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## AN UPDATE ON FACE VENTILATION RESEARCH FOR IMPROVED LONGWALL DUST CONTROL

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## ABSTRACT

Although the number of operating longwall mining systems has remained relatively consistent over the past five years, longwall production levels have increased significantly during this period. Longwall production currently accounts for approximately 50% of U.S. underground coal production. While longwalls are highly productive and offer other advantages, operations employing this method of mining continue to experience dust compliance problems. This increased longwall productivity has meant that far more dust is being produced. An improved understanding of the longwall face ventilation system and advancement of face ventilation technologies are necessary to ensure all face personnel are allowed to work in an environment that is free of excessive levels of airborne respirable coal mine dust.

The Dust and Toxic Substances Control Branch of the National Institute for Occupational Safety and Health's Pittsburgh Research Laboratory has examined several basic principles of the longwall face ventilation system, and has evaluated the effectiveness of numerous improved face ventilation techniques for longwall mining systems. These include identifying improved techniques for measuring face ventilation parameters on longwall mining sections and investigating the fundamental relationship between face air flow and the entrainment and dilution of respirable coal mine dust. Studies have been completed to determine the impact on face dust levels from using belt entry air to ventilate the longwall. Novel methods have been identified to increase the amount of face air flow and to manage face air flow to most effectively minimize face workers' dust exposure. Unique systems of auxiliary face ventilation have been developed and evaluated at full-scale, simulated longwall test facilities. The theoretical and applied aspects of each of these principles and technologies are discussed. Application of these results, throughout the longwall mining industry, as documented from surveys conducted in the early 1980's and 1990's, have reduced the health hazard associated with excessive exposure to respirable coal mine dust.

## INTRODUCTION

Longwall mining equipment and operational practices have improved dramatically throughout the decade from the early 1980's through the mid-1990's. Longwall mining now accounts for approximately 50% of the coal produced underground in the United States. Average shift production has increased from approximately 1,500 tps in 1983, to over 3,200 tps in 1994. Historically, longwall mining operations have had difficulty in maintaining compliance with mandatory Federal dust standards. In the early 1980's, 31% of the compliance samples collected by the Mine Safety and Health Administration (MSHA) exceeded the 2.0 mg/m<sup>3</sup> respirable dust standard. For fiscal year 1994, 20% of MSHA-collected samples exceeded the standard. Although significant gains in longwall dust control have been made, these have been overshadowed by the significant increases in coal extraction rates. The increase in coal extraction rates has been accompanied by a continuing effort to maintain compliance with the respirable dust standard. However, as more coal is mined, more dust is generated (Webster, 1990). The increase in longwall coal extraction rates has meant that far more dust is being produced which must be

controlled. Approximately 25% of longwalls today are capable of extracting in excess of 6,000 tps, with several capable of extraction rates in excess of 10,000 tps.

As with all mining methods, ventilation is the primary means to control dust and methane on longwall operations. Improved ventilation techniques for room-and-pillar mining have been well documented by both industry and Government research. However, detailed scientific study of longwall face ventilation has often been overlooked. Only recently have face ventilation parameters for longwall mining systems been studied and characterized. The Dust and Toxic Substances Control Branch of the National Institute for Occupational Safety and Health's Pittsburgh Research Laboratory (NIOSH-PRL-DTSCB) has recently completed a ten year effort to identify and document the effectiveness of certain improved face ventilation techniques for longwall operations. This has allowed for a thorough documentation of the changes which have taken place in longwall face ventilation practices, and an evaluation of its impact on face dust levels.

The issue of respirable dust control at longwall operations could present a major limitation on the application and extraction potential of this advanced mining technique unless new and improved method of face ventilation are developed and implemented. Consequently, greater operator commitment is being made toward reducing dust levels at existing operations through the application and maintenance of state-of-the-art face ventilation technologies. Additionally, NIOSH is pursuing the advancement of ventilation technologies for dust control on future longwalls so as to enable all face personnel to work in an environment that is free of excessive levels of respirable coal mine dust.

