

# Using Water Sprays to Improve Performance of a Flooded-Bed Dust Scrubber

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Supplemental water sprays were placed along the sides of a continuous mining machine to improve suppression and confinement of the dust cloud under the cutting boom to reduce downwind dust levels. Using a full-scale mock-up of a continuous mining machine, preliminary work showed that these side sprays improved suppression of the dust cloud and redistributed this cloud under the cutting head. This led to reductions in dust levels around the machine and in downwind airways for some positions of the mining machine. This testing also showed that side spray effectiveness was influenced by the distance from the fresh air ventilation device to the cutting surface, termed the ventilation setback distance. These sprays produced larger reductions in machine and return dust levels at smaller setback distances than at larger setback distances. These side sprays then were installed in similar locations on a mining machine at an underground coal mine operation to evaluate their effectiveness for improving suppression and capture of dust by the flooded-bed dust scrubber. Although sampling could not be conducted successfully in the return, sampling around the mining machine and at the machine operator showed that dust levels decreased with use of these sprays. Further analysis showed that these sprays were most effective at the smaller setback distances, a result confirmed by full-scale laboratory testing.

**Keywords** Occupational Health, Dust Sampling, Coal Mining, Continuous Mining, Control Technology

The increased use of flooded-bed dust scrubbers on continuous mining machines generally has been responsible for decreased worker exposures to respirable dusts.<sup>(1)</sup> Much work in government, industry, and academia has been conducted to assess the effectiveness of scrubber-based ventilation schemes under a variety of mining conditions.<sup>(2,3)</sup>

One measure of scrubber performance is related to the capture of dust or the amount of dust that finds its way into the scrubber inlets and then to the scrubber filter. Scrubber capture depends upon many factors such as scrubber capacity, face ventilation method (method used to direct fresh air to areas where coal is being cut, i.e., either blowing or exhausting curtain or tubing), face ventilation capacity (30 CFR 75.325 specifies that at least 1.42 m<sup>3</sup>/sec [3000 cfm] be supplied to each working face where coal is being cut),<sup>(4)</sup> ventilation setback distance (distance from the end of the ventilation curtain or tubing to deepest penetration of the face), and machine location. During coal extraction, reductions in scrubber capture often lead to increased levels of dust rollback (dust not captured or suppressed that flows downwind to other workers).

Scrubber capture was affected by placing water sprays outby (a direction away from the cutting face area) the scrubber inlets on the left and right sides of the continuous mining machine. Sprays placed outby the scrubber inlets were placed between the inlets and the rear of the mining machine. These side sprays induced additional airflow along the sides of the machine to improve containment of the dust cloud under the cutting boom.

This article documents experimental work to examine the effectiveness of these side sprays for improving capture of dust by the flooded-bed scrubber. Assessments are given for two positions of the continuous mining machine and for various ventilation setback distances. The underground application of these sprays also is discussed.

## EXPERIMENTAL DESIGN

This work was conducted in a surface test gallery at the Pittsburgh Research Laboratory of the National Institute for Occupational Safety and Health (NIOSH). This test facility simulated a cut 12.2 meters (40 feet) deep, 5.5 (18 feet) meters wide, and roughly 2.1 meters (7 feet) high. Testing was conducted using a mock-up of a continuous mining machine equipped with a flooded-bed dust scrubber. The flooded-bed scrubber consisted of a standard 40-layer filter screen, water sprays, wave plate mist eliminator, and fan. The scrubber was rated at 2.64 m<sup>3</sup>/s

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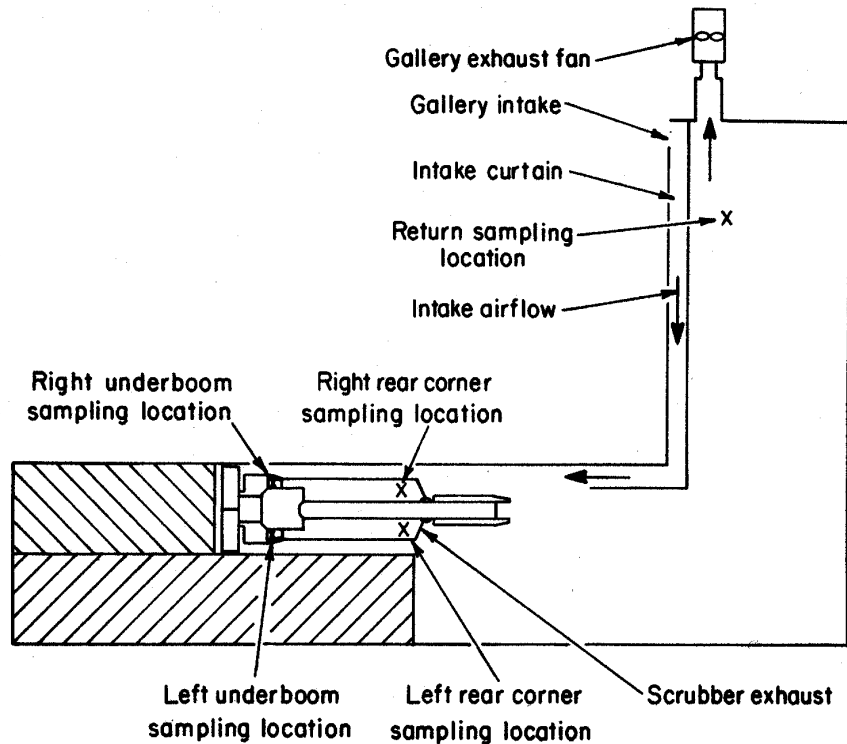


FIGURE 1

Testing arrangement—laboratory study.

(5600 cfm). Dust drawn by a vane-axial fan through three inlets under the cutting boom impacted on a wetted stainless steel screen. The moisture-laden air continued through the screen and across a mist eliminator to remove the water. The air then exhausted on the left side of the machine frame.

