Evaluation of respirable dust control on longwall mining operations

T.F. Tomb, R.S. Ondrey, R.T. Stoltz, R.A. Haney, D.L. Chiz Novakowski, D.J. Atchison and E.J. Gerbec

Abstract—*Although the number of operating longwalls in the United States (approximately 100) has remained relatively constant over the last five years, longwall production levels have significantly increased and in some cases more than doubled. As a result of this production increase, control of respirable dust continues to be a problem. Therefore, the Mine Safety and Health Administration (MSHA), Pittsburgh Health Technology Center, Dust Division, initiated a study to investigate the availability and adequacy of technology for controlling dust on longwall mining operations.*

The study involved 23 longwall mining operations in three different Coal Mine Safety and Health Districts. Each operation was visited for a full shift. Respirable dust samples were collected on face personnel and at fixed locations along the face. Methods being used to control dust were noted, with special emphasis placed on obtaining quantitative data relative to ventilation, headgate dust controls, cutting drum sprays, external machine sprays and cutting sequence.

Attempts were made to correlate dust control practices in place at the time of the visit to dust concentrations measured at the tail and on the tail shearer operator and to the average of all the dust concentration measurements from the occupations sampled. The methods used to control dust were also compared to the gamut of methods known to be available.

This paper presents a discussion on the effectiveness of the methods being used to control dust and on the availability of technology for the control of dust on longwall mining operations.

Introduction

Analysis of coal mine operators' respirable dust samples indicates that dust control on longwall mining sections has been and continues to be a major problem. While operator samples show that industry average dust levels have been reduced to approximately 2.0 mg/m^3, many individual operations still have trouble consistently maintaining average respirable dust levels at or below this standard. At the same time, dust levels have been reduced, and production levels have significantly increased and in many cases more than doubled.

The number of operating longwalls has remained relatively constant at approximately 100 over the last five years. This number is not expected to increase significantly in the immediate future, nor are the production levels expected to increase significantly beyond the current system capacity.

Given the current relatively stable conditions regarding longwall mining, this study was initiated to assess current industry longwall dust control technology and practices. The purpose of this study was to determine whether the continued dust control problems associated with longwall mining were a result of a lack of available dust control technology, a lack of technology implementation or a lack of maintenance of the methods being used to control dust.

The study, conducted between June 1987 and January 1988, involved visits to longwall sections in three Coal Mine Safety and Health (CMS&H) Districts. A total of 23 longwall sections were visited and observed.

Description of operations

Of the 23 longwall operations visited, only 22 were in a producing status. The three districts in which the mines were located were District 2, Monroeville Subdistrict (eight longwalls); District 7, Birmingham Subdistrict (seven longwalls); and District 9, Price Subdistrict (eight longwalls). All of the longwalls visited used a double drum ranging arm shearer. Seam heights ranged from 1.7 to 3.7 m (5.5 to 12 ft), and panel widths ranged from 147.8 to 243.8 m (485 to 800 ft). Unidirectional mining was done on 20 of the longwalls, while bidirectional type mining was done on two. Remote control was used to operate the shearers on 14 of the longwalls. Crushers were used on all of the longwalls.

All of the longwalls were ventilated by directing the intake air from the headgate to the tailgate. Belt air supplemented intake air to ventilate the face on eight of the operations. Measured intake air quantities ranged from 9.1 to 92.5 m^3/sec (19,200 to 196,000 cfm of air).

Procedures

Personal and fixed-point respirable dust samples were collected to determine personal exposures and dust generating sources. All samples were collected using approved Mine Safety Appliances (MSA) personal respirable coal mine dust samplers operated at a flow rate of 2.0 L/min.

Filter cassettes were pre- and post-weighed on an analytical balance to a hundredth of a milligram. Respirable dust concentrations were obtained by dividing the mass of dust collected by the volume of air sampled. In accordance with the work of Tomb (1973), respirable dust concentrations were converted to MRE equivalent concentrations by multiplying by the constant factor 1.38.

Personal samples were collected on at least five face personnel at each mine. The occupations usually sampled included shearer operator(s), shield setters, and the headgate operator. The occupation of gas checker (unique to District 9) was also sampled when present. All personal samples were collected portal to portal.

