# Dust control on longwalls – assessment of the state-of-the-art

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ABSTRACT: Operating practices and resulting production from longwall faces are continually improving. Consequently, longwall operators are continually seeking to improve the dust control capabilities on longwalls. The National Institute for Occupational Safety and Health (NIOSH) has been conducting dust surveys at longwalls throughout the country in an effort to document the types of controls that are being used and to quantify the relative effectiveness of these controls. To date, surveys have been completed at longwalls in Alabama, Colorado, Pennsylvania, Utah, and West Virginia. In addition NIOSH has been reviewing longwall dust parameters provided by mine operators to MSHA to assess the status of dust control technology being used throughout the industry. Results from the underground dust surveys and information obtained from MSHA will be summarized in this paper to provide an update on longwall dust control technology and practices.

## 1 INTRODUCTION

Improvements in longwall mining equipment and mining practices have led to substantial gains in longwall production levels, resulting in longwall mining accounting for 51% of the coal produced underground in the United States. Overall production from U.S. longwall mines in 2004 was over 189.5 million tons. The average output from U.S. longwall mines has increased approximately 115% over the last 15 years, from 1.9 to 4.12 million tons. Longwall panels averaged 288 m (940 ft) wide and nearly 3062 m (10,000 ft) long in 2002, compared to an average of 230 m (750 ft) wide and 2135 m (7000 ft) long in 1994. New longwall panels, currently in the planning stage, may be as wide as 457.2 m (1500 ft) and as long as 4572 m (15,000 ft). Cutting heights in 2002 averaged 215 cm (86 in) and ranged between 121.9 and 396.2 cm (48 and 156 in) (Fiscor, 2003).

Although significant gains in longwall dust control have been made, they have been challenged by substantial increases in coal extraction rates, which result in the potential to generate more dust (Webster et al., 1990). Average production during compliance sampling by mine operators has increased from an average of 2800 tons per shift in 1990 to an average 5600 tons per shift in 2004. Consequently, longwall operations continue to have difficulty in maintaining consistent compliance with the federal dust standard of 2 mg/m$^3$. During a five-year span from 2000 through 2004, mine operators and Mine Safety and Health Administration (MSHA) inspectors collected 7421, and 1587 compliance dust samples, respectively. Analysis of these samples show that 14% of the mine operator samples and 15% of the MSHA samples were equal to or exceeded 2.1 mg/m$^3$, the level at which a citation is issued (Niewiadomski, 2004).

Health surveillance data also indicate that overexposure to respirable dust in underground coal mines continues to lead to the development of lung disease. Results from the most recent full round (1992–1996) of the Coal Worker's X-ray Surveillance Program indicate that approximately 8% of the examined miners with at least 25 years of mining experience were diagnosed with Coal Worker Pneumoconiosis (CWP) (category 1/0+). The continued development of CWP in underground coal mine workers and the magnitude of respirable dust over exposures in longwall mining occupations illustrate the need for improved dust control technology on longwalls.

Ventilating air and water sprays are the primary means used to control dust and methane in longwall operations. This paper describes the on-going research effort to identify the current status of longwall mining and dust control technology being applied in the industry.

## 2 LONGWALL DUST PARAMETERS

Longwall dust parameters provided to MSHA as part of the mine's ventilation plan were reviewed to assess the status of control measures being used throughout the industry. Ventilation plans between the years

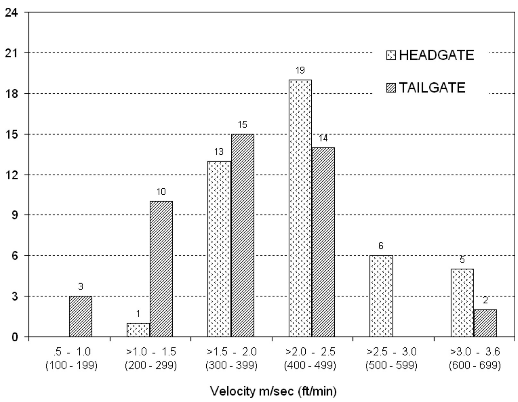


Figure 1. Range of velocity readings.

