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OPTIMIZING WATER SPRAYS FOR DUST CONTROL ON LONGWALL SHEARER FACES

Contract J0308019

Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02254

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15. Abstract (Limit 200 words) Effective control of respirable dust is one of the most serious problems associated with longwall mining in the United States. The major reason is that face workers work in the airstream downwind of the major dust source--the longwall shearer cutting drum. The major approach to dust control has been the increased use of water sprays for dust suppression. These sprays, however, can make conditions worse by creating turbulence and mixing, which forces the dust cloud into the operator's breathing zone. The air upstream of the shearer is clean. If this flow could be split with one split confining and carrying away the dust cloud and the second split blowing over the operators, their dust exposures would be reduced. This report describes the laboratory development and field evaluation of a system that accomplishes this airstream split. The system combines the use of barriers and water sprays to split the airflow and to confine the dust cloud in the dirty split in the face side of the shearer. The system, known as the shearer clearer, has shown 50% reductions in shearer-generated dust measured at the operators.			
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FOREWORD

This report was prepared by Foster-Miller, Inc., Waltham, MA under United States Bureau of Mines (USBM) Contract No. J0308019, This contract was initiated under the Health and Safety Technology Program. It was administered under the technical direction of Pittsburgh Research Center with Mr. Natesa I. Jayaraman acting as Technical Project Officer. Mr. Joseph A. Gilchrist was the contract officer for the U.S.B.M. This report is a summary of the work recently completed as part of this contract during the period December 1979 to April 1983. This report was submitted by the authors in April, 1983.

The technical effort was performed by the Mining Division of the Engineering Systems Group under the direction of Mr. Terry L. Muldoon, with Mr. Steven K. Ruggieri as Program Manager.

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1. INTRODUCTION

This document is the Final Technical Report for United States Bureau of Mines (USBM) Contract No. J0308019 "Optimizing Water Sprays for Dust Control of Longwall Shearer Faces," summarizing the effort expended and the results obtained. This report presents the details of the laboratory development of a novel water spray/passive barrier system for longwall shearer dust control, the results of four underground evaluations of the system, details of the laboratory development of improvements to the basic system, and details of a laboratory evaluation of the dust knockdown and air moving capabilities of water sprays.

Volume II of the report is a field manual which details the design, fabrication, installation, and operation and maintenance of the new system.

1.1 Background

The control of respirable dust is one of the major problems faced by longwall mining in the United States. On longwall faces it poses a greater problem than in room-and-pillar mining, because the ventilation airstream carries the dust generated by the cutting drum directly over downwind operating personnel.

Longwall operators have taken several approaches to dust control. The primary approaches have included:

- a. Increased ventilation for better dilution
- b. Increased water for better suppression
- c. Changes in mining cycles to minimize the number of personnel working downwind.

While these approaches have minimized the number of personnel working downwind of the shearer and have reduced dust levels, they have not, in most cases been able to reduce shearer operator exposures to compliance levels.

The shearer operators operate the shearer from controls located in the body of the machine. This control position places them downwind of one cutting drum.

Increasing the ventilation does improve dust levels at the shearer operators somewhat, by diluting contamination in the airstream upwind of the shearer. Dust generated by the upwind cutting drum, however, does not thoroughly mix with the airstream before it reaches the shearer operators so that the effect of increased airflow is minimized.

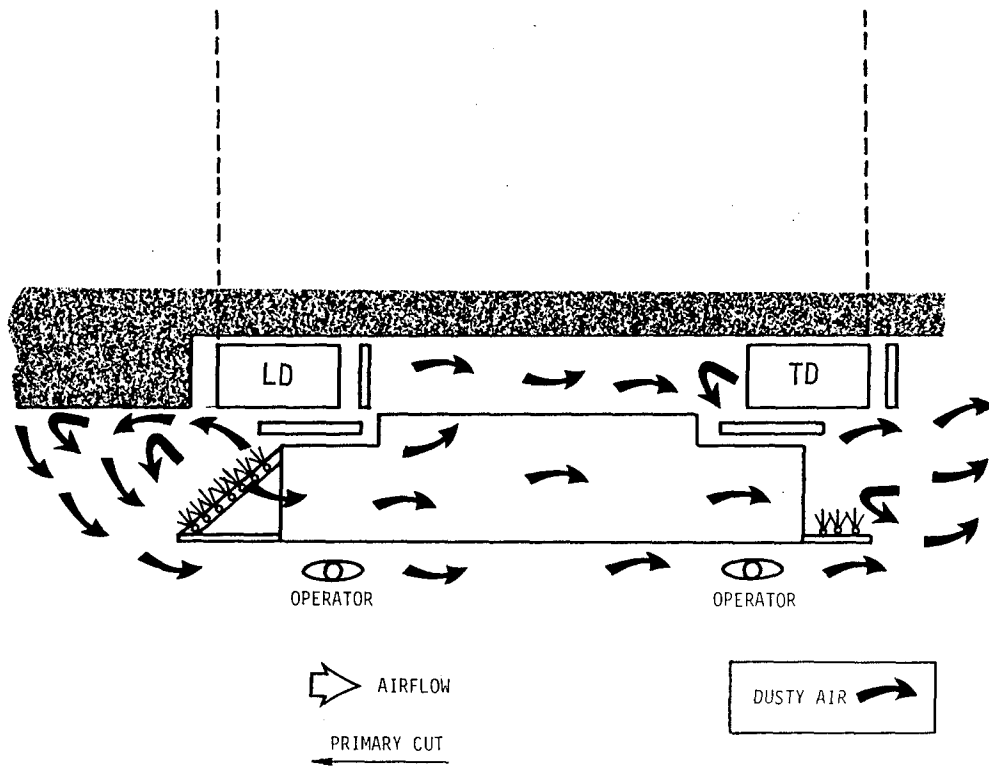
Increasing water for improved suppression has improved conditions when the increased water was released through the cutting drums. Many operators, however, have attempted to further improve suppression by adding additional water sprays mounted on the shearer body. These sprays are generally aimed at the cutting and loading zones of the drum. While these additional sprays may increase suppression, they may also contribute to increased shearer operator dust exposures.

It is well known that water sprays move air like a small fan. Shearer body mounted sprays aimed at the cutting and loading zones of the upwind cutting drum blow dust from that drum upstream where it mixes with the primary airstream. This dust cloud is then carried by the primary airstream over the shearer operators. One such spray system is illustrated in Figure 1a.

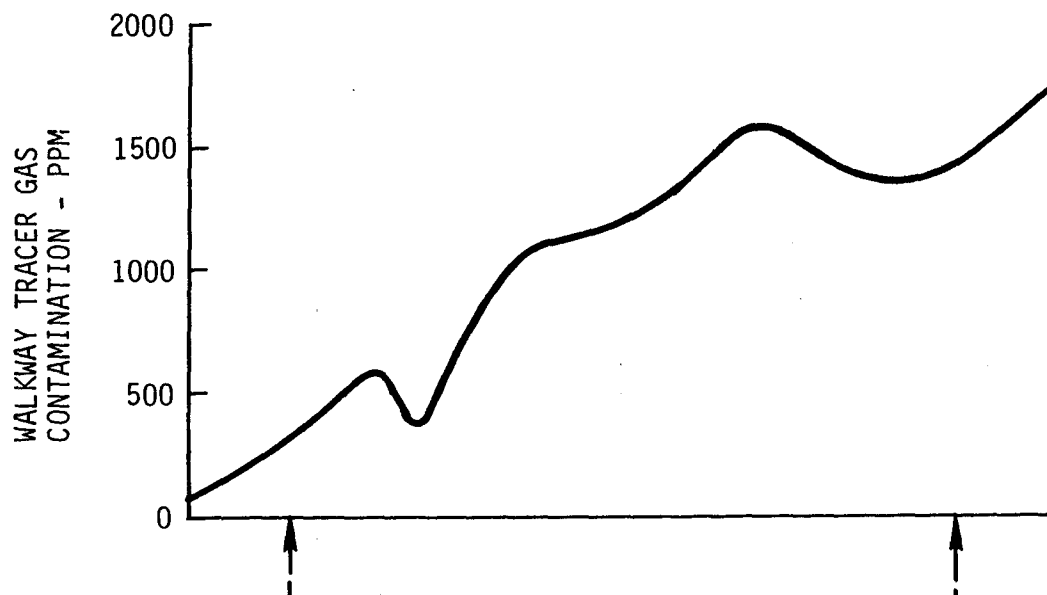
Testing of this spray system in a full scale model of a longwall face, showed the dust cloud being blown as much as 15 ft upstream of the drum when the sprays were operated at 150 psi. The effect of the spray system on walkway contamination levels, measured using tracer gas, is also shown in Figure 1b.

Tests of other spray systems showed similar results. Any sprays mounted on the shearer body, including cooling water discharge sprays, aimed upwind, increase shearer operator dust exposures.

The primary air upstream of the shearer in most U.S. longwall faces is usually relatively clean before it is contaminated by dust from the cutting drum. If this airflow can be split and the dust cloud confined to the face side of the shearer, the operators can be supplied with a split of clean air. Such a system, nicknamed the Shearer Clearer, was developed in this program.



a. CONVENTIONAL WATER SPRAYS PUSH DUST UPSTREAM



b. WALKWAY CONTAMINATION LEVELS WITH CONVENTIONAL SYSTEM

FIGURE 1. - The effect of dust suppression sprays aimed upwind.

1.2 Shearer Clearer Dust Avoidance System

The shearer clearer system uses a conveyor belt barrier extending upwind from the shearer body combined with strategically placed water sprays. The system confines the dust cloud from the upwind drum and pushes it to the face side of the shearer, as shown in Figure 2a. The effect of the spray system on walkway contamination levels is shown in Figure 2b. Levels at the two shearer operator positions are reduced 95 percent from those measured with the dust suppression system shown in Figure 1.

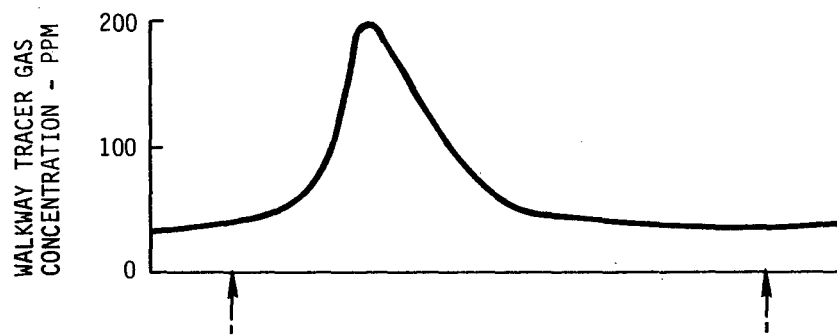
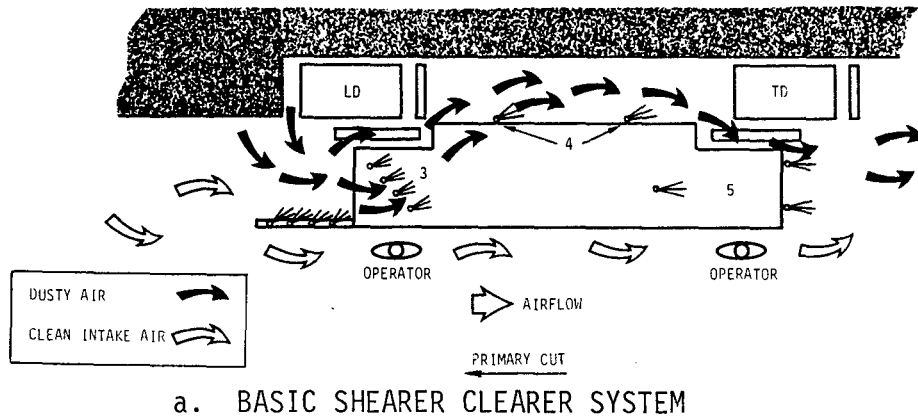
This spray system was then installed and tested on four longwall faces. The system reduced shearer operator exposures from shearer-generated dust by at least 50 percent when the shearer was cutting against ventilation. Reductions of at least 30 percent were measured with the shearer cutting with ventilation.

The system, as shown in Figure 2a, had several sprays mounted on the shearer body using hydraulic hose to elevate the spray nozzles above the shearer body. On many faces, however, these sprays were difficult to maintain because of low clearance between the shearer and roof supports. An improved shearer clearer system was developed to address these problems.

The improved system, shown in Figure 2c, uses the same barrier and sprays on the upwind end of the shearer. All shearer body mounted sprays, however, are now located in two banks on the face side of the shearer. The improved system, while maintaining low contamination in the walkway, is more practical than the original system and shows much lower contamination in the walkway up to 40 ft downstream of the shearer.

Details of the development of the basic shearer clearer system are presented in Section 2 of this report. The results of the underground evaluations are presented in Section 3. The development of the improved system is described in Section 4. Section 5 presents the results of a basic evaluation of the air moving and dust knockdown capability of water sprays.

Details of the installation, operation, and maintenance of the improved shearer clearer system are presented in a companion document - Volume II.



b. WALKWAY CONTAMINATION LEVELS WITH IMPROVED SHEARER CLEARER

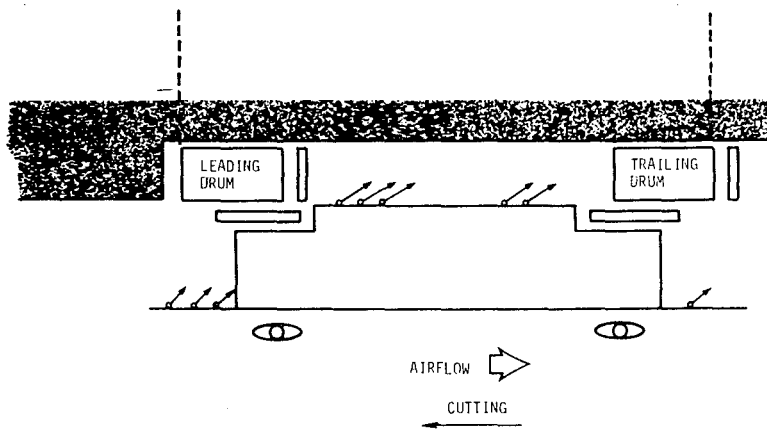


FIGURE 2. - Basic and improved shearer clearer systems.

2. LABORATORY DEVELOPMENT OF THE SHEARER CLEARER WATER SPRAY SYSTEM

2.1 Introduction

Observations on several double-drum shearer faces with the *machine cutting against the primary airflow* showed that:

- a. The cutting and loading action of the lead drum creates a plume of dust that extends upwind of the leading edge of the drum.
- b. Drum sprays, particularly sprays on the gob side of the drum, tend to push this plume farther upstream when the sprays clear the edge of the coal face.
- c. Conventional water spray systems, most of which are aimed at the cutting zone, tend to push the plume as far as 10 to 12 ft upwind of the leading edge of the drum, especially when the sprays are pointed upwind.

This plume of dust tends to spread and mix with the primary ventilation air, contaminating the walkway with dust from the leading drum and engulfing the shearer operators.

The primary airstream on most faces is relatively clean before it is contaminated with the dust generated by the leading drum. It was theorized, therefore, that if the primary ventilation air could be split immediately upstream of the shearer into two streams - a *dusty split* held close to the face, and a *clean split* uncontaminated by the lead drum ventilating the walkway, then shearer operator dust exposures could be significantly reduced.

Testing of this approach was conducted in a full scale longwall test facility. The initial objective of the testing was to identify factors that tend to inhibit airflow splitting and if possible to remove or modify them. Two factors were found to have an important effect:

- a. *Sources of turbulence*, including shearer body-mounted water sprays pointed at the drum for dust suppression, the pumping action of the leading drum and water sprays in the leading drum.

- b. *Physical obstructions* that cause the air to change direction and velocity, particularly the flat surfaces at the end of the shearer body and the tail drum.

Both of these factors cause dirty air from the upwind drum to spread quickly into the walkway engulfing the shearer operators. Based on these observations, it was assumed that if the dust generated by the lead drum could be contained and maintained on the face side of the shearer, the walkway and the two operators could be supplied with relatively clean air.

The following subsections describe the longwall test facility and the development of a novel spray system to accomplish the airstream split approach.

2.2 Longwall Test Facility

Laboratory testing of the improved shearer water spray system was conducted in a full scale model of a longwall face originally constructed under USBM Contract J0387222 and modified under the subject USBM Contract J0308019. The test facility consists of the following major elements:

- a. A simulated longwall face mining 7 ft coal
- b. A model double-ended ranging drum shearer with 63 in. diameter drums
- c. A face ventilation system capable of up to 650 ft/min face velocity (30,000 ft³/min airflow)
- d. A water system permitting simulation of cutting zone flushing drum sprays, shearer cooling water sprays, and shearer mounted dust control sprays
- e. Tracer gas and smoke to simulate respirable dust.

The gallery permitted testing over a wide range of ventilation rates and operating conditions.

The following subsections discuss the gallery design and testing methods in more detail.

2.2.1 Gallery Design and Construction

The gallery, which is constructed from lumber and plywood with plexiglass windows, is 175 ft long and simulates a 7-ft high coal face using Kloeckner 352-ton twin-leg shields. The simulated coal face represents typical cutting conditions at the middle of a shearer pass, with the drums fully sumped in modeling the majority of the shearer cutting cycle.

2.2.2 Longwall Shearer Model

The model shearer is a double drum Eickhoff EDW-300-L. At the time of gallery construction this was the most popular shearer in United States mines. The mockup includes drums which rotate to simulate the effect of rotation on air and dust behavior. The helical vane cutting drums have a helix angle of 20 deg at the top of the vane. Drum width is 31.5 in. (0.8m), drum diameter is 63 in. (1.6m). Each ranging arm is fitted with a loading cowl of single arm construction with a blade radius of 35.5 in. (900 mm) and an overall thickness of 5 in. For the height of seam simulated, the lead drum (the one in the raised position) takes 70 percent of the web and the trailing drum the remainder.

The cutting drums were mounted on a 2 in. shaft supported in either end on bearings. The shafts extend through the gallery wall and are belt-driven by an electric motor mounted on the gallery roof. The system was designed to vary drum speed from 30 to 50 rpm. The cutting drums rotate in opposite directions, with the leading drum cutting from roof to floor and the trailing drum floor to roof.

2.2.3 Primary Ventilation

The gallery is ventilated by a vaneaxial fan with flow capacity up to 30,000 ft³/min (14.2 m³/s). This range of performance gives an achievable face velocity of 620 ft/min (3.15 m/s) well in excess of that generally found on a 7-ft face. Airflow was adjusted with a choke just upstream of the fan. To *simulate the shearer cutting both with and against the primary airflow*, the ventilating fan was moved from one end of the gallery to the other.

2.2.4 Water System

Water is supplied to the shearer through three separate lines. They supply the drum sprays, the cooling water sprays, and the sprays mounted on the shearer body. Each line is fitted with a flowmeter and a pressure gauge. Water is collected from a sump in the gallery and recirculated to a 330-gal (1250-liter) holding tank.

The drum sprays are fed through a rotary union. Twelve sprays are located on the vane of each shearer drum, equispaced on the helix and fed through a high pressure hose. For most of the testing each drum employed twelve 90 deg flat fan spray nozzles which passed 1/2 gal/min each at pressures of 100 psi.

The cooling water and shearer body mounted spray system was designed to facilitate different nozzle configurations. The supply line entered a manifold which accepted a variety of spray nozzles at different angles and positions. The standard Eickhoff spray system consisted of four banks of sprays, two at each end of the machine. Each bank included three 90 deg flat fan nozzles which pass 3/4 gal/min each at 100 psi. This arrangement was duplicated on the mockup shearer. The conventional nozzle banks, located on each gearhead module, are pointed toward the drums and spray over the ranging arm to wet material within the cutting and loading zones. Movable manifolds were used to facilitate the development of the novel shearer clearer system.

2.2.5 Tracer Gas for Dust Simulation

The gallery is designed to model the dispersion of respirable dust using tracer gas. Natural gas (99 percent CH₄) was chosen as the tracer gas for the following reasons:

- a. It can be piped directly into the gallery in controlled volumes.
- b. It is easily and rapidly monitored by a number of standard instruments.

The gas was released in the gallery through manifolds designed to simulate the cutting and loading zones at the two drums. Four release manifolds were used including:

- a. Lead drum - At the top section of the raised buttock, where the drum is cutting the face
- b. Lead drum - At the base of the raised buttock where the coal is loaded off the shelf onto the conveyor
- c. Trailing drum - At the buttock where the drum is cutting the coal shelf left by the lead drum
- d. Trailing drum ranging arm - At the point where coal is thrown over the ranging arm as it is loaded onto the face conveyor.

The gas release rate at each manifold can be independently controlled. When all four manifolds were operated, to simulate the total dust produced by the shearer, the flows were proportioned between the two drums: 70 percent being released from the leading drum, and 30 percent from the trailing drum. These proportions match the ratios of the coal cut by each drum.

2.2.6 Smoke Generation

To aid visualization of both the distribution of dust and the primary airflow patterns, a smoke generator was added to the gallery. This consisted of a canister in which smoke bombs could be safely ignited, and valved ducting to inject smoke into the gallery at desired points. Smoke was sometimes liberated from the tracer gas manifolds, making the dispersion of "dust" visible. Alternatively, smoke could be injected into the entering airstream to observe airflow around the shearer body. This technique was frequently used for preliminary evaluation of a water spray system before large numbers of gas samples were taken.

2.2.7 Flow Measurements

Airflow through the gallery was determined using turbine anemometer traverses, and confirmed with pitot tube measurements downstream of the fan. Water flows to the sprays and drums were monitored using a spring-loaded variable orifice flowmeter. Total methane flow was measured with a 60-ft³/min (28 liter/sec) Brooks rotameter. Flow then divided through 30 ft³/min rotameters to each gas release manifold. Rotameter measurement accuracy is ± 5 percent and repeatable.

2.2.8 Tracer Gas Measurements

Tracer gas concentrations were measured at several locations in the gallery using a Horiba gas analyzer. The instrument was calibrated regularly using a standard calibration mixture. Gas sample locations were selected with a valved manifold. The manifold also provided a fresh air sample from outdoors. After each sample, the instrument was flushed with fresh air, giving a zero check. Gas concentration readings fluctuated due to the airflow patterns within the gallery. To minimize the effect of those fluctuations on the data quality, a number of readings were taken and averaged. Sampling points within the gallery normally included the face ventilation duct and the tail and lead drum operators' positions. Additional points were sampled as needed.

2.3 Baseline Testing of Conventional Water Spray Systems

The initial objective of the laboratory testing was to identify factors that tend to inhibit splitting, and if possible, to remove or modify them. Two factors were found to have an important effect:

- a. *Physical obstructions* which cause the air to change direction and velocity
- b. *Sources of turbulence.*

The primary ventilation travels down the face through a cross section formed by the roof supports, the coal face, and the floor. When the air reaches the shearer, this cross section is suddenly reduced by the shearer body which can occupy up to one half of the available area. This reduction causes the air to change direction and to increase in velocity to travel over and around the shearer body. Dust created by the leading drum upwind of the shearer body is carried by the primary ventilation out into the walkway over the shearer operators as it changes direction to flow around the shearer.

Sources of turbulence also cause the dust from the leading drum to spread quickly throughout the airway. These sources of turbulence include:

- a. The pumping action of the drum
- b. Water sprays in the drum
- c. Body-mounted cooling water sprays
- d. Conventional shearer mounted dust suppression sprays.

2.3.1 Effects of Drum Sprays

The shearer drum is equipped with helical vanes which push the coal outward from the face onto the face conveyor. The volume within these vanes is normally two-thirds filled with broken coal. The remaining one-third of the vane volume is filled with extremely dusty air. As the drum rotates, the air is pumped out of the gob side of the drum into the ventilating airstream.

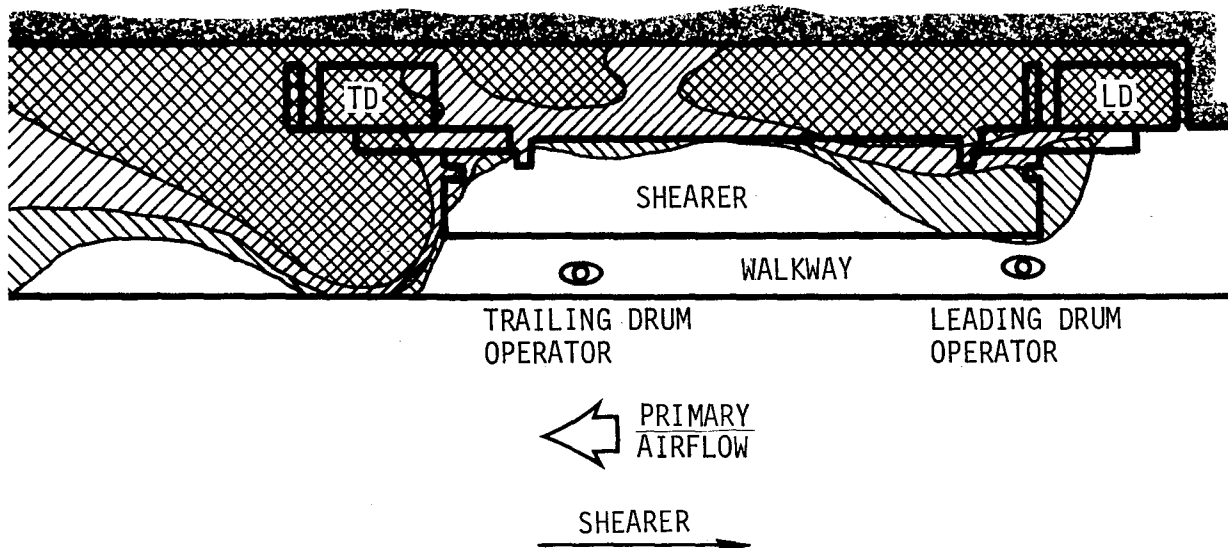
Most shearer drums are equipped with water sprays for dust suppression. The drums on an Eickhoff EDW-300-L, for example, are equipped with 90 deg flat fan cutting zone flushing sprays. These drum sprays, while extremely effective, do not suppress 100 percent of the generated dust. The remaining dust is pumped outward by the drum vanes. This dust can also be pushed upwind by the drum sprays, particularly if the sprays on the gob side of the drum clear the coal face. The effectiveness of drum sprays in preventing and suppressing dust, however, has led to their universal use on United States longwall faces. The shearer, equipped with the Eickhoff factory supplied drum sprays, therefore, was tested as one basic spray configuration.

Test results for the shearer equipped with only drum sprays is illustrated in Figure 3a. The results are in the form of a *tracer gas concentration map* generated by releasing tracer gas at the cutting drums and measuring concentrations through sampling probes located in the roof of the gallery. Gas released from the leading drum is pumped by the drum outward over the leading end of the shearer towards the lead drum operator. Gas concentrations measured using probes located at shearer operator positions showed 185 ppm at the lead operator's and 250 ppm at the trailing drum operator's positions.

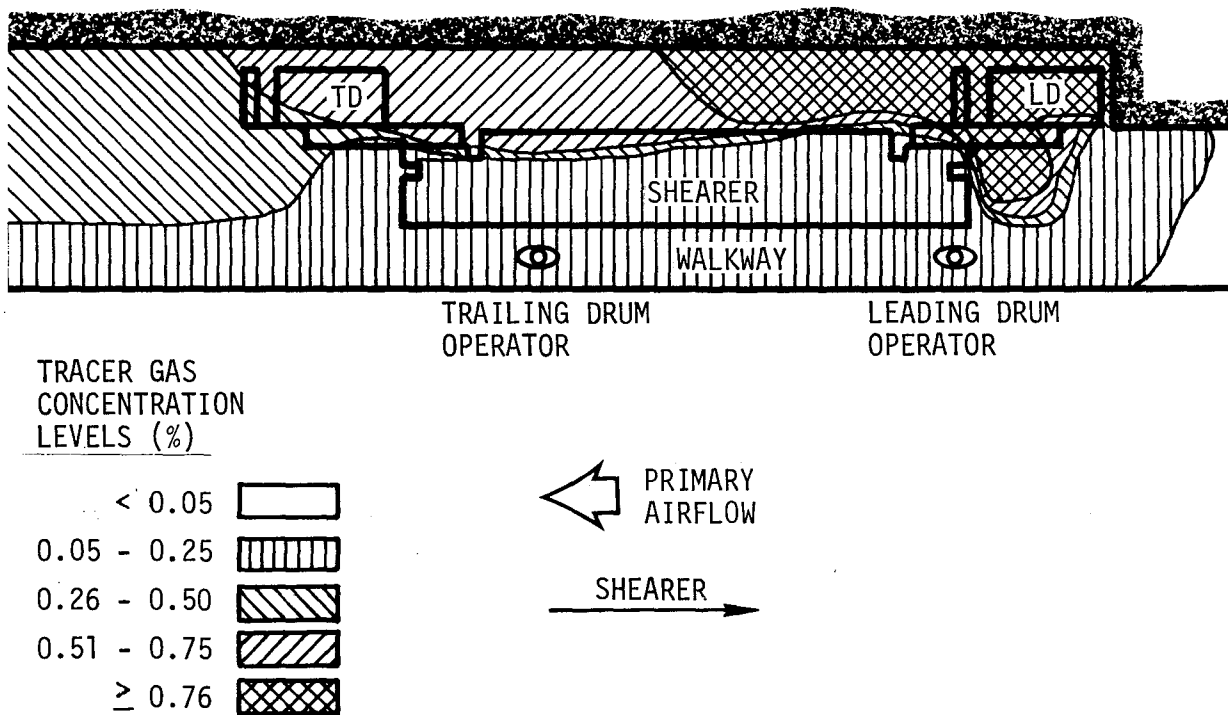
Additional testing was also conducted with drum sprays on the gob side of the drum clearing the face. These sprays force the dust cloud upwind of the drum causing increased mixing with the primary ventilation. Under these conditions, levels went up to 450 ppm at the lead drum operator's position.

2.3.2 Effects of Cooling Water Sprays

Longwall shearers are powered by water cooled electric motors. This water, after passing through the cooling jackets, is normally dumped on the face through spray nozzles. The Eickhoff EDW-300-L, for example, is equipped with two banks containing three



a) SHEARER WITH ONLY DRUM SPRAYS OPERATING



b) SHEARER WITH DRUM SPRAYS AND COOLING WATER SPRAYS OPERATING

FIGURE 3. - Tracer gas maps showing the effects of drum sprays and cooling water sprays on shearer generated dust.

90 deg flat fan spray nozzles on each gearhead. The location and orientation of these sprays is shown in Figure 4. The sprays are pointed toward the cutting drum and spray over the ranging arm to wet material within the cutting and loading zones. The negative impact of these upwind pointing sprays is illustrated in Figure 3b. Comparing map 3a and map 3b shows that the cooling water sprays push contaminant from the leading drum outward towards the walkway and upwind from the drum where it mixes with the primary air. The effect of these sprays is to significantly increase contamination in the walkway airstream.

2.3.3 Effects of Conventional Shearer-Mounted Dust Suppression Sprays

Most United States longwall operators have attempted to control respirable dust on their faces by suppression using water sprays. These sprays are mounted on or suspended from the shearer body or ranging arm. These spray systems generally have one thing in common. The sprays are aimed at the cutting and loading zones of the drums to wet the coal and to knock down airborne dust. Because the leading drum is located upwind of the shearer body, most of these *sprays are aimed upwind* or against the direction of primary ventilation.

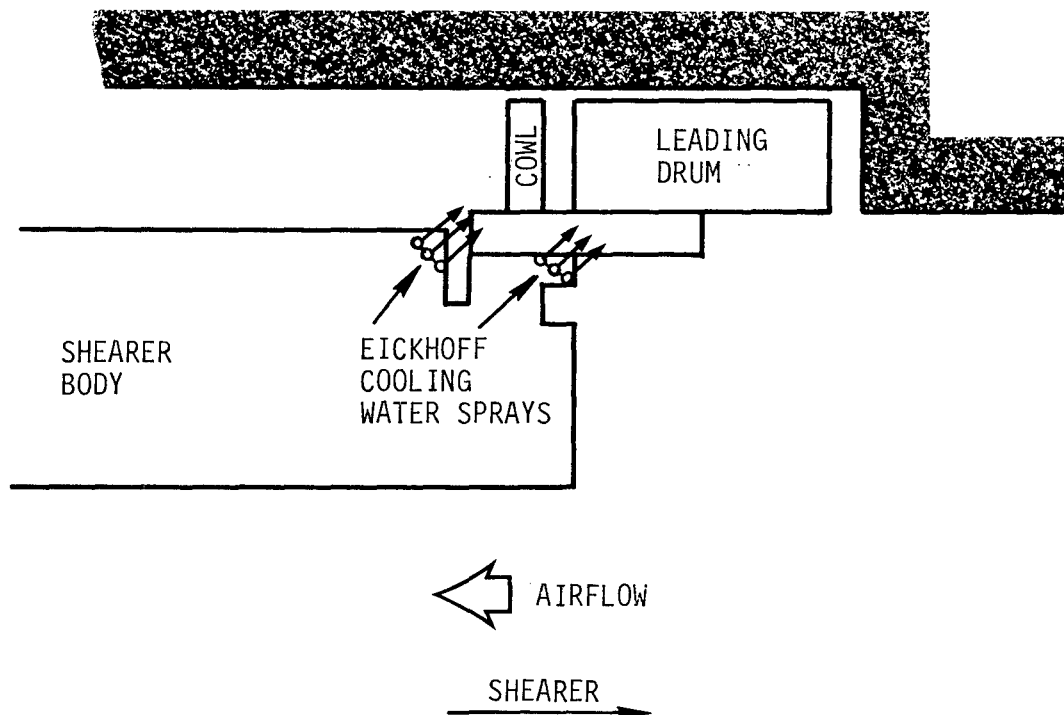


FIGURE 4. - Location and orientation of standard cooling water sprays on the Eickhoff EDW-300-L shearer.

Underground observation on several faces showed a dust cloud or plume appearing to move upwind from the leading drum on shearers cutting into ventilation. This cloud was seen as far as 20 ft upstream of the leading edge of the drum. It was suspected that this cloud was created by the dust suppression sprays along with other sources of turbulence (for example, airflow obstruction of the shearer body).

One system observed in operation underground was modeled in the longwall test facility. The system, shown in Figure 5, consisted of:

- a. Twelve (12) Spraying Systems Co. BD3 spray nozzles mounted on a 42-in. frame suspended from the leading end of the shearer. The sprays were mounted diagonally from the end of the frame to the bottom of the shearer body.
- b. Three (3) Spraying Systems Co. BD3 spray nozzles mounted on a frame suspended from the trailing end of the shearer.

The turbulent effects of these sprays on the airflow patterns are illustrated graphically in Figure 5. The sprays tended to push contaminant from the leading drum upwind as far as 10 to 12 ft. Figure 6 shows the interior of the longwall test gallery with smoke being released at the lead drum during tests with the system operating at 100 psi and a primary air velocity of 300 ft/min towards the shearer. The smoke cloud is pushed upwind of the lead drum where it mixes and spreads into the walkway over the shearer operator.

The tracer gas map produced with this system operating is shown in Figure 7. The sprays aimed at the leading drum push the gas several feet upstream from the drum. The resulting mixing and spreading causes high concentrations in the walkway along the entire length of the shearer. Concentrations at the leading and trailing drum operators were 1250 ppm and 780 ppm, respectively. These levels are several times higher than those measured for the shearer operating with drum sprays only.

The negative effects of the three sprays on the trailing end of the shearer are also clear. Extremely high concentrations are pushed from the trailing drum into the walkway adjacent to the drum. While this does not affect the trailing drum operator at his normal control position, it would expose him to high levels from the trailing drum if operating conditions forced him to move just a few feet downwind. Likewise, jacksetters closely following the shearer would be exposed to higher dust levels.

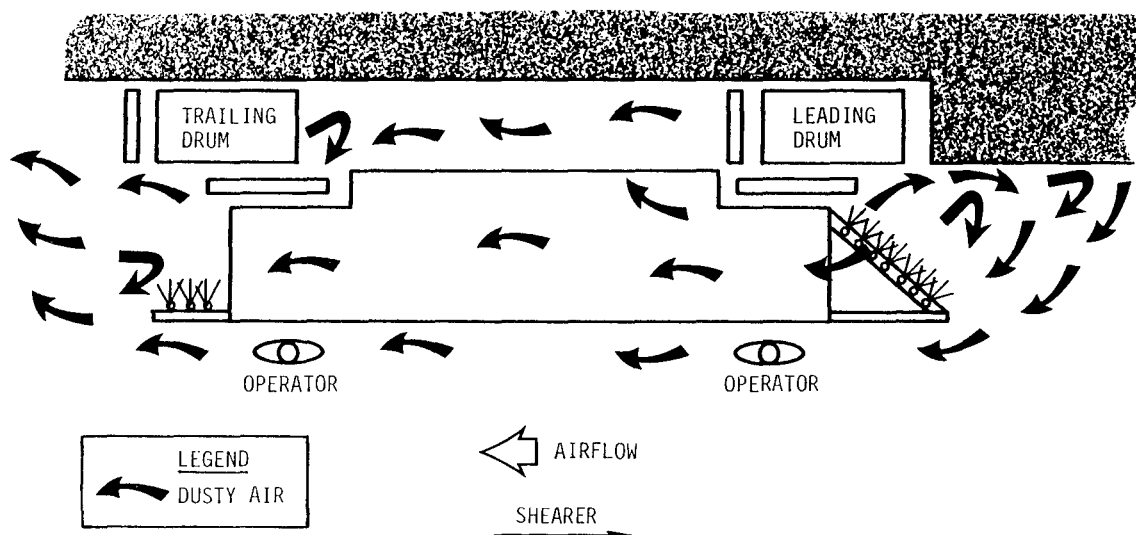


FIGURE 5. - Illustration of dust plume being pushed upstream by a conventional water spray system.

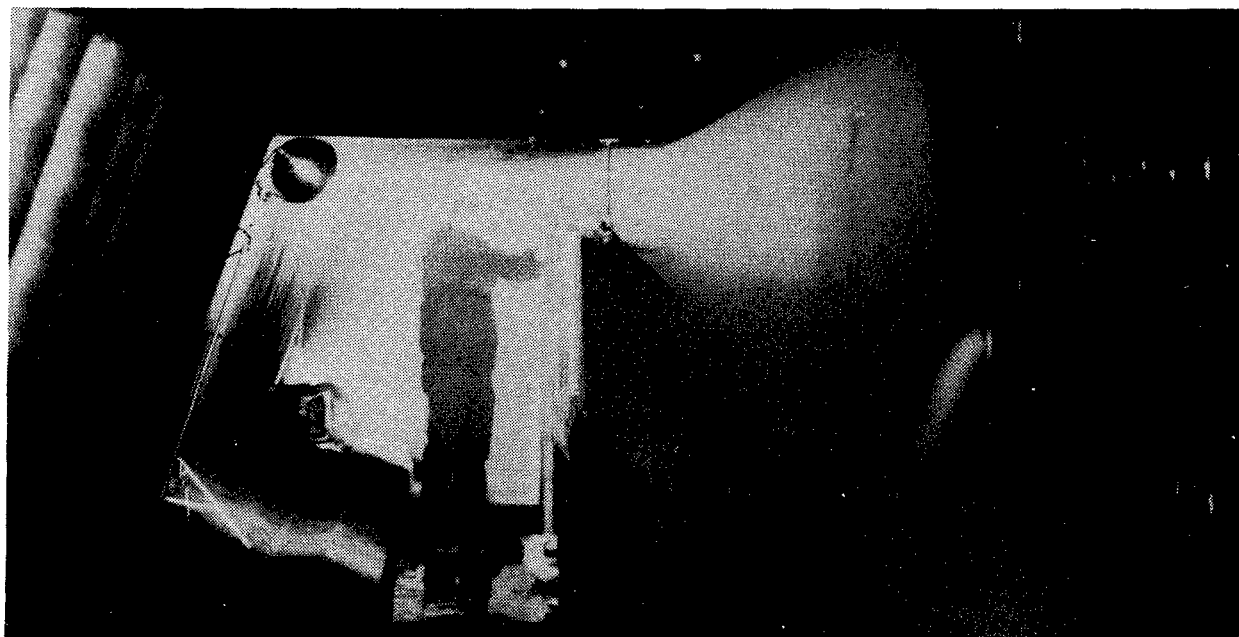


FIGURE 6. - Foster-Miller longwall test gallery with smoke released at the lead drum during a test of conventional water sprays.

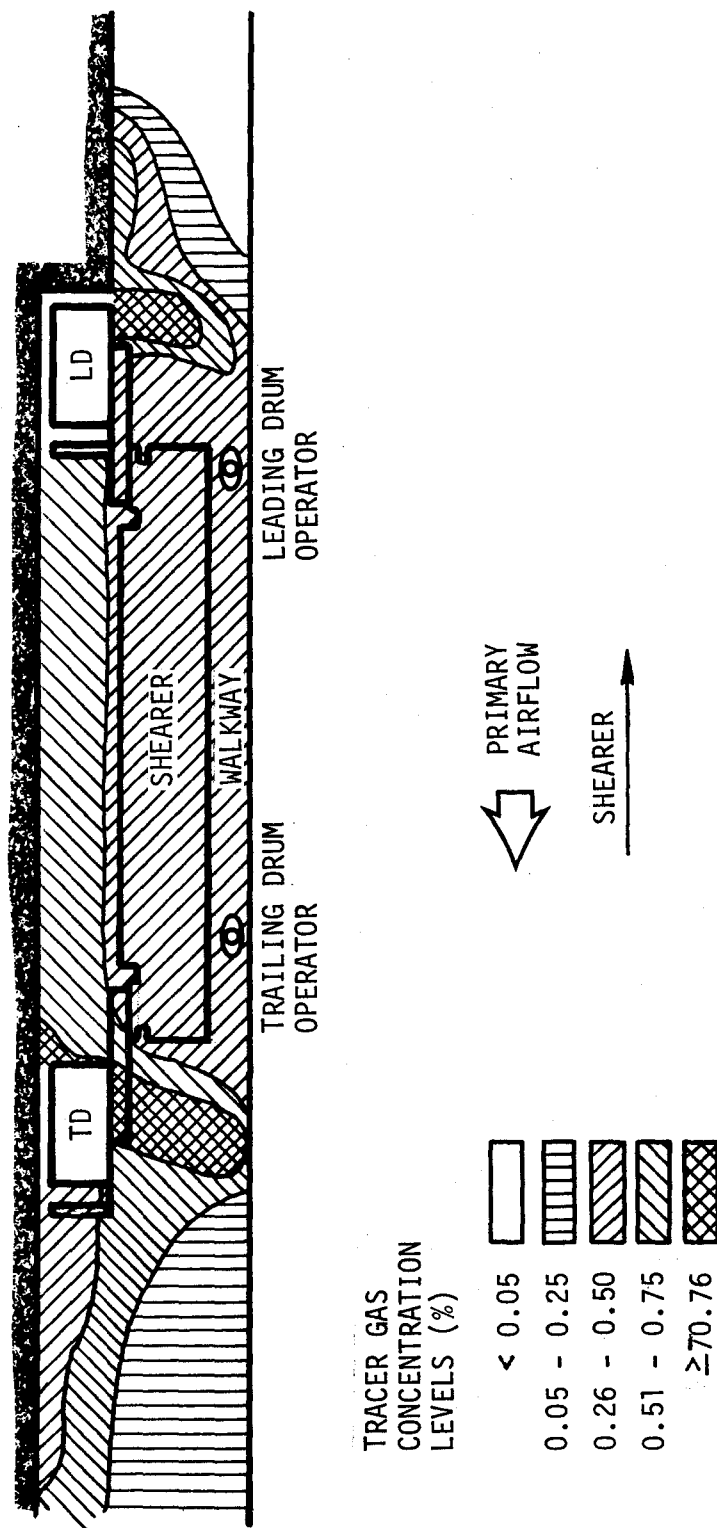


FIGURE 7. - Tracer gas map showing the effect of a conventional dust suppression spray system on shearer-generated dust.

