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REPORT OF INVESTIGATIONS/1989

Impact of Water Sprays on Scrubber Ventilation Effectiveness

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BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

Page

ILLUSTRATIONS

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cfm	cubic foot per minute	min	minute
ft	foot	ppm	part per million
in	inch	psi	pound per square inch

IMPACT OF WATER SPRAYS ON SCRUBBER VENTILATION EFFECTIVENESS

By Jon C. Volkwein[1] and Travis S. Wellman[2]

ABSTRACT

The U.S. Bureau of Mines conducted a study to assess the impact of a directional water spray system on a unique single inlet dust scrubber on a low-profile mining machine. Tests were conducted in a full-scale model mine using a continuous mining machine. Tracer gas was introduced at the face and concentrations of the tracer gas were monitored at the face and in the return. Various parameters tested included mining position, depth of cut, brattice setback, and combinations of scrubber, and directional or symmetrical sprays. Results indicated that either water spray configuration improved the ventilation effectiveness of the scrubber by a factor of 2 to 3. Average face ventilation effectiveness (FVE) values for all testing of the scrubber and directional sprays were 0.95, versus 0.37 for a standard 20-ft blowing curtain without sprays. No FVE values were less than the standard 20-ft blowing results.

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INTRODUCTION

Effective face ventilation is the primary goal of the mine ventilation system. Within the primary blowing or exhaust face ventilation network, equipment such as flooded bed scrubbers or sprayfans have been used to enhance the effectiveness of the respective primary systems. The job of the face ventilation system is to provide fresh air to control dust and methane gas produced during mining.

When blowing ventilation is used, dust from mining passes over the operator locations. Various types of dust scrubbers have been developed to reduce this problem with continuous mining machines. Studies by Peabody Coal, Louisville, KY, the U.S. Bureau of Mines, and others have shown the effectiveness of these dust scrubbers (*1-3*).[3] Other work has demonstrated that scrubbers, in addition to removing dust, also provide effective dilution of methane, and have allowed increased brattice setbacks (*4-5*). Being able to maintain face ventilation at increased brattice setbacks is important, because it is safer and more productive.

For exhaust ventilated faces, sprayfans have been found to enhance the removal of methane from face areas. The effectiveness of these systems has allowed brattice setbacks in excess of 10 ft (*6-7*). When any turbulent face ventilation system is in use, methane levels will be determined by the quantity of fresh air entering the face area (*8-11*).

Typically, intakes to the flooded bed type dust scrubbers are located as close to the face as possible. In low seams where there is no room on the top of the boom to locate the scrubber duct, the inlet may be located as far as 10 or 12 ft from the face. The concern about this distance from the face and gassy mine conditions prompted Rochester & Pittsburgh (R&P) Coal Co. to consider using a sprayfan type or directional water spray gas dilution system in conjunction with a unique single inlet scrubber. Previous work by the Bureau and others had shown that scrubber capture effectiveness is maximized when sources of face turbulence such as high-pressure water sprays or blowing jets are minimized. On the other hand, high face turbulence levels are desirable for methane dilution. Work with sprayfan systems suggested that the air moving power of the sprayfan would overpower the single scrubber inlet and result in poor dust capture. These concerns prompted the full-scale model tests of this specific scrubber and spray arrangement. Other past work, however, did suggest that combination blowing and exhaust ventilation systems are very effective, although difficult to maintain (*12*).

To better understand how the scrubber and directional sprays would interact, the Bureau and R&P conducted a FVE study of the system using the actual machine inside of a full-scale model mine.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the R&P Coal Co. and the Greenwich Collieries, Ebensburg, PA, for their generous cooperation, which made this work possible. Special thanks to Niel Morandi, senior production engineer and Ashley McAfoose, assistant maintenance engineer-R&P, and Ron Bearer, project coordinator, Greenwich Collieries, whose assistance in altering testing configurations and data taking was greatly appreciated.

METHODS

Testing was conducted inside of a 20-ft-wide by 60-ft-long by 54-in-high model mine, constructed in the yard of the Greenwich Collieries preparation plant (fig. 1). A gravel bed was laid for drainage and a nominal 2- by 4-ft lumber frame, covered with 4-mil clear plastic, formed the roof and ribs. The model was adjacent to the repair shop, and close to the power center for the mining machine. The shop provided protected indoor space for the instrumentation and other utilities used in the testing.

