EXTENDED CUT FACE VENTILATION FOR REMOTELY CONTROLLED AND AUTOMATED MINING SYSTEMS

by

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ABSTRACT

Effective coal mine face ventilation, for remotely controlled and automated mining systems, is essential for the control of methane. The evolution of new mining equipment and methods has required changes and improvements in face ventilation methods. One emphasis today is on the use of remotely operated and automated mining systems that can be used to make continuous cuts of 6 m (20 ft) and deeper. U.S. Bureau of Mines research is studying ways to more effectively ventilate these extended cuts. Two face ventilation techniques that utilize either blowing brattice or a jet fan for deep cutting are examined in this paper. Bureau of Mines procedures for evaluating face ventilation systems are also discussed.

INTRODUCTION

Bureau of Mines face ventilation research includes the investigation of techniques that improve the delivery and distribution of air to the mining face. Before 1980, most continuous mining sections used cutting sequences that did not involve cutting depths greater than 6 m (20 ft). Therefore the emphasis of most Bureau research was concerned with improving face ventilation at cutting depths up to 6 m (20 ft). One study, which looked at airflow and methane distribution patterns in an equipment free entry, provided guidelines for establishing maximum brattice or curtain setback distances for blowing and exhausting face ventilation systems (Luxner, 1969).

During the 1980's, the use of remotely operated mining machines in some mines made it possible to increase cutting depths to 12 m (40 ft). As cutting depths increased, providing adequate ventilation for new mining methods and equipment became more difficult. Bureau research focused on providing improved face ventilation for cutting depths between 6 and 12 m (20 and 40 ft). Techniques designed for both blowing and exhausting ventilation were tested and shown to be effective when cutting depths reached 12 m (40 ft) (Volkwein, 1985, 1986).

New mining equipment and ways to use it more effectively continue to evolve. For example, the Bureau of Mines is working on automated mining systems that will be capable of cutting from cross-cut to cross-cut. Finding methods to improve face ventilation for current and future mining systems is an important part of the Bureau's current research program. Developing ways to quickly and accurately evaluate the effectiveness of the ventilation techniques is also a significant part of this work. This paper describes a Bureau of Mines study that was conducted to evaluate the performance of blowing brattice and jet fans in conjunction with deep cutting.

TEST FACILITY

Testing was conducted in a surface facility originally built by the Mine Safety and Health Administration (MSHA). Through a cooperative agreement, MSHA allowed the Bureau to modify the facility and use it for their test program. The "L" shaped building used for the tests is shown in figure 1. The one wing of the building used to simulate a deep cut entry, is 6 m (19 ft) wide by 2 m (7 ft) high, and 37 m (120 ft) long.

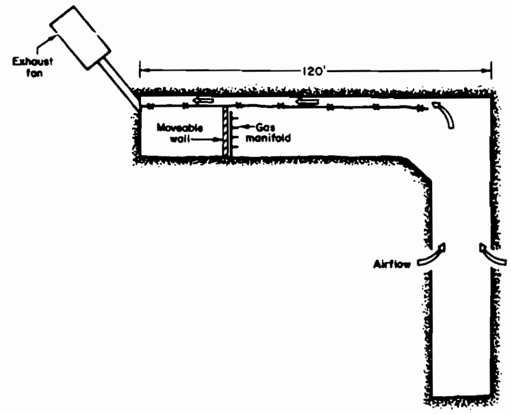

Figure 1. Test facility.

An air-tight wood wall, used to simulate the mining face, was moved within the entry to set the depth of cut. To provide passage of the return air to the exhaust fan, an airtight 90-foot long wall was built 1-m from one side of the entry. For the tests described in this paper the depth of cut was 12 m (40 ft). Natural gas, which is primarily methane gas, was released through holes in four copper pipes that were located .5 m (18 in) in front of the moveable wall.

A vaneaxial fan draws air in through two windows, across one end of the test entry, and behind the 90-foot long wall (fig. 1). The airflow across the test entry is similar to ventilation through the last open cross cut in an underground coal mine. Each face ventilation technique evaluated was designed to move the air from the last open cross cut to the face.

METHANE MONITORING

For testing purposes natural gas was used as a tracer gas. The primary component of natural gas is methane and therefore natural gas and methane behave similarly. The Bacharach' methane monitors, used to measure methane concentrations at eight locations near the face (fig. 2), respond similarly to methane and natural gas.