The fixed-point samples were collected at various locations on section. These locations included the intake, the belt entry (if belt air was used to ventilate the face), the headgate area (near Shield No. 10), on the longwall face (approximately 10 shields from the tailgate entry) and the tail end of the shearer near the operator's controls. Samplers used to collect the fixed-point samples were operated only on section.

T.F. Tomb, R.S. Ondrey, R.T. Stoltz, member SME, **R.A. Haney**, member SME, **D.L. Chiz Novakowski, D.J. Atchison**, and **E.J. Gerbec** are with the Mine Safety and Health Administration, Pittsburgh, PA. SME preprint 90-41, SME Annual Meeting, Salt Lake City, UT, Feb. 26-March 1, 1990. Manuscript Nov. 30, 1989. Discussion of this paper must be submitted, in duplicate, prior to Oct. 1, 1991.

Air velocities were measured at least twice during the shift at the intake(s), at Shield No. 10 and at the tailgate (approximately 10 to 15 shields from the corner). Air quantities were calculated from the velocity measurements and the cross-sectional area of the place where the measurements were made. Water pressure was measured on the shearer's water spray system at various spray locations, and the details of the water delivery system to the shearer were noted. In addition, general information on the longwall section, on specific equipment in use and on the methods being used to control dust was collected and tabulated.

Results and discussion

Table 1 shows a compilation of selected data extracted from the information gathered during the mine visits. The data in Table 1 are only representative of those operations on which a respirable dust measurement was obtained at the tailgate and the headgate.

These data were analyzed to assess the status of respirable dust levels on the longwalls visited and to determine if parameters such as production, ventilating air quantity and face air velocity were related to these levels. This compilation of data does not include data on water application; because the water quantity, pressure and application data were so variable they could not be normalized for analysis. Therefore, the water application data were only used to help explain atypical differences in the data that were analyzed.

The data extracted and compiled in Table 1 for each mine include: production, concentration of dust measured at the headgate, concentration of dust measured on the tail drum shearer operator, average of all occupational exposures measured on the face, number of occupations sampled at each operation, number of occupations sampled that had respirable dust exposures less than 2.0 mg/m^3, quantity of air measured at the head of the panel and quantity and velocity of air measured at the tail of the panel.

Analysis of the data on Table 1 show that of 69 personal samples collected, 42 (60%) are less than 2.0 mg/m^3; and that of the 27 samples that exceed 2.0 mg/m^3, only six were collected on the tail drum shearer operator (the designated occupation). The analysis also shows that on only three of 16 occasions did the tail drum operators' exposures exceed the respirable dust concentration measured at the tailgate, and that the dust concentration measured at the tailgate exceeded 2.0 mg/m^3 on 13 of the 16 operations sampled.

To further evaluate the status of dust levels on these operations, measurements obtained on the tail drum shearer operators, the average exposures of all the face occupations sampled on each operation, and the dust concentrations measured at the tailgate (adjusted for a combined intake and headgate dust concentration of 0.5 mg/m^3) were compared. A value of 0.5 mg/m^3 was used because previous experience has shown this level when headgate controls are properly maintained.

This comparison is shown on Fig. 1. The data for the respective mines are plotted in ascending order according to the quantity of air measured at the tail. Plotting the data according to ascending quantity shows that as air quantities increased, dust levels due to dust generated along the face decreased. This comparison shows that the dust concentrations measured on the tail drum shearer operators exceeded 2.0 mg/m^3 on six of the 16 operations and that the average exposure of all face workers exceeded that of the tail drum operator 30% of the time. The data plotted on Fig. 1 also show that if the concentration of dust at the headgate had been maintained at or below 0.5 mg/m^3, the dust concentration at the tailgate would have been below 2.0 mg/m^3 on eight of the 16 operations.

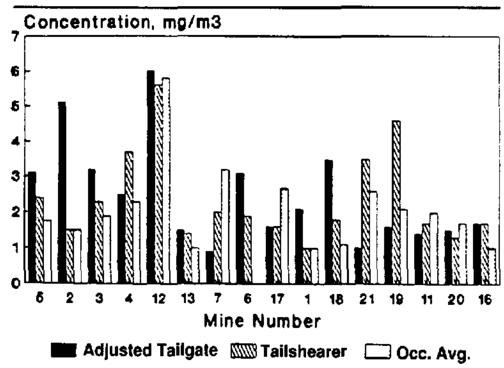

Fig. 1—Comparison of respirable dust concentration, plotted according to ascending tail air quality.