## LONGWALL DUST SOURCES

Previous research was conducted in cooperation with the longwall mining industry during the early 1980's (Jankowski, 1983) and 1990's (Colinet, 1997), to identify the sources and levels of respirable dust, and ventilation practices applicable to typical longwall faces in operation during these time periods. The cutting action of the shearer was identified as the primary source of respirable dust during both surveys. Ventilating air quantity has been shown to impact respirable dust levels downwind of the shearer and with the shearer being the largest dust source on the longwall, increasing the quantity of air supplied to the longwall would be one of the most important changes that a longwall operator can make to improve dust levels. However, contribution of dust from coal transport through the stage loader/crusher, and dust liberated during support advance, are now found to be significant (Figures 1 and 2). During the 1983 study, the open design of the crusher, and modest levels of water application to the coal product, allowed high levels of respirable dust to be generated and released into the primary airstream. By 1994, levels of water applied to the mine product had increased by 200%, and most stage loader crushers were completely enclosed. However, face lengths and shearer tram speeds had almost doubled, requiring rapid and constant support advance with associated increasing levels of dust liberation. The impact of ventilation on support dust liberation has not been established.

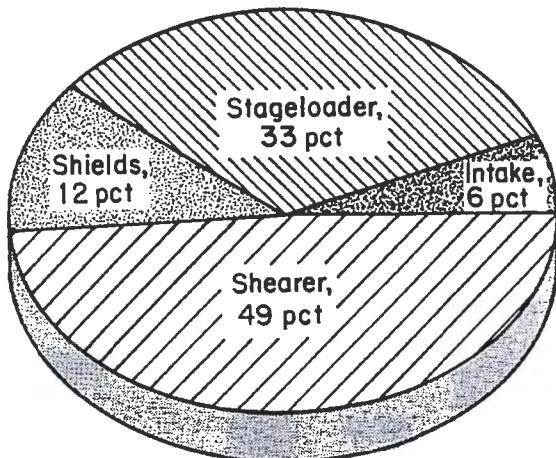


Figure 1. Longwall dust sources, 1980's.

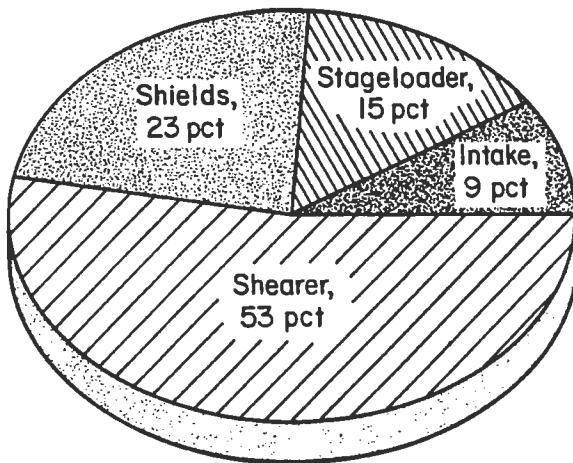


Figure 2. Longwall dust sources, 1990's.

#### VENTILATION PROCEDURES DEVELOPED AND IMPLEMENTED TO MINIMIZE DUST LEVELS

As with all mining methods, ventilation is the primary means to control dust on longwall operations. Providing adequate amounts of air to dilute and carry the airborne dust down the face and prevent its migration to the walkway has presented unique challenges for the longwall mining industry. At first glance the ventilation of a longwall face appears deceptively simple, air comes in on one side, courses over the face, and exits. If workers are to be kept out of the dust, they are simply kept upwind of the dust sources. Unfortunately, there can be high intake dust levels, air that leaks back behind the shields (especially near the shearer), and operators that need to see the downwind drum, all of which potentially place personnel in areas of high dust concentrations. Researchers, in cooperation with the longwall mining industry, have identified and documented the effectiveness of certain improved face ventilation techniques for longwall operations. These studies have shown that assessment of the primary intake alone is not

sufficient; the direction and utilization of the primary airflow is critical for dust control. Substantial improvements can be obtained through application of these advanced techniques.

#### Higher Air Quantities and Volumes Help Control Airborne Dust

In most longwall operations, the face airflow is usually measured at the crosscut in the headgate entry. Although this intake quantity often exceeds 30,000 cfm (14.2 m<sup>3</sup>/s), this measurement is often not representative of face airflow. Ventilation measurements should be taken at every 10th support; the resulting profile can be used to determine "average" face airflow, effective utilization of the primary intake, and air loss to the gob. Airflow along the face is seldom uniform; a measurement at any single location may not be representative of the average face airflow. With a ventilation profile, the mine operator can discover problem areas and more accurately determine the specific ventilation parameters on a given longwall face.

