

NIOSH Research for Controlling Respirable Dust and
Methane Gas on Continuous Miner Faces

by

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ABSTRACT

The importance of controlling respirable dust and methane gas levels in underground coal mining cannot be underestimated. While respirable dust can significantly affect the occupational health of underground coal miners, methane gas accumulations pose significant safety concerns for these same workers. Water sprays and machine mounted dust scrubbers offer effective control of respirable dust exposures and methane gas accumulations. Water must not only be applied carefully to avoid dust rollback to the machine operator but must create sufficient turbulence to remove dead zones that could contain high concentrations of methane gas. While the flooded-bed dust scrubber has been generally responsible for decreased worker exposures to respirable dusts, this device has proved effective in controlling methane levels at the face. This paper reviews practical applications of water sprays and dust scrubbers to control respirable dust and methane gas on continuous miner faces.

NIOSH RESEARCH TO CONTROL RESPIRABLE DUST EXPOSURES

The United States Federal Coal Mine Health and Safety Act of 1969 limits personal exposure to respirable dust to $2,0 \text{ mg/m}^3$. This limit is measured gravimetrically as an 8-hour time weighted average concentration of the respirable coal dust¹. If the respirable dust sample contains more than five percent silica by weight, the respirable dust standard is reduced according to the formula $10 \div (\text{percent silica})$. The 2 mg/m^3 standard with a silica percentage of five percent corresponds to a personal exposure limit for silica of $100 \text{ }\mu\text{g/m}^3$. Because the continuous miner operator is on or near the continuous mining machine, this person is frequently exposed to the greatest levels of respirable dust. In the years 1988 through 1991, nearly forty percent of the continuous miner operator samples analyzed contained more than five percent respirable silica dust². Approximately eleven percent of the continuous miner operator samples exceeded the Federal dust standard of $2,0 \text{ mg/m}^3$. Thirty percent of these samples exceeded $100 \text{ }\mu\text{g/m}^3$ of silica.

Water sprays remain the most widely used technology for limiting exposures to respirable dust. Water sprays control dust exposure by suppressing airborne dust, inducing airflow to drive dust clouds away from personnel, and preventing generation of airborne dust³. Much research by NIOSH and its predecessor, the U.S. Bureau of Mines, dealt with balancing these attributes to provide effective control of respirable coal and silica dusts.

The earliest water sprays on a continuous miner were used for bit lubrication, bit cooling, and dust control. Although these sprays controlled respirable dust exposure to a limited extent, they created large quantities of dust rollback.

To control rollback, sprays were situated atop and beneath the cutting drum (figure 1). The sprays operated at a pressure of approximately 690 kPa and a flow rate of 3,6 liters/min per spray. Two large orifice, deluge-type, sprays were mounted on the left and right underside of the boom and directed to spray into the cutting bits. These sprays operated at a low pressure of roughly 48 kPa and a higher flow rate of 18,9 lpm per spray⁴. Dust rollback decreased because the spray droplets moved only a short distance before impacting on the cutting bits. The short distance also increased coal surface wetting capabilities while minimizing turbulence. In-mine evaluations of these boom sprays showed that miner operator dust exposures were reduced forty percent compared to the factory-issued spray system.

