same samplers for all head-to-tail passes, and a second set for all tail-to-head passes.

The intake air samples will give a measurement of the dust levels in the intake air approaching the section. The samples collected 20 feet on the intake air side of the shearer during the tail-to-head pass will yield a measurement of the dust levels associated with coal transport on the face conveyor and stage loader. The samples collected 20 feet on the intake air side of the shearer (between the shearer and support movement) during the head-to-tail pass can be used to determine the dust levels associated with support movement. The samples collected at the midpoint of

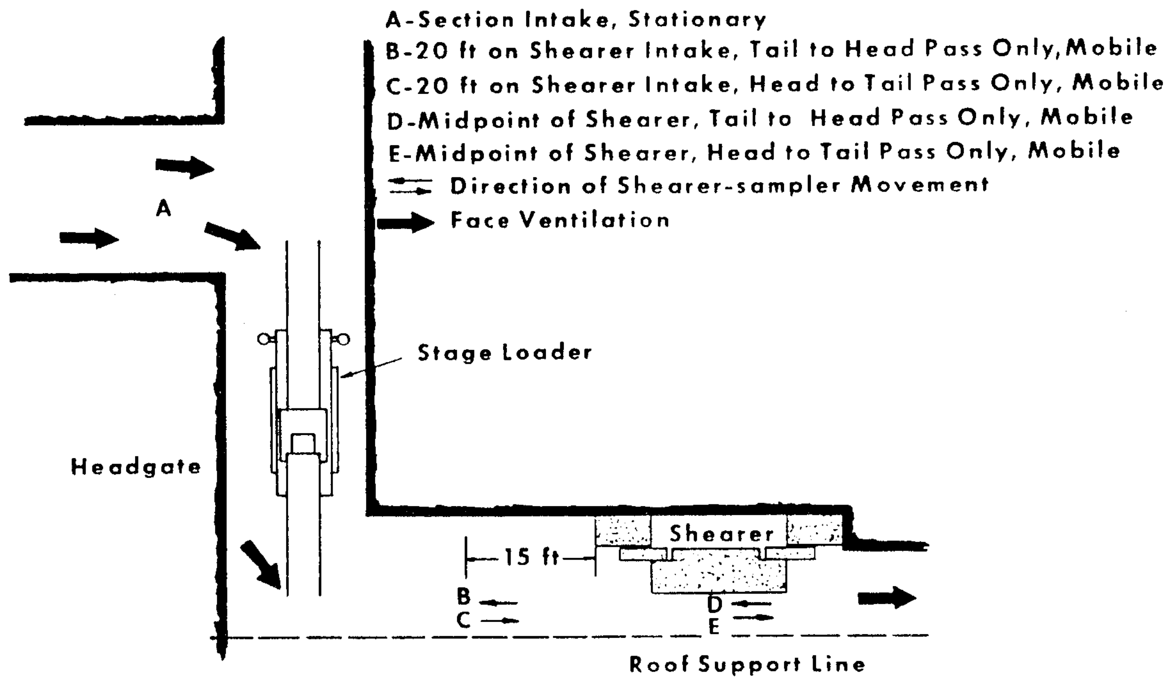

Figure C-3. Sampling Location Designations the shearer will indicate the severity of dust levels produced by the shearer, and the effectiveness of the cutting sequence for minimizing the shearer operator's dust exposure. In addition, if this sampling technique was used during successive mining cycles, with and without a dust-control procedure in operation, the results could be used to evaluate the effectiveness of the control procedure.

The data and calculations shown in Table C-1 are typical results for a dust source evaluation. It should be noted that in this case, 52 percent of the dust is generated on the cleanup pass by the headgate drum. An alternative would be to cut the bottom with the tailgate drum, placing this dust source downstream of both machine operators.

Instantaneous Sampling Strategy

Instantaneous dust monitors are used to obtain dust level profiles on the longwall face. The sampling strategy involves the use of mobile and stationary sampling points. In the mobile method, the dust monitor is carried by a survey engineer walking along with the shearer as it travels across the face. The engineer maintains the same position relative to the shearer across the length of the face. Dust levels and face position (support number) are recorded during all phases of the mining cycle. For example, dust readings can be taken at every fifth support. These measurements can show how changes in airflow along the face, face conditions (rock partings), and cutting sequence (cutting the wedge) affect dust levels.