The use of an arm extending from the end of the shearer to locate sprays nearer the cutting and loading zone of the drum was fairly common practice on longwall panels. In addition, several mines suspended conveyor belting from this arm to the panline to help confine the dust cloud over the panline. The effect of this added barrier is shown in Figure 8. The added barrier does prevent some mixing and spreading, however, the length of the barrier (42 in. from the end of the shearer) is not enough to prevent the contamination pushed upwind by the sprays from going around the end of the barrier into the walkway.

2.3.4 Summary of Baseline Testing

The objective of the baseline testing was to identify factors that tend to inhibit airflow splitting and cause dusty air to spread into the walkway. Tracer gas testing and smoke observations clearly showed:

- a. The decrease in cross-sectional area caused by the obstruction of the shearer body, forces the primary airstream to *accelerate and change direction*.
- b. The pumping action of the cutting drum vanes combined with the turbulence created by the drum sprays *pushes dust* across the shearer towards the shearer operators. The effect of the drum sprays is magnified if the sprays on the gob side of the drum clear the coal face.
- c. Conventional cooling water sprays mounted on the shearer aimed at the cutting drum or face *push dust upwind* where it mixes with the primary air and spreads into the walkway.
- d. Conventional dust suppression sprays (mounted on the shearer or on arms extending from the shearer) pointed upwind toward the drum cutting zone *creates a severe upwind plume* of dust which causes significant contamination of the walkway.

The impact of these factors on operator exposure levels measured using tracer gas is summarized in Table 1.

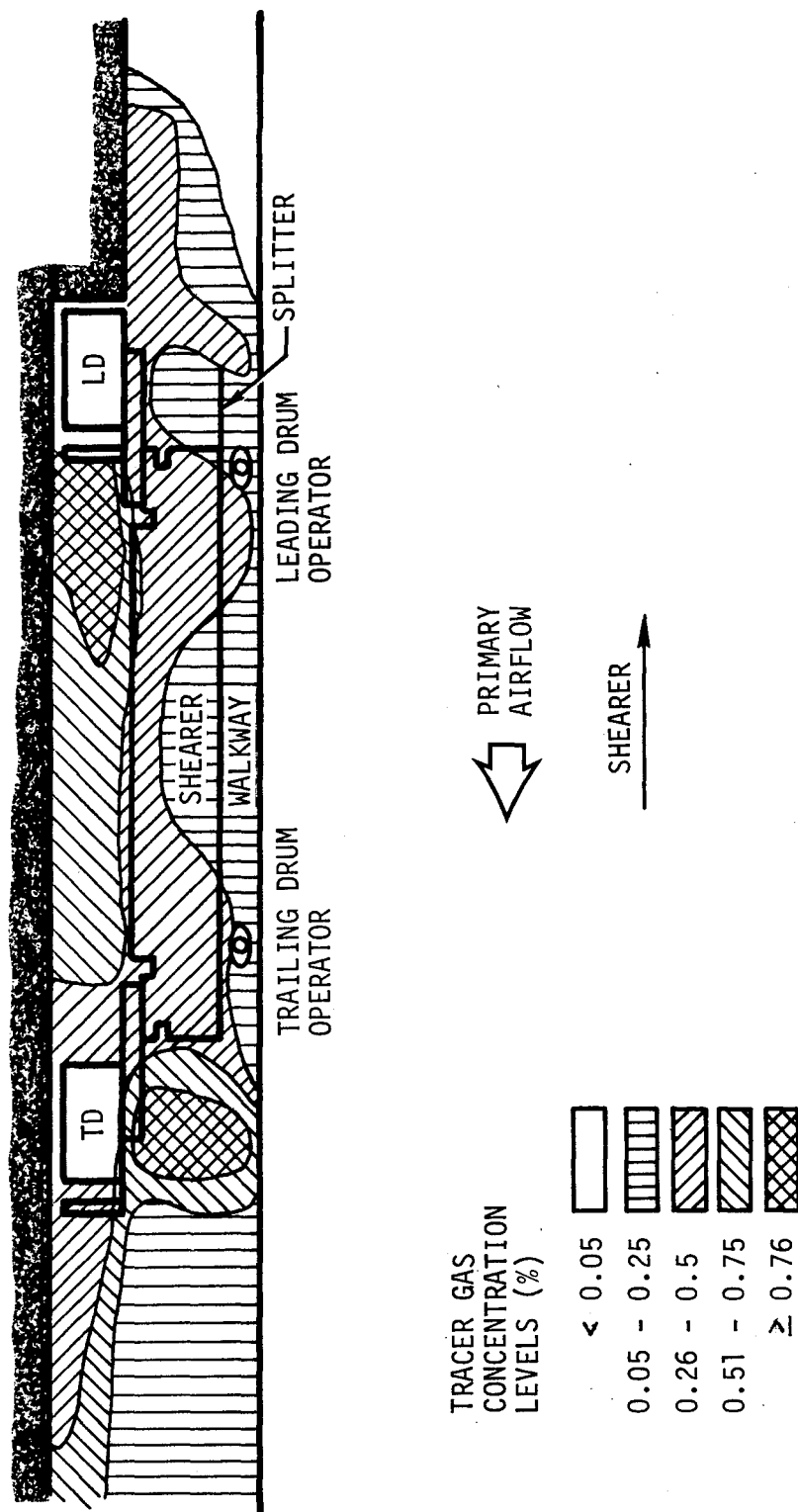


FIGURE 8. - Tracer gas map showing the effect of the conventional spray system with a barrier (splitter) suspended from the spray support frame.

TABLE 1. - Results of testing in the longwall facility
(shearer cutting counter to airflow), ppm

	Leading drum operator concentration	Trailing drum operator concentration
Drum sprays	185	250
Drum sprays with gob side clearing the face	450	Not measured
Conventional sprays	1,250	780

Based on these observations, it was assumed that if the dust generated by the lead drum could be *contained and maintained on the face side of the shearer*, the walkway and the two operators could be supplied with relatively clean intake air. The next step, therefore, was to devise a system to enhance airflow splitting.

2.4 Laboratory Development of the Shearer Clearer for Cutting Against Ventilation

The primary air on a longwall face is relatively clean before it is contaminated by dust generated by the shearer. It was assumed that if this air could be split into two streams - a *clean split* and a *dirty split* - the operators could be supplied with relatively clean air. This would require confining and maintaining the dust generated by the lead drum on the face side of the shearer as illustrated in Figure 9.

The baseline testing indicated that two major factors inhibit splitting:

- a. Sources of turbulence
- b. Physical obstructions that cause the air to change velocity and direction.

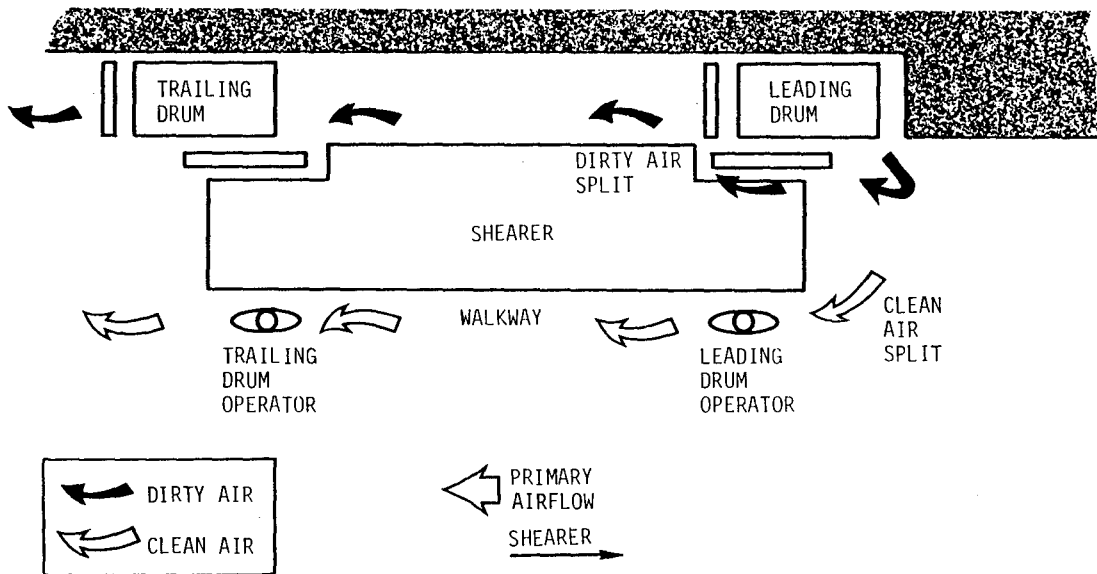


FIGURE 9. - Airstream split approach for longwall shearer dust control.

The major sources of turbulence were found to be both cooling water and dust suppression sprays aimed upwind toward the leading drum. *Removal or reorientation of these sprays* should significantly reduce the extent of the upwind pluming of the dust cloud and subsequent mixing with the primary air. The pumping action of the drum vanes and the turbulence created by the drum water sprays also contributed significantly to walkway contamination. These sources, however, cannot be eliminated and successful airflow splitting would require confining and minimizing their effect on walkway air quality.

The major physical object blocking the primary airflow and causing the flow to change velocity and direction is the shearer itself as shown in Figure 10. The airflow upstream of the shearer is somewhat split by the cable tray. As these two streams reach the shearer, the airflow on the face side of the cable tray

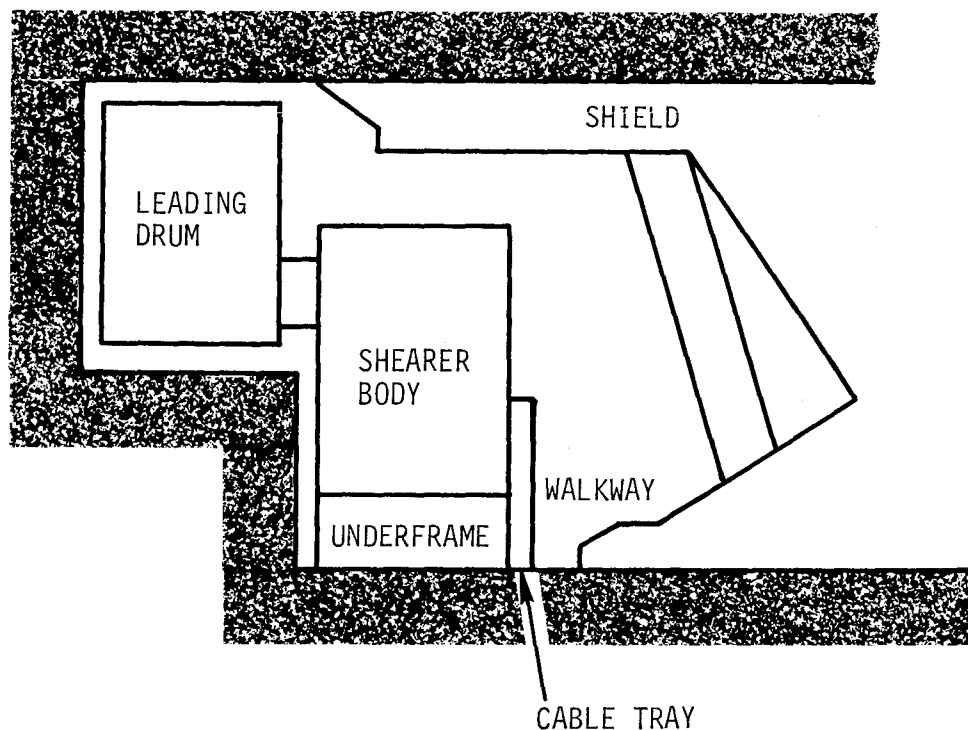


FIGURE 10. - Cross section of a longwall shearer face.

becomes contaminated by dust from the leading drum. This portion of the flow path is blocked by the shearer body. As a result the air must accelerate and change direction to go over and around the shearer. The area between the top of the shearer and the underside of the roof supports, however, is small compared to the area on the walkway side of the cable tray. As a result, dirty air from the face side of the cable tray mixes with and contaminates the walkway air. To minimize mixing would require *forcing the majority of the contaminated air stream through the opening over the shearer.*

If we assume an average face air velocity of 300 ft/min and a shearer body cross-sectional area of 10 ft², then approximately 3000 cfm of additional air must be forced to accelerate over the shearer body through the area between the shearer and roof supports.

Using this information as a base, testing was initiated to develop a system to split the airstream, to confine the dust cloud on the face side of the cable tray and to force the contaminated air over the top of the shearer.

2.4.1 Initial Development of the Upwind Splitter and Water Spray System

Testing was initiated using smoke to visualize the distribution of contaminant from the leading drum. The 42-in. long frame with the conveyor belt barrier tested and the conventional spray system was used to start the airflow split upstream of the shearer. (Throughout the rest of this report this frame and barrier will be called the splitter.)

Spray nozzles were mounted on the top of the splitter arm aimed at the opening between the top of the shearer and the roof supports in the *direction of the primary ventilation*. The purpose of these sprays was to help confine the dust plume from the leading drum and to enhance the splitting action. A second bank of spray nozzles (crossover sprays) was mounted on top of the shearer to accelerate the airflow between the shearer body and roof supports. The sprays were aimed downwind and toward the open area between the shearer body and face cut by the lead drum.

Several combinations of splitter arm and shearer mounted sprays were tested using smoke traces to get a feel for system performance in terms of *modifying the airflow pattern* over the shearer. The most effective system is illustrated in Figure 11. The system consisted of two Spraying Systems Co. BD20-2 nozzles mounted on the top of the splitter and aimed at the opening between the shearer body and roof supports. Five BD20-2 sprays were mounted on top of the shearer body on a line roughly between the operator's position and the lead drum cowl. The sprays were aimed downwind and towards the open area between the cut face and the shearer body. These sprays were elevated above the shearer body using hydraulic hose as shown in Figure 12. This was done to allow the nozzle to produce a full cone without impacting the top of the shearer and to minimize possible nozzle blockage if the system was to be installed underground.

The effectiveness of the system in controlling contamination from the leading drum was then tested using tracer gas. During testing the drum sprays were operated at 100 psi, and the new system spray pressure was varied from 40 to 200 psi. Primary air velocities were held constant at approximately 300 fpm.

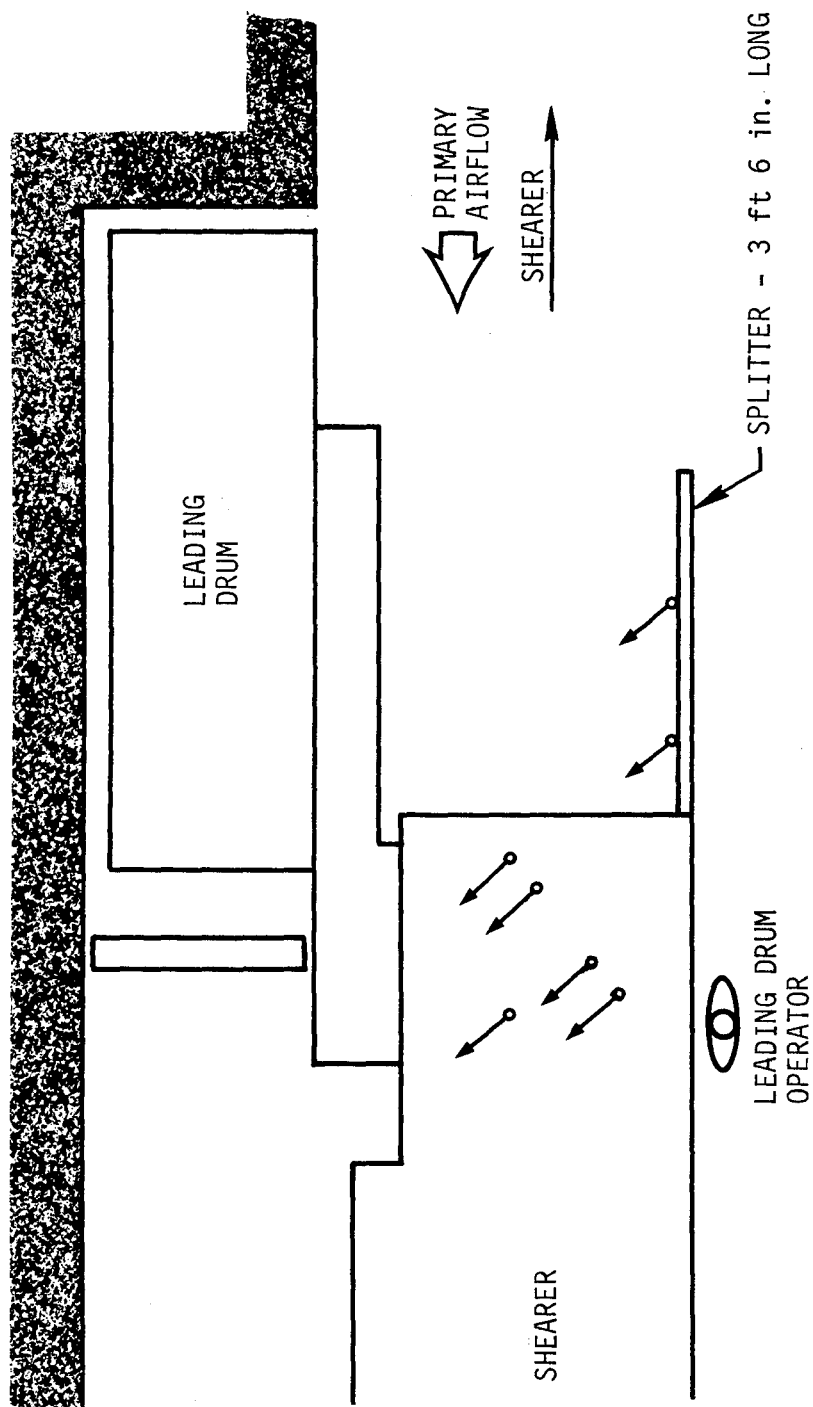


FIGURE 11. - Spray configuration and splitter arm to control dust from the leading drum.

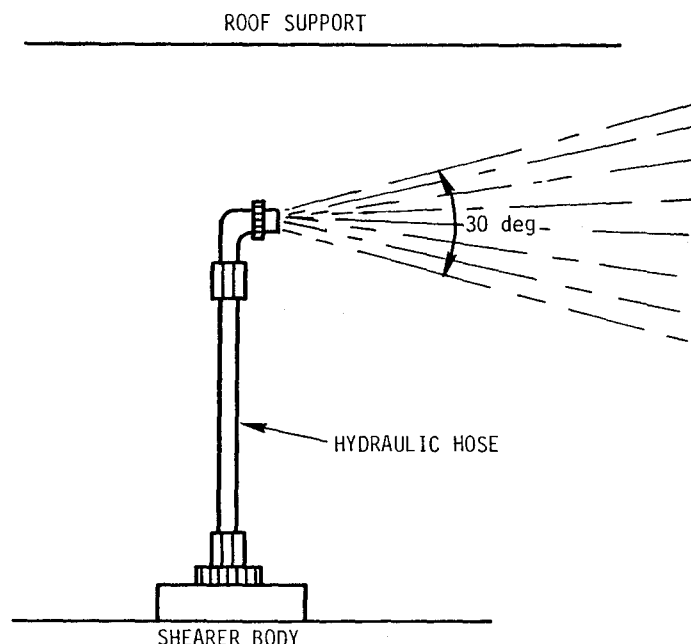


FIGURE 12. - Spray nozzle elevated above the shearer body.

Tracer gas concentrations for the lead and trailing drum operators' positions are plotted in Figure 13 as a function of system pressure. Test results clearly show the effectiveness of the system in reducing levels at the lead drum operator's position. Even at extremely low spray pressures (less than 60 psi) the system shows reductions of over 50 percent from levels measured with only drum sprays operating (185 ppm) and over 90 percent compared to the conventional dust suppression system (1250 ppm). As the pressure was increased the system continued to reduce concentrations at the lead drum operator. At pressures above 120 psi, concentrations at the lead drum operator leveled out at approximately 10 ppm which is a reduction of 95 percent from that measured with drum sprays only.

Test results measured for the tail drum operator also showed significant reductions when the new spray system was operated at low pressure. As system pressure was increased to improve

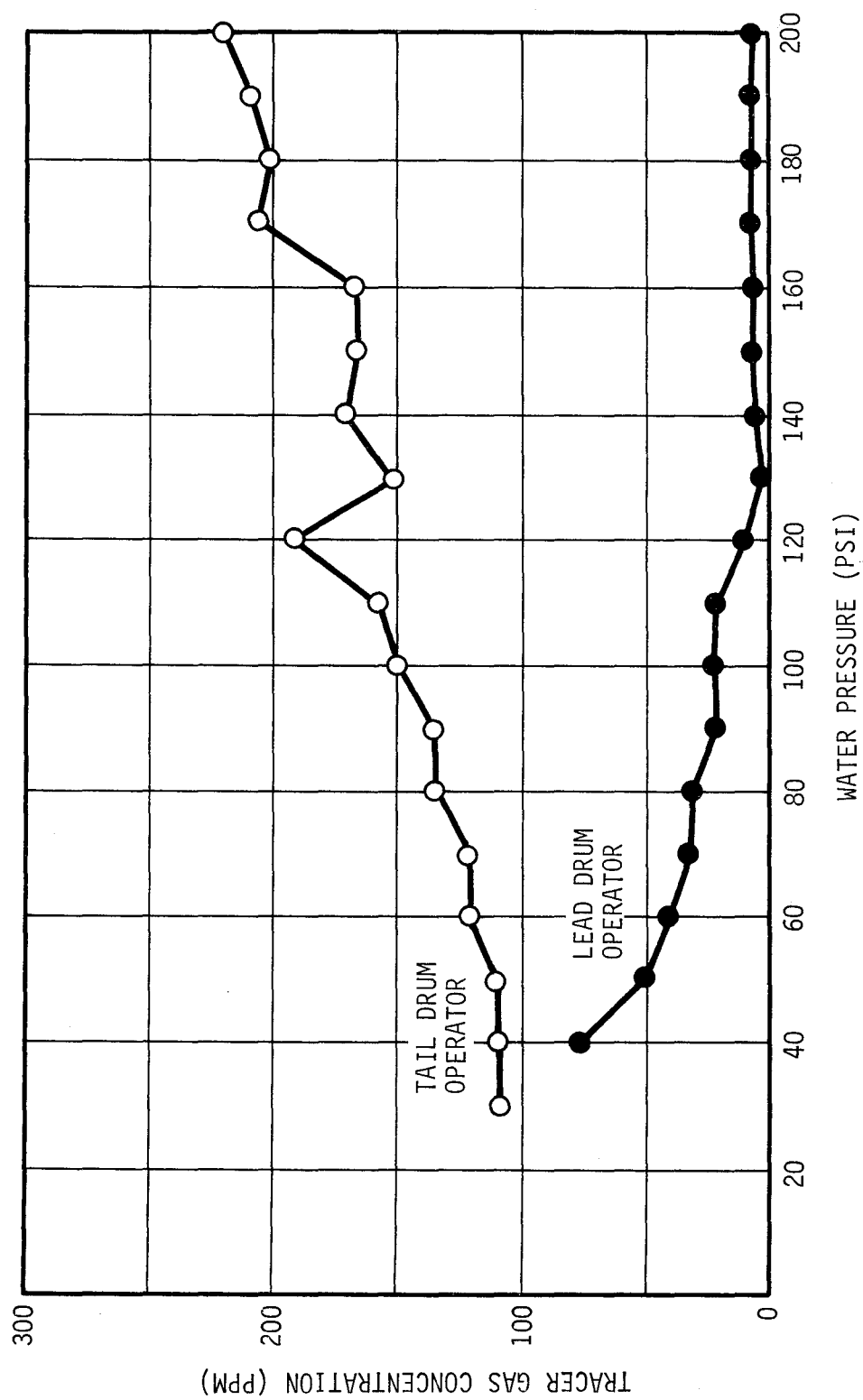


FIGURE 13. - Effect of water pressure on spray system performance (splitter arm and crossover sprays only).

conditions at the lead drum operator, however, concentrations at the trailing drum operator increased. At system pressures over 120 psi, which minimized lead drum operator concentrations, trailing drum operator concentrations deteriorated significantly. Further observations using smoke showed that the air pushed toward the face by the crossover sprays quickly decelerates when it reaches the larger cross-sectional area between the face and the shearer. It was also observed that the trailing drum blocks part of this area on the downstream end of the shearer. This caused smoke pushed to the face by the crossover sprays to quickly spread back across the shearer towards the walkway.

Several new combinations of sprays and barriers were tested using smoke to hold the contaminant on the face side of the shearer and to move it around the trailing drum. The best looking system is illustrated in Figure 14. The system consisted of two Spray Systems Co. BD20-2 spray nozzles mounted above the face side of the shearer body pointed downwind at a 30 deg angle towards the face. A third BD20-2 spray was mounted on top of the shearer near the tail drum operator also pointed downwind and 30 deg towards the face. Two additional BD20-2 sprays were suspended 12 in. down from the trailing drum end of the shearer. The flow path of smoke with these sprays operating is also shown in Figure 14.

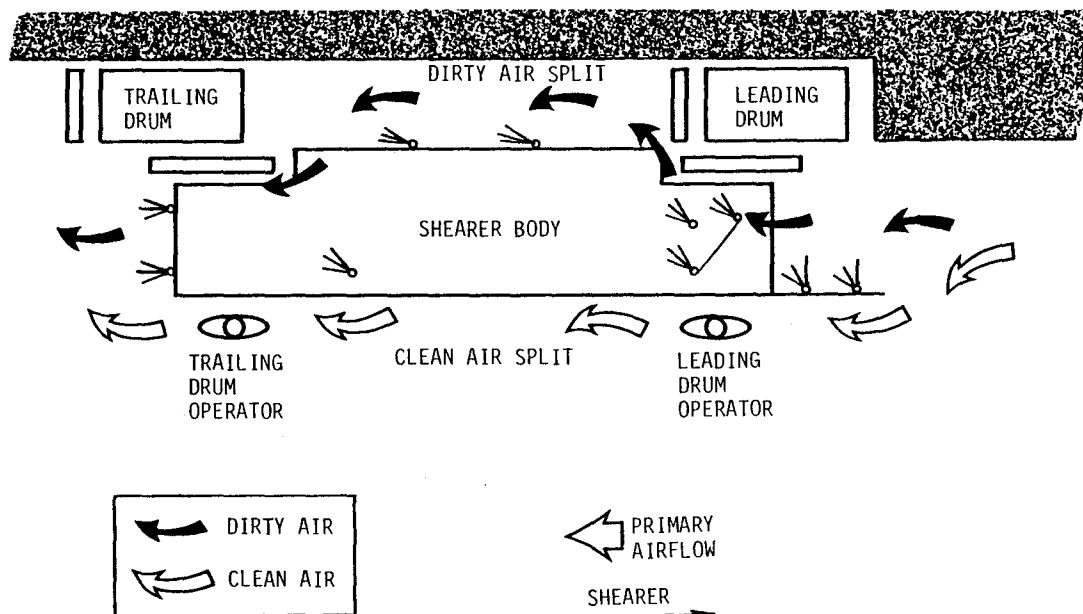


FIGURE 14. - Spray configuration to control contamination of the trailing drum operator's position.

The effectiveness of the system was then tested using tracer gas. Drum sprays were held constant at 100 psi and face air velocity at 300 ft/min. The new spray system was tested at pressures between 80 and 180 psi. Test results at the lead and tail drum operator are plotted in Figure 15 (note that the Y-axis scale differs from Figure 13).

The effectiveness of the system is clear. Tracer gas concentrations which were 185 ppm with just drum sprays and over 1200 ppm with the conventional spray system at the lead drum operator are reduced to less than 20 ppm by the new sprays and splitter arm. Similar reductions from 250 ppm (drum sprays only) and 780 ppm (conventional sprays) to less than 20 ppm were measured at the trailing drum operator. These reductions were obtained at spray pressures over 120 psi. At pressures less than 120 psi system performance deteriorated.

This new system, nicknamed the "*shearer clearer*" was then tested to determine if *drum spray pressure* affected system performance. The face air velocity and shearer clearer spray pressure were held constant at 300 ft/min and 140 psi, respectively, and the drum spray pressure was varied between 80 and 160 psi. Test results, shown in Figure 16, indicate that drum spray pressures less than 120 psi have no effect on system performance. Pressures from 120 to 160 psi increase operator concentrations slightly.

The system was then tested to determine if *face air velocity* affected system performance. Tests were run with the drum spray pressure constant at 100 psi and shearer clearer pressure at 140 psi. Test results for four face airflows, shown in Table 2, indicated that contaminant concentrations measured at the shearer operator's position decreased as face air velocity increased. These levels are over 90 percent less than levels measured with drum sprays only at each air velocity.

Test results in the laboratory at this point clearly showed that the shearer clearer had the potential for significantly reducing shearer operator dust exposures. The decision was made to install and test the system underground in a mine in Northern West Virginia. A complete description of this initial underground evaluation is included in Section 3 of this report.

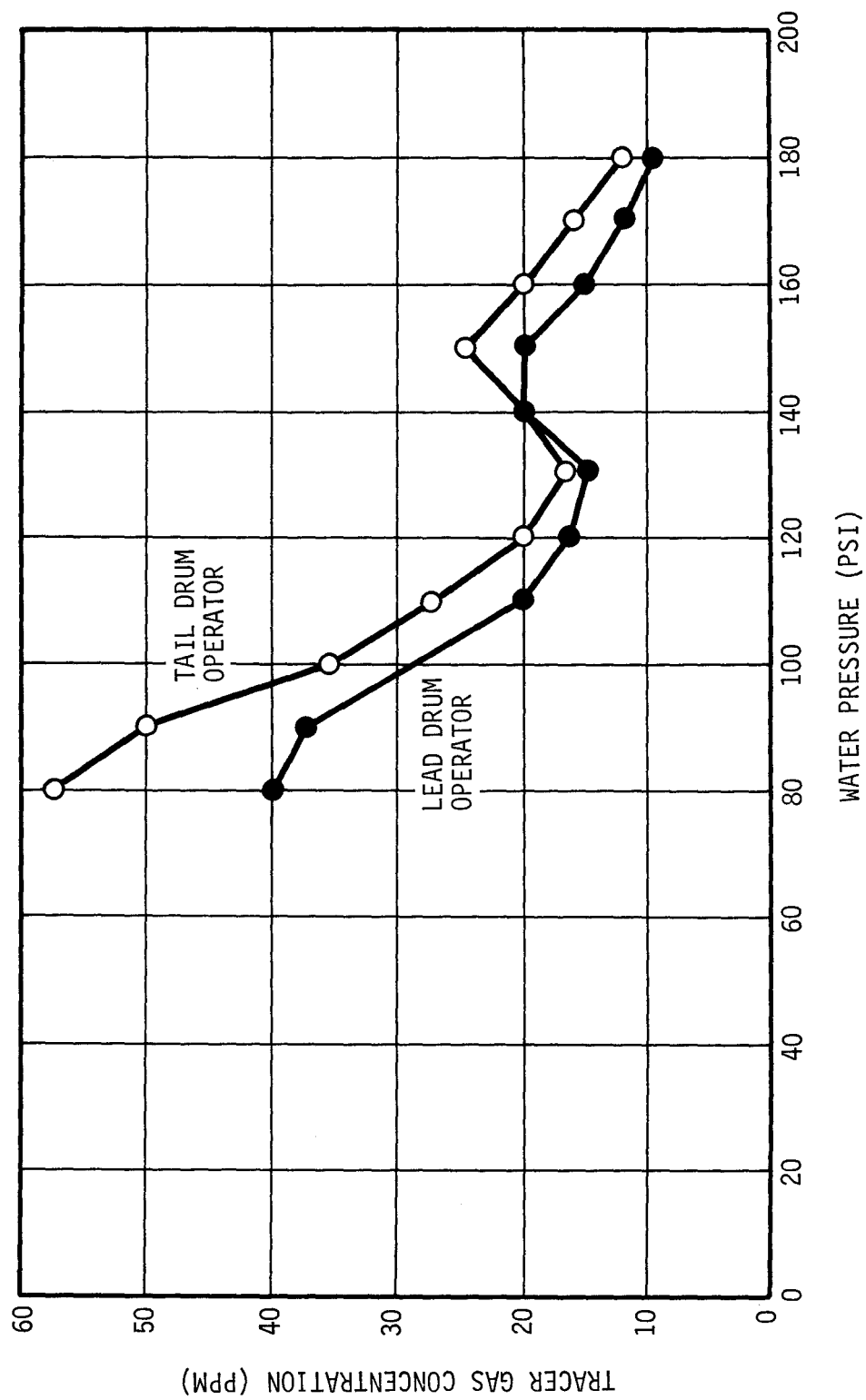


FIGURE 15. - Effect of water pressure on spray system performance with sprays to control trailing drum operator contamination.

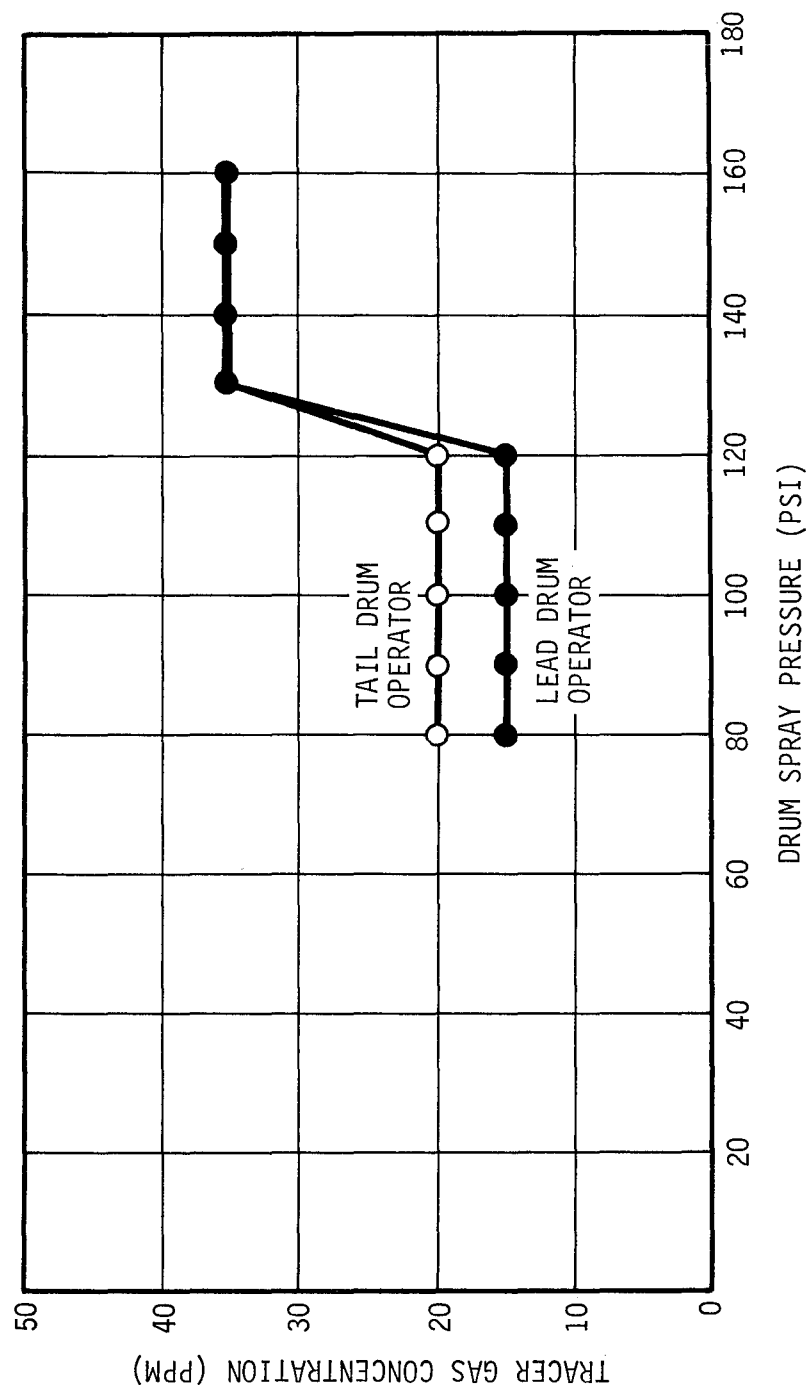


FIGURE 16. - Effect of drum spray pressure on shearer clearer performance.

TABLE 2. - Effect of face air velocity on shearer clearer performance

Face air velocity (ft/min)	Tracer Gas Concentration (ppm)	
	Lead drum operator	Tail drum operator
278	10	10
435	5	7.5
505	2.5	2.5
600	<1	<1

2.4.2 Further System Development with Gallery Changes to Better Model Underground Conditions

Testing of baseline conditions in the gallery had only shown a severe dust plume upwind of the leading drum when the upwind pointing dust suppression sprays were operated. Underground observations prior to and during the first system evaluation, however, showed a plume up to eight (8) feet upstream of the leading drum with only drum sprays operating. A major portion of this plume was pushed around the end of the 42 in. long splitter arm into the walkway. It was also observed that the dust cloud tended to boil back from the end of the shearer body and over the splitter towards the walkway more than was seen in the gallery. These observations led to changes in the gallery and further system development.

The upwind plume was simulated by water sprays mounted on the ranging arm and pointed upwind. Two BD10-3 nozzles, mounted as shown in Figure 17, operating at 140 psi produced a plume which most closely represented what was observed underground. A tracer gas concentration map of the plume is illustrated in Figure 18. Operating the plume sprays with the drum sprays increased the baseline concentration at the lead drum operator from 185 ppm to over 550 ppm.

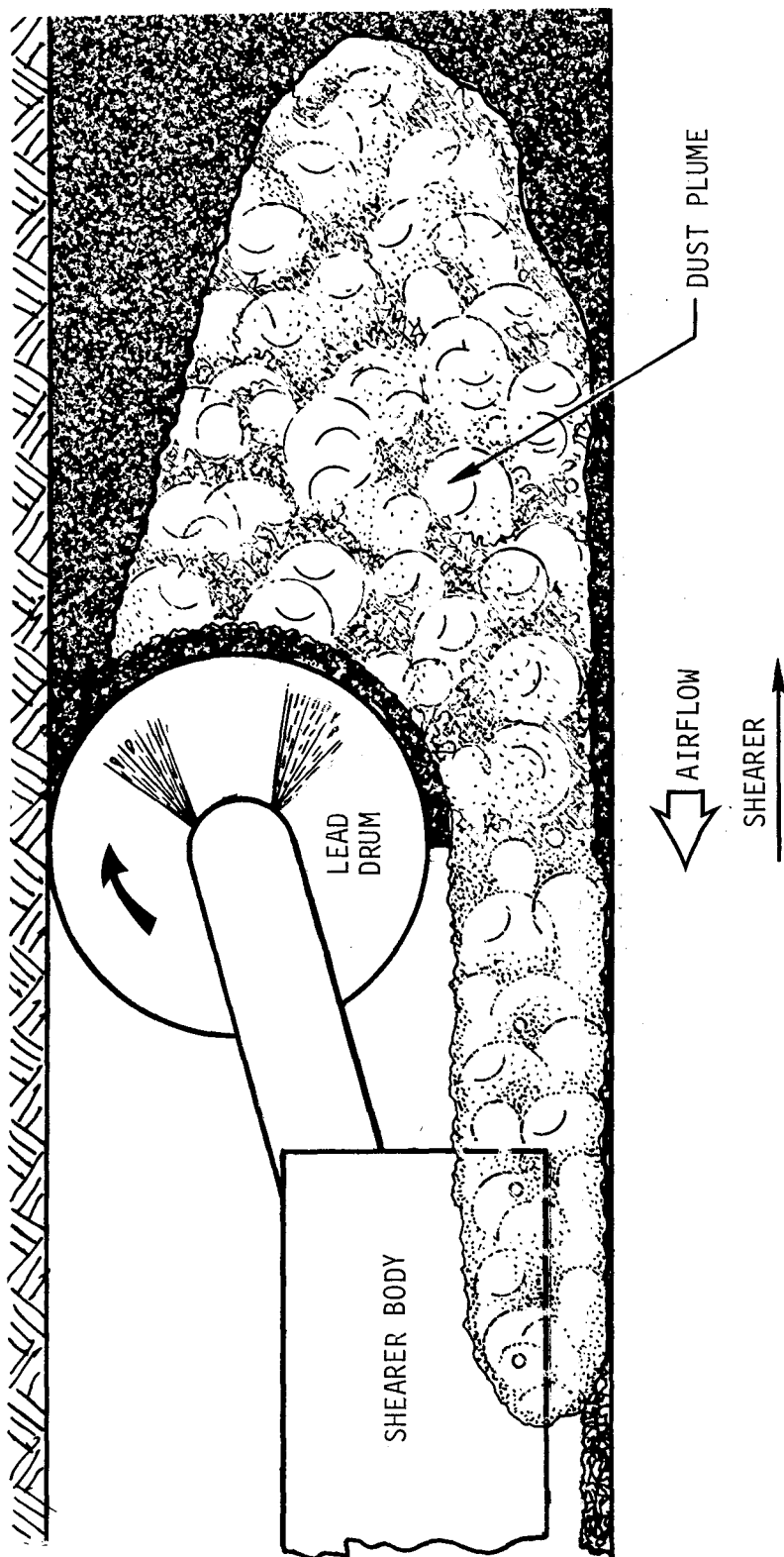


FIGURE 17. - Sprays mounted on the ranging arm to simulate the upwind plume.

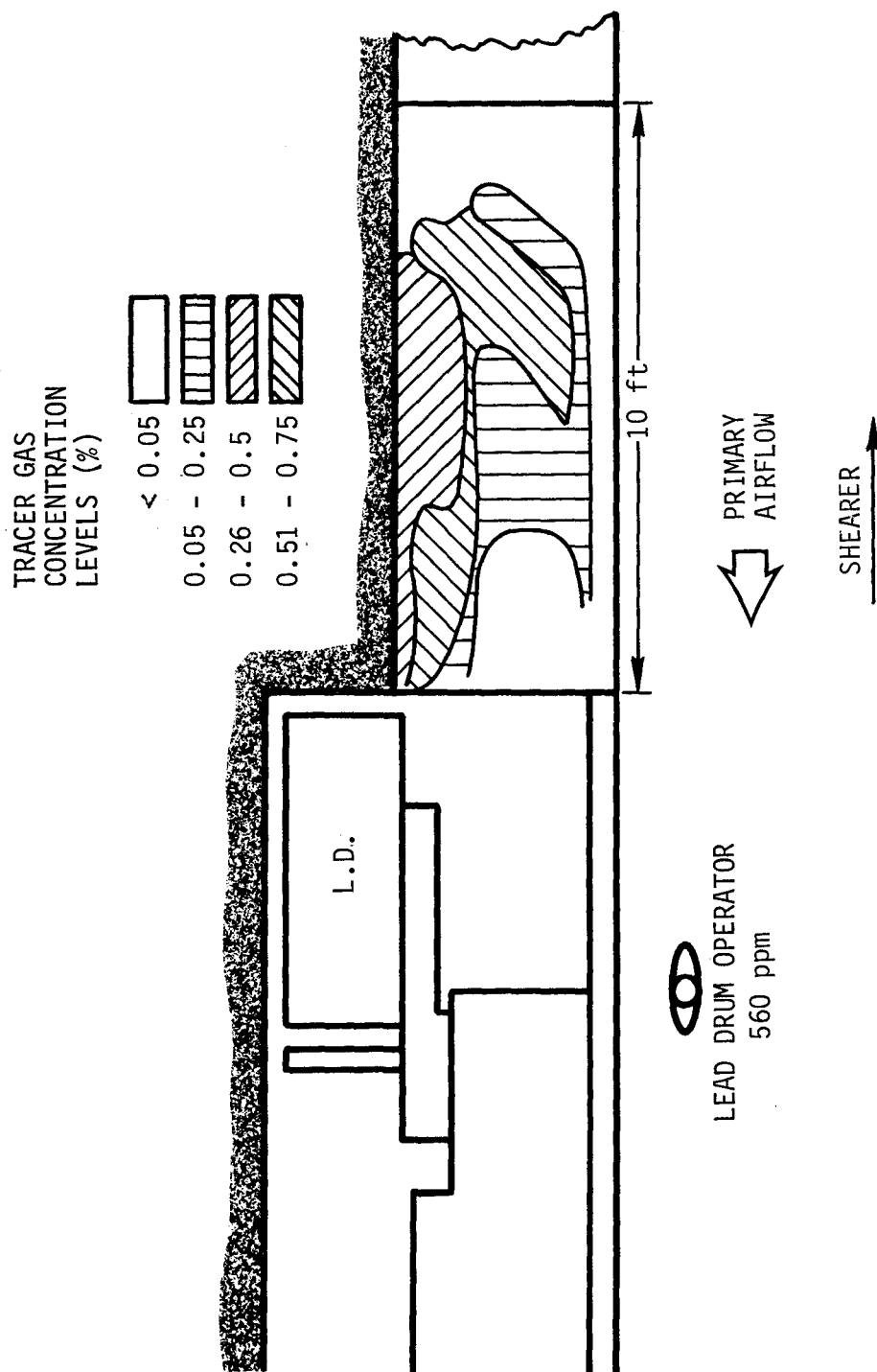


FIGURE 18. - Tracer gas concentration map of the upwind plume created by two sprays mounted on the ranging arm.