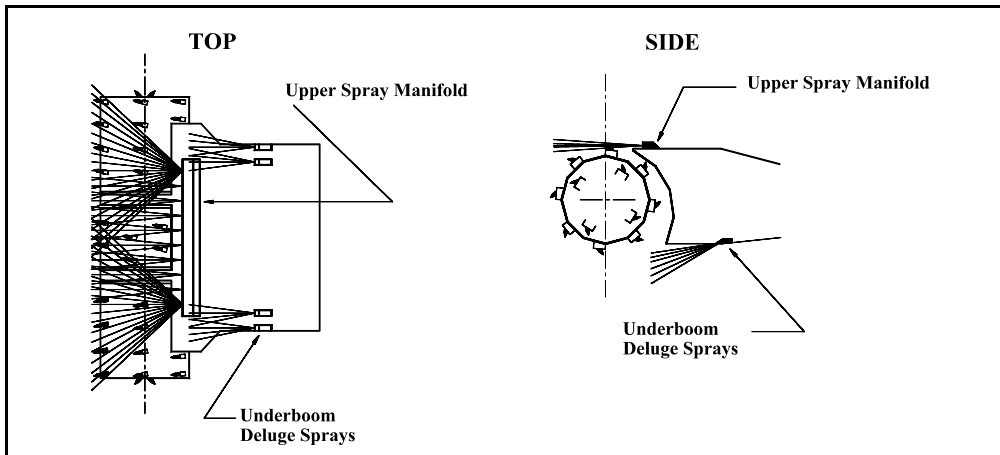


Figure 1. Sprays to control dust rollback

Half the respirable silica generated in underground coal mining has a size between 1,0 and 3,5 microns⁵. The small sizes of these particles make their capture difficult with larger water droplets produced by conventional water sprays. Higher-pressure sprays generate smaller water droplet sizes and increased spray velocities required to capture these smaller-sized particles.

High-pressure sprays swept underboom dust behind the return curtain when installed at the rear corner of the shovel on the side opposite the curtain (figure 2). Extensive underground testing showed that the shovel sprays reduced coal dust exposures by sixty percent at the miner operator's location while virtually eliminating exposures to respirable silica dust⁴. These sprays also were placed on top of the cutting boom and oriented into the cutting head to reduce dust levels nearly sixty percent with the most dramatic dust reductions occurring in the size range below 2,9 microns. In fact, the reduction more than doubled for 1,8 micron particles with the addition of high-pressure sprays.

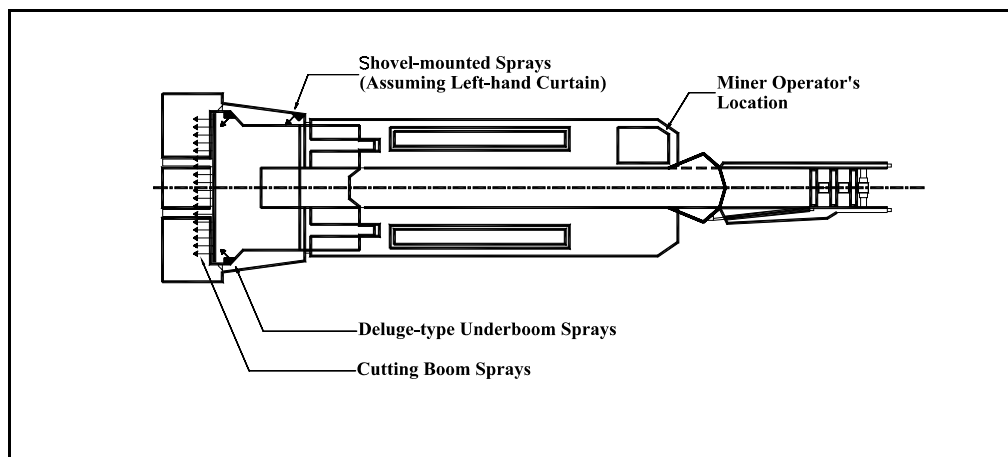


Figure 2. Shovel-mounted sprays control underboom dust

Past work showed that flooded-bed scrubbers effectively controlled occupational dust exposures when used with either blowing or exhausting face ventilation schemes. As of 1997, approximately sixty percent of the operating continuous mining machines used a flooded-bed dust scrubber to control occupational dust levels. The U.S. Mine Safety and Health Administration requires air quantities measured at the curtain mouth to be equal to or

slightly greater than the rated capacity of the dust scrubber⁶. Excessive airflow at the mouth of a blowing curtain is thought to overpower the scrubber and blow dust by the scrubber inlets. However, excessive airflow at the mouth of an exhausting curtain does not appear to significantly affect dust capture⁷.