Other features of the model test facility included 10-ft-long movable panels from which simulated box or slab mining configurations were constructed. Conventional brattice was hung in the appropriate manner for blowing or exhaust ventilation. A 14,000-cfm vanaxial portable fan was used to ventilate the model; its flow restricted to provide 5,000 cfm of air at the brattice mouth.

A Joy 12 CM 10-AA[4] (fig. 2) was used for testing. This machine had a maximum profile height of 30 in and two 4,000-cfm flooded bed scrubbers. One scrubber was mounted conventionally on the left rear fender of the mining machine and had a single inlet located above the leading edge of the left caterpillar track, immediately behind the pan. The second scrubber was in the former location of the operator's cab (this machine is either cable or radio remotely controlled). The single inlet to this scrubber unit was located directly opposite the left unit. Both scrubber inlets were 12 ft from the leading edge of the bits.

[3]Italic numbers in parentheses refer to items in the list of references at the end of this report.

[4]Reference to specific products does not imply endorsement by the U.S. Bureau of Mines.

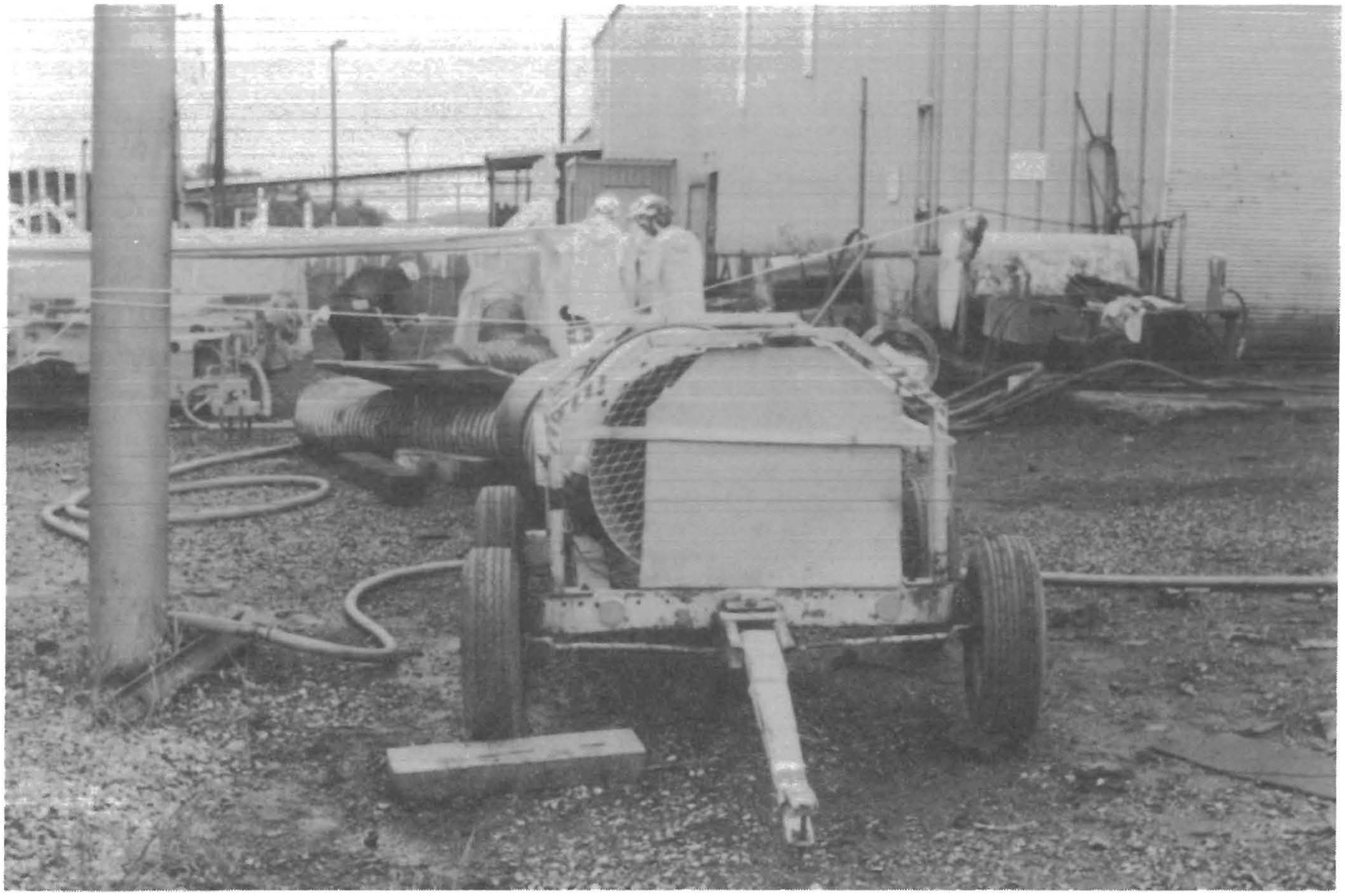

Figure 1.-Overview of model test facility.