Air from the main gallery fan was drawn through a series of curtains to mimic a blowing curtain ventilation scheme. Airflow, as measured at the mouth of the blowing curtain, ranged from 2.78 m<sup>3</sup>/s to 3.02 m<sup>3</sup>/s (5900 cfm to 6400 cfm). This curtain was positioned on the right side of the test gallery (Figure 1).

The continuous mining machine used a conventional face spray system consisting of 40 hollow-cone sprays positioned above, below, and along the sides of the cutting boom. Tests also were run with additional sprays positioned on the left and right sides of the continuous mining machine, roughly 61 cm (24 inches) from the left and right side scrubber inlets. These sprays were angled outward 30 degrees from the body of the mining machine (Figure 2). These sprays were the flat-fan variety, instead of hollow-coned or full-coned, to place more water from each spray along the body of the machine rather than impacting on the sides of the machine. Spraying System Company nozzles H3/8U-4010 rated at 3.78 lpm at 344.7 kPa (one gpm at 50 psi) were used during testing. Due to the parameters available for this testing, an unbalanced arrangement of sprays was discovered to be best for controlling dust under the boom. Consequently, two sprays were placed on the left side of the machine and one was

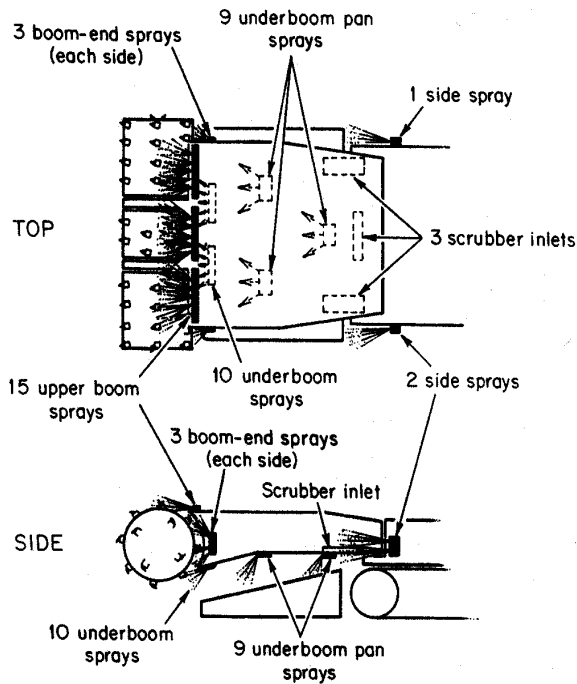
used on the right side. A water pressure of 344.7 kPa (50 psi), measured at the spray manifolds, was maintained for all tests. Water flow to the miner was approximately 125 lpm without the side sprays in use and 136 lpm with these side sprays in use.

For this testing, a mix of silica dust in coal dust was used. Samples of this silica-coal feed dust were sent to an independent laboratory for P-7 silica analysis that showed that the mix averaged 13.0 ± 0.7 percent silica.<sup>(5)</sup> This dust was introduced into the gallery at the miner cutting head via a compressed air/eductor system. One hose discharged on the left side of the cutting drum while the other discharged on the right side of the drum. The cutting head was rotated at 50 revolutions per minute to insure adequate mixing of the dust with the ventilation airflow.

For dust sampling, constant flow pumps pulled dust-laden air through 10-mm nylon cyclone separators at a rate of 2 liters/min to deposit the respirable mass onto preweighed 37-mm filters.<sup>1</sup> All filters were subsequently weighed and dust levels calculated. These levels were not corrected to MRE (Mining Research Establishment) equivalents.<sup>2</sup> Selected filters sent to an independent laboratory for silica analysis using the P-7 method.

<sup>1</sup>30 CFR 74.3 gives the specifications for approved dust sampling units in underground coal mining; 30 CFR 70.205 requires that approved sampling devices operate at a flow rate of 2.0 liters/minute.

<sup>2</sup>30 CFR 70.206 requires that respirable dust concentrations measured with an approved sampling device be converted to an equivalent concentration measured with an MRE device. Currently, MRE equivalent concentrations are



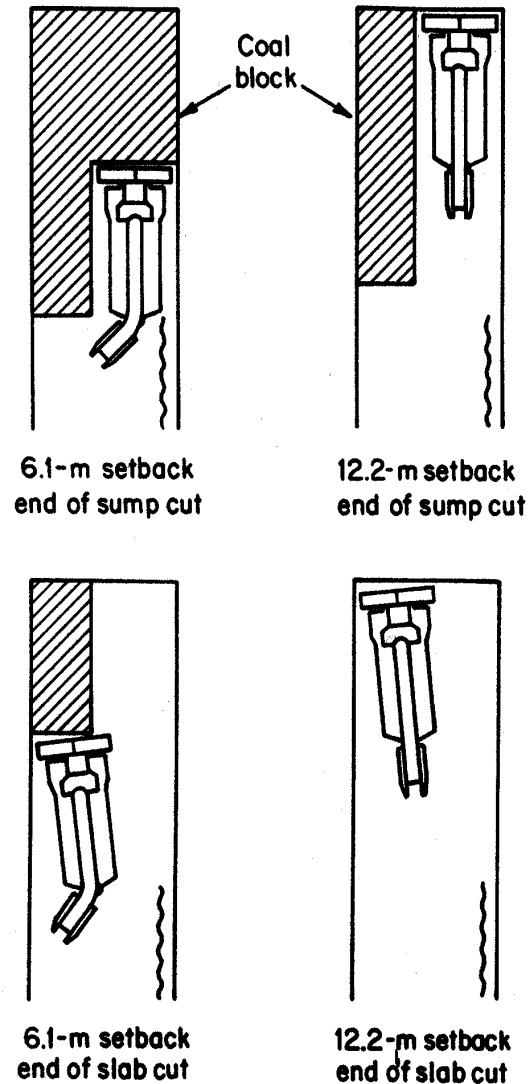
**FIGURE 2**  
Spray configuration—laboratory study.