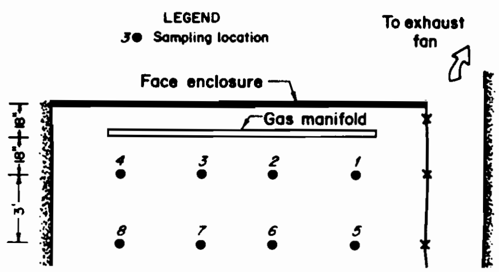

Figure 2. Methane monitor sampling locations.

All monitor heads were located 0.5 m (18 in) from the roof. Sampling time for each test was approximately 10 minutes. As a safety precaution, natural gas flow into the gallery was stopped, and testing terminated, whenever the methane concentration at any sampling location reached 2 pct.

Methane concentrations were continuously recorded using Metrosonics 331 data loggers. Average concentrations were calculated for each test using Metrosonics computer software. Graphs for sampling data were prepared with Lotus 1-2-3.

TEST PLAN

The ventilation experiments were conducted to determine the relative effectiveness of two face ventilation techniques, blowing brattice and jet fan, for removing and diluting methane gas near the face of a deep cut. For each test the entry to be ventilated was empty, i.e. it contained no "mining equipment." Either the jet fan or blowing brattice was placed at the upstream corner of the last open crosscut, where it was 12 m (40 ft) from the movable wall. In a normal deep cut situation the fan or curtain could not be moved closer to the face due to unbolted roof.

During all tests the following parameters were maintained constant:

- Natural gas flow rate at face... .0084 m^3/s (18 cfm)
- Ventilated flow rate through last open cross cut... 6.14 m^3/s (13,000 cfm)
- Depth of cut (distance from the ventilation curtain or fan)... 12 m (40 ft)

JET FAN AND BLOWING BRATTICE

Blowing brattice

Most sections that practice deep cutting use blowing brattice to direct air to the face. The evaluation of a blowing brattice system was included as part of this current research to determine the effectiveness of the brattice, and also to establish a baseline to which the performance of other ventilation techniques could be compared.

Figure 3 shows the position of the blowing brattice in the test entry. The brattice was hung 0.6 m (2 ft) from the left wall. Originally it was planned to vary the air flow

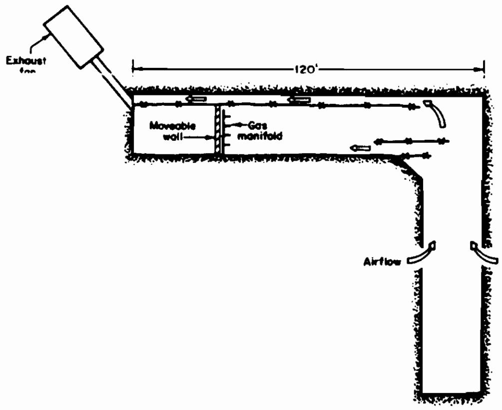

Figure 3. Blowing brattice in test entry.

behind the brattice between 1.90 and 3.30 m^3/s (4,000 and 7,000 cfm). However, the initial tests with brattice, conducted at 3.30 m^3/s (7,000 cfm), could not be completed because methane concentrations in the entry quickly increased to 2 pct. Further testing showed that, to maintain the methane concentration below 2 pct, a minimum of air flow of 4.34 m^3/s (9200 cfm) was required. Subsequent brattice testing was conducted only at the 4.34 m^3/s (9200 cfm) flowrate.

Jet Fan

A jet fan is a free standing fan having little or no attached ducting. Previous research by the Bureau showed that jet fans can be used in metal and nonmetal mines to ventilate entries with large cross-sectional entries (Matta, 1978). Research had not been conducted to evaluate these fans in mines having smaller entries, such as would normally be found in coal mines.

A Joy, 0.5 m (18 in) diameter vaneaxial fan was used for the jet fan study. A 1.2 m - (4 ft) long, straight piece of solid tubing (called an "extender") was attached at the fan exhaust (fig. 4) to improve collimation of the high velocity jet as it left the fan. Figure 5 shows the position of the fan in the test entry. Flow rate through the fan was controlled with a vane axial flow control

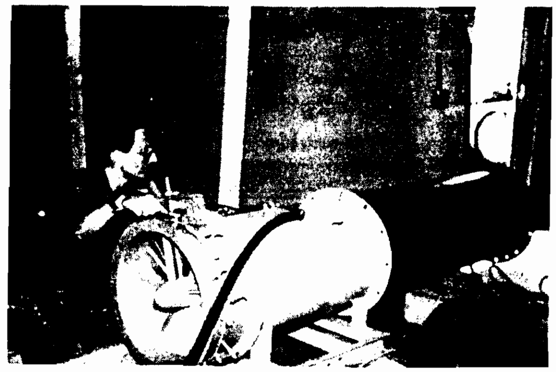

Figure 4. Jet fan with extender tube.