The machine was designed to operate in a split ventilation system where the return may be on the right or left side of the machine. Currently, either the right or left scrubber functions at any one time. Use of both scrubbers simultaneously is not planned.

It is not possible to place a crossover duct on top of the boom in such a low-profile machine, nor can the scrubber inlets be moved closer to the face. There was concern that fresh air could enter directly into the inlets and not reach the face. Therefore, a directional water spray was requested by R&P and included by Joy Manufacturing Co. on this machine. Right and left side spray systems were provided for ventilation, and interlocked with the scrubber side chosen. The sprays in combination with a scrubber in a blowing ventilation setup provided additional air moving capabilities at the immediate face. In fact, the scrubber inlet located 12 ft from the face is similar to a fixed exhaust tube inlet at that location.

Tracer gas studies were used to determine the FVE of the scrubber and sprays used together. Ideally methane gas would have been the preferred gas since it would most accurately simulate mining conditions, however, none was available. Propane was selected as the tracer, since it is easily measured with a total hydrocarbon analyzer.

Propane flow was regulated to a few inches water gage pressure; the flow rate was measured with a dry gas meter. Since propane is denser than air, premixing and turbulent diffusion of the gas into the air at the face was needed. A compressed air venturi operating at about 26 cfm was connected in line with the propane supply line. This created the premixing and turbulence needed to disperse the gas at the leading edge of the cutterhead. Figure 3 shows the gas distribution manifold in place.

To determine the ventilation effectiveness of the system, concentrations of the tracer gas were measured at the face and in the return. The face samples were collected about 12 in below the roof and about 3 in from the face, at three locations across the face. These samples mixed after passing through three equal 10-ft lengths of 1/8-in-diam plastic tubing. The face sample then passed through a single length of tubing to the hydrocarbon analyzer. Return samples were collected from three locations in the duct transition from the model mine to the fan. These were near the top, the middle, and the bottom of the

