

RI

8408

Bureau of Mines Report of Investigations/1979

**NATIONAL MINE HEALTH & SAFETY ACADEMY
REFERENCE COPY
Do Not Remove From Learning Resource Center**

Dust Control for a Borer-Type Continuous Miner Using a Venturi Scrubber on a Transfer Car

By Natesa I. Jayaraman



UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 8408

Dust Control for a Borer-Type Continuous Miner Using a Venturi Scrubber on a Transfer Car

By Natesa I. Jayaraman



**UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary**

**BUREAU OF MINES
Lindsay D. Norman, Acting Director**

This publication has been cataloged as follows:

Jayaraman, Natesa I

Dust control for a borer-type continuous miner using a venturi scrubber on a transfer car.

(Report of investigation • U.S. Bureau of Mines ; 8408)

Bibliographies.

Supt. of Docs. no.: I 28/23

1. Coal mines and mining—Dust control. 2. Mine ventilation. 3. Coal-mining machinery. I. Title. II. Series: United States. Bureau of Mines. Report of investigations ; 8408.

TN23.U43 [TN312] 622'.08s [622'.8] 79-607043

CONTENTS

	<u>Page</u>
Abstract.....	1
Introduction.....	1
Acknowledgments.....	2
Description of hardware.....	2
Laboratory testing.....	6
In-mine research tests.....	7
Inlet capture efficiency with exhaust ventilation.....	7
Sampling at operator position.....	9
Operational constraints.....	10
Conclusions.....	11
Appendix.--Specification for transfer car.....	12

ILLUSTRATIONS

1. Transfer car with top ducting.....	3
2. Schematic drawing of venturi scrubber.....	3
3. Venturi scrubber on transfer car.....	4
4. Water-control circuit for scrubber operation.....	5
5. Side view of transfer car.....	6
6. Variations in collection efficiency with changes in size of venturi opening and pressure drop.....	7
7. Variation of flow rate with changes in size of venturi opening.....	7
8. Arrangement for sampling in face return.....	8
9. Return respirable dust concentration versus time, for 3-min cutting operations.....	9
10. Arrangement for sampling at miner operator position with face ventilated using the exhaust mode.....	11
11. Arrangement for sampling at miner operator position with face ventilated by blower tubing.....	11

TABLES

1. Dust levels showing effect of scrubber ventilation in the immediate face return.....	8
2. Dust levels showing effect of scrubber ventilation at miner operator position with face ventilated using the exhaust mode.....	10
3. Dust levels showing effect of scrubber ventilation at miner operator position with face ventilated by blower tubing.....	10

DUST CONTROL FOR A BORER-TYPE CONTINUOUS MINER USING A VENTURI SCRUBBER ON A TRANSFER CAR

by

Natesa I. Jayaraman¹

ABSTRACT

The Bureau of Mines, in conjunction with the Goodman Equipment Corp. and the Old Ben Coal Co., designed, built, and tested a transfer car to carry the major components of a ventilation system designed for use with a borer-type continuous miner. Dusty air was pulled through a 6,500-cfm venturi scrubber by a centrifugal fan mounted on the transfer car. The air passed through ducting installed on the miner and through flexible tubing between the miner and the transfer car.

Field results indicated that this machine-mounted ventilation system achieved a respirable dust reduction of 66 pct at the miner operator position with the face ventilated using the exhaust mode.

Since blowing-tube ventilation is presently practiced in some borer-type mining sections, the addition of a scrubber and machine-mounted fan could bring these sections into compliance with the 2-mg/m³ dust standard required by the Federal Mine Safety and Health Act of 1977. However, use of a transfer car attached to a borer-type miner posed handling problems and decreased productivity. An integral borer-mounted scrubber would avoid these problems.

INTRODUCTION

Twin borer-type continuous miners are better suited than ripper-type miners for excavating certain types of coal seams with friable roofs because the borer-type miner leaves a more evenly cut roof surface. However, a disadvantage of the borer-type miner is that effective ventilation of the coal face is difficult to achieve because the machine occupies the entire entry cross section. Some borer sections are ventilated by a blowing tube, but dusty air tends to pass over the miner operator and shuttle car operator when this method is used.

Laboratory studies² have shown that if a machine-mounted exhaust ventilation system and a blowing face system are used together, the dust concentration

¹Mining engineer, Pittsburgh Research Center, Bureau of Mines, Pittsburgh, Pa.

²Breslin, J. A., and Strazisar, A. J. Dust-Control Studies Using Scale Models of Coal Mine Entries and Mining Machines. BuMines RI 8191, 1976, 20 pp.

may be lowered at the miner operator position, provided that the exhaust airflow exceeds the blowing airflow. Maintaining exhaust airflow at a rate in excess of the blowing airflow allows fresh air to be drawn over the operator. Contaminated air goes out through an exhaust tubing or brattice.

The Bureau of Mines, in conjunction with the Old Ben Coal Co. and Goodman Equipment Corp., designed a transfer car to be attached to the miner. The car contains a venturi scrubber, a centrifugal exhaust fan, a mist eliminator, and a slurry removal system. The transfer car is wheel-mounted, and towed by the miner during cutting; but it can be removed separately from the entry.

