Effect of Water Sprays on Airflow Movement and Methane Dilution At the Working Face

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ABSTRACT: The National Institute for Occupational Safety and Health (NIOSH) has been conducting research to determine the influence of mining machine mounted water sprays on airflows and methane concentrations at the face when blowing ventilation systems are used. Tests were conducted in a full-scale ventilation gallery. Airflow speeds and directions were measured at several locations near the face with ultrasonic anemometers. Methane was released from the face and concentrations were measured in the entry at locations above the mining machine using fixed point methanometers. Changes in airflow speed, direction, and methane concentrations were correlated with water spray operations. The test results using different spray arrangements and water pressures showed that operation of the machine-mounted sprayers can improve face ventilation effectiveness by increasing the velocity of airflow moving toward and away from the face. The improved ventilation resulted in reduced methane levels near the face.

1 INTRODUCTION

Mining machine-mounted water sprays help provide dust control by wetting the coal surface and agglomerating the dust particles. Past NIOSH studies (Volkwein 1985) have shown that machine-mounted water sprays, in addition to reducing dust, also move considerable amounts of air, and can have a significant effect on the dilution and redistribution of methane liberated at the face. Water sprays can be especially helpful for maintaining adequate airflow at the face when cutting depths exceed 6.1 m (20 ft).

Sprays can reduce methane by increasing airflow velocities and improving the mixing of methane and intake air. Individual water sprays move air like a small fan. When sprays at the front of the mining machine are directed 30 degrees toward the return side of the entry, they can move air across the face and help clear methane gas (Ruggieri 1984, Taylor 2001).

2 TEST EQUIPMENT AND PROCEDURE

2.1 *Gallery and mining machine*

Testing was conducted in the NIOSH, Pittsburgh Research Laboratory, Ventilation Test Gallery. One side of the “L” shaped building is designed to model an underground mining entry that is 5 m (16.5 ft) wide by 2.1 m (7 ft) high (Fig. 1). A box, 1.2 m (3.5 ft) by 12.2 m (40 ft) long, was built along the right side of the face to simulate an uncut slab of coal. The resulting entry simulated a 4 m (13 ft) wide box cut.

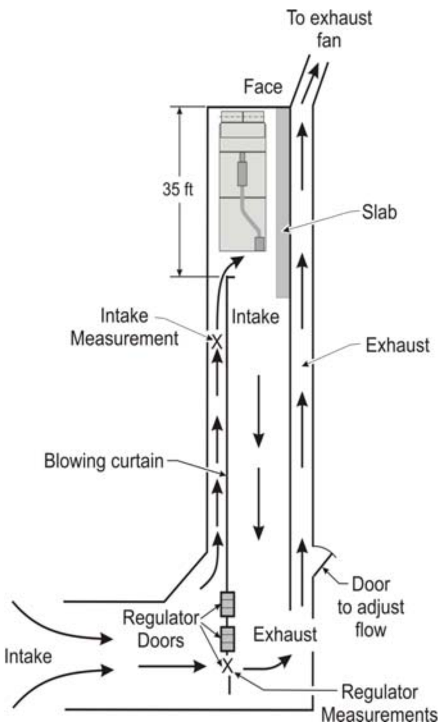

Figure 1.Ventilation test gallery.

A brattice curtain constructed 0.6 m (2 ft) from the left side of the wall directed airflow toward the face. The curtain setback distance for all the tests was 10.5 m (35 ft). Two intake airflow quantities were used for these tests, i.e. 1.9 or 2.8 m^3/s (4000 or 6000 ft^3/min). Airflows at the end of the curtain were varied by adjusting regulators.

