Controlling dust exposures in longwall mining utilizing a simple barrier

D.D. SWEENEY, J.M. SLAGLEY, D.A. SMITH AND J.P. RIDER

Daniel D. Sweeney, Jeremy M. Slagley and **David A. Smith,** are industrial hygiene master's student, industrial hygiene director, graduate industrial hygiene program and environmental engineering and sciences director with the Department of Systems and Engineering Management with the Air Force Institute of Technology, Wright Patterson Air Force Base, OH; **James P. Rider,** member SME, is acting team leader, dust control, respiratory hazards control branch with the National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory, Pittsburgh, PA.

Abstract

The United States coal mining industry has traditionally experienced difficulty in controlling dust levels below the occupational exposure limit. While improvements in face ventilation and water spray nozzles have decreased dust exposures, approximately eight percent of experienced coal miners are still developing Coal Worker's Pneumoconiosis. This investigation tested the feasibility of enhancing existing engineering dust controls by mounting a simple barrier on a longwall shearer that separated the operators from the cutting drums. The barrier was constructed and tested above ground at the National Institute for Occupational Safety and Health Pittsburgh Research Laboratory longwall gallery test facility. A 96-percent reduction of respirable dust occurred at the headgate sampling position when tested at 2.4 m/sec (480 ft/min). The average dust level decreased from 39 mg/m^3 to 1.5 mg/m^3 by utilizing the barrier.

Introduction

In spite of engineering controls, the United States coal mining industry exposes miners to dust levels exceeding the 2 mg/m^3 regulatory limit. In fact, because of the historical difficulties associated with controlling hazardous dust levels within the mining industry, the National Institute for Occupational Safety and Health (NIOSH) has identified its top strategic goal for the mining industry as reducing respiratory diseases (NIOSH, 2008). Furthermore, dust samples collected over a four-year period from 1995 to 1999 (Niewiadomski, 1999) showed that 20 percent of longwall miners are overexposed to dust. An additional five-year study, from 2000 to 2004 (Niewiadomski, 2004), showed overexposure rates to be between 14 % and 15%. These high exposure rates have led approximately 8% of longwall miners with at least 25 years of mining experience to develop coal worker's pneumoconiosis (Rider & Colinet, 2001).

A possible engineering control for lowering dust exposures to longwall miners is the use of an air splitting barrier. A 1994 study using a full mesh partition barrier during underground longwall mining indicated a 52- percent dust reduction 31 m (100 ft) downstream of the shearer during the head-to-tail pass, but no reduction during the tail-to-head pass (U.S. Bureau of Mines, 1994). The conclusions of the study indicated a dust reduction was possible in underground longwall mining with the use of a barrier. However, the mesh barrier used limited visibilty to the point of being impracticle. Another disadvantage the study noted was the possbility of less air mixing due to the barrier, which could create higher concentrations of methane in gaseous mines.

This current study investigates the feasibility of using either a partial or a full barrier mounted to a simulated coal mine longwall shearer between the cutting drum and the shearer operator. As with the 1994 study, this investigation utilizes the barrier as an engineering control in conjunction with ventilating air to keep the dust generated by the cutting drum entrained in the airway separated from the operator. The primary differences with the current study are the barrier was constructed of clear acrylic for greater visibility and mounted to the shearer rather than the shield canopy.

Procedures

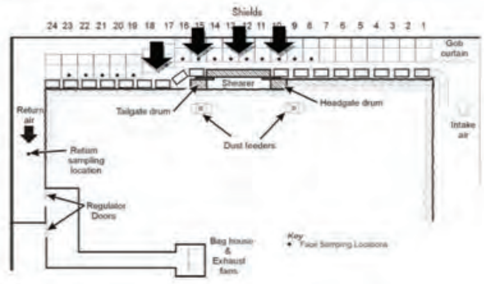
Dust production and monitoring. To measure the effectiveness of the full and partial barrier, tests were performed in an above-ground, full-scale longwall test facility at the NIOSH Pittsburgh Research Laboratory (PRL). The simulated face is 38.13-m- (125-ft-) long and the height from floor to roof is 3.05 m (10 ft) as shown in Fig. 1 (Rider and Colinet, 2001). Twenty-four simulated shield supports 1.52-m- (5-ft-) wide cover the length of the test facility. A full scale wooden mock-up of a Joy 4LS double ranging arm shearer was located approximately one half of the distance from the headgate to the tailgate. Ventilation for the longwall gallery was provided by three exhaust fans capable of supplying approximately 59.9 m^3/sec (127,000 cu ft/min) of air along the face. A water spray system was available, but not used during this simulation.

Commercially available respirable coal dust was fed into the longwall gallery at the headgate and tailgate drums and at three points near the headgate drum by a screw type feeder into mini educators. Compressed air carried the coal dust from the educators into the gallery to produce dust at or near the headgate and tailgate drums.