Face air velocities of at least 400 to 450 fpm (2.0 to 2.3 m/s) appear to be the minimum appropriate for dust control (Mundell, 1979). Once again, these values are for the average face velocity profile and should be maintained for the entire face length. With optimum air utilization, these values would equal minimum average intake air quantities of 20,000 cfm (9.4 m<sup>3</sup>/s) for a 5-ft (1.5-m) coal seam and 30,000 cfm (14.2 m<sup>3</sup>/s) for a 7-ft (2.1-m) seam. In the past, air velocities above 650 fpm (3.3 m/s) were thought to cause entrainment of dust from coal transport and dust liberation during support movement. Recent studies by MSHA (Tomb, 1992) now show that as face air quantities increase even beyond 1,200 fpm (6.1 m/s), respirable dust levels due to dust generated along the face decrease. NIOSH is currently attempting to identify a cooperative mine site at which to conduct further studies of the impact of air velocity increases on dust entrainment along the face.

Minimum average face air velocities of 400 to 450 fpm (2.0 to 2.3 m/s) help to control respirable dust in three ways. The higher air velocities provide greater air quantities for better dilution of intake dust as well dust generated during support movement. Higher velocities over the shearer help to confine the dust to the face area and lower contamination in the walkway. Finally, these higher velocities improve diffusion of dust from stagnant areas in the headgate and along the support line.

#### Curtains in Headgate Provide Better Direction of Primary Airflow

Often, loss of air into the gob in the headgate area prevents maximum utilization of the air available to ventilate the longwall face. The gob behind the first few supports remains open owing to the roof bolts in the headgate entry, and a large gap usually exists between the first support and the entry rib. As a result, a substantial portion of the ventilation air from the headgate entry leaks back into the gob, lowering the airflow along the face. Moreover, this air laden with dust generated during gob falls may reenter the face area, compounding the dust problem.

A gob curtain, installed between the first support and the rib in the headgate entry, can force the ventilation airstream to make a 90° turn, staying on the face side of the supports, rather than leaking into the gob. The curtain is suspended from the roof to the floor and advanced with the supports at each pass.

Previous researchers (Jankowski, 1983) have collected extensive face air velocity data with and without the gob curtain in use. The average face air velocity with the curtain installed was approximately 35% greater than without the curtain. The biggest improvement due to this curtain is seen at the first 25 to 30 supports, where the increased air volume lowers dust concentrations through dilution. The gob curtain is easy to use, install, and maintain, and it is fabricated from material that is readily available in all mines (Fig. 3).

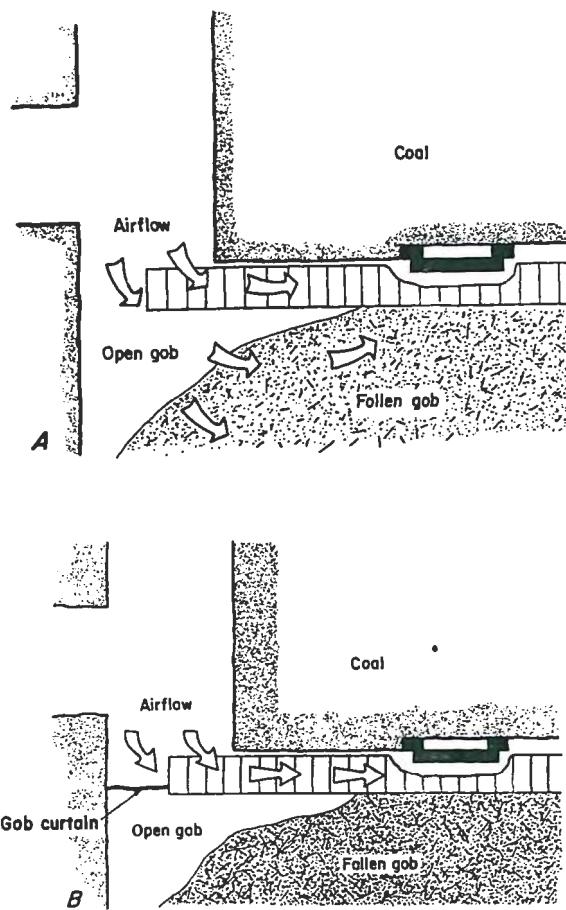


Figure 3. Location of gob curtain at longwall headgate.

