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Atomization of Water Sprays for Quartz Dust Control

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The use of water spray systems for respirable dust control on continuous mining machines has been a traditional and relatively effective approach. However, with the implementation of more stringent dust standards due to quartz, the efficacy of these systems has been questioned. In response, the Bureau of Mines, U.S. Department of Interior, has undertaken a study to determine the relationship between spray pressure, total respirable dust control, and specific quartz dust control. Laboratory and full-scale model studies have been completed in an effort to evaluate the effectiveness of low-pressure, high-pressure, and combination water spray systems.

Results of these tests indicate that high-pressure atomized sprays will improve reduction of all respirable dusts, especially dust in the 3.0- μm size range and below. These are also the size ranges that have been shown to contain the most significant amounts of airborne respirable quartz dust. Improved control techniques, such as those presented in this article, may be required in mine sections where more stringent dust standards are in effect. Jayaraman, N.I.; Jankowski, R.A.: *Atomization of Water Sprays for Quartz Dust Control*. *Appl. Ind. Hyg.* 3:327-331; 1988.

Introduction

The current method of dust suppression in coal mines is based on the use of conventional water sprays mounted on mining machines and generally operating at about 518 to 1380 kPa (75 to 200 psi). The spray systems vary from mine to mine and from machine to machine with respect to differences in the number, type, and location of nozzles.⁽¹⁾ The dust reduction efficiencies at the machine operator locations also vary. For any spray system, efficiency depends on the water flow and pressure, together with coverage and orientation of nozzles. Because most water spray systems adequately suppress dust, most coal mines are in compliance with the 2-mg/m³ standard for respirable dust exposure. However, there are hundreds of coal mine sections that must comply with more stringent dust standards due to respirable quartz. Therefore, it is preferable to develop spray systems that are more effective than the conventional spray systems in suppressing respirable quartz dust and thus reduce the quartz dust exposure of face workers.

The respirable dust suppression spray system acts in three ways:⁽²⁾

- By wetting the surface of broken coal to prevent the dust

from becoming airborne.

- By controlling the air flow pattern at and near the face to minimize dust roll back to the operator's position.
- By dust knockdown; i.e., airborne capture or scrubbing of airborne dust from the air.

This investigation was concerned with airborne capture only and related to the atomization of water sprays for quartz dust control.

To achieve the objective of differential dust control, a knowledge of the source and character of respirable quartz mine dust is necessary. Taylor *et al*⁽³⁾ indicate that the major source of quartz is the continuous miner cutting the roof, floor, or middleman (a rock band in the middle of the coal seam). Stobbe *et al*⁽⁴⁾ have investigated dust from the return of continuous miner face for size fractions. The results indicate that the size of about 40 percent of the respirable quartz dust is between 1 and 3.5 μm .

The probability of knocking down the smaller fractions of respirable dust particles increases as the size of the water droplets decreases and as the speed of the droplets increases. However, compared with the larger droplets, the smaller droplets decelerate faster to their falling speed in air. The use of a multiple number of high-pressure sprays to effect high-velocity droplets can result in such excessive air movement that sometimes more dust is dispersed by such sprays than is captured by the droplets.⁽⁵⁾ The results indicate, however, that an optimum combination of high water pressure and number of nozzles can result in high dust knockdown efficiencies.

While testing conventional nozzles in a full-scale model mine, best airborne capture results were obtained with four Spraying Systems BD-3 nozzles placed under the boom operating at 2,760 kPa (400 psi). Total respirable dust reduction was greater than 60 percent in the face return when compared with dry testing. This result directed Bureau of Mines researchers to evaluate an underboom spray system using a minimum number of nozzles and pressures of about 17,250 kPa (2,500 psi). The system was installed symmetrically in order to obtain the best antirollback performance, and tests were executed with a "conventional" front spray bar arranged with a total system flow of about 1.26 L/sec (20 g/min). This article describes a full-scale model study as well as tests in a cubical dust box with 1.8-m (6-ft) sides.

Reference to specific equipment does not imply endorsement by the Bureau of Mines.