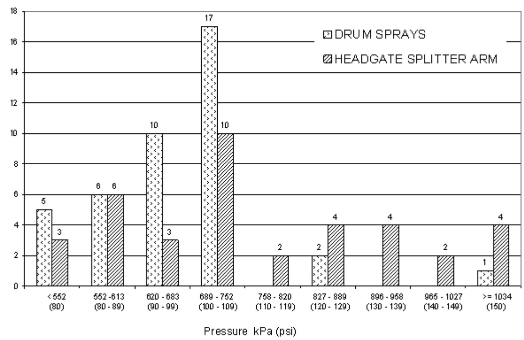


Figure 2. Pressure ranges for shearer drums sprays and splitter arm sprays.

2000 to 2003, representing 44 longwall panels, were analyzed to identify and quantify the different types of longwall control features used to limit the miners' exposure to respirable dust. A variety of dust control measures were encountered when the dust parameters were reviewed. Each longwall operator had a different and unique approach to control respirable dust levels.

Figure 1 shows the range of minimum mean air velocities required at the headgate and tailgate. The average minimum headgate velocity was approximately 2.2 m/sec (430 ft/min) for all longwall operations. Eastern mines averaged 2.2 m/sec (440 ft/min), while western operations averaged 2.0 m/sec (390 ft/min). The average minimum volume of air reported in the dust plans was approximately 24.5 $m^3$/sec (52,000 $ft^3$/min). As expected, minimum air quantities were significantly higher for western operations, 32.1 $m^3$/sec (68,000 $ft^3$/min), compared to 21.1 $m^3$/sec (45,000 $ft^3$/min) in the east. Approximately 28% of the mine operators reported the use of beltway air as a means to supplement the total volume of air reaching the face. Nearly one-half of the longwall operators in eastern U.S. mines utilize air deflectors on the first 3 or 4 shields as a means of helping move the air onto the face and controlling dust levels when the shearer was cutting out at the headgate.

The quantity, type, and pressure of the shearer cutting drum sprays reported by longwall operators varied with each longwall operation. The number of sprays ranged between a low of 30 and a high of 62. According to the ventilation plans, between 75 and 90% of the drum sprays are required to be operational when mining. The type of spray preferred by the majority of the operators was the Conflow 2801 with either full-cone, flat-fan, or hollow-cone spray patterns. The range and frequency of drum spray pressures are shown in figure 2. Sixty-one percent of the longwalls reported drum spray pressures between 620.5 and 758.4 kPa (90 and 110 psi). The average drum spray pressure was 620.5 kPa (90 psi). Thirteen operations reported using crescent sprays on the ranging arms as a means of controlling fugitive dust. The number of crescent sprays ranged between 4 and 11, with an average spray pressure of 586.1 kPa (85 psi), and varied between 448.2 and 689.47 kPa (65 and 100 psi).

The ventilation plans showed that 39 out of 44 operations utilized a headgate splitter arm as a means of either suppressing or moving fugitive dust away from the personnel operating the shearer. The length of the splitter arm, type of sprays, distance between sprays, angle of the sprays, and spray pressure varied greatly between mines. The number of sprays mounted on the splitter arm ranged between 2 and 20. The majority of the ventilation plans stated that at least 90% of the splitter arm sprays are required to be operational when mining. Approximately 15% of the operations reported utilizing an extension of the splitter arm that angled between 30 and 45 degrees toward the face. A variety of spray patterns were used, including full cone, hollow cone, vee-jet and flat fan. Approximately 30% of the operators reported using venturi sprays. Splitter arm sprays were angled 20 to 30 degrees up or down and directed toward the shield tips or pan line. The angle of the sprays directed with the airflow ranged between 10 and 45 degrees. The majority of the splitter arm sprays were aimed at the headgate drum, especially the sprays positioned on the splitter arm upwind of the cutting drum. Headgate splitter arm spray pressure varied greatly, as shown in figure 2. Sixty-eight percent of the sprays operated with spray pressure at or above 689.5 kPa (100 psi).

Manifolds located on the tailgate side of the shearer or tailgate splitter arms were reported on nearly all the longwall operations. The majority of the western operations used the splitter arm technology to direct fugitive dust downwind, while most eastern operations utilized spray manifolds to suppress or move dust generated by the tailgate drum. The number of sprays on the tailgate splitter arm ranged between 3 and 10, while the spray pressure varied between 551.6 and 689.5 kPa (80 and 100 psi). The sprays were either directed at the tailgate drum or angled from 10 to 45 degrees in the direction of the airflow. Nearly 60% of the operations utilized a manifold located on the tailgate side of the shearer or in the lump breaker area. Manifolds positioned on the tailgate side of the shearer directed the spray plume downwind. Spray pressures ranged between 344.8 and 861.8 kPa (50 and 125 psi). All but 4 operations operated with spray pressure below 689.5 kPa (100 psi), with the average pressure of approximately 551 kPa (80 psi). Lump breaker manifolds consisted of 4 to 6 sprays with pressures ranging between 620.5 and 827.4 kPa (90 and 120 psi) and directed toward the pan line.