A full-scale model continuous miner was located at the center of the entry to simulate a mining machine at a box-cut face (Fig. 2). Ten Spraying Systems Company model 3/8-BD-3 hollow cone nozzles (Disclaimer: Mention of any company or product does not imply endorsement by NIOSH) were aligned and mounted in each of the two 3.0 m (10 ft) long spray bars. The spray bars were constructed of 3.8 cm (1.5 in) diameter plastic pipe and mounted on top of the miner boom behind the cutting drum (Fig. 3). The nozzles were placed approximately 0.3 m (1 ft) apart. At this position on the boom the spray nozzles were approximately 1 m (41 in) back from the face.

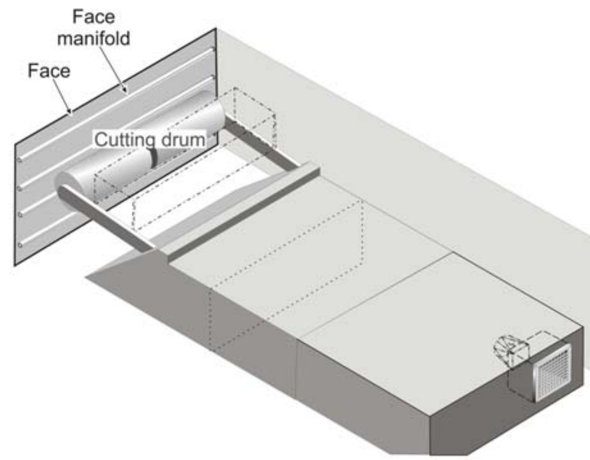

Figure 2. Model mining machine at gallery face.

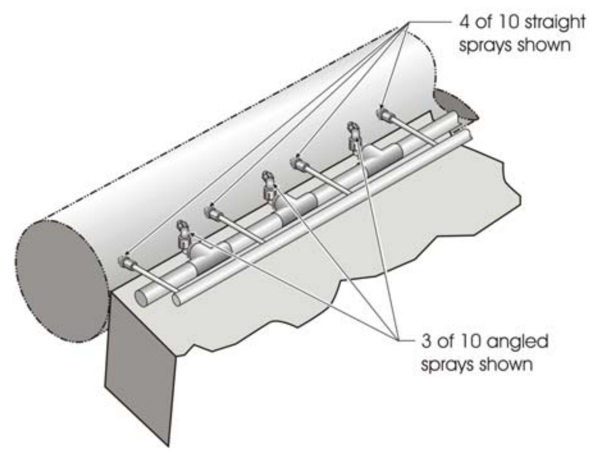

Figure 3. Straight and angled water sprays on model mining machine.

Water pressure was measured with a gauge mounted near the spray manifolds. Water spray tests were conducted with "high" and "low" water pressures. Water line pressure, 483 kPa (70 psig), was used for the low pressure tests. A centrifugal pump provided a pressure of 1200 kPa (174 psig) for the high pressure tests. Water flow rates from the sprays were measured for two nozzles in each of the two pipes. The average water flow rate for a nozzle was 0.0025 m^3/s (0.7 gal/min) at 483 kPa (70 psig) water pressure and 0.004 m^3/s (1.1 gal/min) at 1200 kPa (174 psig) water pressure. Therefore, the total water flow rate for each set of 10 nozzles was 0.025 m^3/s (6.7 gal/min) at 483 kPa (70 psig) and 0.040 m^3/s (10.6 gal/min) at 1200 kPa (174 psig) pressure.

2.2 *Airflow Measurements*

Two, three-axis anemometers (Windmaster) and one, single-axis anemometer (Solent), manufactured by Gill Instruments Ltd. Great Britain, were used to make the airflow measurements. The three sampling locations are shown in Figure 4. The three-axis sensor heads at locations 1 and 2 were positioned 61 cm (2 ft) from the roof and 1.5 m (5 ft) from the face. The sensor head for the single-axis instrument was located at the center-point behind the curtain (location 3).