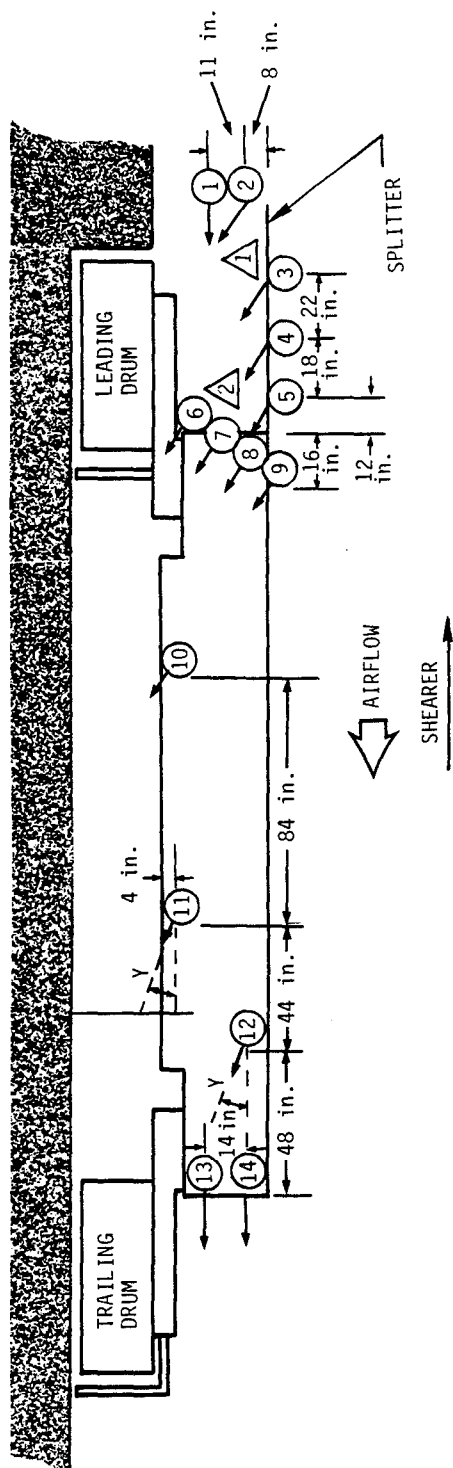
Initial attempts to control the plumes involved lengthening the splitter arm to 6 ft 6 in. This placed the end of the splitter 18 in. upwind of the leading edge of the drum. Testing of the shearer clearer with the splitter extended showed levels at the lead drum operator over 180 ppm. Observations with smoke showed the plume still going around the end of the splitter and over the splitter near the end of shearer into the walkway.

To better confine the plume, various sprays were added to both the top and end of the splitter and tested using smoke. The optimum configuration is shown in Figure 19.

The configuration consisted of 14 Spraying Systems, Inc. BD20-2 spray nozzles mounted and oriented as shown in Figure 19. Nozzles 1 and 2 were added on an arm mounted to the end of the splitter to help confine the upwind plume. One additional spray was added to the top of the splitter arm, and the arrangement of the crossover sprays was changed slightly. This new configuration reduced both the lead and tail drum operator concentrations to approximately 10 ppm with the shearer clearer sprays operating at 140 psi.

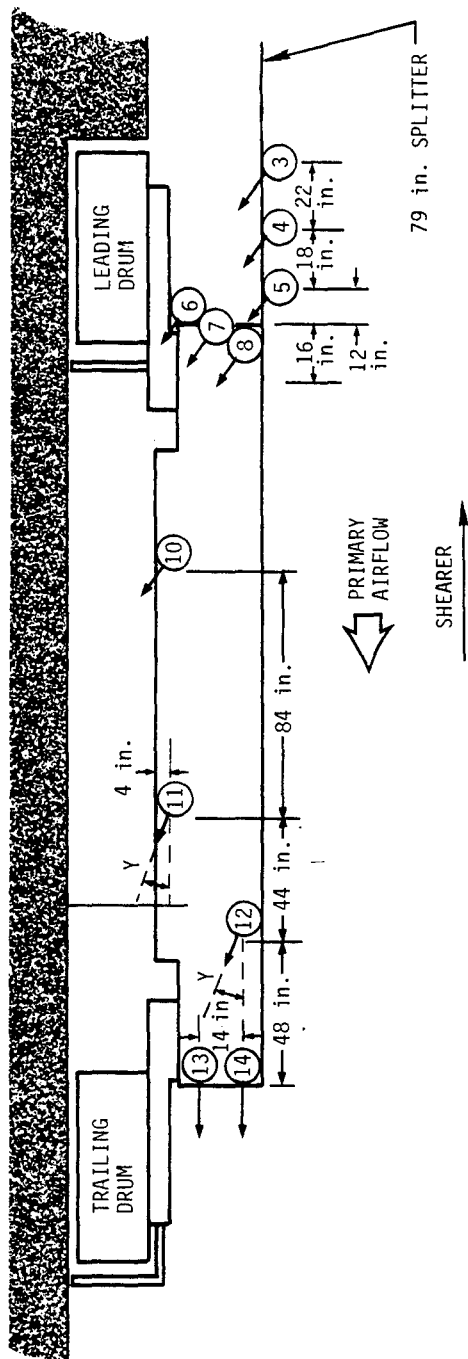
This system was then evaluated underground. The results are detailed in Section 3 of this report. The underground testing highlighted one additional problem not addressed in the laboratory. In the laboratory, all testing had been conducted with a tight seal between the splitter and the end of the shearer. This tight seal could not be achieved underground and significant quantities of dust escaped into the walkway.

Additional testing was conducted in the laboratory with a 4 in. wide opening between the splitter and the shearer body. As expected, levels at the operator significantly increased. Further testing showed that sprays 1 and 2, (Figure 19,) tended to push contaminant out through this opening. These sprays, therefore, were eliminated. The final system configuration for *cutting against ventilation* is shown in Figure 20. The performance of the shearer clearer system using smoke traces is shown in Figure 21. The airflow velocity and smoke release point is the same as in Figure 6 which illustrates the performance of a *conventional dust suppression system*.



NOZZLE NO.	NOZZLE DESCRIPTION	ANGLE TO PLANE		2	NOTES:
		X	Y		
1	BD-20-2	45° DIP	45°		ALL NOZZLES LISTED HERE ARE MANUFACTURED BY SPRAYING SYSTEMS, INC.
2	BD-20-2	30° DIP	10°		
3	BD-20-2	0°	30°		Y - ANGLE FORMED BETWEEN A LINE PARALLEL WITH THE FRONT EDGE OF THE SHEARER AND THE NOZZLE CENTERLINE (MEASURED CLOCKWISE).
4	BD-20-2	0°	30°		
5	BD-20-2	0°	30°		X - ANGLE FORMED BETWEEN A PLANE PARALLEL WITH THE SHEARER TOP AND THE NOZZLE CENTERLINE.
6	BD-20-2	0°	20°		
7	BD-20-2	0°	30°		
8	BD-20-2	0°	30°		
9	BD-20-2	0°	30°		
10	BD-20-2	0°	30°		
11	BD-20-2	0°	30°		
12	BD-20-2	0°	20°		
13	BD-20-2	0°	0°		
14	BD-20-2	0°	10°		

FIGURE 19. Shearer clearer nozzle layout.



NOZZLE NO.	NOZZLE DESCRIPTION		2	NOTES:
	TYPE	ANGLE TO PLANE		
		$\frac{X}{Y}$		
3	BD-20-2	$\frac{0^{\circ}}{30^{\circ}}$	1 ALL NOZZLES LISTED HERE ARE MANUFACTURED BY SPRAYING SYSTEMS, INC. 2 Y - ANGLE FORMED BETWEEN A LINE PARALLEL WITH THE FRONT EDGE OF THE SHEARER AND THE NOZZLE CENTERLINE (MEASURED CLOCKWISE). X - ANGLE FORMED BETWEEN A PLANE, PARALLEL WITH THE SHEARER TOP AND THE NOZZLE CENTERLINE.	
4	BD-20-2	$\frac{0^{\circ}}{30^{\circ}}$		
5	BD-20-2	$\frac{0^{\circ}}{30^{\circ}}$		
6	BD-20-2	$\frac{0^{\circ}}{20^{\circ}}$		
7	BD-20-2	$\frac{0^{\circ}}{30^{\circ}}$		
8	BD-20-2	$\frac{0^{\circ}}{30^{\circ}}$		
10	BD-20-2	$\frac{0^{\circ}}{30^{\circ}}$		
11	BD-20-2	$\frac{0^{\circ}}{30^{\circ}}$		
12	BD-20-2	$\frac{0^{\circ}}{20^{\circ}}$		
13	BD-20-2	$\frac{0^{\circ}}{0^{\circ}}$		
14	BD-20-2	$\frac{0^{\circ}}{10^{\circ}}$		

FIGURE 20. - Final shearer clearer nozzle layout for cutting against airflow.

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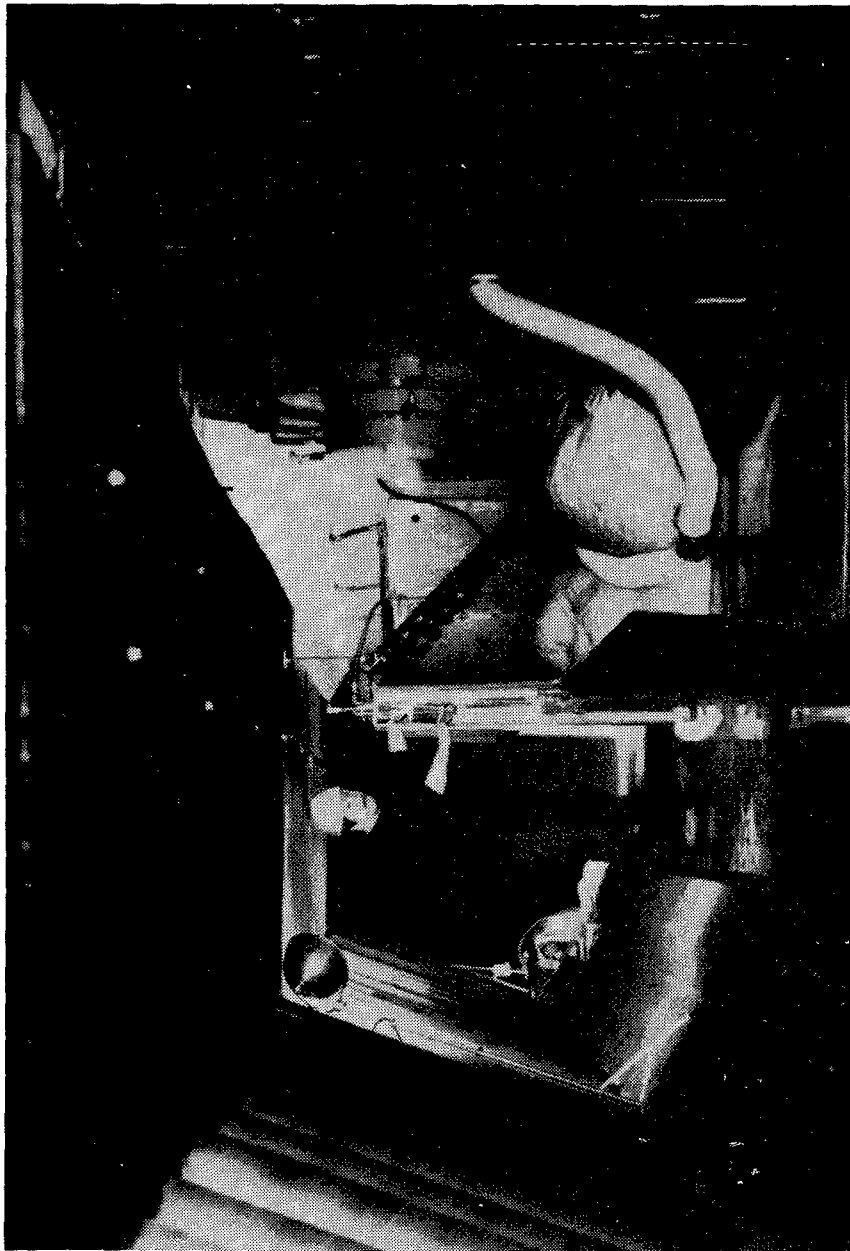


FIGURE 21. - Foster-Miller longwall test gallery with smoke released at the lead drum during a test of the shearer clearer system.

2.5 Laboratory Development of the Shearer Clearer for Cutting with Ventilation

The initial development of the shearer clearer was concentrated on developing a system for cutting against the primary ventilation. It was felt that this cut direction was most critical since it places the shearer operators downwind of the primary cutting drum producing the most dust. A significant number of faces, however, *cut unidirectionally with the primary airflow*, and some faces continue to cut bidirectionally.

In this cut direction, the trailing drum cutting the bottom bench is on the upwind side of the shearer. While this drum cuts less than half the coal produced by the lead drum, it still produces sufficient dust to cause significant exposures for the shearer operators. This is particularly true when the trailing drum is used for trimming bottom rock.

The following subsections describe baseline testing and the development of a new spray system for shearers cutting with ventilation. Please take note that *since this section discusses cutting with ventilation the leading drum is now downwind and the trailing drum upwind of the shearer operators' positions*.

2.5.1 Baseline Testing of the Shearer Cutting with Ventilation

Baseline testing of the shearer cutting with ventilation was conducted with only the drum sprays operating. Test results with both smoke and tracer gas showed that contamination from the leading drum has no effect on the shearer operators' positions. Contamination from the trailing drum, (upwind of operator's positions), however, does cause significant contamination of the lead drum operator's position.

A tracer gas concentration map for the shearer with drum sprays only is shown in Figure 22. Gas released at the trailing drum spreads quickly across the top of the shearer. Levels measured at the operators' positions showed concentrations of approximately 50 ppm at the trailing drum operator and 375 ppm at the leading drum operator.

The much higher levels at the lead drum operator are caused by the lead drum cowl and drum (raised) obstructing the airflow down the face side of the shearer. Observations with smoke showed the air being stalled by the obstruction and being forced out across the top of the shearer towards the walkway.

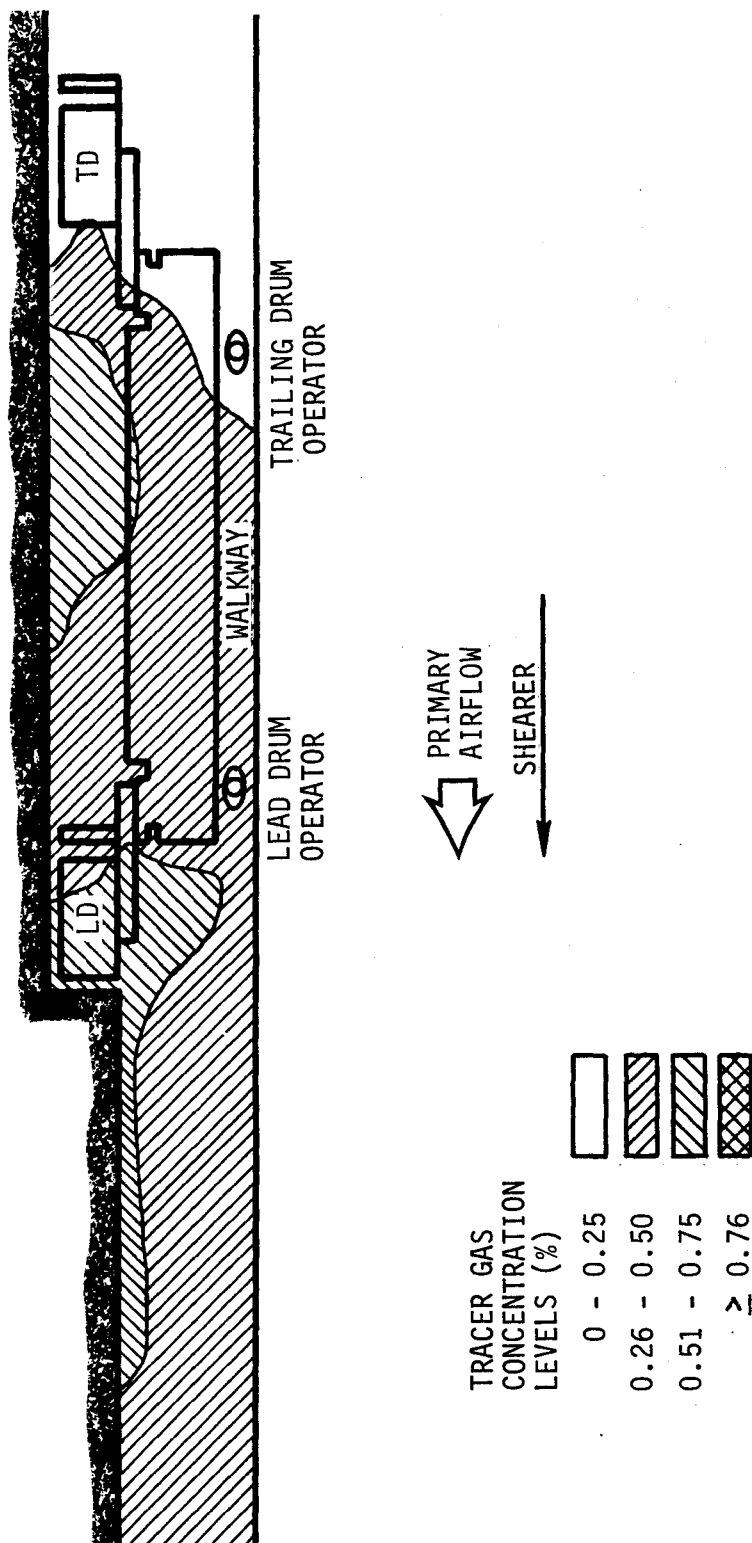


FIGURE 22. - Tracer gas concentration map showing the effects of drum sprays on shearer generated dust.

It was felt, however, that the low level measured at the trailing drum operator was not a true representation of underground conditions: Observations and measurements underground showed an upwind plume similar to that observed cutting against the airflow. To *simulate this plume*, a Spraying Systems Co. BD10-2 nozzle was added to the trailing drum ranging arm in a manner similar to that previously shown. The addition of the plume spray increased trailing drum operator levels to approximately 150 ppm and leading drum operator levels to 790 ppm.

Testing of conventional dust suppression or cooling water spray systems was only conducted using smoke. As expected these systems, with sprays pointed upwind significantly increased the boil out of contamination into the walkway and further testing was not warranted.

2.5.2 Development of the Shearer Clearer System for Cutting with Airflow

The full shearer clearer system was installed as shown in Figure 23. The system, as installed, was an exact mirror image of the system cutting against ventilation. Test results with the full system at 140 psi showed a significant reduction at the trailing drum operator. Levels at the lead drum operator, however, increased. This increase was due to increased airflow on the face side of the shearer caused by the shearer clearer sprays. This increased airflow, blocked by the lead drum and cowl, increased boil out of contaminant over the lead drum operator as shown in Figure 24.

Additional testing of the system with all sprays at the same pressure showed the following:

- a. Increasing system pressure reduced trailing drum operator levels but significantly increased lead drum operator levels.
- b. Decreasing system pressure reduced lead drum operator levels but increased trailing drum operator levels.

Although reducing total system pressure improved lead drum operator levels, they were still higher than those measured without the shearer clearer operating. The system, as designed for against the flow cutting, was *not suitable* when the shearer was cutting with the airflow.

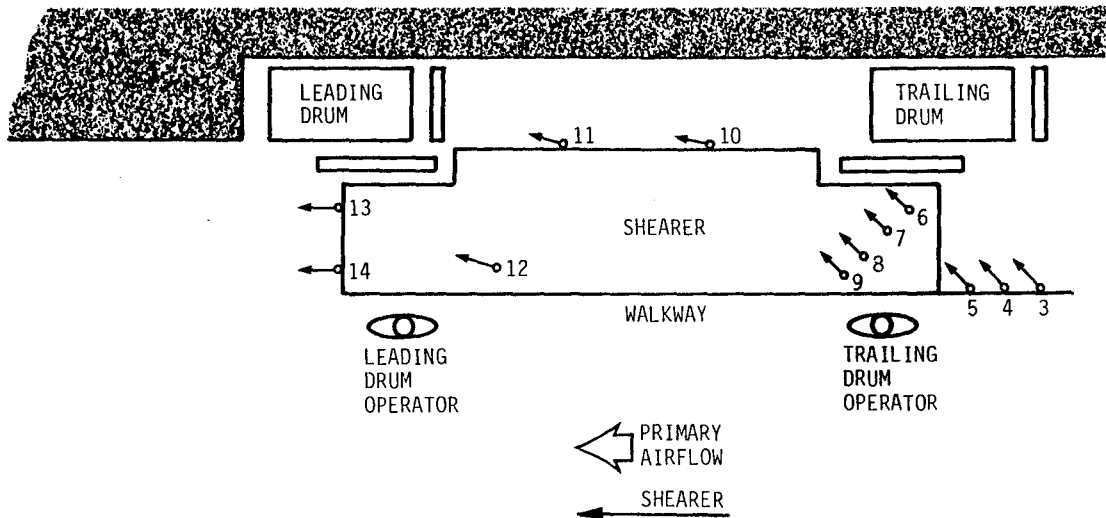


FIGURE 23. - Shearer clearer installed for testing with the shearer cutting with ventilation.

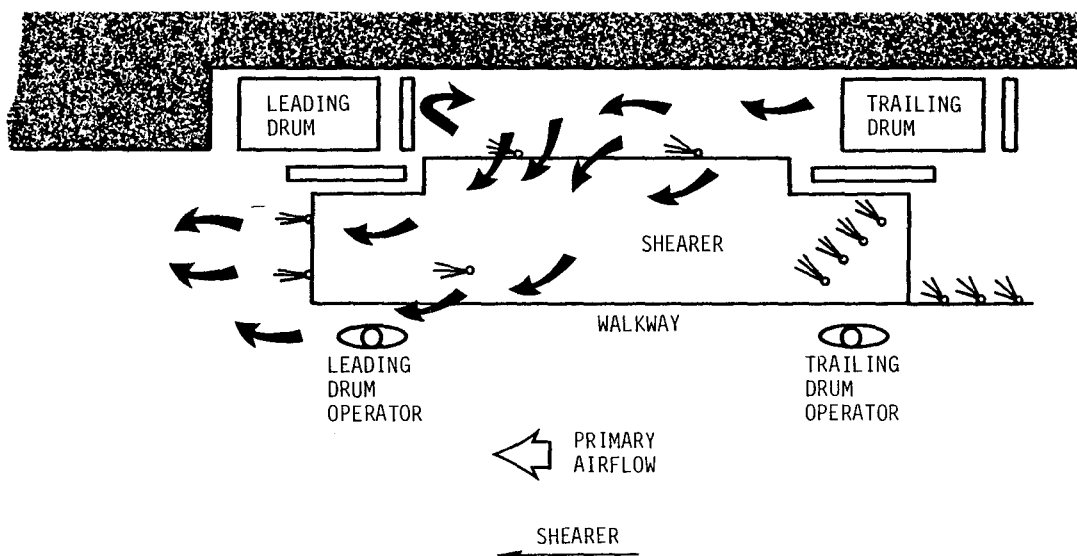


FIGURE 24. - Boil out of dust caused by operating the shearer clearer at 140 psi with the shearer cutting with ventilation.

Further system development was initiated using smoke. Initial testing was conducted with sprays 3-11 operating at 140 psi. (This pressure was the same as that for the system cutting against airflow and had provided excellent reductions for the trailing drum operator cutting with airflow). Control at the lead drum operator was attempted by increasing the number and pressure of sprays on the lead drum end of the shearer. Several spray configurations, with nozzles mounted on the shearer body and ranging arm pointed downwind, significantly reduced lead drum operator levels. The number of nozzles required, however, was judged to be impractical. It was concluded, therefore, that power on the upwind end of the shearer would have to be reduced.

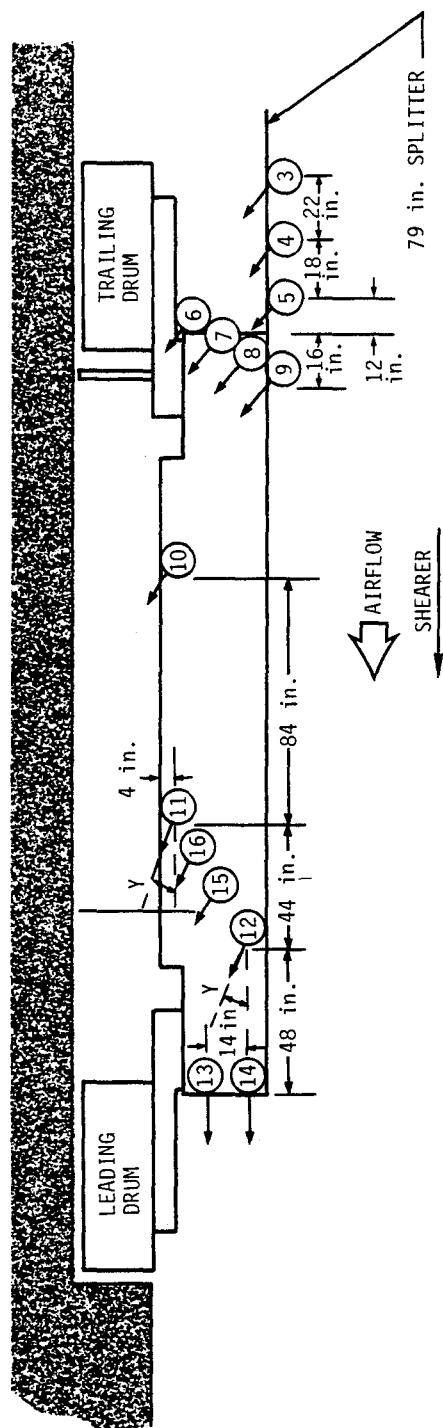
In the next test sequence, pressure on sprays 10-14 was held constant at 140 psi, and pressure on sprays 3-9 was reduced. Reducing the pressure on sprays 3-9 to 60 psi showed the following:

- a. Trailing drum operator levels were reduced approximately 70 percent from those measured without the system operating.
- b. Leading drum operator levels were reduced to those measured without the system operating.

This testing showed that the shearer clearer with reduced pressure on the upwind end provided adequate control for the trailing drum operator. It did not, however, provide any improvement for the lead drum operator. It was concluded, therefore, that increased power was needed on the lead drum end of the shearer.

This additional power was gained by adding two sprays (15 and 16) mounted on the shearer body between nozzles 11 and 12 as shown in Figure 25. Both sprays were pointed downwind. Operating the system with sprays 3-9 at 60 psi and sprays 10-16 at 140 psi reduced levels at the lead drum operator to less than 100 ppm, a reduction of close to 90 percent as compared to no system. The trailing drum operator's level for the system operating was down close to 60 percent.

The system was then installed and evaluated underground as described in Section 3 of this report.



NOTES:

NOZZLE DESCRIPTION

NOZZLE NO.

TYPE

ANGLE TO PLANE

X

Y

2

1

2

ALL NOZZLES LISTED HERE ARE MANUFACTURED BY SPRAYING SYSTEMS, INC.

Y - ANGLE FORMED BETWEEN A LINE PARALLEL WITH THE FRONT EDGE OF THE SHEARER AND THE NOZZLE CENTERLINE (MEASURED CLOCKWISE).

X - ANGLE FORMED BETWEEN A PLANE PARALLEL WITH THE SHEARER TOP AND THE NOZZLE CENTERLINE.

3	BD-20-2	0°	30°
4	BD-20-2	0°	30°
5	BD-20-2	0°	30°
6	BD-20-2	0°	20°
7	BD-20-2	0°	30°
8	BD-20-2	0°	30°
9	BD-20-2	0°	30°
10	BD-20-2	0°	30°
11	BD-20-2	0°	30°
12	BD-20-2	0°	20°
13	BD-20-2	0°	0°
14	BD-20-2	0°	10°
15	BD-20-2	0°	30°
16	BD-20-2	0°	30°

FIGURE 25. - Shearer clearer nozzle layout for cutting with airflow.

2.6 Laboratory Development of a Low Profile Shearer Clearer System

The basic shearer clearer systems described in subsections 2.4 and 2.5 used hydraulic hoses to elevate the nozzles above the shearer body. This was done for two reasons:

- a. To keep the spray cone from hitting the top of the shearer.
- b. To keep the nozzles from being blocked by rubble building up on the top of the shearer.

Discussions with mine personnel and underground observations, however, indicated that elevated sprays would be difficult to maintain in some mines due to low clearance between the shearer and roof supports. A short development program was initiated to determine if an effective system could be designed with the shearer body mounted sprays lowered.

In designing a low profile system, we knew that the spray cone should not impact the top of the shearer if we were to maintain maximum air moving capability. The sprays used in the basic system have a 30° cone angle. If the low profile system used nozzles angled upwards 15°, the spray cones would not hit the shearer body. Figure 26 shows a low profile block manifold with the nozzle centerline angled up 15°.

The low profile system was tested with the shearer cutting against the primary airflow. Test results with spray nozzles 6-12, originally elevated, replaced by low profile sprays as shown in Figure 27 showed no deterioration in system performance.

2.7 Laboratory Development of a Shrouded Spray Shearer Clearer System

Shrouded sprays are nozzles mounted so they spray through a tube. A variety of both rectangular and circular tubes are produced by several spray manufacturers. Many mines use shrouded sprays for their shearer dust control systems for the following reasons:

- a. Easier to mount on the shearer
- b. Affords additional protection for the spray nozzle

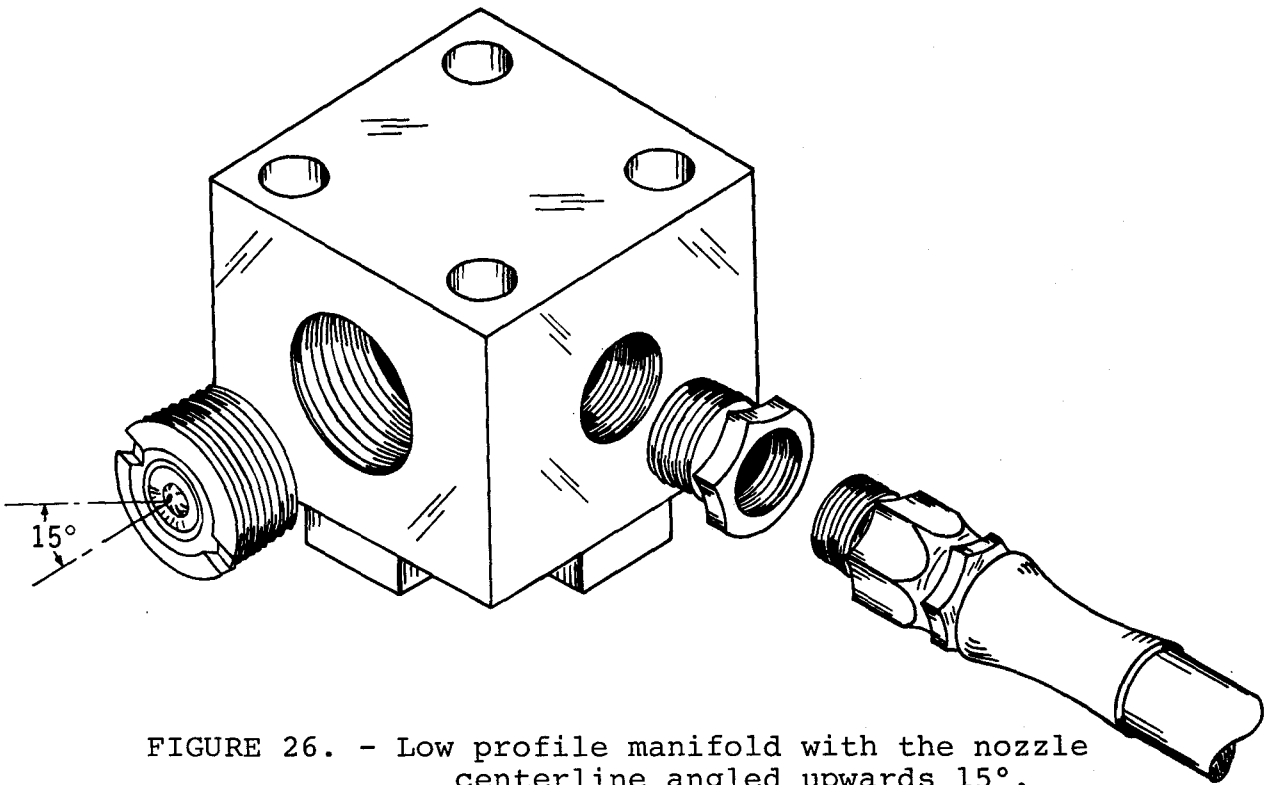


FIGURE 26. - Low profile manifold with the nozzle centerline angled upwards 15°.

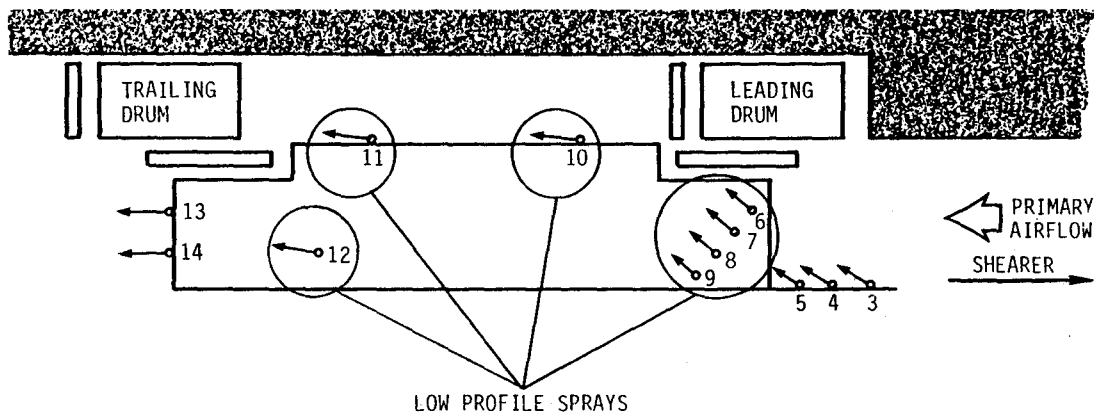


FIGURE 27. - Shearer clearer system with low profile sprays at positions 6-12.

- c. Shrouded sprays are *advertised* to provide effective dust knockdown and air movement.
- d. Better directional control because the spray is confined.

The purpose of this testing was to determine the impact of using shrouded sprays for part or all of the shearer clearer system.

The shrouded spray used for the testing is shown in Figure 28. The shroud was 4 in. in diam and 6 in. long. The nozzle was the same used with the basic shearer clearer - a Spraying Systems BD20-2. The nozzle was mounted 1-3/4 in. outside the shroud to provide maximum air-moving efficiency.

Testing preparation consisted of replacing "banks" of open sprays with shrouded sprays. The four "banks" or sections are shown in Figure 29. Each bank was replaced and evaluated *individually* and then the *whole system* was changed over. Testing was conducted at 140 psi. Test results showed virtually no difference in performance between shrouded and open sprays.

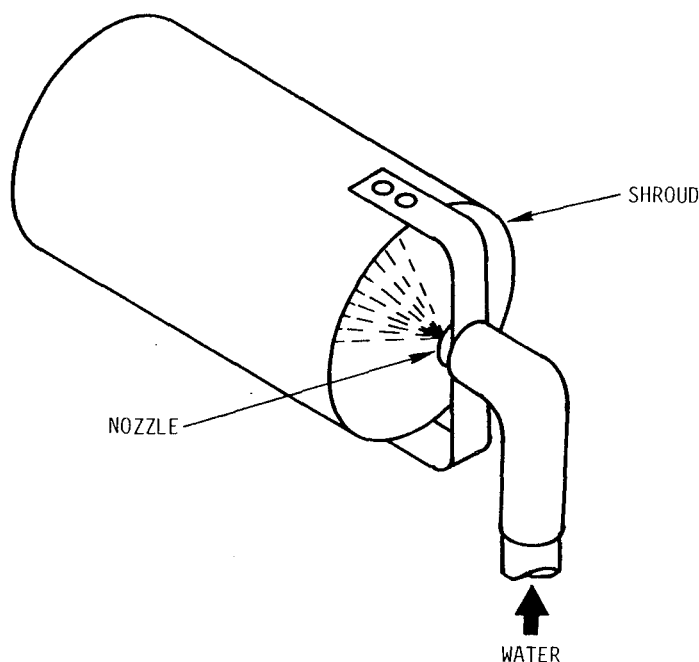


FIGURE 28. - Shrouded spray used for shearer clearer system testing.

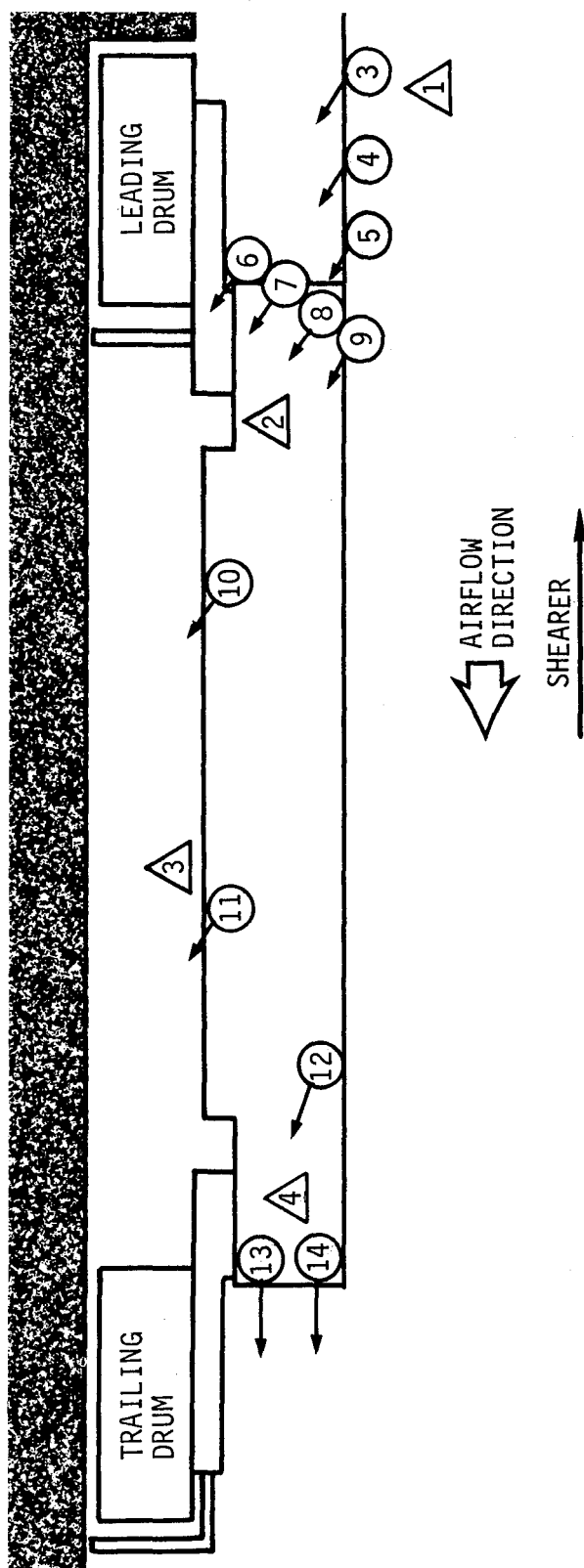


FIGURE 29. - Shearer clearer nozzle layout for testing shrouded sprays.

One final test was conducted to determine if the four individual shrouded sprays in bank No. 2 could be replaced by one larger rectangular shroud containing all four nozzles. Test results showed that this change caused significant deterioration in system performance.

3. FIELD EVALUATION OF THE SHEARER CLEARER.

3.1 Introduction

A preliminary underground evaluation of the shearer clearer concept was conducted in a mine in northern West Virginia working the Pittsburgh Seam. The results of this initial test indicated that the system could achieve significant reductions in shearer generated dust at the operators' positions when cutting against ventilation. It also highlighted several areas not addressed by the early system development which required further laboratory testing and refinement.

This development was followed by three additional underground evaluations of the system. These tests were conducted on a bi-directional face in Pennsylvania, a unidirectional face in Illinois, and a unidirectional face in Utah.

Details of each of the underground evaluations of the shearer clearer system are described in the following subsections.

3.2 Consolidation Coal Company - Blacksville No. 1 Mine

The initial field evaluation of the shearer clearer system was started with a preliminary visit to the Blacksville No. 1 Mine in early March 1980. General section conditions are summarized in Table 3.

TABLE 3. - General face information

Seam Height:	78 in.
Type of Shearer:	Eickhoff EDW 170L DD
Drum Diameter:	60 in.
Web Depth:	30 in.
Average Face Air Velocity:	330 fpm
Mining Sequence:	Modified full face: Tail to head primary cut, head to tail cleanup pass, roof supports, and conveyor advanced on the head to tail pass.

3.2.1 Face Conditions During the Preliminary Visit

The water spray system in use during the preliminary visit is shown in Figure 30. The system consisted of the following:

- a. Three Senior Conflow venturi sprays mounted on a splitter support frame on the headgate end of the shearer. These sprays were aimed at the leading edge of the cutting drum.
- b. One Senior Conflow venturi spray suspended 1 ft below the top of the shearer on the tailgate end. This spray was aimed at the downwind edge of the trailing drum.
- c. Three flat fan sprays on the face side of each ranging arm to discharge cooling water.
- d. Twenty-four Spraying Systems 110074H1/4VV sprays to flush the cutting zone in *each* drum.

The dynamic water pressure measured at the shearer was 125 to 150 psi.

Dust levels were not measured during the preliminary visit. Visual observation of the dust cloud generated by the upwind (headgate) drum, cutting tailgate to headgate, slowed shearer generated dust being pushed against the airflow and spreading into the walkway over the shearer operators.

