EVALUATION OF DUST CONTROL FOR DEEP CUT COAL MINING SYSTEMS USING A MACHINE MOUNTED DUST COLLECTOR

by

Kenneth G. Fields, Mining Engineer
David J. Atchison, Mining Engineering Technician
Robert A. Haney, Supervisory Mining Engineer
Mine Safety and Health Administration
Pittsburgh, Pennsylvania

Abstract. Mining systems with greater than a 20-foot face advance (deep cut) have become popular due to their increased productivity and safety. The face dust collection system used in many of the mines employing the deep cut systems, incorporates a machine mounted dust collector with either a blowing or exhausting line brattice and a remote control operated continuous miner. In order to characterize and quantify the parameters used to control dust with these systems, the Dust Division conducted studies on four mining sections using continuous miners with deep cut mining systems. On each section, the dust control system incorporated line brattice with a machine mounted dust collector. The remote control made it possible for the continuous mining machine to advance further while permitting the operator to remain under supported roof and away from dust generated during mining. The purpose of these studies was to evaluate the effectiveness of deep cut mining systems using dust collectors to control respirable dust exposure.

This paper summarizes the results of the studies conducted. At each mine face workers were sampled to determine their full-shift dust exposure. Additionally, fixed point dust samples were collected at various locations to determine relative concentrations of dust generated from mining. Air quantities were measured at each working place to determine the amount of air delivered to the face area. Evaluations were made by comparing worker exposures to respirable dust samples taken at appropriate locations upstream and downstream of the coal faced being mined. An estimate of the amount of the respirable dust being generated at the face during mining and the amount of respirable dust being removed by the dust collectors was made by balancing the air quantities and the dust concentrations immediately upstream and downstream of the coal face.

Results of the studies showed that the dust control systems, were effective for controlling workers exposure to respirable dust. Dust collector efficiencies were determined to be approximately 85 percent. While the dust collectors were effective in removing respirable dust, the success of the systems with line brattice greater than twenty feet from the face, was dependent on the use of the remote control which permitted the continuous miner operator to remain out of the high concentration dust cloud in the working face. Dilution from intake air, combined with the dust collector efficiency, maintained exposure of other section workers below applicable standards.

INTRODUCTION

In order to increase productivity and at the same time maintain a safe and healthful work place, many coal mining companies are utilizing mining methods designed to permit "deep cuts" or face advances greater than twenty feet. To assure that the health or safety of workers is not compromised while employing these mining methods, traditional 10 foot exhaust face ventilation systems have been replaced by dust control systems that incorporate dust collectors or spray fan systems with blowing or exhaust face ventilation systems.

In accordance with CFR, Title 30, Part 75.316 (1989), a ventilation system and methane and dust control plan suitable to the conditions and mining system, must be approved for each mining section. When a deep cut system is employed, this plan sets out, among other things, the maximum brattice distance and minimum face air quantity and dust collector air quantity to control both respirable dust and methane. Typically, these parameters are evaluated by enforcement personnel prior to approval of the plan.

The Dust Division of the Pittsburgh Health Technology Center conducted studies on mining sections utilizing a "deep cut" mining method in conjunction with a dust collector. The purpose of these studies was to evaluate the effectiveness of deep cut mining systems using dust collectors to control respirable dust exposure.

Deep cut systems also incorporate a remote controlled continuous miner. Remote control allows the continuous mining machine to advance up to forty feet beyond the last row of roof bolts while the machine operator remains under the protection of supported roof. Typically the line brattice is initially extended to the last row of roof bolts to direct air across the face to dilute methane and dust. The machine mounted dust collector is designed to draw in a large portion of the dust generated at the face during cutting, filter it out of the mine atmosphere, and discharge clean air at the rear of the mining machine.

Studies were conducted on four mining sections. Two of the sections utilized a blowing system of face ventilation and two of the sections studied utilized an exhausting system of face ventilation. On the blowing sections the dust collector air flow capacity was greater than the face air flow quantity. On the exhausting sections, the dust collector air flow capacity was less than the face air flow quantity. For the exhaust face ventilation systems, both the line brattice and dust collector discharge were on the same side of the entry. For blowing face ventilation systems, the line brattice and dust collector discharge were on opposite sides of the entry.