Table 1—Data compiled for analysis

MINE	PRODUCTION metric tons	TGconc. (mg/m^3)	HGconc. (mg/m^3)	TSconc. (mg/m^3)	OCCavg (mg/m^3)	# OCCS SAMPLED	OCCS<2.0 (mg/m^3)	HEAD (m^3/sec)	TAIL (m^3/sec)	VELtail (m/sec)
1	1996	2.2	0.6	1.0	1.0	4	4	15.6	13.8	2.4
2	2105	5.0	0.4	1.5	1.5	4	4	8.7	8.4	1.4
3	980	3.0	0.3	2.3	1.9	5	2	6.2	8.5	1.5
4	1089 *	3.2	1.2	3.7	2.3	4	2	10.9	9.0	1.6
5	1905	3.7	1.1	2.4	1.8	5	4	8.2	7.4	1.3
6	2177	3.4	0.8	NM	0.2			12.0	10.9	2.2
7	1270	3.5	3.1	2.0	3.2	5	2	10.4	10.9	1.7
11	3810	2.5	1.6	1.7	2.0	5	4	28.5	33.7	4.3
12	2177	8.2	2.7	NM	5.8	5	0	11.3	9.4	1.2
13	1089	1.5	0.5	1.4	1.0	5	5	14.2	9.4	1.0
16	1315	1.7	0.5	1.7	1.0	4	4	62.8	49.6	7.1
17	2958	4.2	3.1	1.6	2.7	5	1	21.2	13.7	2.2
18	1043	3.3	0.3	1.8	1.1	4	4	28.3	28.3	5.6
19	1089*	3.0	1.9	4.6	2.1	4	2	34.9	31.9	5.2
20	1367	1.9	0.9	1.3	1.7	5	4	47.7+	39.9	5.5
21	1089 *	2.7	2.2	3.5	2.6	5	0	31.3	25.2	6.8

TGconc. = concentration measured at tailgate
HGconc. = concentration measured at headgate
TSconc. = concentration measured on tailshearer operator
OCCavg. = average concentration of all occupations

* estimated since no values available
\+ intake value used
NM not measured

It was concluded from the analysis of the dust measurement data that while in most instances dust measurements obtained at the tailgate were above 2.0 mg/m^3, the majority of occupational exposures were less than 2.0 mg/m^3. This can be explained by the data tabulated in Table 2, which shows that prudent work practices were being used to reduce personal exposures to respirable dust, and by the fact that personal samples are collected portal-to-portal while samples collected at the tailgate were operated only during the time they were on the working section. It was also concluded that dust generated at, and outby, the headgate was a major contributor to dust concentrations measured on 10 of the operations.

The effect of production on dust levels was assessed by comparing the concentration of dust measured at the tailgate (corrected for dust measured at the headgate) and the concentration of dust to which the tail shearer operator was exposed (also corrected for dust measured at the headgate) to the amount of material produced when these measurements were made. These comparisons are shown on Figs. 2 and 3, respectively. As the comparisons show, the tail drum shearer operator's (normally the designated occupation) exposure and the concentration of respirable dust measured at the tailgate do not appear to be dependent on the amount of material mined.

Similar comparisons between the concentration of dust measured at the tailgate and air quantities and velocities measured at the same location are shown on Figs. 4 and 5. The concentrations plotted were first corrected for dust measured at the headgate and then, as previously done, 0.5 mg/m^3 was added to allow for an intake air dust level of 0.5 mg/m^3. These comparisons indicate that if the concentration of respirable dust at the headgate is controlled to 0.5 mg/m^3, operations ventilating the face with more than 14.2 m^3/sec (30,000 cfm of air) will have a high probability of complying with the 2.0 mg/m^3 respirable dust standard. The relative importance of air quantity vs. air velocity on dust levels could not be differentiated, since the net relative effect of using higher air quantities was higher air velocities. The fact that face dust levels stayed relatively constant for face air velocities above 2.0 m/sec (400 ft per min) indicates that the effect of dilution on the dust concentration more than compensated for dust that may have been entrained by velocities above 2.0 m/sec (400 ft per min).