In the stationary sampling method, the survey engineer stands with the dust monitor at a fixed location on the face. As the shearer approaches, the dust level and distance to the shearer are recorded. Dust concentrations can be recorded based on time or distance the shearer travels. For example, readings can be taken at 10-second or 5-foot intervals. Typically, measurements start

TABLE C-1. IDENTIFYING DUST SOURCES

Dust Conc. in Section Intake	0.6 mg/m^3 (A)
Dust Conc. 20' on Intake of Shearer, Tail-to-Head Cut:	1.5 mg/m^3 (B)
Dust Conc. 20' on Intake of Shearer, Head-to-Tail Cleanup:	2.2 mg/m^3 (C)
Dust Conc. at Midpoint of Shearer, Tail-to-Head Cut:	3.1 mg/m^3 (D)
Dust Conc. at Midpoint of Shearer, Head-to-Tail Cleanup:	11.7 mg/m^3 (E)

Source	Amount (mg/m^3)	Time Fraction of Mining Cycle (%)	Total (mg/m^3)	% of Total
Section Intake	0.6	100	0.6	10
Stage Loader/ Conveyor	0.9 (B-A)	100	0.9	15
Support Movement	0.7 (C-B)	33	0.3	5
Shearer (Cut Pass)	1.6 (D-B)	66	1.1	18
Shearer (Cleanup)	9.5 (E-C)	33	3.2	52
		TOTAL	6.1	

when the shearer is 20 feet from the sampling position and continue as the shearer passes the position until it is 20 feet away on the other side. Dust profiles around the machine are obtained at several fixed locations along the face only while the shearer is operating.

A permissible tape recorder may be used to record data (face location, dust level, shearer locations, etc.) which can be transcribed into hard copy at the end of the shift.

Sampling locations are selected to determine:

- o Dust levels on the upwind side of the shearer: dust monitor is carried at a constant distance (25 feet) on the upwind side of the shearer

- o Dust level at the shearer operator's work location: dust monitor is carried at the midpoint of the shearer, less than 10 feet from the shearer operator

- o Dust level at the location(s) where a control technique is designed to reduce dust: dust monitor is placed at a stationary location and dust recordings are taken as the shearer approaches and passes this location

The following examples (2) will demonstrate the instantaneous sampling strategy:

Example 1 - The mine operator wanted to determine the reason for a significant increase in the 8-hour average respirable dust exposure of the tail-drum shearer operator. The "moving sample" method was used during successive phases of the unidirectional cutting sequence, Figure C-4. Measurements made at 25-foot intervals represent the average of six passes across the longwall face. These measurements indicate that the primary source of the tail-drum operator's exposure is the dust generated by the head-drum when it cuts bottom rock during head-to-tail cleanup. This information allowed control efforts to be concentrated on the dust-generating operation responsible for the operator's exposure.

Example 2 - The objective was to compare two modified water-spray systems installed on the same shearer in a way that they could be operated independently. Based on this comparison, the operator would select one of the systems for use on six operating longwall sections. The "moving sample"

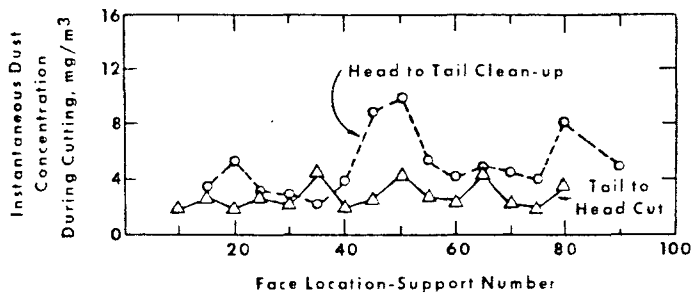

Figure C-4. Dust Profile at Mid-point of Shearer

method was used during successive passes, alternating between the two spray systems, Figure C-5. Measurements made at 25-foot intervals represent the average of 20 passes for each system. Both spray systems control dust generated by the shearer effectively; but system #2 is more effective when the shearer cuts out the wedge at the headgate end of the longwall face.

Example 3 - The objective was to evaluate a newly developed shearer water-spray system. The effectiveness of the new spray system depended on relatively clean intake air approaching the machine. A unidirectional tail-to-head cutting sequence was employed. The "stationary sample" method was used to make measurements in the walkway at three locations along the face as the shearer traversed from 20 feet on the intake air side to 10 feet on the return air side of the sampling position. Results represent the average measurements for four passes across the longwall face, Figure C-6. The solid line, which