ACKNOWLEDGMENTS

The author thanks Eugene T. Moroni, senior vice president, and Michael O'Day, chief mine inspector, Old Ben Coal Co., Benton, Ill., and Walter Silks, manager of design engineering, Goodman Equipment Corp., Chicago, Ill., for their cooperation in designing and building the transfer car and in conducting underground tests; Thomas E. Rosendahl, branch chief, Project Analysis and Development, Carbondale Energy Research Center, Carbondale, Ill., who was extensively involved in designing, assembling, and testing the venturi scrubber, fan, and mist eliminator; Raymond Kacmar, electrical engineer, Mine Safety and Health Administration, U.S. Department of Labor, for assistance in underground tests; Warren Cross and Frank Nagy, physical science technicians, Pittsburgh Research Center, Pittsburgh, Pa., for help in conducting underground tests and processing data; and Fred Kissell, research supervisor, Dust Control and Ventilation, and Welby Courtney, supervisory research chemist, Fire and Explosion Prevention, Pittsburgh Research Center, Pittsburgh, Pa., for technical guidance and discussions.

DESCRIPTION OF HARDWARE

The transfer car and top ducting are shown in figure 1. The dust cloud generated by the cutting operation is drawn from the face through the top duct. An expanded metal screen prevents large pieces of coal from entering the duct inlet. The rear part of the top duct is connected to the venturi scrubber by flexible spiral-reinforced tubing.

The venturi scrubber has a capacity ranging from 4,500 cfm to 6,500 cfm, depending on the width of the variable venturi opening. Figure 2 is a schematic diagram showing the scrubber with nozzles and adjustable opening. Figure 3 shows the scrubber with four water sprays in its opening. The left arrow points to the throat where scrubbing takes place and the right arrow points to the water eliminator. Slurry collects in the sump at the bottom of the water eliminator and is pumped up to the coal conveyor.

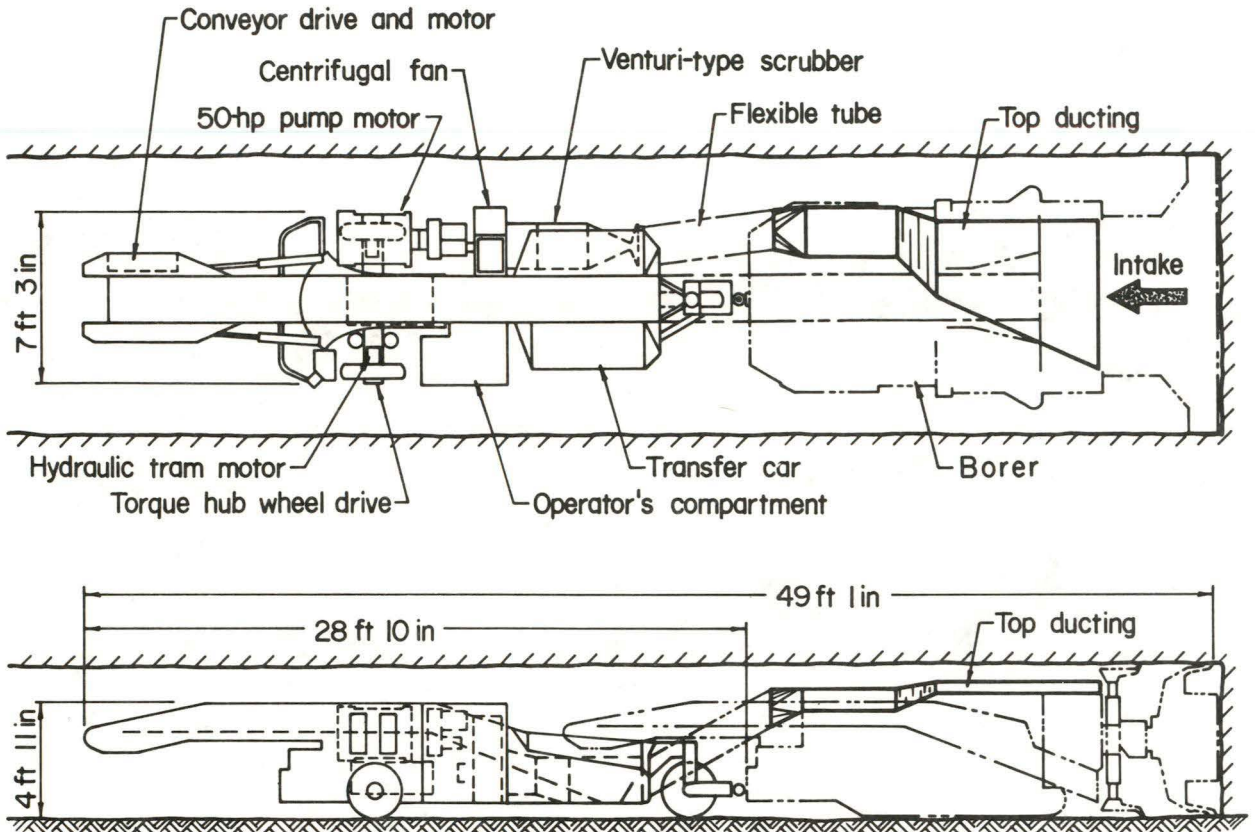


FIGURE 1. - Transfer car with top ducting. Illustration shows motor and drive (left) and ducting on top of twin borer-type miner (right).