The deep cut or extended line brattice mining method examined in these studies incorporated the use of a machine mounted dust collector with either a blowing or exhausting line brattice. Luxner (1968) showed that when brattice discharge velocities exceed 800 fpm, the blowing method of face ventilation had a better penetration of air and methane dilution than the exhausting method of face ventilation. However, when brattice inlet or discharge velocities are less than 400 fpm there is little difference in performance between blowing and exhausting face ventilation. This is illustrated in Figure 1 for a 20 foot brattice set back. Air flow is considered to have the same dilution effect on respirable dust as it has on methane. Typical discharge velocities for blowing face ventilation systems in underground coal mines are less than 400 fpm. The primary advantage of the blowing face ventilation system therefore, is the easier installation of the line brattice which for a blowing system requires less framing or support. The disadvantage of the blowing face ventilation system is that miners may be required to work in the immediate return airway, exposing workers to high concentrations of respirable dust particularly if the dust collector efficiency and/or an adequate face air quantity is not maintained.

TEST PROCEDURES

The systems were evaluated by the use of ventilation and respirable dust measurements collected at various places on the working section. Ventilation measurements were taken at the inby end of the line brattice and in the immediate face return. Section intake and return airflow was also measured and the dust collector capacity was determined.

Personal dust samples were collected on section workers to determine employee exposure. Fixed point samples were collected to determine dust generation sources. Typically six personal and five fixed point respirable dust samples were taken on each production shift. Each section was sampled for two to four shifts. Personnel sampled included the miner operator, miner helper, roof bolter, roof bolter helper, and bridge conveyor operators or shuttle car operators.

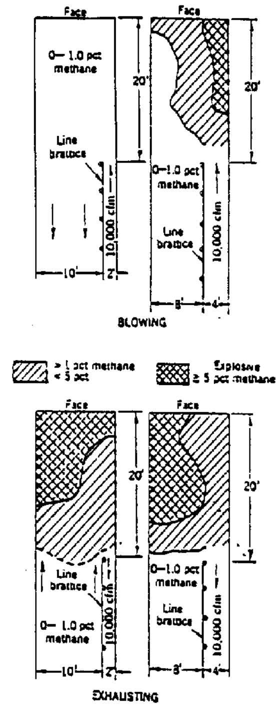

Figure 1. Comparison of Blowing and Exhausting Face Ventilation at 400 and 800 fpm Brattice Velocity

The fixed point samples were taken in the intake cross-cut or near the inby end of the line brattice (immediate intake), in the last open cross-cut adjacent to the mouth of the working place (immediate return), and in the intake air outby the last permanent intake stopping (main intake). Figure 2 shows a typical section map with the fixed point dust sample locations indicated.

Respirable dust samples were collected utilizing approved coal mine respirable dust samplers calibrated and operated at a flow rare of 2.0 Lpm. Samples were collected on type FWS-B 37 mm polyvinylchloride filters. The filters were pre- and post-weighed on an analytic balance to the nearest hundredth of a milligram. MRE equivalent concentrations were calculated by the formula:

MRE Equivalent Concentration (time weighted average) =

$$\frac{\text{Dust Weight (mg)} \times 1000\ (\text{L/m}^3) \times 1.38}{2.0\ (\text{Lpm}) \times \text{Time (min)}}$$

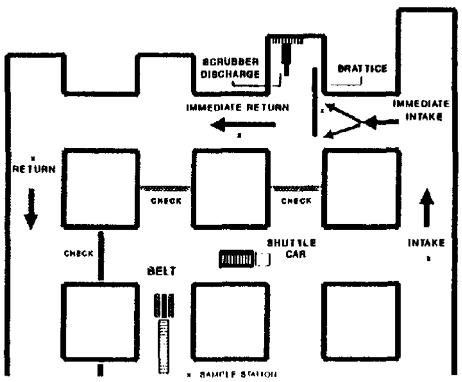

Figure 2. Typical Mining Section.

