Optimal Spray System Designs for Continuous Miner Dust Control

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Abstract

Water sprays are the most widely-used technology in the coal mining industry for limiting worker exposure to respirable dust. They control exposure by suppressing airborne dust, influencing airflow patterns to keep personnel in clean air, and wetting coal surfaces to prevent airborne dust generation. Optimal spray system design depends upon the proper balance of these three mechanisms.

Worker exposures to coal and silica dusts have been reduced by water sprays strategically mounted on the continuous mining machine. These sprays have been placed above and below the cutting boom, in the loading shovel, and along the sides of the continuous miner. When a flooded-bed type scrubber is used for dust control, sprays must be used with caution to avoid inducing airflow beneath the cutting boom which can result in decreased scrubber efficiency. In practice, water sprays have been positioned near the scrubber inlets to contain the dust cloud beneath the cutting boom, thus improving capture of the dust. A high level of effectiveness has been attained in continuous miner dust control, although serious non-compliance can result from the improper application of water spray technology. This paper summarizes past research plus laboratory and in-mine studies with water sprays for effective continuous miner dust control

Key Words: coal mining, industrial hygiene, water sprays, occupational exposure

Introduction

The United States Federal Coal Mine Health and Safety Act limits personal exposure to respirable dust to 2.0 mg/m^3. This limit is measured gravimetrically as an 8-hour TWA concentration of the respirable coal dust [4]. If the respirable dust sample contains more than 5 percent silica by weight, the respirable dust standard is reduced according to the formula 10/(% silica). The 2 mg/m^3 standard and a silica percentage of 5% corresponds to a PEL for silica of 0.10 mg/m^3. The National Institute for Occupational Safety and Health (NIOSH) recommended lower limits for respirable silica and coal dusts. It endorsed a recommended exposure limit (REL) for coal dust of 1.0 mg/m^3. The current NIOSH REL for respirable silica is 0.05 mg/m^3. Both RELs are measured as TWA dust concentrations for up to 10 hours/day during a 40 hour work week [5].

Because the continuous mining machine operator is located on or near the continuous mining machine, this person is frequently exposed to the greatest levels of respirable dust. Of all continuous miner operator samples taken in the years 1988 through 1991, nearly 40% of those analyzed contained more than 5% respirable silica dust [1]. Approximately 11% of the continuous miner operator samples exceeded the PEL of 2.0 mg/m^3 for respirable coal dust.

Water sprays remain the most widely used technology for limiting operator exposure to respirable dust. Water sprays control dust exposure by suppressing airborne dust, inducing airflow to keep personnel in fresh air, and preventing generation of airborne dust.

Mechanisms for Controlling Dust Exposures With Water Sprays

Water sprays control dust exposure by suppressing airborne dust. Prior work evaluated the effects of spray nozzle design (i.e. flat fan, hollow-cone, *full*-cone), water flowrate, and pressure on the ability to suppress airborne dust [3]. Flat fan sprays and hollow-cone sprays are superior for suppression of airborne dust. Full cone sprays are least effective for dust suppression.

Dust suppression increases with the flowrate of water through the spray nozzle. Doubling the flowrate results in a nearly four-fold improvement in suppression. Although suppression also is proportional to spray pressure, the optimal pressure is 690 kPa (100 psi). Generally, dust suppression is best for sprays operating at higher flowrates and pressures of 690 kPa (100 psi).

Water sprays also control dust exposure by inducing airflow patterns to reduce dust exposure for the mining machine operator. However, these sprays must be oriented with the face ventilation airflow to avoid turbulence that can increase dust rollback. Rollback occurs with the use of a poorly designed spray system. Because water sprays can be effective air movers, improper use of sprays can produce unwanted motion of the dust cloud. If ventilation airflow at the face is low, the water sprays can overpower the ventilation and drive the dust cloud from the cutting bits back to the continuous mining machine operator.

Water pressure and spray flowrate affect the ability of sprays to induce airflow [2]. Induced airflow levels increase as spray pressure and flowrate increase. However, water sprays are most effective for inducing airflow when operated at lower flowrates and higher pressures. Spray type (i.e. full-cone, hollow- cone, or flat fan) does not significantly influence spray performance.

