IMPACT OF UNBALANCED INTAKE AND SCRUBBER FLOWS ON FACE METHANE CONCENTRATIONS

Charles D. Taylor, James P. Rider, and Edward D. Thimons
Pittsburgh Research Center, Pittsburgh, Pennsylvania

ABSTRACT

Research was conducted to investigate how ventilation of a mining face is affected when scrubber flow is greater or less than intake flow. Tests were conducted in a full-scale surface test gallery built to simulate a mining entry with a continuous mining machine at the face. Methane gas was released at constant flow at the mining face. Gas measurements taken at six locations near the face were used to evaluate how well the face was being ventilated. Increasing scrubber flow resulted in lower methane levels even when scrubber flow was much greater than intake flow.

INTRODUCTION

Cutting depths for continuous mining machines are getting deeper. More than half of the operating continuous miner sections have received approvals to cut deeper than 6.1 m (20 ft). A ventilation research program at the NIOSH Pittsburgh Research Center has been dedicated to looking at those factors that affect the ventilation of extended cuts. The goal is to provide methods for maintaining ventilation effectiveness for a variety of operating conditions including increased set back distances.

Flooded bed scrubbers are widely used on mining machines to reduce airborne dust levels during cutting. Research by Volkwein (1986) and Gillies (1982) has shown that operation of scrubbers also help reduce face methane levels by increasing face airflow. Research conducted by Taylor (1996) and others at the Pittsburgh Research Center has further documented the role that machine-mounted scrubbers play, especially during the mining of extended cuts. The earlier research at the Pittsburgh Research Center showed that operation of the scrubber resulted in reduced face methane levels as long as:

- the scrubber exhaust didn't interfere with intake airflow, and,
- intake and scrubber flow were equal.

Common practice in most mines that use scrubbers is to maintain scrubber and intake airflows within 0.5 M^3/s (1000 cfm). This practice is based on the assumptions that:

- When intake flow is greater than scrubber flow, dust concentrations increase due to decreased dust collector inlet efficiency.
- When intake flow is less than scrubber flow, methane concentrations increase due to increased scrubber recirculation.

To conform to underground practice, intake and scrubber flows were kept equal during earlier research tests conducted at the Pittsburgh Research Center. The objective of the current research is to determine how face methane levels are affected by unbalanced scrubber and intake flows. All combinations of three intake and three scrubber flows were tested. With these conditions it was possible to test the assumption that when intake flow is less than scrubber flow higher methane levels result.

DESCRIPTION OF TEST GALLERY

Testing was conducted in the Pittsburgh Research Center's Methane Test Gallery. One side of the "L" shaped building (figure 1) is designed to model an underground mining face entry which has dimensions, 4.7 m (16.5 ft) wide by 2 m (7 ft) high by 37 m (120 ft) long. The return air from the face exits the entry behind a brattice and wood wall located on the right side of the entry.

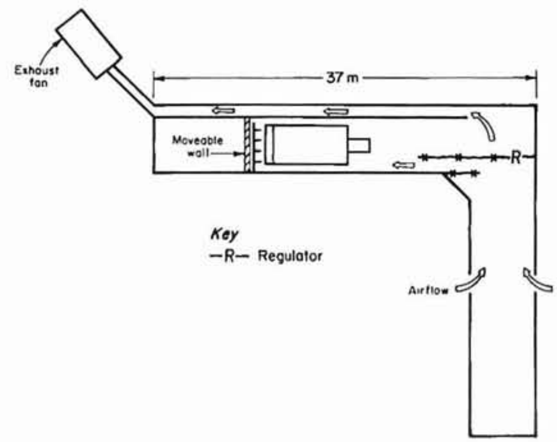

Figure 1. Methane test gallery.

Mining Machine

A full-scale model mining machine with water sprays, and dust scrubber system (figure 2), was located at the center of the face. Panels made of brattice and wood 0.9 m x 0.9 m (3 ft x 3 ft) were constructed on each side of the cutting head to simulate blocks of uncut coal. The center line of the cutting head was 1.2 m (4 ft) from the floor.