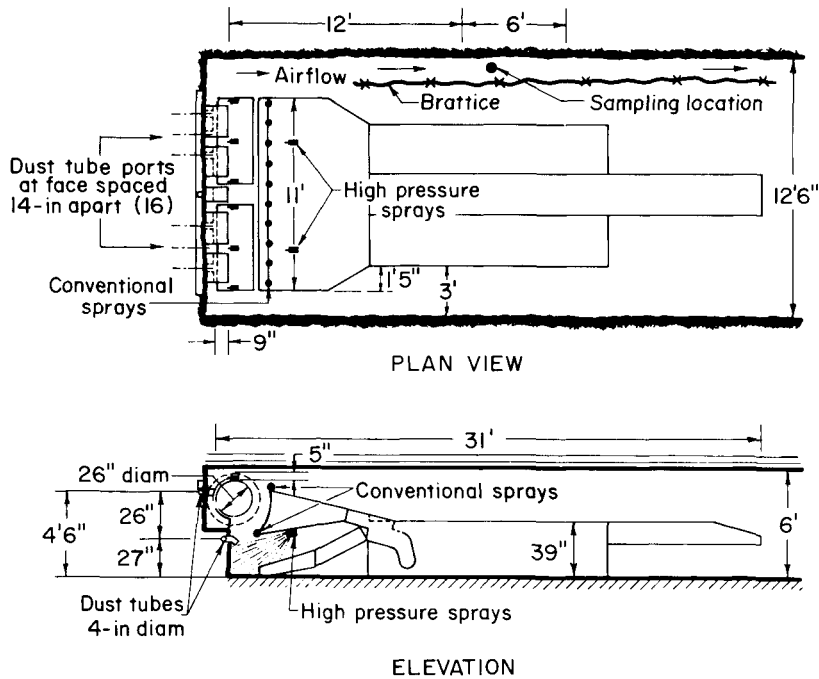


FIGURE 1. Spray installation in a full-scale model entry.

Bruceton Test Facility and Procedure

The full-scale model facility at Bruceton, PA, has been used in the past⁽⁶⁾ to simulate dust control techniques in underground coal mines. Foster Miller, Inc., under a contract with Bureau of Mines, has used the model mine entry to evaluate the effects of continuous miner sprays on dust rollback and airborne dust knockdown. The following sections describe the test facility, test methods, and results.

Facilities and Equipment

Tests were conducted with a full-scale wooden mockup of a Joy 12CM continuous miner in a 4.2-m (14-ft) wide × 1.8-m (6-ft) high entry. The rotating cutter head was in a sump position to a depth of one-half the drum diameter at the top of the entry (Figure 1). Air flow to the entry was provided by a 2,350-L/sec (5,000-cfm) fan. Plain brattice was hung from the roof at a distance of 75 cm (30 in.) from one side. Minus 200-mesh Pittsburgh seam coal dust was supplied by a screw-type feeder and discharged by a 94-L/sec (200-cfm) centrifugal fan at the front of the model entry.⁽⁷⁾ Tubes 10 cm (4 in.) in diameter conveyed the dusty air to the recess in front of the cutting drum. The dust feed rate was 1600 g/hr.

Dust Suppression System

Spraying Systems Type 104 (tungsten carbide) nozzles appeared to be good test nozzles because of their antiabrasive quality at high water pressures. Each nozzle discharged 0.08 L/sec (1.4 g/min) at 17,250 kPa (2,500 psi). The two nozzles were centrally located, as shown in Figure 1, under the boom (about 0.6 m [2 ft] from each other) and directed so that the spray cone just touched the underboom surface when aimed directly at the face. The nozzles were placed 0.9 m (3 ft) from the front bottom edge of the boom.

A positive-displacement, piston-type pump coupled with a pressure regulator provided the required 17,250 kPa (2,500-psi) pressure. However, the volumetric capacity of the pump was low at 0.21 L/sec (3.5 g/min). The nozzles were connected to the pump

through a flexible hose of 1.25-cm (0.5-in.) internal diameter that had been reinforced to handle the high pressures. A firm mounting was required to maintain the desired orientation of the spray, even though undue vibration of the nozzle was not noticed.

Sampling Procedure

The face layout with sampling and nozzle locations is shown in Figure 1. Sampling instrumentation consisted of two real-time aerosol monitors (RAM-1) placed at two heights, 0.6 and 1.2 m (2 and 4 ft), in the face return with 10-mm nylon cyclones for size classification to the respirable range.