In many longwall operations, misapplication of the primary airflow may actually contribute to increased dust levels. One source of extreme concentrations of respirable dust for longwall shearer operators is the headgate shearer drum as it cuts through into the headgate entry. As the drum cuts into the entry, it is exposed to the primary ventilation airstream. The high-velocity air passes through and over the drum, picking up large quantities of dust; this dust is carried into the walkway and over the shearer operators. Although this operation is usually of

short duration, the resulting dust levels are extremely high. Concentrations ranging from 20 to 30 mg/m<sup>3</sup> have been measured at several mines, using instantaneous dust monitors at the operator position. Thus, the cumulative effect on full-shift exposure levels can be significant, particularly on high-production faces where this operation may be performed six to eight times per shift.

To overcome this problem, some coal mine operators use a "cutout" curtain in the headgate to shield the lead drum from the ventilation airstream as it cuts out into the headgate. The curtain redirects the primary air so that it flows out and around the drum. The curtain is usually located 4 to 6 ft (1.2 to 1.8 m) back from the corner of the face, so that maximum shielding is provided without interference with the drum, and is suspended from the roof between the panel side rib and the stage-loader. The curtain need only be in place during the actual cutout operation and is advanced every other pass (Fig. 4).

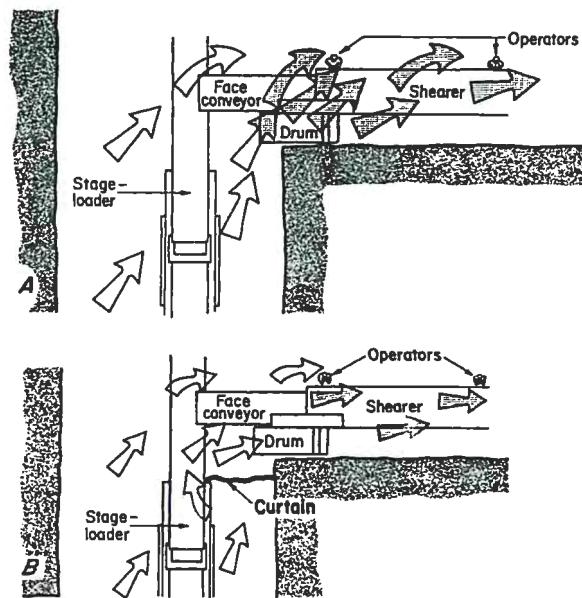


Figure 4. Location of cutout curtain at longwall headgate.

Previous researchers (Jankowski, 1986) have conducted underground evaluations to document the improvements achieved through installation of a cutout curtain. Dust levels at the operator positions were monitored using instantaneous dust monitors as the shearer cut out and cleaned up at the headgate. Concentrations monitored with and without the curtain indicated that the curtain can reduce the exposure of the tailgate shearer drum operator by 50 to 60% during this phase of the mining cycle. To achieve these improvements, the curtain must be installed tightly against the mine roof and must extend sufficiently into the headgate entry.

#### Impact of Belt Entry Air

An increasing number of mines are either using or petitioning to use belt entry air to ventilate active longwall face areas. Using the belt entry as an intake entry may allow delivery of more air to the face, providing better dust and methane dilution.

NIOSH, as part of its goal to improve the health of the Nation's miners, recently conducted underground dust surveys to further explore this topic (Potts, 1992). Results of these studies have shown that a 1,000-ft (300-m) increase in belt entry length or a 200- to 500-st (181- to 453-mt)-per-shift increase in production resulted in roughly a 0.1-mg/m<sup>3</sup> increase in dust. Dust levels inby the belthead appeared to be independent of belt entry airflow, over the range of airflow observed during the surveys. During the 1993 study, six of the operations surveyed were utilizing belt air to ventilate the longwall face. The average dust level in the belt entry just outby the stage loader was 0.6 mg/m<sup>3</sup>, while the average intake concentration was 0.5 mg/m<sup>3</sup>. Any potential increase in face intake dust levels appears to be negated by the potential for increased dilution that can be obtained with additional air brought up the belt entry.