3.2.2 Underground Evaluation

The underground evaluation at Blacksville No. 1 began in early March 1980. The test program involved two phases:

- a. 3-8-80 to 3-13-80 Shearer Clearer/conventional system comparison testing
- b. 3-17-80 to 3-18-80 Modified Shearer Clearer/conventional system comparison testing
and 5-17-80 to 5-20-80

The Shearer Clearer System installed for the first phase of testing is shown in Figure 31. The system consisted of two Spraying Systems Co. BD20-2 nozzles mounted on the splitter frame pointed 30 deg toward the face. Seven BD20-2 nozzles were

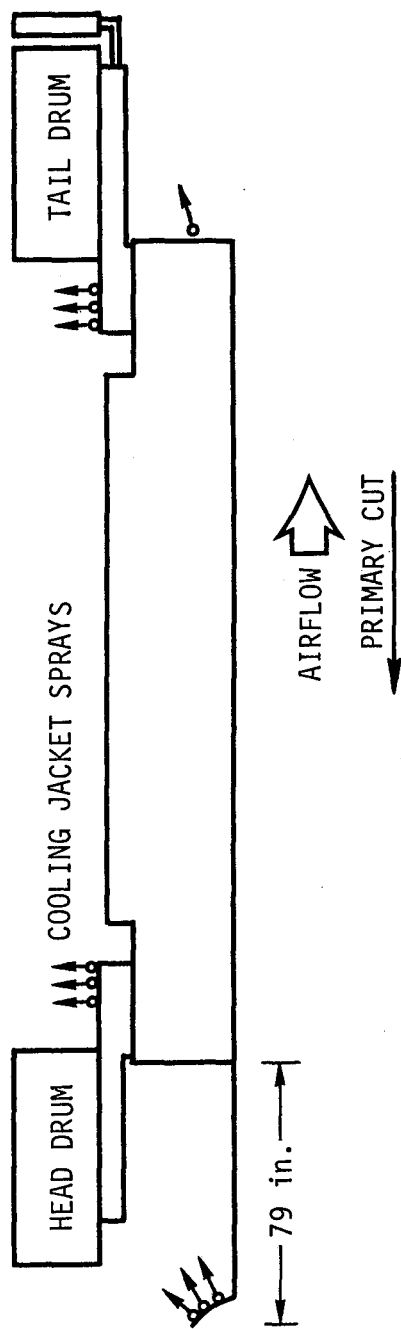


FIGURE 30. - Existing conventional water spray system.

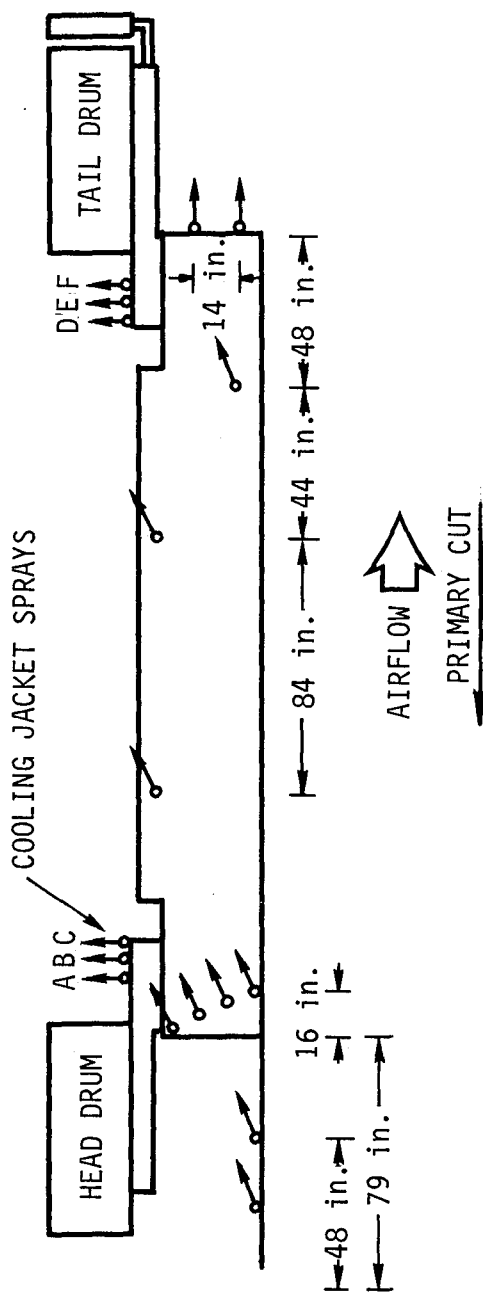


FIGURE 31. - Shearer clearer water spray system.

mounted on the shearer body directed as shown. These sprays were elevated above the shearer body using a high pressure hose. Two BD20-2 sprays were suspended 12 in. down from the tailgate end of the shearer angled slightly towards the face. The drum and cooling water sprays were also valved to operate with the shearer clearer. System water pressures were 125 psi for the shearer clearer sprays, and 100 psi for the drum sprays.

Testing of the shearer clearer and conventional spray systems on a pass by pass basis was initiated on March 10, 1980. Respirable dust levels were measured using gravimetric samplers worn and carried by three individuals; two stationed at the shearer operator's positions, and the third positioned 25 ft upwind of the shearer. Each individual had four samplers. Reported dust levels are an average of these four measurements.

Sampling was conducted only in the tail to head cutting passes and only during the times when the shearer was cutting. The samplers were turned off during down time and also during the sumping operation. These sample data, therefore, *cannot be viewed as 8 hr shift measurements.*

For this study, the data measured 25 ft upwind of the shearer was subtracted from the levels measured at the shearer operators. In this way, effects due to changes in the intake air are eliminated. Changes in the shearer operator samples between different spraying systems only reflects the difference in the control of shearer generated dust and not changes occurring upwind.

On March 13, 1980, gravimetric sampling, as described above, was carried out on four tailgate-to-headgate cutting passes. During the first and third passes, the conventional spray system was operated. During the second shearer clearer pass (pass 4), two of the sprays on the headgate splitter arm were inoperable due to spray nozzle plugging.

The average respirable dust concentrations at the shearer operators' positions, with the intake contamination subtracted out are shown in Table 4. The average concentrations for the conventional system at the lead drum operator was 32.6 mg/m^3 ; for the shearer clearer, it was 16.2 mg/m^3 . This represents a *50 percent reduction of shearer generated dust* exposure for the lead drum operator. The average concentrations for the tail drum operator were 16.8 and 10.4 for the conventional and shearer clearer systems, respectively. This represents a 38 percent reduction.

TABLE 4. - Average respirable dust concentrations at the shearer operators' positions (minus intake contamination)

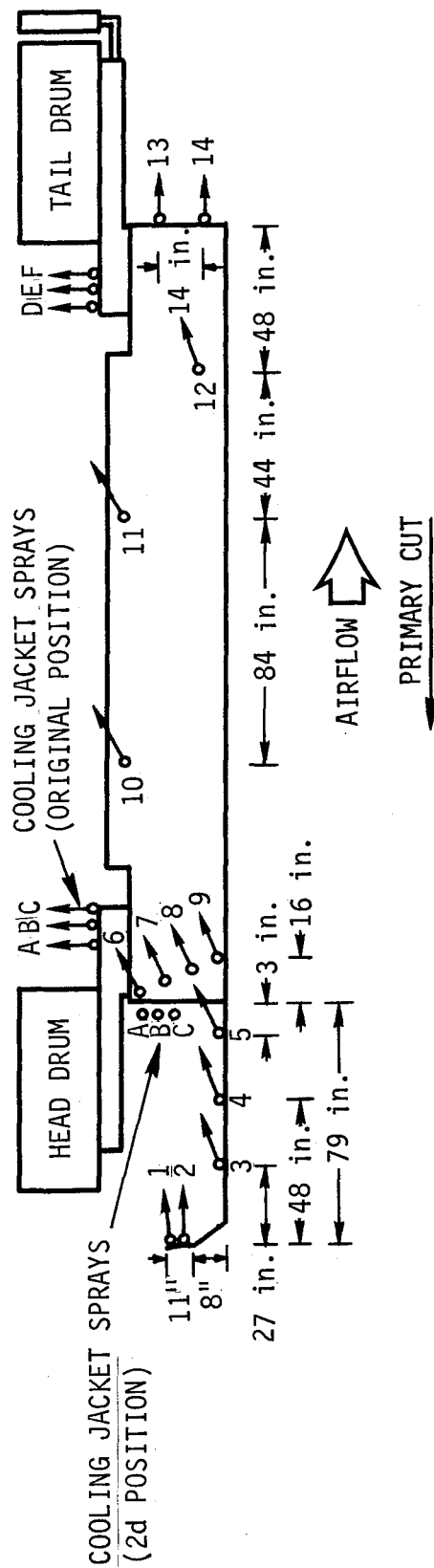
Date	System	Shift	Pass	Total Sampling Time (min)	Lead Drum Oper $\frac{\text{mg}}{\text{m}^3}$	Tail Drum Oper $\frac{\text{mg}}{\text{m}^3}$
3/13/80	Shearer Clearer	2	2+4	50	16.2	10.4
3/13/80	Conventional	2	1+3	44	32.6	16.8
3/17/80	Modified Shearer Clearer	2	1	36	7.2	8.0
3/17/80	Conventional	2	2	17	12.3	12.6

Upon reviewing the March 13 data and observations on the face, several changes and improvements were made. These included:

- a. The cooling water sprays on the headgate gearhead were relocated to the headgate end of the shearer body pointed straight down on the panline.
- b. Three sprays were added to the headgate splitter arm as shown in Figure 32. The sprays added are numbered 1, 2, and 5 on the figure. Sprays 1 and 2 were Senior Conflow Co. venturis; spray 5 was a Spraying Systems Co. BD20-2.

The relocation of the cooling water sprays was done primarily to reduce the recirculation of dust and water mist caused by these sprays. During the first week of sampling, it was observed that these three sprays mounted on the gearhead blow into and rebound off the face and cowl back towards the lead drum operator increasing both dust and water mist at his operating position. Relocating these sprays also helps to wet the coal in the panline which may reduce intake contamination. It should be noted that the relocated water sprays were valved to operate with both the conventional and shearer clearer system.

The addition of the three sprays to the shearer clearer system was to improve control of the dust cloud generated by the



SPRAYS	NOZZLES
1, 2	SENIOR CONFLOW CO. - VENTURI
3-14	SPRAY SYSTEMS CO. - BD20-2

FIGURE 32. - Modified shearer clearer water spray system.

leading drum. During the first week of testing dust from the leading drum was pushed upstream beyond the upwind edge of the splitter. Sprays 1 and 2 were added to help confine the dust cloud. It was also observed that dust was being pushed up and over the splitter where it met the shearer body into the lead operator's breathing zone. Spray 5 was added to push this cloud towards the crossover spray bank on the shearer.

Following these modifications, sampling was started again on March 17. During the first pass, the modified shearer clearer was operated. Approximately two minutes into the pass, a roof fall damaged the headgate splitter arm and bent it downward 20 deg making proper orientation of the sprays mounted on the arm impossible. Sampling, however, continued despite the damage. Results for that pass, and the next pass with the conventional system operating are also shown in Table 4. The average dust levels were significantly less for both systems than those measured on March 13th. Levels at the lead drum operator, with the conventional system operating had been reduced by over 60 percent; at the tail drum operator, they were down 25 percent. Levels at the lead drum with the shearer clearer operating were reduced by over 55 percent; at the tail drum operator they were down 23 percent. It was felt that these improvements are generally attributable to the changes made to both systems between March 13 and March 17. It should also be noted that, with the improvements, the shearer clearer system continued to show over 40 percent lower levels at the lead drum operator and over 35 percent lower levels at the tail drum operator than those for the improved conventional system.

Testing on March 18 was suspended because of bad roof conditions on the face. These conditions forced the mine to advance the shields immediately over the shearer making valid sampling impossible. Roof conditions, coupled with a miner's strike in northern West Virginia, forced suspension of further testing until early May.

On May 17, 1980, the shearer clearer system together with a new spring loaded splitter arm were reinstalled. Sampling however, again had to be suspended because of roof conditions. No further attempts were made to test the shearer clearer at the Blacksville No. 1 Mine.

The performance of the system, however, during the limited time when valid sampling was possible, was extremely encouraging. Reductions approaching 50 percent were documented, despite the abnormal roof conditions which prevented the system from being made fully operational.

3.3 Old Ben Coal Company - Old Ben Mine No. 25

The field evaluation at Mine 25 was initiated with a preliminary visit to the No. 2 longwall in September 1980. General section conditions are summarized in Table 5.

TABLE 5. - General face information

Longwall section surveyed	No. 2
Seam Height	84 in.
Type of shearer	Eickhoff EDW 300L
- Drum diameter	66 in.
- Web width	30 in.
Average face air velocity	200 to 230 fpm
Mining sequence	Uni-directional; head-to-tail primary cut; tail-to-head cleanup pass with trailing drum trimming bottom; roof supports and face conveyor advanced on head-to-tail pass.

3.3.1 Face Conditions During Preliminary Visit

The water spray system on the shearer during the preliminary visit is shown in Figure 33. The system consisted of the following:

- a. One cylindrical and one flat fan venturi mounted on a splitter support frame on the tailgate end of the shearer.
- b. One cylindrical venturi mounted on a short frame extending from the headgate end of the shearer.

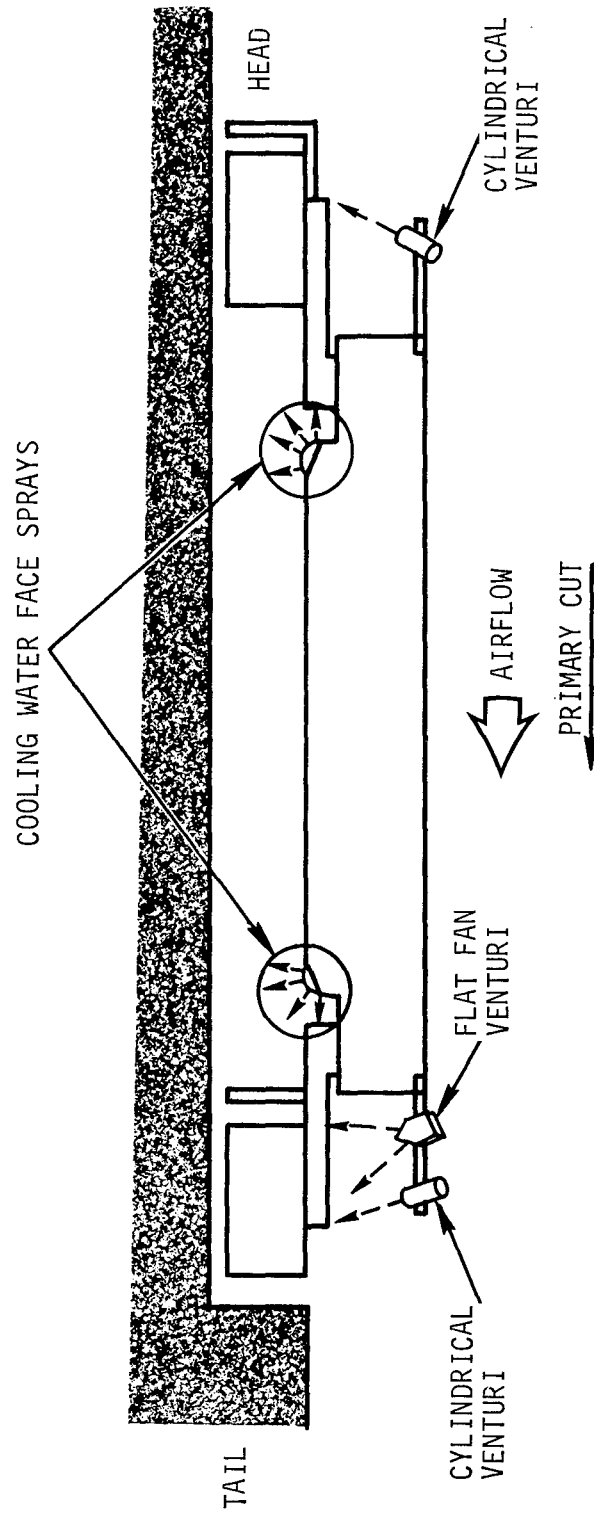


FIGURE 33. - Existing conventional water spray system.

- c. Four factory installed 90 deg flat fan sprays mounted on the face side of each gearhead unit to discharge cooling water.
- d. Thirty-two 90 deg flat fan sprays to flush the cutting zone in each drum.

An analysis and measurements of the section water supply system showed the following:

- a. The total water flow to the shearer during the head-to-tail cut fluctuated between 55 and 75 gal/min with all sprays (cooling and drum) fully open. Water flow to the shearer during the tail-to-head cleanup pass was 30 gal/min (valves one-half open).
- b. 66 percent of the flow ($\simeq 40$ gal/min) was used by 64 drum sprays.
- c. 34 percent of the flow ($\simeq 20$ gal/min) was used for cooling and discharged through the venturis and the factory installed spray manifolds.
- d. The dynamic pressure in the water supply line near the headgate was 300 psi while the operating pressure at the nozzle on the face manifolds was 75 psi. The operating pressure of the drum sprays was 25 psi. This resulted in respective pressure drops of 225 and 275 psi from the headgate to the shearer sprays.

Analysis of the section water supply system resulted in the following recommendations:

- a. To reduce the piping losses, the 1-1/4 in. I.D. supply hose between the headgate and the shearer should be replaced with 1-1/2 in. I.D. hose. This should result in a pressure recovery as great as 100 psi.
- b. To reduce the frequency of nozzle plugging, the Cuno disc-type water filter at the headgate should be replaced with a Conflow reverse flushing strainer. The Cuno type filter is normally supplied as the factory installed water filter on many continuous miners. It is not of sufficient size to handle the water flows found on longwall sections and results in a large pressure loss.

Dust data measured at the shearer operator's position during a head-to-tail cutting pass are shown in Figure 34. These levels, measured with an instantaneous dust monitor averaged 4.5 to 6.5 mg/m³ during normal cutting and over 10 mg/m³ when the shearer was cutting rock. Levels measured on the intake side of the shearer averaged 2 to 2.5 mg/m³. Combining these two sets of data indicates that shearer-generated dust was contributing 2 to 4 mg/m³ to the operators' exposure during normal cutting on the head-to-tail pass.

This conclusion was confirmed by data measured in the walkway by a stationary observer as the shearer cut to and past his sampling position. A typical dust profile is shown in Figure 35 for a head-to-tail cutting pass. Concentrations 15 ft on the intake side of the shearer average 2 to 2.5 mg/m³. As you get closer to the trailing drum, the levels increase to 4.5 to 6.5 mg/m³ and stay at that level along the shearer. This increase is due to the dust generated by the trailing drum cutting the bottom bench. As you approach and pass the leading drum, which is downwind of the operators, the levels increase to over 15 mg/m³ in the walkway.

Data measured during the tail-to-head cleanup pass and during sumping at the headgate, are shown in Figure 36. During most of this pass, dust levels are less than 4 mg/m³ indicating little shearer-generated dust at the operator's position. During the sumping operation, however, levels peaked at over 20 mg/m³ with most of this increase due to the dust generated by the leading drum.

During the preliminary visit, face ventilation velocities were also measured using a direct reading anemometer. Data measured during a typical head-to-tail pass is plotted in Figure 37 as a function of face location (shield number). The average face velocity was approximately 225 ft/min with some variation along the face.

The data from this preliminary visit indicated that shearer generated dust was a significant contributor to shearer operator exposures. An installation and evaluation of the shearer clearer system, therefore, was scheduled for late 1980.

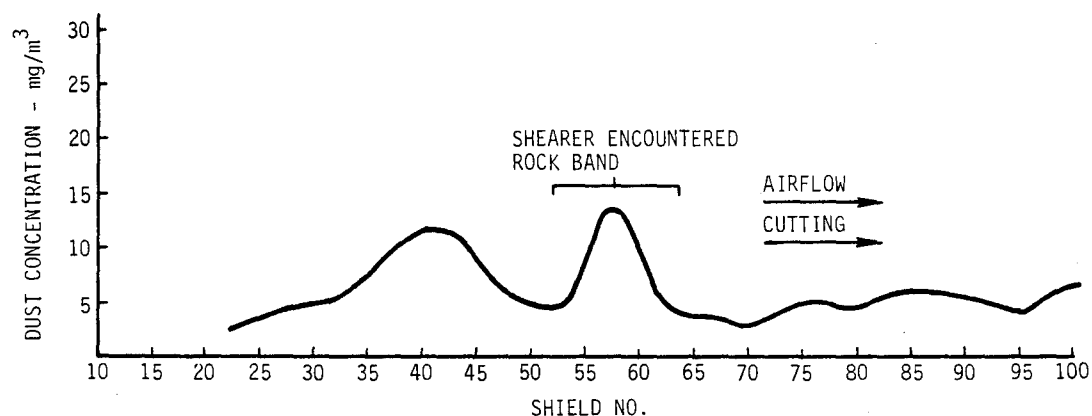


FIGURE 34. - Respirable dust concentrations, shear operator's position; head-to-tail pass.

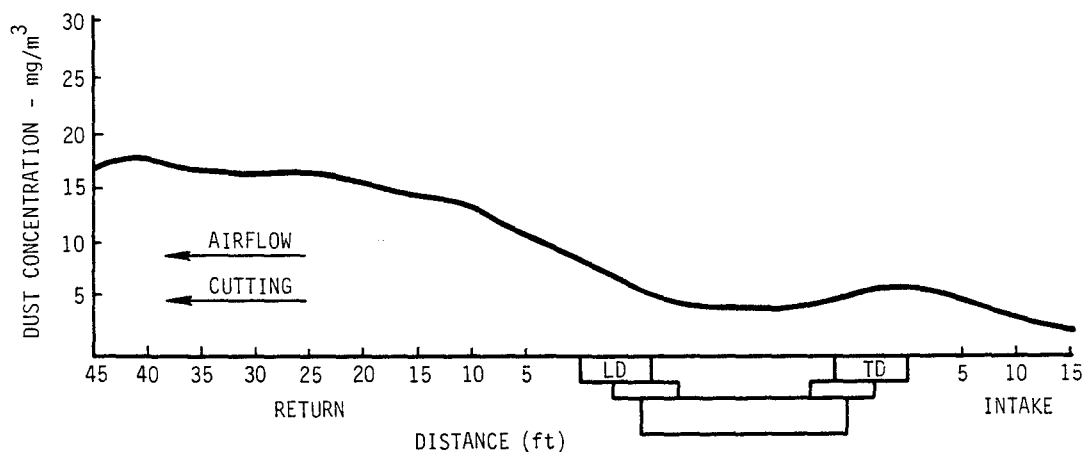


FIGURE 35. - Respirable dust concentration profile at shield no. 55; head-to-tail pass.

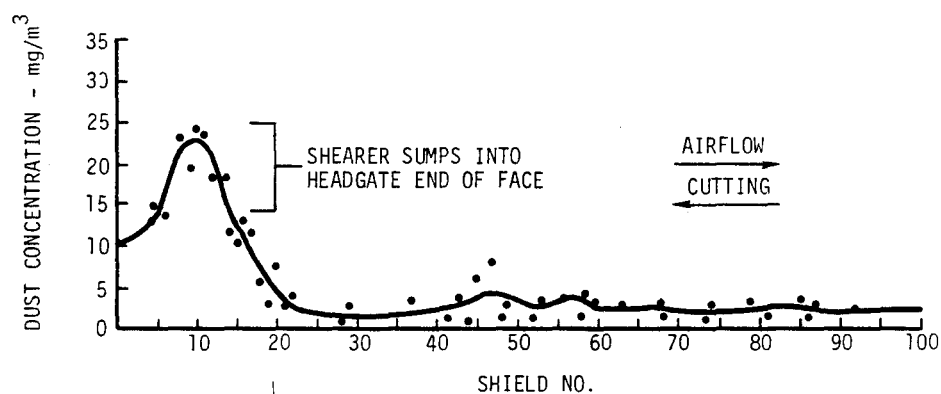


FIGURE 36. - Respirable dust concentrations. Shearer operator's position; tail-to-head pass.

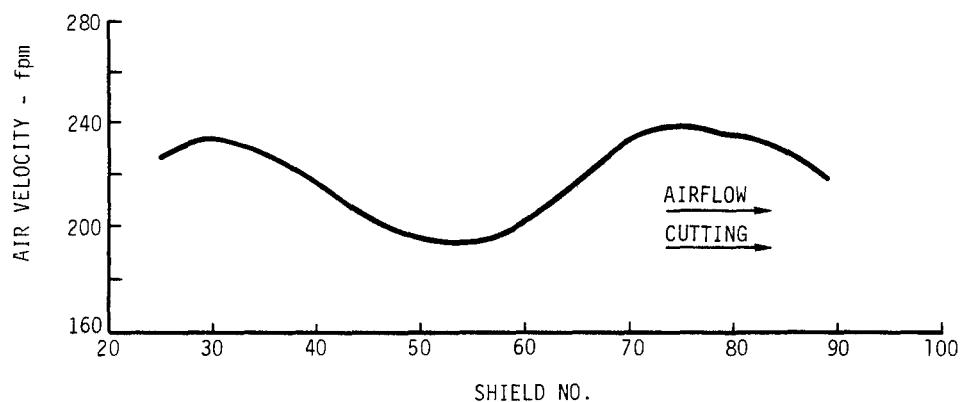


FIGURE 37. - Air velocity profile. 20 ft downwind from shearer; head-to-tail pass.

3.3.2 Underground Evaluation

The underground evaluation at Old Ben began in early November 1980. The test program involved two phases:

- a. November 10, 1980 to November 14, 1980 - First week of Shearer Clearer/Conventional System comparison testing
- b. November 17, 1980 to November 20, 1980 - Second week of Shearer Clearer/Conventional System comparison testing after system modifications.

Phase I: First Week - Installation and Testing

Between the preliminary survey and the first week of testing, mine personnel had performed the following modifications to the conventional water spray system (Figure 38):

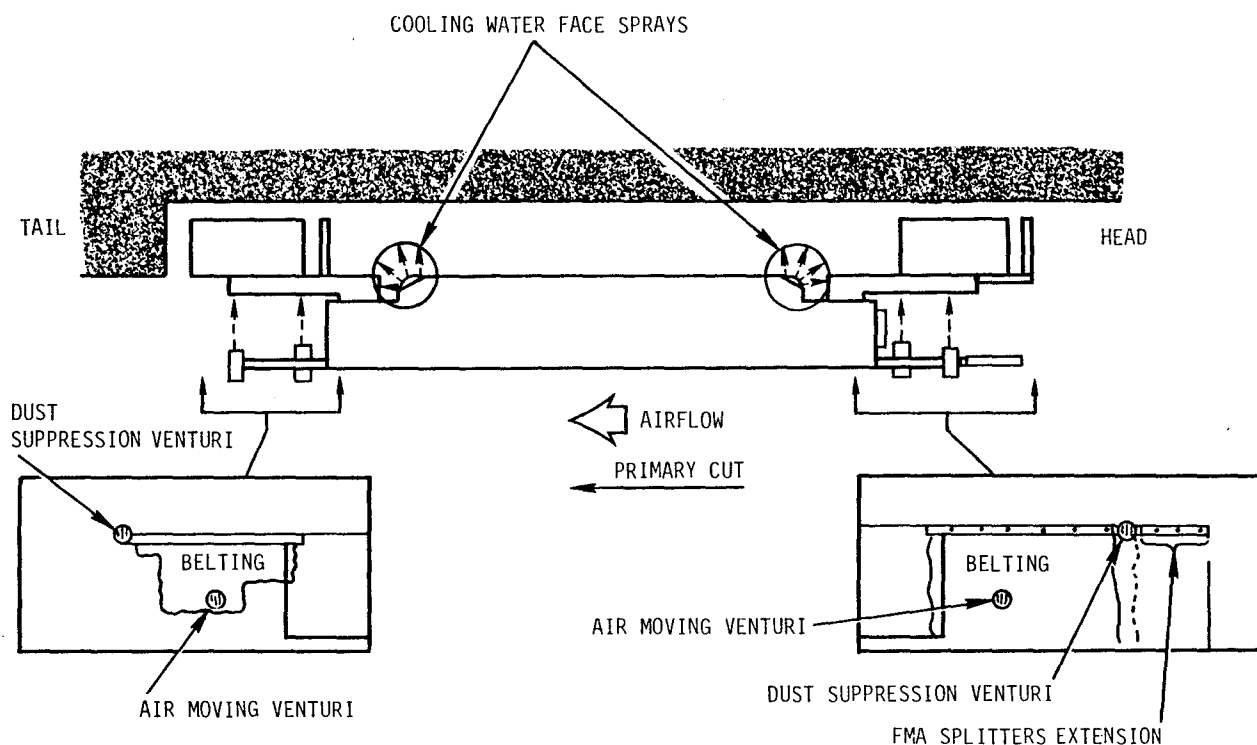


FIGURE 38. - Modified conventional water spray system.

- a. Two cylindrical venturis (one for air moving capability and one for dust suppression capability) were mounted on the splitter support frames on either end of the shearer.
- b. A flat fan venturi was attached to the headgate end of the shearer and directed down toward the panline.

The drum sprays and cooling water sprays were unchanged from the preliminary visit and the face water supply system had not been upgraded. As a result the dynamic water pressure measured at the shearer remained at 75 psi. Face ventilation, however, had been increased from approximately 200 to 290 ft/min. The mine had also modified their cutting sequence. During the head-to-tail cutting pass, the trailing drum was raised so that it performed little, if any, cutting. The bench left on the head-to-tail pass was then cut by the trailing drum (the downwind drum) on the tail-to-head cleanup pass.

The shearer clearer system installed for the first week of the demonstration is shown in Figure 39. The system consisted of 11 sprays (Spraying Systems BD20-2) mounted on the shearer body as indicated. These sprays were elevated above the shearer

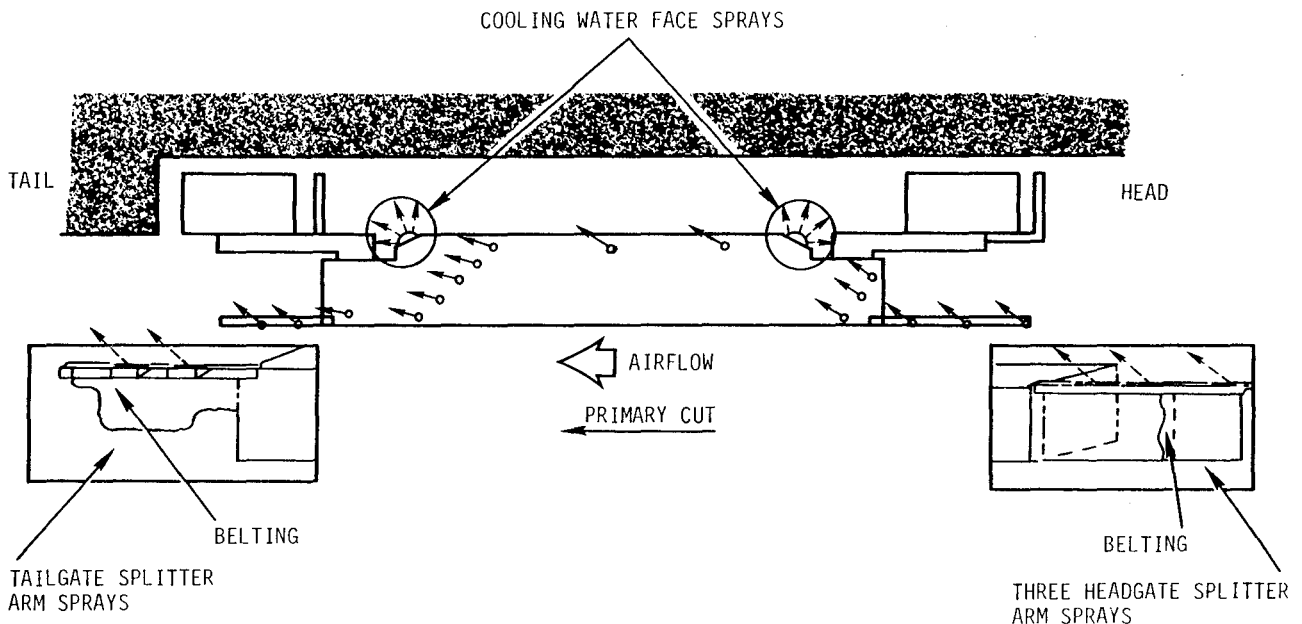


FIGURE 39. - Shearer clearer water spray system.

body using machined blocks and hydraulic hose to minimize spray blockage by rubble on top of the machine body. Three additional sprays were mounted on the headgate splitter support frame and two sprays were mounted on the tailgate splitter support frame. The drum sprays, cooling water face sprays and panline spray were operated with the shearer clearer. The shearer clearer and conventional systems were valved to allow the use of each spray system on alternating passes. System water pressure with the shearer clearer was also 75 psi, which is below system specification.

Testing of the conventional and shearer clearer and modified conventional systems on a pass by pass basis was initiated on November 19, 1980. Test results for the modified conventional system showed that modifications on the face since the preliminary trip had significantly reduced dust levels during the head-to-tail cutting pass.

Figure 40 shows dust levels measured at the shearer operator for typical head-to-tail passes during the preliminary visit and during the first week of testing. Test results showed a reduction of approximately 50 percent to 2.5 mg/m^3 . This level is close to the level measured on the intake side of the shearer indicating that shearer generated dust was having little impact on operator exposure levels.

Similar results (approximately 2 to 2.5 mg/m^3) were measured for the shearer clearer system. This result is to be expected in that the system is designed to control shearer generated dust. When little shearer generated dust is affecting the shearer operator's exposure, the shearer clearer will not show any improvement over a well designed conventional system.

Testing of the two systems on the tail-to-head cleanup passes also showed similar results. Again, the changes on the face resulted in little shearer generated dust at the operator's position during cleanup. The shearer clearer did show some improvement during the sump and cutout at the headgate. This improvement, however, was limited due to the lack of adequate water pressure.

Between testing weeks 1 and 2, several modifications were made including:

- a. The face water supply hose was changed from a 1-1/4 in. diam to 1-1/2 in. diam to decrease losses and increase water pressure at the shearer.

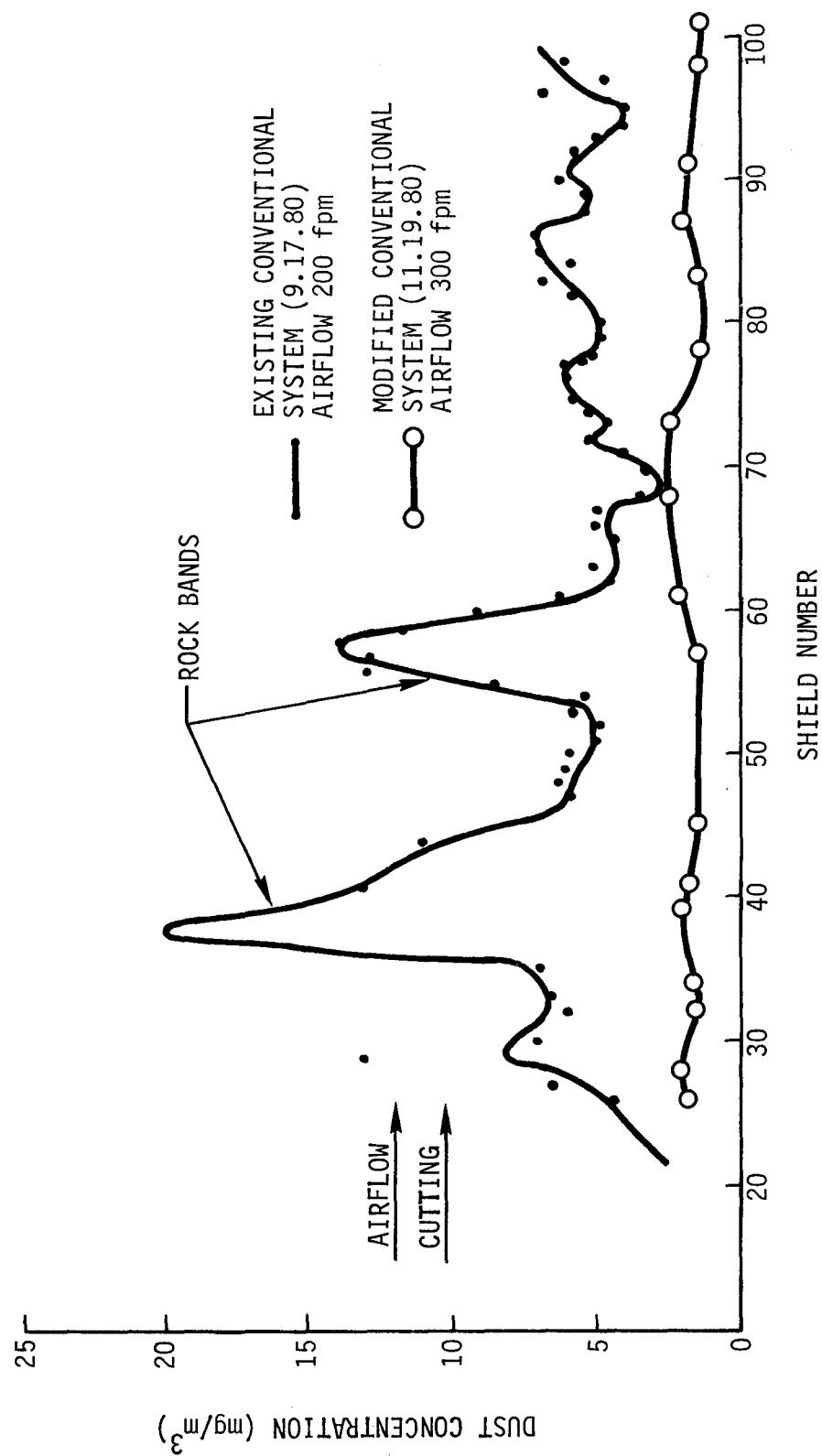


FIGURE 40. - Average respirable dust concentrations. Shearer operator's position; head-to-tail pass.

- b. The cooling water sprays were reoriented to spray downward onto the bench to reduce recirculation to the operators' positions.
- c. The shearer clearer system was modified, as shown in Figure 41 to reduce the airborne water mist. Modifications included removing four shearer mounted sprays at the tailgate end of the shearer and removing one spray from the headgate splitter frame.

The second week of testing was initiated on November 17, 1980. Again the test results showed no significant difference between the conventional spray system and the shearer clearer on both the head-to-tail cutting pass, and the tail-to-head cleanup pass. The shearer clearer system, however, did show significant improvements during the headgate cutout due to the increased pressure level.

Dust levels measured at the operators' positions during typical headgate cutouts using the conventional and shearer clearer systems are shown in Figure 42. Dust levels using the conventional system gradually increase as the shearer sumps starting at about shield 20 reaching 10 mg/m^3 before the drum cuts out into the headgate. As the drum cuts out, dust levels jump to over 18 mg/m^3 . With the shearer clearer operating, dust levels also start increasing at about shield 20 but level off at $5\text{-}6 \text{ mg/m}^3$ and jump to only $7\text{-}8 \text{ mg/m}^3$ as the drum cuts out. This represents a reduction of approximately 50 percent at the shearer operator.

With the shearer clearer showing no significant improvement over the conventional system, except during the headgate cutout, the testing strategy was changed. The purpose of the new strategy was to try to determine what changes made by the mine had caused the significant improvement between the preliminary trip and the evaluation period for the conventional system.

One of the changes was the increase in face air velocity from approximately 200 ft/min to 290 ft/min. To assess the effects of this change, the mine reduced the face ventilation to 200 ft/min for several passes. Dust levels at the shearer operator measured during typical passes at the two face airflows are shown in Figure 43. A comparison of the two passes shows that an increase in face airflow from 200 to 290 ft/min reduces the average concentration at the operator by approximately

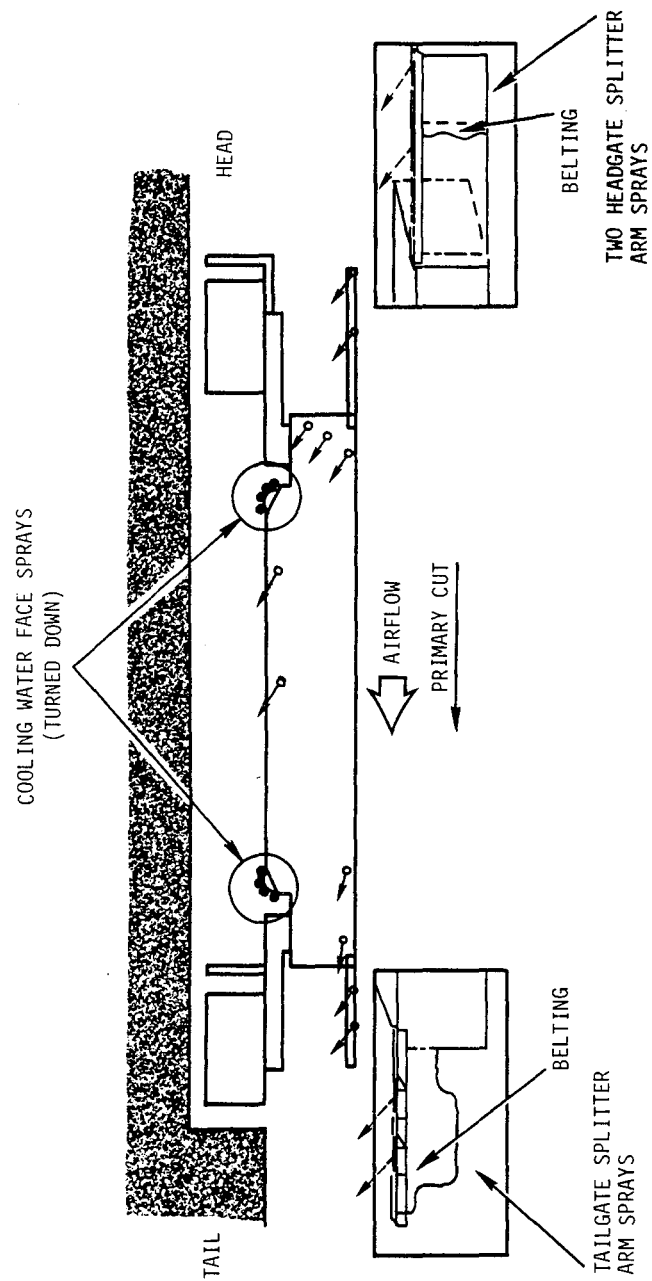


FIGURE 41. - Modified shearer clearer water spray system.

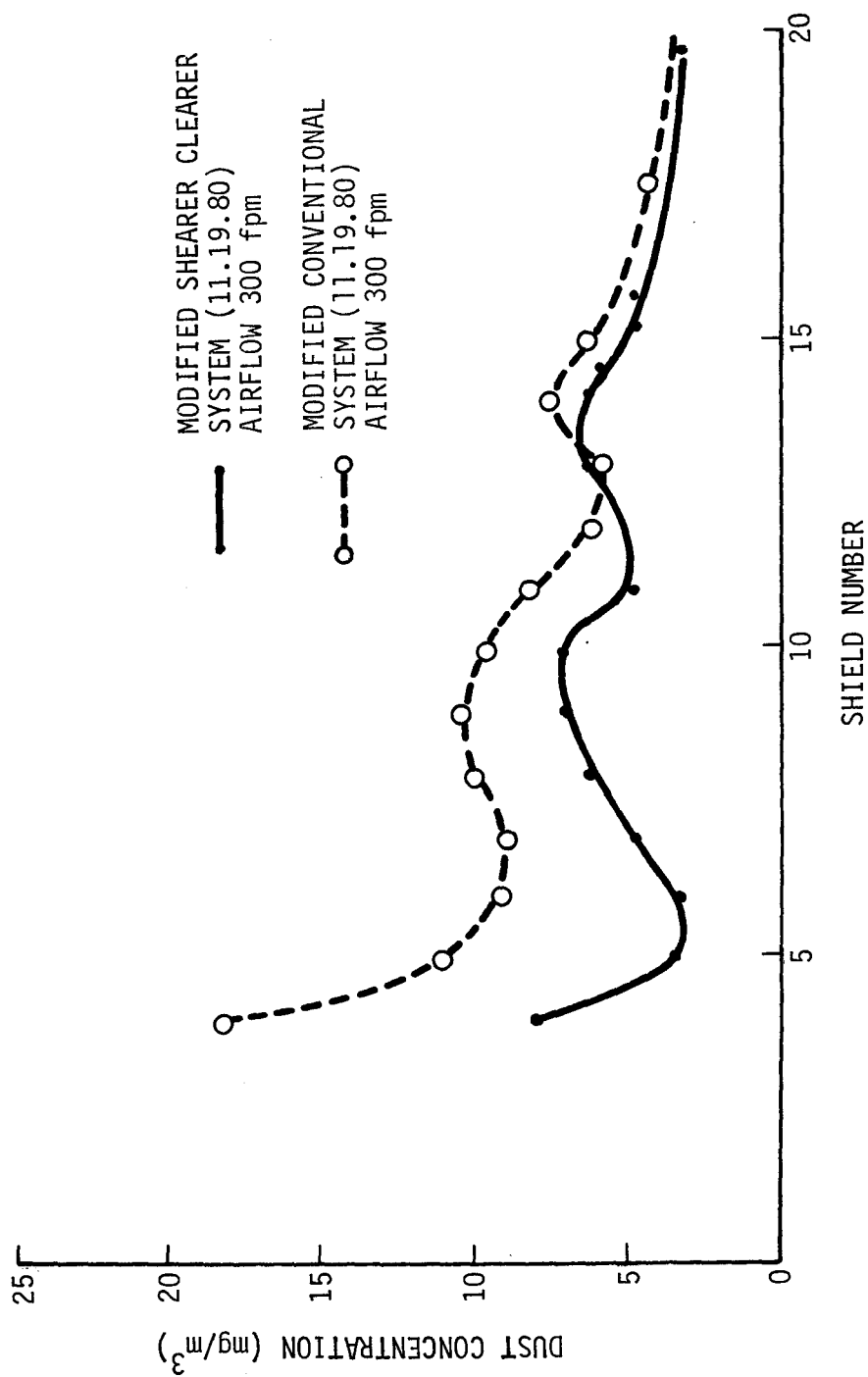


FIGURE 42. - Average respirable dust concentrations. Conventional versus modified shearer clearer spray system. Shearer operator's position; headgate cutout.