For this testing, two samplers were placed under the miner boom at the left or off-curtain side scrubber inlet and the right or curtain side scrubber inlet (Figure 1). These instruments were hung roughly 13 cm (5 inches) beneath each inlet. The scrubber inlet samples served as relative measures of scrubber capture, where higher dust levels measured at these locations corresponded to increased dust flow into the scrubber and thus increased capture of dust.

Two samplers also were placed on the left and right rear corners of the mining machine. Dust concentrations measured at these two locations reflected dust rollback levels. For instance, lower dust levels at the rear corners reflected an increased capture of dust by the scrubber. Finally, a set of two gravimetric samplers was placed in the return airway to monitor downwind dust levels.

A RAM (Realtime Aerosol Monitor, GCA Corp., Bedford, Massachusetts) dust monitor also was placed in the return to monitor pre-test or baseline conditions. Prior to each test, dust was injected at the cutting head for 10 minutes with the cutting head rotating and only the blowing curtain ventilation in operation. During this baseline period, the dust cloud was allowed to stabilize before operating the scrubber and water sprays. A ratio was then calculated by dividing the average RAM baseline reading for a series of tests (similar setback distance, similar mining

obtained by multiplying the respirable dust concentration measured with an approved sampling device by the factor 1.38.<sup>(6)</sup>



**FIGURE 3**  
Positions of mining machine and ventilation curtain—laboratory study.

machine position, similar side spray usage) into the RAM baseline reading for that test being normalized. This ratio was used to adjust the average gravimetric concentrations for any variations in dust feed.

In underground coal mining, a continuous mining machine removes coal in blocks. Although removal or extraction sequences can differ between mining operations, the following sequence was used for this testing (Figure 3). The sequence begins with the mining machine cutting on the right side for a distance of 6.1 meters. This initial cut is termed a sump cut because solid coal is present on both sides of the cutting head. The distance from the end of the ventilation curtain to the cutting head, or the

ventilation setback distance, is 6.1 meters. The machine continues mining the sump cut for another 6.1 meters for a total distance of 12.2 meters. The ventilation setback distance is now 12.2 meters. The machine then backs out and moves to the left side and removes the remaining coal block. This is termed a slab cut because solid coal is present on one side of the cutting head. Curtain setback distances vary again from 6.1 meters to 12.2 meters.

Tests were conducted with and without the side sprays in operation. The continuous mining machine was positioned in the sump cut or in the slab cut with curtain setback distances of 6.1 meters or 12.2 meters. Each test ran for 50 minutes to provide measurable dust quantities for all samples. All tests were replicated. Concentrations for each test run were calculated using the average of the concentrations for each set of two samplers. Concentrations for each series of test conditions were calculated using the average concentrations for each of the tests comprising that set of conditions.

#### ANALYSIS OF LABORATORY DATA

Appendix 1 shows average dust levels and standard deviations calculated for sump and slab cut positions of the continuous mining machine, 6.1 meter and 12.2 meter ventilation setback distances, and use of the side sprays. This data shows that the highest dust levels were measured in the vicinity of the left and right scrubber inlets. This was expected due to the suction action provided by the scrubber fan and the rotation of the cutting drum which forced dust-laden air toward the scrubber inlets.

The impact of the side sprays was assessed by comparing the mean dust level at each sampling location without the side sprays in operation (for each combination of mining machine position and setback distance) to the mean dust level measured with these sprays in operation (similar position and setback distance). Hypothesis testing was then used to assess the significance of the difference between these mean dust levels. With the null hypothesis being no difference in mean dust levels, t-tests were used to accept or reject this assumption. Two tails were specified to account for any increase or decrease in dust levels with the added sprays. Subsequent analyses constructed 95 percent confidence intervals for the difference in mean dust levels.

An interval containing zero stated that the difference between the two mean dust levels was not statistically significant at this level of confidence.

Table I shows the effects of the side sprays at the left and right scrubber inlets for various curtain setback distances and machine positions. With the machine in the sump cut, the supplemental sprays generally reduced underboom dust levels. These reductions were statistically significant when measured at the left scrubber inlet, possibly a result of improved suppression provided by the additional sprays on that side. The added sprays had little significance on dust levels at the right inlet at either the 6.1-meter setback distance (p-value > 0.20) or 12.2-meter setback distance (p-value = 0.10).

With the mining machine in the slab cut, however, the side sprays increased dust levels at the right inlet and decreased dust levels at the left inlet. All changes were statistically significant, with the exception of the left inlet sample at the 6.1-meter setback distance (p-value = 0.18). The increases measured at the right inlet, however, indicate more dust in the vicinity of this inlet which, in turn, could lead to improved capture of the underboom dust cloud at the right scrubber inlet.

Two possible mechanisms could account for the impacts of the additional side sprays on dust levels measured near the scrubber inlets. One, these sprays improved suppression of the airborne dust in the underboom region by placing more water on the dust cloud. This could have led to the decreases measured at the left inlet. Two, the unbalanced arrangement of sprays could have pushed the dust cloud from the left inlet toward the right inlet. The ability of water sprays to suppress airborne dust and induce airflow movement is well documented in the literature<sup>(10)</sup> and one or more of these mechanisms could have resulted in the change in dust levels measured during this testing.

The data in Tables II and III show that the side sprays did not have a consistent effect on dust levels measured at the left and right rear corners of the mining machine and in the return. Significant results were found with the mining machine in the sump cut and a 6.1-meter ventilation setback distance. The reduction at the left rear corner and in the return was significant at the 95 percent confidence level, while the reduction at the right rear corner was significant at the 90 percent confidence level.