The dust generator together with the fan dispersed the dust in the face area of the full-scale model. A series of seven 2-min continuous dust samples was taken in the return, four with sprays off and three with sprays on. Wet and dry readings were then averaged, and the efficiency of the nozzle arrangement was cal-

TABLE I. Dust Concentrations for Dry and Wet Tests and Percentage Reduction (air flow = 4,500 cfm)

Type of Sprays (water flow in g/min)	Dry Concentration mg/m ³	Wet Concentration mg/m ³	Reduction % Dry-wet Dry
2 High-pressure sprays only (2,500 psi and 2.8 g/min)	16.60	11.35	30.26
	16.70	11.35	
	17.45	13.40	
	18.25	—	
20 conventional nozzles (100 psi and 18.8 g/min)	17.25	12.03	29.89
	19.00	13.55	
	19.55	13.70	
	18.45	12.70	
Conventional and high pressure combined 21.6 g/min)	19.00	13.32	58.50
	19.45	7.90	
	20.10	8.35	
	19.85	8.60	
	20.40	—	
	19.95	8.28	

culated. The dust reduction, R, of a spray system relative to a dry system is given by

$$R = (1 - W/D) \times 100\%$$

where: W and D represent the total respirable dust measured behind the brattice when water sprays were used and not used, respectively.

Analysis of results

Results are given in Table I. It is apparent from the table that the conventional sprays and high pressures are equally effective in knocking down the respirable dust when they are applied independently of each other. In other words, 20 Spraying Systems BD-3 nozzles discharging 1.13 L/sec (18.8 g/min) of water at 690 kPa (100 psi) knocked down the same proportion of the dust cloud as did two nozzles discharging 0.17 L/sec (2.8 g/min) of water at 17,250 kPa (2,500 psi). An even more dramatic result occurred when they were operated together. They almost doubled the knockdown percentage of each of the systems acting separately. The superior effectiveness of high-pressure sprays lies in the velocity and atomization of the water droplets. The smaller and faster the droplets, the more efficient they are in knocking down the respirable dust. No attempt was made, however, to determine the droplet sizes or the velocity for the high-pressure sprays. Visual inspection of the face return showed no significant fogging during the combined test, indicating that the conventional sprays helped to agglomerate and remove the fine water droplets. To understand the effect of droplet atomization on dust particles of different sizes in the respirable range, a series of tests was conducted in a dust box.

Experimental Procedure for Dust Box Tests

Tests were performed in a cubical box with 1.8-m (6-ft) sides. Figure 2 shows the components for the experimental setup. A screw feed picked up the dust from a vibrating hopper and injected it into an airstream coming into the dust box. The dust blower at the top and exhaust fan at the bottom produced a total air flow of 59 L/sec (125 cfm) through the box. The water spray was located at the top of the box, pointing downward. The conventional nozzle was operated at approximately 690 kPa (100 psi) and the high-pressure nozzle at 17,250 kPa (2,500 psi). The water flow was 0.09 L/sec (1.5 g/min) for the conventional nozzle and

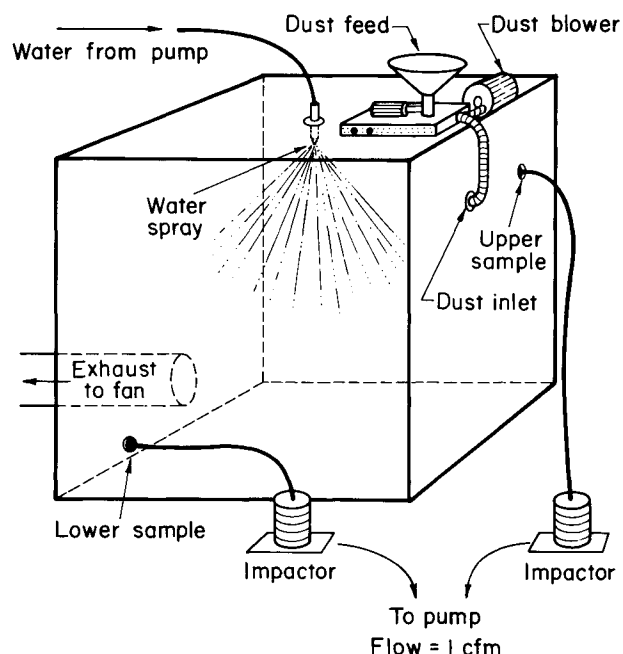


FIGURE 2. Experimental dust box setup for spray evaluation.