Increased emphasis on controlling occupational dust exposures led to increases in face airflow and scrubber airflow. Although physical constraints limit scrubber performance, scrubber airflow was increased by reducing the density of the scrubber filter. However, this reduction suggested lower dust collection efficiencies and thus increased occupational exposures to respirable coal and silica dusts. Recent work investigated silica collection efficiencies of filters containing 10, 15, 20, and 30 layers of stainless steel meshing⁸. The 20-layer scrubber filter is the most common filter in use in the U.S. mining industry. Also investigated was a filter panel containing a non-woven synthetic fiber and one containing an array of nylon brushes. Multiple scrubber duct velocities were tested.

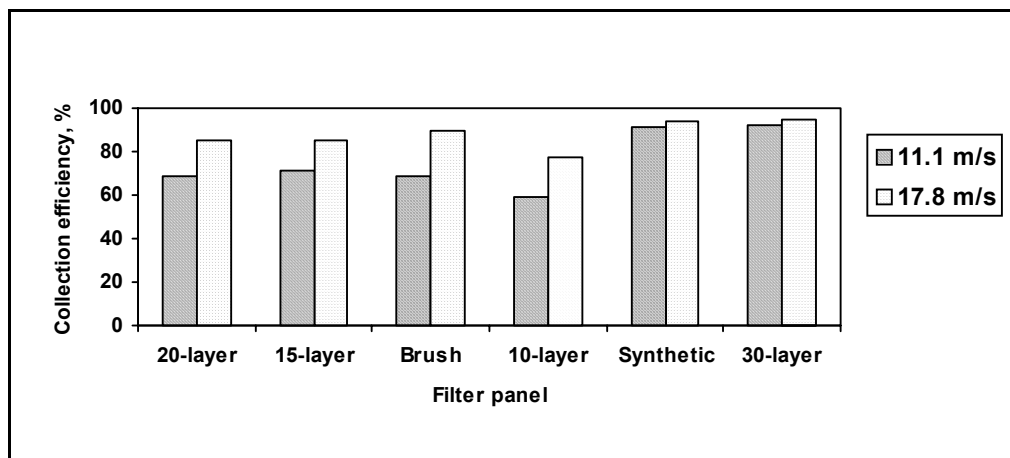


Figure 3. Silica collection efficiencies for various filters and scrubber velocities

Over the range of velocities tested, respirable silica collection efficiencies ranged from 69 percent to 84 percent for the standard 20-layer scrubber filter. Efficiencies for the denser 30-layer and synthetic fiber filters varied from 91 to 95 percent. The 10-layer filter panel had the lowest collection efficiencies ranging from 58 percent to 76 percent. All filter panels showed improved silica collection at higher scrubber velocities.

Dust scrubbers are most effective when dust is contained beneath the cutting boom, allowing this cloud to be drawn into the scrubber inlets. However, movement of the continuous mining machine at the face can sometimes cause dust to roll out from under the boom. Supplemental water sprays were placed along the sides of the continuous miner to improve suppression and confinement of the dust cloud beneath the cutting boom. Testing showed that these added sprays not only improved dust suppression but also redistributed the dust cloud beneath the cutting boom. This led to increased amounts of dust entering the scrubber inlets that reduced dust concentrations around the machine. This work showed that the supplemental sprays were most effective at smaller ventilation curtain setback distances⁹.

NIOSH RESEARCH TO CONTROL METHANE GAS LEVELS

Federal regulations require that methane levels in the face area be maintained below 1 percent. Methane readings obtained with a hand held methane monitor are usually taken as close to the face as practical although they cannot be taken closer than 0,3 m from the

roof, face, ribs, and floor (30 CFR§75.342)¹⁰. Machine-mounted methane monitors are used to continuously monitor methane levels on the mining machine. Whenever methane readings are 1 percent or higher, mining must stop until concentrations are reduced below this level.