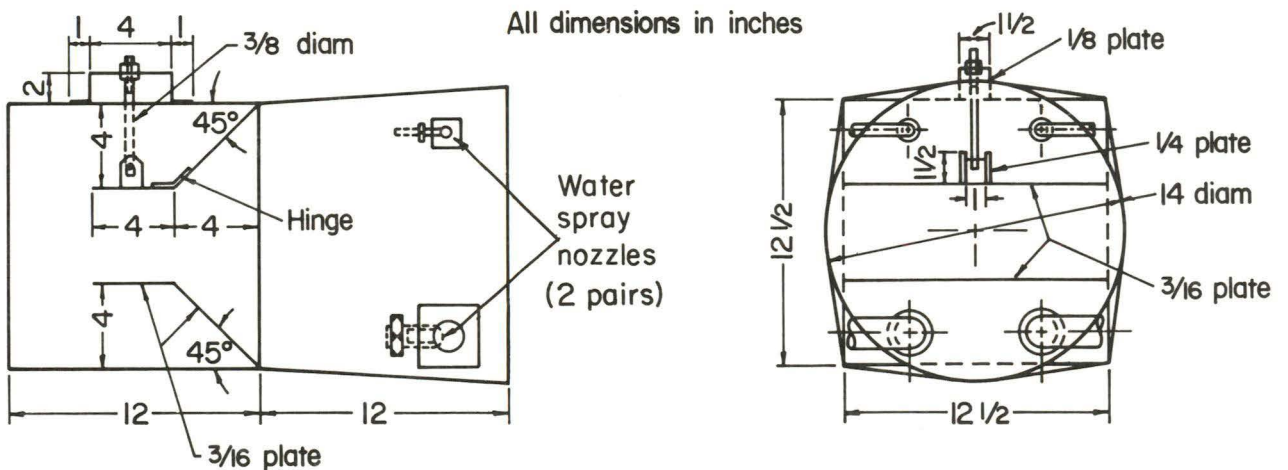


FIGURE 2. - Schematic drawing of venturi scrubber.

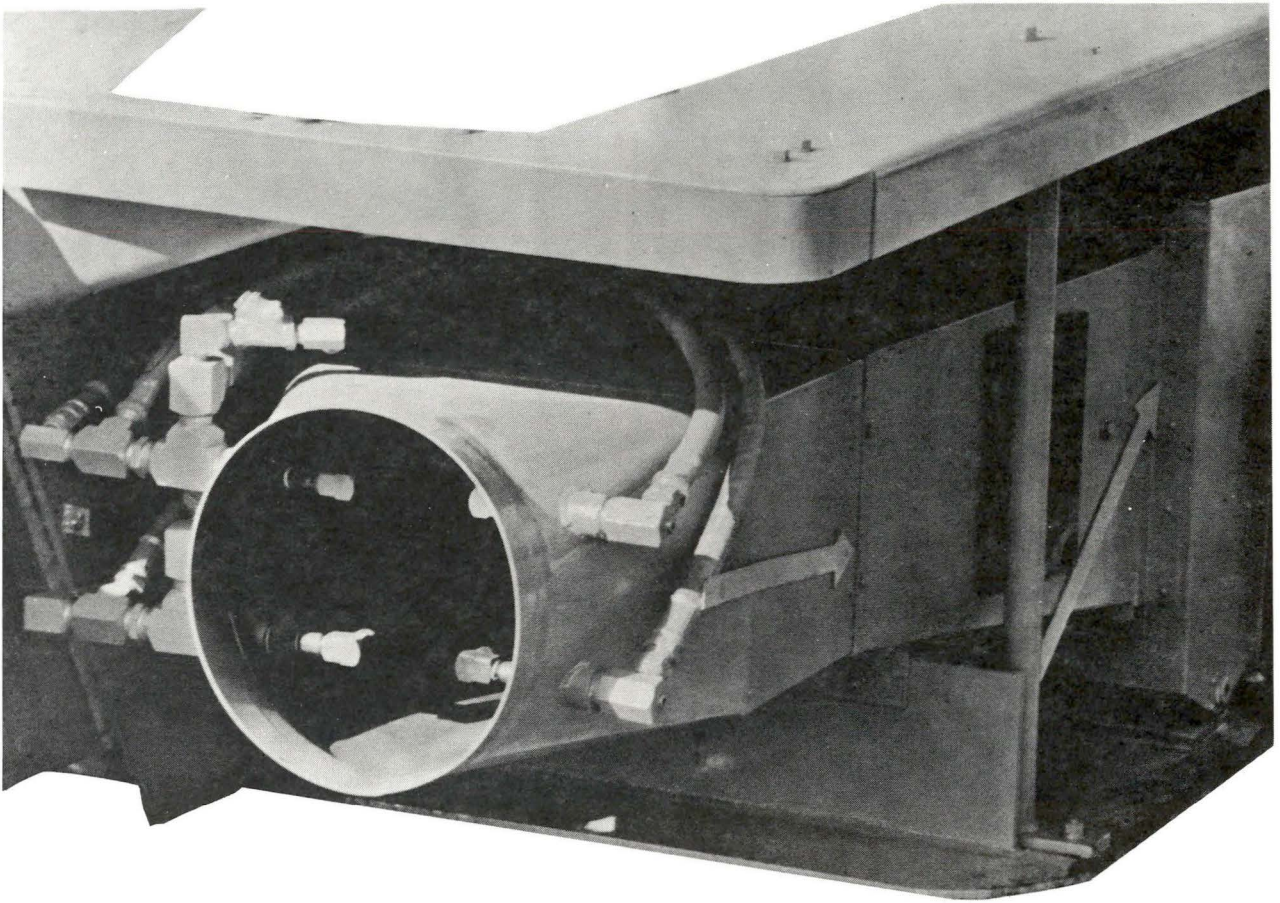


FIGURE 3. - Venturi scrubber on transfer car. Arrows show point where actual scrubbing takes place (left arrow) and location of water eliminator (right arrow).