**TABLE I**  
Effects of added side sprays at the left scrubber and right scrubber inlet sampling locations

| Machine position:<br>Setback<br>(m) | Left scrubber inlet  |  |  | Right scrubber inlet |  |  |
|-------------------------------------|----------------------|--|--|----------------------|--|--|
|                                     | Number of<br>samples | Standard error<br>(mg/m <sup>3</sup> ) | Confidence interval <sup>A</sup><br>(mg/m <sup>3</sup> ) | Number of<br>samples | Standard error<br>(mg/m <sup>3</sup> ) | Confidence interval <sup>A</sup><br>(mg/m <sup>3</sup> ) |
| Sump cut: 6.1                       | 5                    | 0.71                                   | -2.92 ± 2.26 <sup>B</sup>                                | 4                    | 0.85                                   | 0.44 ± 3.66  |
| Sump cut: 12.2                      | 6                    | 1.42                                   | -6.30 ± 3.95 <sup>B</sup>                                | 6                    | 0.78                                   | -1.33 ± 2.17   |
| Slab cut: 6.1                       | 5                    | 1.19                                   | -2.13 ± 3.78   | 6                    | 0.32                                   | 3.62 ± 0.89 <sup>B</sup>                                 |
| Slab cut: 12.2                      | 6                    | 0.88                                   | -5.84 ± 2.45 <sup>B</sup>                                | 6                    | 1.59                                   | 7.84 ± 4.42 <sup>B</sup>                                 |

<sup>A</sup>95 percent confidence interval for difference in mean dust levels. Negative values indicate a reduction in dust levels at that sampling location due to added sprays.

<sup>B</sup>Confidence interval is statistically significant at 95 percent.

**TABLE II**  
Effects of added side sprays at left rear corner and right rear corner sampling locations

| Machine position:<br>Setback<br>(m) | Left rear corner     |  |  | Right rear corner    |  |  |
|-------------------------------------|----------------------|--|--|----------------------|--|--|
|                                     | Number of<br>samples | Standard error<br>(mg/m <sup>3</sup> ) | Confidence interval <sup>A</sup><br>(mg/m <sup>3</sup> ) | Number of<br>samples | Standard error<br>(mg/m <sup>3</sup> ) | Confidence interval <sup>A</sup><br>(mg/m <sup>3</sup> ) |
| Sump cut: 6.1                       | 6                    | 0.38                                   | -1.41 ± 1.06 <sup>B</sup>                                | 6                    | 0.51                                   | -1.19 ± 1.42 <sup>C</sup>                                |
| Sump cut: 21.2                      | 6                    | 0.30                                   | 0.51 ± 0.83  | 5                    | 0.32                                   | -0.50 ± 1.02   |
| Slab cut: 6.1                       | 6                    | 0.26                                   | -0.03 ± 0.72   | 6                    | 0.15                                   | -0.06 ± 0.42   |
| Slab cut: 12.2                      | 6                    | 0.36                                   | 0.48 ± 1.00  | 6                    | 0.32                                   | 0.26 ± 0.89  |

<sup>A</sup>95 percent confidence interval for difference in mean dust levels. Negative values indicate a reduction in dust levels at that sampling location due to added sprays.

<sup>B</sup>Confidence interval is statistically significant at 95 percent.

<sup>C</sup>Confidence interval is statistically significant at 90 percent.

(p-value = 0.08). Changes in dust levels at the left and right rear corners with the mining machine in the slab cut were not significant (p-value ≥ 0.20). However, return dust levels did decrease significantly in the return with use of the additional side sprays at the 6.1-meter setback distance.

At the larger 12.2-meter ventilation setback distance, the results were somewhat confounding. Dust levels did not decrease significantly at the left and right rear corners of the mining machine (p-values ≥ 0.20), indicating that the additional side sprays were not as effective at the larger setback distance. This is confirmed by the return dust levels which showed only a weak effect in the slab cut with use of the additional side sprays (p-value = 0.08). No effect was seen with the mining machine in the sump cut (p-value > 0.20).

Due to cost considerations, silica analyses were conducted only on selected filters. To avoid small sample sizes that could have led to questionable results, silica samples from sump and slab cut tests were combined according to side spray use and setback distance. For example, all left and right scrubber inlet samples taken without the side sprays in use and with a 6.1-meter setback distance were considered as a single sample set. The silica levels of these samples were then compared to those scrubber inlet samples taken with the sprays in use and with a 6.1-meter

setback distance. Similar comparisons were made for all under-boom samples taken at a 12.2-meter setback distance. All silica samples taken at the left rear and right rear corner locations of the mining machine were combined to form a general machine sample set and analyzed in a similar manner. The return samples were combined by ventilation setback distance and side spray use.

Combining samples in this manner eliminated any analysis of silica dust variation due to mining machine location, that is, sump cut or slab cut. However, the previous analysis showed that the effectiveness of the side sprays was most influenced by ventilation setback distance.

Hypothesis testing and two-tailed t-tests were again used to assess the significance of the difference in mean silica dust levels measured with and without the added sprays. A 95 percent level of confidence was assigned to this evaluation.

The results of the silica analyses are shown in Table IV and show that silica percentages were essentially unchanged with the use of the additional side sprays. With the exception of the return samples at a 12.2-meter ventilation setback distance, all other silica levels were not significantly affected by these sprays (p-value ≥ 0.20). This apparent lack of impact on silica dust levels is not surprising. Previous work showed that capture of the smaller, denser silica particles increased directly with water

**TABLE III**  
Effects of added side sprays at the return sampling location

| Machine position:<br>Setback<br>(m) | Return               |  |  |
|-------------------------------------|----------------------|--|--|
|                                     | Number of<br>samples | Standard error<br>(mg/m <sup>3</sup> ) | Confidence interval <sup>A</sup><br>(mg/m <sup>3</sup> ) |
| Sump cut: 6.1                       | 6                    | 0.13                                   | -0.62 ± 0.36 <sup>B</sup>                                |
| Sump cut: 12.2                      | 6                    | 0.10                                   | -0.08 ± 0.28   |
| Slab cut: 6.1                       | 5                    | 0.06                                   | -0.49 ± 0.19 <sup>B</sup>                                |
| Slab cut: 12.2                      | 5                    | 0.20                                   | -0.52 ± 0.64 <sup>C</sup>                                |

<sup>A</sup>95 percent confidence interval for difference in mean dust levels. Negative values indicate a reduction in dust levels at that sampling location due to added sprays.