Finally, water sprays control dust exposure by wetting the surface of the coal to prevent airborne dust generation. To be effective, however, water sprays should be positioned as close as possible to the dust source. Sprays placed closer to a dust source provide improved wetting of the coal surfaces than sprays placed farther from the source. Water sprays positioned closer to a dust source also move less air than sprays located farther away. Thus, sprays placed close to the dust source improve surface wetting while reducing the chance that spray-induced airflow will stir or disperse the dust cloud.

Anti-Rollback Sprays

The anti-rollback spray system provided adequate dust suppression while reducing dust rollback. This system consists of a top spray bar containing 15 to 25 flat fan sprays with the spray pattern oriented parallel to the top of the cutting drum (figure 1). These flat sprays operate at a pressure of approximately 690 kPa (100 psi) and a corresponding flowrate of 3.6 liters/min (0.95 gpm) per spray. Dust rollback is reduced because the spray droplets move only a short distance before impacting on the top of the cutting drum. According to the design principles outlined earlier, the short spray distance reduces the potential for dust rollback by reducing the air movement caused by these sprays. The short distance also increases coal surface wetting capabilities.

The anti-rollback system also includes two large orifice, deluge-type, flat fan sprays mounted on the left and right underside of the boom near the cutting head. Each spray is oriented 30 degrees below horizontal and directed to spray into the cutting bits. Deluge-type sprays are used because they operate at a low pressure of roughly 48 kPa (7 psi) and a higher flow rate of

18.9 liters/min (5 gpm) per spray. Because these underboom sprays operate under low pressure, dust rollback is reduced. The high flowrate offered by these large orifice sprays improves the suppression of dust coming off the cutting drum.

This spray system was installed on a continuous miner for in-mine testing. The results showed that the anti-rollback sprays reduced machine operator dust exposure by 40% [2].

Shovel Sprays

Additional sprays have been installed to improve dust control in the underboom area. Two hollow cone sprays are located at the rear corner of the shovel on the side opposite from the ventilation curtain (figure 2). These sprays are used with exhaust ventilation only. Each spray operates at a pressure of 1206 kPa (175 psi) with a flowrate of roughly 8.5 liters/min (2.3 gpm). Due to the high spray pressure and high flowrate, these sprays induces significant airflow beneath the cutting boom. This not only sweeps the underboom dust into the return airway, but also improves suppression of this dust.

Extensive underground testing of the shovel sprays showed that reductions of 60% were measured at the continuous miner operator's location. Subsequent analyses showed that these shovel sprays also were quite effective in controlling respirable silica dust produced by the continuous miner [2]. In fact, silica dust levels at the operator's location were virtually eliminated. The anti-rollback sprays, with the shovel sprays, are an effective means of reducing respirable dust exposure for the mining machine operator.

Two Phase Sprays

Subsequent work examined the use of two-phase sprays for limiting exposures to respirable dust [4]. Two-phase sprays use a combination of water and air issuing from the same spray. This results in a discharge of fine mist from the spray rather than a discharge of water. In testing, the spray mist was found to have excellent airmoving capabilities and, as such, were placed on the shovel of the mining machine to sweep dust from the region under the cutting head.

For this work, two different shovel spray arrangements were tested. The first configuration mounted four two-phase sprays on the right side of the shovel while the second configuration mounted two sprays at the same location. All two-phase sprays used a water pressure of 228 kPa (33 psi) and an air pressure of 241 kPa (35 psi). The sprays were oriented to sweep dust-laden air away from the machine operator. Each shovel spray arrangement contained eighteen hollow-cone sprays mounted above the cutting head. The resulting dust levels measured with these two shovel spray configurations were compared to a baseline dust level obtained with the eighteen hollow-cone sprays in operation and no shovel sprays.

Dust levels were reduced more than 90% at the operator's location with use of either shovel spray configuration. Most surprisingly, these reductions were achieved with two-phase sprays using 63 percent less water than conventional water sprays. Although two-phase sprays do require an air supply to the continuous mining machine, they represent a dust control alternative for coal mining operations concerned with high water usage.