Methane gas at the mining face is controlled by providing sufficient intake air to the face to maintain methane levels below 1 percent. Although adequate air quantity may be available in the heading, a fraction of this intake air never reaches the face. Generally, the quantity of air reaching the face decreases as tubing or curtain setback distance increases. Although water sprays and scrubbers are designed primarily for dust control, research has shown that they also can be used to reduce methane levels by increasing the amount of intake air that reaches the face. They have been shown to be effective with either blowing or exhausting face ventilation schemes.

Exhaust face ventilation systems, rather than blowing systems, are generally preferred for dust control because the dust is removed from the face area before it passes over the mining machine operator's location. However, for given setback distances and intake air quantities, exhaust ventilation generally supplies less airflow to the face than blowing ventilation. This can lead to higher face methane concentrations.

Water spray systems designed for use with exhaust face ventilation schemes can maintain and improve face airflow at longer setback distances¹¹. The nozzles in the spray system are oriented to move air from the intake to return side of the entry. Each spray nozzle acts as a small fan and the system is referred to as a spray fan system. Tests showed that increasing water pressure and flow rate increased the air moved by the sprays. Although typical flow pressure for the spray fan system was at least 689 KPa, high water pressure often created turbulence that led to dust roll back. This can result in higher dust exposures for the mining machine operator¹².

The orientation and location of spray nozzles on the mining machine are also important factors in determining face airflow. Nozzles on the mining machine boom should be directed toward the return side to maintain airflow across the face. Nozzles on the intake side of the machine should be oriented to maintain intake airflow to the face. The best design for a particular mining face is the one that provides the greatest airflow quantity with consistent flow patterns (intake to return) at the face. Smoke or discharge from a fire extinguisher can identify face airflow patterns to compare effects of sprays on face airflow. Test results show that, when compared to a 3-m primary ventilation brattice, the spray fan system consistently provided better face ventilation up to and including a 13-m brattice setback¹³. Use of the spray fan system allowed increases in curtain setback distances while maintaining the effectiveness of the exhausting face ventilation system.

When used with a blowing face ventilation scheme, early studies indicated that water spray systems had little effect on face methane levels¹⁴. Spray systems usually were directed toward the face and were not intended, as with the spray fan system, to direct air from the intake to return side of the face.

Using a dust scrubber with exhausting face ventilation reduced face methane levels and these reductions increased as scrubber flow increased¹⁵. The mouth of the exhaust curtain must be positioned outby the exhaust of the scrubber. With the curtain mouth inby the scrubber exhaust, air recirculation to the face increases and, more importantly, intake air reaching the face is reduced. This can lead to increases in face methane levels.

For a given ventilation setback distance, blowing face ventilation systems typically provide more airflow to the mining face than exhausting systems. Thus, blowing systems are

more effective controllers of face methane concentrations. Scrubbers are used with most blowing systems to reduce the amount of dust that passes over the mining machine operator's work location. Dust control and ventilation plans approved by the U.S. Mine Safety and Health Administration typically permit blowing curtain ventilation flows to exceed the rated capacity of the dust scrubber by no more than $0,50 \text{ m}^3/\text{sec}$. This additional face airflow helps control face methane levels.

Methane levels at the face were lower with blowing schemes than exhausting schemes due to the higher intake air velocities created by the blowing system. Greater reductions in face methane levels were also seen at higher scrubber flows. With blowing curtain ventilation, analysis of face airflow patterns indicated that the scrubber maintained intake airflow on the curtain side of the entry (figure 4).