<sup>B</sup>Confidence interval is statistically significant at 95 percent.

<sup>C</sup>Confidence interval is statistically significant at 90 percent.

**TABLE IV**  
Effects of added side sprays on silica dust levels

| Setback distance   | Underboom         |                                  | Rear of machine   |                                  | Return            |                                  |
|--------------------|-------------------|----------------------------------|-------------------|----------------------------------|-------------------|----------------------------------|
|                    | Number of samples | Confidence interval <sup>A</sup> | Number of samples | Confidence interval <sup>A</sup> | Number of samples | Confidence interval <sup>A</sup> |
| 6.1-meter setback  | 8                 | 0.10 ± 0.49                      | 8                 | -0.32 ± 1.10                     | 4                 | -0.35 ± 2.40                     |
| 12.2-meter setback | 8                 | -0.42 ± 0.74                     | 8                 | 0.82 ± 2.10                      | 4                 | 1.10 ± 0.43 <sup>B</sup>         |

<sup>A</sup>95 percent confidence interval for difference in mean silica levels. Negative values indicate a reduction in dust levels at that sampling location due to added sprays.

<sup>B</sup>Confidence interval is statistically significant at 95 percent.

droplet speed and indirectly with water droplet size.<sup>(7)</sup> In that testing, spray pressures of 17.2 Mpa (2500 psi) were used to generate the high droplet speed and the lower droplet size. The testing described in this work used much lower water pressures. Hence, the added water sprays would have had little significant effect on silica dust levels.

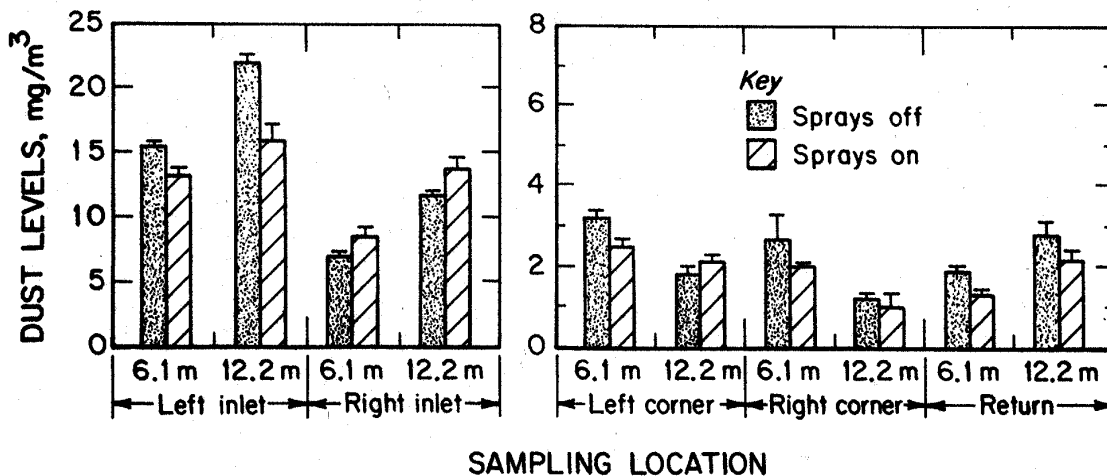
Field study data collected by NIOSH personnel suggested that 60 percent of the total cut time was spent in the sump cut, and the remaining 40 percent was spent in the slab cut.<sup>(9)</sup> This 60:40 ratio was used to weight the average sump and slab cut dust levels in Appendix 1 to define impacts of the side sprays at the two setback distances tested (Figure 4). For both 6.1-meter and 12.2-meter setback distances, the side sprays reduced average dust levels at the left scrubber inlet and increased levels at the right scrubber inlet. These sprays also produced larger reductions of rear corner and return dust levels at the 6.1-meter setback distance than at the larger 12.2-meter distance.

The previous data showed that these added water sprays likely induced airflow to move the dust cloud from the left scrubber inlet toward the right scrubber inlet. With nothing to restrain the dust, it could have continued to flow past the right inlet and

could have flowed from under the cutting boom. This would have led to dust rollback and increased dust levels downwind of the continuous mining machine. At the smaller setback distance of 6.1 meters, air from the intake curtain was sufficient to keep dust from flowing out the right side of the cutting boom. At the larger setback distance of 12.2 meter, the intake curtain flow dissipated while traveling toward the cutting head. This flow was inadequate to limit the amount of dust flowing from under the cutting boom. Consequently, dust rollback levels increased and could have led to the higher dust levels measured around the mining machine.

**FIELD EVALUATION OF SIDE SPRAYS**

These side sprays were evaluated at an underground mining operation to further assess their ability to control dust exposures. Face ventilation was provided by an exhaust tube hung along the left side of the entry. Tubing quantity changed with the entry and varied from 5.3 m<sup>3</sup>/s to 6.5 m<sup>3</sup>/s (11,300 to 13,700 cfm). To increase the cross-sectional area of the exhaust ventilation, a curtain was hung around the mouth of the tube (Figure 5). Face equipment consisted of a continuous mining machine equipped



**FIGURE 4**

Side spray impact on average dust levels at different curtain setback distances—laboratory study.