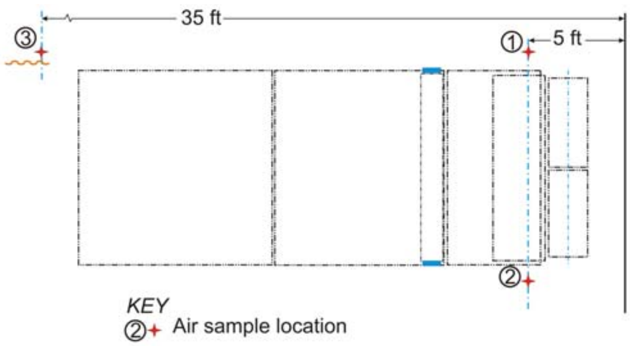

Figure 4. Airflow sampling locations (1-3) on model mining machine.

The three-axis instruments were used to measure the airflow velocity between the curtain and the face where flow direction frequently changes. The instruments were positioned vertically so that velocity measurements were made in plane parallel to the top and bottom of the entry (Fig 5). The vector components in the horizontal plane, measured by the anemometer, were used to calculate flow in this plane and in the direction of the flow. Although the three-axis instrument also measures flow in the vertical direction, velocities were calculated only for the airflow in a horizontal plane.

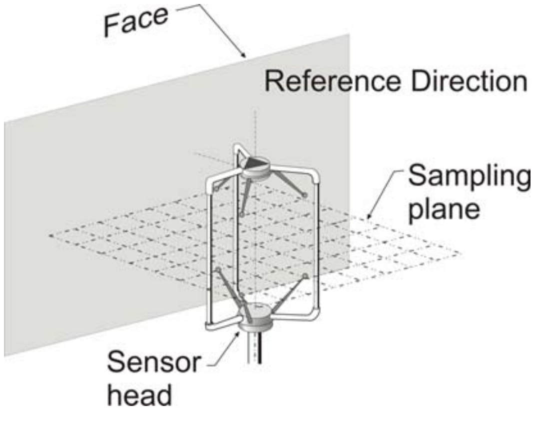

Figure 5. Vertically mounted three-axis anemometer sensor head.

To simplify the comparison of the velocities measured between the curtain and the face, measurements from the three-axis anemometers were used to calculate flow velocities perpendicular to the face. By convention, if the airflow was toward the face it was positive, and away from the face it was negative.

All anemometers were programmed to record average airflow data once per second. A software program written by NIOSH (ANEMVENT 2003) recorded the three-axis instrument data, and Hyper Terminal software (Hilgraeve, Inc.) was used to record data from the single-axis instrument. Data was transferred to EXCEL spreadsheets for analysis. The average velocities were then calculated for the duration of each test (2 to 3 minutes).

2.3 *Methane Measurements*

To evaluate the distribution of methane concentrations over the mining machine, natural gas (approximately 96 pct methane) was released into the gallery through four interconnected horizontal 3.7 m (12 ft) long by 3.8 cm (1.5 in) diameter copper pipes. Holes were drilled 2 mm (0.06 in) in diameter and 6.3 cm (2.5 in) apart on top and bottom of each pipe. The four pipes were equally-spaced vertically, and located 0.1 m (4 in) away from the face to provide a uniform release of gas.

Methane concentrations were measured at 15 locations above the mining machine (Fig. 6). All 15 locations were 43 cm (17 in) from the roof. A vacuum pump pulled air samples through plastic tubing from each of the sampling locations to one of 15 Bacharach methane heat of combustion sensors. The fifteen locations (1-15) were monitored simultaneously.