Real-time aerosol monitors (RAM), for instantaneous dust measurements were employed to collect the dust samples during testing. The RAM is a portable dust measurement device where dust-laden air was pulled at

FIGURE 1

Simulated full-scale longwall facility at NIOSH-PRL. Arrows indicate RAM locations.



2 L/min through a 10-mm (0.4-in.) cyclone that separated the respirable dust and passed it through a light source. The amount of light deflection in the chamber was considered to be representative of the dust concentration (GCA, 1979).

Four RAMs were used to measure dust levels. The cyclones (Fig. 2) were suspended from the shield supports at breathing zone level near shields 10, 12, 15 and 18 to approximate the shearer operator and the jacksetter positions. Measurements were averaged and recorded every two seconds. The instantaneous dust concentrations were downloaded to a multichannel data acquisition system for monitoring throughout the test and for subsequent analysis. Although not considered a primary standard for dust levels, the RAMs were used to measure dust in relative concentrations throughout the experiment. A 2007 study on RAMs concluded that the analyzers provided accurate relative dust levels for ventilation face velocities greater than 1 m/s (200 ft/min). The study concluded real time sampling is beneficial in research studies for measuring relative rather than absolute concentrations; therefore, values reported in this article should be considered relative rather than absolute concentrations (Listak et al, 2007)

Dust tests were conducted at three different ventilation face velocities for each barrier configuration: no barrier, the partial barrier and the full barrier. Each test was run for 10 minutes. The face velocity remained relatively consistent between configurations for each respective ventilation speed, which was measured upstream of the mock shearer near shield number six with a direct read anemometer. The results are shown in Table 1 for each test configuration (± one standard deviation).

Barrier construction

Two barrier configurations were tested on the mock shearer (Fig. 3A), a partial barrier leaving approximately a 0.6 m (2 ft) gap between the top of the barrier and the shield (Fig. 3B) and a full barrier extending to the top of

Table 1

Face velocities for each configuration.

Fan speed	No barrier (m/sec)	Partial barrier (m/sec)	Full barrier (m/sec)
Low	2.4 ± 1.0	2.5 ± 0.8	2.5 ± 0.8
Medium	3.4 ± 1.1	3.4 ± 1.0	3.4 ± 1.0
High	4.2 ± 1.4	4.3 ± 1.4	4.3 ± 1.4

FIGURE 2

Suspended cyclone.

the shields (Fig. 4).

The full barrier was constructed of 1.22-x-0.61 m (4-x-2 ft) clear acrylic sheets with a thickness of 0.95 cm (0.37 in.). Each sheet was mounted in series to a wooden frame that extended the full length of the shearer just beyond each cutting drum. Rubber sheets attached to the top of the barrier created a flexible seal that could adjust with the shield height as shown in Fig. 4. The partial barrier was constructed by removing the flexible rubber from the top of the acrylic sheets, leaving approximately a 0.6-m (2-ft) gap between the top of the barrier and the upper shield. The blue portion shown in the figure was a protective coating on the acrylic sheets that was later removed.

Results

The results of each 10 minute test session were compiled to obtain an average (n=300) respirable dust exposure level in mg/m^3. Results were compared for statistical significance using JMP software (SAS Institute Inc., Cary, North Carolina). Each configuration was compared using analysis of variance (ANOVA) with a significance level of alpha less than 0.05. When a significant difference was observed between groups, Tukey-Kramer comparisons were used to determine which configuration within the group showed a statistically significant difference.

The greatest reduction in measured dust levels was at the headgate sampling position with the average face velocity at 2.4 m/sec (480 ft/min). The reduction varied between 39 mg/m^3 without the barrier to 1.5 mg/m^3 with the partial barrier, equating to a 96-percent reduction. Similar reductions were noticed at the mid and high ventilation velocities for the headgate sampling position, bringing the dust levels close to zero with either barrier in place. At the remaining two shearer operator positions, dust levels also decreased significantly with both the partial and full barriers compared with no barrier for all ventilation rates (Prob > F 0.0001 for all cases). For example, at the taildrum position at the high ventilation rate, a 59-percent decrease in dust level was measured. This result demonstrates that even at lower concentrations, which may be closer to true underground exposure levels, the barrier is still very effective at reducing dust levels. Although in most cases, a significant difference was also found between

FIGURE 3

Mock longwall shearer with: A: no barrier and b: the partial Barrier.

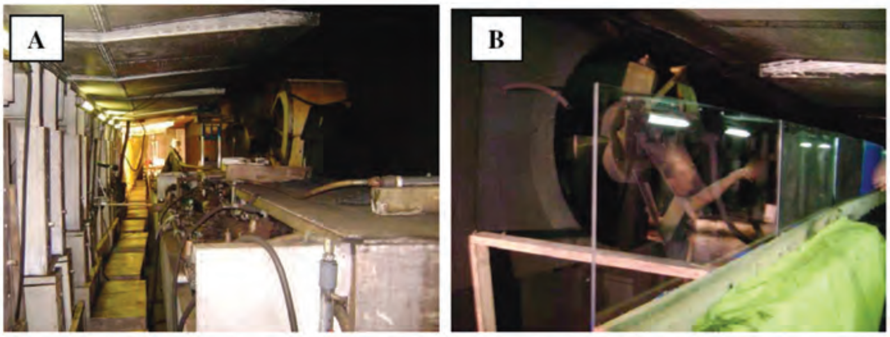


FIGURE 4

Full barrier mounted on mock-shearer.