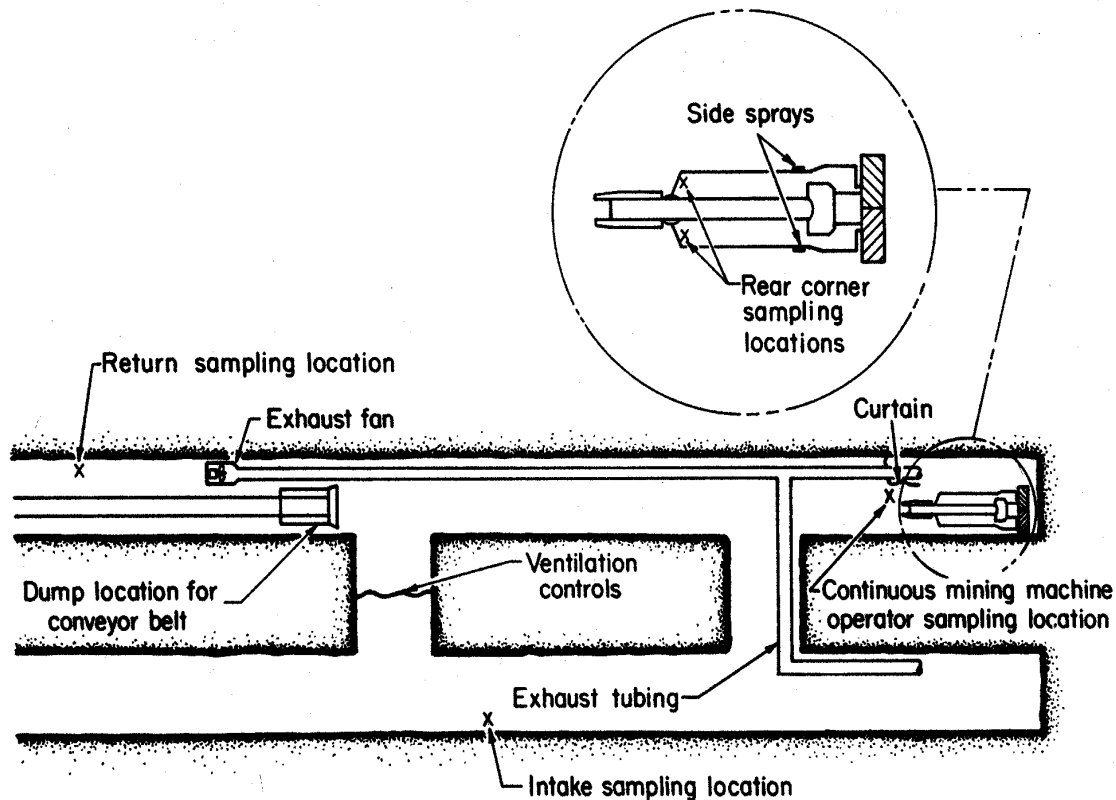


FIGURE 5

Testing arrangement—field study.

with a flooded-bed dust scrubber. The scrubber, rated at  $4.4 \text{ m}^3/\text{s}$  (9300 cfm), discharged on the left side of the machine.

This mining machine used a spray system composed of 45 hollow cone sprays positioned above, below, and along the sides of the cutting boom, in the throat and along the frame of the machine (Figure 6). Due to the large volume of water used at this operation, it was decided to place two side sprays each on the left and right sides of the continuous mining machine to confine the dust cloud under the boom. These sprays were located roughly 1.2 meters (48 inches) from the scrubber inlet (5.2 meters from the cutting bits) and 1.3 meters (52 inches) off the bottom.

Each set of sprays was mounted in a 20-cm (8-inch) block constructed from 6.4 cm (2-1/2-inch) steel stock. On each block, two spray orifices were machined approximately 15.2 cm (6 inches) apart. Due to restrictions on nozzle size at this operation, bigger water sprays were used in this phase of the study. Spraying Systems Company nozzles H3/8U-5010 rated at 6.0 lpm/nozzle (1.6 gpm/nozzle) at 689.5 kPa (100 psi) were selected. Spray pressure was 689.5 kPa (100 psi) with and without the use of these additional sprays.

Two entries (underground passages used for haulage, ventilation, or equipment movement) were developed on this section.

The rightmost was the intake airway that supplied fresh air to the miners. The leftmost entry served a dual purpose. It was not only the return entry, carrying dusty air away from the mine workers, but was also the belt entry, containing the belt conveyor that carried the coal away from the continuous mining machine. These entries were approximately 6.1 meters wide by 2.7 meters high (20 feet by 9 feet).<sup>3</sup>

Dust sampling instrumentation consisted of one RAM instantaneous dust monitor and two gravimetric samplers positioned together at the left rear and right rear corners of the continuous mining machine operator. A RAM monitor was not used at this location. The two gravimetric samplers were not worn by the operator, but were worn by a researcher who stayed within several feet of this individual. The operator typically stood away from the continuous mining machine on the left side of the entry. The gravimetric dust concentrations at each of these sampling locations were calculated using the average of the two gravimetric

<sup>3</sup>A nine-foot seam height encountered in this field work is higher than typically found in domestic underground coal mining operations. The national average seam height for current operations lies between five and six feet.<sup>(8)</sup>

dust levels. Selected filters were shipped to an independent laboratory for silica analysis using the P-7 method.

Sampling also was conducted in the return airway (leftmost airway) roughly 15.2 meters (50 feet) downwind from the exhaust fan. Preliminary data from the return sampling site showed dust levels higher than those measured at other locations. This was later determined to be caused by rock dusting in the return airway. Rock dust is routinely applied during mining to coat underground coal mine surfaces with a layer of inert material, typically limestone dust. Unfortunately, this material contains a respirable fraction that makes it difficult to discriminate between the mass deposited by mining and the mass deposited by rock dusting. For this reason, return dust levels were not used in this analysis. Also, underboom sampling could not be conducted due to harsh conditions found near the cutting head. Finally, intake dust levels were monitored during the study. These levels ranged from 0.66 mg/m<sup>3</sup> to 0.74 mg/m<sup>3</sup> (average = 0.70 mg/m<sup>3</sup>) during the study.

Due to equipment breakdowns and major production delays, only one shift of exposure data was gathered with the side sprays operating and one shift without these sprays operating. Over 320 minutes of sample time was accumulated for each of the shifts, the remainder of the time taken for travel in and out of the mine and for lunch. Dust concentrations were not adjusted

for equipment downtime because the sampling pumps could not be safely reached to shut them off. The pumps near the mining machine operator, being worn by a researcher, were shut off during equipment moves and downtimes. For this reason, sample times for the machine operator were much less (Table V).