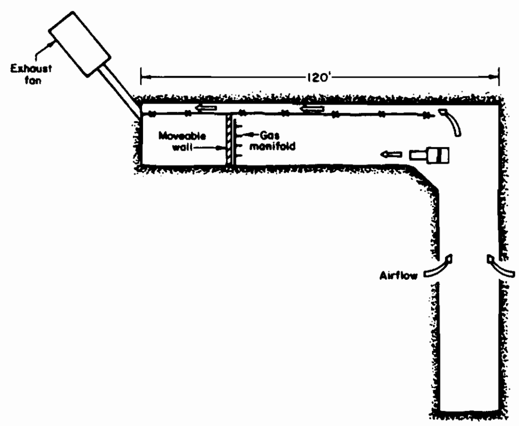

Figure 5. Jet fan in test entry.

valve that was connected at the fan inlet. Tests were conducted with fan flow rates of 1.70, 2.74, 3.21 m^3/s (3600, 5800, and 6800 cfm).

To reduce recirculation of air, a jet fan is usually located on the intake side of the entry, and close to the last open cross cut. Reducing recirculation improves fan performance by reducing the amount of contaminated air directed toward the face. Using the jet fan with the attached extender tubing as the basic jet fan design, several changes were made to vary airflow patterns near the fan and thus affect the amount of recirculation.

TEST RESULTS

The data in figure 6 compares methane concentrations measured at the eight locations sampled during blowing brattice and jet fan tests. It can be seen that the jet fan operating at 3.21 m^3/s (6800 cfm) was almost always more effective in controlling methane concentrations at the face than the blowing brattice operating at 4.34 m^3/s (9200 cfm). The difference is especially obvious at sampling locations 4 and 8.

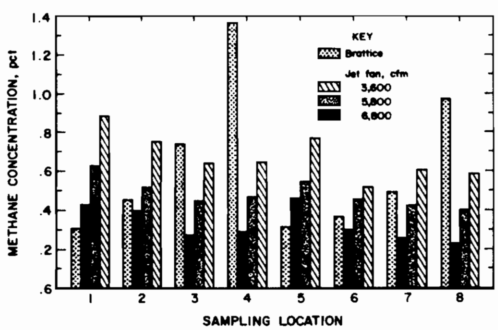

Figure 6. Comparison of effectiveness, blowing brattice and jet fan.

While using blowing brattice, additional methane samples were collected .6 to 4.3 m (2 ft to 14 ft) outby sample location 8. All of these sample locations (Labeled A, B, C, and D on figure 7 were 1 m (3 ft) from the left wall. At a distance up to 3.8 m (12 ft) from the face, methane levels were much higher than at other locations twelve foot and further from the face.

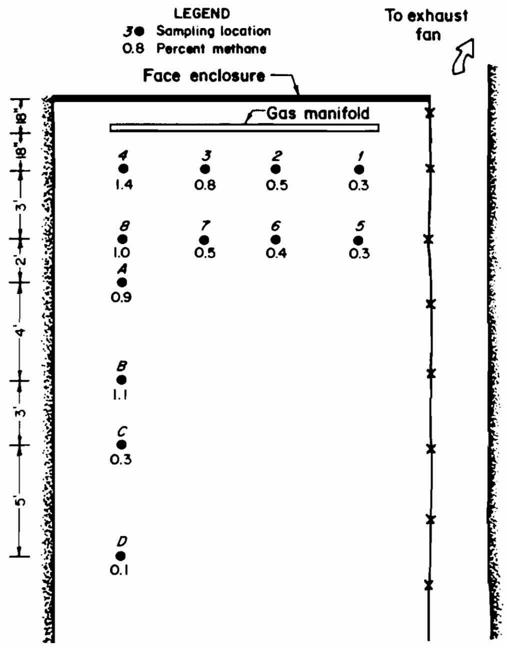

Figure 7. Methane concentrations with blowing brattice.

Smoke tubes were used to draw flow patterns that describe the direction of air flow in the face area. Airflow patterns produced by using jet fan and blowing brattice can be compared by looking at figures 8 and 9. At 12 m (40 ft), a portion of the collimated flow from the jet fan reached the left hand corner of the face (fig. 8), "swept" the face, and returned back down the entry. However, the lower velocity air stream from the blowing curtain "detached" from the left wall, and moved toward the right corner of the face (fig. 9).