Compliance data analyzed by MSHA (MSHA, 1989) have shown that mines using belt entry air to ventilate work areas did not have significantly different respirable dust levels at the designated occupation than mines not using belt air. According to MSHA, in one district, mines using belt entry air had a significantly lower mean dust concentration than mines not using belt air. From a theoretical standpoint, applying the dilution formula shows that if belt entry air represents additional air brought to the face and if belt entry dust levels, including those at the stage-loader and crusher, can be maintained below the average dust level measured at the designated occupation, it is beneficial from a dust compliance perspective for the mine to use belt entry air to ventilate work areas.

Using the belt entry as an additional source of intake air results in an increased number of outby dust sources. The conveyor belt itself is a source of dust, and the stage-loader and crusher are always in intake air if the belt entry is used to ventilate the face. Researchers have conducted extensive research and have demonstrated effective technology to control dust from these sources (Organiscak, 1982).

#### **IMPACT OF WATER SPRAY SYSTEMS ON FACE VENTILATION EFFECTIVENESS**

Design and operational parameters of the shearer water spray system can have a significant impact on face ventilation effectiveness. Water sprays oriented perpendicular to, or upwind into the primary ventilation can cause high levels of dust to be transported away from the face area and into the primary airstream. Water sprays are very efficient air movers, and if applied properly can be used to augment the primary airflow and reduce the amount of shearer generated dust which is transported into the face walkway.

#### **Operating Spray Pressure**

All shearer cutting drums in operation since the late 1970's have been equipped with drum mounted water sprays. The purpose is to apply water for dust suppression directly at the point of coal fracture, and to add moisture to the product to minimize dust liberation during coal transport off the longwall face. Once respirable dust becomes airborne and is released into the primary airstream, it remains airborne the entire length of the longwall face. Although very effective at minimizing

dust generation at the point of coal fracture, shearer drum water sprays can actually increase airborne respirable dust levels if operated at too high a water pressure level. Instead of suppressing dust generation, these sprays force the dust out away from the cutting drum, and allow it to mix with the primary airflow, where it is then carried throughout the entire cross-sectional volume of the longwall face. Studies (Pimental, 1984) have shown that increasing shearer drum water spray pressures above 100 psi can increase the shearer operators dust exposure by 25 pct. At operating pressures exceeding this level, the drum sprays force dust out away from the face and overwhelm the dilution capacity of the primary ventilation. The optimum operating drum spray pressure appears to be between 480 to 700 kPa (70 to 100 psi). Water flow rate should be increased by increasing the nozzle orifice size, rather than the operating spray pressure.

#### **Air-Directional Water Spray Systems**

Water sprays are very effective air-moving devices. Water sprays mounted on the shearer body act very much like small fans, moving airflow and entrained dust in the direction of their orientation. Poorly designed shearer-mounted spray systems with nozzles directed upwind at the cutting drum actually carry the dust away from the face and upstream of the drum, where it mixes with the clean intake air and is carried out into the walkway over the shearer operators.

Researchers have devised a novel shearer spray system, called the shearer clearer (Jayaraman, 1985), which takes advantage of the air moving capabilities of water sprays. It consists of several shearer-mounted water sprays oriented downwind to augment the primary ventilation airflow, and one or more passive barriers which split the airflow around the shearer into clean and contaminated air-splits. The air-split is initiated by a splitter-arm, extending from the gob-side corner of the shearer body, from which conveyor belting hangs down to the panline. Spray manifolds mounted on the splitter-arm confine the dust cloud generated by the cutting drum, further enhancing the air split. The dust-laden air is drawn over the shearer body and is held against the face by two spray manifolds positioned between the drums. The air is then directed around the downwind drum by a set of sprays located on a downwind splitter arm. Operating pressure must be approximately 150 psi (1,035 kPa), measured at the nozzle, to assure effective air movement.

In underground tests, the shearer clearer has reduced operator exposure from shearer-generated dust by approximately 50 pct when cutting against face ventilation, and 30 pct when cutting with ventilation. Although a properly installed and operated shearer clearer system controls dust at the operators's position more effectively than does a conventional spray system, it cannot compensate for insufficient primary ventilation, or reduce operators exposure from other dust sources.