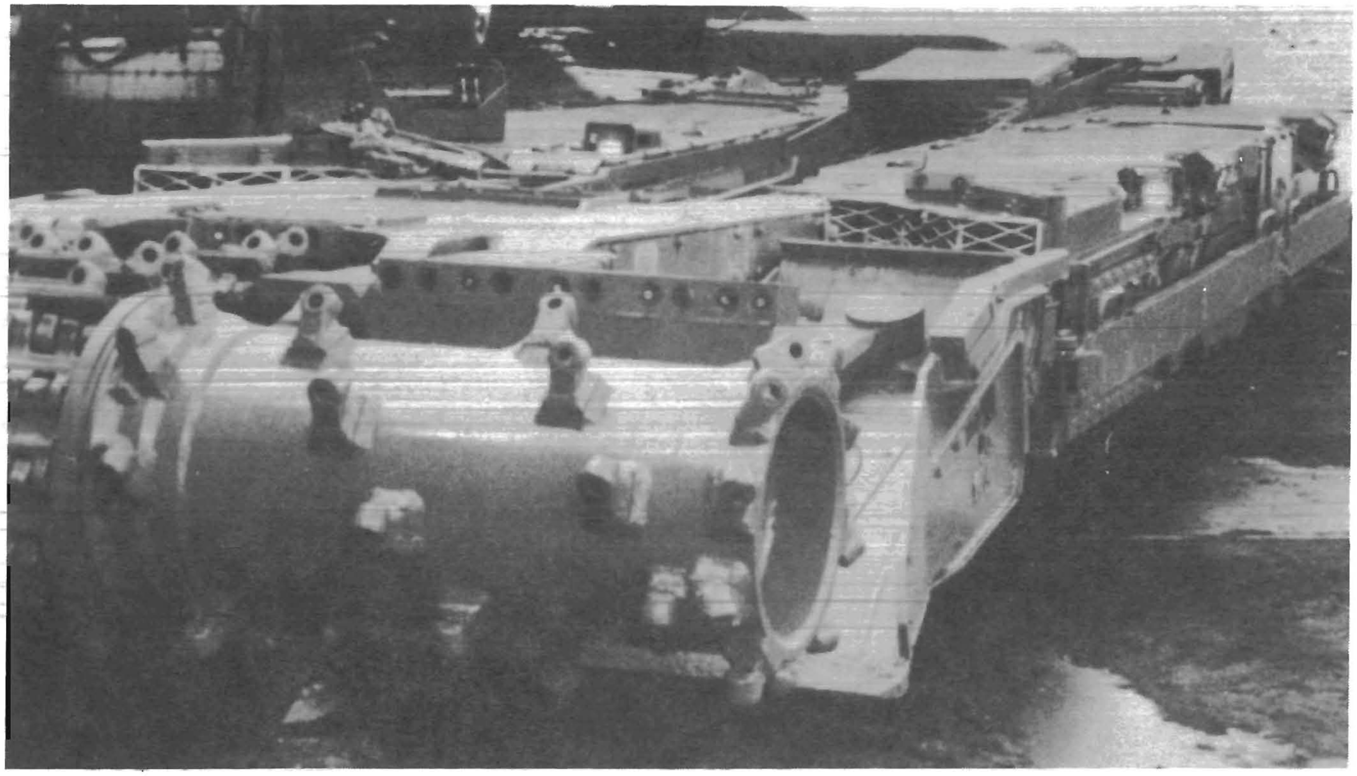

Figure 2.–Joy 12 CM 10-AA with dual scrubber used in testing.

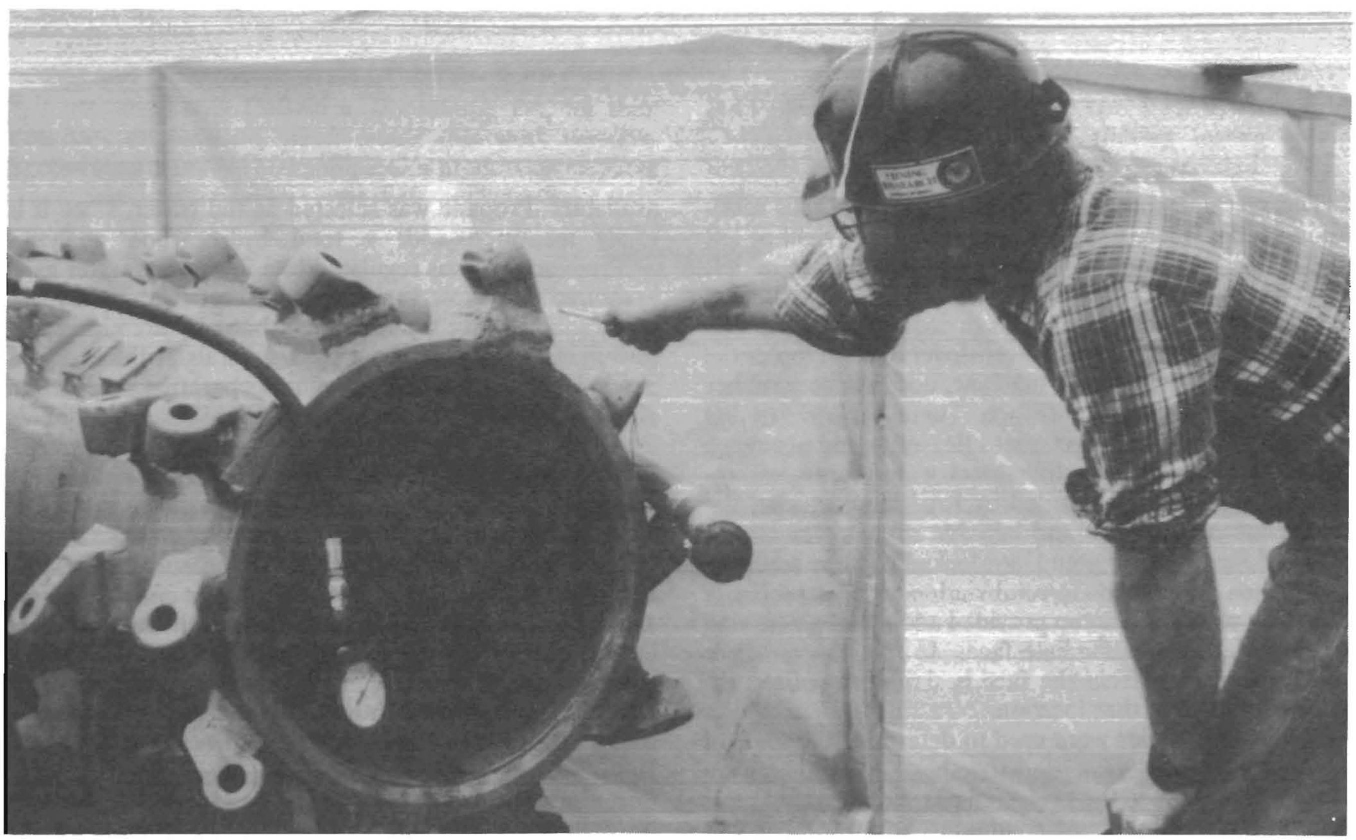

Figure 3.–Gas distribution manifold.

transition, connected in a similar manner as the face samples, and a single tube run to the instrument.