Thirty-five operations reported using sprays on the top deck or on the face side of the shearer to confine and move dust away from the mine operators. Nineteen of the thirty-five operations utilized between 2 and 6 spray manifolds spaced evenly across the shearer. Each manifold was equipped with a range of 2 to 16 sprays. Shearer body spray configurations consisting of 3 spray manifolds with 3 or 4 sprays per manifold were the most commonly reported spray system and were utilized by nearly 25% of operators. One out of five operations used between 4 and 6 venturi sprays spaced evenly and positioned either at the shearer centerline or the gob side of the shearer. Shearer spray pressure ranged between 482.6 and 1034.2 kPa (70 and 150 psi). Approximately 40% of the shearer sprays operated with pressures at or above 689.5 kPa (100 psi).

## 3 LONGWALL SURVEYS

### 3.1 *Sampling methodology*

Gravimetric dust samplers, identical to those used in compliance sampling, were operated at 2L/min in conjunction with a 10-mm Dorr-Oliver nylon cyclone. Samplers were utilized at stationary and mobile sampling locations to quantify the levels of respirable dust generated at prominent sources along the longwall face. Gravimetric sampling was conducted on-section for 4 to 6 hours, and mine personnel did not wear any of the samplers. Calculated concentrations were not converted to Mining Research Establishment (MRE) equivalent dust levels and should not be compared to compliance sampling concentrations.

Personal DataRAMS (PDRs) were used adjacent to the gravimetric samplers at select sampling locations to obtain a time-related profile of dust levels generated during each sampling period. The PDR is an MSHA-approved, instantaneous dust measuring device where dust-laden air passes through a sampling chamber and a light source. The amount of light deflection in the chamber is measured and provides a relative measure of the dust concentration. The PDR samples were utilized in an active sampling mode where dust laden air was pulled through a 10-mm Dorr-Oliver cyclone at a flow rate of 2 L/min. Instantaneous dust levels were stored at 10 second intervals in an internal data logger and then downloaded onto a computer for analysis. Dust levels measured with the PDR can be calculated for any time period of interest (e.g., head-to-tail or tail-to-head passes).

Mobile dust sampling to determine the amount of dust generated by the shearer and by movement of advancing shields was conducted by a three-member NIOSH sampling team. Ideally, the UPWIND sampling location was approximately 5.2–7.6 m (25–50 ft) upwind of the headgate cutting drum and measured intake dust levels reaching the shearer. The SHEARER sampling location was located between mid-shearer and the tailgate end of the shearer. The sampling crew member was usually positioned within a shield or two of the tailgate shearer operator. This data provided an indication of the amount of dust that has migrated from the face between the cutting drums. When possible, the DOWNWIND sampling location was approximately 5.2–7.6 m (25–50 ft) downwind of the tailgate drum. Due to shield movement patterns, this sampling location had to be adjusted at certain mines. Each team member maintained their relative position with the shearer as it moved across the face. The difference in dust levels between the UPWIND and DOWNWIND locations was dust generation attributed to the shearer. In addition, similar mobile sampling was conducted upwind and downwind of shield movement on selected head-to-tail passes to isolate dust liberated during shield advance.

At each of these mobile sampling positions, each sampling crew member wore a sampling vest that contained two gravimetric pumps and four cyclones with appropriate filter cassettes. Two of the four cyclones [attached to the sampling vest on the left and right sides of the chest area] were connected to the gravimetric pumps and used to sample dust levels during head-to-tail passes. The other two cyclones, also attached to the sampling vest on the left and right sides of the chest area, were used for sampling tail-to-head passes. If the shearer was stopped for an extended period (>3 minutes), the gravimetric pumps were paused so that mobile sampling along the face was representative of dust levels during active mining. Along with the gravimetric sampling package, members of the sampling crew carried a PDR sampler.