Fig. 6 shows a plot of the data similar to that shown in Fig. 4, except in this figure, the quantity of air (Q) measured at the tail was normalized to the tons (T) of material mined. This plot shows the importance air quantity has on reducing dust levels. The operations shown with a Q/T ratio of greater than 50 all utilized more than 28.3 m^3 (60,000 cfm) of air to ventilate the face. For those operations using greater than 28.3 m^3/sec (60,000 cfm), only one had an adjusted tailgate concentration greater than 2.0 mg/m^3.

Fig. 7 and 8, respectively, show a comparison of the measurements obtained on the tail drum shearer operators, adjusted for dust generated at the headgate and an intake air dust level of 0.5 mg/m^3, to the similarly adjusted dust concentration and velocity measurements obtained at the tailgate. The data plotted on these figures show that there is no relationship between the tail drum shearer operator's dust exposure and the concentration of dust measured at the tailgate and that increases in face air velocity (quantity) are not related to the tail drum shearer operators' dust exposure.

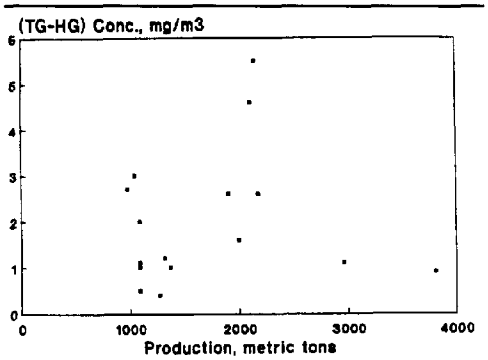

Fig. 2—Tailgate (TG) – headgate (HG) concentration vs. production.

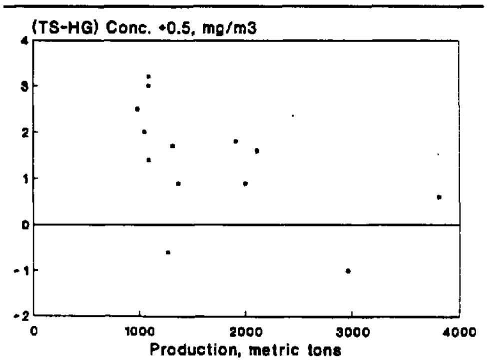

Fig. 3—Adjusted tailshearer operator concentration vs. production.

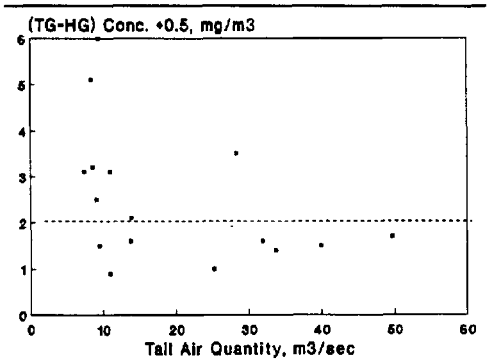

Fig. 4—Adjusted tailgate concentration vs. quantity of air at the tail.

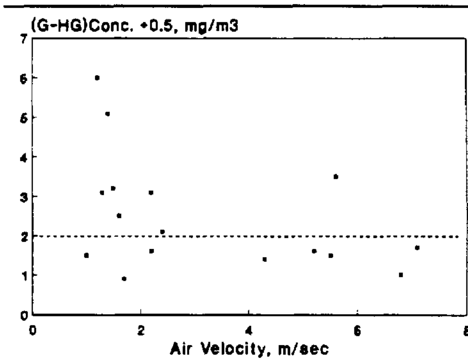

Fig. 5—Adjusted tailgate concentration vs. air velocity at the tail.

Availability of technology

The question of the adequacy of available technology to control dust to the applicable standard was addressed by studying the influences of the dust control measures in place at the time of the visit on occupational exposures and on the dust levels measured at the tail of the face (adjusted as previously discussed). Of the technologies developed and tested, those that have been primarily adopted and utilized to any extent by industry are:

1) Use of barriers on the shearer to provide a clean split of air over personnel operating the shearer.

2) Use of remote control devices to reduce exposure of machine operators.

3) Use of a "shearer clearer" system to divert dusty air away from the shearer operators.

4) Optimization of work practices to reduce the exposure of face personnel.

5) Enclosure of stageloaders and crushers.