Gas samples entered and were measured by using two flame ionization detector hydrocarbon analyzers by Colombia Instruments, Austin, TX, model HC 500-2C. Before each test day, the instruments and recorders were zeroed and calibrated. Spot checks of the calibration were periodically conducted and drift of less than 10 ppm during the day observed. The 0- to 1,000-ppm scale was used. Gas flows into the model were set in attempts to keep the testing within range of the instruments. Concentrations above 1,250 ppm were truncated. This occasionally happened at the face for especially poor ventilation conditions.

The FVE factor was calculated by dividing the return concentration by the face concentration, for each mining configuration tested. In those cases, where the face concentrations were truncated, the FVE values should be even lower, representing even poorer ventilating conditions. This FVE factor is a measure of how well the available air is being used. It is a good measure of methane dilution, however, its application to dust concentrations may not be as accurate.

Smoke tubes, fire extinguishers, telltales, and smoke bombs were used to simulate dust at various mining positions. These data were recorded by two observers.

Both exhaust and blowing ventilation systems were evaluated in this model study. Engineering parameters examined included brattice setbacks at 10, 20, 30, and 38 ft, slab and box cuts of 10, 20, 30, and 38 ft, scrubber on and off, directional or conventional sprays at 50 psi on or off. Logical combinations of these parameters were also tested. A total of 122 separate configurations were evaluated. Baselines for blowing and exhaust were established and subsequent results compared with these values.

A typical test began with the mining machine being positioned in the entry, and a slab or box constructed around the mining machine. Next, brattice setback distance was established, airflow of the brattice adjusted to a nominal 5,000 cfm and the gas released. With scrubber and/or sprays turned on, the system was allowed to come to steady state (about 1 min). The conditions operated for 5 min, during which time smoke maps and fire extinguisher releases were mapped by mine personnel. The head and gathering arms of the machine were not operated. Data were simultaneously recorded by a dual pen strip chart recorder and Metrosonic DL 331 data loggers for later computer analysis.

RESULTS AND DISCUSSION

A baseline measurement for current operating conditions was established for this model test facility. With no mining machine in the model, figure 4 shows face and return concentrations for both exhaust and blowing ventilation. With a nominal 5,000-cfm-airflow, the FVE factors are 0.11 for a 10-ft exhaust curtain; 0.16 for a 20-ft blowing curtain; and 0.15 for a 30-ft blowing curtain.

When the mining machine is in position, the entry cross sectional area is restricted and the FVE increased to 0.27 ($\pm$0.21) for the 10-ft exhaust and 0.37 ($\pm$0.03) for the 20-ft blowing curtain. These baseline values are used to compare the effect of changing engineering parameters on the ventilation effectiveness of subsequent tests.

A typical strip chart recording of four individual tests is shown in figure 5. Brattice setback and mining machine positions were established, and the various combinations of systems were turned on and off. Several interesting points can be seen in this example. First, the return concentration is smoothed out when the scrubber is in operation, this is caused by the turbulence in the entry created by the scrubber. Second, the peak in the face concentration that occurred when the spray systems were changed from directional to conventional sprays was due to a brief interval when no water was used. Finally, operating only the scrubber, face concentrations increased to nearly those of no scrubber at all.

The individual results have been summarized using the FVE calculations. Results operating the scrubber alone were low, with an FVE of 0.34. When the directional water sprays were turned on, the FVE rose to 0.95, nearly a threefold increase in ventilation effectiveness. Any water spray system, however, could create turbulence that would result in a faster face gas removal rate. A symmetrical water spray, as opposed to a directional spray was installed and tested at similar water pressures. The resulting FVE increased to 0.77, or a 2-1/4-fold increase. Figure 6 summarizes these data and suggests that conventional water sprays on all types of scrubber-equipped machines are an important element for not only dust control, but for methane control.