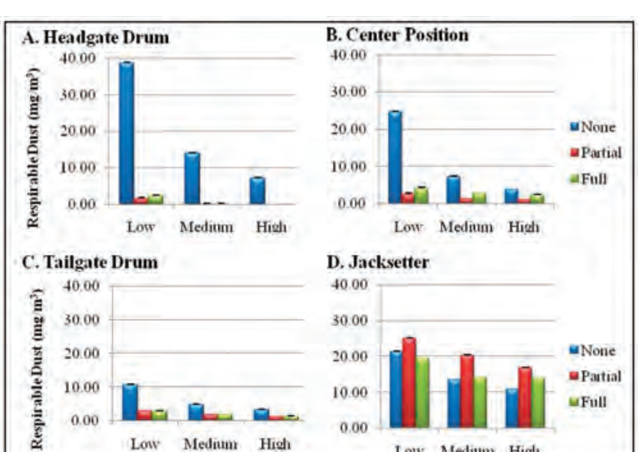
the dust levels for the partial versus the full barrier, these differences were not of practical significance. Figure 5 summarizes the dust level results.

At the jacksetter sampling position, the dust levels increased significantly with the placement of the barrier, with the exception of the full barrier at 2.4 m/sec (480 ft/min), which had a slight decrease in the dust levels (Prob > F 0.0001 for all cases).

At all positions, increasing ventilation rate decreased dust levels with and without the barrier in place with the highest decrease in dust levels measured at the headgate drum by 84 percent from the low to high ventilation.

FIGURE 5

Respirable dust levels for low, medium and high relative face velocities.



Discussion

The results of this study suggest a barrier mounted on a longwall shearer in combination with forced ventilation may reduce dust exposure to shearer operators. Additionally, increasing the ventilation rate further reduces the dust exposure. The current study, however, indicates a significant decrease in dust concentration can be achieved by either a full or partial barrier. One drawback to the barrier is there may be an increase in dust exposure to the jacksetter. A possible cause of the increased downwind exposure may be that eddy currents were created at the end of the barrier, which resulted in a turbulent area downwind of the barrier. Utilizing a series of sprays in the tailgate drum area in conjunction with the barrier could result in the dust plume being directed toward the face and may increase the size of the clean air envelope created by the barrier. Further testing of the barrier in combination with water spray nozzles needs to be conducted to determine if the downwind dust exposure could be decreased.

The barrier may also reduce operator visibility of the cutting drum. Figure 6 demonstrates the visibility of the cutting drum while the dust was being generated. Although the coal dust adhered to the acrylic sheeting, a water spray system could be utilized to keep the shield clean. Additionally, the operator would be able to see the top of the drum by simply looking over the barrier.

Furthermore, the barrier constructed in this study would not have been sturdy enough to withstand the harsh conditions faced in underground coal mining. In order to be of practical use, the barrier would need to be constructed of hardened materials, such as a bullet-proof clear acrylic, be mounted on a flexible hinge and be capable of continuous or rapid cleaning so as not to block the operator's view of the longwall face. The final product would need to withstand bombardment from coal shrapnel as well as not interfere with the top of the shields.

Finally, as noted in the 1996 mesh partition study, a barrier may increase methane concentrations near the coal face. This might not occur as the barrier is mounted to the shearer and, therefore, constantly moving. Methane concentrations would need to be closely monitored during underground testing of this barrier design.

Conclusions

The test results indicate that a significant reduction of respirable dust can be achieved from either a partial or full barrier mounted between the cutting drums of the longwall shearer and the shearer operators. As high as a 96 percent reduction in respirable dust levels was measured at the shearer operators' positions with low ventilation rate. Additionally, at the high ventilation rate, dust levels were reduced by 59 percent. Dust exposure was also reduced by increasing the ventilation face velocity with or without the barrier in place by as much as 80 percent. While the barrier used in this study was not built to withstand the rigorous conditions found in underground longwall operations, the model demonstrates the preliminary feasibility of such a control.

The barrier may decrease the operators' visibility of the coal face and would likely need a self cleaning mechanism such as a spray cleaner. Additionally, the barrier may increase methane concentrations. Therefore, any underground testing would require close monitoring of methane levels at the coal face.

Disclaimer

The views expressed in this paper are those of the authors and do not reflect the official policy or position of the United States Air Force, the Department of Defense, the National Institute for Occupational Safety and Health or the United States government.

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FIGURE 6

View of headgate cutting drum through partial barrier.

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