Scrubber Blocking Sprays

Flooded-bed dust scrubbers consist of a fan, wetted filter, and wave plate mist eliminator. Dusty air is drawn by a fan through a series of inlets near the cutting head. This airflow then passes through the wetted filter where the dust is captured on the filter. The excess moisture is removed as the airflow passes through the wave plate mist eliminator (figure 3). Dust scrubbers operate most efficiently when the dust cloud is contained beneath the cutting boom. If the dust cloud rolls out from under the cutting boom, it becomes very difficult to capture with a scrubber. Water sprays, therefore, must be located to provide adequate dust suppression and coal surface wetting without inducing significant airflow under the cutting boom.

Water sprays placed on the left and right sides of the cutting boom can increase containment of the dust cloud under the boom and thus improve the capture of this dust by the scrubber. This, in turn, reduces both dust rollback and dust exposure for the machine operator. These sprays were tested at an underground operation. One manifold, each containing two flat fan sprays, was mounted on each side of the continuous miner, near the scrubber inlets (figure 4). Sprays were selected to deliver 6.1 liters/min (1.6 gpm). Due to restrictions in the mine water supply system, spray pressure was limited to 690 kPa (100 psi).

Dust levels were measured at the continuous miner operator location with and without the side sprays in operation. Despite the lack of water pressure during testing, coal and silica dust levels decreased, although these reductions were marginal in some instances. It is likely that the decreases in dust concentrations arose from a combination of improved suppression and improved capture by the dust scrubber.

Summary

Continuous miner dust control technology currently exhibits a high level of effectiveness for controlling personal dust exposures. Water sprays represent the most widely used technique for limiting worker exposure to respirable coal and silica dusts. Water sprays control exposures by suppressing airborne dust, inducing air movement to sweep dust away from personnel, and wetting the surface of the coal to prevent airborne dust generation. Spray system designs to limit dust exposures make frequent use of these principles.

For instance, the anti-rollback spray system places low pressure and high flowrate sprays above and below the cutting boom to improve dust suppression and surface wetting. The top sprays are positioned close to the cutting head to reduce airflow movement and limit dust rollback to machine operator.

Additional sprays often are located in the shovel to induce additional airflow movement under the cutting head. This sweeps dust-laden air from beneath the cutting head area and directs it away from the machine operator. These sprays operate at higher pressure and lower flow rate. Two-phase sprays, using a combination of air and water in the same spray, also have been located in the shovel.

Because water sprays are effective air movers, they must be used to maximize dust suppression and surface wetting without inducing significant airflow movement. Application of water spray technology to continuous miners with a dust scrubber includes the location of flat fan sprays on either side of the cutting boom. They induce airflow along the sides of the cutting boom to improve containment of the dust cloud under the boom.