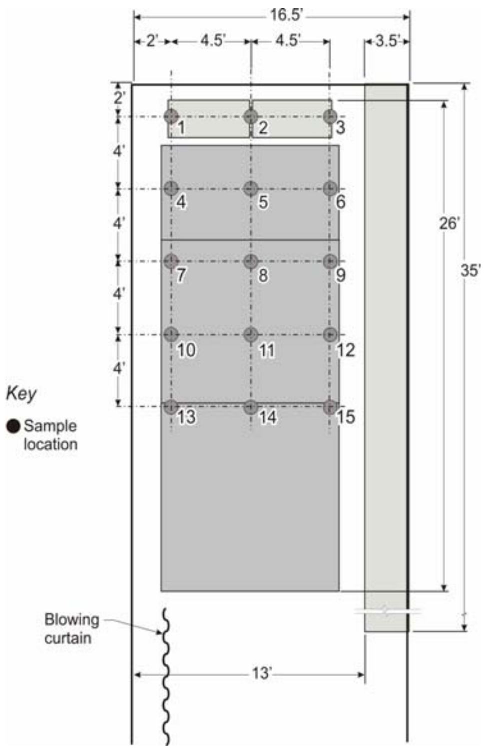

Figure 6. Methane sampling locations (1-15) above model mining machine.

A methane flow rate of 0.015 m^3/s (32 ft^3/min) was set with a globe valve and monitored by passing the gas through a rotameter. Gas flows were reduced to 0.0095 m^3/s (20 ft^3/min) for some tests to prevent methane concentrations in the gallery from exceeding 2.5 pct. For the reduced methane flow tests, measured concentrations were adjusted by multiplying the recorded concentrations by the ratio of the methane flows (i.e. 0.015/0.0095 = 1.6) so that comparisons of effects could be made at equal methane input flows. Before making measurements, methane was released into the gallery for 5 minutes to allow it to mix with air and reach a relatively constant concentration. After mixing for five minutes, methane concentrations were recorded each second for the next 5 minutes.

Methane concentration data was downloaded to a computer via an analog-to-digital conversion board using Labtech commercial data acquisition software. Time averaged concentrations were then calculated for each sampling location.

2.4 *Test Conditions*

Straight sprays (directed perpendicular to the face), and angled sprays (directed 30 degrees to the right) were tested at high and low water pressures [483 and 1200 kPa (70 and 174 psig)] and intake airflows of 1.9 and 2.8 m^3/s (4000 and 6000 ft^3/min).

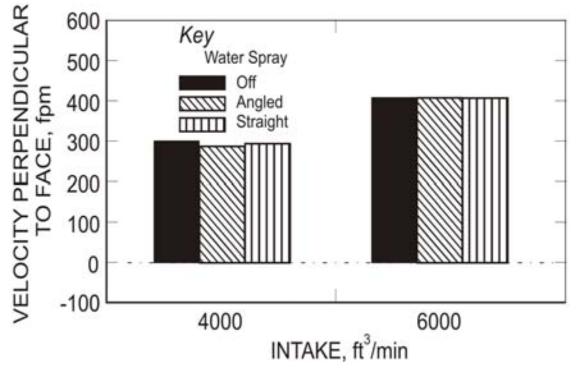

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Figure 7. Effect of water sprays on air intake velocities.

Airflow direction towards and away from the face varied depending on whether the sprays were on or off, and if straight or angled sprays were used. With the sprays off, airflows moved toward the face on the right side of the machine (location 2), and away from the face on the left side of the machine (location 1) (Fig. 8). Increasing the intake airflow from 1.9 to 2.8 m^3/s (4000 to 6000 ft^3/min) increased the air velocities a small amount at both locations.

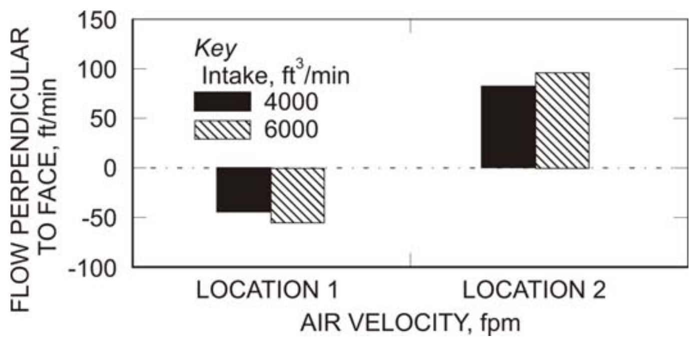

Figure 8. Airflow movement at the face without sprays (+ toward face, - away from face).