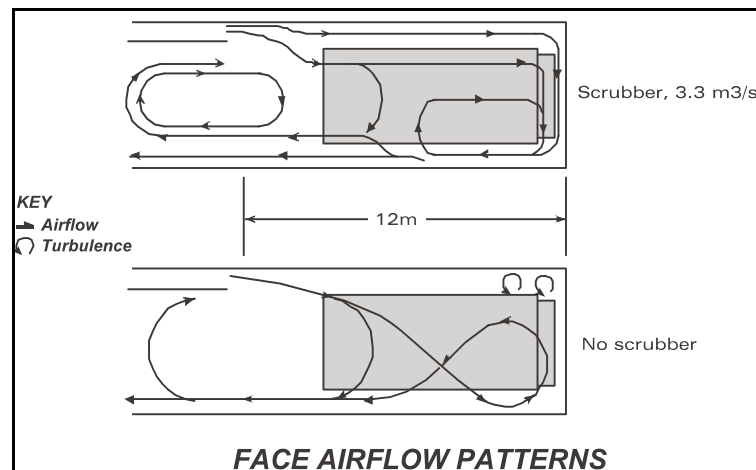


Figure 4. Face airflow patterns with and without scrubber

Test results showed that the scrubber sustained intake airflow reaching the face as curtain setback distance increased from 7,5 to 15 meters¹⁶. Not surprisingly, intake air velocities measured at the end of the blowing curtain increased with the scrubber operating. These increases were greater at the higher scrubber flows and lower intake flows. Face methane levels decreased with increasing scrubber flow, even when scrubber flow was greater than intake flow (figure 5)¹⁷.

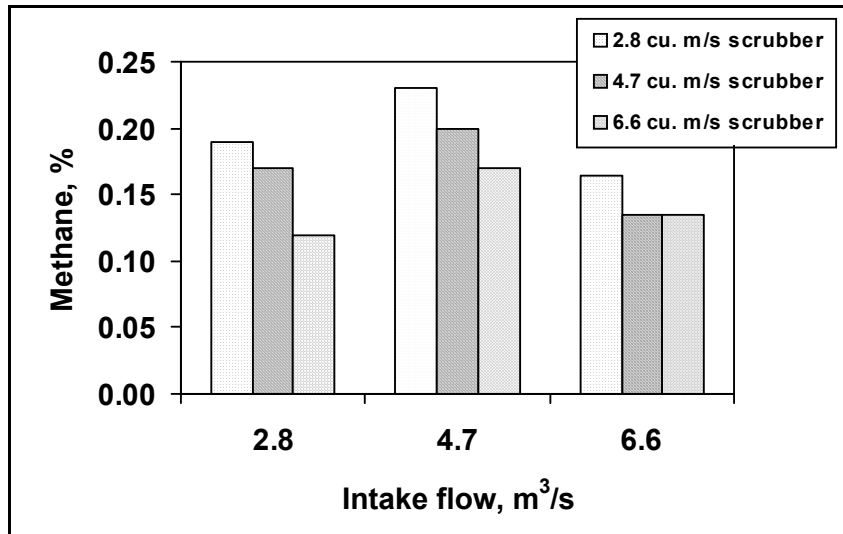


Figure 5. Face methane levels with varying intake and scrubber flows

SUMMARY

Water sprays remain the most widely used method for controlling respirable dust exposures. NIOSH research has evaluated sprays to reduce dust rollback from the cutting head, high-pressure sprays to control exposures to respirable silica dust, and sprays to improve performance of a flooded-bed dust scrubber. The dust capture properties of various wetted screens used in the dust scrubber have been evaluated.

Face methane concentrations at the cutting face have been reduced using water sprays and flooded-bed scrubbers. NIOSH research has shown that water sprays can be used to maintain and improve face airflow at longer setback distances with exhaust face ventilation systems. This work has also shown that dust scrubbers increase intake airflow with either blowing or exhausting face ventilation systems. Higher face ventilation flows are needed to control face methane concentrations.