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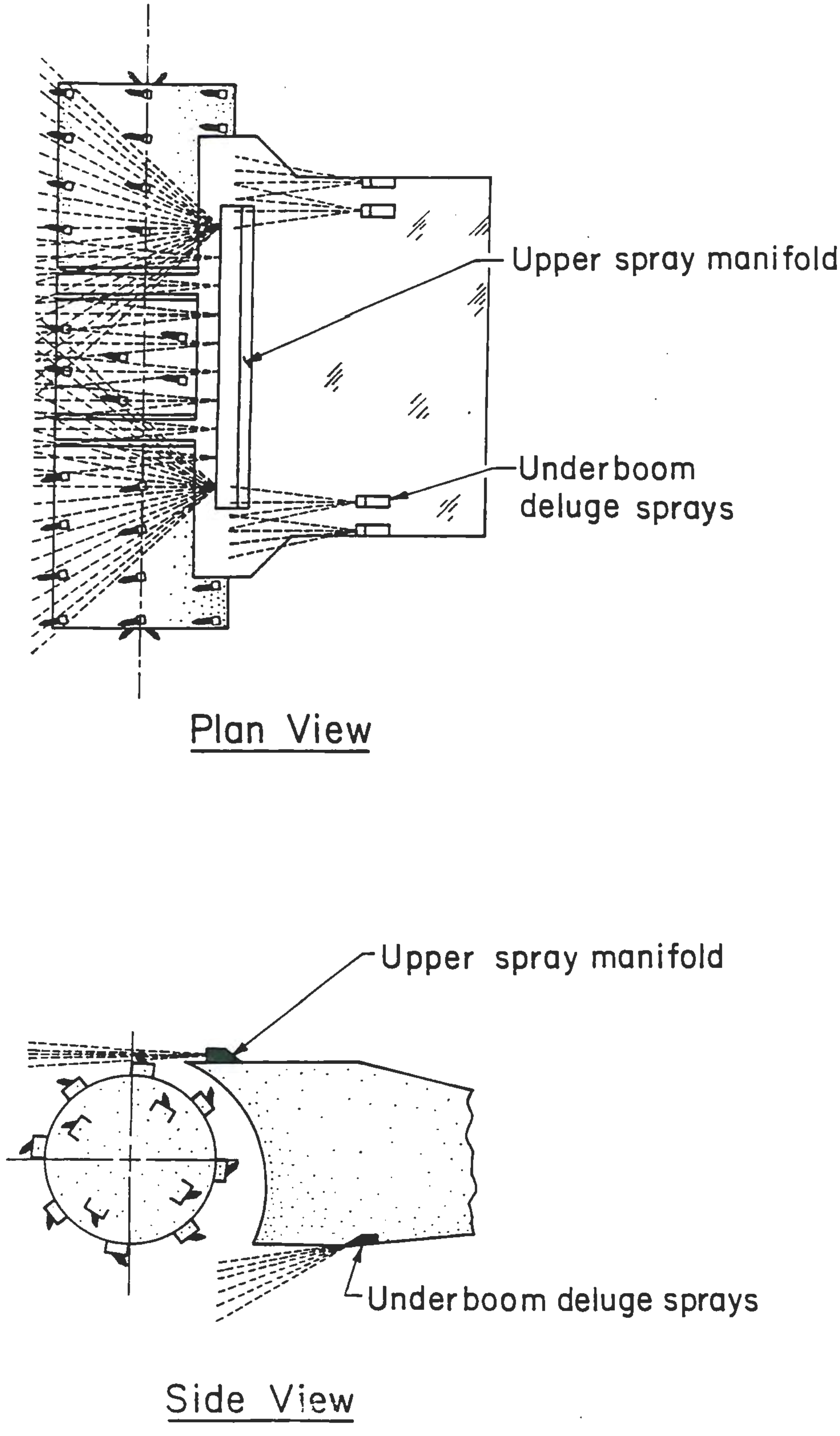