Shearer cooling water has historically been discharged through spray nozzles oriented against the primary airflow or directed into the face, causing dust to be carried back into the walkway. An alternative for discharging cooling water are panline spray manifolds, mounted at both ends of the shearer, aimed down onto the panline. This minimizes turbulence

caused by face-side sprays. Respirable dust reductions of up to 35 pct at the shearer operators location can result (Jayaraman, 1985).

#### ASSESSMENT OF CHANGES IN FACE VENTILATION PRACTICES

As previously stated, researchers at NIOSH's Pittsburgh Research Laboratory conducted extensive in-mine surveys which can be used to obtain an insight into the changes which have taken place in longwall face ventilation practices, and an evaluation of its impact on face dust levels at operating longwall from the early 1980's to 1990's. Twelve longwalls, representing the eastern, mid-western, and western U.S. coal mining regions, were surveyed during each time period, and represent a cross-section of conditions existing during each period. Several generalities can be drawn from analysis of these data sets, and certain specifics can be obtained from six mines which were surveyed during both surveillance periods.

Based on MSHA compliance records (Niewiadomski, 1993) for all longwalls operating in the early 1980's, 31% of the longwall designated occupation(DO) samples exceeded the respirable dust standard, with an average value of 2.3 mg/m<sup>3</sup>. For fiscal year 1994, 20% of MSHA-collected DO samples exceeded the respirable dust standard, with an average value of 1.7 mg/m<sup>3</sup> (Niewiadomski, 1996), for a typical dust reduction of 26 percent. As previously stated, during the same time period, coal extraction rates increased from approximately 1,500 to 3,250 tps, for an average increase of 117 percent.

Tables 1 and 2 list a summary and averages of longwall ventilation parameters and dust levels from the twelve operations surveyed during the two surveillance periods. In general, these values are in good agreement with national averages reported yearly, and with results of a 1995 survey of high production longwall mining sections (Jankowski, 1994). On average, results of this study indicate that average face air velocity has increased by approximately 27%, from 327 fpm(1.7 m/s) in 1983 to 415 fpm(2.1 m/s) in 1993. When comparing only the six longwalls surveyed during both periods of surveillance, average face air velocity has increased by 20%, from 374 fpm(1.9 m/s) in 1983 to 453 fpm(2.3 m/s) in 1993. Results of a similar study showed the average face air velocity on longwalls increased by 100 fpm(0.5 m/s) during the same time period. During the same time period, longwall panel face lengths have increased by approximately 40%, meaning that on average, longwall mine operators are delivering approximately 10,000 cfm(4.7 m<sup>3</sup>/s) of additional air to the longwall panel in 1993 than was being delivered in 1983.

When comparing changes in dust levels during the same time period, average dust levels at the tailgate location decreased by approximately 47%, from 6.6 mg/m<sup>3</sup> in 1983 to 3.5 mg/m<sup>3</sup> in 1993. Similar dust reductions (46%) are observed when comparing only the six longwalls surveyed during both surveillance periods. Headgate dust levels decreased approximately 30%.

Comparison of these statistics make it apparent that significant gains have been achieved in the area of longwall dust control, however, applying a simple dilution formula for

ventilation cannot explain the magnitude of dust level reductions observed. Coal extraction rates have increased approximately 120%. As stated previously, when more coal is mined, more dust is generated. There are a number of factors in addition to ventilation which have allowed the longwall industry to advance extraction rates while continuing to reduce respirable dust levels along the longwall face. Obviously, the increases in face air velocity and quantity have contributed, as have the changes in machine design, increases in water application, and the use of remote control. However, the longwall mining industry has adopted and implemented a broader, more scientific approach to longwall face ventilation, based on results of the research conducted during the past decade. Face air velocities in the range of 400 to 500 fpm(2.0 to 2.5 m/s), as observed during the 1990's surveys, appear to be most appropriate for dust control. As noted previously, these higher air velocities provide greater air quantities for better dilution of intake dust as well dust generated during support movement. Higher velocities over the shearer help to confine the dust to the face area and lower contamination in the walkway. And finally, these higher velocities improve diffusion of dust from stagnant areas in the headgate and along the support line. Projections from recent surveys suggest that half of the longwalls in operation today utilize the belt entry to bring intake air to the longwall face, resulting in an average face air quantity of approximately 55,000 cfm(25.8 m<sup>3</sup>/s). Over 90% of the longwall faces in operation today utilize headgate curtains to assist in directing the primary intake onto the face, avoiding air loss to the gob in the headgate area. Average face air velocities can be significantly improved through the installation of headgate curtains.