Except for item 5 above, all of these technologies when appropriately utilized can reduce the dust exposure of targeted individuals; however, they do not reduce the concentration of dust in the mine environment. Therefore, even though the exposure of the targeted individuals may be reduced to applicable standards, there is no assurance that the exposure of other individuals will be reduced to the same level.

The primary methods used to reduce the dust levels in mine environments are dilution with the ventilating air, wetting of particles before they become airborne, removing airborne particulates from the air using sprayed water and reducing the amount of dust produced or liberated into the mine environment. The effectiveness of these methods depends on optimizing the parameters governing their application (i.e., pressure, quantity and application of sprayed water, air quantity and machine cutting parameters).

Table 2 (following page) shows a detailed list of the methods currently being used to control dust in coal mines. Also shown are the methods in use at the respective operations when they were visited. The data show that nearly all the mines visited were using enclosures and sprayed water at the headgate to control dust, had at least 9.4 m^3/sec (20,000 cfm) of air ventilating the face, were cutting unidirectionally with shields being advanced upwind of the shearer and were using sprayed water applied internally through the cutting drums and externally via spray nozzles strategically located on the machine.

The data also show that about 50% of the mines were using remote control, passive barriers and rotation of personnel to reduce exposures to dust. Of four operations that were using all of these administrative controls to reduce exposure, two mines (listed as 5 and 8) had average occupational exposures that exceeded 2.0 mg/m^3. Both of these operations had production levels of approximately 1179 t per shift and were using approximately 9.4 m^3/sec (20,000 cfm) of air to ventilate the face. Of the 16 mines for which measurement data are presented, seven of the shearers were operated by remote control. On five of these seven operations the shearer operator's exposure was below 2.0 mg/m^3.

As previously discussed, Fig. 1 shows data comparing respirable dust concentrations measured at the tailgate after they were adjusted for a headgate dust level of 0.5 mg/m^3. As these data show, the adjusted tailgate concentration on eight of the operations was less than 2.0 mg/m^3. Examination of the control measures used on these eight operations shows that five of the operations had face ventilating air quantities greater than 28.3 m^3/sec (60,000 cfm).

The data also show that all but one of the mines using face ventilating air quantities of 28.3 m^3/sec (60,000 cfm) and greater would meet the 2.0 mg/m^3 respirable dust standard if the dust concentration of the air at the headgate were maintained at 0.5 mg/m^3. However, examination of the data for that one operation shows that the measurement obtained at the tailgate was atypically high compared to other concentrations obtained on the face.

The other eight operations visited during this study utilized ventilating air quantities (as measured at the tail of the face)

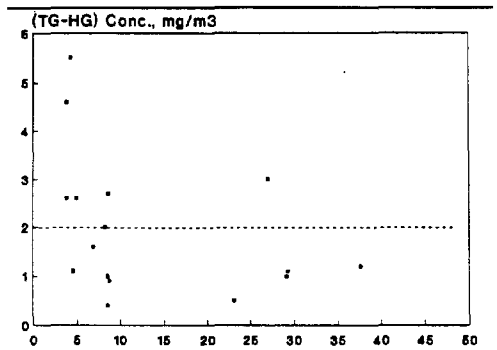

Fig. 6—Tailgate (TG) – headgate (HG) concentration vs. tail air quantity normalized for production.

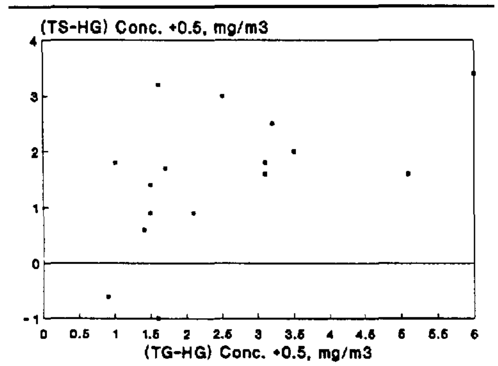

Fig. 7—Adjusted tail shearer (TS) vs. adjusted tailgate (TG) measurements.

