

Characterization of airborne float coal dust emitted during continuous mining, longwall mining and belt transport

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Abstract ■ Float coal dust is produced by various mining methods, carried by ventilating air and deposited on the floor, roof and ribs of mine airways. If deposited, float dust is re-entrained during a methane explosion. Without sufficient inert rock dust quantities, this float coal dust can propagate an explosion throughout mining entries. Consequently, controlling float coal dust is of critical interest to mining operations. Rock dusting, which is the adding of inert material to airway surfaces, is the main control technique currently used by the coal mining industry to reduce the float coal dust explosion hazard. To assist the industry in reducing this hazard, the Pittsburgh Mining Research Division of the U.S. National Institute for Occupational Safety and Health initiated a project to investigate methods and technologies to reduce float coal dust in underground coal mines through prevention, capture and suppression prior to deposition.

Field characterization studies were performed to determine quantitatively the sources, types and amounts of dust produced during various coal mining processes. The operations chosen for study were a continuous miner section, a longwall section and a coal-handling facility. For each of these operations, the primary dust sources were confirmed to be the continuous mining machine, longwall shearer and conveyor belt transfer points, respectively. Respirable and total airborne float coal dust samples were collected and analyzed for each operation, and the ratio of total airborne float coal dust to respirable dust was calculated. During the continuous mining process, the ratio of total airborne float coal dust to respirable dust ranged from 10.3 to 13.8. The ratios measured on the longwall face were between 18.5 and 21.5. The total airborne float coal dust to respirable dust ratio observed during belt transport ranged between 7.5 and 21.8.

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Introduction

During the extraction of coal, various dusts are produced that can be classified into two categories of interest: respirable and float coal dust. Respirable dust, with particle diameter $\leq 10 \mu\text{m}$, has the capability to penetrate beyond the terminal bronchioles and become deeply embedded in human lungs, leading to respiratory disease complications (Potts, McCawley and Jankowski, 1990). Float coal dust is defined as coal dust with particle diameter $\leq 74 \mu\text{m}$ (Harris et al., 2009). During the mining process, float coal dust can be deposited on the floor, roof and ribs of mine airways. With the proper mixture of methane gas — between 5 and 15 percent — and an ignition source, a methane gas explosion can occur

(Barker and Humphreys, 1996). The resulting explosion can develop a pressure wave that lifts the deposited float coal dust material into the air, propagating a disastrous coal mine explosion (Harris et al., 2010).

The current technique to safeguard against the propagation of a coal mine explosion is to treat the mine airways with incombustible rock dust, typically limestone, maintaining an 80 percent total incombustible content of the deposited material. The U.S. National Institute for Occupational Safety and Health (NIOSH) initiated a project to investigate control technologies that could be aimed at reducing the amount of float coal dust allowed to deposit in mine airways using three approaches: prevention, capture and suppression

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prior to deposition. Reducing the float coal dust that is generated during mining processes, and capturing or suppressing airborne float coal dust prior to deposition would in turn increase the efficiency of the rock dust applied to prevent mine explosions.

The objective of this work was to characterize the dust emitted during three separate surveys. Gravimetric samples of respirable and total airborne float coal dust were collected from a continuous miner section, a longwall section and a conveyor-belt coal transport system. The information gathered will be used to design dust control systems targeting dust size distributions observed during the study.

Sampling methods

For this work, sampling stations were developed that contained the necessary equipment to collect duplicates of airborne float coal dust and respirable dust gravimetric samples. The sampling equipment was selected to be intrinsically safe, which allowed for safe operation in the various mining environments.

Gravimetric respirable dust samplers. Coal mine dust personal sampling units were used to determine the airborne mass concentrations of respirable coal dust emitted from each mining process. These samplers consisted of a 37-mm (1.5-in.)-

diameter filter cassette, a 10-mm (0.4-in.) Dorr-Oliver cyclone and a permissible Escort ELF air sampling pump (Zefon International Inc., Ocala, FL) operated at 2 L/min.

