LABORATORY TESTING TO QUANTIFY DUST ENTRAINMENT DURING SHIELD ADVANCE

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ABSTRACT

As longwall shields are lowered in preparation for advance, dust from the canopy falls directly into the air stream with the potential of becoming entrained. Historical dust sampling data from the early 1980s shows that shield advance contributed an average of 12 percent to the airborne respirable dust levels found on longwalls in the United States. Data from the 1990s indicates that shield dust liberation had increased to an average of 23 percent. Increased longwall production levels over this time resulted in the need to move a larger number of shields during each shift, while an increase in air velocities on the face was also occurring. These factors combine to suggest that greater quantities of shield dust are being entrained into the face air. A series of controlled laboratory tests were conducted in a test stand simulating shield dust entrainment to evaluate changes in airborne respirable dust levels at different air velocities. Significant differences in respirable dust entrainment were observed. The test facility, test methodology, and dust sampling results will be reviewed and discussed

KEYWORDS

Longwall, coal dust, shield dust, dust entrainment, engineering controls

INTRODUCTION

Longwall mining operations continue to be an increasing contribution of coal production, now accounting for approximately 50% of the underground coal produced in the U.S. (Energy Information Administration, 2000). Although advances have been made at mitigating airborne respirable dust along longwall faces, many operations still have difficulty maintaining compliance with federal dust standards. Entrainment of dust along longwall faces contaminates the work place for face workers, thus increasing the risks of coal workers pneumoconiosis and silicosis.

Figure 1 compares the contribution of longwall dust from the major sources during the 1980's and 1990's (Colinet and Jankowski, 1997). During the early 1980's, face air velocities ranged from 0.6 to 3.3 m/s (125 to 650 fpm) (Jankowski and Organiscak, 1983), while average production was 810 tons/shift (890 st/shift) in 1981 (Niewiadomski, 2000). During the early 1990's, the range of air velocities increased to 1.0 to 7.6 m/s (195 to 1500 fpm) (Colinet and Jankowski, 1997), while the average production nearly increased four-fold to 3180 tons/shift (3500 st/shift) in 1993 (Niewiadomski, 2000). During this period, dust control technology has concentrated on reducing the dust generated by the two largest sources: shearer and stageloader. Improved water spray application at the shearer and enclosing the stageloader while adding water sprays helped control dust liberation from these sources despite increased production. However, little research addressed dust liberation during shield advance as suggested in Figure 1, which shows that the percent of dust contribution attributed to shield movement has almost doubled. The primary factors which have lead to this increase are most likely a combination of higher production and lack of effective control technology. Higher production rates have led to increased shearer speeds which requires that shields be moved faster and in greater numbers. As shield supports are lowered and advanced, broken coal and/or rock fall from the top of the shield canopy directly into the airstream ventilating the longwall face.

In addition, it has been noted that the air velocities being found on longwall faces have significantly increased. These factors combine to increase the potential for entraining greater quantities of dust during shield advance.

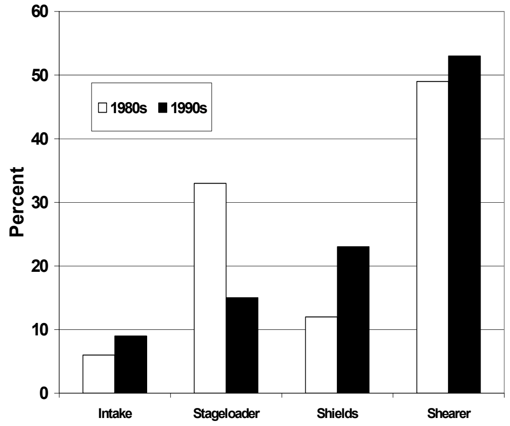

Figure 1. Comparison of dust source contributions on longwalls

Shield spray systems that wet material on top of the shield canopy are available but the effectiveness of these systems have not been documented. Two factors that are of concern with the shield spray systems are how uniformly the sprays wet the material across the canopy and how long do these sprays operate as designed. Several mines have indicated that it is difficult to maintain the shield sprays throughout the life of a longwall panel. Wetting can be an effective means of controlling shield dust, however, to achieve maximum benefits from water sprays, it is imperative that the sprays be maintained to function as designed.