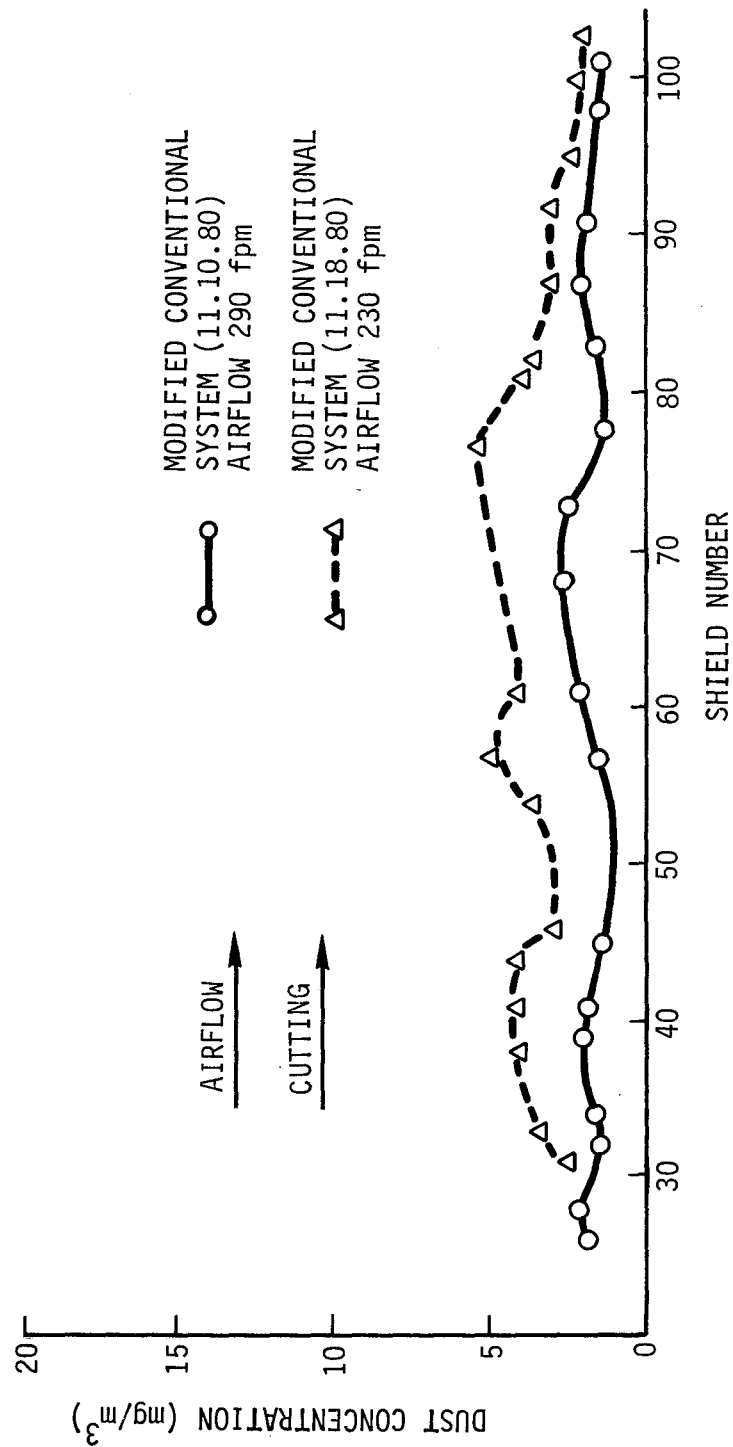


FIGURE 43. - Average respirable dust concentrations, shearer operator's position; two passes with the modified conventional system differing in airflow velocities.

50 percent to 1.9 mg/m^3 . This level is not significantly greater than that measured on the intake side of the shearer. It was concluded, therefore, that the increase in airflow was the most significant factor in reducing dust concentrations at the shearer operator during the cutting and cleanup passes.

3.4 Florence Mining Company - North American
Coal Corporation - Florence
No. 1 Mine

The field evaluation at Florence No. 1 Mine was initiated with a preliminary visit to the mine in June, 1980. General section conditions are summarized in Table 6.

3.4.1 Face Conditions During the Preliminary Visit

The preliminary visit to the Florence No. 1 Mine was made when the face was nearing the end of the panel. On that panel the water spray system consisted of the following:

- a. Four cylindrical venturi sprays were mounted on a splitter support frame which extended 5 ft 6 in.

TABLE 6. - General face information

Seam Height:	78 in.
Type of Shearer:	Anderson Mavor 300
Drum Diameter:	50 in.
Web Width:	30 in.
Average Face Air Velocity	200 - 300 fpm
Mining Sequence:	Bi-directional

from the headgate end of the shearer. These sprays were aimed at the cutting drum.

- b. Two cylindrical venturi sprays were mounted on a splitter support frame which extended 26 in. from the tailgate end of the shearer. These sprays were aimed at the cutting drum.
- c. Cooling water was dumped on the face through an open hose.
- d. Each drum was equipped with thirty-five pick point flushing sprays.

Dust measurements showed that the shearer operators were exposed to significant levels of shearer generated dust during both cutting directions. Visual observations showed that the dust cloud when cutting from head-to-tail was being pushed 15 ft upstream from the trailing drum and carried into the walkway by the primary ventilation. The cloud was particularly heavy when the upwind drum was cutting bottom rock. The upwind cloud was also evident when cutting from tail-to-head. In the cut direction the cloud could be seen as far as 20 ft upstream from the leading drum.

Plans were made to install the shearer clearer system on the shearer during a surface rebuild between panels, and to evaluate the system once the new panel was in full production.

3.4.2 Underground Evaluation

The shearer clearer was installed in late September, 1980 in Florence Mining's rebuild shop. The underground evaluation at Florence No. 1 was started in early December 1980 after the gob fall on the new panel. The test program involved two phases:

- a. December 2 to 12, 1980: First week of shearer clearer/conventional system comparison testing.
- b. January 5 to 9, 1981: Second week of shearer clearer/conventional system comparison testing with upgraded water supply system.

The conventional spray system on the shearer during the first week of the evaluation is shown in Figure 44. The system included:

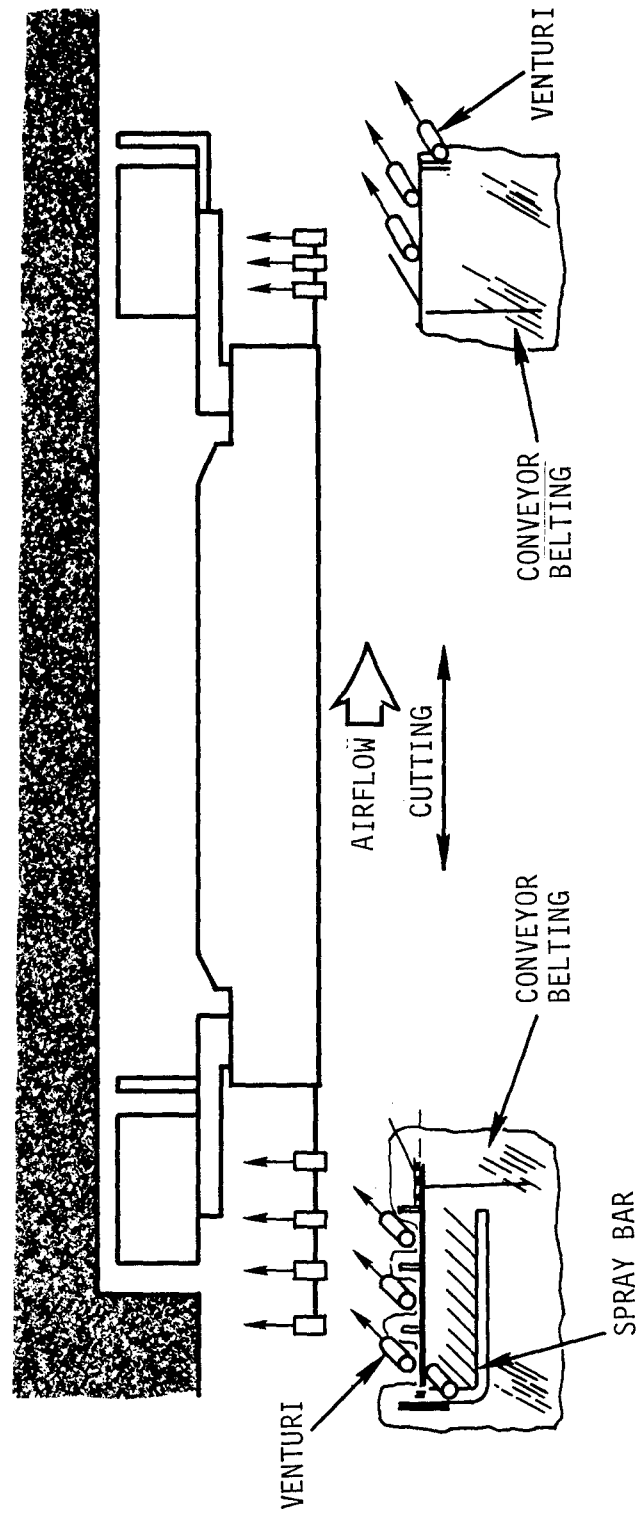


FIGURE 44. - Conventional water spray system.

- a. Four cylindrical venturis mounted on a splitter support frame extending from the headgate end of the shearer. The sprays were aimed at the cutting drum, perpendicular to the primary airflow and angled slightly upward.
- b. Fifteen Spraying Systems Type 1/4 VV6503 flat fan sprays were mounted on an L-shaped bracket suspended from the headgate splitter arm. These sprays were also aimed at the drum, perpendicular to the primary airflow and slightly upward.
- c. Three cylindrical venturis were mounted on a short splitter arm extending from the tailgate end of the shearer. These sprays were aimed at the drum, perpendicular to the primary airflow and slightly upward.
- d. Thirty-five pick point flushing pencil jet sprays in each cutting drum.
- e. A spray nozzle with a drilled-out orifice was used to dump cooling water on the face side of the machine.

The dynamic water pressure at the shearer was approximately 75 psi with a total flow of 45 gpm.

The shearer clearer system installed for the first week of the demonstration is shown in Figure 45. The system consisted of ten sprays (Spraying Systems BD20-2) mounted on the shearer body as shown. These sprays were elevated above the shearer body using machined blocks and hydraulic hose to minimize spray blockage by rubble on top of the machine body. An additional five sprays were mounted on the splitter support frame on the headgate end of the shearer and two sprays were mounted on the tailgate splitter support frame.

The two systems were valved to allow the use of each spray system on alternating passes. Testing of the two systems was initiated on December 8, 1980.

During the first week test results showed the following:

- a. Intake contamination levels measured upstream from the shearer were much higher than had been measured on the preliminary visit. These higher levels were

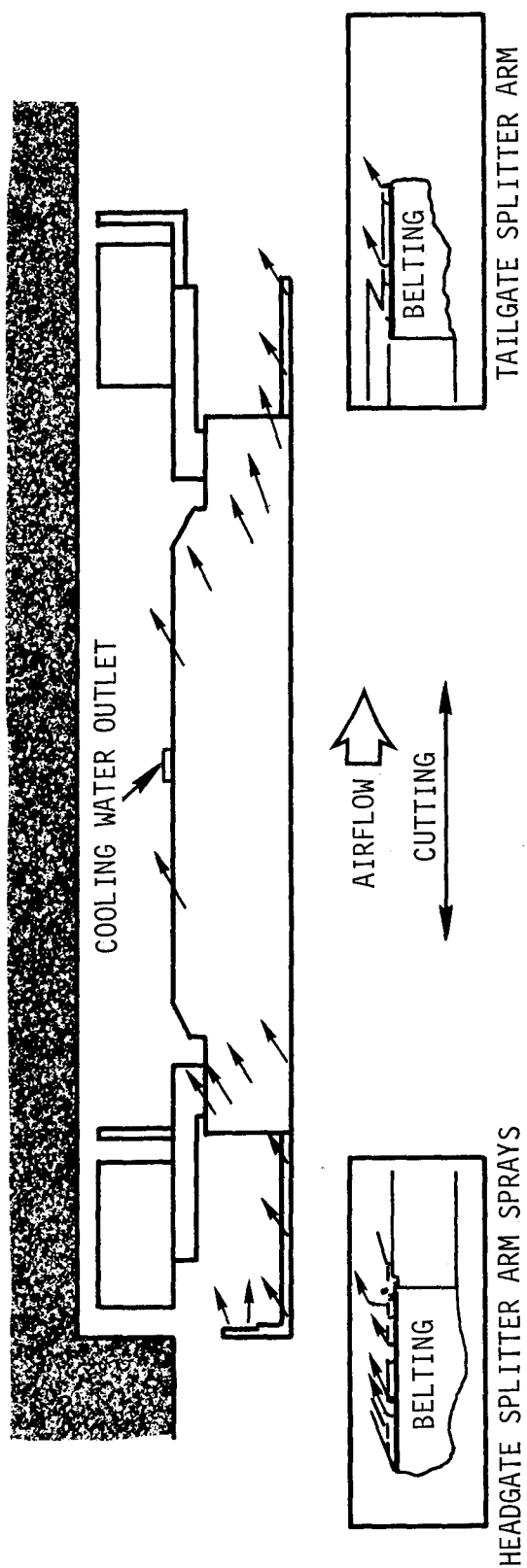


FIGURE 45. - Shearer clearer water spray system.

mainly due to dust being generated at the face conveyor to stageloader transfer point and at the headgate crusher.

- b. Significant quantities of air were leaking to the gob between the rib and the first shield, causing low face velocities along the face.
- c. There was inadequate water pressure (75 psi) at the shearer for the shearer clearer to operate properly.
- d. Inadequate filtration of the face water supply was causing excessive spray nozzle plugging.
- e. The shearer clearer sprays mounted on the top of the tailgate end of the shearer were creating excessive water mist which reduced operator visibility.

Between the first and second weeks of testing, mine personnel performed the following modifications:

- a. The water pump was rebuilt, which increased the output pressure from approximately 450 to 675 psi.
- b. A flushable Y strainer (1/8 in. perforated screen) was installed in line with a hydrocyclone (Krebs Model W4U) inby the pump.
- c. A partial enclosure was fabricated for the crusher discharge chute in the headgate. A manifold with eight Spraying Systems Type 1/4 VV 6503 flat fan sprays was installed inside the enclosure. Sprays inside the crusher enclosure which were plugged during the first week of testing were refurbished.
- d. Two Spraying Systems BD3 sprays were installed at the transfer from the face conveyor to the stageloader. A third BD3 spray was installed at the transfer from the crusher chute to the panel belt.
- e. A curtain was installed between the first shield and the rib to minimize intake air losses to the gob.
- f. Eight sprays on the gob side of each drum were blocked and reducing orifices were installed on each drum circuit.

- g. A Spraying System BD20-2 nozzle was installed on the cooling jacket circuit outlet to increase flow and pressure to the shearer mounted sprays. The spray was mounted on the face side of the shearer protected by a shroud and pointed with the primary airflow.
- h. The L-shaped bracket and sprays mounted on the lower support frame of the splitter on the headgate end of the shearer were removed.
- i. The shearer clearer system was modified as shown in Figure 46. Five of the shearer mounted sprays were removed. One spray was added in the tailgate splitter arm.

The results of the testing performed during the two phases at Florence No. 1 are presented in the following subsections:

- a. Air Velocity Profiles: Comparison of weeks 1 and 2
- b. Intake Contamination on the tail-to-head pass: Comparison of weeks 1 and 2
- c. System Comparisons:
 - 1. Respirable dust concentrations at the shearer operator
 - 2. Respirable dust concentration profiles.

For all testing, instantaneous respirable dust concentrations were monitored only while the shearer was cutting and loading coal at normal haulage speeds.

Air Velocity Profiles: Comparison of Weeks

During both weeks of the demonstration, the air velocity along the face was monitored as a function of face position. The velocities were measured approximately 20 ft on the intake side of the shearer. Figure 47 shows the average face velocities measured during the first and second weeks as a function of shield number. The average velocity increased by approximately 30 percent during the second week. This increase was due mainly to the installation of the curtain between the first shield and the rib, minimizing the loss of intake air to the gob at the headgate.

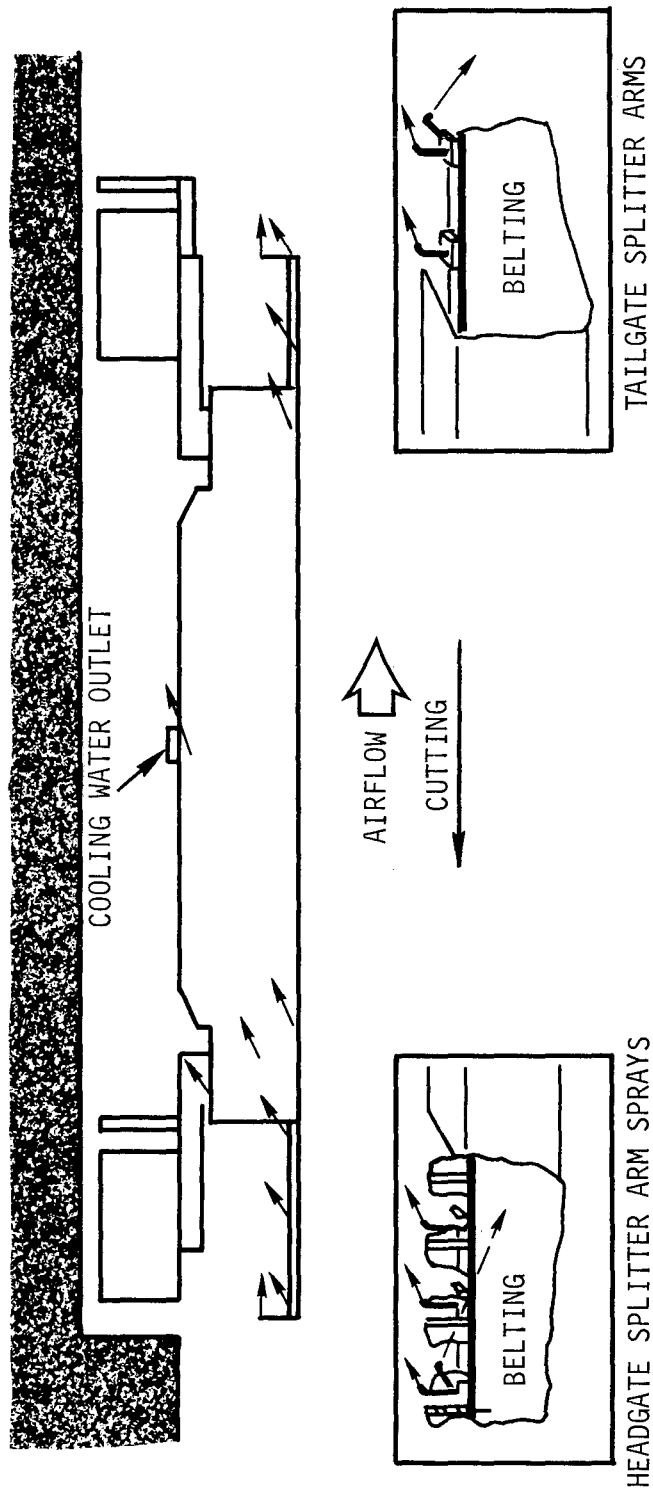


FIGURE 46. - Modified shearer clearer water spray system.

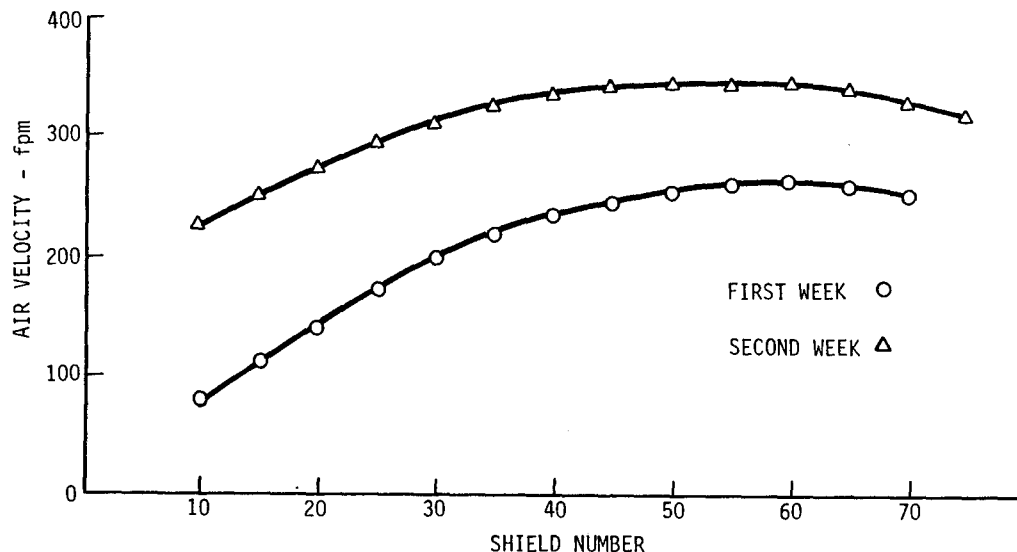


FIGURE 47. - Average face air velocity profiles.

Intake Contamination on the Tail-to-Head Pass: Comparison of Weeks

Intake contamination was monitored for each pass of the evaluation as a function of position on the face. Figure 48 shows the average intake concentrations for tail-to-head passes for both weeks. A significant reduction in intake contamination was achieved during the second week. This was largely due to the addition of belting and sprays in the headgate and the increased face velocities. Intake concentrations monitored during head-to-tail passes showed similar reductions. However, dust concentrations were higher and more variable than those measured on tail-to-head passes due to shield generated dust upstream of the shearer.

Respirable Dust Concentrations at Shearer Operator's Position

The effectiveness of the changes made between weeks 1 and 2 and the operation of the shearer clearer system is shown for the tail-to-head pass in Figure 49. The average total respirable dust concentrations at the shearer operator's position are plotted as a function of shearer position on the face (shield number). Concentrations are shown for the conventional system (weeks 1 and 2) and for the shearer clearer (week 2).

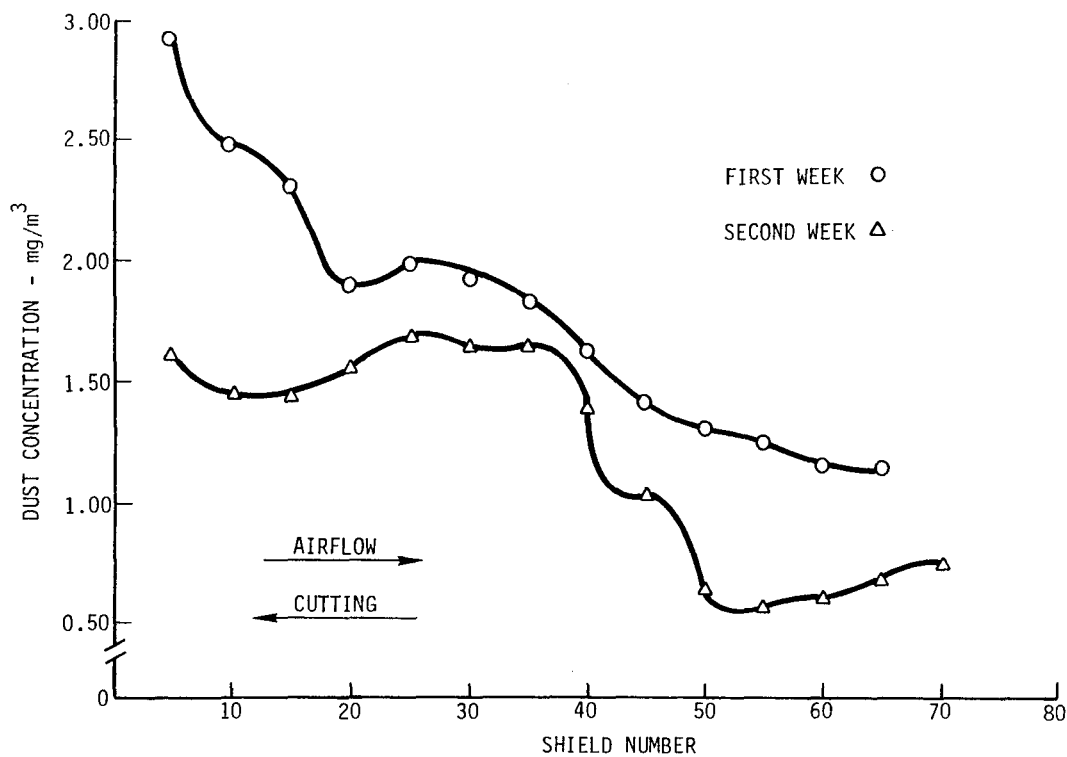


FIGURE 48. - Average intake respirable dust concentrations. Tail-to-head pass.

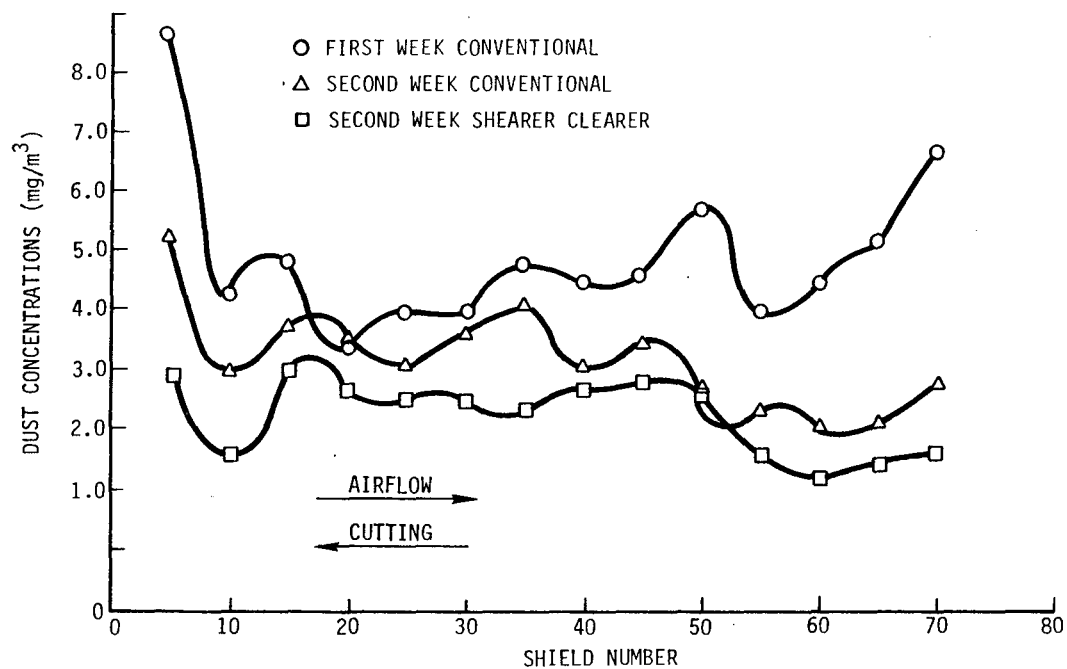


FIGURE 49. - Average respirable dust concentrations. Shearer operator's position; tail-to-head pass.

The improvement (percent reduction) between the conventional system of week 1 and the shearer clearer system of week 2 is shown in Figure 50 as a function of shield number. The average reduction achieved during the demonstration was 40 percent for the tail to head pass.

Figures 51 and 52 show similar results for the head-to-tail pass. The average reduction achieved was 49 percent between the conventional spray system of week 1 and the shearer clearer system of week 2.

Respirable Dust Concentration Profiles

Figures 53 and 54 show respirable dust concentration profiles around the shearer for tail-to-head and head-to-tail passes respectively. Profiles are shown for the conventional spray system and the shearer clearer system. These profiles

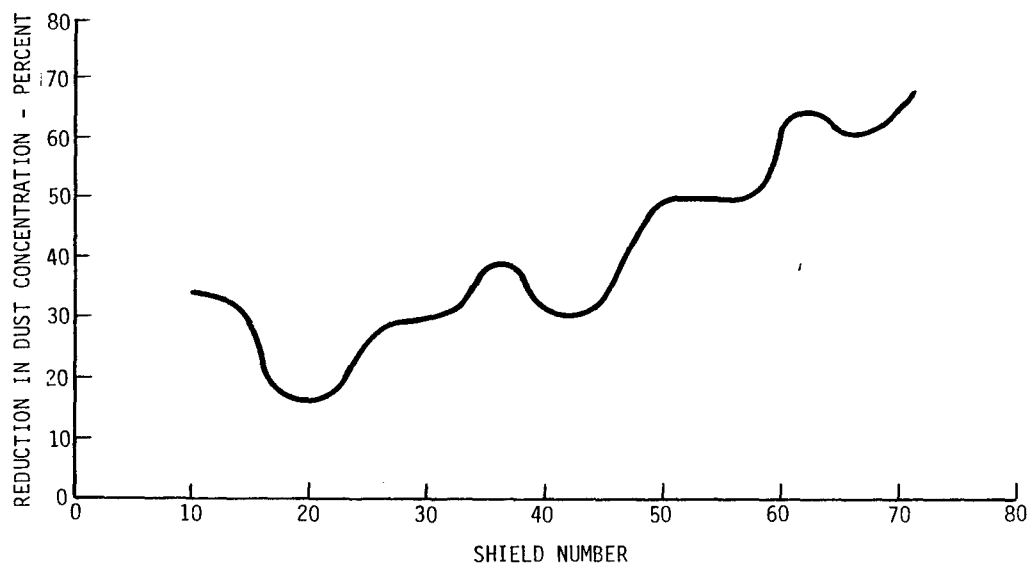


FIGURE 50. - Reduction in average respirable dust concentrations. Conventional versus modified Shearer Clearer Spray System. Shearer operator's position; tail-to-head pass.

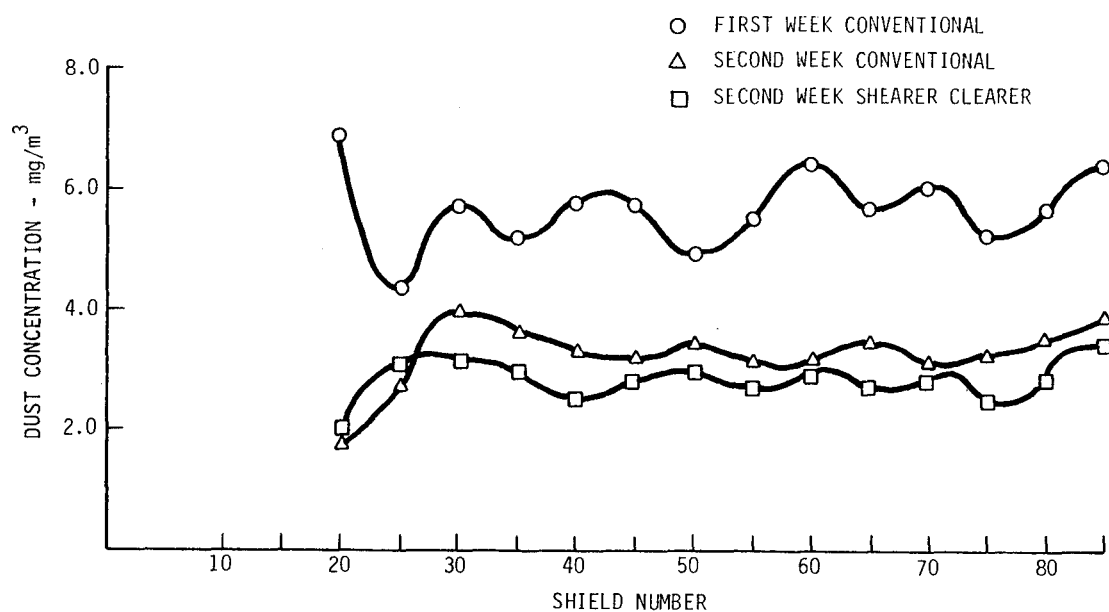


FIGURE 51. - Average respirable dust concentrations. Shearer operator's position; head-to-tail pass.

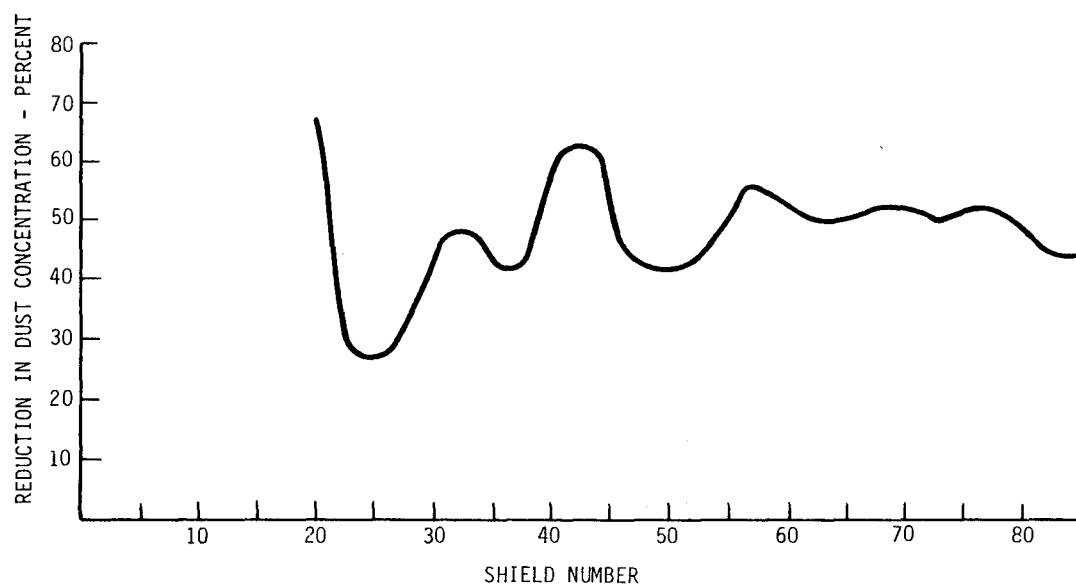


FIGURE 52. - Reduction in average respirable dust concentrations. Conventional versus modified Shearer Clearer Spray System. Shearer operator's position; head-to-tail pass.

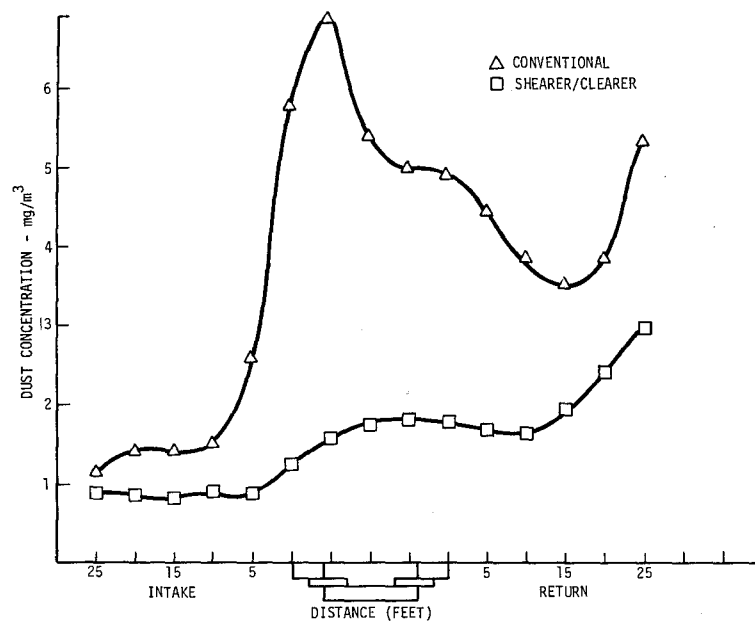


FIGURE 53. - Respirable dust concentration profiles around the shearer; tail-to-head pass.

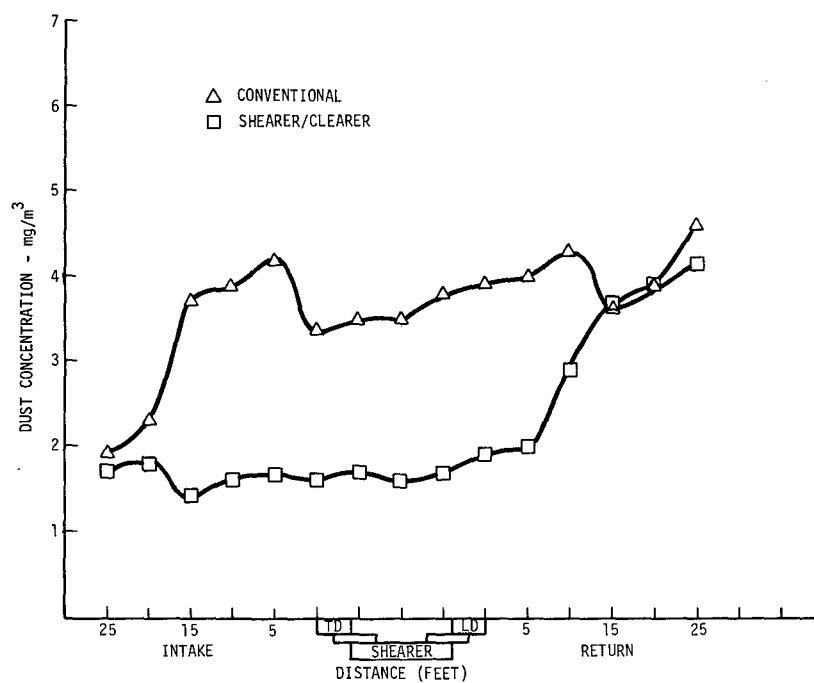


FIGURE 54. Respirable dust concentration profiles around the shearer; head-to-tail pass.

were monitored by sampling personnel using instantaneous dust monitors at a fixed face location. The dust data represents concentrations in the walkway as the shearer cuts to and past the sampling position.

The effectiveness of the shearer clearer in controlling shearer generated dust, is clearly illustrated by these profiles. On the tail-to-head cutting pass, the concentration in the intake air measured 20 ft upstream of the shearer, is approximately 1 mg/m^3 for both systems. As the leading drum approaches the sampling position, the dust concentration in the walkway with the conventional system operating starts to increase 10 ft upstream of the drum and peaks at over 6 mg/m^3 near the lead drum operator's position. The level in the walkway continues at over 4 mg/m^3 along the entire length of the shearer. With the shearer clearer system, the concentration in the walkway is maintained at less than 2 mg/m^3 until the shearer has completely cut past the sampling positions.

This difference between the two systems is mainly due to the shearer clearer confining the dust cloud generated by the leading drum and preventing it from spreading into the walkway.

The effectiveness of the shearer clearer is also clear in the profiles measured during the head-to-tail cutting pass. On this pass the dust concentrations with the shearer clearer operating are essentially maintained at the level measured in the intake, until the sampling position is downwind of the leading drum. The concentrations with the conventional system, on the other hand, start increasing 10 to 15 ft upwind of the trail drum and average 2 to 2.5 mg/m^3 higher than the intake level along the entire length of the shearer.

3.5 Emery Mining Corporation - Deer Creek Mine

The field evaluation at the Deer Creek Mine was initiated with a preliminary visit to the mine in August, 1980. General section conditions are summarized in Table 7.

3.5.1 Face Conditions During the Preliminary Visit

The water spray system on the shearer during the preliminary visit is shown in Figure 55. The system consisted of the following:

TABLE 7. - General face information

Seam Height:	102 - 104 in.
Type of Shearer:	Eickhoff EDW 300L
Drum Diameter:	72 in.
Web Width:	32 in.
Average Face Velocity:	150 - 200 fpm
Mining Sequence:	Uni-directional; head-to-tail primary cut; tail-to-head clean-up pass with drums trimming bottom; roof supports and conveyor advanced on the head-to-tail pass.

- a. Twelve Senior Conflow Type 1188/41 spray nozzles were mounted on a spring loaded arm on the headgate end of the shearer. The sprays were oriented as shown in Figure 55.
- b. Twelve Senior Conflow Type 1188/41 spray nozzles were mounted on a spring loaded arm in the tailgate end of the shearer and oriented as shown.
- c. Two manifolds, each containing four Senior Conflow Type 1188/41 spray nozzles were mounted on the top of the shearer towards the tailgate end and aimed toward the tailgate drum.
- d. Six Spraying Systems Company Type BD3 nozzles were mounted on the underside of the shearer body spraying into the underframe.
- e. Eight flat fan spray nozzles were mounted on both the headgate and tailgate gearheads to discharge cooling water. The location and orientation of these sprays are shown in Figure 55.