The scrubber's water-control circuit (fig. 4) consists of a filtration system designed to prevent particulates from entering the spray nozzles. Filtration is necessary because some of the water for the spray system is recycled slurry water. Water entering the system first flows through a Y-shaped strainer that screens out particles larger than one-eighth inch in diameter. Next, the water whirls through a hydrocyclone, where most of the remaining smaller particles are removed and passed into the accumulator compartment. The water then flows through a final filter and through a pressure regulator usually set at 60 psi. Adjustable flow-rate control valves are also incorporated in the spray system.

Six oil-operated automatic pilot valves are also incorporated in the water circuit to regulate water flow, depending upon whether the coal conveyor is on or off. The mine water supply is opened to the venturi scrubber at a preset flow rate (usually 10 gpm). Opening a slurry valve allows the continuously running pump to remove slurry from the drop eliminator and throw it into the hopper to be carried away with the coal. Because dirty water is carried out by conveyor with the coal, it does not accumulate on the floor of the coal seam, where it could cause problems in the handling of heavy equipment.

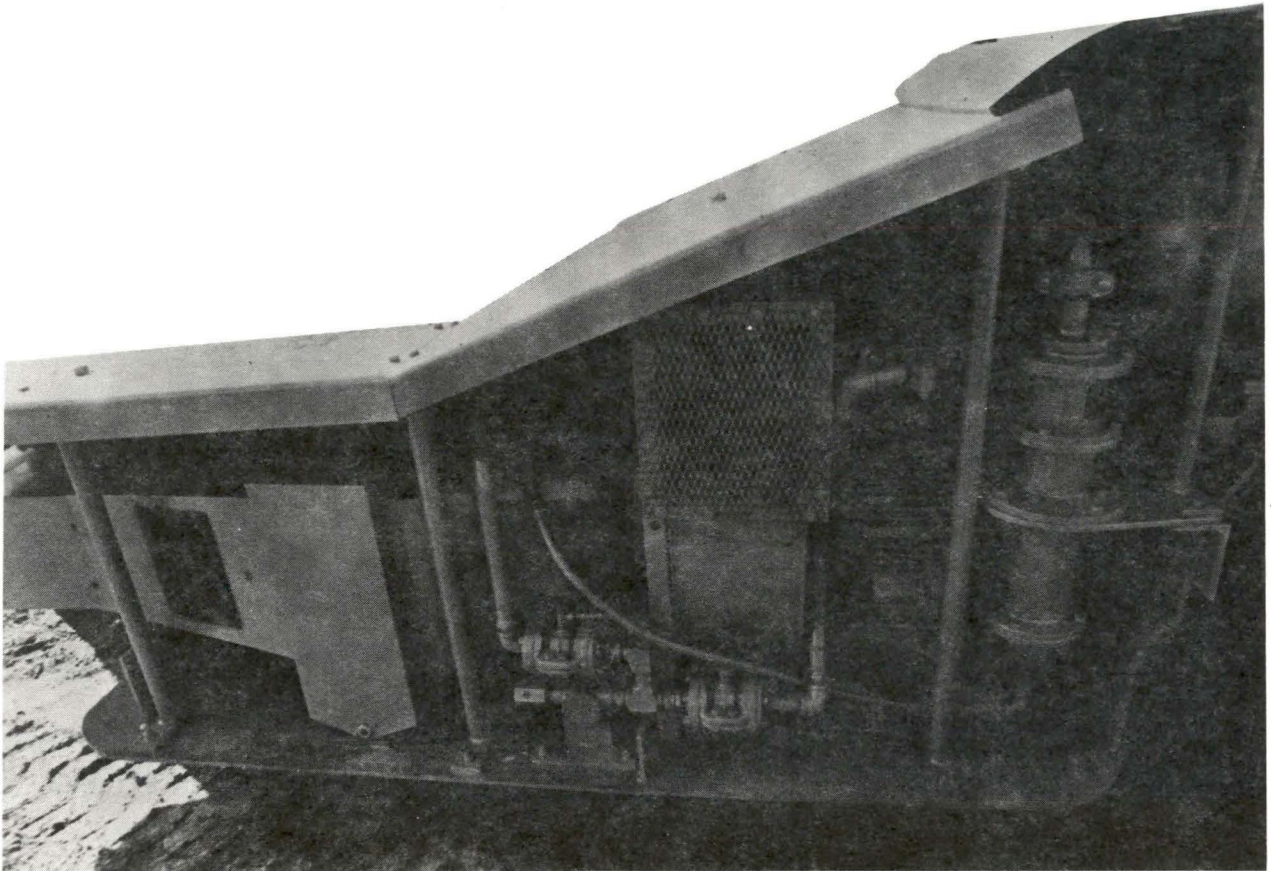


FIGURE 5. - Side view of transfer car. Components shown are the scrubber (far left), the water eliminator with sump (center), and inlet for centrifugal fan (covered with screen).