Mobile sampling was augmented with stationary sampling packages. At each stationary sampling location, two gravimetric samplers were located adjacent to one another and operated over the same sampling period. Stationary sampling locations included the intake, belt entry, shield 10, and approximately

10 shields from the tailgate. Intake samplers were typically located in the last open crosscut and used to isolate the dust contamination from sources outby the longwall face. If the mine was utilizing the belt entry as an additional intake, gravimetric samplers were located outby the last open crosscut and the stage loader to monitor dust levels liberated in the belt entry. The shield 10 samplers were used to monitor the dust concentrations of air coming onto the face. The difference between dust levels measured at shield 10 and the intake and belt sources represent an estimate of dust liberated by the stage-loader/crusher dust source. The tailgate sampling package provided an indication of the total dust generated along the face. The samplers were typically started after arrival upon the longwall face and operated continuously until sampling was completed. PDR samplers were also placed at the shield 10 and tailgate sampling locations.

In addition to dust measurements, sampling personnel monitored airflow and water quantities on the longwall section. During each shift of sampling, spot air velocity readings were taken with hand-held anemometers at 10-shield intervals down the face. These measurements were one-minute readings taken approximately one foot above the spill plate of the face conveyor. Also, a rough estimate of the area at each velocity sampling location was calculated to estimate the air quantity present. If possible, water flow meters were installed in the water line supplying the shearer and the line supplying the stageloader/crusher sprays. Periodic readings were taken from each of these meters to monitor the quantity of water being used to suppress dust.

### 3.2 *Survey results*

A variety of operating conditions were encountered when surveys were conducted at the different mines throughout the country. Six of the eight mines surveyed to date utilized a bidirectional cutting sequence, with two mines employing unidirectional cutting. Face panel widths ranged between 237.7 and 304.8 m (780 and 1000 ft), and the average face width was 272.2 m (893 ft). Comparing panel widths observed in this latest series of surveys with panel widths reported in a 1995 longwall study (Colinet et al., 1995) showed close to a 25% increase. The average cutting height was 2.7 m (9 ft) with a range between 2.1 and 3.4 m (7 and 11 ft).

During the surveys, daily spot velocity readings were recorded approximately every 10 shields along the longwall face and were used to calculate the average face velocity. The average velocity of the surveyed longwalls was 3.4 m/sec (665 ft/min), which represents an increase of over 0.8 m/sec (50 ft/min) when compared to average air velocities reported in the 1995 longwall study. Seven of eight longwalls had average air velocities greater then 3.0 m/sec (600 ft/min), with two mines averaging over 4.1 m/sec (800 ft/min). Along with air velocity calculation, a rough estimate of the area under the shields at each velocity sampling location was used to calculate average air quantity for each face. The average volume of air moving down the face was approximately 31.6 $m^3$/sec (67,000 $ft^3$/min), with a range between 24.3 to 39.1 $m^3$/sec (51,000 to 83,000 $ft^3$/min). Air quantity observed for six of the eight longwalls was greater than 30.2 $m^3$/sec (64,000 $ft^3$/min). Average air quantities calculated in this current series of longwall surveys increased approximately 65% when compared to the mid-1990 longwall study.

Along with an escalation of air down the face, the use of water to the shearer has increased in an effort to control dust liberating from the face. The average water usage at the shearer observed during the eight most recently completed surveys was 492.0 L/min (130 gpm). The number of shearer drum sprays ranged between 35 and 62, and the average drum spray pressure was approximately 1034.2 kPa (150 psi). In the 1995 study, the average water usage at the shearer was 378.5 L/min (100 gpm) with an average drum spray pressure of 965.3 kPa (140 psi). One-half of the surveyed mines utilized six to eight crescent sprays on the ranging arms.

Studies (O'Green et al., 1994) have shown that shearer drum water sprays are very effective at minimizing dust generated at the point of coal fracture but can increase airborne respirable dust levels if operated at overly high water pressure. Instead of suppressing dust, the drum sprays may force the dust out away from the cutting drum causing excessive turbulence around the cutting drums. The increased turbulence leads to higher dust levels at the shearer and downwind. Larger orifice sprays could be utilized to increase water volume and reduce operating pressure. Increased flow to the drum-mounted sprays should result in a more uniform wetting of the coal product, which may also reduce conveyor-generated dust.