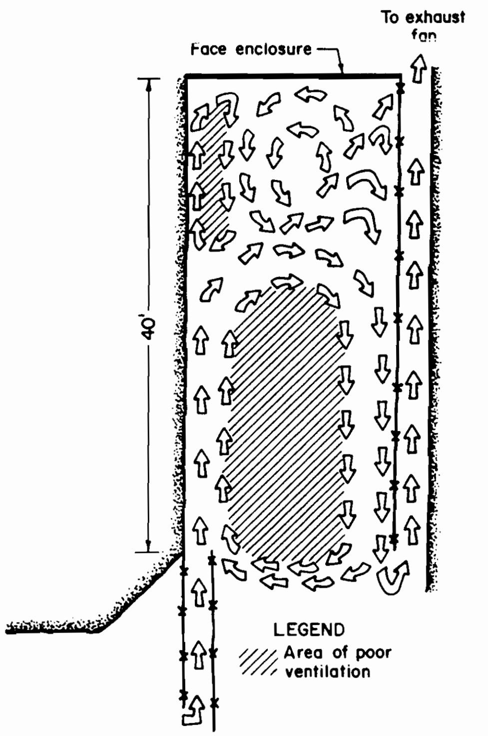

Figure 8. Airflow pattern with jet fan.

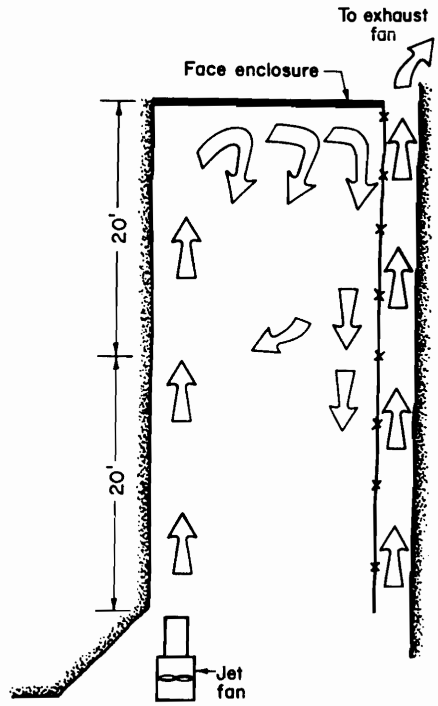

Figure 9. Airflow patterns with blowing brattice.

As shown, airflow movement across the face was in opposite directions for the jet fan and blowing brattice.

At jet fan flow rates of 3.21, 2.74 and 1.70 m^3/s (6800, 5800, and 3600 cfm) performance was directly related to the quantity of air through the fan (fig. 10). In order to try to reduce the amount of recirculation through the fan, several changes were made to modify airflow near the jet fan intake. Of the three changes made, modifying the jet fan by using upstream tubing was the most effective for reducing the methane concentrations at the face. This can be attributed to a reduction in recirculation.

DISCUSSION

Test results showed that, for the empty entry, the jet fan provided more effective ventilation than the blowing brattice, this in spite of the fact that the latter provided about 30 pct more airflow. Air velocity was the primary factor determining how much air reached the face. At the outlet of the jet fan (flow rate equal to 3.21 m^3/s) and end of the line brattice (flow rate equal to 4.34 m^3/s) the exit air velocities were 23 and 3.3 m/s (4900 and 650 fpm) respectively. The higher velocity was much more effective in delivering air to the face. When using the jet fan, methane levels decreased as the quantity of air through the fan increased from 1.70 to 3.21 m^3/s (3600 to 6800 cfm). For the gas liberation rate (.0084 m^3/s) used during these tests, the volume of air delivered by the jet fan (1.70 to 3.21 m^3/s) and the blowing brattice (4.34 m^3/s) was adequate to keep methane levels at most sampling locations below 1 pct.

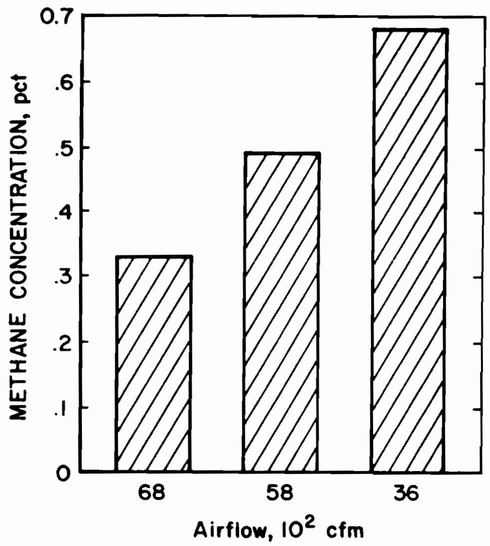

Figure 10. Jet fan flow rate versus average face concentration.