LABORATORY TESTING

Dust collection efficiency was evaluated with a full-scale mockup of the air-scrubbing apparatus. Pulverized coal dust was introduced into the air-stream through four pipes equally spaced across the inlet of the mockup. Dust concentrations and size distributions were determined with eight-stage cascade impactors. The respirable dust concentration for each impactor stage was calculated using the Atomic Energy Commission--American Council of Governments on Industrial Hygiene definition for respirable dust. Respirable dust collection efficiencies of 95.1 and 97.1 pct were obtained for 19- and 24.2-inch drops in water-gage pressure across the venturi. Figure 6 shows the variations in collection efficiency for various venturi openings with corresponding pressure drops. Figure 7 shows the effect on the airflow rate of varying the venturi opening. An airflow rate of 6,250 cfm was obtained when the throat was opened to a width of 3 inches, the maximum that is used underground.

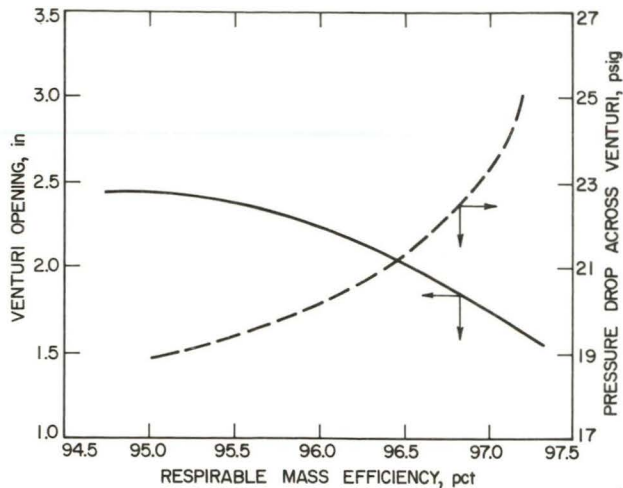


FIGURE 6. - Variations in collection efficiency with changes in size of venturi opening and pressure drop.

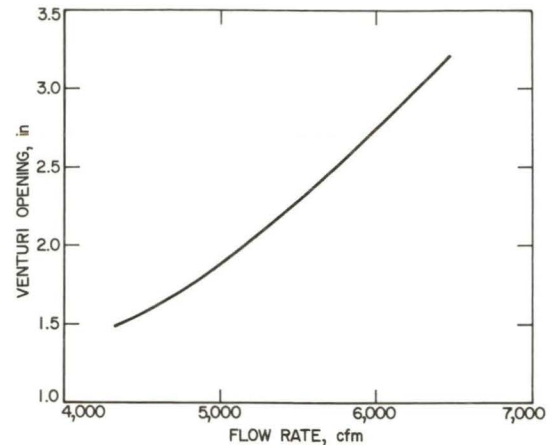


FIGURE 7. - Variation of flow rate with changes in size of venturi opening.

IN-MINE RESEARCH TESTS

A section of a mine at the Old Ben Coal Co. was used to test the efficiency of the scrubber. The mine entry was about 13 feet wide and 6.5 feet high.

Inlet Capture Efficiency With Exhaust Ventilation

The arrangement for measuring inlet capture efficiency³ in the face return is shown in figure 8. The face airflow was 6,500 cfm. The miner was operated for periods of 3 min. With the scrubber fan off, a test to determine the total quantity of respirable dust generated during a 3 min period was conducted behind the exhaust curtain. This dusty air was sampled with a 10-mm nylon cyclone and a light-scattering dust monitor.⁴ The signal output from the monitor was transmitted to a portable recorder and the instantaneous concentrations were recorded. Figure 9 shows two typical graphs of respirable dust concentration versus time that compare dust concentrations with the scrubber on and with the scrubber off. These measurements were taken during 3-minute cutting operations, and also included the time required for dust concentrations to return to the baseline level, or background dust concentration. Background dust concentrations were caused by dust from outby sources, and are represented in the graphs at each end of the two curves, at concentration levels near

³Inlet capture efficiency is the ratio, expressed as a percentage, of respirable dust captured by the inlet to the total respirable dust generated during the cutting operation.

⁴Lapple, C. E., and C. F. Schadt. Portable Mine Dust Concentration Instrument. BuMines Open File Rept. 6-73, 1973, 217 pp.; available from National Technical Information Service, Springfield, Va., PB 215 150/4.