External spray systems with air-moving directional sprays were observed at the headgate side of the shearer on seven of the eight surveyed longwalls. The splitter arm technology used to keep fugitive dust away from the shearer operators was unique to each mining operation. The lengths varied between 2.7 and 4.6 m (9 and 15 ft) with the number of sprays ranging between 6 to 19. Spray spacing on the splitter arm and the directional angle of the sprays varied greatly at each operation. Extension arms attached to the end of splitter arms and angled between 30 and 45 degrees toward the face were utilized at three mines. Venturi sprays located on top of the splitter arm were observed at two operations. Splitter arm spray pressures were approximately 689.5 kPa (100 psi) when hollow cones sprays

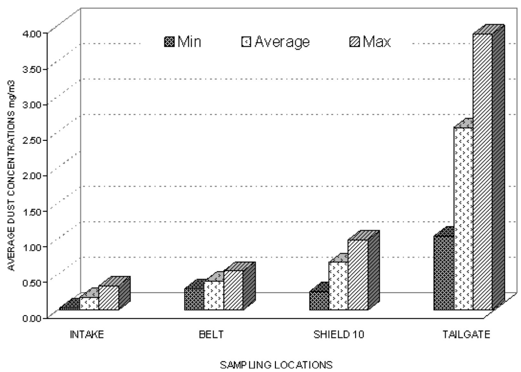


Figure 3. Range of dust concentrations measured at the stationary sampling locations.

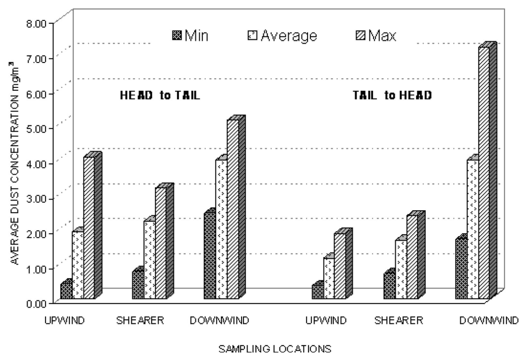


Figure 4. Range of mobile sampling measurements.

were utilized and in excess of 1551.3 kPa (225 psi) when venturi sprays were operated.

A variety of spray configurations were employed on the body of the shearers during the mine surveys. Deflector or sloughing plates were observed at three western mine sites. One of the three operations used a single plate spanning the length of the shearer with 6 venturi sprays evenly spaced across the top of the deflector plate. Deflector plates were split into three independent sections on two of the longwall operations. Each section had five hollow cone sprays evenly spaced across the top of the plate. At eastern mine sites a series of spray manifolds were used the majority of the time. Three or four manifold consisting of four or five sprays were evenly spaced across the length of the shearer. The manifold were either located on the face side of the shearer or on the top of the shearer close to the face. One mining operational moved the spray manifolds toward the middle of the shearer and elevated the manifolds 15.24 to 30.48 cm (6 to 12 in) off the shearer body.

The majority of the surveyed mines made use of manifolds located above the lump breaker or on the shearer body to control dust in the tailgate drum area. A minimum of 4 and maximum of 16 sprays were directed toward the cutting drum or down onto the conveyor. One mining operation utilized a series of higher pressure sprays and directed them downwind just inside the spill plate. The sprays formed a water curtain that was effective at keeping fugitive dust out of the walkway. A tailgate splitter arm was observed at one mine.

The minimum, average and maximum dust levels for stationary gravimetric sampling locations are shown in figure 3. Intake dust levels were consistently low indicating very little dust contamination was occurring from outby sources. The maximum dust level measured was 0.34 mg/m$^3$ with the majority of the operations below 0.20 mg/m$^3$. Half of the longwalls surveyed used belt air as a supplementary air source. For these longwalls, the average dust level in the belt entry was 0.41 mg/m$^3$, while the average intake concentration was 0.18 mg/m$^3$, approximately 2.5 times less than the belt entry dust concentrations. Although the average dust levels in the belt entry levels are relatively low on average, the belt entry has the potential to add to face dust levels. However, according to past research studies (Potts and Jankowski, 1992) potential increases in face dust levels seemed to be negated by the potential for increased dilution with the additional air reaching the face.

The dust level monitored at shield 10 is a good indication of the dust entering the face from the stageloader/crusher along with intake and belt outby sources. Average dust concentration found at shield 10 was 0.67 mg/m$^3$. The difference between intake/belt dust levels and shield 10 concentrations is primarily the dust contributed by the stageloader/crusher. On average, the amount of dust that was attributed to the stageloader/crusher was 0.48 mg/m$^3$. Dust levels measured at the tailgate sampling location provided a good indication of the amount of total dust generated along the face that reaches the tailgate area. Dust levels ranged between 1.04 mg/m$^3$ to 3.88 mg/m$^3$ and averaged 2.56 mg/m$^3$.