Traditionally, dust control technology has employed air and water as a means to limit, direct, and/or, eliminate respirable dust. Dilution is another method used to control dust and often times, the face airflow is increased as a means to further dilute the dust generated by all sources. Studies have shown (Tomb *et .al*., 1990, Breuer, 1972) that with adequate moisture on the coal, such as that provided by sprays, air flow may be increased without significantly increasing the dust entrainment on the face. The addition of water will increase the surface moisture of the particles and should increase their adhesion properties resulting in particle agglomeration. Other studies examined velocities from 0.5 to 4.6 m/s (100 to 900 fpm), and showed that a minimum longwall face air velocity of 2.0 to 2.3 m/s (400 to 450 fpm) is required for proper dilution of dust along the face (Foster-Miller Assc., 1982, Breuer, 1972). However, due to the presence of methane, higher air velocities are often required for dilution of gas. When air velocity increases above 2.0 m/s (400 fpm), an increase in dust levels can occur if the moisture content of the dust is insufficient to prevent entrainment into the airstream (Hall, 1956, Hodkinson, 1960). A more recent study (Tomb *et. al.*,1990) shows that as face air quantities have increased, even beyond 5.1 m/s (1000 fpm), dust exposure levels due to dust generated along the face decrease when adequate controls are used. Currently, some U. S. longwall operations are using face velocities in excess of 7.6 m/s (1500 fpm).

These studies clearly indicate that higher air velocities do not increase dust generation from controlled sources such as the shearer or stageloader if adequate dust control systems are employed. However, this observation may not be the case for shield dust. As previously stated, water can be an effective means of controlling dust. However, sprays on the tops of shields are difficult to maintain and as a result soon become inoperable. More importantly, controlling shield dust using increased air dilution is difficult because increasing the air velocity provides greater potential for dust entrainment since the dust falls directly into the airstream under the canopy edges. This entrainment, in the absence of effective control technology, is the most likely source of increased dust contribution from the shields. In an effort to better understand the effects of high air velocity on the entrainment associated with shield dust, a test facility capable of entraining dust in a wind tunnel was designed and constructed at the NIOSH Pittsburgh Research Laboratory. The wind tunnel enabled laboratory studies to be conducted under controlled conditions that would simulate dust entrainment similar to that created by shield movement. This research is being conducted to provide fundamental information on the entrainment characteristics of dust at high air velocities and eventually provide solutions to shield dust generation and control.

TEST APPARATUS

The test apparatus consisted of four main components as shown in figure 2: 1) Dust entrainment tunnel, 2) Variable speed axial vane fan, 3) Vibratory material feeder, and 4) Dust sampling station.

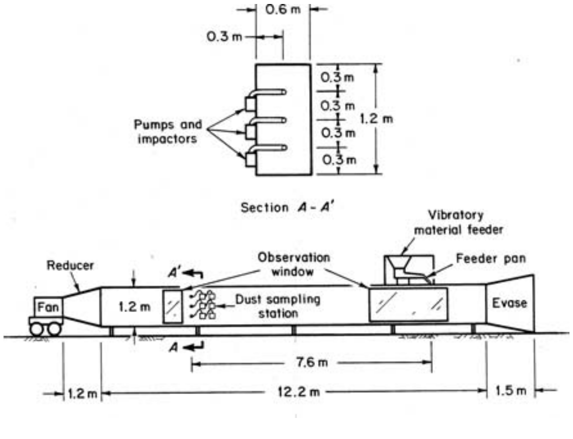

Figure 2. Dust entrainment tunnel schematic

Dust Entrainment Tunnel

The tunnel provided an enclosed and controlled area in which to entrain the dust. It was constructed of 12.7 mm (½-in) plywood and 50.8 by 101.6 mm (2 x 4 in) wood framing. The dimensions of the tunnel were 0.6 × 1.2 m (2 × 4 ft) providing an area of 0.7 m^2 (8 ft^2). The length of the wind tunnel was 12.2 m (40 ft) with a 1.5 m (5 ft) long evase at the open end to reduce head loss and turbulence as air entered the tunnel. The interior of the tunnel was waterproof painted and all seams sealed with caulking. A clean-out was provided in the tunnel to wash accumulated dust from the interior surface with water after each test. Two observation windows were built into the tunnel at the material dump point and at the sampling station to observe conditions during testing.