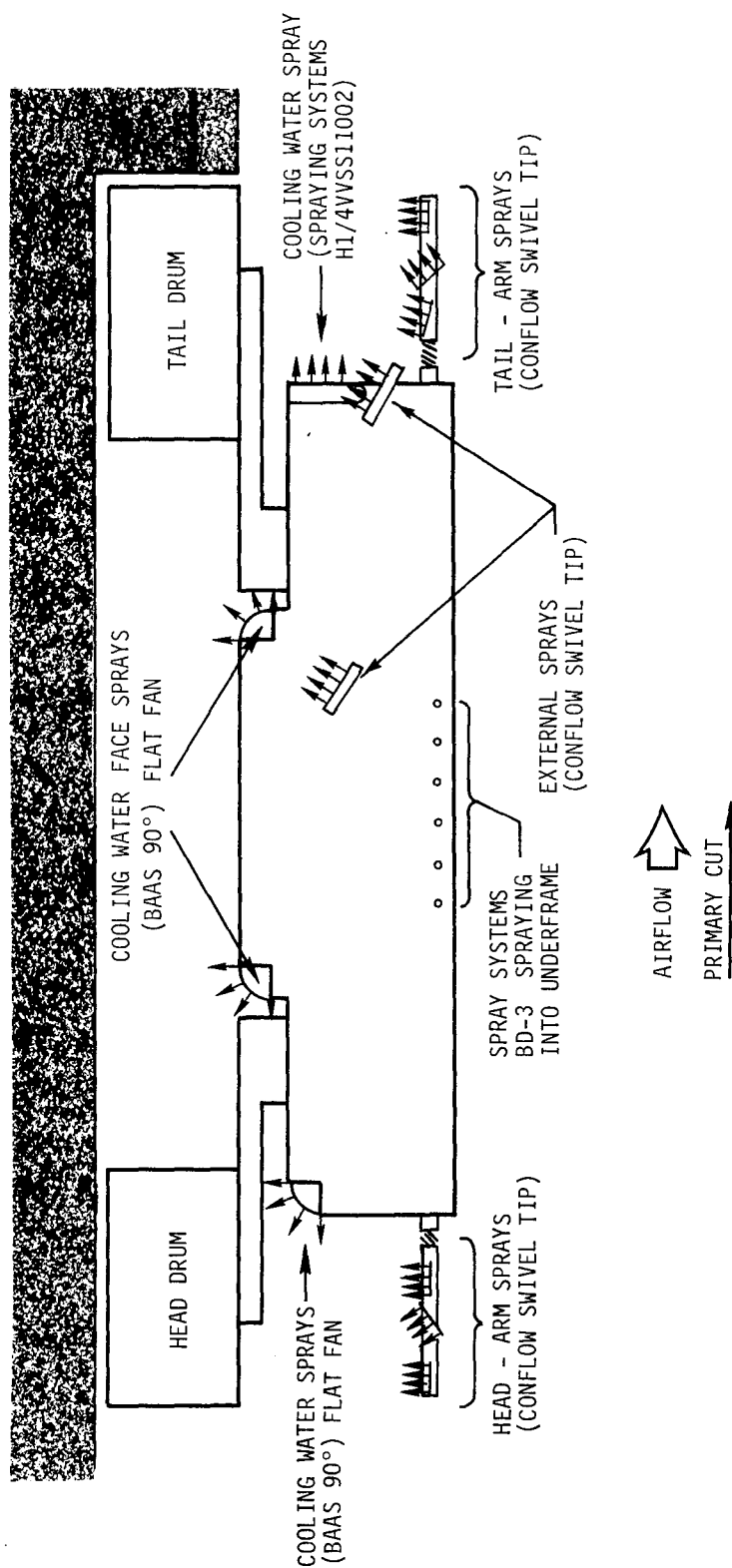


FIGURE 55. - Existing conventional water spray system.

- f. Each drum was equipped with cutting zone flushing type sprays. *These sprays, however, were inoperable.*

In addition to the shearer mounted sprays, the section was equipped with shield mounted sprays. Every fifth shield was equipped with three Spraying Systems Company Type BD3 spray nozzles. These sprays were only operated on the tail-to-head cleanup pass. The sprays were turned on by the shearer operators.

An analysis and measurements of the section water supply system showed that the section water supply pump was operating at 650 psi. The operating pressure at the shearer spray nozzles was only 70 psi. Total flow on the shearer was approximately 43 gpm.

Further analysis of the water supply system accounted for the following system pressure losses.

- a. Forty (40) psi was lost in the 2,000 ft of 3 in. hard pipe leading to the panel from the pump.
- b. Seventy (70) psi was lost in the 1-1/4 in. hose leading from the hard pipe to the headgate.
- c. Twenty (20) psi was lost in the Conflow reverse flushing strainer (assuming it was clean).
- d. One hundred eighty-five (185) psi was lost in the 1-1/4 in. hose between the headgate and the shearer.
- e. Ten (10) psi was lost in miscellaneous fittings and hosing in the shearer.

While this accounts for only 325 psi of the 580 psi pressure drop measured, it gave an indication of where losses arose. The discrepancy may be accounted for by plugged filters, obstructions in the line, and kinked hoses.

Dust level measurements, using instantaneous samplers, on the head-to-tail cutting pass showed an average concentration at the shearer operator's position of approximately 8.5 mg/m³. Measurements made 20 ft upstream of the shearer showed intake contamination averaging 2.0 mg/m³. The difference between the

two indicated that the shearer was contributing approximately 6.5 mg/m^3 to the operator's exposure during cutting.

Data for the head-to-tail pass measured by a fixed point sampler in the walkway as the shearer cut to and past the sampling point, is shown in Figure 56. Results for three sampling positions (shields 30, 70, 100) are shown. Dust levels on the intake side of the shearer average 2 to 2.5 mg/m^3 . As the sampling point gets closer to the trailing drum, the levels increase to 5 - 10 mg/m^3 and continue to increase along the lengths of the shearer, again indicating the significant contribution of shearer generated dust to operator exposure levels during cutting.

Data measured during the tail-to-head cleanup pass showed an average intake concentration of 1.0 mg/m^3 and an average operator concentration of 3.6 mg/m^3 . The difference between the two indicated that the shearer was adding approximately 2.5 mg/m^3 to the operator's exposure during the cleanup pass.

The analysis of the dust data indicated that a shearer clearer spray system could significantly reduce operator dust exposures. The water system analysis, however, showed that existing water pressure at the shearer would be inadequate for good system performance. To improve pressure to the shearer, the following recommendations were made:

- a. The 1-1/4 in. I.D. hose sections between the hard pipe and the headgate, and between the headgate and the shearer, should be replaced with 1-1/2 in. I.D. hose.
- b. The strainer baskets at the headgate and pump should be replaced.
- c. The sheave on the Kobe RGB-150 pump should be changed to increase pump output.
- d. An improved filtration system should be installed.

This information, together with specifications for the shearer clearer were forwarded to Emery.

3.5.2 Underground Evaluation

The underground evaluation was started in early August, 1981. This evaluation was different in that the testing of the conventional and shearer clearer systems was carried out separately

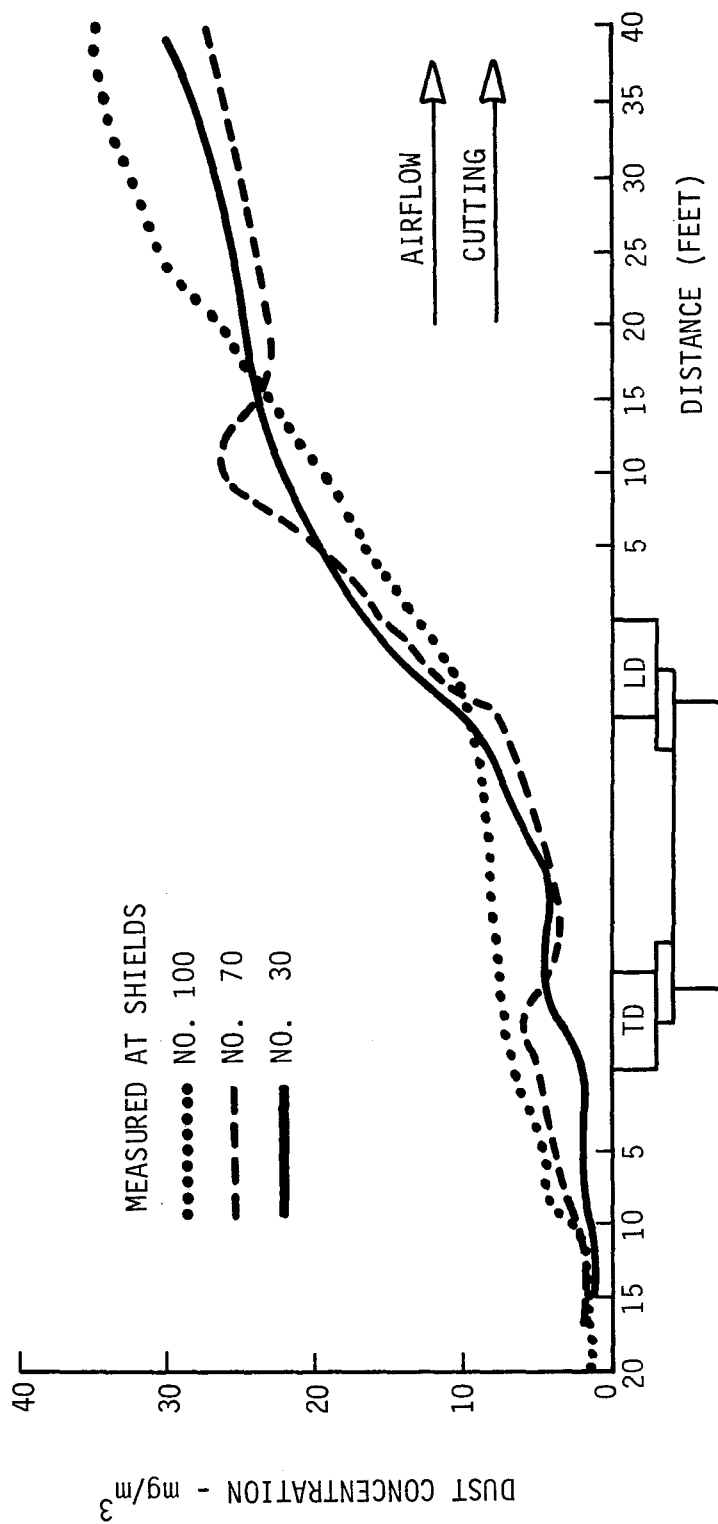


FIGURE 56. - Respirable dust concentration profiles around the shearer; head-to-tail pass.

rather than on a pass-by-pass basis. The program was carried out in three phases:

- a. August 3 to August 8 - Evaluation of Emery's conventional spray system with shield sprays operating
- b. August 9 to August 15 - Evaluation of Emery's conventional spray system *without* shield sprays operating
- c. August 16 to August 26 - Installation and evaluation of the shearer clearer system.

The conventional spray system was the same as that used during the preliminary visit and shown in Figure 55. The mine had instituted several of the recommended changes for the water system. These changes increased the dynamic pressure at the shearer to 300 psi and the total flow to 70 gpm. In addition, up to 20 sprays per drum were now operating, and the average face velocity had been increased to 250 to 300 fpm.

During testing, instantaneous dust levels were measured at the operator's position and on the intake side of the shearer when it was cutting and loading coal. Table 8 presents the average concentrations for both sampling positions for the head-to-tail cutting pass and the tail-to-head cleanup pass. These data represent conditions with the shield sprays operating.

Table 8. - Average respirable dust concentrations with conventional spray system and shield sprays.

Sampling Position	Concentration - mg/m ³	
	Head-to-Tail Pass	Tail-to-Head Pass
Shearer Operator	3.24	3.81
Intake (20 ft outby Operator's Position)	2.44	1.40

The results for this test condition are very similar to those measured during the preliminary trip on the tail-to-head cleanup pass. Dust concentrations at the operator's position during the head-to-tail cutting pass, however, are significantly reduced. Intake levels for this pass are approximately the same, which indicates that there is significantly less shearer generated dust affecting the operator than had been seen on the preliminary trip. This reduction was suspected due to the increased flow and pressure to the shearer, the refurbishment and use of drum sprays, and the increase in airflow on the face.

During the second week of testing, dust levels were again monitored using instantaneous samplers. The conventional spray system was used, but the shield sprays were turned off. Average respirable dust concentration data for this week of testing is shown in Table 9.

Comparing the results for sampling with and without shield sprays shows no significant difference. This would indicate that shield sprays under the conditions in this face were having no significant effect on dust concentrations at the shearer operators positions while the shearer is cutting and loading coal.

Table 9. - Average respirable dust concentrations with the conventional spray system alone.

Sampling Position	Concentration - mg/m ³	
	Head-to-Tail Pass	Tail-to-Head Pass
Operator	3.26	2.83
Intake (20 ft outby Operator's Position)	2.60	0.94

In preparation for the third week of testing, on August 15, the conventional system was removed and the shearer clearer system was installed as shown in Figure 57. The shearer clearer installation included:

- a. A passive barrier (or "splitter arm" cantilevered from either end of the shearer
- b. Eight sprays (directed downwind) mounted on top of the shearer body
- c. Three sprays mounted on each splitter arm (directed downwind)
- d. Redirected cooling water discharge sprays
- e. Blocking the gap in the underframe between the gear drives with belting.

Evaluation of the shearer clearer spray system began on Monday, August 17. Monday was the *only* day that valid test results were obtained. Thereafter, severe clearance problems were encountered in the headgate entry and along the face as the cut seam height pinched down. Conditions deteriorated as the week progressed, virtually eliminating the clearance over the top of the shearer body. This resulted in severe damage to the system and made further testing invalid.

The small amount of data collected during the week is not sufficient to make any *detailed* comparisons between the conventional and shearer clearer systems. However, the data *did* indicate that the shearer clearer would be effective in reducing dust concentrations at the shearer operator's position, if adequate clearance over the top of the shearer body could be maintained. Performance of the system during the headgate cutout was particularly promising. Dust concentration reductions of up to 50 percent were recorded at the operator's position during the cutout.

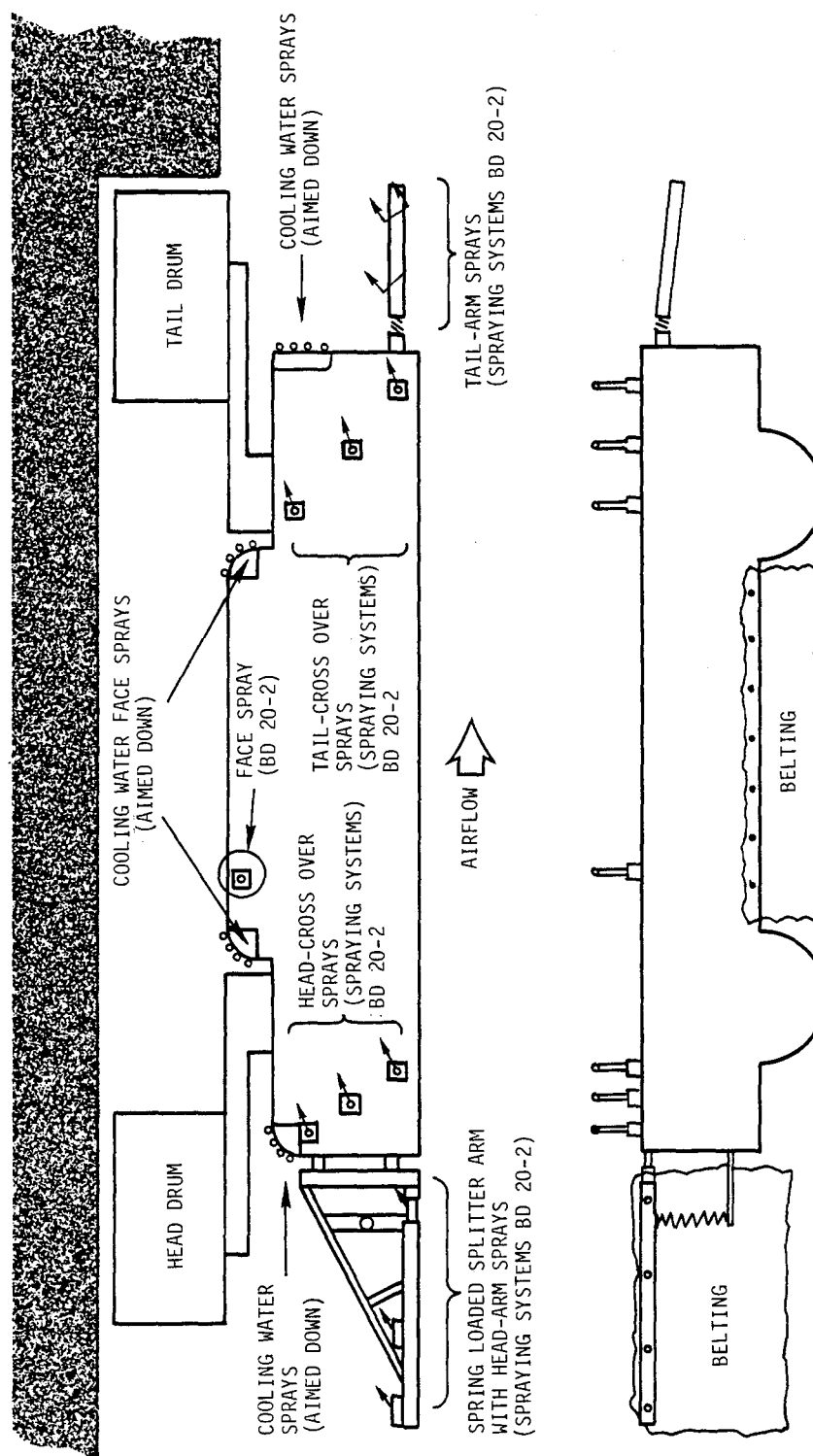


FIGURE 57. Shearer clearer water spray system.

4. OPTIMIZATION OF THE SHEARER CLEARER SYSTEM

The laboratory development of the shearer clearer system described in Section 2 resulted in two basic systems:

- a. One system for cutting against ventilation
- b. One system for cutting with ventilation.

For faces cutting bidirectionally, each system required valving to allow independent operation for each cut direction. These systems were installed and evaluated on four operating longwalls as described in Section 3. In addition, a number of mines installed the system on their own. Feedback from the field, coupled with our own field testing experience, indicated that the system was being modified to suit particular mine conditions. For example, sprays on top of the shearer were being removed either because of maintenance problems or due to excessive water mist.

As a result of this feedback, the program was expanded in scope. This additional work included:

- a. A field survey of mines using shearer clearer and shearer clearer-like systems
- b. Laboratory study of improved spray systems.

The results of this effort led to the development of an improved more practical shearer clearer system.

Details of this field survey, laboratory study, and development of an improved shearer clearer system are included in the following subsections.

4.1 Field Survey

The purpose of the field survey was to *gather and document information concerning the operating history, acceptance, and current use of shearer clearer and shearer clearer-like water spray systems* in use on several longwall faces across the United States. Specific areas documented in detail include:

- a. Shearer water spray locations, types, quantities and orientations
- b. The section water supply system and capacities
- c. The shearer plumbing layout
- d. Shearer splitter arm designs
- e. Awareness and degree of acceptance of face personnel to the use of shearer clearer-like spray systems
- f. Problems (and solutions) encountered in the installation and use of shearer clearer-like systems
- g. Water spray manifold designs
- h. Drum spray systems
- i. Face dust levels during coal production (intake and shearer position dust measurements).

A general longwall survey was also performed at each site to collect relevant information pertaining to:

- a. Face air quantities and velocities
- b. Cutting sequence used
- c. Face equipment
- d. Roof and coal seam conditions
- e. Other face spray systems in use (such as transfer point sprays, shield sprays, etc.)
- f. Any other novel dust control techniques used.

Six mines were visited including:

- a. Old Ben Coal Company, Nos. 25 and 27 Mine
- b. Western Slope Carbon, Inc., Hawk's Nest West Mine
- c. Kaiser Steel Corp., York Canyon Mine
- d. Price River Coal Company, No. 5 Mine
- e. Kaiser Steel Corp., Sunnyside No. 1 Mine.

Of the six mines visited, only Sunnyside No. 1 Mine was not using a shearer clearer system at the time of the survey. The other five faces all had made use of external water sprays, spray bars or splitter arms in a shearer clearer-like system to modify airflow patterns over the shearer body. The following briefly describes the system in use at each mine.

Old Ben Coal Company, Mine Nos. 25 and 27

Both faces at Old Ben cut from head to tail and cleanup on the return pass. Their unidirectional cutting sequence is unique in that they cut little, if any, coal with the upwind drum. During the head-to-tail cutting pass the upwind drum is raised and allowed to free wheel. The bottom bench is then cut on the tail-to-head pass using the trailing (downwind) drum. The upwind drum is only used to make the sump at the headgate. This cutting sequence, coupled with good primary face ventilation exposes the shearer operators to very little shearer-generated dust.

The external spray system consisted of two cylindrical venturis mounted on a splitter on the headgate end of the shearer, one cylindrical venturi mounted on a short tailgate splitter, and one cylindrical venturi mounted on top of the shearer towards the tailgate end of the machine. The sprays were all pointed slightly downwind.

Cooling water was discharged through face side sprays on each gearhead and through open hoses over the panline on each end of the shearer.

Western Slope Carbon, Inc., Hawk's Nest West Mine

The face at Hawk's Nest West Mine also uses a head-to-tail unidirectional cutting sequence with the headgate drum not cutting coal. The tailgate drum cuts the bottom bench on the tail-to-head cleanup pass.

Their face used a spray system very similar to the developed shearer clearer in combination with passive barriers mounted on top of the machine, as illustrated in Figure 58. The passive barrier was 12 in. high, 1 in. thick belting, supported by angle iron, running the full length of the shearer body.

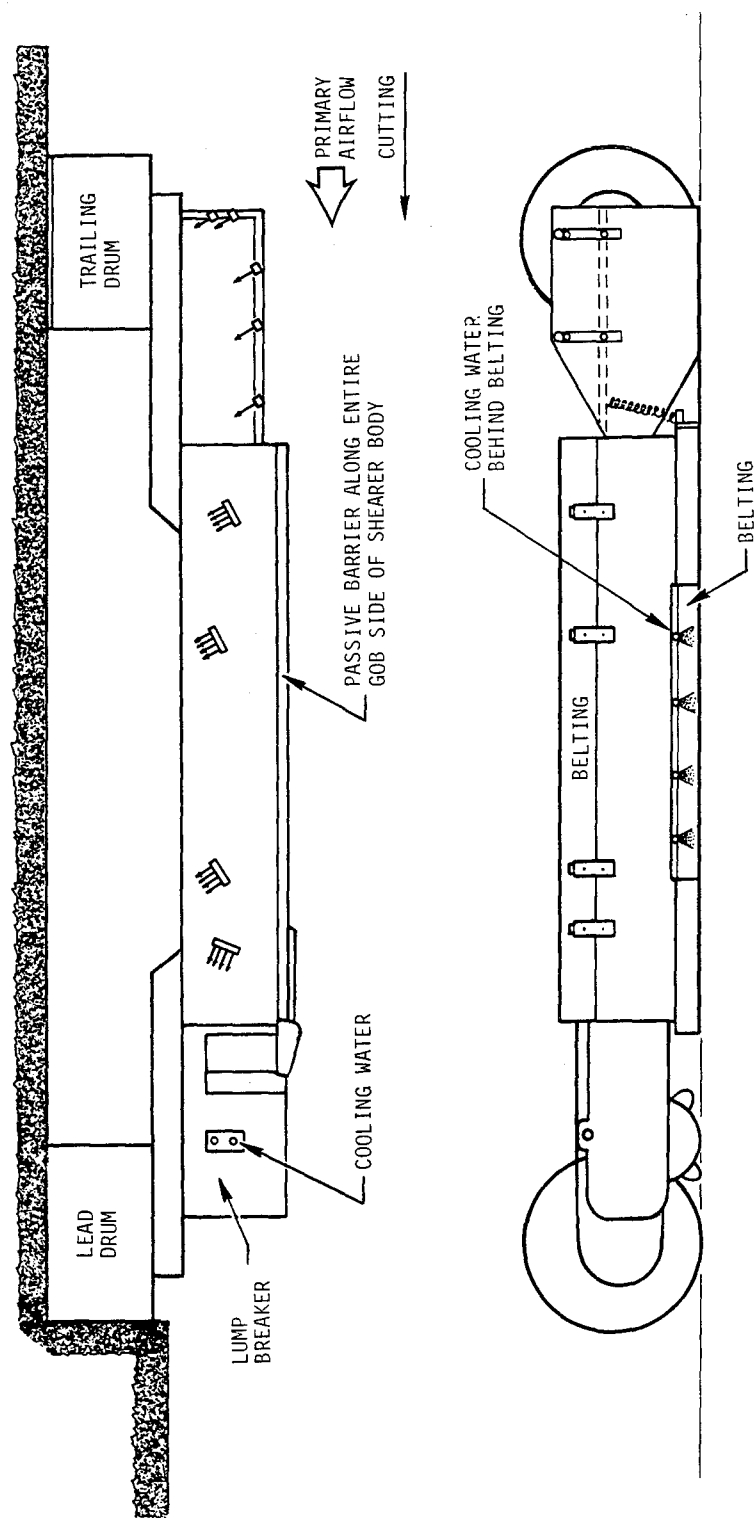


FIGURE 58. - Western Slope Carbon, Inc., Hawk's Nest West Mine shearer clearer and passive barrier system.

The water spray system used Conflow adjustable swivel tip flat fan nozzles. Single sprays were mounted on the headgate splitter arm as shown. The four spray locations on top of the shearer each had four nozzles mounted on a welded steel support.

Cooling water was dumped through two sprays at the lump breaker on the tailgate end of the shearer and four sprays into the shearer underframe.

Price River Coal Company, No. 5 Mine

The face at Mine No. 5 cut bidirectionally. This face used a combination water spray and passive barrier system on top of the shearer as shown in Figure 59. The passive barrier consisted of three conveyor belt panels mounted on top of the shearer angled diagonally approximately 30 deg to the airflow. The barriers varied from 24 in. high to 30 in. high with the shorter barrier on the upwind end. This barrier also had a cutout so the operator could see the cutting drum.

The spray system consisted of the following:

- a. Three flat fan sprays mounted on a 9 ft long splitter extending from the upwind end of the machine. Two of these sprays were aimed across the airflow, one was aimed slightly downwind.
- b. Four sprays, three flat fan and one cylindrical venturi, were mounted on the face side of the upwind end of the shearer body. Two of the flat fan and the venturi sprays were aimed downwind.
- c. Two flat fan sprays were mounted on the downwind gear-head with one aimed downwind and one aimed at the face.
- d. A crescent ring containing 13 sprays was mounted on the upwind ranging arm with sprays aimed into the drum.

Kaiser Steel Corp., York Canyon Mine

The shearer at York Canyon cuts from tail-to-head with cleanup going from head-to-tail. This face used a spray system with splitter arms on the upwind and downwind end of the shearer very similar to the shearer clearer as shown in Figure 60. Five

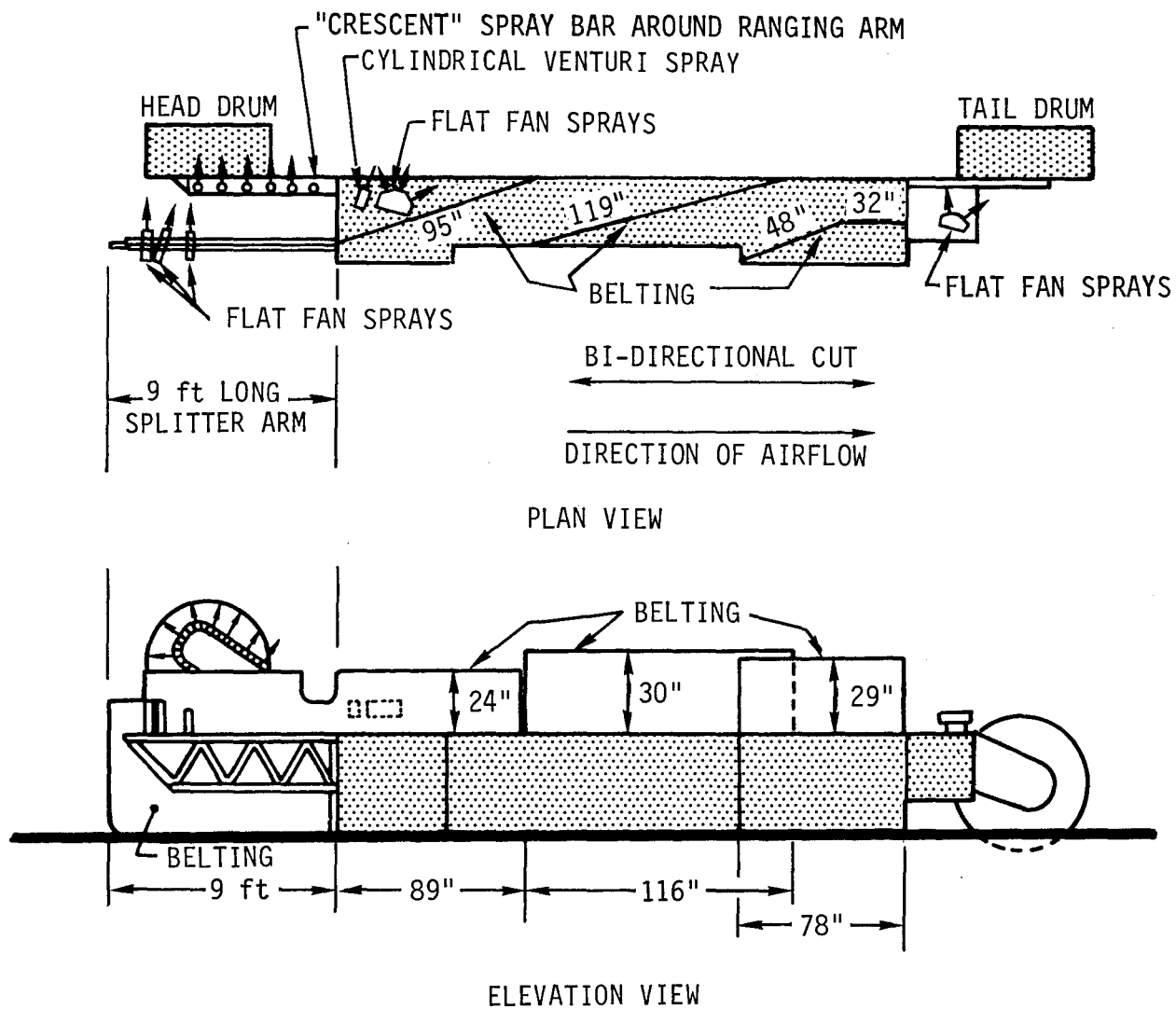


FIGURE 59. - Passive barriers and water sprays in use at Price River Coal Co., No. 5 Mine.

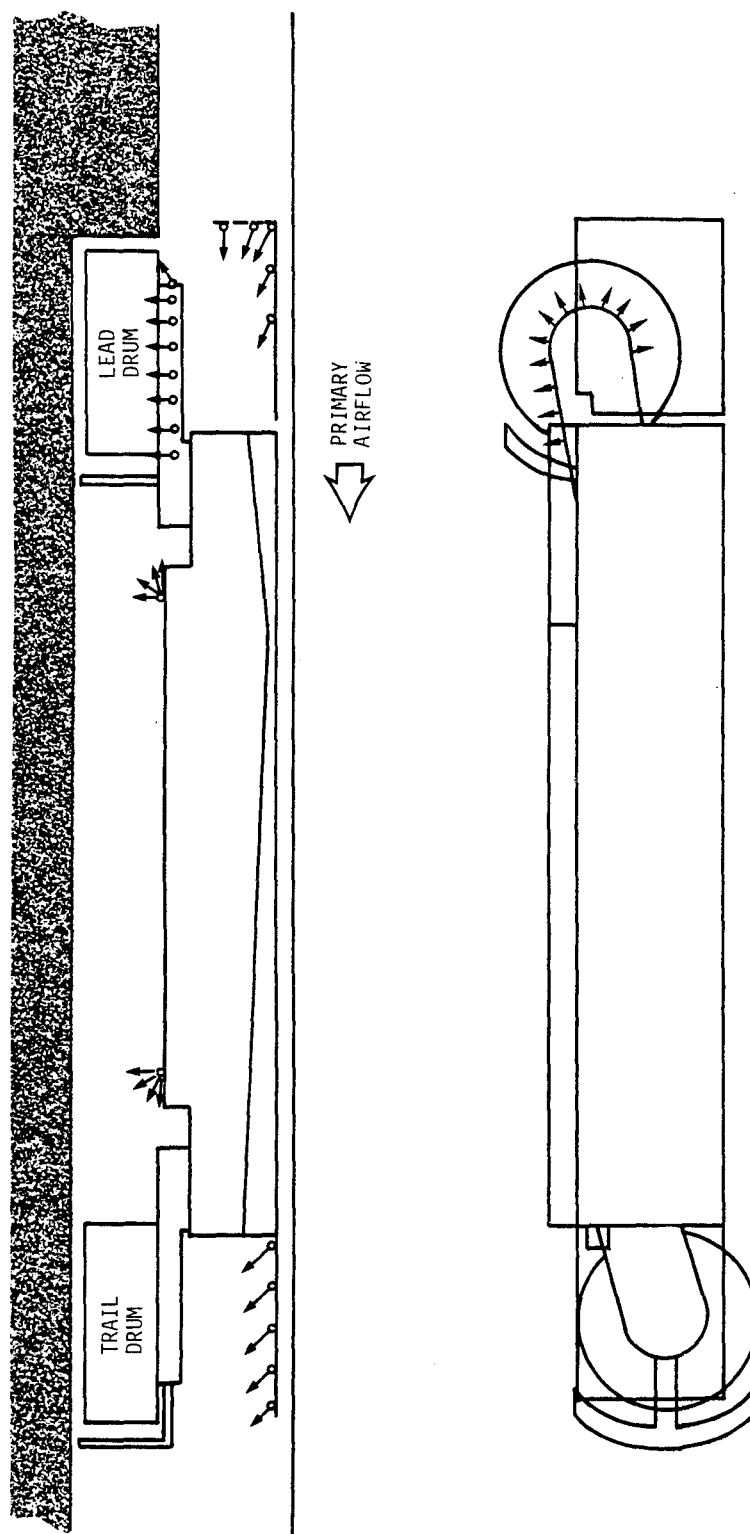


FIGURE 60. - Passive barriers and water sprays in use at Kaiser Steel Corp., York Canyon Mine.

Spraying Systems Co. BD20-2 nozzles were mounted on both the upwind and downwind splitter arms as shown. The mine, however, had chosen not to install the shearer clearer sprays on top of the shearer body. Cooling water was dumped on the face side of each gearhead through four flat fan nozzles as installed by the shearer manufacturer. A crescent spray ring was mounted on the upwind ranging arm.

The shearer was also equipped with a 12 in. high conveyor belt barrier running the full length of the shearer body.

Many innovative spray system construction techniques, mounting arrangements, and manifold designs were noted during the visits. This information was used in the preparation of the companion Volume II on the subject contract, "Installation Guide to Improved Water Spray Systems for Dust Control on Longwall Shearers."

Two of the observed systems were mocked up in the laboratory to compare their performance against the full shearer clearer system. The results of these evaluations are discussed in subsection 4.2.

4.2 Laboratory Evaluation of Shearer Clearer-Like Systems

Two shearer clearer-like spray systems observed during the field visits were installed and evaluated in the laboratory. The two systems included:

- a. The combination water spray/barrier system at Price River Coal's No. 5 Mine
- b. The combination water spray/barrier system at Kaiser Steel's York Canyon Mine.

The results of these two evaluations are presented in the following subsections.

4.2.1 Laboratory Evaluation of the Price River Coal Co. System

The system as described and shown in Figure 59 was installed on the model shearer cutting against the primary airflow. The system was tested with drum sprays at 100 psi, the shearer clearer at 140 psi, and a primary air velocity of 350 fpm. Test results

using tracer gas showed that the lead drum operator levels were comparable to those obtained with the actual shearer clearer system. The concentrations measured at the trailing drum operator, however, were extremely high.

Smoke visualization showed that the system was forcing too much air into the face which rebounded into the walkway at the tailgate operator's position. The system was modified to lessen the impact of this effect by eliminating one spray on the headgate splitter arm and redirecting the face side and tailgate spray nozzles further downwind more in line with the airflow. A test of this slightly modified system yielded a large reduction in contamination at the tailgate operator's position and further improved the headgate operator's position.

4.2.2 Laboratory Evaluation of the Kaiser Steel Corp.'s System

The system as described and shown in Figure 60 was installed on the shearer cutting against the primary airflow. The system was tested with sprays operating at 140 psi, drum sprays operating at 100 psi, and a primary air velocity of 350 fpm.

Tracer gas concentrations measured in the face walkway are plotted in Figure 61. Results for the basic shearer clearer system are plotted for comparison. The Kaiser system shows extremely high levels immediately downstream of the leading drum at the operator's position. These levels fall off somewhat but are extremely high along the entire length of the shearer. This was somewhat unexpected in that the system employs the same splitter arm and sprays on the upwind end of the shearer as the basic shearer clearer system.

The Kaiser system, however, had no shearer clearer body mounted sprays, but did have cooling water sprays mounted on the gearhead pointed upwind. Further testing using smoke showed that the splitter arm and sprays confined the upwind plume and tended to push it toward the opening between the shearer and roof supports. The upwind pointing cooling water sprays, coupled with the lack of crossover sprays, tended to boil contaminate immediately away from the face back across the shearer over the barrier and into the walkway producing the high levels previously noted.

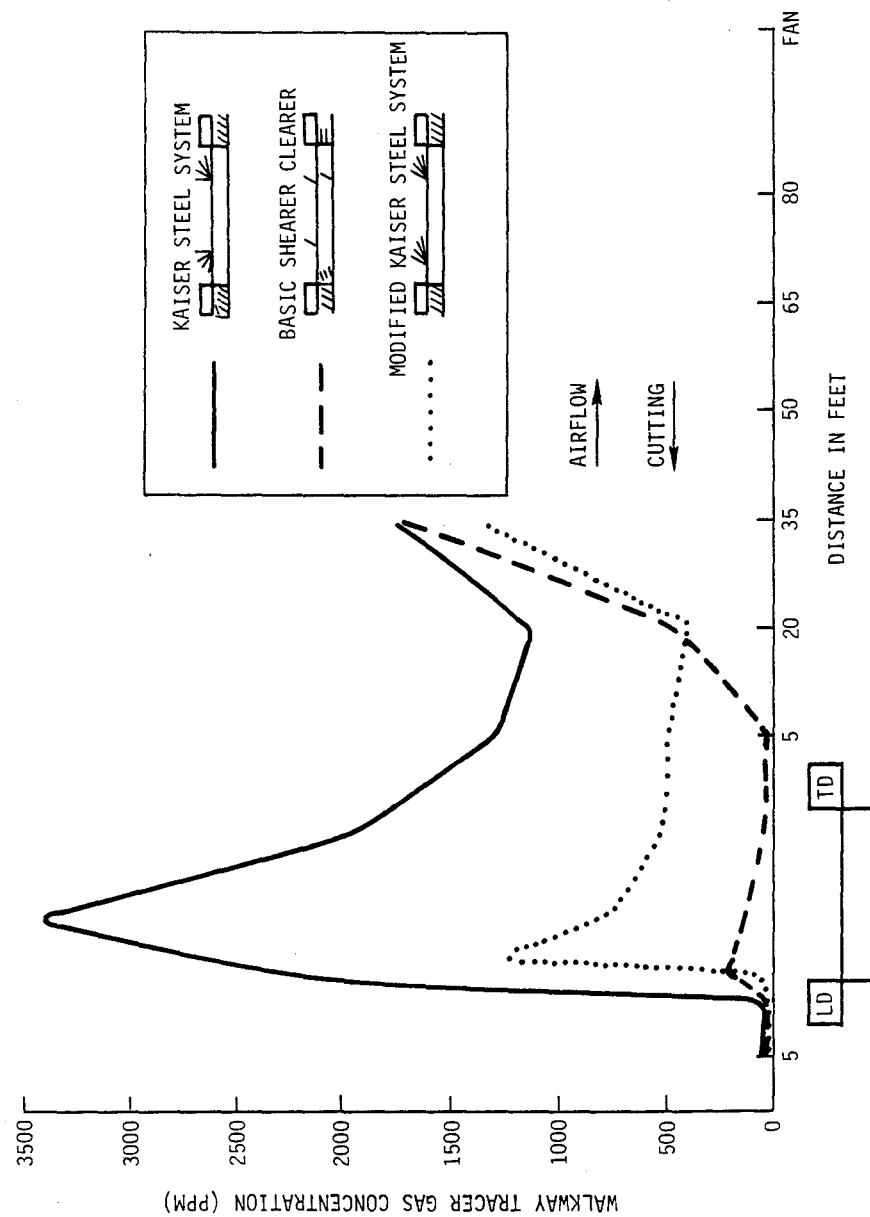


FIGURE 61. - Comparison of tracer gas concentrations measured in walkway with the shearer cutting against the primary airflow.

The system was then modified by aiming all the cooling water sprays downwind. Test results with this modification are also included in Figure 61. Re-aiming the cooling water sprays resulted in significant reductions at both operators.

While the modified system did not achieve the performance of the full shearer clearer system, the achieved levels were low enough to warrant further investigation of the system.

4.3 Laboratory Development of an Improved Shearer Clearer System

The basic shearer clearer system as described in Section 2 of this report used several sprays mounted on top of the shearer. These sprays pushed and confined the dust cloud to the face side of the shearer. These sprays were typically mounted above the top of the shearer using hydraulic hose.

Field experience, however, showed that these sprays were difficult to maintain, particularly on faces with low clearance between the shearer and roof supports. If these sprays could be eliminated without significantly sacrificing system performance, the system would be more universally accepted.

Laboratory testing, described in subsection 4.2, had shown that a system using a splitter arm with shearer clearer sprays, coupled with downwind pointing cooling water sprays, achieved levels approaching those of the full shearer clearer system.

It was felt that repositioning and reorienting of these face side cooling water sprays may result in a system with performance close to that of the full shearer clearer.

The following subsections describe the development and testing of the improved shearer clearer system.

4.3.1 Development of the Improved Shearer Clearer Cutting Against Ventilation

Initial Development and Evaluation

The purpose of this testing was to determine if the shearer clearer could be made more practical by eliminating sprays mounted on top of the shearer. Initial testing concentrated on relocating

the crossover sprays on the upwind end of the shearer body from the basic system. Mounting and maintaining these sprays were a particular problem. Some shearers, for example, do not have an independent ranging arm for raising the drum. On these machines, the entire end of the shearer tilts upward making proper positioning and aiming of sprays difficult. These sprays are also vulnerable in areas of low clearance (for example, when the shearer cuts into the headgate).

Several spray combinations were tested using smoke and tracer gas and compared to the full shearer clearer system. Tracer gas concentrations measured in the walkway are plotted in Figure 62. Results with the primary airflow at 350 fpm and the system operating at 150 psi show that eliminating the crossover sprays causes a significant increase at the lead drum operator, but only a minor increase at the trailing drum operator.

Moving the sprays to the ranging arm pointing downwind as shown in Figure 63 reduced levels at the lead drum operator to that of the full shearer clearer but showed significantly higher levels at the trailing drum operator. From a practical standpoint, this arrangement suffers some of the same shortcomings as the original crossover sprays. They would be difficult to maintain and would be difficult to mount and orient in many shearer models.

The most practical system, face side sprays (shown in Figure 64) shows levels at the operators' positions somewhat higher than those for the shearer clearer. Levels immediately downstream of the trailing drum operator, however, are significantly higher. This deterioration in performance could affect both the trailing drum operator and jacksetters following closely behind the shearer. The practicality of the spray location, however, justified further evaluation.