Eleven hollow cone (BD-3) water sprays were mounted on top of the boom and directed 10 degrees to the right. Three additional hollow cone sprays were mounted at the left front of the miner chassis. Two of these sprays were directed to the right and one toward the left corner of the face. Water pressure and flow were kept constant 827 kPa and 83.3 lpm (120 psi and 22 gpm) for all tests.

The scrubber system (figure 2) consisted of:

- inlets on each side of the mining machine, approximately 3.7 m (12 ft) from the mining face,

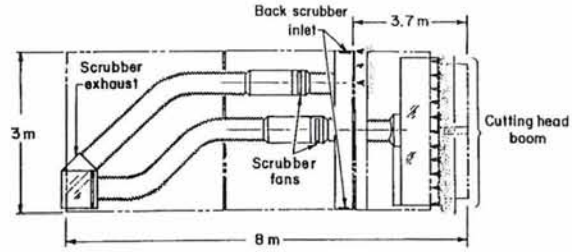

Figure 2. Model mining machine (plan view).

- an exhaust at the right rear of the machine chassis, and
- two fans with attached ducting to move the air from the inlets to the exhaust. Scrubber flows were 2.8, 4.7 and 6.6 m^3/s (6000, 10000 and 14000 cfm).

Both fans were needed to obtain scrubber flows of 6.6 and 4.7 m^3/s (14000 and 10000 cfm), and only one fan was used for tests when scrubber flow was 2.8 m^3/s (6000 cfm). Orifice plates were positioned in the scrubber ducting to adjust the flow. Scrubber flow was measured about 1.5 m (5 ft) downstream from each fan using a pitot tube and magnehelic gauge (10 point traverse).

Face Ventilation

The scrubber was tested with a blowing brattice face ventilation system. Fresh air was directed to the face with brattice cloth attached to a wood frame constructed 0.9 m (3 ft) from the left side of the entry. The area behind the brattice was 1.9 m^2 (21 ft^2). Tests were conducted for brattice setback distances of 7.6 and 10.7 m (25 and 35 ft).

A regulator door in the intake brattice was opened or closed to vary brattice airflow during testing. Traverses were made with a vane anemometer, at the end of the blowing brattice, to measure the average intake air velocity.

Methane Tracer Gas System

Methane was released through four perforated horizontal pipes located 0.5 m (18 in) outby the face. For all tests, the methane flow rate was set at 0.5 m^3/min (17.5 cfm) using a rotameter. As a check on methane release rate, a methanometer in the return continuously monitored methane concentration.

Methane concentrations were measured at the six locations shown on figure 3. Locations 1, 2, and 3 were 0.3 m (1 ft) outby the gas manifold and 0.3 m (1 ft) from the roof. Locations 4, 5, and 6 were at the top front of the mining boom, approximately 1.2 m (4 ft) from the face and 1.2 m (4 ft) from the roof.

Plastic tubing was extended from the rear of the mining machine to each of the six sampling locations. A vacuum pump was used to draw an air sample from each location and direct it over a separate methanometer sensor head. Each sensor was attached to a Bacharach methane monitor. [Reference to specific products does not imply endorsement by the NIOSH Pittsburgh Research Center.] For the duration of each test, data from each methanometer was down-loaded every two-seconds to a personal computer via a Metrabyte A/D conversion board. For each location sampled, the average methane concentration for the 5 minute sampling period was calculated using Lotus 1-2-3.

Before each test, the desired operating conditions (intake airflow, scrubber airflow, and setback distance) were configured,

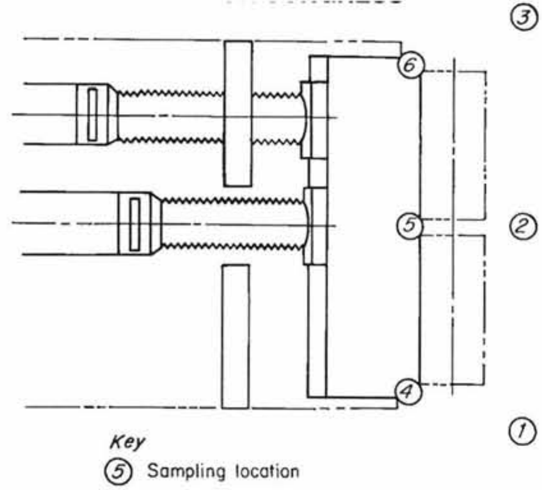

Figure 3. Methane sampling locations.

and methane flow into the gallery was initiated. To allow time for the gas to mix and concentrations to stabilize, methane flow into the gallery was begun 5 minutes prior to collecting data. After allowing time to attain steady state air flow conditions, data was collected for 5 minutes at each of the sampling locations.