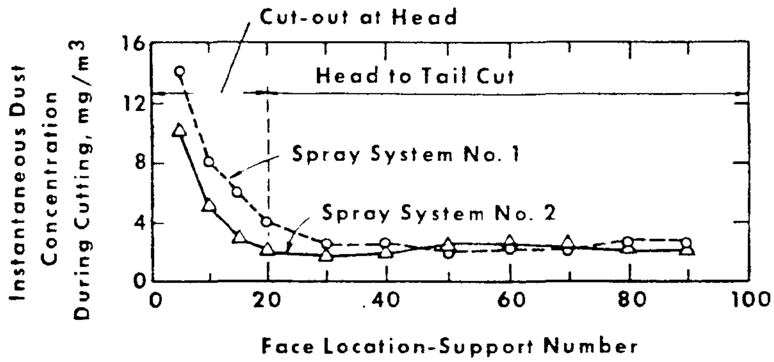

Figure C-5. Dust Profiles Comparing Two Spray Systems

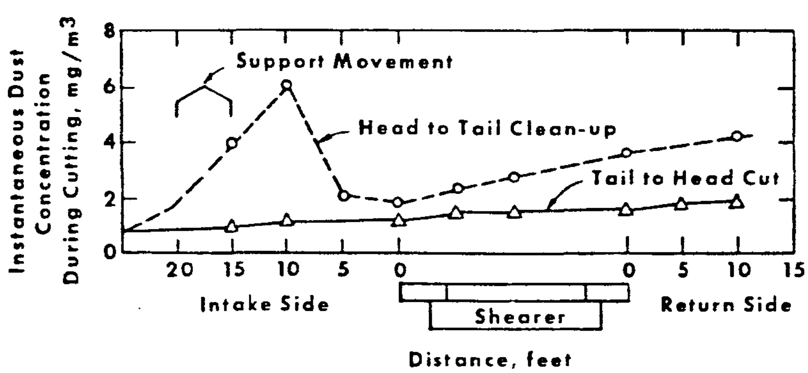

Figure C-6. Average Dust Level Profile Measured in the Walkway represents the dust level measurements for the tail-to-head cut pass, shows that water usage and high ventilation airflow effectively controlled dust generated during this phase of the mining cycle. The dust level measurements for the head-to-tail cleanup pass (dotted line) indicate that the high air velocity (800 to 1,000 fpm) needed to control the large methane emissions entrained substantial amounts of dust on the intake air side of the shearer when the roof supports were being moved. Consequently, efforts were concentrated on controlling support dust, and the shearer spray system was abandoned with considerable savings in hardware cost and with an increase in production.

DUST SOURCE CONTRIBUTIONS FOR SHEARERS IN COMPLIANCE

To aid the operator in interpreting sampling data, the U.S. Bureau of Mines has published (3) typical double-drum shearer dust source contributions obtained from a survey of six longwalls regularly in compliance. Table C-2 presents two quantities for each major dust source: the range of dust concentrations measured and the percentage range of each dust source's contribution. It should be emphasized that the concentrations shown were obtained during actual cutting and cleanup operations, and do not represent full-shift averages and cannot be used for compliance purposes.

TABLE C-2. TYPICAL LONGWALL DOUBLE-DRUM SHEARER DUST SOURCE CONTRIBUTIONS

Dust Source (Airflow Head-to-Tail)	Range of Average Source Contributions During Cutting, mg/m^3	Range, Percent of Total Contribution
Section intake	0.2 - 0.8	9 - 18
Stage loader--conveyor:		
Cutting	0.3 - 0.8	7 - 19
Cleanup	0.1 - 1.0	5 - 20
Support movement	0.0 - 0.3	0 - 7
Shearer:		
Head-to-tail cut	0.1 - 2.0	4 - 45
Tail-to-head cut	0.9 - 2.5	20 - 63
Head-to-tail cleanup	0.2 - 2.5	5 - 54
Tail-to-head cleanup	0.7 - 1.0	16 - 45

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APPENDIX D

MANUFACTURERS AND SUPPLIERS OF NOVEL DUST-CONTROL EQUIPMENT

AIR HELMET

Racal Airstream, Inc.
7309A Grove Road
Frederick, MD 21701
301/695-8200

Whitecap Products
Personal Environment Systems/3M
300 South Lewis Road
Camarillo, CA 93010
805/482-1911

COMPRESSED AIR FOAM SYSTEMS

Diversified Services
P.O. Box 207
Johnson City, TN 37601
615/542-9100

Valerin Technologies
23-A Lemp Road
St. Louis, MO 63122
314/966-8787

INSTANTANEOUS DUST SAMPLERS

GCA/Technology Div., Environmental Instruments
213 Burlington Road
Bedford, MA 01730
617/275-5444

Rotheroe & Mitchell Ltd.
Victoria Road, Ruislip
Middlesex, England HA4 OYL
011-44-1-422 9711

JET SPRAY AIR MOVER (JSAM)

Donaldson Company, Inc.
Box 1299
Minneapolis, MN 55440
612/887-3265

VENTILATED SHEARER DRUM

NCB Mining Research and Development Establishment
Ashby Road, Stanhope Bretby
Burton-on-Trent, Staffs DE15 0QD
England
011/44-283-216161

WATER INFUSION GROUT TUBES

Material for Tube Fabrication

Hughson Chemicals
2010 W. Grandview Blvd.
P.O. Box 1099
Erie, PA 16512
814/868-3611

Prefabricated Tubes

Spiratek Company
P.O. Box 2278
Dearborn, MI 48123
313/278-3400

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