The gravimetric samplers at the left and right rear corners of the continuous mining machine and near the mining machine operator were initially analyzed. However, tonnages were not consistent during the study, because 980 tons were produced with the additional sprays operating and 640 tons without these sprays. All gravimetric dust levels were consequently normalized to an average production of 810 tons.

At times, gravimetric dust levels showed considerable variation between adjacent samplers. Due to this and the small sample sizes, it was difficult to define meaningful confidence intervals for assessing the effects of the additional side sprays. Hence, standard deviations are shown for the collected data (Table V).

Table V shows several trends. One, dust gravimetric dust levels were much higher on the left corner of the mining machine than on the right corner. This is not surprising given that ventilation flows from the right side toward the exhaust tube on the left side. The standard deviations are also higher on the left side, likely a result of the increased turbulence on that side of the mining machine. Although the side sprays did reduce dust levels at

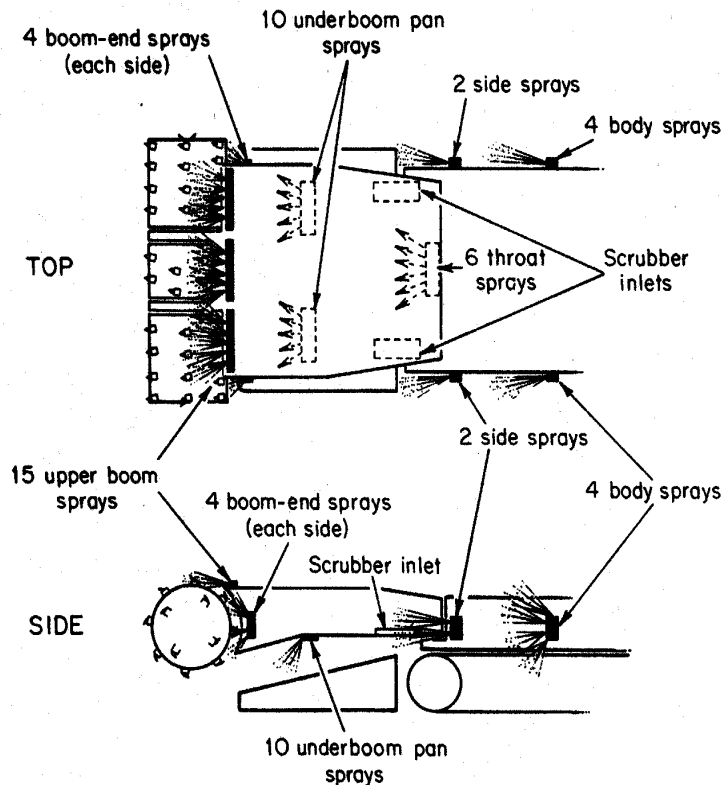


FIGURE 6  
Spray configuration—field testing.



the rear corners of the mining machine, small sample sizes did not allow analyses of statistical significance.

The effect of the sprays was more pronounced at the machine operator's sampling location where dust concentrations decreased from 2.64 mg/m<sup>3</sup> to 1.87 mg/m<sup>3</sup>. By limiting dust levels at the rear corners of the mining machine, the sprays offered increased protection of the machine operator from the high dust levels generated during the mining process.

The data in Table V also reveal that silica dust levels decreased with the use of the side sprays. Due to the limited data set, it is unclear whether the reduction was caused directly by the side sprays or by a localized geological change in the silica content of the surrounding rock. Operating at 700 kPa (100 psi), these sprays would have greater ability to control finer-sized silica particles than sprays operating at, say, 350 kPa.<sup>(10)</sup> Table V also shows that the distribution of silica dust levels across the rear of the continuous mining machine was essentially constant. The added sprays did not change this condition, although silica dust levels did decrease. Silica levels also decreased at the machine operator's sampling location. As with respirable dust levels, silica dust levels at the machine operator's location were tied to silica levels measured at the rear corners of the mining machine.

Of particular interest in this study was the effect of the added sprays on measured dust levels at various ventilation setback distances. This required the measurement of dust levels for discrete time periods corresponding to certain ventilation setback distances. The RAM monitors provided such a time-based record of dust levels at the left rear and right rear sampling locations. The ratio of average gravimetric concentration to average RAM dust level at each location provided a means to extract equivalent dust concentrations for these time periods. Multiplying this ratio by the average RAM reading for the time period in question gave a weighted gravimetric response for that period.

Time study data showed that the average curtain setback distance was roughly 9.1 meters (30 feet). Thus, the analysis

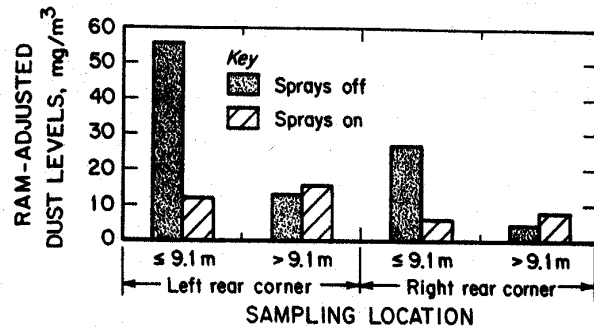


FIGURE 7

Side spray impact on average dust levels at different curtain setback distances—field study.

compared dust levels at setback distances less than or equal to 9.1 meters to those at setback distances greater than 9.1 meters. Appendix 2 gives the RAM-adjusted data collected during underground testing and shows that tonnages varied for each of the curtain setback distances. Hence, all dust levels were normalized to an average tonnage of 410 tons.