As previously stated, design and operational parameters of the shearer water spray system can have a significant impact on face ventilation effectiveness. Results of this study have shown that the longwall mining industry has thoroughly embraced this development. Over 95% of the longwalls in operation today have implemented some type of air directional water spray system on the shearer to augment the primary face airflow, confine shearer generated dust to the face area, and lower dust levels in the face walkway. This concept, and its acceptance and application by the industry, is illustrated in Figure 5. The average respirable dust level profiles around the shearer are shown for the six mines which were surveyed during both surveillance periods. The average respirable dust level 20-ft on the intake air side of the shearer remain unchanged, and are not impacted significantly by the air directional water spray system on the shearer body. However, the respirable dust level at the midpoint of the shearer, and 40-ft downwind of the shearer have been reduced between 20 to 25%.

#### SUMMARY

During the early 1980's, many longwall mining operations did not optimize the application and utilization of the primary face air flow as a method to reduce respirable dust levels along the face. Over the past decade, considerable research has been conducted to identify and document the effectiveness of several improved face ventilation techniques, and the longwall mining industry has aggressively applied results of these research developments. Providing adequate amounts of air to dilute and carry the airborne dust down the face and prevent its migration

Table 1. Summary of Longwall Operating Parameters and Dust Levels.

Mine	A	B	C	D	E	F	Average
HGD83	1.1	1.2	1.8	1.6	1.8	1.2	1.5
HGD93	1.4	1.0	1.8	2.1	1.2	0.6	1.4
TGD83	5.4	5.1	5.5	8.4	6.1	1.8	5.9
TGD93	2.7	2.9	5.6	3.0	3.0	1.0	3.2
VEL83	1.7	2.0	1.2	2.4	0.6	3.3	1.9
VEL93	1.9	1.5	1.1	3.0	2.7	3.8	2.3
FL83	190	147	176	161	163	163	166
FL93	238	168	176	224	212	224	207
EXR83	15.8	8.2	11.9	9.5	15.5	10.1	11.8
EXR93	23.1	18.9	31.5	21.0	26.6	11.3	20.1
AuxV93	No	No	No	Yes	Yes	Yes	
Mine	G	H	I	J	K	L	Average
HGD83	1.6	1.2	1.0	1.6	1.3	2.6	1.6
TGD83	10.9	7.2	4.2	8.2	4.3	8.4	7.2
VEL83	1.8	1.2	1.8	1.4	1.0	1.3	1.4
FL83	127	138	138	138	148	127	135
EXR83	8.8	8.0	8.5	10.0	5.2	9.2	8.3
Mine	G*	H*	I*	J*	K*	L*	Average
HGD93	0.9	0.8	1.1	1.4	0.4	1.0	0.9
TGD93	1.7	3.2	2.1	3.3	2.2	10.0	3.8
VEL93	1.9	2.5	1.5	1.8	2.3	1.6	1.9
FL93	184	260	240	193	284	176	224
EXR93	12.4	30.6	21.7	35.4	24.2	14.3	23.1

\* Mines G-L represent different mining operations, but similar mining regions across the U.S. and were only used to identify generalities drawn from analyses between these data sets.

HGD = Headgate Dust Level, mg/m<sup>3</sup>  
FL = Face Length, m

TGD = Tailgate Dust Level, mg/m<sup>3</sup>  
EXR = Extraction Rate, t/min.