Variable Speed Axial Vane Fan

The fan provided a means to adjust air velocity in the tunnel. Air velocity was controlled with a 29.7 kw (40 hp) Joy axial vane fan capable of producing air velocities in the tunnel in excess of 10.2 m/s (2000 fpm). This was coupled with an Allen-Bradley variable speed controller to adjust fan rpm as needed. A 1.2 m (4 ft) long reducer duct between the tunnel and fan was used to transition the round fan opening to the rectangular tunnel and served to reduce shock loss and turbulence on the intake side of the fan. The exhaust side of the fan was connected by duct to a bag house (not shown) which filtered the dust from the air for environmental concerns.

Vibratory Material Feeder

The feeder provided a controlled means to introduce the material (dust and coarser coal) into the tunnel for each test. The unit was positioned on top of the tunnel as shown in figure 2. The feeder was a Eriez Model FBV-513 with a 0.1 m^3 (4 ft^3) hopper and dual controls to adjust vibration and feed rate. The feeder was retrofitted with a 56 cm (22 in) wide feeder pan that distributed the material across the entire width of the tunnel.

Dust Sampling Station

The sampling station provided a means to collect dust samples for each test. Dust samples were collected using gravimetric sampling pumps and personal impactors through three ports located in the sides of tunnel. Sampling probes were inserted into each port, which allowed the sampling pumps and impactors to be located on the outside of the tunnel. The distance between the material dump point and the location of the downstream sampling probes was 7.6 m (25 ft), as shown in figure 2.

TEST AND SAMPLING PROTOCOL

Instrumentation

Marple cascade impactors were chosen as the primary sampling instrument as the objective of the tests as it relates to air velocity were twofold: 1) to study the entrainment characteristics of both total dust (< 50 microns) and respirable dust (< 10 microns) and 2) to study the change in dust concentration and size distribution of the dust. The cascade impactor is an instrument that measures the size distribution of airborne particles and is used for particle size classification of dust in many industries. In use, the dust laden aerosol is drawn into the multi-stage instrument and separated into aerodynamic size classes. The aerosol stream moves with low velocity over the upper stages and increases in velocity at each subsequent stage. The collection process is made possible through the use of mylar substrates on each of the instrument's stages. Those particles with higher inertia (larger particles) will 'impact' the mylar substrate and be collected on the upper stages, whereas smaller particles will pass and be collected on the subsequent lower stages. The mylar substrates were coated with silicone grease to minimize particle bounce from one stage to the next. The substrates are pre- and post-weighed to determine the mass distribution on each stage of the impactor. The dust concentration and size distribution of the dust cloud at each test velocity were then determined.

Sampling Method

Isokinetic sampling, a sampling method by which dust laden air is drawn into a sampling nozzle at a velocity equal to that of the air in the tunnel (Brockmann, 1993, Quilliam, 1994), was employed. The nozzle diameter required to match the velocity in the wind tunnel is a function of the sampling pump air volume. Pumps were operated at 2 liters/min and tests were performed at four velocities, 2.0, 4.1, 6.1, and 8.1 m/s (400, 800, 1200, and 1600 fpm). To match these velocities, nozzle diameters of 4.6, 3.2, 2.6, and 2.3 mm (0.180, 0.127, 0.104, and 0.090 in) respectively were used. The inset of Figure 2 shows a cross sectional view of the arrangement of isokinetic probes in the tunnel. Three probes were placed on 0.3 m (1 ft) spacings in relation to each other and the sides of the tunnel. The use of a three-point sampling grid to calculate an average concentration over the area of the tunnel minimized the variation in dust levels that may occur due to dust gradients within the tunnel.

Fan Settings

Fan settings at the four selected air velocities were established using a pitot tube with manometer through a cross-sectional traverse which consisted of averaging the velocity over sixteen quadrants within the tunnel. Air velocity profile measurements were conducted at the sampling station to determine fan settings for the test velocities. Velocity measurements should be made at least 7.5 duct diameters away from any major upstream disturbances, in this case the material dump point (Guffey and Booth, 1999). The distance between the material dump point and the sampling station is 7.6 m (25 ft) which is approximately 7.5 duct diameters for a round duct of equivalent area of 0.7 m^2 (8 ft^2). It is important that turbulent flow exits to insure that satisfactory dispersion and removal of dust (Hartman, 1961). The critical velocity for this tunnel was calculated and the tests velocities exceed the velocity necessary for turbulent flow.