Figure 7 shows that setback distance affected side spray effectiveness. The side sprays decreased dust levels at the left and right rear sampling locations for setback distances less than or equal to 9.1 meters. For example, dust levels at the left rear corner decreased from over 50 mg/m<sup>3</sup> without the side sprays to nearly 10 mg/m<sup>3</sup> with the sprays. At the right rear corner, dust levels decreased from over 25 mg/m<sup>3</sup> to 6 mg/m<sup>3</sup> with the side sprays in operation. For setback distances greater than 9.1 meters, use of these sprays actually led to slight increases or, at the least, insignificant changes in dust levels. This suggests that, as verified by full-scale laboratory testing, the side sprays are more effective in controlling dust rollback at smaller setback distances than at larger setback distances.

TABLE V  
Gravimetric analysis of field data

| Sampling locations | Number of samples | Sample time (minutes) | Average dust concentration (standard deviation mg/m <sup>3</sup> ) | Average silica dust percentage (standard deviation) (%) |
|--------------------|-------------------|-----------------------|--|---|
| Side sprays off    |                   |                       |  |   |
| Left rear corner   | 2                 | 321                   | 9.74 (2.38)  | 20.0 (4.38)   |
| Right rear corner  | 2                 | 321                   | 4.58 (0.16)  | 23.2 (2.26)   |
| Machine operator   | 2                 | 103                   | 2.64 (0.02)  | 6.2 <sup>B</sup>  |
| Side sprays on     |                   |                       |  |   |
| Left rear corner   | 2                 | 338                   | 8.00 (0.89)  | 9.4 <sup>A</sup>  |
| Right rear corner  | 2                 | 340                   | 4.40 (0.01)  | 12.5 (0.28)   |
| Machine operator   | 2                 | 120                   | 1.86 (0.43)  | 0.7 <sup>B</sup>  |

<sup>A</sup>Due to low weight gains, two machine operator dust samples composited (combined) into a single sample for silica analysis.

<sup>B</sup>Only one sample analyzed for silica at left rear corner location. Sample dropped at analysis laboratory.

## SUMMARY

Additional water sprays were placed along the left and right sides of a continuous mining machine to improve suppression and capture of the underboom dust cloud. A full-scale mock-up of a continuous mining machine was positioned in either the sump cut or slab cut with ventilation setback distances of 6.1 meters or 12.2 meters. The test results revealed that the side sprays not only improved suppression of the underboom dust cloud, but also pushed this cloud toward the right scrubber inlet. At the smaller 6.1-meter ventilation setback distance, there was sufficient airflow along the right side of the cutting boom to keep the dust cloud from flowing out of the underboom area. Consequently, scrubber capture of this dust may have increased. At the larger 12.2-meter setback distance, the airflow dissipated along the right side of the cutting boom and dust flowed out from the cutting boom. This led to increased downwind dust levels.

These sprays were then installed on a continuous mining machine at an underground operation. Although sampling could not be conducted at the scrubber inlets or in the return, dust concentrations measured on the machine and at the mining machine operator did decrease with the use of these sprays. Further analysis showed that these sprays were more effective at the smaller setback distances, a finding confirmed by laboratory testing.

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## APPENDIX 1

Experimental data collected

| Machine position | Curtain setback (m) | Scrubber inlet dust levels (mg/m <sup>3</sup> ) |              | Machine dust levels (mg/m <sup>3</sup> ) |                   | Return dust levels (mg/m <sup>3</sup> ) |
|------------------|---------------------|---|--------------|--|-------------------|---|
|                  |                     | Left inlet                                      | Right inlet  | Left rear corner                         | Right rear corner |   |
| Side sprays off  |                     |   |              |  |                   |   |
| Sump             | 6.1                 | 13.95 ± 3.41                                    | 7.28 ± 4.31  | 3.74 ± 3.32                              | 3.05 ± 9.16       | 1.91 ± 0.27                             |
| Sump             | 12.2                | 23.22 ± 3.28                                    | 15.80 ± 1.32 | 1.24 ± 0.84                              | 1.24 ± 0.54       | 1.03 ± 0.22                             |
| Slab             | 6.1                 | 17.70 ± 1.42                                    | 6.34 ± 1.59  | 2.45 ± 0.50                              | 2.27 ± 0.45       | 1.79 ± 0.10                             |
| Slab             | 12.2                | 19.58 ± 2.31                                    | 5.51 ± 2.06  | 2.33 ± 0.40                              | 1.15 ± 0.55       | 1.73 ± 2.70                             |
| Side sprays on   |                     |   |              |  |                   |   |
| Sump             | 6.1                 | 11.03 ± 2.26                                    | 7.72 ± 9.88  | 2.33 ± 0.73                              | 1.86 ± 0.54       | 1.31 ± 0.27                             |
| Sump             | 12.2                | 16.92 ± 5.19                                    | 14.47 ± 3.08 | 1.75 ± 0.99                              | 0.74 ± 1.07       | 0.95 ± 0.35                             |
| Slab             | 6.1                 | 15.89 ± 6.47                                    | 9.96 ± 0.57  | 2.61 ± 0.84                              | 2.21 ± 0.55       | 1.30 ± 0.09                             |
| Slab             | 12.2                | 14.41 ± 3.03                                    | 13.35 ± 5.26 | 2.81 ± 0.79                              | 1.41 ± 1.24       | 1.2 ± 0.60                              |

Note: 95 percent confidence intervals shown.

**APPENDIX 2**  
RAM-adjusted dust levels from underground testing (mg/m<sup>3</sup>)

| Ventilation setback distance (m) | Left rear corner | Right rear corner | Tonnage |
|----------------------------------|------------------|-------------------|---------|
| <b>Side sprays off</b>           |                  |                   |         |
| ≤9.1 m                           | 19.5             | 6.0               | 160     |
| >9.1 m                           | 13.7             | 3.1               | 480     |
| <b>Side sprays on</b>            |                  |                   |         |
| ≤9.1 m                           | 13.9             | 5.0               | 570     |
| >9.1 m                           | 14.0             | 4.7               | 410     |