0.88 L/sec (1.35 g/min) for the high-pressure nozzle. A mixture of dust containing 95.7 percent coal dust and 4.3 percent quartz dust was fed into the box. The particle size distribution for the dust feed is given in Table II. The dust feed rate was set at 150 g/hr. Dust was sampled with Andersen Cascade Impactors operating at 0.47 L/sec (1 cfm). The 3/8-in. diameter entrance to the Andersen impactor was joined to 1-in. diameter tube with a 90 degree bend and 17.5-cm (7-in.) radius of curvature.

Mean aerodynamic particle sizes collected on the various impactor stages were modified to include particle density of 1.3. A test involved dust sampling during a dry run and then, after installing fresh collector paper, dust sampling during a wet run.

Experimental Results

The efficiencies of the two spray systems in reducing the respirable dust measured on stages 0 to 5 of Andersen impactor are summarized in (Figure 3). Efficiency values were calculated in

TABLE II. Results of Sub-sieve Particle Size Analysis on Bureau of Mines Samples

Size (μm)	Cumulative Volume % Greater than Indicated Size		Size Range (μm)	Differential Volume % in Indicated Size Range	
	Quartz Dust	Coal Dust		Quartz Dust	Coal Dust
0.794	(100.0)	(100.0)	0.794 - 1.00	1.1	0.7
1.00	100.0	100.0	1.00 - 1.26	1.7	1.0
1.26	98.2	99.3	1.26 - 1.59	2.5	1.4
1.59	95.8	98.0	1.59 - 2.00	4.2	1.9
2.00	91.6	96.0	2.00 - 2.52	6.2	2.9
2.52	85.5	93.1	2.52 - 3.17	7.8	3.6
3.17	77.7	89.5	3.17 - 4.00	9.2	4.2
4.00	68.5	85.3	4.00 - 5.04	11.8	5.2
5.04	56.8	80.0	5.04 - 6.35	14.6	7.1
6.35	42.2	73.0	6.35 - 8.00	14.6	9.0
8.00	27.5	64.0	8.00 - 10.08	14.0	10.3
10.08	13.5	53.7	10.08 - 12.7	10.0	12.1
12.7	3.3	41.6	12.7 - 16.0	2.8	17.3
16.0	0.4	24.2	16.0 - 20.2	0.4	13.6
20.2	0.0	10.5	20.2 - 25.4	0.0	10.6

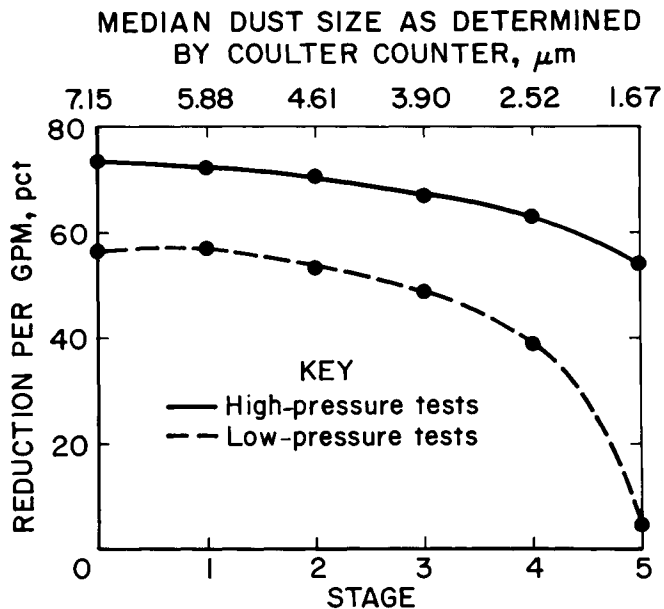


FIGURE 3. Reduction efficiencies for high-pressure and low-pressure sprays.

the same manner as full-scale model tests. The average dust reduction per gram per minute of water flow, for low-pressure testing, was 43 percent in stages 0 to 5. The efficiency of high-pressure sprays, on the other hand, was 67 percent in the same size range. This shows that the high-pressure spray is 56 percent superior to the low-pressure spray in respirable dust knockdown under the conditions tested. Stages 3 to 5 show a reduction of 61 percent for high pressure and 31 percent for low pressure. Thus, there is a 97 percent gain in dust knockdown for 3.90- μm size and below by switching from low pressure to high pressure.