Feed Material

The feed material consisted of crushed coal (coarse) and finely ground bituminous coal dust. A previous shield dust study (Organiscak, *et. al*., 1985) showed that mines that left coal as immediate roof had higher amounts of support generated respirable dust than those with non-coal roofs. Therefore, initial studies were conducted using coal as the feed. However, most longwall operations today mine the entire seam and a rock roof is more typical on today's operations. Therefore, subsequent testing in this apparatus will use rock as the feed material. The coal dust, Keystone Mineral Black 325BA, is a commercially available material, manufactured by Keystone Filler and Manufacturing Company. The physical properties of this material are consistent, having a maximum particle size of 50 microns, sixty-five percent of which is <10 microns, and a moisture content of <1%. The purpose of the larger sized coal was to simulate the coarser debris that falls into the airstream as face supports are advanced and may enhance/hinder entrainment of the respirable portion of the coal dust. Air dry loss analysis on the total material mixture was <1%.

Initially, preliminary tests were conducted to determine the relationship between two key material parameters: 1) material weight and mix proportions, and 2) feed rate of material. The objective was to achieve a balance between the amount of material introduced into the tunnel and the time or rate of introduction. Material weight introduced into the tunnel varied between 9.1 to 18.2 kg (20 to 40 lbs), consisting of a mix of 50 percent coal dust (less than 50 microns), 25 percent coal 4.75 to 1.18 mm (0.18 to 0.05 in), and 25 percent coal 9.5 to 4.75 mm (0.37 to 0.18 in). The feed rate was varied so test runs were between 20 to 60 minutes in length. A series of preliminary tests were run and it was determined that a material weight of 18.2 kg (40 lbs) introduced into the tunnel in 30 minutes time gave sufficient weight gains on the impactor mylar filters with no filter overloading problems at the different velocities. This material weight and time were standardized for each test. Six test were run at each air velocity for a total of 24 tests.

DATA ANALYSIS

As previously stated, a minimum face air velocity of 2.0 to 2.3 m/s (400 to 450 fpm) is required for improved dust control along a longwall face. Therefore, a velocity of 2.0 m/s (400 fpm) was used as a baseline velocity for data collection and to make comparisons with increased air velocities. The data collected from the dust entrainment tests are shown in Table I. The table shows the total and respirable dust concentrations for each of the six tests conducted at each air velocity. Respirable fractions of the collected dust samples were calculated using methods previously defined in earlier research (Potts et.al., 1990). The table also shows the average and standard deviation of the concentrations, and the 95% confidence interval using a t-distribution. Dust measurements collected by the impactors were also analyzed for size distribution characteristics relative to changes in air velocity.

Dust Concentrations

The data from Table 1 clearly show that, as velocity increases in the entrainment tunnel, average dust concentrations rise in both the total and respirable ranges. Figures 3 and 4 show the mean and the 95% confidence interval for total and respirable dust concentrations respectively, as a function of velocity. These figures show graphically how the dust concentrations rise with each air velocity increase. At a 95% confidence level, statistically significant differences in mean dust levels at each air velocity were observed except for the total dust levels between 6.1 and 8.1 (1200 and 1600 fpm). Adding a regression line to each of the data sets show a positive correlation between the two variables, and high (>98%) coefficients of determination (R^2), indicating that a strong relationship exists between the total and respirable dust concentrations and air velocity.

The average total dust concentration at 2.0 m/s (400 fpm) is 18.6 mg/m^3, as shown in figure 3. At 8.1 m/s (1600 fpm), average total dust concentration was measured to be 117.08 mg/m^3, an increase of more than 6 times the concentration at 2.0 m/s (400 fpm). Since dust concentration is a function of mass and air quantity, increasing air velocity would increase air quantity in the test structure and for the same quantity of introduced-dust, should dilute the dust cloud and result in lower concentrations. However, sampling results suggest that there is substantially less particle deposition at the higher velocities allowing significantly more of the total dust to reach the sampling station, thus overcoming dilution effects. Higher air velocities have the energy necessary to entrain larger particles and transport these particles greater distances before deposition occurs. In addition, moisture can affect the agglomeration of particles and impact the entrainment and transport potential of dust particles. Elevated levels of moisture increases the bond between particles and increases the energy needed to separate agglomerated particles (Breuer, 1972). Representative samples of the feed material were air-dried and found to have an average moisture content of <1.0%. Consequently, the increased energy available at the high air velocity and relatively low moisture content of the feed material combine to allow total dust levels to rise significantly as air velocities increase. Unfortunately, rock and coal crushed above the shield canopies of longwall face supports can often have low moisture content and as previously indicated, air velocities on longwalls are increasing. The test results show that when these factors are combined the potential for greater entrainment of total dust from shields along longwall faces also significantly increases.