Figure 9 compares the effects of spray configurations, water pressures and intake airflows on airflow velocities at location 1. Both water spray systems caused airflows on the left side of the mining machine (location 1) to move toward the face. The airflow velocities were 27 to 60 pct higher when the angled sprays were used. When using the higher water pressure, the airflow velocities were 103 to 209 percent higher. Increasing the intake airflow had only a small effect on airflow velocity at location 1.

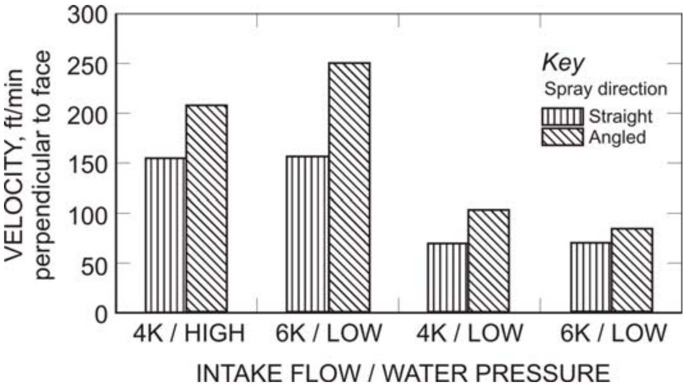

Figure 9. Effect of spray configurations, intake airflows, and water pressures on face air velocities on the left side (Location 1) of the model mining machine.

Figure 10 compares airflow velocities on the right side of the entry (Location 2) for different intakes, spray configurations and spray pressures. Airflow velocities increased, either toward or away from the face, when the intake airflow was increased. Airflow direction changed depending on the spray configuration. Air moved away from the face with the angled sprays, and toward the face with the straight sprays. Increased water spray water pressure resulted in higher velocities for both the straight and angled nozzle orientations.

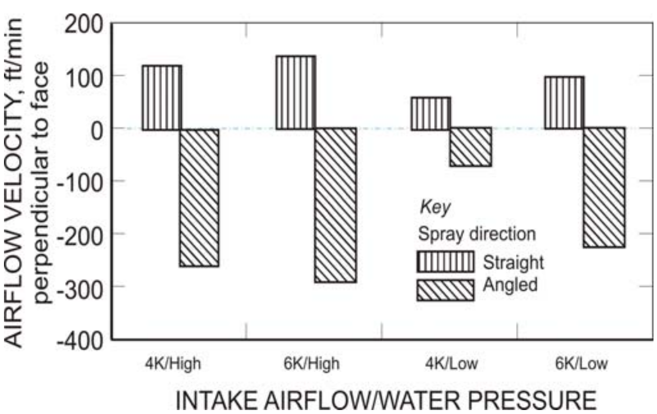

Figure 10. Effect of spray configurations, intake airflows, and water pressure on face air velocities on the right side (Location 2) of the model mining machine (+ toward face, - away from face).

2.5 *Methane Measurement Results*

Methane concentrations measured above the mining machine for tests with 1.9 m^3/s (4000 ft^3/min) and 2.8 m^3/s (6000 ft^3/min) intake airflows are shown on Figures 11-12. Methane concentrations were averaged for each of the 5 rows of samples to evaluate how these concentrations varied with distance from the face. The distribution of the methane over the mining machine shows how airflow patterns are distinctly different for the various intake and water spray combinations. In general, the methane concentrations measured over the mining machine were higher closer to the face where the methane was released, and lower on the left side of the machine where the intake air curtain was located (Figs. 11-12).