Figure 1. Diagram of Anti-Rollback Sprays

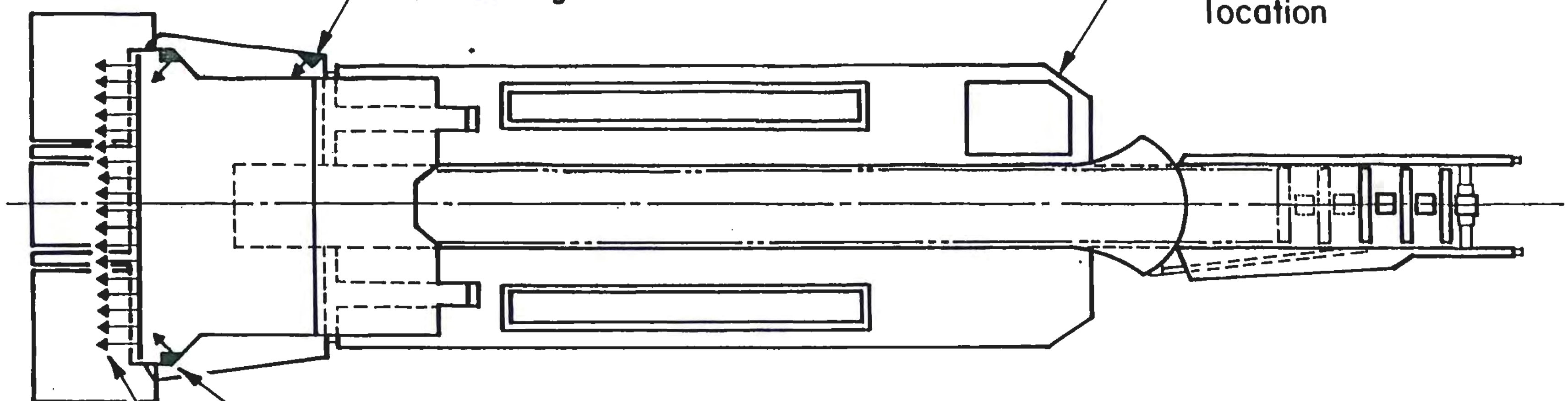

Figure 2. Diagram of Shovel Sprays

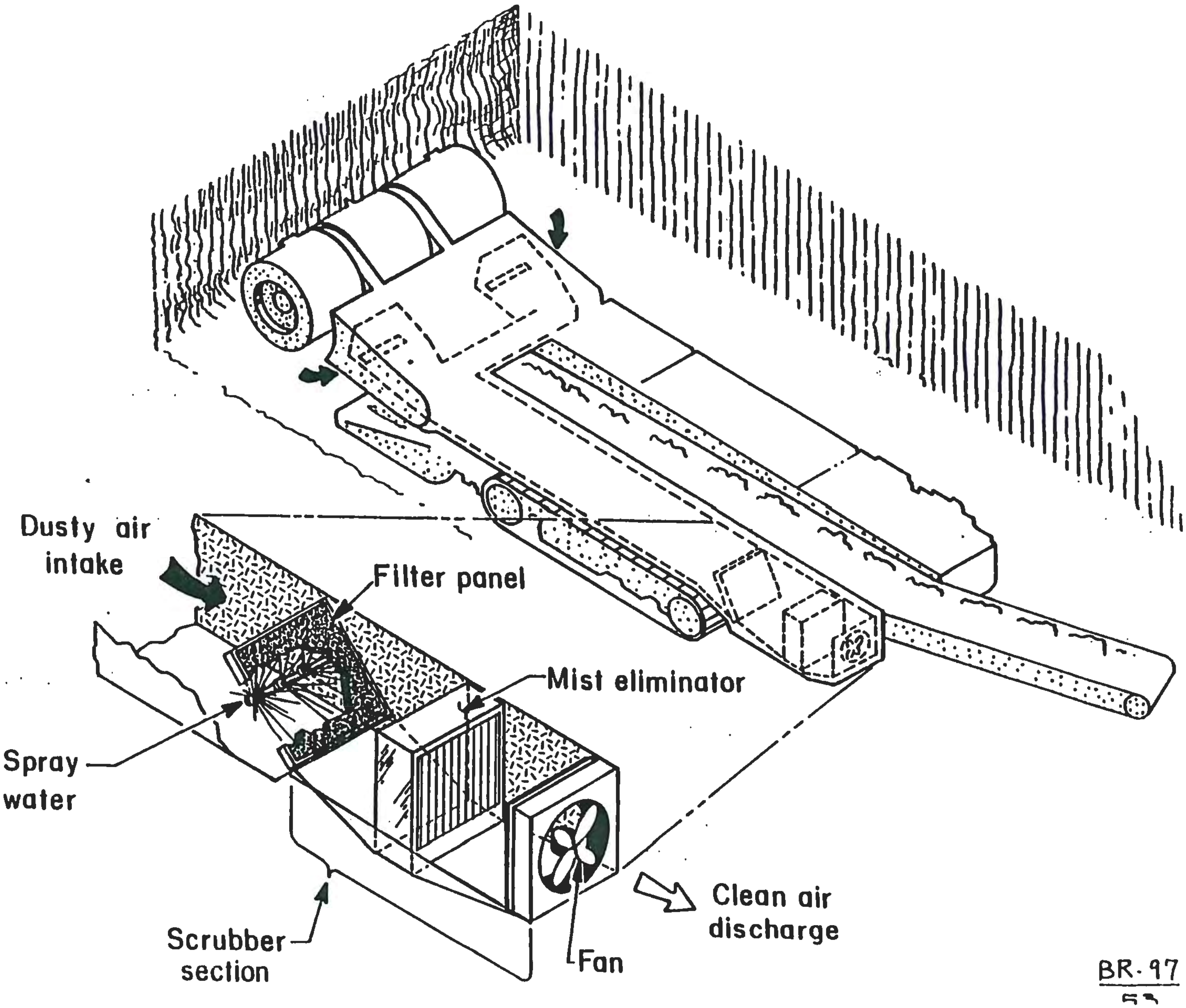

Figure 3. Details of Flooded-Best Dust Scrubber.