Gravimetric airborne float coal dust samplers. Float coal dust particles are 74 μm or less in diameter, and a permissible dust sampler is not available to isolate this fraction of airborne dust. Consequently, NIOSH used an inhalable dust sampler with 50 percent cut point, D_{50} , of 100 μm as a surrogate to determine the mass concentration of airborne float coal dust. The sampling assembly consisted of an Institute of Occupational Medicine (IOM) sampler operated at 2 L/min and containing a 25-mm (1-in.) filter. An adapter was designed to attach to the inlet of the IOM sampler, which allowed for the insertion of an isokinetic sampling nozzle (Fig. 1). Isokinetic sampling (Wilcox, 1956), which is a technique where the sampling velocity is equal to the air-stream velocity, was chosen to ensure the samples collected were representative of the dust concentrations present in the mine air. A vane anemometer was used to measure the mine air velocity. Janisko et al. (2015) compared airborne float coal dust samples and float coal dust deposition samples collected in a return entry to evaluate float coal dust reductions provided by a wet scrubber. The calculated dust reduction efficiencies for these two sampling methods were within 5 percent of each other, indicating that the IOM sampler equipped with an isokinetic nozzle is a viable surrogate for the traditional float coal dust deposition method. The evaluation and design are further described in Barone et al. (2016) and Janisko et al. (2015).

Figure 1

IOM sampler equipped with an adapter and isokinetic nozzle.



Figure 2

Custom-cut cyclones: 10, 20 and 40 μm .



Multicyclone array. Custom-machined multicyclone arrays were used to provide aerodynamic sizing of airborne float coal dust. Using a permissible Escort ELF air sampling pump operating at 2 L/min, three cyclones with D_{50} designed for 10, 20 and 40 μm (Fig. 2) (Mesa Laboratories Inc., Butler, NJ), sized the dust particles, which were deposited on 37-mm (1.5-in.)-diameter polyvinyl chloride filters. The cyclones were affixed with an isokinetic sampling nozzle. The mass concentrations measured with these custom-machined cyclones were used to develop a size distribution of the collected particles. For example, the mass collected using the 20- μm cyclone can be subtracted from the mass collected using the 40- μm cyclone to determine the gravimetric distribution of particles collected that were between 20 and 40 μm .

Field characterization study of a continuous miner section

A field characterization study was performed on a continuous miner section to measure the respirable and airborne float coal dust concentrations produced during mining. This miner was supported by two shuttle cars and a twin-boom roof bolter. An auxiliary fan located in the return was used in conjunction with tubing to provide exhaust face ventilation. During the study, the ventilation rate in the return entry averaged 2.8 m/s (551 ft/min). NIOSH collected dust samples during two working shifts at discrete locations in the return entry by placing sampling units 30, 75 and 120 m (98, 246 and 394 ft) downwind from the discharge of the auxiliary fan (Fig. 3). With approval from the U.S. Mine Safety and Health Administration (MSHA), normal rock dusting was

Table 1

Continuous mining operation average dust sampling results.

Dust type	Dust concentration (mg/m ³)		
	30 m ^a	75 m ^a	120 m ^a
Float	90.1	76.1	68.6
Respirable	6.5	6.4	6.7
Float/respirable ratio	13.8	11.8	10.3

^aDistance downwind from discharge of auxiliary fan.

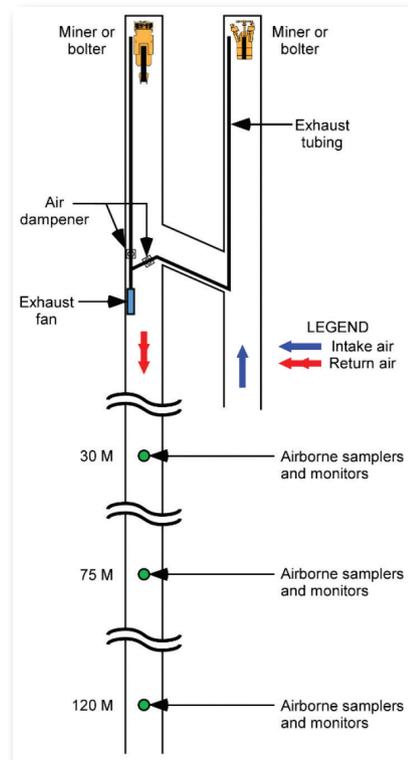
suspended during the study to reduce the amount of rock dust interference during dust sampling.

Continuous mining operation results. The measurements from the two shifts sampled were averaged, and the results are provided in Table 1. Respirable dust concentrations remained relatively constant as the dust plume advanced down the return airstream. However, larger float coal dust particles were conceivably falling out of the airstream and depositing in the return entry, as indicated by the reduction in airborne float coal dust levels from the 30-m (98-ft) to the 120-m (394-ft) sampling locations. Also, the ratio of airborne float coal to respirable dust dropped as the distance down the return entry increased. Past laboratory studies support the findings from this investigation. Cortese and Perlee (1998) found that the median particle size for dispersed dust decreases with distance from the source because the larger particles are the first to deposit. The study revealed a 30 percent reduction in mean particle diameter over a distance of 50 m (164 ft) at ventilating air velocities ranging from 0.9 to 2 m/s (177 to 394 ft/min).