Table 1. Total and respirable dust concentrations at each air velocity

Total Dust										
Velocity m/s (fpm)	**Average Concentration, mg/m^3**						**Mean**	**Standard Deviation**	**Ratio to Baseline Dust**	**95% Confidence Interval (+/-)**
	Test									
	T1	**T2**	**T3**	**T4**	**T5**	**T6**				
2.0 (400)	14.43	14.38	15.70	22.94	28.60	15.57	18.60	5.86	-----	6.15
4.1 (800)	62.75	64.40	57.34	59.71	77.60	51.06	62.14	8.90	3.30	9.34
6.1 (1200)	80.77	103.03	92.60	93.40	92.16	75.06	89.50	10.00	4.80	10.49
8.1 (1600)	82.24	122.76	132.41	118.68	114.70	129.72	117.08	17.40	6.30	18.26
Respirable Dust										
Velocity m/s (fpm)	**Average Concentration, mg/m^3**						**Mean**	**Standard Deviation**	**Ratio to Baseline Dust**	**95% Confidence Interval (+/-)**
	Test									
	T1	**T2**	**T3**	**T4**	**T5**	**T6**				
2.0 (400)	1.03	1.42	1.35	1.51	2.30	1.18	1.47	0.44	-----	0.47
4.1 (800)	5.14	6.03	5.52	4.78	7.39	5.04	5.65	0.96	3.80	1.00
6.1 (1200)	8.25	16.43	14.25	13.25	14.03	11.51	12.95	2.80	8.80	2.94
8.1 (1600)	15.39	19.67	24.89	20.73	16.54	21.84	19.84	3.49	13.50	3.67

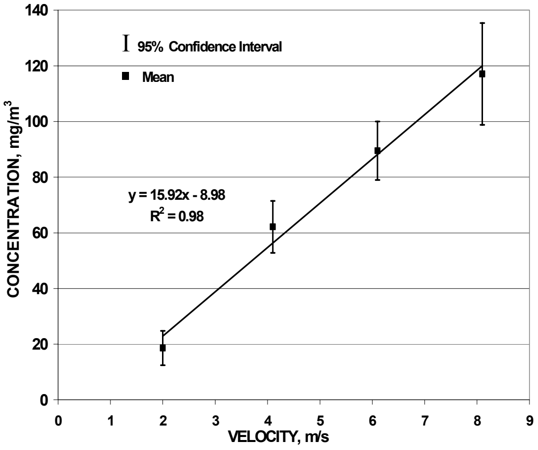

Figure 3. Relationship between total dust concentration and air velocity

The average respirable dust concentration at 2.0 m/s (400 fpm) is relatively low at 1.47 mg/m^3. Figure 4 shows that respirable dust levels rise at each velocity increase, with respirable dust levels at 8.1 m/s (1600 fpm) found to be 13.5 times greater than baseline levels. These dust level increases are contrary to a study by Tomb (Tomb *et. al*., 1990) which found that as face air velocities increase above 5.1 m/s (1000 fpm), respirable dust exposure levels decrease. However, in the study by Tomb, water spray systems were being utilized at primary dust sources (shearer and stageloader), which indicates that there was moisture added into the material to promote particle agglomeration. In addition, the dust generated at these sources was being shielded from the face airflow by physical barriers and/or water sprays in an effort to minimize entrainment.