RESULTS

The average methane concentration was calculated for the six face locations. A summary of the average methane concentrations for the six sampling locations and the corresponding operating conditions are given in Table 1. Each test was repeated once. The average difference between concentrations for the replicated tests was statistically insignificant (95% confidence interval). The average methane concentration for all tests conducted at the 7.6 m (25 ft) setback distance and the average methane concentration for all tests conducted at the 10.7 m (35 ft) setback distance were equal (0.17 pct). Therefore, during further analyses, the data from both setback distances was combined.

Table 1. Intake Scrubber Setback Methane

Intake Flow, cfm	Scrubber Flow, cfm	Setback Distance, ft	Methane Conc., pct
6000	6000	25	.21
6000	6000	35	.18
6000	10000	25	.19
6000	10000	35	.15
6000	14000	25	.13
6000	14000	35	.11
10000	6000	25	.22
10000	6000	35	.24
10000	10000	25	.21
10000	10000	35	.21
10000	14000	25	.18
10000	14000	35	.18
14000	6000	25	.14
14000	6000	35	.18
14000	10000	25	.12
14000	10000	35	.15
14000	14000	25	.12
14000	14000	35	.13

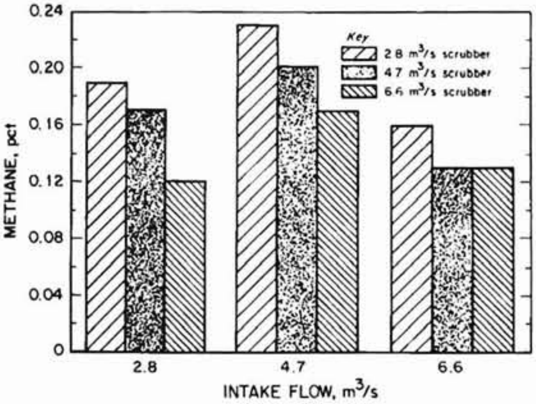

Figure 4. Effect of scrubber flow on methane concentration.

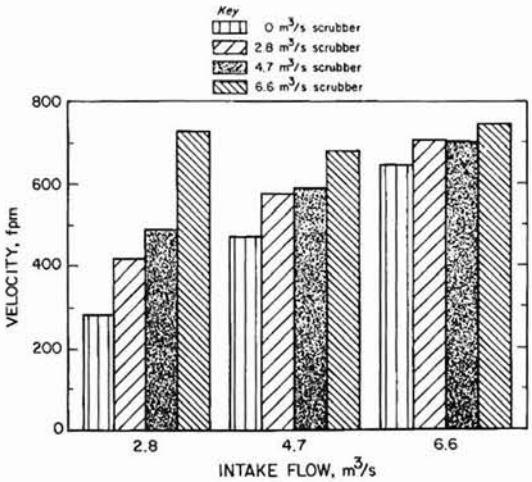

Figure 5. Variation in intake velocity with scrubber flow.