Vel = Face Velocity, m/s  
AuxV = belt air used to ventilate

Table 2. Percentage Change, Longwall Operating Parameters and Dust Levels, 1980's vs. 1990's

All Mines Surveyed		Six Mines Surveyed 1983/1993	
AvgHGD83	1.6	AvgHGD83	1.5
AvgHGD93	1.2	AvgHGD93	1.4
% Change	33%	% Change	7%
AvgTGD83	6.6	AvgTGD83	5.9
AvgTGD93	3.5	AvgTGD93	3.2
% Change	47%	% Change	46%
AvgVEL83	1.7	AvgVEL83	1.9
AvgVEL93	2.1	AvgVEL93	2.3
% Change	27%	% Change	20%
AvgFL83	150	AvgFL83	165
AvgFL93	215	AvgFL93	207
% Change	43%	% Change	25%
AvgEXR83	10.1	AvgEXR83	11.8
AvgEXR93	21.6	AvgEXR93	20.1
% Change	114%	% Change	70%

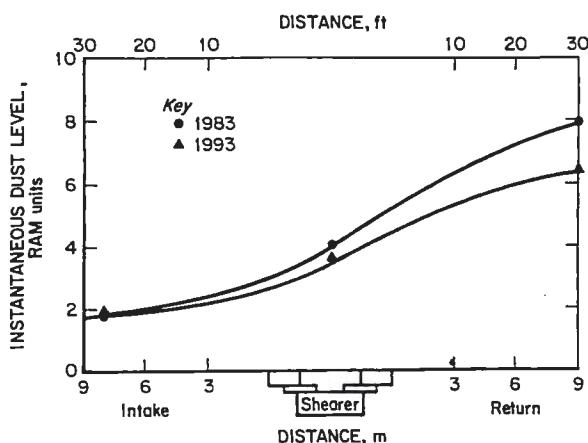


Figure 5. Directional water spray systems augment primary face airflow.

to the walkway has presented unique challenges for the longwall mining industry. NIOSH, in cooperation with the longwall mining industry, has identified and documented the effectiveness of certain improved face ventilation techniques for longwall operations. Researchers at NIOSH's Pittsburgh Research Laboratory have conducted extensive in-mine surveys which can be used to obtain an insight into the changes which have taken place in longwall face ventilation practices, and an evaluation of its impact on face dust levels at operating longwall from the early 1980's to 1990's.

Face air velocities of at least 400 to 450 fpm (2.0 to 2.3 m/s) appear to be the minimum appropriate for dust control. Minimum average face air velocities in this range help to control respirable dust in three ways. The higher air velocities provide greater air quantities for better dilution of intake dust as well

dust generated during support movement. Higher velocities over the shearer help to confine the dust to the face area and lower contamination in the walkway. Finally, these higher velocities improve diffusion of dust from stagnant areas in the headgate and along the support line. Average face air velocity has increased by approximately 27%, from 327 fpm(1.7 m/s) in 1983 to 415 fpm(2.1 m/s) in 1993. Longwall mine operators are delivering approximately 10,000 cfm(0.5 m<sup>3</sup>/s) of additional air to the longwall panel in 1993 then was being delivered in 1983. Often, loss of air into the gob in the headgate area prevents maximum utilization of the air available to ventilate the longwall face. A substantial portion of the ventilation air from the headgate entry leaks back into the gob, lowering the airflow along the face. A gob curtain, installed between the first support and the rib in the headgate entry, can force the ventilation airstream to make a 90° turn, staying on the face side of the supports, rather than leaking into the gob. An increasing number of mines are using belt entry air to ventilate active longwall face areas. Using the belt entry as an intake entry may allow delivery of more air to the face, providing better dust and methane dilution.

Design and operational parameters of the shearer water spray system can have a significant impact on face ventilation effectiveness. Water sprays are very effective air-moving devices. Water sprays mounted on the shearer body act very much like small fans, moving airflow and entrained dust in the direction of their orientation. A typical shearer clearer system design consists of several shearer-mounted water sprays, oriented downwind, and one or more passive barriers to divide the airflow around the shearer into clean and contaminated air splits. Results of this study have shown that the longwall mining industry has thoroughly embraced this development. Respirable dust level at the midpoint of the shearer, and 40-ft downwind of the shearer have been reduced between 20 to 25%.

These statistics make it apparent that significant gains have been achieved in the area of longwall dust control. Average dust levels at the tailgate location have decreased by approximately 47%, from 6.6 mg/m<sup>3</sup> in 1983 to 3.5 mg/m<sup>3</sup> in 1993. The longwall mining industry has adopted and implemented a broad, scientific approach to longwall face ventilation based on results of the research conducted during the past decade. Continuing joint research efforts are underway which should represent the next generation of longwall face ventilation technology and enable all face personnel to work in an environment that is free of excessive levels of respirable coal mine dust.

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