RESULTS AND DISCUSSION

Table 1 presents the average respirable dust concentration and ventilation and production data for the four sections studied. Personal and fixed-point respirable dust results along with the type of face ventilation system, dust collector capacity and average air flow at the inby end of the line brattice are shown for each section. The average measured airflow through the flooded bed dust collectors mounted on the continuous miners were 10,000 cfm, 6,000 cfm, 3,000 cfm and 4,000 cfm, respectively, at immediate intake air quantities of 7,600 cfm, 5,600 cfm, 5,800 cfm and 6,700 cfm, respectively. For the two blowing systems the dust collector capacity exceeded the air flow at the inby end of the line brattice.

Table 1. - Average Respirable Dust Concentrations and Ventilation Data for Deep Cut Mining Sections

Sample Location	Average Dust Concentration (mg/m³, MRE)			
Personal Samples	Section-1	Section-2	Section-3	Section-4
Miner Operator	0.90	1.10	0.74	0.62
Miner Helper	1.03	0.90	0.67	0.64
Roof Bolter	0.48	0.90	0.71	0.67
Roof Bolter	0.86	0.80	0.51	0.72
Haulage Personnel	0.61	0.55	0.36	0.38
Section Average	0.78	0.85	0.60	0.61
Fixed-Point Samples				
Main Intake	0.10	0.06	0.07	0.15
Immediate Intake	0.29	0.05	0.24	0.24
Dust Collector Bypass *	24.07	31.83	11.93	3.67
Dust Collector Discharge *	3.61	2.19	1.79	0.55
Face Dust *	3.61	4.62	6.69	1.81
Immediate Return	1.45	2.08	2.16	1.07
Production (Tons)	625	600	400	650
Ventilation Data				
Face Ventilation	Blowing	Blowing	Exhaust	Exhaust
Dust Collector Capacity (cfm)	10,000	6,000	3,000	4,000
Immediate Intake (cfm)	7,600	5,600	5,800	6,700
Immediate Return (cfm)	23,400	13,700	13,000	14,400

* Calculated Value

For the two exhausting systems the air flow at the end of the line brattice exceeded the dust collector air flow. Average production ranged from 400 to 650 tons per shift. For each section surveyed, production was at normal levels.

Personal respirable dust samples indicated that all sections, regardless of air flow, were in compliance with the 2.0 mg/m³ standard. The highest exposure measured was 1.1 mg/m³, on the continuous miner operator. The highest exposed workers were generally the miner operator or the miner helper. While the exhaust line brattice systems had average section exposures below those of the blowing sections, because of the limited number of samples collected and the variations in measurements and in production, it could not be determined if the differences between the systems were statistically significant.

The average fixed point respirable dust samples taken on the four sections, along with average air quantities measurements taken in the immediate intake (face) and immediate return were used to quantify dust generation on each section. Immediate return air quantities were approximately two to four times the face air quantity. This air quantity provided dilution of dust generated in the face area, reducing exposure of workers in outby areas of the sections.

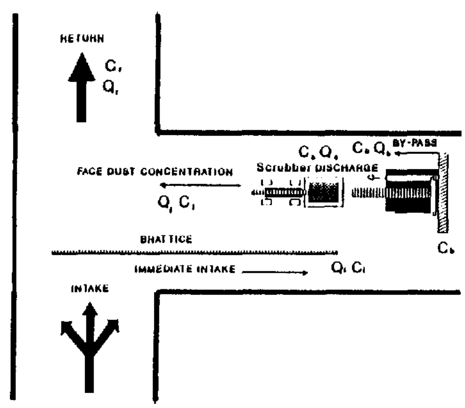

Figure 3. Physical Location of Dust Control Parameters in the Working Place.

Additionally three calculated values are given in Table 1. These values include the face dust concentration, the by-pass dust concentration and the dust collector efficiency. The physical location of where these values would be measured is indicated in Figure 3. The face dust concentration represents the average face area respirable dust level in the immediate face return at the inby end of the line brattice. This value can be calculated from the equation:

$$C_f = \frac{(C_r - C_i) \times Q_r}{Q_i} + C_i$$

Where:

- C_f = Average face dust concentration, mg/m^3,
- C_r = Immediate return dust concentration, mg/m^3,
- C_i = Face intake dust concentration, mg/m^3,
- Q_r = Average immediate return air quantity, mg/m^3, and
- Q_i = Average face intake air quantity, cfm.