The volume of air introduced on longwall faces in recent years has had a major impact on dust levels at the stationary sampling locations. Average dust levels at the intake sampling location were reduced by 53% when compared to the average intake samples measured during the previous (1995) longwall surveys. Reductions in dust levels at the other stationary sampling locations ranged between 27% and 39% when compared to the 1995 study.

Average dust concentrations at the UPWIND and SHEARER mobile sampling locations were higher for the head-to-tail passes (figure 4). Dust levels at these two sampling locations reflect dust liberated from

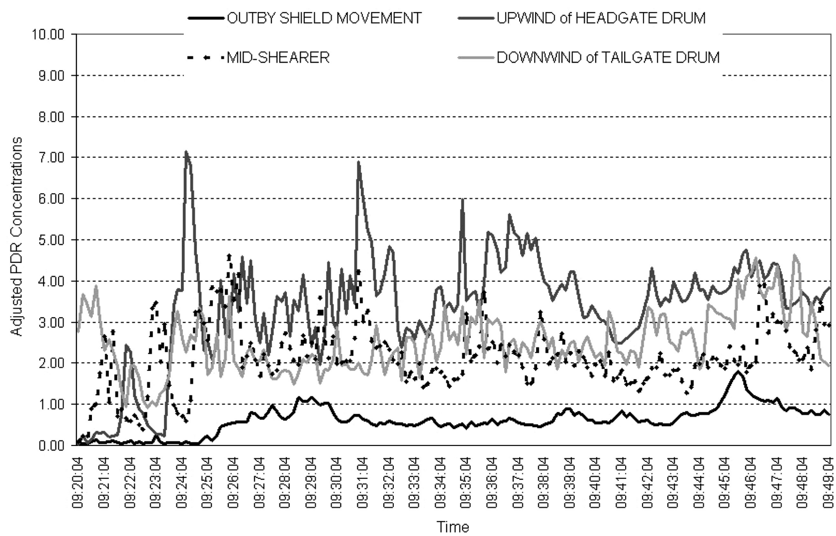


Figure 5. Adjusted PDR concentrations for a typical head-to-tail pass.

shields being advanced when mining head-to-tail. At the SHEARER sampling location dust generated by the shearer, primarily the headgate drum is also included. Isolating dust generated by the shearer is accomplished by subtracting the UPWIND sampling concentrations from the DOWNWIND concentrations. Average shearer-generated dust was found to be 2.06 mg/m$^3$ when mining head-to-tail and 2.82 mg/m$^3$ while cutting tail-to-head. Higher dust levels produced by the shearer were evident while mining tail-to-head when the headgate drum is the primary cutting drum. Shearer operators downwind of the headgate drum may be exposed to fugitive dust caused by the cutting action of the drum. This is not the case when mining head-to-tail when the dust generated by the primary cutting drum (tailgate drum) is downwind of the headgate shearer operator and possibly the tailgate shearer operator.

Comparing dust levels at shield 10 with UPWIND samples for tail-to-head passes showed an increase of 0.49 mg/m$^3$. Dust liberated by face spalls, from the face conveyor, and dust migrating from the gob may be causing the increase in dust levels.

When comparing average dust levels from the UPWIND and SHEARER sampling locations, dust levels increased 0.51 mg/m$^3$ for tail-to-head cuts and 0.31 mg/m$^3$ for head-to-tail cuts. In the 1995 study, the increase in dust levels was 1.85 mg/m$^3$ and 1.29 mg/m$^3$ for tail-to-head and head-to-tail cuts when comparing the two sampling locations. This suggests that the increased air velocity down the face in conjunction with the directional spray systems have had a positive effect of confining fugitive dust close to the face and away from the walkway.

Instantaneous dust samples measured with the PDR were used to calculate relative dust concentrations at each sampling location along the face. These relative dust measurements calculated from PDR data were based upon time study data obtained on a per-pass basis. Extended downtimes and wedge cut dust concentrations were excluded from the average PDR dust concentration. The PDR dust levels were adjusted based upon the ratio between the average dust concentrations obtained from the two gravimetric samplers divided by the dust concentration obtained from the PDR.