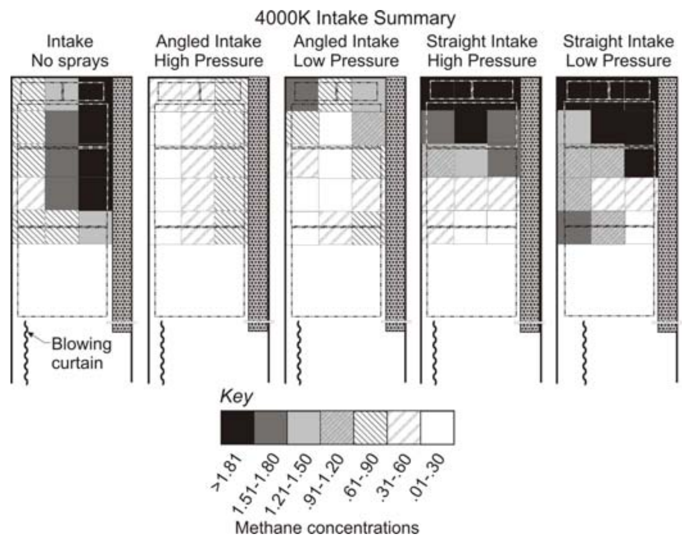

Figure 11. Methane distributions (4000 ft^3/min intake).

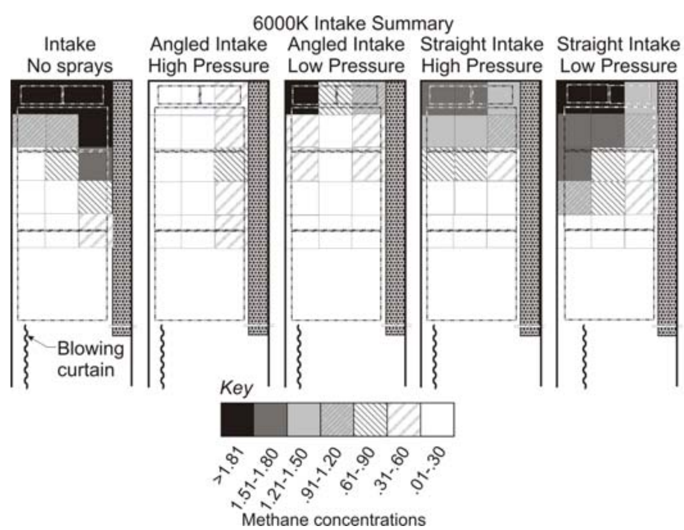

Figure 12. Methane distributions (6000 ft^3/min intake).

Additionally, methane concentrations versus distances from the face were plotted (Figs. 13-15). The data (Figs. 13-15) show that increasing the intake airflow reduced methane levels approximately the same amount at all distances from the face (Fig. 13). Angled sprays were more effective for reducing methane levels at all sampling locations, but were more effective at locations closer to the face (Fig. 14). The higher water pressure had the greatest effect on methane levels at the locations nearest [0.6 m (2 ft)] the face (Fig. 15).