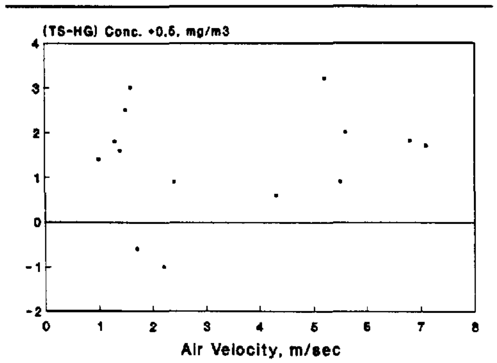

Fig. 8—Adjusted tailshearer concentration vs. tail air velocity.

Table 2—Methods Used to Control Dust

MINE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	%
HEADGATE CONTROLS																						
ENCLOSURES	X	X	X		X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	85
BELTING AT OPENINGS	X	X										X	X		X		X		X			33
CROSSFRAME/SIDE DISCHARGE	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	90
CUT OUT CURTAINS																						0
VENTILATION																						
≥9.4 m^3/sec INTAKE AIR	X			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	85
2.032 m/sec VELOCITY AT TAIL	X										X			X	X	X	X	X	X	X	X	47
GOB CURTAIN		X						X					X	X	X	X		X	X		X	43
BELT AIR AT FACE					X		X				X	X	X				X	X	X			38
WORK PRACTICES																						
UNIDIRECTIONAL CUTTING	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	90
BIDIRECTIONAL CUTTING		X					X															9
OPERATOR ROTATE EACH CYCLE		X	X	X	X		X						X	X		X	X	X				47
TAIL OPERATOR LEAVES FACE	X		X	X									X			X	X	X				33
SHIELD SETTER LEAVES FACE	X		X	X									X	X		X		X				33
SHIELD CONTROLS																						
ELEC. HYDRAULIC SHIELDS	X	X		X	X	X								X					X			33
ELEC. HYDRAULIC SHIELDS USED	X	X																	X			19
SHIELDS ADVANCED UPWIND	X	X		X								X	X	X	X	X	X	X		X	X	85
SHIELDS ADVANCED DOWNWIND		X					X			X	X						X		X		X	33
SHIELD WASHDOWN				X				X	X			X										19
MACHINE PARAMETERS																						
REMOTE CONTROL CAPACITY	X	X	X	X	X	X	X	X	X	X	X		X	X	X							67
UMBILICAL REMOTE USED	X	X		X	X	X	X	X	X		X			X	X							52
RADIO REMOTE USED										X			X									10
INTERNAL SPRAY SYS >689X10^3 Pa		X					X															10
EXTERNAL SPRAY SYSTEM	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	95
PROPER SPRAY DIRECTION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	100
EXTERNAL SPRAY SYS >698X10^3 Pa	X	X		X										X	X							24
BOOSTER PUMP USED			X		X	X		X		X	X	X	X	X								43
PASSIVE BARRIER USED	X	X		X			X					X	X	X	X		X	X		X	X	57
DRUM SPEED <40 RPM	X	X	X		X	X		X	X	X	X	X				X	X					57
WETTING AGENT USED							X								X		X					14
WATER INFUSION USED																X						5

of less than 14.2 m^3/sec (30,000 cfm). Of these eight only three would have had an adjusted respirable dust concentration at the tail of 2.0 mg/m^3 or less.

Based on the facts that 83% of the operations using air quantities greater than 28.3 m^3 (60,000 cfm) would have had tailgate dust levels of less than 2.0 mg/m^3 (provided the headgate dust level is maintained at or below 0.5 mg/m^3), and that there are procedures available that when properly utilized will enable face personnel to work in "clean air," it is concluded that technology is available to control dust exposures to the applicable 2.0 mg/m^3 respirable dust standard.

Summary

Compliance with the 2.0 mg/m^3 respirable dust standard continues to be a problem on underground coal mining operations employing the longwall method of mining. As a consequence, a study was initiated several years ago to determine whether the problem was a result of a lack of technology or a lack of implementation of existing technology to control dust.

Twenty-two producing longwall mining operations were visited during the study. During these visits, full-shift respirable dust measurements were obtained, and details of the mining operation and procedures in place to control dust were documented. The methods used to control dust were compared to technology that is considered available for use and an attempt was made to determine the influence of the various methods on dust levels, as measured at the tailgate of the longwall panel as well as on occupational exposures.

Evaluation of dust measurement data indicated that technology is available to control dust to 2.0 mg/m^3. However, compliance will necessitate upgrading practices used to control dust at the headgate of the panel and using larger quantities of air to ventilate the face.

References

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