The capture zone of an exhaust inlet decays quickly as distance from the inlet increases. Campbell (*11*) indicated the approximate velocity contours of the scrubber inlets (fig. 7). This is taken from a boom-mounted inlet location and even the lowest velocity contour does not reach the outby edge of the cutterhead. Clearly the scrubber alone does not create adequate ventilation in the immediate cutting zone of the miner. Conventional dual inlet scrubbers always operate in conjunction with symmetrical water sprays, and these sprays create the turbulent action necessary to move face contaminants from the cutting zone to the scrubber inlets. Because of the poor suction profile of the unique single inlet scrubber, the Joy 12 CM 10-AA tested was equipped with the directional sprays to help move face contaminants to the single inlet.

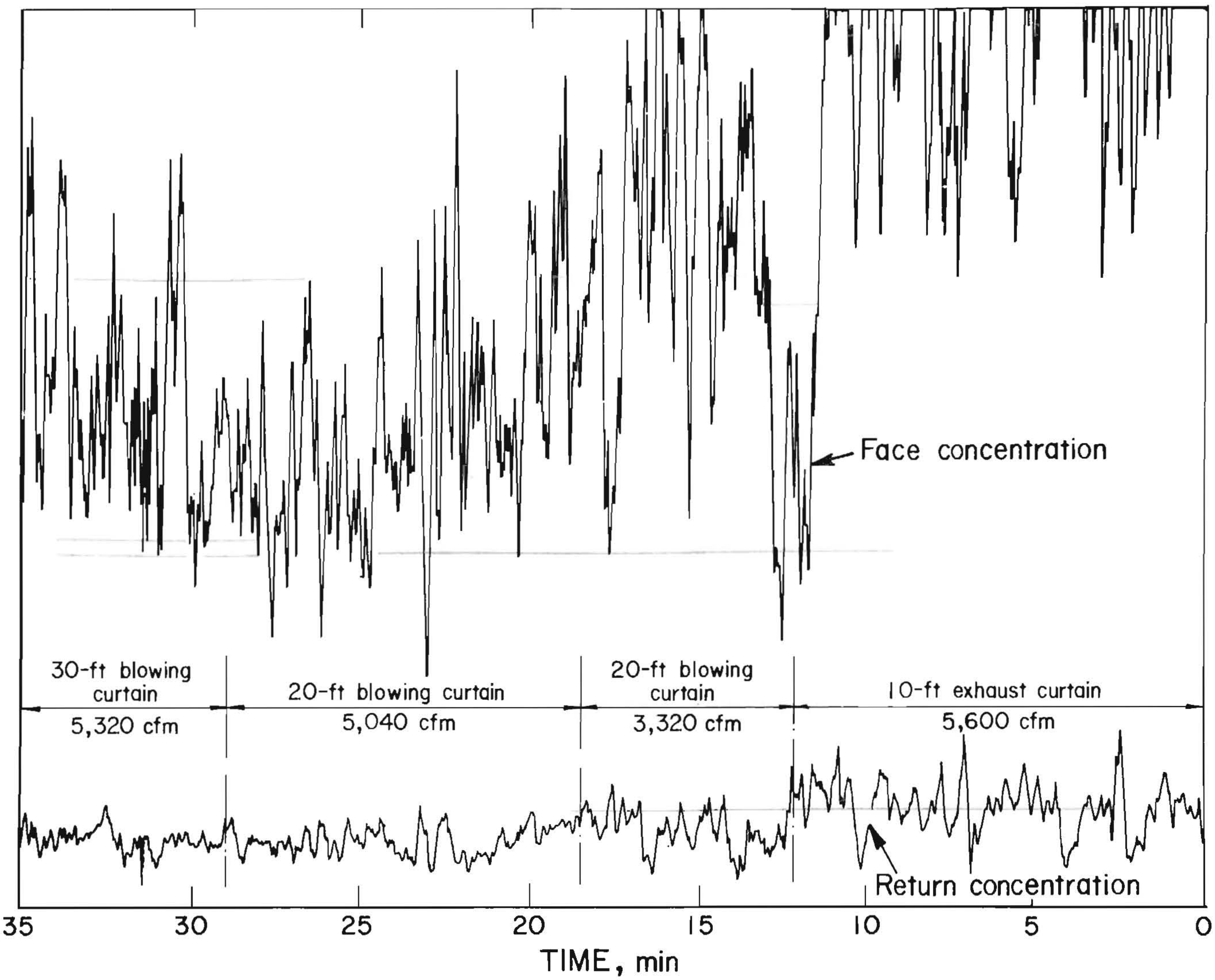

Figure 4.–Baseline methane levels in model for exhaust and blowing primary ventilation and no mining machine in place.