Air recirculation occurs when air that has already been used to ventilate the face passes through the fan and is redirected to the face. Because the fan is moving contaminated air back to the face, ventilation effectiveness is reduced. A jet fan is typically placed on the intake side of the last open cross cut to keep recirculation through the fan to a minimum. Recirculation is affected by partially isolating the fan intake from airflow in the entry. To investigate the effects of certain jet fan modifications on recirculation, the following changes were made to the basic jet fan design:

1. A curtain hung over the jet fan and half way across the entry.

2. Tubing attached to the upstream end of the fan.

3. A combination of curtain and upstream tubing.

Using the upstream tube with the jet fan, average methane concentrations in the face area were reduced about 20 pct (fig. 11).

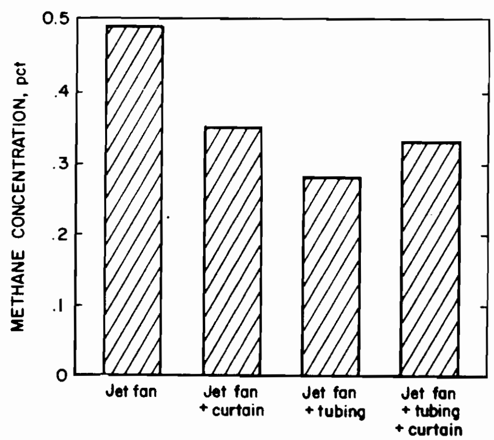

Figure 11. Jet fan performance.

Underground ventilation studies must be conducted to assure that safe operating conditions are being maintained and regulatory requirements are met. However, research studies conducted underground to evaluate the effectiveness of face ventilation techniques are expensive and time consuming. Prior to underground evaluations more extensive and accurate monitoring of methane levels can be conducted in a surface facility designed to simulate underground conditions.

SUMMARY AND CONCLUSIONS

The work described in this paper shows some ways in which a Bureau designed facility was used to evaluate selected face ventilation techniques. This facility was specially designed to simulate mining situations encountered during deep cutting, and was used to evaluate blowing brattice and the jet fan used for a 12-meter deep cut. Although specific underground mining conditions cannot be duplicated in the test facility, its design is flexible enough to encompass the range of conditions that would be encountered underground during deep cutting.

The methane sampling results were used to demonstrate differences in methane concentrations for different ventilation techniques. Air velocity was directly related to the amount of mixing of methane and air at the face. Study of air flow patterns at the face using smoke further helped to explain why methane concentrations varied depending on use of the jet fan or brattice.

Part of the face ventilation technology employed for deep cutting is an adaptation of methods used for shallower cuts. The primary changes made for deep cutting have been the addition of machine-mounted devices, such as the spray fan system and dust scrubber, that act as auxiliary air movers. Although these devices have been shown to be effective for distributing air across the working face, their inclusion in the face ventilation plan has made it more difficult to specify the best operating parameters for effective methane control. Numerous studies have been conducted to determine what parameters result in the most effective control of methane at cutting depths up to 12 m (40 ft).

The research described in this paper is the first phase of work that will look at many different combinations of operating parameters that affect face ventilation effectiveness at cutting depths of 12 m (40 ft) and greater. The evaluation of ventilation techniques for the empty deep cut mining entry may be viewed as an uncomplicated, common face ventilation problem. Each time the mining machine completes the cut and leaves the entry the empty cut must be ventilated. However, in an empty entry there is no auxiliary means to provide airflow inby the last row of bolts.

Future work will include studies to evaluate the ventilation of deep cuts with conditions to simulate mining operations at cutting depths between 12 and 24 m (40 and 80 ft). For this case the use of auxiliary air movers, such as the spray fan system, will be critical for the effective use of either jet fan or blowing brattice. A model continuous mining machine that includes a simulated scrubber and spray fan system, will be tested at a 12 m (40 ft) set back distance. Emphasis will be placed on developing ventilation techniques that can be easily adapted for use with existing remote control mining machines but can be adapted for use with new evolving automated systems.

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[1] Reference to specific manufacturers does not imply endorsement by the U.S. Bureau of Mines.