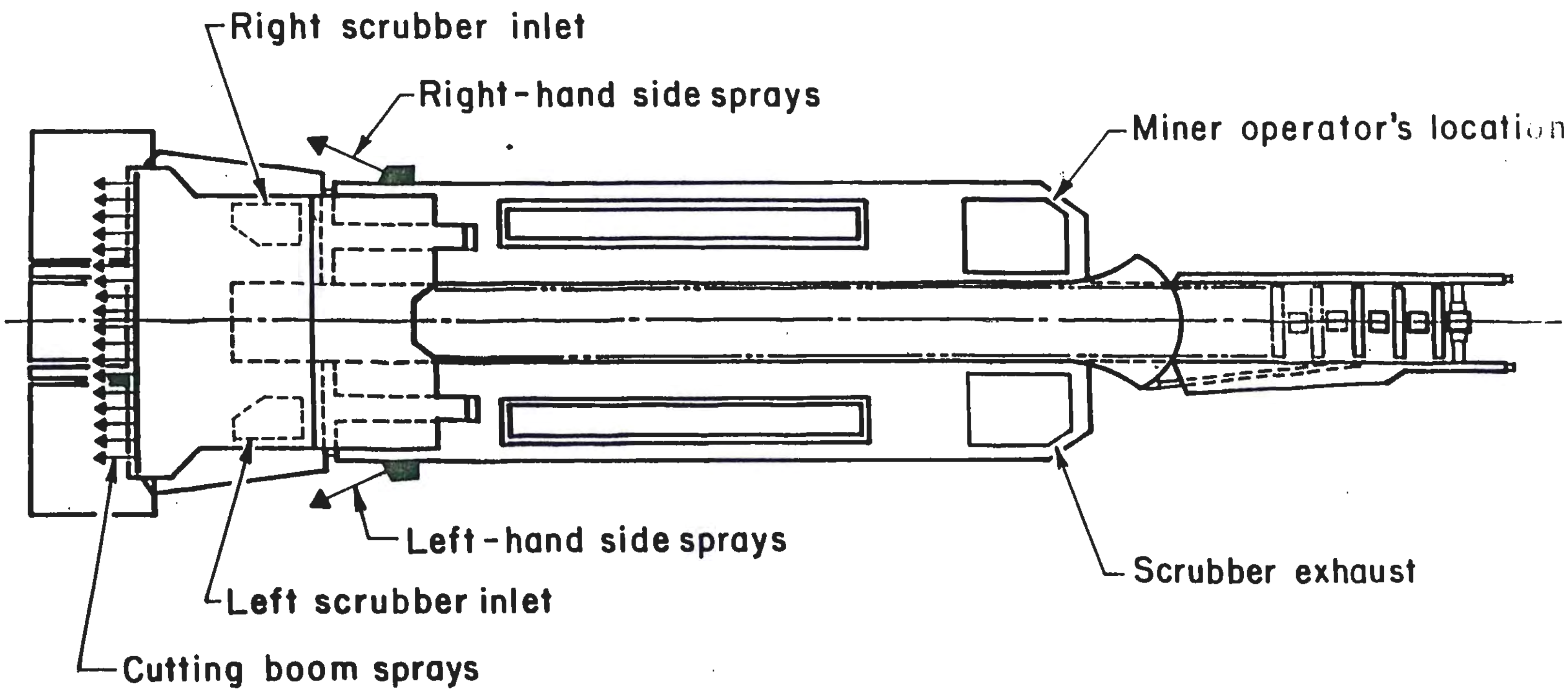

Figure 4. Diagram of Scrubber Blocking Sprays

Advances in the Prevention of Occupational Respiratory Diseases

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