REFERENCES

1. National Institute for Occupational Safety and Health. Occupational Exposure to Respirable Coal Mine Dust, Criteria for a Recommended Standard. U.S. Dept. of Health and Human Services, Centers for Disease Control and Prevention, 1995, 336 pp.
2. Ainsworth, S.M., Gero, A.J., Parobeck, P.S., and Tomb, T.F. Quartz Exposure Levels in the Underground and Surface Coal Mining Industry. *Am. Ind. Hyg. Assoc. Journal*, vol. 56, no. 10, 1995, pp.1002-1007.
3. Goodman, G.V.R. and Jankowski, R.A. Optimal Spray System Designs for Continuous Miner Dust Control. *Proceedings, 9th Intl. Conf. on Advances in Prevention of Occ. Resp. Diseases*, Chiyotani, K., Hosoda, Y., and Aizawa, Y. (eds.), Kyoto, Japan, 1997, pp 1081-1087.

4. Foster-Miller, Inc. Development of Optimal Water Spray Systems for Dust Control in Underground Mines. *Contract Report No. H0199070*, U.S. Bureau of Mines, 1986, 146 pp.
5. Jayaraman, N.I. and Jankowski, R.A. Atomization of Water Sprays for Quartz Dust Control. *Appl. Ind. Hyg.*, vol. 3, no. 12, 1988, pp. 327-331.
6. Schultz, M.J. and Fields, K.G. Dust Control Considerations for Deep Cut Mining Sections. *Preprint 99-163*, Soc. of Mining Engineers, Ann. Mtg., Denver, CO, 1999, 4 pp.
7. Colinet, J.F. and Jankowski, R.A. Dust Control Considerations for Deep-Cut Mining When Utilizing Exhaust Ventilation and a Scrubber. *Report of Investigations 9615*, U.S. Bureau of Mines, 1996, 12 pp.
8. Colinet, J.F. and Jankowski, R.A. Silica Collection Concerns When Using Flooded-Bed Scrubbers. *Preprint Number 98-131*, Soc. of Mining Engineers, Annual Mtg., Orlando, FL, 1998, 7 pp.
9. Goodman, G.V.R. Using Water Sprays to Improve Performance of a Flooded-Bed Dust Scrubber. *Appl. Occup. Envir. Hyg.*, to be published in vol. 15, 2000. pp. 550-560.
10. Mineral Resources. Code of Federal Regulations, Title 30, Parts 70 and 75, U.S. Government Printing Office.
11. Foster-Miller, Inc. Improved Diffuser and Sprayfan Systems for Ventilation of Coal Mine Working Faces. *Contract Report No. JO113010*, U.S. Bureau of Mines, 1985, 292 pp.
12. Goodman, G.V.R. and Listak, J.M. Variation in Dust Levels with Continuous Miner Position. *Mining Eng.*, Vol. 51, No. 2, 1999, pp. 53-58.
13. Volkwein, J.C., Ruggieri, S.K., McGlothlin, C., and Kissell, F.N. Exhaust Ventilation of Deep Cuts using a Continuous-Mining Machine. *Report of Investigations 8992*, U.S. Bureau of Mines, 1985, 16 pp.
14. Gillies, A.D.S. Studies in Improvements to Coal Face Ventilation with Mining Machine Mounted Dust Scrubber Systems. *Preprint No. 82-24*, Soc. of Mining Engineers, Annual Mtg., Dallas, Texas, 1982, 13 pp.
15. Taylor, C.D., Rider, J., and Thimons, E.D. Changes in Face Methane Concentrations Using High Capacity Scrubbers with Exhausting and Blowing Ventilation. *Preprint 96-167*, Soc. of Mining Engineers, Annual Mtg., Phoenix, Arizona, 1996, 6 pp.
16. Ingersoll Rand Research, Inc. Feasibility of a Machine Mounted Scrubber System for Ventilating Coal Mine Working Faces. *Contract Report No. JO199080*, U.S. Bureau of Mines, 1984.
17. Taylor, C.D., Rider, J., and Thimons, E.D. Impact of Unbalanced Intake and Scrubber Flows on Methane Concentrations. *Proceedings, 6th International Mine Ventilation Congress*, Ramani, R.V. (ed.). Pittsburgh, PA, Soc. for Mining, Metal., and Exploration, 1997, pp. 169-172.