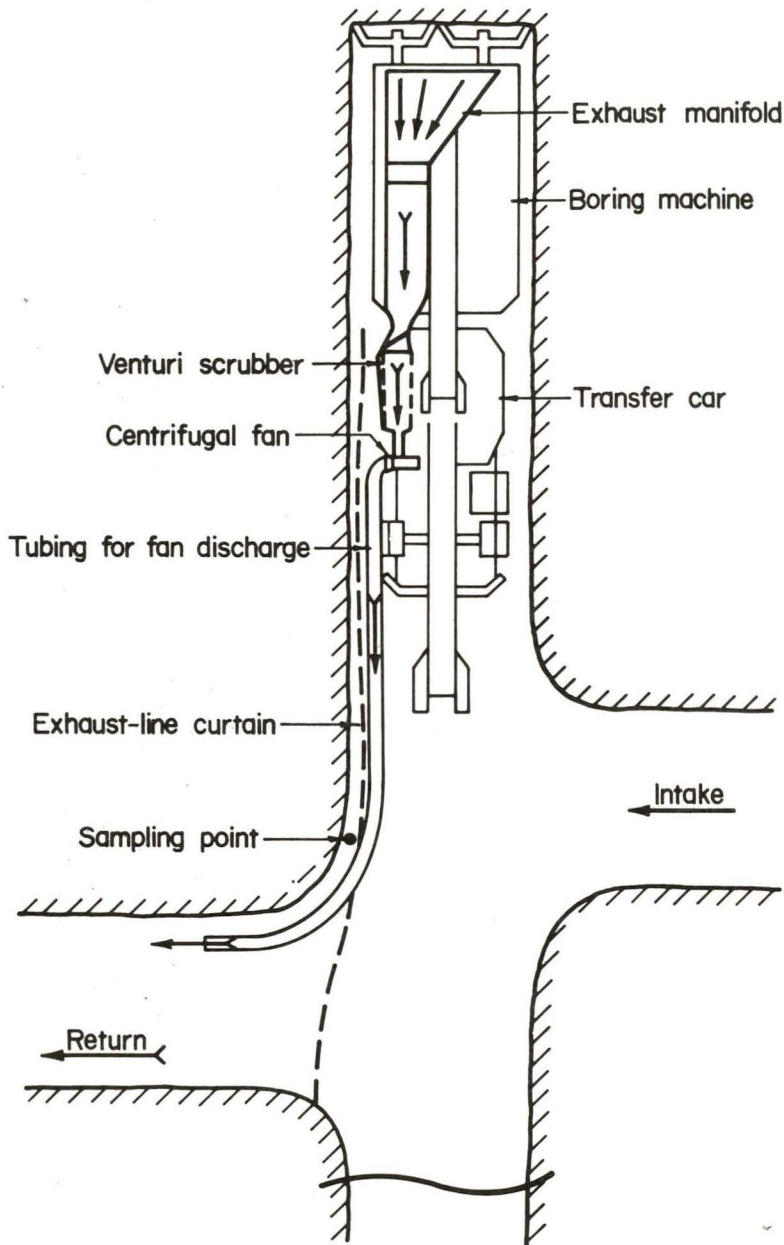


FIGURE 8. - Arrangement for sampling in face return.

0.2 mg/m³. The total mass of respirable dust generated at the working face and carried in the air behind the exhaust-line curtain, through the immediate face return, was determined by multiplying the total area under each curve by airflow quantity.

A collapsible 18-inch-diameter tube was installed on the discharge end of the centrifugal fan to obtain a set of measurements taken with the scrubber off and on. When the fan was on, scrubbed air was discharged beyond the sampling point so the sample was collected only from the portion of the dusty air not captured by the scrubber inlet. This procedure was necessary because dust concentrations could not be accurately measured in the high-velocity airstream of scrubbed air discharged by the fan. Calculations using measurements with the scrubber on and off indicated how much dust was pulled by the fan.

Table 1 compares dust levels with the scrubber on and with the scrubber off. Five tests were conducted with the scrubber on and five with the scrubber off.

TABLE 1. - Dust levels showing effect of scrubber ventilation in the immediate face return

	Total respirable dust mass, mg	
	Scrubber on	Scrubber off
Test 1.....	1,600	3,500
Test 2.....	1,500	2,472
Test 3.....	353	3,564
Test 4.....	331	2,664
Test 5.....	389	3,236
Mean.....	744	3,081
Standard deviation...	597	504