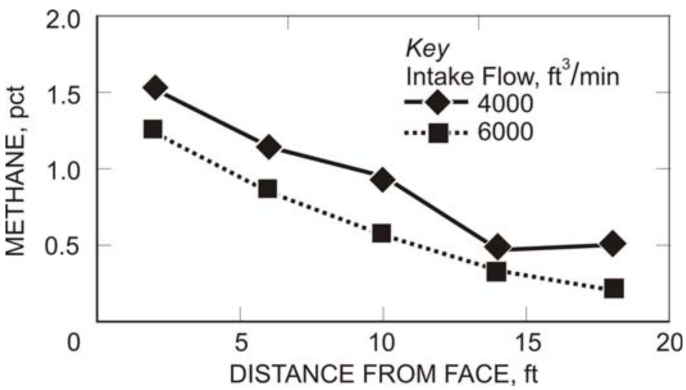

Figure 13. Effect of intake airflow on methane concentrations

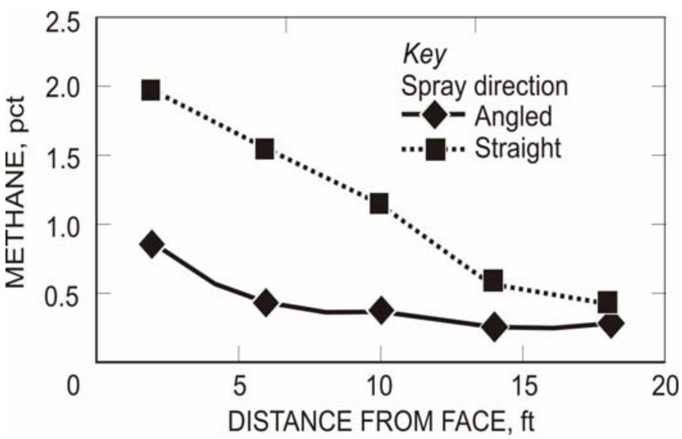

Figure 14. Effect of nozzle direction on methane concentrations.

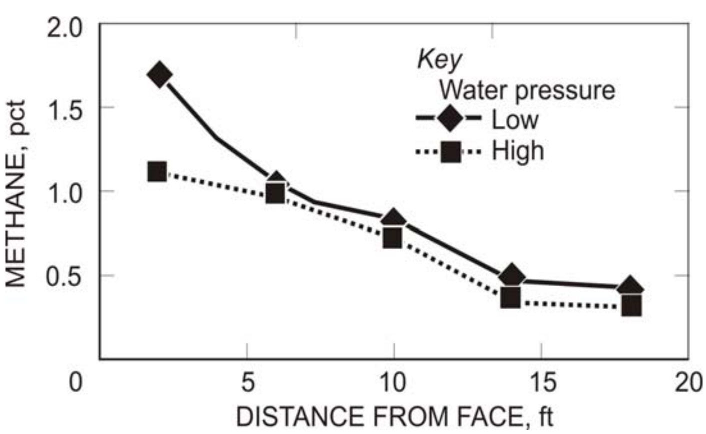

Figure 15. Effect of spray pressure on methane concentrations.

3 CONCLUSIONS

This NIOSH study evaluated how the use of machine-mounted water sprays installed on the front of a model continuous mining machine can increase face airflow movement and improve the dilution and removal of methane released at the mining face. Airflow velocities toward and away from the face were measured with ultrasonic anemometers located on each side of the machine.

With angled sprays, airflow velocities increased as air moved toward the face on the left side of the machine and away from the face on the right side of the machine. Airflow movement across the face was left to right. The straight sprays increased air velocities moving toward the face on both sides of the mining machine. Airflow away from the face was over the top of the machine. Increasing the water pressure for angled and straight spray configurations more than doubled the air velocities moving perpendicular to the left (intake) side of the face. Increasing the intake air quantities had minimal effects on airflow velocities moving toward the face. The angled water spray, high water pressure, and high intake airflow configuration had the greatest effect near the face where air velocities were highest resulting in efficient methane dilution.

In general, the use of angled sprays with higher water pressure resulted in the highest airflows near the face, and the best methane dilution over the mining machine. Methane levels were lower for both straight and angled sprays when water pressure was increased. Angled water sprays operating at the higher pressure reduced methane levels the most at the locations closest to the face. Farther from the face, the sprays had less of an effect on airflow velocities and the methane levels above the machine were approximately the same with either spray system.

The effective use of water sprays assumes that all nozzles can be kept clear of blockage from particles in the water supply. For these tests, each of the nozzles was frequently removed from the tubing and its orifice cleaned. In actual use in the mining environment, the addition of an in-line water flow indicator and a stainless steel mesh particulate filter is strongly recommended (Southern 2003)

4 DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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