With an auxiliary fan and tubing providing face ventilation, engineering controls for reducing float coal dust deposition can be applied at the mining face or at the fan before dust-laden air is discharged into the return entry. NIOSH made a return visit to this mine to evaluate an experimental wet scrubber, placed inline with the auxiliary fan, that was designed to remove airborne float coal dust before the dust reached the return. The results of that study (Janisko et al.,

Figure 3

Continuous miner section dust sampling configuration (sampling locations as noted).



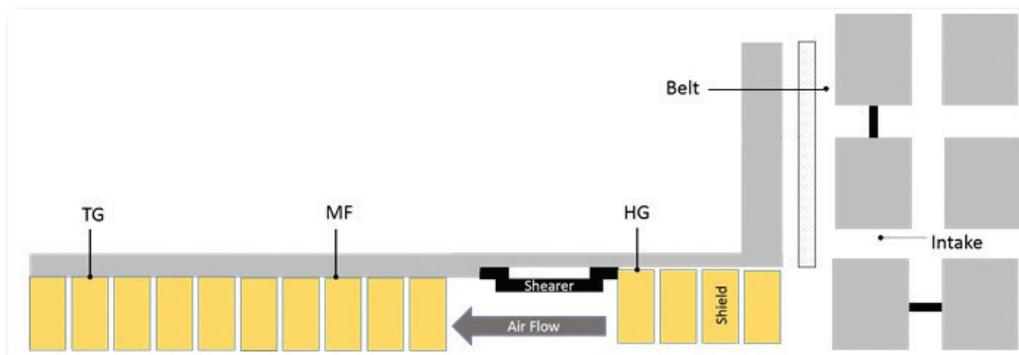
2015) showed an airborne float coal dust reduction of more than 90 percent.

Field characterization study of a longwall mining section

A field characterization study was performed on a longwall section to measure the respirable and airborne float coal dust concentrations produced during mining. Bidirectional cutting was employed at this face, with shield advance initiated manually. The longwall face was approximately

Figure 4

Longwall section dust sampling configuration (sampling locations as noted).



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300 m (984 ft) long, with an average face air velocity of 5.8 m/s (1,142 ft/min) observed during the study.

Sampling was performed during three working shifts at discrete locations along the longwall face and in the immediate intake airstreams to determine airborne float coal dust levels (Fig. 4). Five sampling locations were monitored. On-face samplers were located on shield 55 at the headgate (HG), 120 m (394 ft) downwind from the HG sampling location at the midface (MF), and 200 m (656 ft) downwind from the HG sampling location at the tailgate (TG). These on-face samplers were suspended from the shield canopy and situated above the panline. The HG and TG samplers were operated continuously during the study period, while the MF samplers were operated only when the shearer was upwind, to isolate the dust generated by shearer activity. In addition, outby samplers were located in the intake (last open crosscut) and belt entry (outby stage loader-to-belt transfer), and they were operated continuously throughout the shift.

Longwall mining operation results. Table 2 summarizes the dust sampling results from the five sampling locations. The air used to ventilate the longwall face contained relatively low levels of airborne float coal dust, with the intake air averaging 0.50 mg/m³ during the study. The air traveling along the belt entry averaged 1.44 mg/m³ across the three days. The increase in belt entry dust was observed with respirable dust as well, with the intake and belt airways containing averages of 0.02 and 0.25 mg/m³, respectively.

Average airborne float coal dust concentrations on the face ranged from 8.43 to 56.60 mg/m³. The HG sampling location averaged 14.76 mg/m³. This increase in dust concentrations over the intake sampling location cannot be solely

attributed to the stage loader/crusher as there was significant shearer activity upwind of the HG sampling location, including the HG cut out and wedge cut. The MF location measured the highest airborne float coal dust concentration of 56.60 mg/m³, while the TG averaged 52.60 mg/m³.

Custom-cut cyclones with 10- μ m, 20- μ m and 40- μ m cut points were used to determine the size distributions of the collected dust. The cyclones were located in close proximity to the total dust samplers located at the HG, MF and TG sampling locations (Table 3).