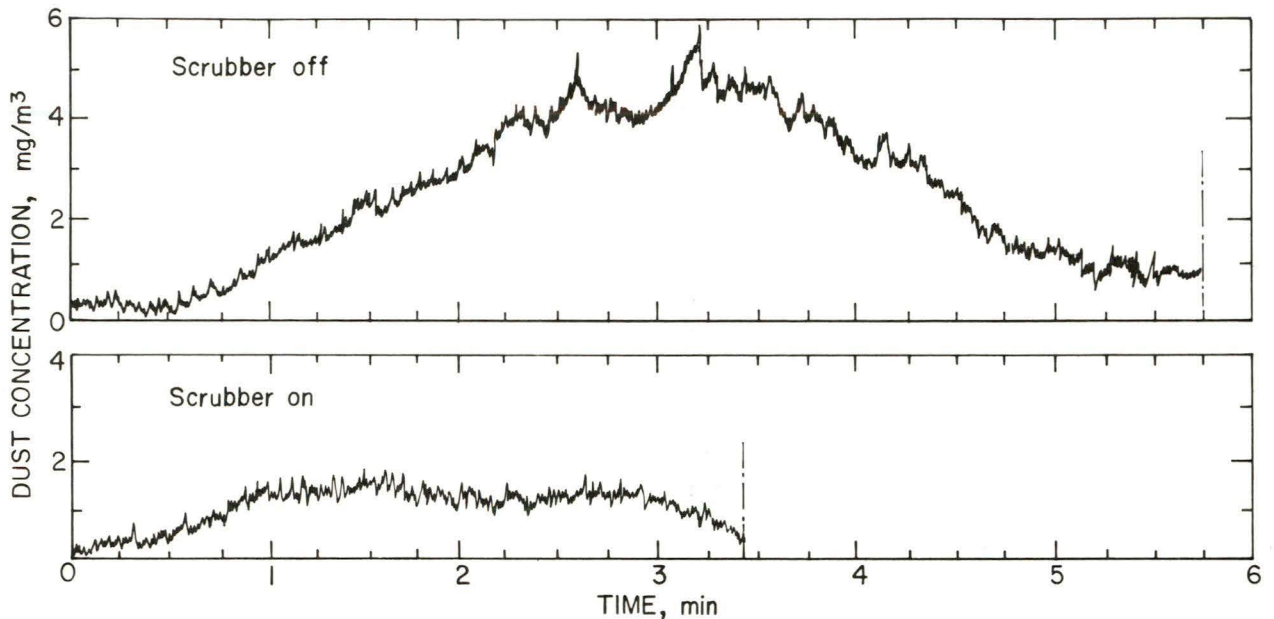


FIGURE 9. - Return respirable dust concentration versus time, for 3-min cutting operations.

The large difference between the readings for tests 1 and 2 with the scrubber on and the remaining three tests in the same column was caused by a rock intrusion of varied thickness in the coal face.

The dust reduction of a scrubber ventilation system relative to a system with no operating scrubber is given by

$$E = (1 - A/B) \times 100 \text{ pct,}$$

where A and B represent the total dust mass measured behind the brattice when the scrubber is on and off, respectively. The average inlet capture efficiency (E) was found to be 76 pct, using the data from table 1.

Efficiency was less than anticipated because restrictions in the ducting and scrubber reduced the scrubber airflow to 3,000 cfm (capacity was 6,500 cfm). A flexible connection between the ducting on the borer head and the ducting on the main body of the machine was crushed by falling coal during testing. Also, dust generated by coal falling from the borer to the transfer car and from the transfer car to the shuttle car did not necessarily go through the scrubber inlets, which created an extraneous source of dust that also decreased scrubber efficiency. This extraneous dust was even more significant when the water sprays on the borer head were shut off. Even with the scrubber on, the dust concentration from the conveyor was so high that working conditions were uncomfortable.

Sampling at Operator Position

Table 2 shows the results of sampling at the miner operator position with the face ventilated using the exhaust mode, and figure 10 shows the sampling

point. An airflow of 4,500 cfm at the face was used to determine the total respirable dust mass. Air passed through the scrubber at 4,000 cfm. A dust reduction of 66 pct was obtained when the average dust level at the operator position was compared with the scrubber on and with the scrubber off.

TABLE 2. - Dust levels showing effect of scrubber ventilation at miner operator position with face ventilated using the exhaust mode

	Total respirable dust mass, mg	
	Scrubber on	Scrubber off
Test 1.....	709	1,301
Test 2.....	402	1,820
Test 3.....	730	1,418
Test 4.....	191	1,460
Mean.....	508	1,499
Standard deviation.....	259	244

Table 3 shows the results of sampling at the miner operator position with the face ventilated by a blowing tube, and figure 11 shows the sampling location. The blowing tube discharged 2,600 cfm of air at a point about 10 feet behind the transfer car operator. The dust reduction of 69 pct indicates that the scrubber is approximately equal in effectiveness at the miner operator position whether the face is ventilated by the blowing or by the exhaust mode. The data also indicate that this reduction is approximately equal to the reduction achieved when the face is ventilated using the exhaust mode with no scrubber in operation. A blower tube is usually required to operate a borer-type continuous miner; the addition of a scrubber and a machine-mounted fan can bring the borer section into compliance with the 2-mg/m³ dust standard.

TABLE 3. - Dust levels showing effect of scrubber ventilation at miner operator position with face ventilated by blower tubing

	Total respirable dust mass, mg	
	Scrubber on	Scrubber off
Test 1.....	1,231	3,885
Test 2.....	2,867	6,729
Test 3.....	637	4,437
Mean.....	1,578	5,014
Standard deviation.....	1,154	1,502

Operational Constraints

Addition of the transfer car between the miner and the shuttle car created operational difficulties. The wheels of the transfer car bogged down in the soft floor, which at times brought the miner to a standstill. Face-to-face travel consumed more time and productivity was decreased by 15 to 20 pct when the transfer car was used, because of the time required to train personnel. The mining crew was unenthusiastic about the introduction of the transfer car because it was impractical to operate.