The face dust concentration is the respirable dust level to which the workers have the potential of being exposed. The miner operator and helper have the greatest potential for this exposure because they remain in the face area during the majority of the production period. For the four sections studied, this value ranged from 1.81 to 6.69 mg/m^3. On each of the studies the miner operators' exposure was less than the face dust concentration. The difference between these two values was attributed to exposure time in the working place and the use of remote control. The miner operators' dust exposure was between one-quarter and one-half of the calculated face dust level.

The proper matching of scrubber and intake airflow has caused much discussion relative to proper system operation. As seen from the results in Table 1, even when the face dust level exceeds the 2.0 mg/m^3, through the use of the remote control, miner operators' exposure can be maintained below the 2.0 mg/m^3 standard regardless of the face air flows to scrubber air flow ratio. Additionally, when the face and section air flows are sufficient for dilution of dust, the scrubber capacity can exceed the face air flow without adversely effecting dust control.

The face dust concentration can also be used to calculate the concentration of dust (weighted for air flow) bypassing the dust collector. When the face air quantity exceeds the dust collector air quantity, the concentration of dust entering and bypassing the dust collector can be approximated from the following equation:

$$C_b = \frac{(C_f \times Q_i) - (C_s \times Q_s)}{(Q_i - Q_s)}$$

Where:

- C_b = Concentration of dust in the air bypassing the dust collector, mg/m^3,
- C_f = Average face dust concentration (see previous calculation), mg/m^3,
- C_s = Concentration of dust in air flowing out of the dust collector, mg/m^3,
- Q_i = Air quantity in the immediate intake, cfm,
- Q_s = Air quantity in dust collector, cfm.

The bypass concentration can also be used in conjunction with the dust collector discharge concentration to calculate the dust collector efficiency. The efficiency of the dust collector (E_s) can be calculated by subtracting the ratio of inlet to discharge concentration from 1:

$$E_s = (1 - (C_s / C_b)) \times 100$$

Where:

- E_s = Efficiency of the dust collector, percent.

Laboratory studies (Colinet, 1990) have shown efficiencies of irrigated filter collection systems to range from approximately 90 to 95 percent. By assuming a field dust collector efficiency of 85 percent and solving the above two equations simultaneously, values of C_s and C_b were determined. Values of C_b shown in Table 1 range from 3.7 to 31 mg/m^3. These values indicate the level of dust that would be present if the dust collector were not operating.

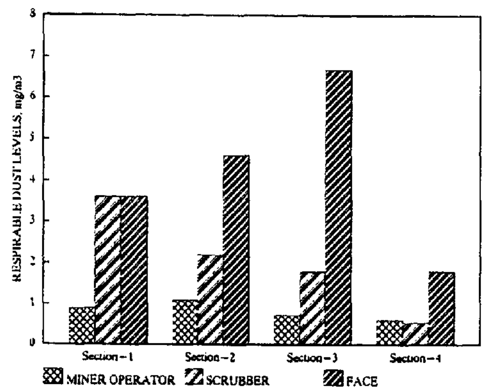

Figure 4. Comparison of Average Miner Operator, Dust Collector Discharge and Face Area Dust Concentrations.

Figure 4 shows a comparison of the miner operators' average exposure, the scrubber discharge concentration and the face dust level for each section. Depending on intake and dust collector air flow, the face dust concentration ranged from two to four times the dust collector discharge concentration. The miner operators' exposure ranged between the scrubber discharge and one quarter of the dust collector discharge.