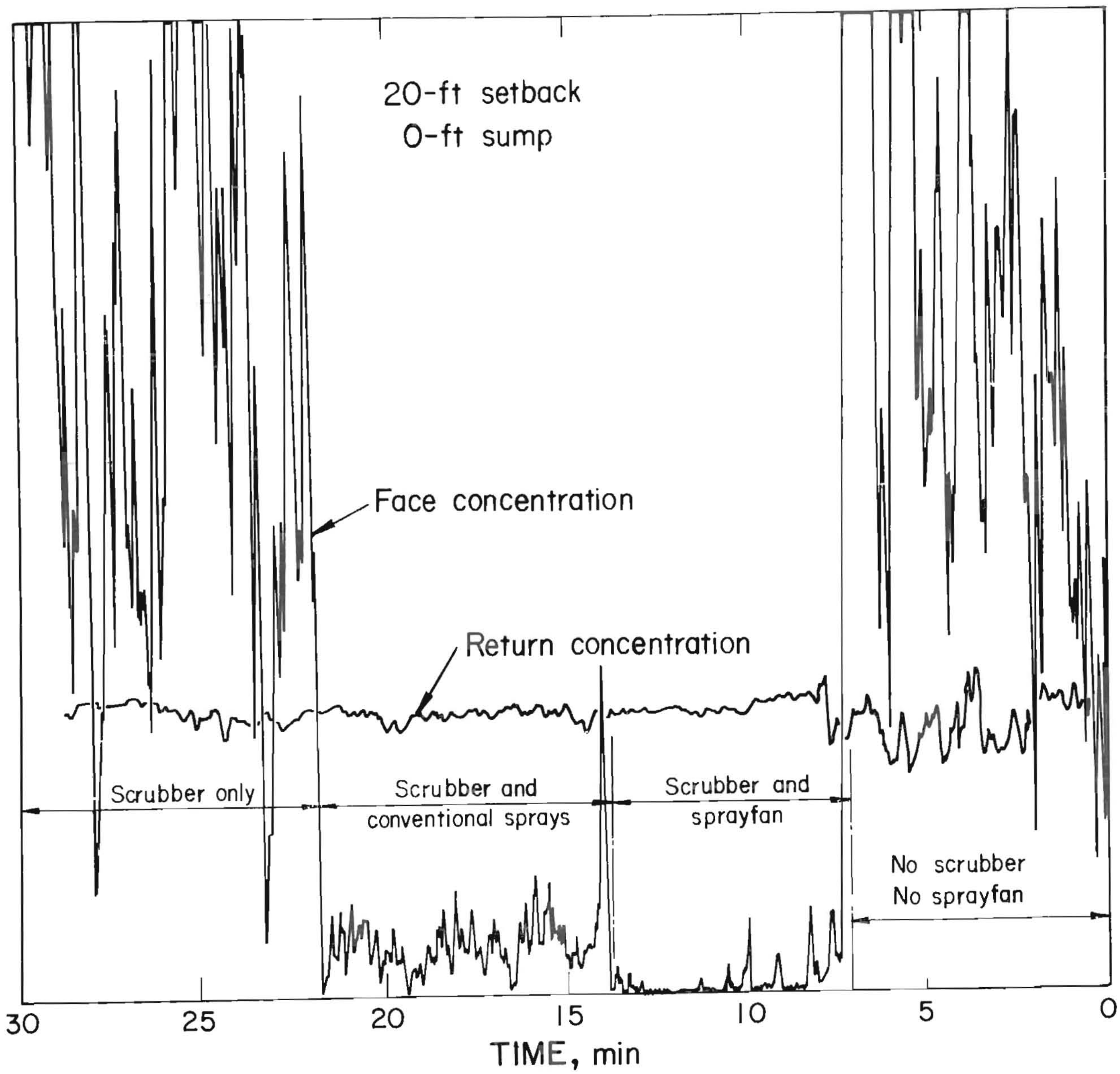

Figure 5.–Typical strip chart recording of four individual tests.