Figures 5 and 6 illustrate adjusted PDR mobile sampling results from a typical head-to-tail and tail-to-head pass. Figure 5 shows that OUTBY shield movement dust levels are relatively low [averaging approximately 0.50 mg/m$^3$]. Significant increases in dust levels are found at the UPWIND sampling location. This supports the hypothesis that much of the dust liberated during head-to-tail passes is generated by advancing shields. Examining data at the SHEARER sampling location shows that the directional spray system in conjunction with the high velocity/volume of air moving down the face has a positive effect at diluting high dust levels generated by shield movement. Dust levels at the DOWNWIND sampling location [approximately 1 shield inby the tailgate shearer operator and 1 to 2 shields outby shield movement] are approximately equivalent to the dust levels recorded by the SHEARER samplers.

Figure 6 shows dust levels to be relatively low at the three shearer sampling locations when mining tail-to head. These dust levels are very similar to the outby dust levels measured at Shield 10 and the OUTBY

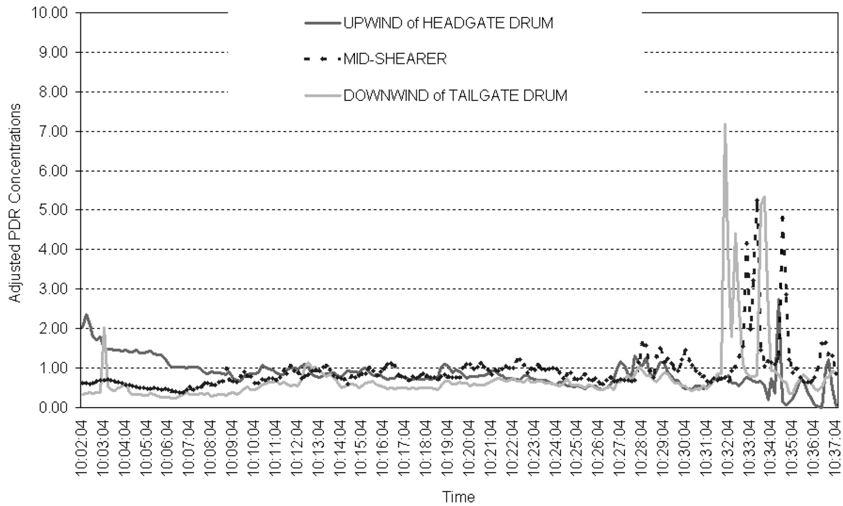


Figure 6. Adjusted PDR concentrations for a typical tail-to-head pass.

sampling location. The spike in dust levels at the SHEARER and DOWNWIND sampling locations as the shearer approached the headgate is explained by shield advances. Because of unstable roof conditions, shields were pulled in advance of the shearer. The SHEARER and DOWNWIND samplers were inby the advancing shields and significant increases in dust levels were evident. These dust levels closely correspond to dust levels at the UPWIND sampling location when mining head-to-tail.

## 4 CONCLUSION

Although the number of longwall sections has decreased over the past decade, the production and productivity from today's operating longwalls is much greater. Consequently, the potential to liberate significantly more respirable dust exists. Mine operators have made substantial increases in the application of dust control technology in an effort to control dust exposure on longwalls.

Longwall dust parameters obtained from MSHA ventilation plans and sampling data from eight surveys conducted by NIOSH indicate that a wide variety of control technology applications exists across the industry. These differences may in part be a reflection of differing operating conditions and equipment. Regardless, a number of similarities also exist and indicate that these controls are viewed as keys for successful dust control:

- Intake dust levels are generally well controlled.
- The velocity and quantity of air being utilized has been increased.
- The volume of water supplied to shearer dust control sprays has also been increased.
- All operations are using a version of directional water sprays (shearer clearer) in an effort to confine dust near the face and away from workers.
- The vast majority of operations are using some form of splitter arms on the headgate side of the shearer to contain dust liberation from the headgate drum.
- Splitter arms and/or directional sprays are being used successfully at the tailgate end of the shearer to provide protection for the tailgate shearer operator.

In addition, sampling results indicate that significant dust liberation and worker exposure is resulting during shield advance. Given that the majority of sampled longwalls are utilizing bidirectional cutting sequences, the shearer operators are being exposed to this dust during the head-to-tail cutting pass. Additional research is needed to identify effective control technologies for limiting dust exposure to shield dust.

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