The effect of air flow on relative face, bypass and dust collector discharge dust concentrations can be seen graphically in Figure 5 for a 90 percent efficient dust collector. For low brattice velocities, the only air reaching the face is that being drawn by the dust collector. Figure 5 shows relative dust concentrations for a constant dust collector capacity and varied face air flow. The relationships shown were generated using a constant dust collector capacity of

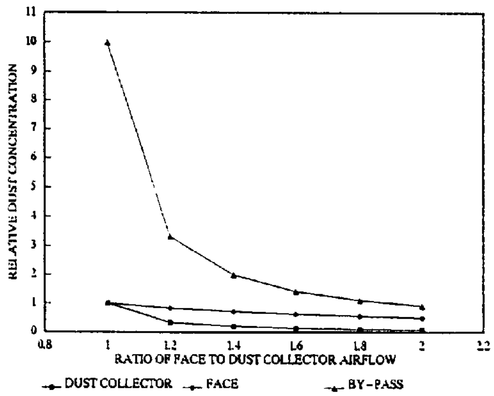

Figure 5. Relative Dust Levels for Constant Dust Collector Capacity and Varying Face Air Flows.

5,000 cfm; dust collector discharge and inlet concentrations of 1.0 and 10.0 mg/m^3 respectively, at a face airflow of 5,000 cfm; and the above relationships for C_b and E_s.

Figure 5 shows that as the face air flow increases both the dust collector discharge and face dust concentration decrease. While this decrease in dust concentration continues as the air flow increases, there appears to be an optimal dilution effect at face air flows of approximately 1.2 to 1.4 times the dust collector capacity.

On blowing face ventilation systems, haulage workers such as shuttle car or bridge conveyor operators are exposed to the dust concentrations in the face area while coal is mined and loaded. Unlike the miner operators, generally these workers are not working in the direct flow of intake (fresh) air and are required to work in the immediate face return airflow. In these mining sections, air flowing from the main intake is split outby the working place and directed into the immediate return (last open cross-cut) or towards the face behind the line brattice. As shown in Figure 3, when the haulage equipment is required to be completely in the working place, the operator is exposed to the dust being blown through the dust collector and also the dust bypassing the dust collector. However, because of dilution, once the haulage operators leave the working place, the dust concentration to which they are exposed is reduced.

During these studies, several additional observations relative to dust control became apparent. Because of the increased length of cut, there are fewer places mined during a shift when a deep cut system is utilized. Dust control parameters in place during any individual cut can significantly impact respirable dust levels. Air flow, work practices or cut sequence could effect worker dust exposure.

Work practices that contribute to lowering dust exposure include positioning the operator in fresh air and keeping roof bolters on the intake side of the mining machine. A cut sequence should be adopted so that all cut throughs are made from intake to return. Section airflow distribution should be maintained through proper installation of line curtains and back checks.

SUMMARY

1. In accordance with CFR, Title 30, Part 75.316, a ventilation system and methane and dust control plan suitable to the conditions and mining system, must be approved for each mining section. When a deep cut system is employed, this plan sets out the maximum brattice distance and minimum face air quantity and dust collector air quantity to control both respirable dust and methane.

2. Increasing the dust collector air quantity above the minimum required to control respirable dust does not adversely effect dust control.

3. Increasing the face air quantity above the minimum required to control respirable dust does not adversely effect dust control, in fact, through dilution, a higher air quantity enhances dust control.

4. When the face and section air quantities are sufficient for dilution of methane and dust, the scrubber capacity can exceed the face air flow without adversely effecting dust control.

5. The use of the remote control, which permits the operator to remain in intake air, is the primary factor reducing dust exposure for the continuous miner operator.

6. Dilution from section air flow in combination with scrubber efficiency provide dust control for other section workers.

REFERENCES

Office of the Federal Register, 1989, Code of Federal Regulations, Title 30, U. S. Government Printing Office.

Luxner, J. V., 1969, "Face Ventilation in Underground Bituminous Coal Mines - Airflow and Methane Distribution in Immediate Face Areas - Line Brattice", U. S. Bureau of Mines IR 7223.

Colinet, J. F., McClelland, J. J., Erhard, L. A., and Jankowski, R. A., 1990, "Laboratory Evaluation of Dust Collection Efficiency of Irrigated Filter Collection Systems", U. S. Bureau of Mines IR 9313.