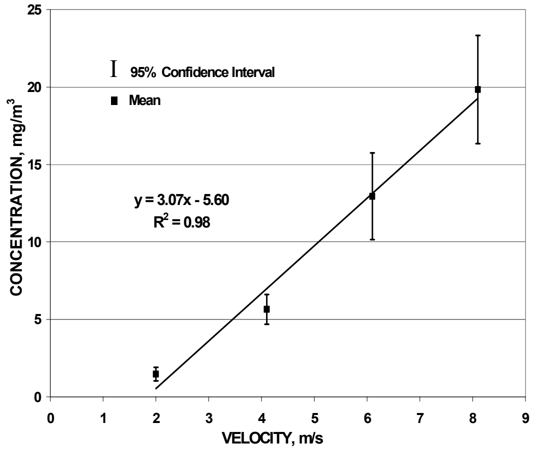

Figure 4. Relationship between respirable dust concentration and air velocity

Respirable sampling results from the laboratory tests suggest that some agglomeration was occurring within the feed coal but moisture levels were not high enough to keep all of this material agglomerated as the higher air velocities were encountered. Therefore, at the low end of the test velocity, 2.0 m/s (400 fpm), these particles remained agglomerated and were deposited in the tunnel before they reached the sampling station or were deposited on the upper stages of the impactors. At higher velocities, the adhesion and auto-adhesion forces become less dominant allowing more of the particles to be entrained into the airstream as respirable-sized dust particles. Figure 5 supports this conclusion by showing the respirable and total dust concentrations and the percent of respirable dust observed at each velocity. As shown, the percent of respirable dust in the collected dust sample increases as the velocity increases. The largest increase in respirable dust content occurred when the air velocity increased from 4.1 to 6.1 m/s (800 to 1200 fpm).

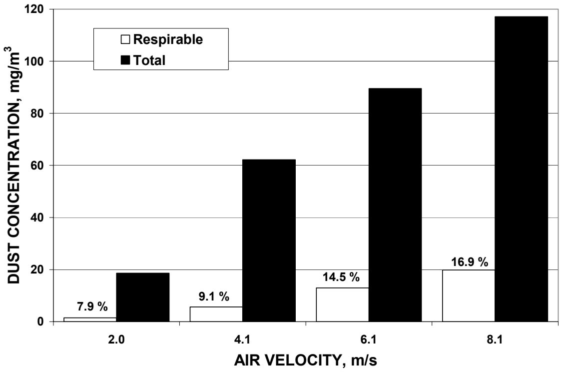

Figure 5. Percent of respirable dust in impactor samples at each air velocity

Figure 6 shows the increase in dust concentration from one velocity to the next for both total and respirable dust. As evident from the graph, the largest increase in total and respirable dust concentrations occurs from the 2.0 to 4.1 m/s (400 to 800 fpm) and 4.1 to 6.1 m/s (800 to 1200fpm), respectively. After 6.1 m/s (1200 fpm), the increase in dust concentrations level off. Previous studies (Foster-Miller Assc., 1982, Breuer, 1972) have shown that, increases in dust levels begin to occur at about the 2.0 to 2.3 m/s (400 to 450 fpm) velocity range for dust having moisture content of about 3%. Data collected during this study are consistent with the findings from these studies.

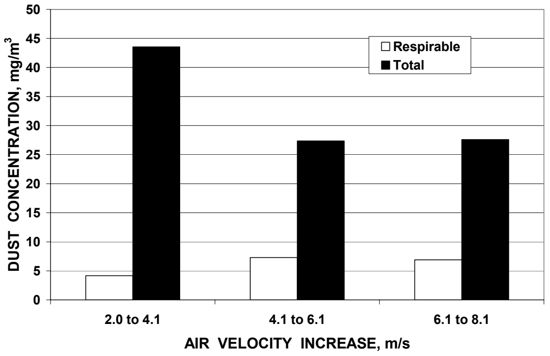

Figure 6 Rise in dust concentration for each air velocity increase

Size Distribution

Particle size classification is important to examine how dust is transported and to determine its potential health effects on workers. To characterize the dust, multiple stage impactors were used to classify dust particle size in the entrainment tunnel. Table 2 shows the impactor stages and associated cut points, and the average particle weight for each stage at each velocity. Mass median diameters (MMD) of the dust sample at each velocity were determined and are also shown in Table 2. The MMD gives an overall measure of the size distribution of the particles and specifically is the particle size at which 50% of the particles are greater than the MMD and 50% of the particles are smaller than the MMD.