Several face side spray combinations were tested and compared to the full shearer clearer system. Three combinations and the test results obtained are shown in Figure 65. For this testing, all sprays mounted on top of the shearer have been eliminated and replaced by face side sprays. All three combinations produced levels at the operator close to those obtained with the full shearer clearer system. The only real difference

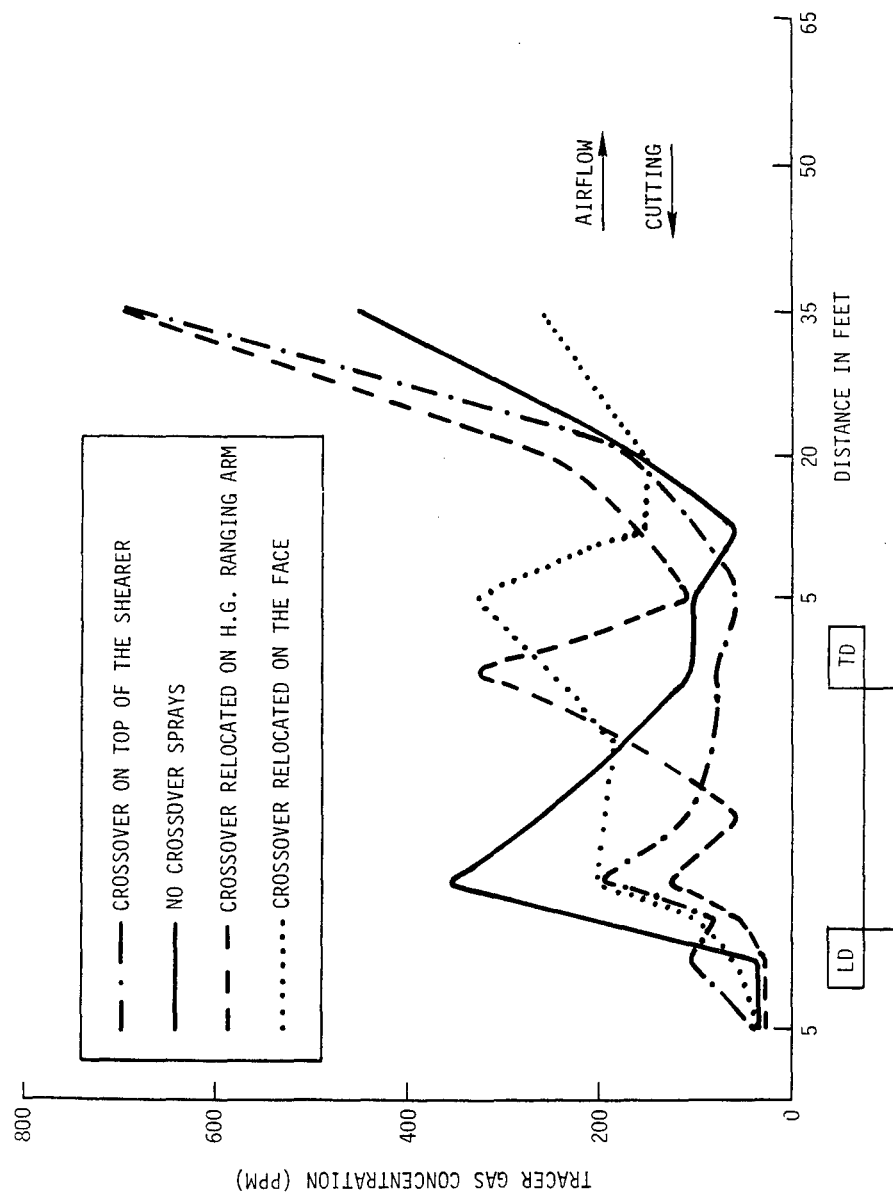


FIGURE 62. - Effects of relocating crossover sprays.

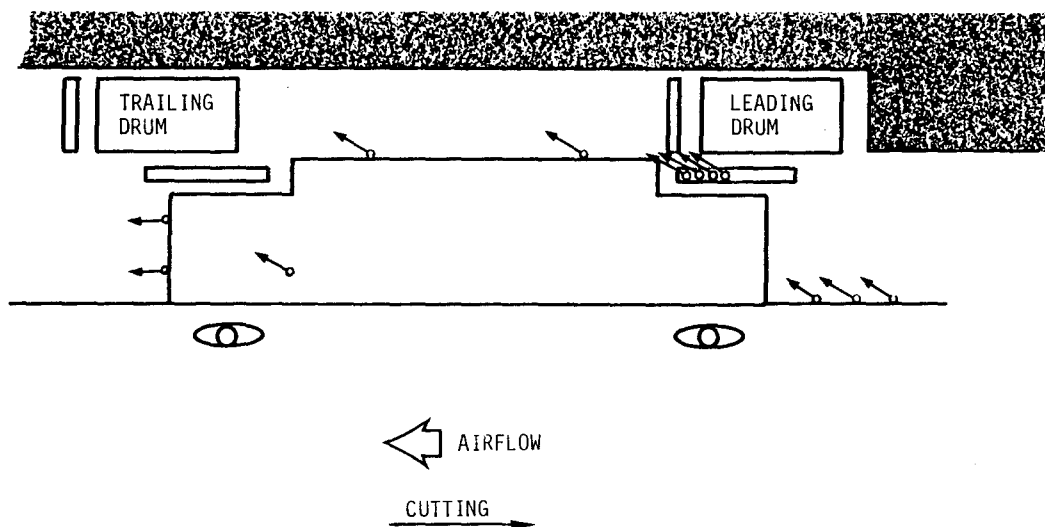


FIGURE 63. - Shearer clearer with the crossover sprays relocated on the ranging arm.

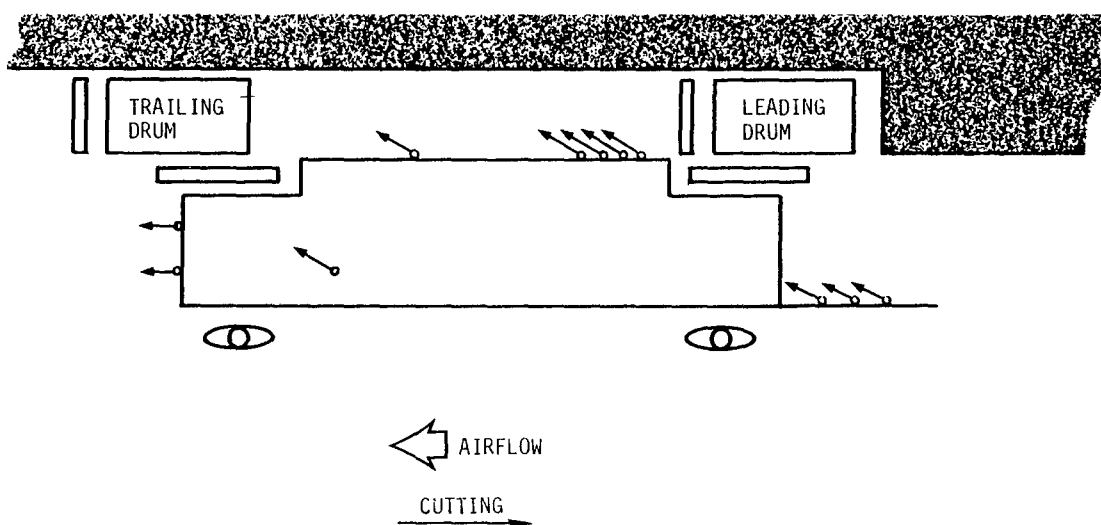


FIGURE 64. - Shearer clearer with the crossover sprays relocated to the face side of the shearer body.

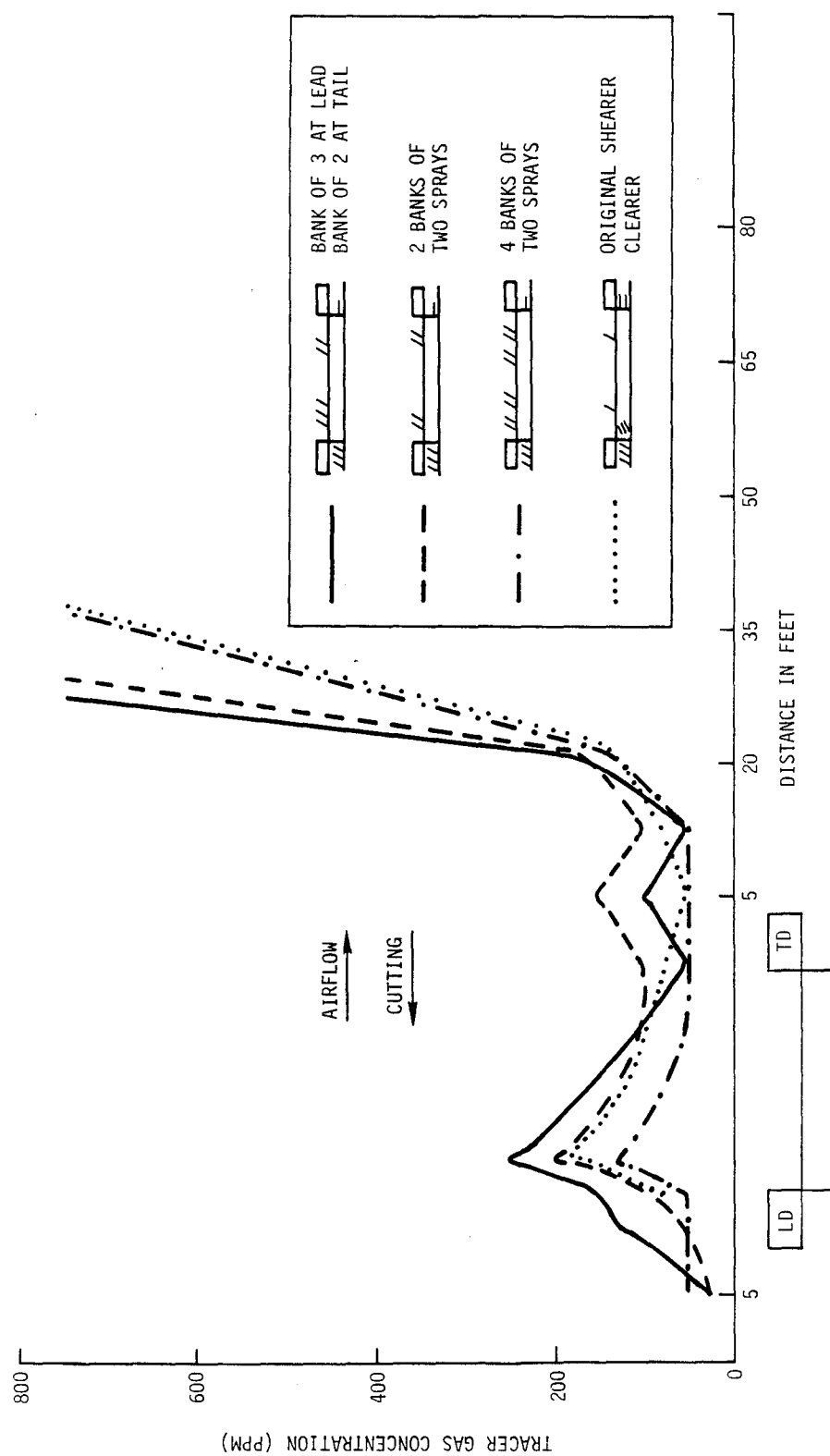


FIGURE 65. - Comparison of face side spray performance.

between them is in their performance downstream of the shearer and in their ease of installation. The four banks of two sprays combination, while it performs well, would require fabrication and installation of two additional spray manifolds. Comparing the two bank combinations shows the one having three sprays on the upwind end maintaining lower concentrations further downstream of the shearer. This system, with three sprays on the upwind face side of the shearer, and two sprays on the downwind face side of the shearer was selected for further evaluation.

The improved system was tested using various spray combinations on the downwind tailgate end of the shearer. This testing was aimed at further reduction in the walkway contamination levels downstream of the shearer to improve conditions for support personnel. Of the spray locations and orientations tested, one spray mounted on the downwind splitter aimed in the direction of the primary airflow proved to be the most effective.

The final spray configuration for the improved system is shown in Figure 66. The improved system eliminates all sprays mounted on the top of the shearer body and uses fewer sprays than the original system. A comparison of the two systems, shown in

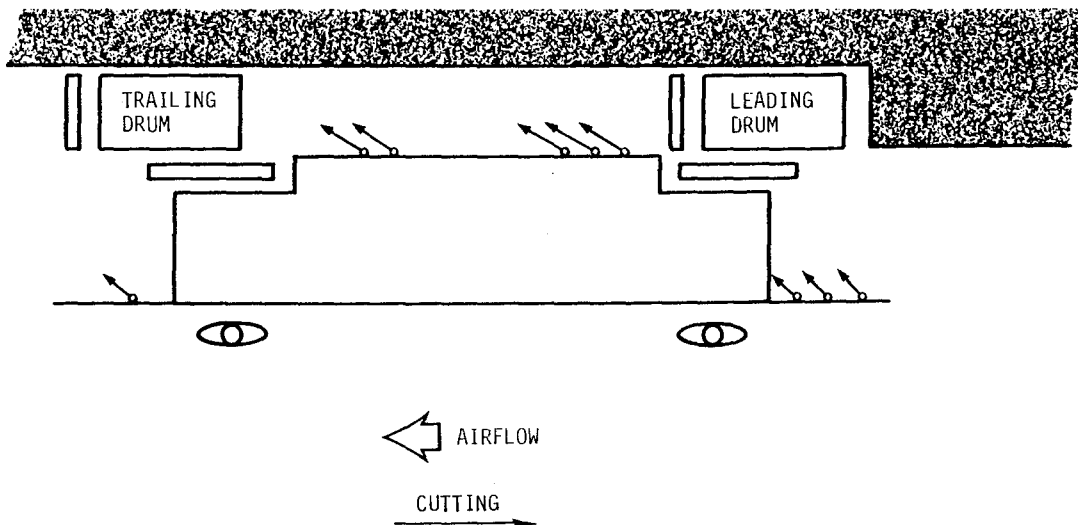


FIGURE 66. - Improved shearer clearer spray configuration.

Figure 67, shows that these practical improvements did not deteriorate system performance, and in fact, improved downstream contamination levels. All testing to this point had been done at one face airflow and one spray pressure. The system was then tested to determine if its performance was sensitive to changes in either system pressure/degradation or face air velocity.

Further Testing of the Improved System

The improved shearer clearer was tested to determine if variations in either face airflow or system pressure affected system performance. The system was tested at 120 and 250 psi and compared to the results obtained at 140 psi. Results measured at a primary airflow of 350 fpm are shown in Figure 68. Operating the system at higher pressures improves performance along the shearer, but causes significant increases in contaminate levels downstream. Lowering system pressure reduces system effectiveness somewhat along the shearer with no impact downstream. These results indicated that the system performance along the shearer is not extremely sensitive to system pressure. For mines cutting against ventilation with support advance following the shearer, system pressures should be kept below 200 psi to minimize the spread of downstream contamination into the walkway.

The system was also tested at face airflows ranging from 200 to 500 fpm. As expected, the higher the airflow, the lower the contaminate level in the walkway.

4.3.2 Development of the Improved Shearer Clearer Cutting with Ventilation

Initial Development and Evaluation

Once the improved shearer clearer was developed and tested for shearers cutting against ventilation, a similar improvement program was initiated for shearers cutting with ventilation. To start testing, the full against the flow system was installed as shown in Figure 69.

Laboratory testing of the system at 150 psi with a primary air velocity of 350 fpm indicated that the system provided excellent control at the trailing drum operator as shown in Figure 70. The full system, however, provided little reduction at the leading drum operator. The full system also created excessive water mist

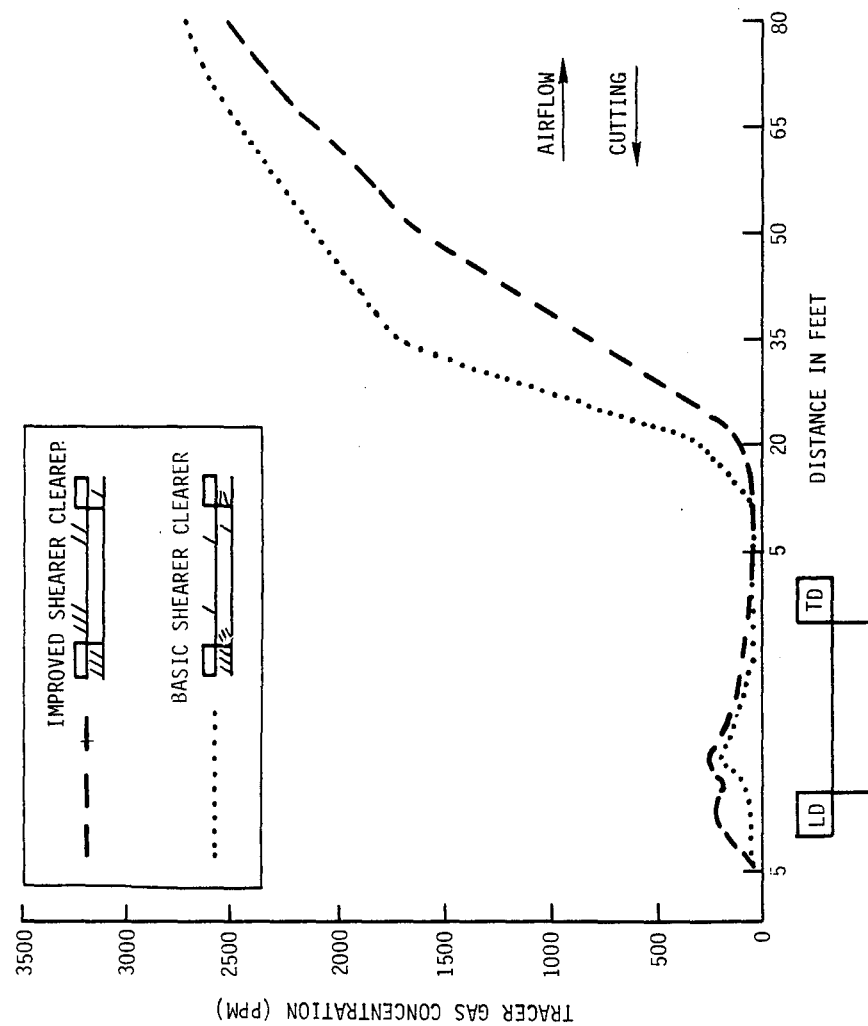


FIGURE 67. - Comparison of basic and improved shearer clearer performance.

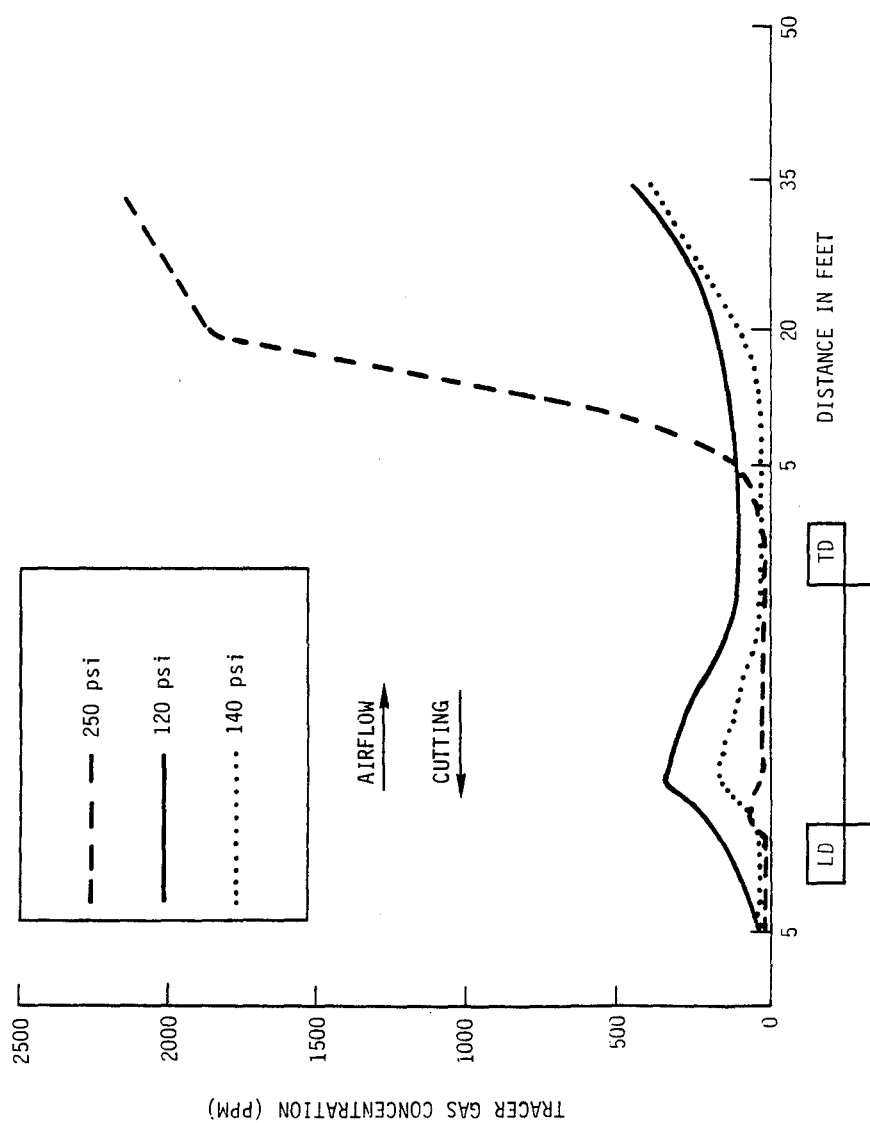


FIGURE 68. - Comparison of improved shearer clearer performance as a function of system pressure.

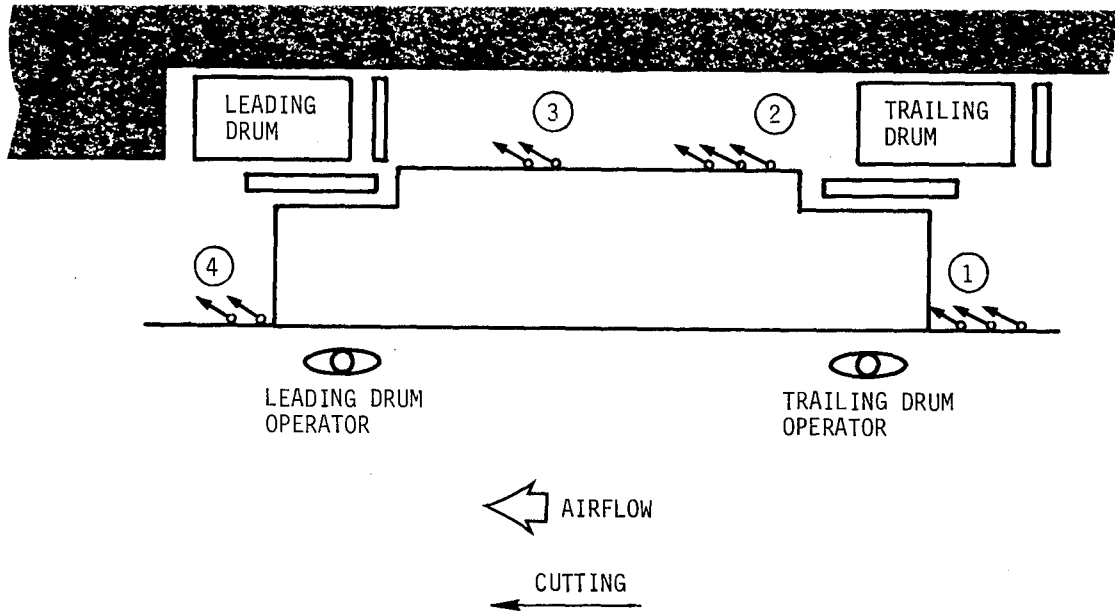


FIGURE 69. - Improved shearer clearer system installed on the shearer cutting with ventilation.

in the walkway starting five feet upstream of the leading drum operator's position. This was not unexpected. Similar results were shown with the basic shearer clearer system before additional spray power was added to the downwind end of the shearer. This additional spray power, however, caused excessive water mist and was not well accepted underground.

The initial change made to the system was a reduction in system pressure to 50 psi. This reduction, however, caused a significant deterioration in system performance.

The full system was then tested with increased power in the downwind end of the shearer. Sprays were added and the pressure at spray banks 3 and 4 (Figure 69) was increased. Increasing power on the downwind end of the shearer improved contaminant levels at the leading drum operator's position. The increased power, however, again created excessive water mist which would impair the operator's view of the leading drum.

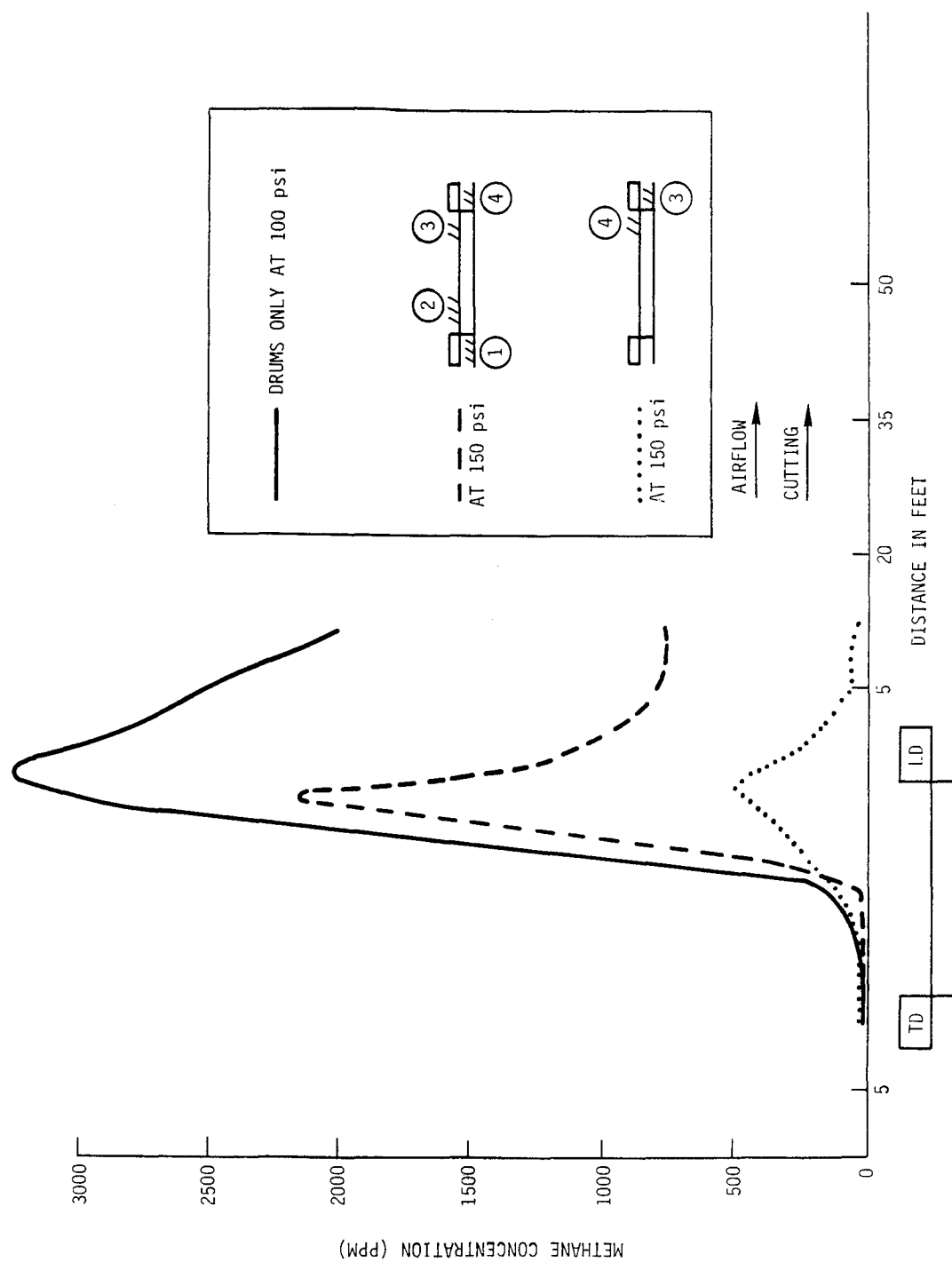


FIGURE 70. - Performance of the improved shearer clearer cutting with ventilation.

Testing to this point eliminated the idea of one system performing well in both cutting directions. Increasing the number or operating pressure of the sprays on the downwind end of the shearer was also judged to be undesirable. Laboratory and underground test results, however, had shown that the trailing drum operator was exposed to very little contamination from the upwind drum. It has also been observed that the contamination from the upwind drum stays on the face side of the shearer until the airflow is blocked by the leading drum cowl. It was concluded, therefore, that full power on the shearer clearer sprays on the upwind end of the shearer (banks 1 and 2) was not needed to confine the upwind drum dust cloud. It was also concluded that the airflow acceleration caused by these sprays operating at 150 psi was actually causing an increase in boilout to the lead drum operator's position.

A series of tests were then run with spray banks 1 and 2 at reduced pressures. Results in Figure 70 showed that completely eliminating spray banks 1 and 2 significantly improved conditions at the lead drum operator's position without significantly affecting the trailing drum operator.

The improved system for cutting with ventilation is shown in Figure 71. The system consists of spray banks 3 and 4 on the downwind end of the shearer used for the against the flow system. This improved system for cutting with the airflow was then tested to determine how its performance was affected by system pressure and face airflow.

Further Testing of the Improved System

The improved system was tested at operating pressures ranging from 100 to 250 psi and face airflows from 350 to 550 fpm. Test results are shown in Figure 72. Increasing system water pressure improves system performance. Boosting the pressure from 150 to 250 psi, for example, reduces levels at the leading drum operator by approximately 50 percent.

Increasing face airflow causes system performance to deteriorate somewhat. This, again, is not unexpected in that increasing face airflow increases the amount of air being blocked by the leading drum which creates more boilout into the walkway. Most faces in the United States, however, operate with face airflows typically less than 450 fpm. At these flows, system performance is not significantly affected.

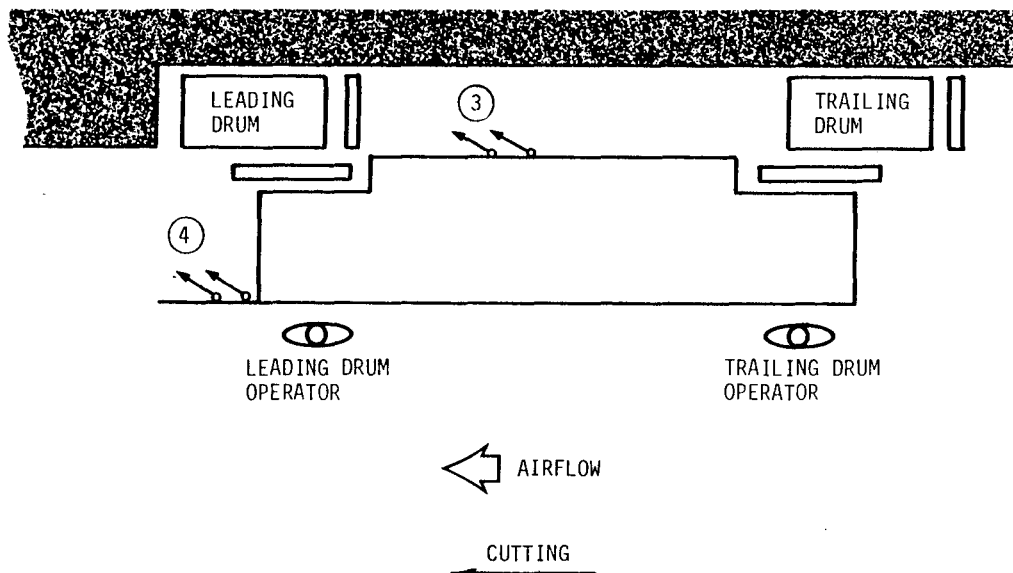


FIGURE 71. - Improved shearer clearer system installed on the shearer cutting with ventilation.

4.3.3 Improved Shearer Clearer System - Final Configuration

The final configuration of the improved shearer clearer system is illustrated in Figure 73. The table of nozzle orientations presents the proper discharge angles for optimum air-moving performance on most shearers. *For complete installation instructions and fabrication details, refer to the companion Volume II - "Installation Guide to Improved Water Spray Systems for Dust Control on Longwall Shearers."*

The improved system uses only 10 spray nozzles mounted in seven manifolds with none mounted on the top of the shearer body. For faces cutting against ventilation, all ten sprays are operated at 150 psi. For faces cutting with ventilation, only spray manifolds 5, 6, and 7 are operated. On bidirectional faces, the full system would be installed and valved to turn on all seven manifolds when the machine is cutting against ventilation, and to cut off manifolds 1 through 4 when cutting with ventilation.

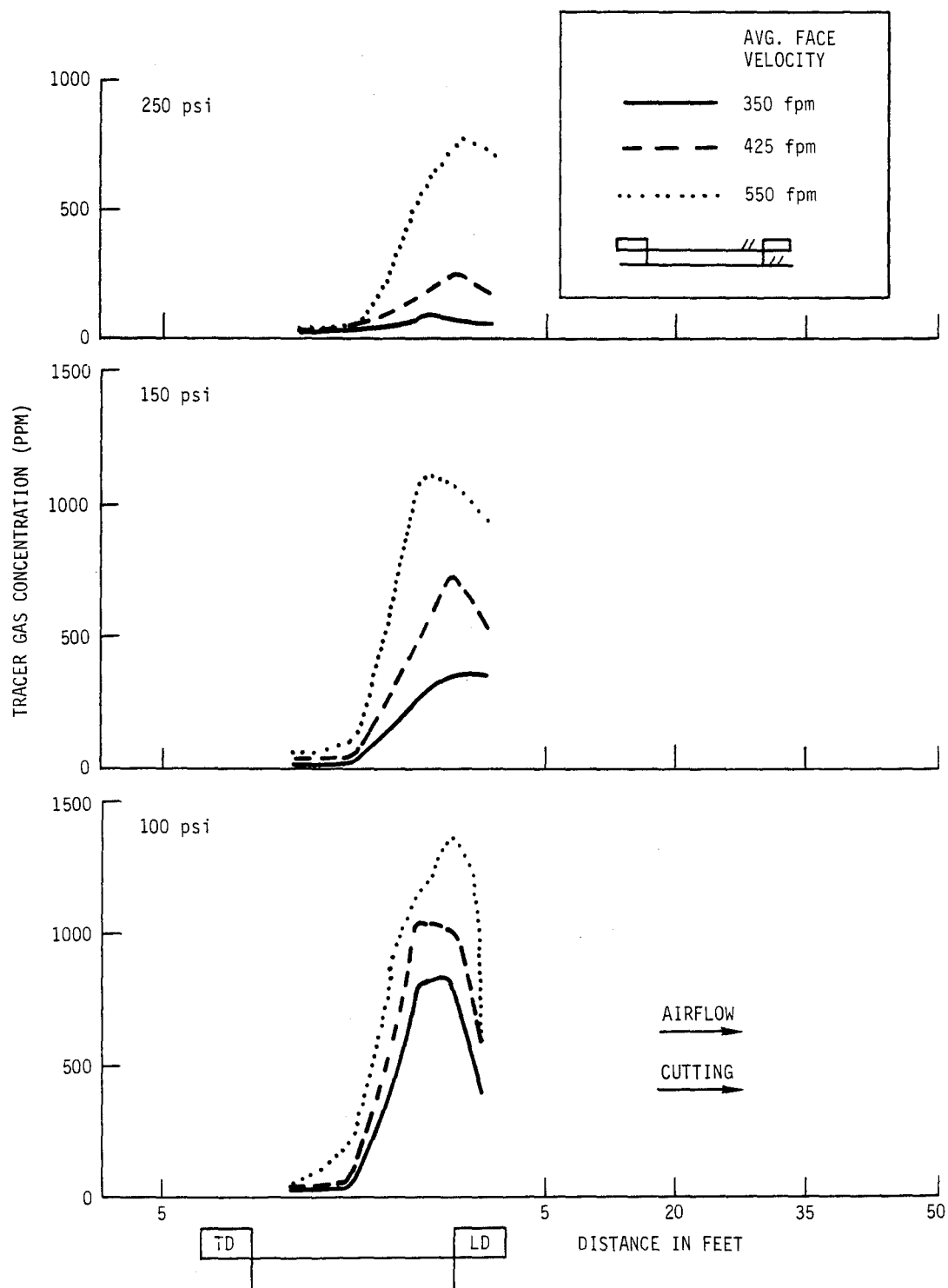
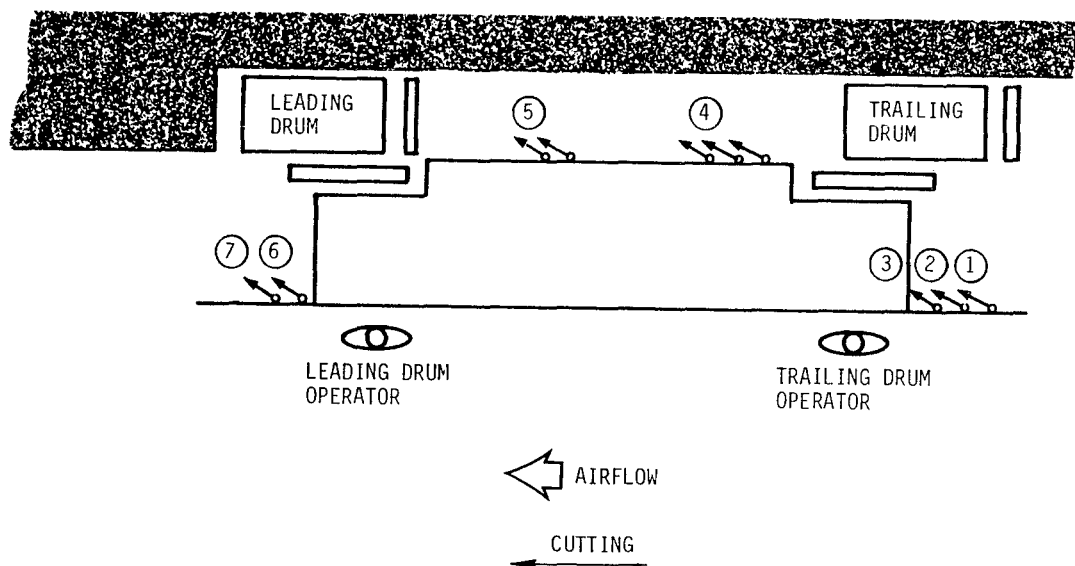


FIGURE 72. - Performance of the improved system at various system pressures and face airflows.



Shearer clearer nozzle location guide

Manifold	No. of nozzles	Location on shearer	Spray discharge angle	
			"x"	"y"
①	1	Nozzle located 8 in. in from outby end of splitter arm	20 deg toward face	15 deg up
②	1	Midway between manifolds ① and ③	30 deg toward face	15 deg up
③	1	Nozzle located 12 in. out from headgate end of shearer	40 deg toward face	30 deg up
④	3	Outby end of manifold located approximately 12 in. from end of headgate ranging arm	30 deg toward face	20 deg up
⑤	2	Inby end of manifold located approximately 40 in. from end of tailgate ranging arm	30 deg toward face	20 deg up
⑥	1	Nozzle located 8 in. out from tailgate end of shearer	25 deg toward face	15 deg <u>down</u>
⑦	1	Nozzle located 6 in. from inby end of tailgate splitter arm	25 deg toward face	15 deg <u>down</u>

FIGURE 73. - Improved shearer clearer system specifications.

4.4 Evaluation of Effective Ways to Discharge Shearer Cooling Water

Underground and laboratory test results have shown that factory installed cooling water discharge sprays, particularly those mounted on the face side of the shearer, make inefficient use of the water at best. In the worst case, these sprays, aimed at the face or even upwind, are extremely detrimental in that they push dust across the shearer towards the walkway.

This water could be used by the face side sprays, manifolds 4 and 5 (Figure 73), of the improved shearer clearer. The smaller nozzle sizes recommended for the system, however, could reduce total cooling water flow.

The water could be dumped on the face side of the machine through the existing cooling water nozzles by either pointing or deflecting the spray downward. This would eliminate the detrimental effects of the sprays. It would not, however, make efficient use of this water from a dust suppression standpoint.

Two systems to make more efficient use of this water were investigated:

- a. Crescent spray rings
- b. Panline sprays.

These two systems are illustrated in Figure 74.

The crescent spray ring system consists of a number of sprays mounted on the ranging arm pointed in towards the drum. This system has been used by several mines for increasing water flow into the cutting and loading zones. This system was tested with the shearer clearer to ensure that it would not have a detrimental impact on system performance. Several spray types and mounting orientations were tested. Tests were conducted with a crescent spray ring on both the leading and trailing drums in each cutting direction.

In general, test results showed that a crescent spray ring on the upwind drum is not recommended when the shearer is *cutting with ventilation*. These sprays create turbulence and significantly increase the contamination levels at the downwind operator's position. When the shearer is *cutting against ventilation*, however, the crescent ring on the upwind drum showed no

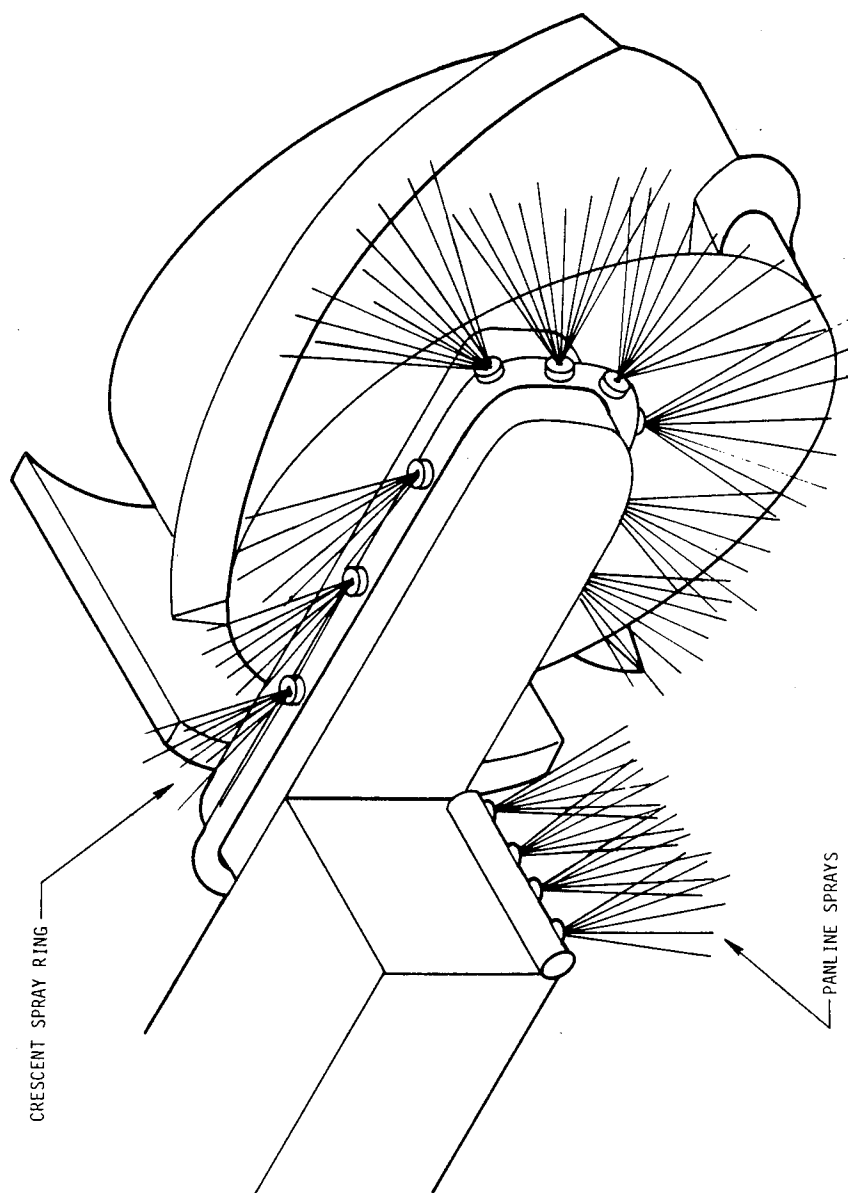


FIGURE 74. - Alternative cooling water locations.

detrimental effect on air turbulence. In this direction, the crescent sprays will provide additional dust suppression by wetting the cutting and loading zone upwind of the operators. Laboratory results also showed that the crescent ring can be used on the downwind ranging arm in both cutting directions. The optimum system consisted of flat fan sprays oriented slightly inward so that the spray hit the circumference of the drum. Sprays on top of the ranging arm are angled slightly downwind. Test results for this system, shown in Figure 75, show that the system, which provides significantly more water to the cutting and loading zones, has virtually no impact on contamination levels in the walkway.

The panline spray system dumps the cooling water onto the coal on the conveyor through downward pointing sprays on each end of the shearer. This system was also tested using various spray types and sizes. Results show that panline sprays, while they provide better wetting of the coal on the panline, have no impact on shearer clearer performance. Results for the system using four flat fan sprays, which ensure wetting of the entire width of the panline are also shown in Figure 75.