In general, dust sizes measured at MF and TG were similar. Respirable dust concentrations remained relatively constant between the MF and the TG sampling locations, with slight reductions in the mass concentrations measured using the 10- μ m, 20- μ m and 40- μ m cyclones of 23, 4 and 18 percent, respectively. Roughly 27 percent of the particles collected gravimetrically at the MF sampling location were smaller than 40 μ m. The gravimetric particle distribution at TG was similar to that at MF. At TG, 23.7 percent of the collected particles were smaller than 40 μ m. A study performed by Ramani and Qin (1995) simulated the dust dispersion on a longwall face and showed similar results to the present field investigation in regard to dust particle size distribution. The size data of gravimetric dust samples measured at various locations along a 175.3-m (575-ft)-wide longwall panel showed that a small deviation in size distribution exists between the midface and tailgate sampling locations. The study concluded that the settling of the particles was dampened out across a longwall face due to the moving dust sources (shearer and shields).

Control systems located along the longwall face could be used to target larger float coal dust particles, suppress-

Table 2

Longwall mining operation average dust sampling results.

Dust type	Dust concentration (mg/m ³)				
	Intake	Belt	Headgate (HG)	Midface (MF)	Tailgate (TG)
Float	0.50	1.44	14.76	56.60	52.60
Respirable	0.02	0.25	0.80	2.63	2.65
Float/respirable ratio	25.00	5.76	18.45	21.52	19.85

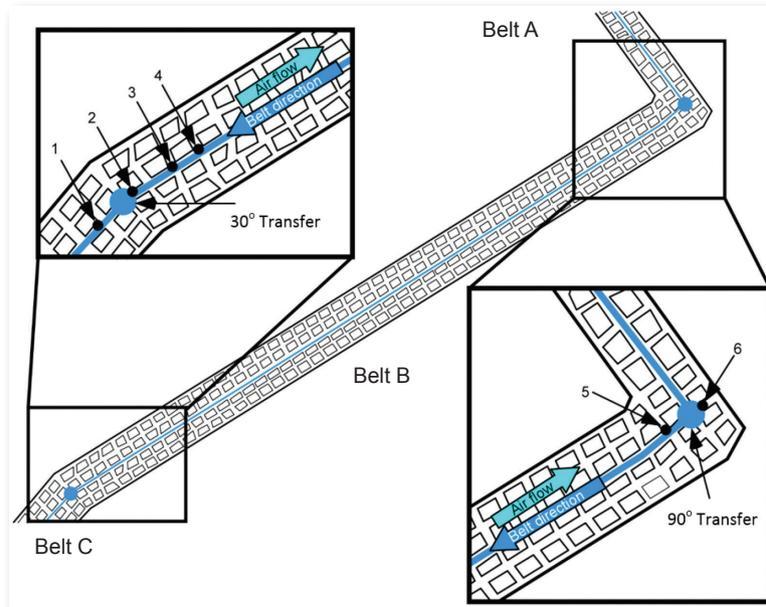
Table 3

Longwall mining operation average dust concentration by particle size.

Dust size, D ₅₀ cut point	Dust concentration (mg/m ³)		
	Headgate (HG)	Midface (MF)	Tailgate (TG)
Respirable	0.80	2.63	2.65
10 μ m	1.46	9.88	7.60
20 μ m	1.77	12.32	11.84
40 μ m	2.27	15.14	12.45
IOM (total)	14.76	56.60	52.60

Figure 5

Belt entry dust sampling configuration (dust sampling locations numbered 1 through 6).



ing them prior to the return airway. Assuming constant rock dust application, this would result in an improved ratio of incombustible to combustible deposited particles, lowering the risk of a coal dust propagation explosion.

Field characterization study of a belt entry

A field characterization study was performed on a coal handling facility to measure the respirable and airborne float coal dust concentrations produced during the transport of coal on a conveyor belt. Dust sampling was conducted along three belts and around the two transfer points that were located within the belt entry of the mine. Belt A transferred onto Belt B at a 90-degree transfer point. Belt B then transferred onto Belt C at an approximately 30-degree transfer point.