Table 2. Mass on each impactor stage for test velocities

		Average Mass per Stage, mg			
Stage	**Cut Points microns**	**2.0 m/s**	**4.1 m/s**	**6.1 m/s**	**8.1 m/s**
1	21	0.159	0.461	0.512	0.599
2	15	0.153	0.400	0.433	0.570
3	10	0.330	0.990	1.171	1.421
4	6	0.232	0.969	1.449	1.691
5	3.5	0.113	0.505	1.041	1.488
6	2	0.048	0.195	0.514	0.770
Final	0.25	0.012	0.022	0.062	0.132
MMD, microns		10.84	9.82	8.22	7.70

Figure 7 shows the dust weights that were collected on each stage for the four different air velocities during the test. The x-axis shows the particle size of each of the stages ranging from 21 to 0.25 microns.

The four curves represent the weight per stage for each of the four test velocities. As is evident in figure 7, an overall trend can be seen for each velocity and at each stage. In general, as the velocity increases from one speed to the next, the weights on each of the individual stages also increase. Therefore, as can be expected, as the velocity increases, less deposition is occurring and more of the dust is being transported further down the airstream. However, the stage weights at 2.0 m/s (400 fpm) remain consistently distributed over the entire range of stages relative to the other weights at the other velocities. The curves representing the three higher velocities show sharp increases in stage weights from 15 to 10 micron cut points and continues to increase into the respirable dust range (<10 microns). The differential in weight for all stages is the greatest at the 6 micron cut point.

Comparing the 3.5 and 6 micron cut points to cut points 21 and 15 shows that dust collected at the non-respirable range was small compared to the respirable range.

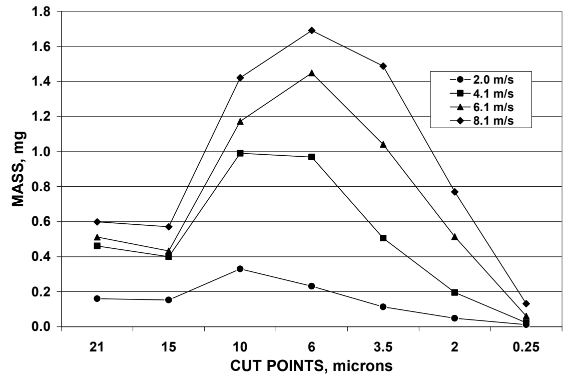

Figure 7 Average dust distribution by impactor cut points

A graph of the mass median diameter at each air velocity is shown in figure 8, and identifies the decrease in particle size as velocities increase. The fact that finer dust is being collected at the higher velocities further suggests that the increased energy of the higher velocity air promotes separation of loosely agglomerated particles. This observation is in agreement with other studies (Shankar and Ramani, 1995) that showed similar findings from reentrainment wind tunnel tests.

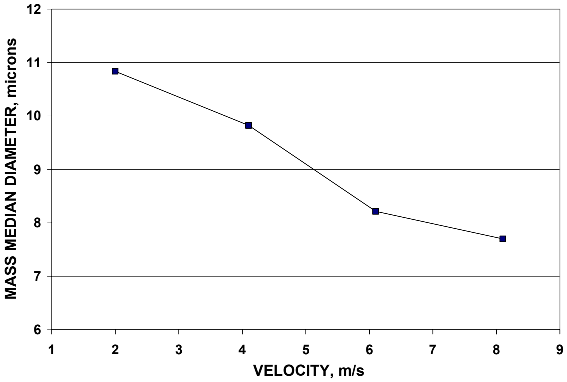

Figure 8. Mass median diameter for each test velocit

Increased Moisture

Past research has indicated that the addition of water to a mined product will reduce the quantity of respirable dust that becomes airborne. Consequently, mine operators utilize water sprays to wet run-of-mine coal (e.g., underboom sprays on continuous miners, stageloader sprays on longwalls, sprays at belt transfer points) in an effort to reduce dust liberation during coal transport. Similarly, shield spray systems have been installed to wet the unconsolidated coal/rock on the tops of shields before it becomes exposed to ventilating air during shield advance. The objective of the next series of tests was to simulate the effect of these sprays by adding moisture to the feed product and determine the impact on dust liberation at elevated moisture levels.