If the high-pressure spray is superior in total dust knockdown, how does the dust collected on the impaction stages fare with respect to size distributions? Figure 4 shows the difference. The median particle size of the size distribution was calculated from the total mass of collected dust. Andersen sampling showed that the median sizes were 4.6 μm for dry runs, 3.4 μm for low-

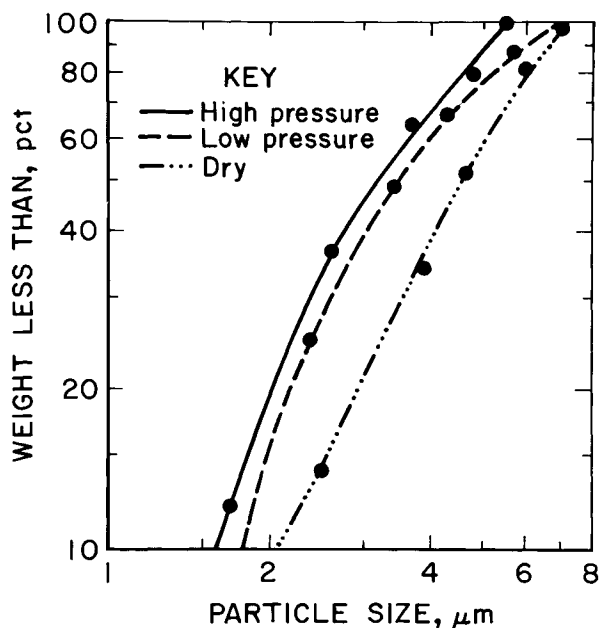


FIGURE 4. Effect of spray pressure on median size of residual dust.

pressure spray, and 3.1 μm for high-pressure spray. The significance of these median values can be explained as follows:

1. To bring the median value down from 4.6 to 3.4 μm , a greater percent of dust sizes larger than the 3.4- μm size will have to be suppressed.
2. Similarly, for the high-pressure spray to bring the median value down to 3.1 μm , a greater percent of dust sizes larger than 3.1 μm will have to be suppressed.

All in all, as the spray pressure increases, the median size of the dust collected on impactor plates decreases.

Quartz Content in Dust Samples

A p-7 method of analysis⁽⁸⁾ was made for quartz percentage in each of the stages of the Andersen impactor. Percent reduction was also calculated just for the respirable quartz fraction. The results of a low-pressure test show that the reduction percentage was a high of 74 for 5.8- μm particles and a low of 48 for 1.8- μm particles. The results of the high and low pressure combined tests show that the values are nearer 90 percent for the top size and 78 percent for smallest size (Figure 5).

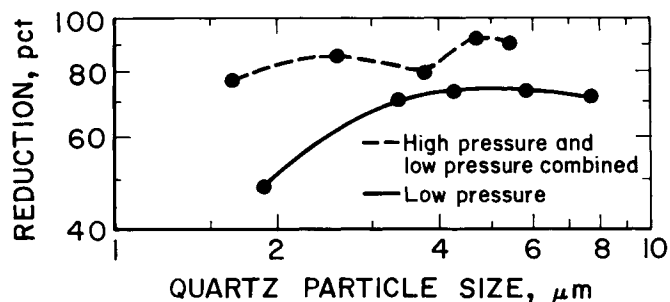


FIGURE 5. Reduction efficiency for quartz dust with two different spray systems.

Conclusions/Recommendation

An improved spray method has been identified and tested under controlled conditions for respirable dust control. The results of these tests indicate that the use of atomized sprays will improve the dust reduction of all respirable dust including quartz dust. The most pronounced increase in dust reduction was in the 2.89- μm range and below. Percent reduction can be more than doubled for 1.8- μm particles by the addition of a high-pressure spray to a low-pressure spray in a dust box. Improved dust control techniques like these are required in mining sections where more stringent dust standards are in effect. Additional research is needed under actual underground conditions to study the effects of atomization of sprays, as well as the location and number of nozzles.

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Errata Notice

The article, "Solid Sorbent Media for Collection of Formaldehyde in Air" by Reimar R. W. Gaertner (*Appl. Ind. Hyg.* 3(9):258-262, 1988) contains an error. Under the "Experimental" section on page 259, the third sentence should read:

"The 13X molecular sieves 45/60 mesh (lot 533281) and ORBO-53 silica gel tubes 400/200 mg (lot 557-15), Custom ORBO tubes with 5%, 10%, and 20% bisulfite on silica gel 300/150 mg (lot 528-87) were purchased from Supelco Inc. The 150/75 mg silica gel tubes 226-10 (lot 300) were purchased from SKC Inc."

We regret any inconvenience this omission may have caused.