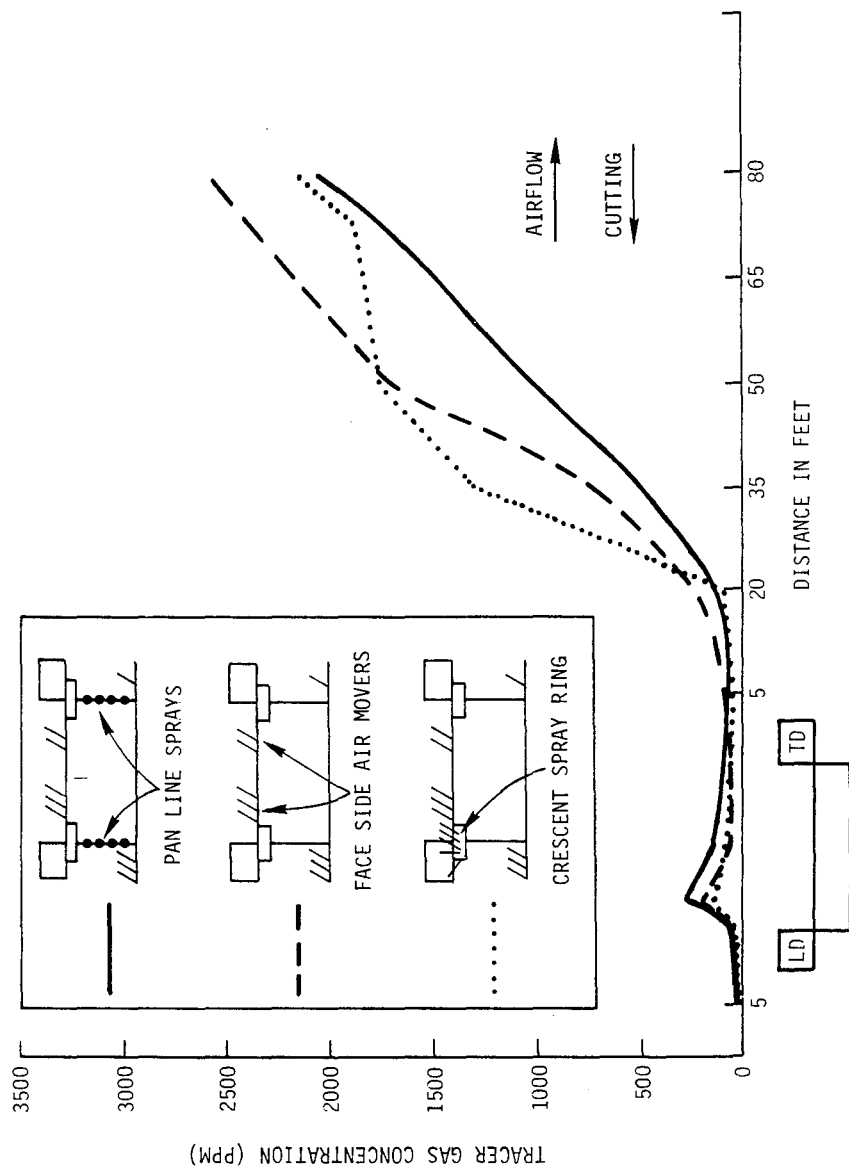


FIGURE 75. - Performance of the improved shearer clearer with alternative cooling water discharge systems.

5. FUNDAMENTAL NOZZLE TESTING

5.1 Introduction

The objective of this task was to determine whether spray nozzle types varied in dust knockdown capability, and if so, to rank them. A test was devised in which standard dust was mixed in air in a closed volume; then "cleaned" by a free spray. The decay rate of the dust concentration in the booth due to the action of the spray was measured and used to rank nozzle types. The mathematical modelling and data analysis used are discussed in Appendix A.

Nozzles were ranked for scrubbing capability in terms of a figure of merit (C_n) defined as follows:

$$C_n = \eta Q / p^{1.08}$$

Deviation of this formula is given in Appendix A; briefly:

- Q = airflow induced by the spray
- η = scrubbing efficiency of the spray
- p = water pressure at spray nozzle (psi)

Since the boundary of the volume within which the spray's scrubbing work takes place cannot be accurately determined, Q (the flow through that volume) cannot be directly measured. Consequently η cannot be evaluated. However, the product ηQ ("clean air volume produced by the scrubber") can be directly measured (for varying pressure) by means of the experiment described in Appendix A.

The power factor 1.08 applied to spray pressure produces a satisfactory fit to the data. This factor accounts for:

- a. Increase of flow with pressure
- b. Increase of velocity with pressure
- c. Increase of specific surface with pressure resulting from decreased mean droplet diameter.

The use of this factor allows comparison of nozzles tested at different pressure levels.

The project ηQ as measured for a free spray can be used for direct comparison with any other scrubber of any type for which flow and scrubbing efficiency are known. The larger ηQ , the more effective the scrubber, regardless of scrubber type or configuration. A more useful comparison of scrubbers of various forms using water droplets would be scrubbing capability normalized for flow, or $C\eta/q_0$, where q_0 is the quantity of water passing through the system at a standard pressure. Table 10 shows spray nozzles of various types and their associated figures of merit $C\eta$ and $C\eta/q_0$. For this table q_0 was established at 300 psi.

Measurement of ηQ for nozzles under various test conditions showed:

- a. *Nozzle type and size does affect dust knockdown. More specifically, choice of type affects dust removed/gallon of water used.*
- b. Variations in dust knockdown resulting from nozzle type and configuration and nozzle position in the dust booth correspond with results for airflow induction (Q) alone obtained in a different experimental arrangement. *Sprays which move more air knockdown more dust.*
- c. Dust knockdown capability increases with pressure at a slightly better than linear rate (1.08), within the range of test (50-100 psi).

In the following, the experimental arrangement is described and detailed results given.

5.2 Test Arrangement

The test arrangement is shown in Figure 76. Dust is injected into the chamber. Forced mixing is maintained by a circulation fan. The water pipe centers the test nozzle in the booth, pointed straight downwards. The test format is as follows:

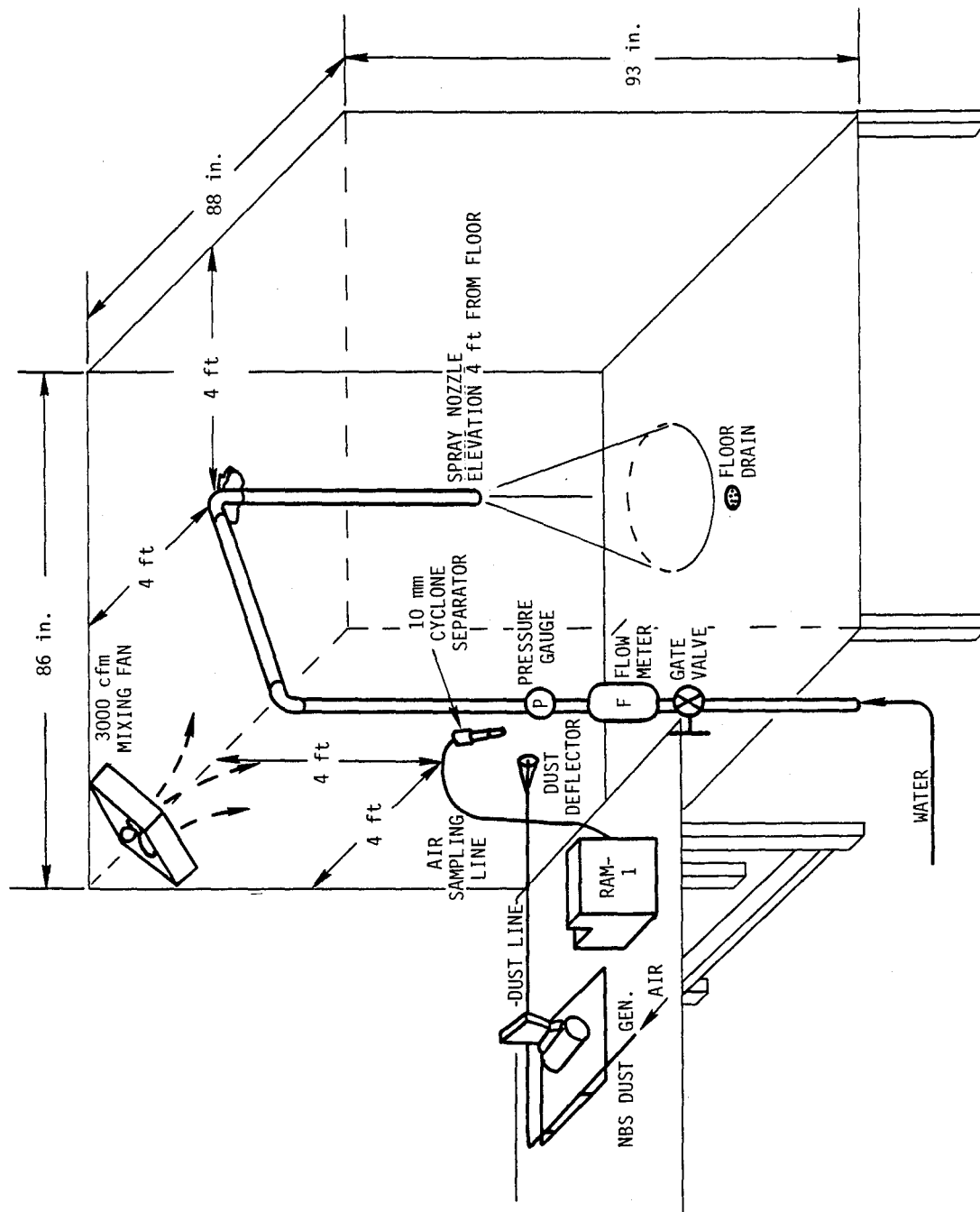


FIGURE 76. - Dust knockdown chamber

- a. Dust is injected into the chamber with the fan on, and the steadily rising concentration is monitored. At a predetermined concentration, dust feed is shut off. The dust concentration then decays due to gravity, diffusion to wall surfaces, etc. The rate of concentration decay measured in this period is the "background" decay rate. When the spray is turned on, the dust reduction rate due to the scrubbing action of the spray is added to this background rate.
- b. When the concentration settles to a predetermined level, the spray is turned on. Pressure is controlled and flow is measured. When the dust concentration reaches a lower (also predetermined) level, the spray is stopped.
- c. Further decay of the dust concentration is also monitored.

A sample decay curve is shown in Figure 77.

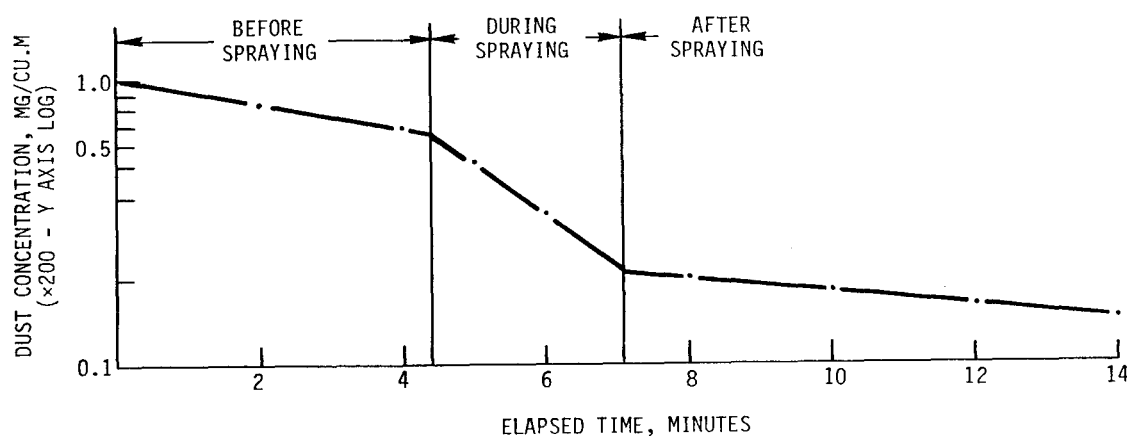


FIGURE 77. - Test data format

The independent variable in this test is time. ηQ can be taken as the difference in decay rate of the dust concentration between the initial interval (no sprays on) and the rate while the spray is operating (see Appendix A).

Continuous sampling with a GCA RAM-1 dust monitor and recording the output on a Rustrak Model 201 chart recorder simplified operation of the test. Tests run with oven-dried dust were significantly more repeatable than with dust stored in ambient conditions.

5.3 Discussion of Ranking Results

The objective of comparative testing was to determine whether nozzle *selection* can improve dust control underground by increasing airborne capture. The nozzles tested are already widely used in dust control applications in mines.

Sufficient testing was done to show that:

- a. *The most important variable affecting dust knockdown is air moving capability. This was shown most clearly when reductions in dust knockdown capability of multiple nozzle arrangements matched reductions in air moving capability in corresponding tests.*
- b. *Narrower angle sprays with the same flow parameter (gpm) knock down more dust. Water mass distribution in the spray cone affects the development of a coherent air-stream - the narrower the spray angle, the more effective the air movement, and therefore the dust knockdown.*

Rankings given in Table 10 were supported by independent tests run with sets of four identical nozzles on a single spray bar in a simulated continuous miner heading (on another USBM program). Five nozzle types (BD 3-3, BD 8-1, GG 3009, GG3, HV 6506) had the same rank order in both tests.

To determine the approximate effect of a nozzle type change on dust knockdown, remember:

- a. Knockdown increases *approximately* linearly with flow and pressure
- b. Knockdown decreases as spray angle increases.

Air-moving tests conducted on another USBM program have shown that effects of nozzle *grouping* on air movement are relatively unaffected by changes in nozzle type.

5.4 Additional Results

Figure 78 summarizes all testing with BD 3-3 nozzles between 50 and 200 psi:

- a. The best fit line shows the relationship of ηQ to

$$\eta Q/6 = 0.292 [\text{pressure (psi)}]^{1.08} + \text{background*} \quad (1)$$

0.292 is the C_η cited in Table 10.

- b. The lines give a 95% confidence band for the fit.
- c. Equation (1) is for data taken with the spray 4 feet from the surface at which it is directed. Data taken with the spray *closer* shows dust knockdown capability reduced. Data taken with the spray at 7 feet is presumably affected by the ceiling of the booth, which is at 8 feet.
- d. The effect of spray water heated to 114° (three tests) is also shown.
- e. Tests with *surfactants* run with this nozzle and other types showed no significant effect.

These results were verified by spot checking with other nozzle types throughout the pressure range (50-1000 psi).

*Decay taking place in the booth with no spray operating was initially used for this equation, but fit became increasingly poor with larger nozzles and combinations of nozzles. This was attributed to breakdown of the assumption of complete mixing by the fan; in other words, mixing was significantly enhanced by the sprays themselves. This enhanced mixing accelerated the "background" processes discussed in Appendix A. A background of $\eta Q = 60$ was found to make goodness of fit to equation (1) insensitive to flow quality (nozzle orifice size).

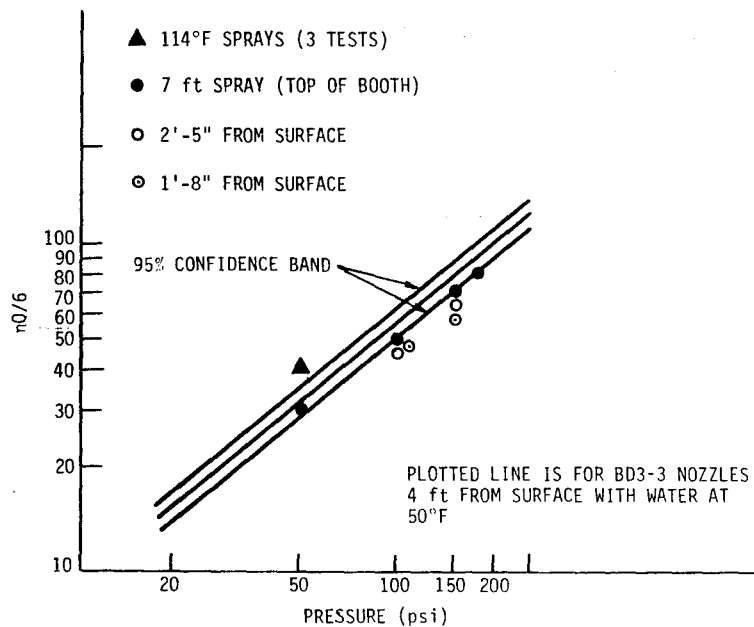


FIGURE 78. - Results of dust knockdown tests for the spraying systems BD3-3 Whirljet nozzle.

5.5 Spray Nozzle Velocity Fields

This task attempted to map the velocity field around an air-moving spray nozzle. A satisfactory rule-of-thumb equation was fitted to the measurements taken. When it was established that no further development of the equation would be of any practical value, work was discontinued.

5.5.1 Experimental Arrangement

The general plan of the experiment was to traverse the spray cone of a nozzle (operating in a large but enclosed duct) much in the manner that air quantities flowing in a duct are determined. To accomplish this, a special pitot probe (Figure 79) was mounted on a trolley (Figure 80) constructed to permit three repeatable traverses of the spray cone (Figure 81).

TABLE 10. - Comparative evaluation of spray nozzle types for dust knockdown

	C_n	$C_n/\text{gal/min}$	Range of test (psi)	
Spray system BD 3-3	0.292	0.22	0-200	Hollow-cone nozzles
Spray system BD 5-5	0.368	0.13	0-200	
Spray system BD 8-1	0.256	0.20	0-1000	
Spray system BD 8-2	0.372	0.22	0-1000	
Spray system BD 10-10	0.632	0.14	0-200	
Spray system BD 20-2	0.390	0.17	0-200	
Spray system 1/8 GG 3	0.232	0.19	0-200	Solid-cone nozzles
Spray system 1/4 GG 3	0.295	0.19	0-1000	
Spray system GG 3009	0.302	0.13	0-200	
BETE L 54	0.359	0.20	0-200	Atomizing nozzles
BETE L 66	0.457	0.17	0-200	
Spray system H 1/4 VV 6506	0.391	0.27	0-1000	Flat-fan nozzles
Spray system H 1/4 VV 9506	0.404	0.26	0-1000	
USS PD 1746	0.339	0.21	0-1000	Sprays in Shrouds
DERON 070	0.038	0.02	0-200	

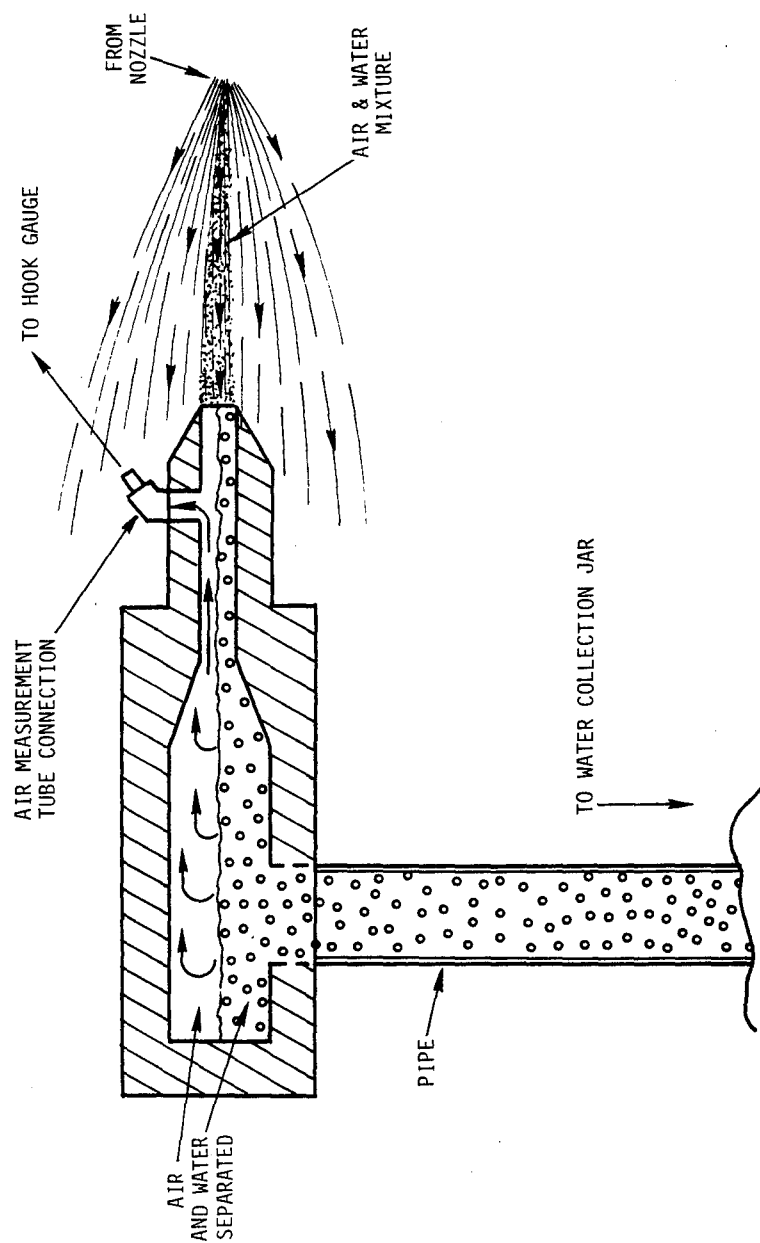


FIGURE 79. - Wet pitot probe

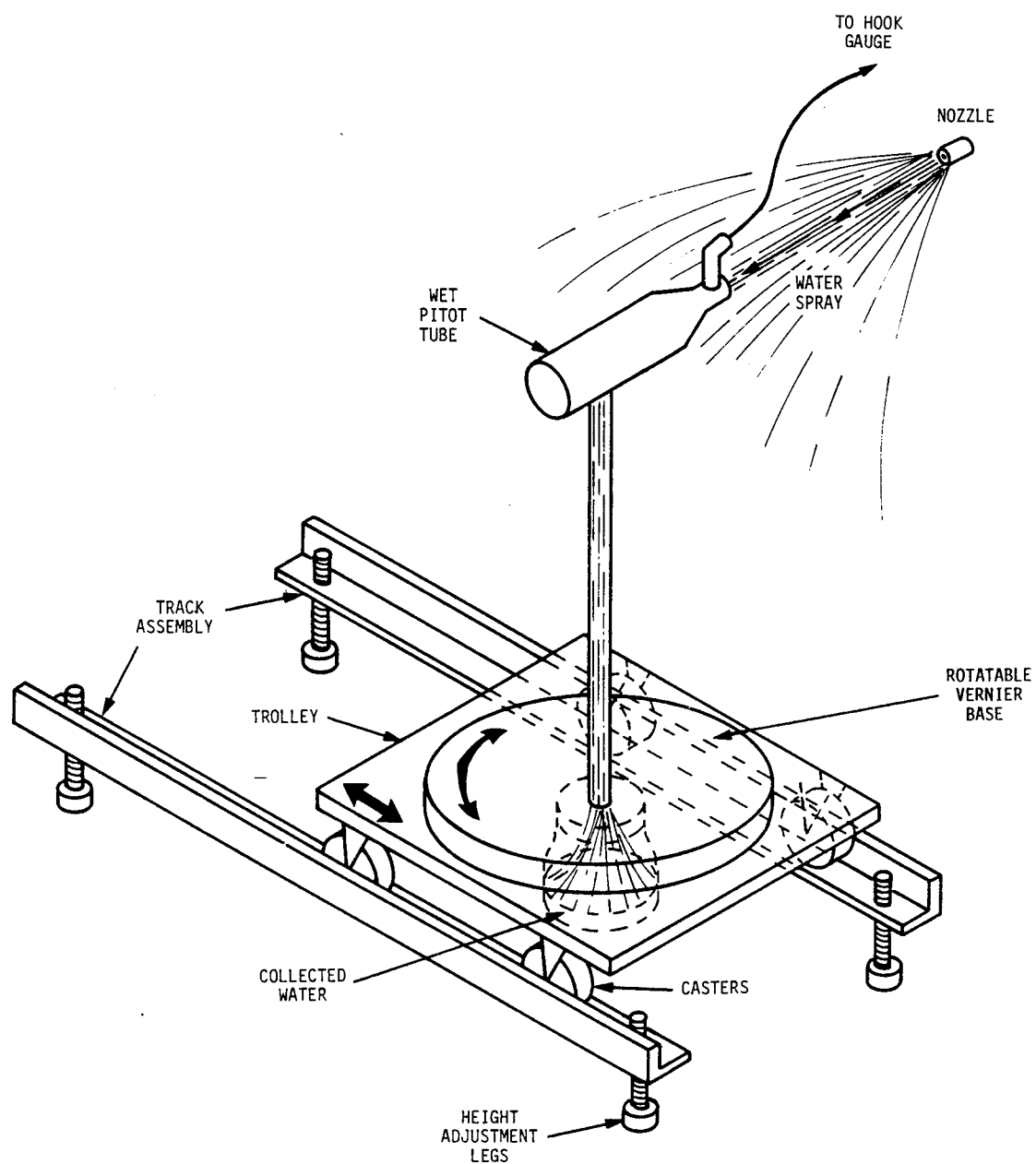


FIGURE 80. - Probe traverse arrangement

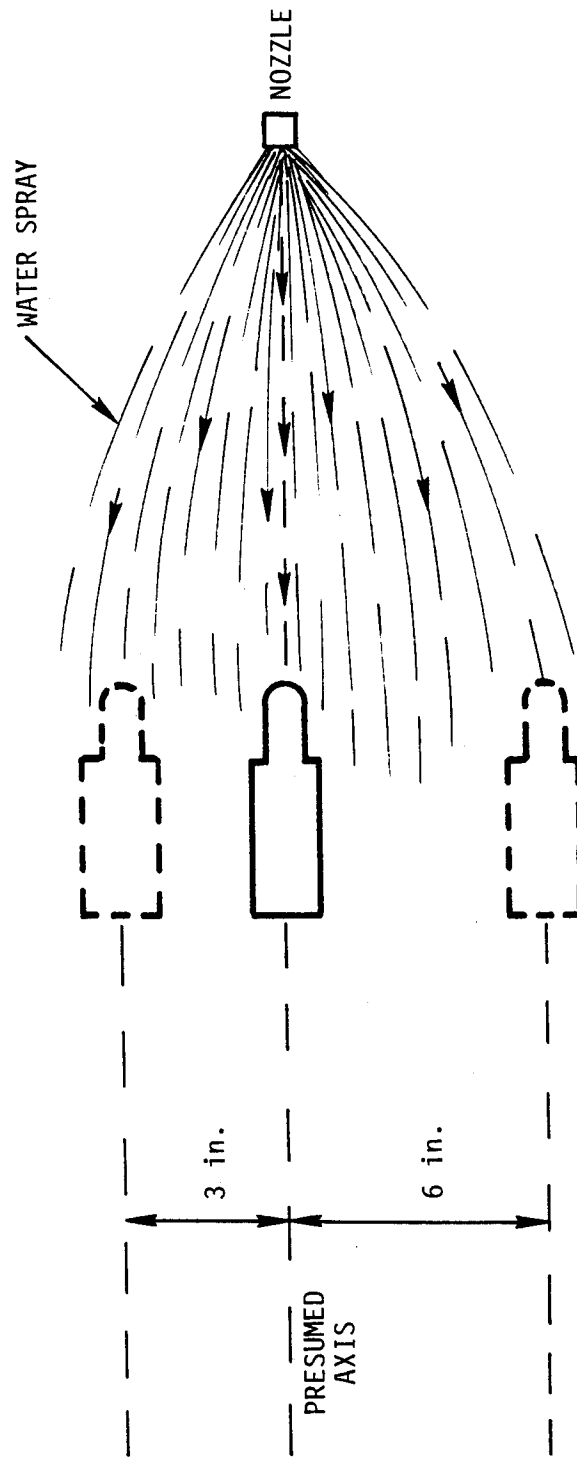


FIGURE 81. - Location of spray cone traverses

Velocity pressures from the pitot probe were measured on an electronic hook gauge. Since there was considerable real-time fluctuation in pressures (especially the lower ones) each pressure was read five times, and the average of these readings used as a test datum.

The data was then matched against several equations by using a computer to evaluate the variance between predicted and actual data. The criterion for good fit was that the total variance of the fit should be well distributed over the three subsets of data from the three separate traverses; one across the spray axis, one 3 inches above, and one 6 inches below. Data was taken at three pressures (75, 125, 175 psi) and distances ranging from 2 to 8 feet. Figure 82 shows variance between a predicting equation and the actual measured data.

Worsening fit as measurements approached the nozzle itself is attributed to asymmetrical water mass distribution. Data taken by the Dust Branch of the U.K.'s National Coal Board (Figure 83) supports this.

5.5.2 Best Empirical Fit

Fits in Figure 81 were obtained with the equation

$$v = V_o \exp \left[-\frac{R^2}{D} \right]$$

where:

v = velocity measured by wet pitot probe

V_o = axial velocity at the place containing the measurement normal to the nozzle axis

R = distance between the nozzle axis and the point of measurement in the plane of measurement

D = a constant specific to the nozzle.

This equation fit significantly better than others given in the literature, in particular:

$$v = V_o \exp \left[-\frac{R}{D} \right] \quad \text{and} \quad v = V_i C_v \tan^2 (R/d)$$

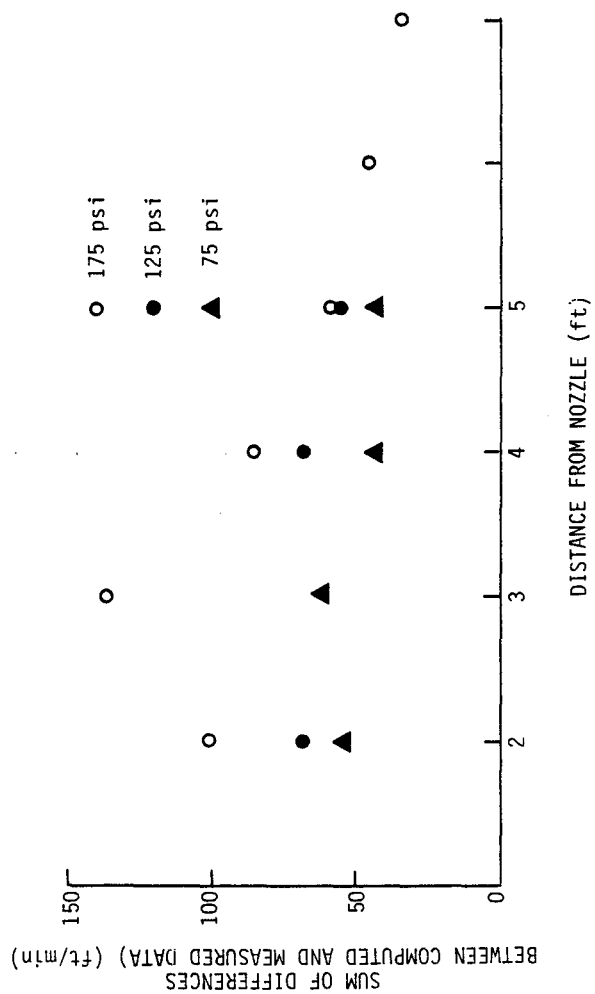


FIGURE 82. - Match between real and predicted data -
spraying systems BD3-3

AVERAGE DISTRIBUTION OF WATER IN SPRAYS
(4 SAMPLES EACH)

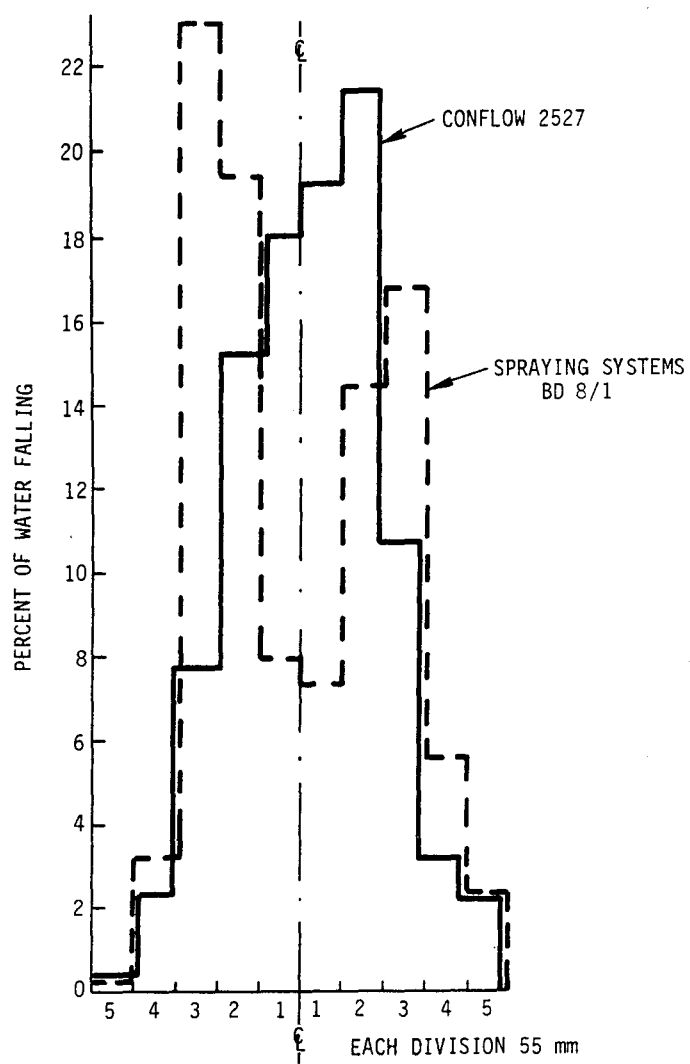


FIGURE 83. - Mass distribution around spray
nozzle centerline

(where V_i is the initial velocity, C_v a volume flow coefficient, and d the distance between the nozzle and the plane of measurement).

5.6 Conclusions

Results can be summarized as follows:

- a. *Dust knockdown rank of a nozzle depends upon quantity of air moved/gallon of water used, which depends upon spray pattern. The best indication of an efficient spray pattern is a narrow spray angle. The narrower the spray angle, the more efficiently air is moved, and the more dust knocked out.*
- b. *Dust knockdown capability decreases as the nozzle approaches a flat surface perpendicular to the nozzle axis. This effect is detectable as far away as 3 ft at normal mine operating pressures.*
- c. *Any obstacle in a nozzle's velocity field will interfere with air moving capability and therefore with dust knockdown. Obstacles may include solid objects behind the spray, solid objects alongside the spray, or shrouds - such as a venturi shroud.*
- d. *Increasing water temperature increases dust knockdown.*

There is need for further work in determining the value and applicability of these results. For example, a nozzle which moves more air may indeed knock down more dust in a closed booth, but may, under more open conditions, *dilute* dust concentrations more rapidly as well. The net effect of this needs to be determined by actual field experience.

APPENDIX A

UNDERLYING HYPOTHESES OF DUST BOOTH TESTING

This section covers the theoretical background of the dust booth data analysis and further assumptions made in the data analysis.

Delay in the Dust Booth: Consider a free spray operating in an enclosed, well-mixed dust cloud. If the dust removal efficiency of the spray were known, the scrubbing capability would still be undetermined, because the air volume flow rate through the spray droplet cloud (Q) would not be known.

All scrubbers, including free sprays, can be compared by a figure of merit which is the product of scrubbing efficiency (η) and air throughput volume (Q). The following analysis, therefore, would apply to any generalized scrubber (wet scrubber, filter, ESP, etc.) operating in the well-mixed cloud in the dust booth.

If C is the concentration in the chamber, then the rate of mass removal is:

$$\frac{dM}{dt} = -C\eta Q$$

If M is the dust mass in the chamber and V its volume,

then:

$$C = \frac{M}{V}$$

and

$$V \frac{dC}{dt} = -C\eta Q$$

or

$$\frac{dC}{C} = -\frac{\eta Q}{V} dt$$

integrating:

$$\ln\left(\frac{C}{C_0}\right) = -\frac{\eta Q}{V}t$$

where C_0 is the *initial* concentration. These equation models decay in C_0 dust concentration due to the scrubber (spray) alone.

The other factors contributing to dust removal (settling, impact-adhesion, etc.) must also be accounted for. The initial assumption was that the monitored dust (respirable range) is small enough to be considered monodispersed. This is in fact not the case with Arizona Road dust. Measured concentration decay rate decreases slowly with time as the absolute concentration decreases.

Furthermore, the stability of the "background" depends upon the mixing fan (3,000 cfm) dominating the environment as regards to settling, impact-adhesion, etc. Examination of the data suggests that the additional mixing due to the sprays (or wetting of the booth) increases the background decay by as much as a factor of 3. Fortunately, this is one or two orders of magnitude lower than the bulk of results. (By inspection of plotted data, an ηQ of 60 was assigned to the booth as background for periods when nozzles were operating).

The generalized decay model is:

$$V \frac{dC}{dt} = -C(\eta Q + F)$$

This is a reasonable fit to the data. F - the background "scrubbing" effect of the booth - varies ± 20 percent over the region of concern (130 mg/m^3 to 50 mg/m^3) where the bulk of measurements are made, and is, as mentioned, small in comparison to the spray knockdown (ηQ). $\eta Q + F$ was measured with sprays on, and ηQ determined by subtracting the assumed F .

Data Analysis: Plotting measured ηQ against pressure shows a linear or higher-power relationship. Empirical measurements of air movement by sprays (Q) carried out by Foster-Miller,

Inc., under constant geometry, had shown that air movement by a spray varied with water pressure raised to the 0.75 power.

In addition, dust knockdown depends on capture cross section, which also varies with water pressure. Specifically;

$$\text{capture cross section} = 1.5 q/D_{32}$$

where q is the water flow and D_{32} is the Sauter (volume-surface) mean. Assuming, based upon the work of Dundas*, that all means vary with pressure as the median droplet size:

$$D_{32} \propto (\text{pressure})^{-0.33}$$

then a dust knockdown merit factor depending only on Q and specific surface would obey the relationship:

$$\eta Q \propto (\text{pressure})^{1.08}$$

This relationship fits the data. Measured $\eta Q + F$ quantities were fitted to the equation:

$$\eta Q + F = C_{\eta} \cdot (\text{psi})^{1.08} + 60$$

with good success. The derived constant (C_{η}) was used to rank nozzles.

Several factors were taken into account in extracting data from plots of decaying concentration:

*Dundas, P.H., "The Scaling of Sprinkler Discharge: Prediction of Drop Size" Proposal Report No. 10 in "Optimization of Sprinkler Fire Protection" Technical Report RC73-T-40. Factory Mutual Research Corporation, June 1974.

- a. Several seconds are required for a stable "steady state" airflow to develop in the booth which is representative of the spray's actual knockdown capability. *This steady state exhibits a uniform log slope ($\eta Q/V$).*
- b. After a uniform period, the log slope begins to decrease. This is understood to show that the spray is more efficient on some part of the measured dust fraction, and has removed the bulk of that part. Evaluations of ηQ were made before any change of log slope in the data.
- c. Within these limitations, all measurements of ηQ were made in 10 sec intervals beginning as near as possible to 100 mg/m³ in order to minimize effects of time and absolute concentration on ηQ .

These techniques resulted in considerable reduction of scatter in the data.

It was also determined that pre-drying of the Arizona Road dust before testing reduced scatter in the data; probably caused by agglomeration due to humidity.

Comparison Between Arizona Road Dust and Coal Dust: Figure 1 shows *cumulative* ηQ for two identical tests (using a spraying systems BD 3-3 nozzle at 150 psi) comparing the two dusts. The slope of the initial straight section of the cumulative curve is the "steady state" ηQ . Apparently the effect of the spray is similar but the efficiencies differ, due to different particle size distributions.

The particle size distributions of the two types of dust are given in Table 1. It is assumed, since the RAM-1 essentially does not see dust $>10\mu$, that knockdown *efficiency* (η) increases as particle size decreases. (This is in accord with other published results). The significance of this result lies in the relatively small difference in efficiency (10 percent) for a considerable shift in particle size distribution.

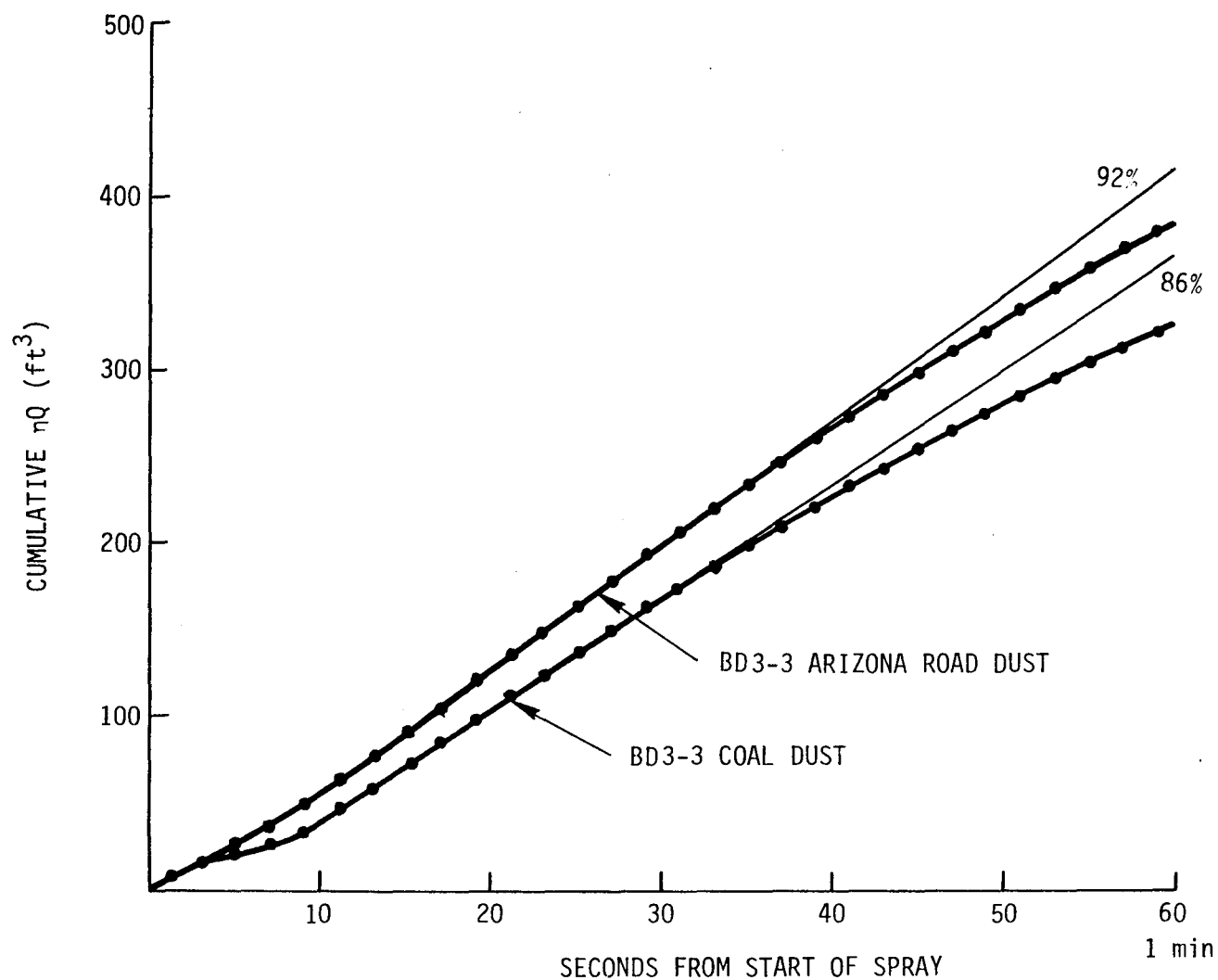


FIGURE 1. - Comparison: coal dust and Arizona Road dust - BD3-3 at 150 psi.

Table 1. - Particle size distribution of test dust

	Percent of Total Mass			
	<3 μ	3-5 μ	5-10 μ	>10 μ
Arizona Road Dust	16	<1	3	20
Coal Dust Used in Test	56	9	12	23