The ventilation system was antitropical with the fan located at the end of Belt C. The mine air velocity was measured using a vane anemometer and averaged 0.45 m/s (89 ft/min) during the study. Six sampling locations were selected for the study (Fig. 5). Sampling location 1 was 12.2 m (40 ft) upwind of the 30-degree transfer point, while locations 2, 3 and 4 were 3, 15 and 23 m (10, 49 and 75 ft) downwind of the trans-

fer, respectively. Sampling location 5 was 1,125 m (3,690 ft) downwind of sampling location 4 and 12 m (39 ft) upwind of the 90-degree transfer. Sampling location 6 was 3 m (10 ft) downwind of the 90-degree transfer. Dust sampling was conducted during three shifts. The average dust concentrations measured are summarized in Table 4.

Conveying operation results. Similar to the belt entry sample collected in the longwall study, sampling location 1, measuring belt dust emissions upwind of the transfer points had relatively low airborne float coal dust levels with an average near 1 mg/m³. Airborne float coal dust concentrations were elevated directly after each transfer point as measured at dust sampling locations 2 and 6. The airborne float coal dust plume quickly dissipated downwind of the transfer point. The distance between sampling location 2 and 3 is 12 m (39 ft), and had an average gravimetric reduction of 76 percent of airborne float coal dust due to a combination of deposition and dilution. Respirable dust concentrations quickly declined as well from the 30-degree transfer point, but then held steady, averaging 0.34 mg/m³, as the air traveled along belt B.

Table 4

Conveying operation average dust sampling results.

Dust type	Dust concentration (mg/m ³)					
	1	2	3	4	5	6
Float	0.97	13.27	3.20	3.03	2.69	11.85
Respirable	0.09	0.61	0.34	0.31	0.36	0.94
Float/respirable ratio	10.78	21.75	9.40	9.77	7.47	12.60

Table 5

Conveying operations average dust concentration by particle size.

Dust size, D_{50} cut point	Dust concentration (mg/m ³)					
	1	2	3	4	5	6
Respirable	0.09	0.61	0.34	0.31	0.36	0.94
10 μ m	0.53	3.61	2.07	1.72	1.35	4.68
20 μ m	0.71	6.69	3.27	3.05	2.44	8.79
40 μ m	0.63	8.09	3.98	3.43	2.80	9.73
IOM (total)	0.96	13.27	3.20	3.03	2.69	11.84

The ratio of airborne float coal to respirable dust remained between 7.5 and 10.8 along the belt line. Custom-cut cyclones were located within 1 m (3.3 ft) of the total dust samplers at all six sampling locations, and their results are presented in Table 5. Unlike the longwall sampling results, the dust concentration differences between the 40- μ m cyclones and the IOM samplers in the belt entry were not very large, and in the cases of sampling locations 3, 4 and 5, the IOM concentrations were actually lower. On average, 62 percent of the particles collected directly after the transfer points were smaller than 20 μ m.

These data indicate that float coal dust is not being liberated during belt transport, and that float coal dust liberation at the transfer points is the primary source of float coal dust generation and should be the focus of control efforts.

Conclusions

Airborne float coal dust sampling studies were conducted at continuous miner, longwall and coal handling operations. Comparison of the airborne float coal dust concentrations at each of these operations shows that the continuous mining operation had the highest concentration of airborne float coal dust, while the longwall had the highest ratio of airborne float coal dust to respirable dust. The continuous miner and longwall shearer were determined to be the highest producers of float coal dust. The belt transfers and belt lines generated the lowest airborne float coal dust levels.

Mines could make use of the airborne float coal dust to respirable dust ratio by taking respirable dust samples and then using their respective ratio to obtain an indication of the quantity of float dust that would be generated, which in turn could be used to estimate the quantity of rock dust that would be required to inert the generated float coal dust. This method would be site-specific but could prove to be a useful tool for an operation once a ratio has been developed. Additional studies are necessary to more fully develop this tool.

Air velocity appeared to have a major impact on the settling characteristics of the airborne float coal dust. At the continuous miner return entry, air velocity averaged 2.8 m/s (551 ft/min) and airborne float coal dust levels dropped by approximately 24 percent over a 90-m (295-ft) distance. At the belt transfer, air velocity was less than 0.5 m/s (98 ft/min), and airborne float coal dust levels dropped by 76 percent over a distance of 12 m (39 ft). In contrast, respirable dust

levels remained relatively constant at the sampling sites.

Information from these studies will be used to guide the development of control strategies aimed at reducing float coal dust deposition in mine airways. The study has determined that the continuous miner, longwall shearer and belt transfer points should be the principal focus for the development of float dust control technologies. ■

Disclaimer

Mention of any company or product does not constitute endorsement by the NIOSH. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of NIOSH.

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