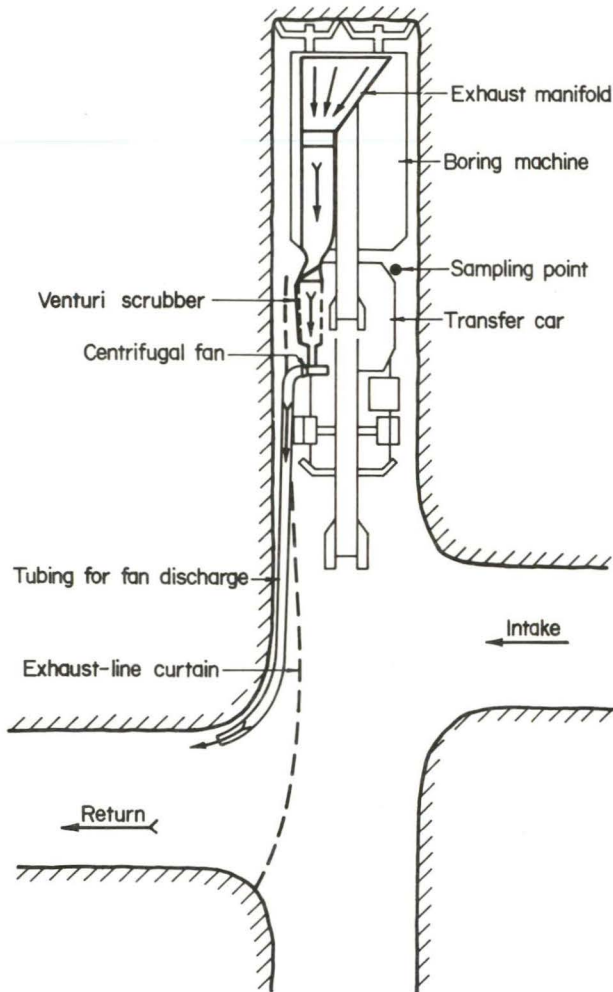


FIGURE 10. - Arrangement for sampling at miner operator position with face ventilated using the exhaust mode.

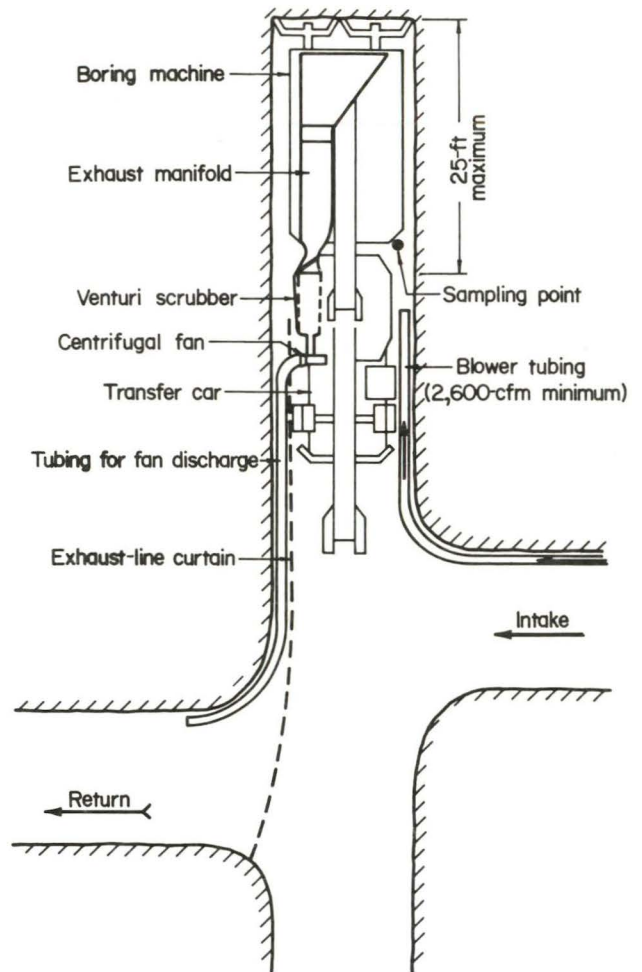


FIGURE 11. - Arrangement for sampling at miner operator position with face ventilated by blower tubing.

CONCLUSIONS

1. A transfer car together with a dust scrubber can significantly reduce respirable dust concentrations in the return and at the miner operator position, even when a blowing tube is used for face ventilation.
2. However, the transfer car in combination with the miner poses handling problems and decreases productivity. This problem could be avoided if an integral borer-mounted scrubber were designed and built. A compact scrubber could be installed at the throat where coal enters the conveyor from the face.

APPENDIX.--SPECIFICATION FOR TRANSFER CAR

One 50-hp motor, 440 volts, three-phase, 60 hertz.

One 6,000-cfm scrubber.

One headlight.

Tram speed, 0 to 50 fpm.

Conveyor chain pitch, 2 inches.

Conveyor speed, 425 fpm.

Conveyor width, 24 inches.

Ground clearance, 8 inches.

Height, 4 feet 11 inches.

Remote control (for borer only), pendant, 120 volts, 14 functions. Umbilical cord (normally operated from cab on transfer car) is removable and can be hung on borer.

Fire protection, two 30-pound dry-chemical tanks, eight nozzles.

Cylinder pump, gear-type, 10 gpm.

Tram pump, variable-volume axial piston, 25 gpm maximum.

Conveyor pump, axial piston, 20 gpm.

Lube pump, gear-type, 1-1/2 gmp.

Length, 28 feet 10-1/2 inches.

Width, 7 feet 3 inches.

Weight, 37,600 pounds (estimated).

Boom overhang, 8 feet 6 inches.

Minimum clearance under boom, 2 feet 9 inches.

Tires, two rear, one front; 10:00 X 15 inches (demountable rims)
Front and rear wheels can be steered independently. Rear-wheel drive only.

Operator's cab, 4 feet 3 inches fixed height.
Hydraulically positioned.

Hopper, 6 feet by 5 feet 6 inches.

Oil tank, 95 gal.