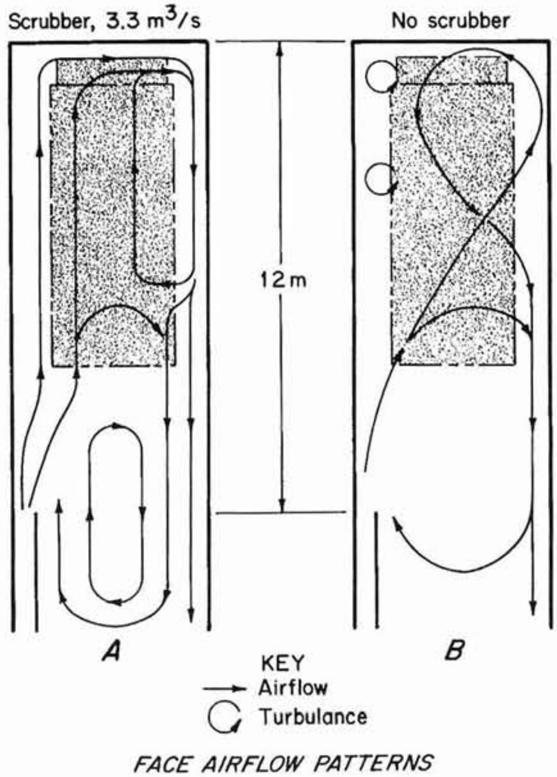

Figure 6. Face flow patterns with scrubber on (A) and off (B).

For each intake flow, an increase in scrubber flow reduced the average face methane concentrations (see figure 4). An analysis of variance (ANOVA) showed that the decreases in methane concentration due to scrubber flows were significant at the 95% confidence level. Methane levels did not increase when scrubber flows exceeded intake flows.

Intake airflow velocities were measured at the end of the blowing brattice with and without the scrubber operating for each of the three intake flows. The data given in figure 5 shows that:

- Intake air velocities increased when the scrubber was operating.
- In most cases increasing the scrubber flow increased the intake air velocity. Scrubber flow had the greatest effect on intake velocity at the 2.8 m^3/s (6000 cfm) intake flow and the least effect when intake flow was 6.6 m^3/s (14000 cfm).

SUMMARY AND DISCUSSION

The purpose of this research was to examine the effects of unbalanced scrubber and intake flow on average face methane concentrations. Scrubber and intake airflows were varied from 2.8 to 6.6 m^3/s (6000 to 14000 cfm) for brattice setback distances of 7.6 and 10.7 m (25 and 35 ft). The effectiveness of each ventilation system was based on the measurements of average face methane concentration. The assumption that methane levels will increase when intake flow is less than scrubber flow is incorrect.

Operation of machine-mounted dust scrubbers promotes better dilution of face liberated methane by increasing airflow turbulence at the front of the mining machine. Face airflow patterns and intake velocities were studied to find why use of the scrubber results in lower face methane levels.

Air flow patterns, shown in figure 6, were drawn with the aid of smoke tubes. The smoke was released approximately 0.9 m (3 ft) below the roof of the entry, and the flow patterns represent air movement at that level. The mining machine was at the face and the brattice setback distance was 12.2 m (40 ft). Typical flow patterns are shown with the scrubber on (6A) and the scrubber off (6B).

Flow patterns changed inby and outby the scrubber exhaust due to scrubber operation. With the scrubber operating, intake flow moved directly up the left side of the entry, and, from left to right across the face. Without the scrubber operating, intake airflow moved toward the off-side corner of the entry, and, from right to left across the face, creating a "Figure Eight." The "Figure Eight" flow pattern is associated with less efficient ventilation of the face and consequently higher methane levels.

Face airflow patterns also show that, with or without the scrubber operating, some of the air exhausted from the face travels back toward the face (figure 6). Recirculation occurs whether scrubber flow is greater than or equal to the intake flow. It can be assumed that the quantity of recirculated air increases with increasing scrubber flow. Determining how much air recirculates to the face for different combinations of scrubber and intake flow is beyond the scope of this paper. [An experimental technique for estimating the amount of air recirculated by a scrubber is described by Goodman (1983).]

During earlier research (Taylor), one test was designed so that the scrubber exhaust was aimed directly against the intake flow. The scrubber exhaust interfered with intake flow toward the face and methane concentrations increased. To reduce interference between scrubber and intake flow, the scrubber exhaust and intake brattice or tubing should always be placed on opposite sides of the entry.

This study provides information on the performance of a blowing ventilation system used with a machine-mounted dust scrubber. The impact of the test parameters would have to be evaluated by a mine operator for mine-specific conditions. These tests do not consider the effects of changes in scrubber and intake flows on airborne dust levels, and, therefore, should not be used alone to develop a ventilation system for effective dust control.

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