The original feed product was quite dry and only contained approximately 1% surface moisture. The goal was to add sufficient surface moisture to the feed material so that it contained approximately 7% to 9% moisture. No information could be found to identify a suitable means of wetting the feed coal. Initially, an attempt was made to operate humidifiers in a sealed chamber to raise moisture levels. After 72 hours of continuous operation, the moisture content had only increased to approximately 3%. Subsequently, to expedite the process a water spray manifold was constructed that contained 5 atomizing nozzles. These nozzles were operated at 689.5 kPa (100 psi), resulting in a flow rate of 0.038 lpm (0.01 gpm) per nozzle.

The coal feed material was spread onto a flat platform that could be pulled under the spray manifold at a controlled rate of speed of 0.08 m/s (16 fpm) It was determined that the feed material needed to pass under the spray manifold 10 times in order to disperse the desired quantity of water onto the feed product to achieve the 7% to 9% moisture range. After each pass, the feed material was combed to evenly distrubute the water through the product. Five separate tests were conducted and samples were collected and analyzed for surface moisture at an independent laboratory. Results of this analysis indicate that this wetting technique increased the surface moisture to the desired range and could be applied in a reproducible manner. This method has been adopted for preparation of feed material for subsequent tests. The tests to evaluate the impact of added moisture have been initiated. It is anticipated that the preliminary results of these tests will be available for discussion during the conference presentation.

SUMMARY

Substantial gains in longwall production levels have occurred and longwall operators have increased the levels of air and water applied in an effort to control dust generation and worker exposure. Research and application of control technologies have focused on the shearer and stageloader/crusher, which were the two highest sources of respirable dust as characterized by a U.S. Bureau of Mines study in the 1980 s. A similar study by the Bureau in the 1990s indicated that dust liberation during shield movement has emerged as a significant contributor to dust generation on longwalls. As shields are advanced, material drops off of the shield canopy directly into the airstream, which would facilitate entrainment of dust into the airstream. Higher production levels have resulted in faster shield advance, greater numbers of shields being moved, and air velocity increases. These factors combine to elevate the dust problems associated with shield advance. Past studies (Hall, 1956, Hodkinson, 1960) have shown that, for low moisture dust, velocities in excess of about 2.3 m/s (450 fpm), can cause dust concentrations to rise. To better understand the effects of dust entrainment at air velocities being observed on today's longwall faces, research was conducted in a wind tunnel at test velocities of 2.0, 4.1, 6.1, and 8.1 m/s (400, 800, 1200, and 1600 fpm). This study examined dust entrainment characteristics in the absence of any dust control technologies.

Higher air velocities result in higher air quantities which can serve to dilute dust and should therefore, lower concentrations in the wind tunnel. However, both total and respirable dust concentrations rose at each successive higher air velocity indicating that particle entrainment was greater than dilution effects for these tests. Total dust concentration increased from 18.6 mg/m^3 at 2.0 m/s (400 fpm) to 117.1 mg/m^3 at 8.1 m/s (1600 fpm). Similarly, respirable dust concentrations increased from 1.47 mg/m^3 at 2.0 m/s (400 fpm) to 19.84 mg/m3 at 8.1 m/s (1600 fpm). Statistical analysis of the concentrations measured at each velocity resulted in significant differences at a 95% confidence interval.

Size distribution of the sampled dust shows that as velocities rise, a higher percentage of the dust particles in the airstream are finer (< 10 microns) than what was collected at 2.0 m/s (400 fpm). At 2.0 m/s (400 fpm), 7.9% of the collected dust was in the respirable size range, while at 8.1 m/s (1600 fpm), 16.9% of the collected dust was respirable. The mass median diameter was found to be 10.8 microns at 2.0 m/s (400 fpm) and decreased to 7.7 microns at 8.1 m/s (1600 fpm). Higher concentrations and finer particle size distributions suggest that at a moisture content of approximately 1%, a portion of the dust particles were loosely agglomerated and remained agglomerated at the 2.0 m/s (400 fpm) velocity. As the velocity increased, the adhesion forces are overcome by the increased energy supplied to the system resulting in higher concentrations and smaller particle sizes in the airstream.

Past research has indicated that higher surface moisture in the mined product may serve to reduce airborne dust concentrations at higher air velocities. An entrainment study using test material with higher moisture content has been initiated and the results will be compared to the current study to quantify the effects of increasing moisture content. Results of these tests will be provided at the conference.

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