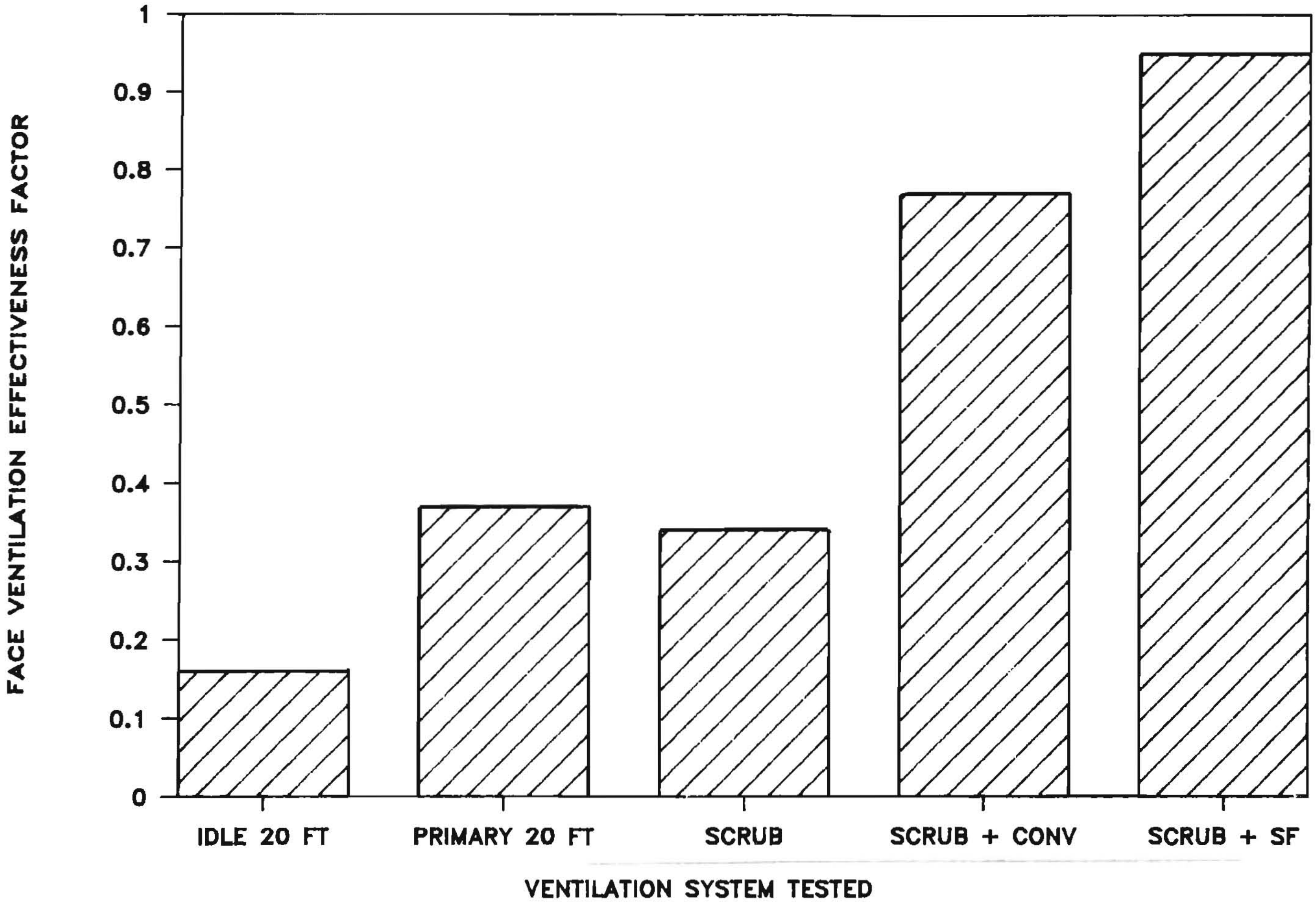

Figure 6.–Effect of different spray arrangements on FVE.

With only the scrubber operating, figure 8 shows how the blowing primary air entered the face and was captured by the left scrubber's zone of influence. When the directional sprays were turned on they created a sweeping action from right to left across the face (fig. 9). The directional sprays had never been used in a blowing face before and the researchers were concerned that the sweeping action of the directional sprays would blow the air and dust into the off curtain corner, away from the scrubber inlet. This in fact occurred, however, the scrubber inlet was far enough away from the face to allow the dust time to turn and enter the inlet. When the head of the machine sumped into the cut, the sweeping action was directed by the rib of the cut to the scrubber inlet. Past attempts to use sprays to enhance scrubber capture efficiencies had been unsuccessful. Another factor contributing to the successful capture of face air was the derating of the directional spray pressures to 50 psi. The low seam height and low mean entry air velocities dictated the lower spray pressure.

The location of the scrubber inlet is similar to using an exhaust ventilation tube at a constant 12-ft setback from the face. Preliminary underground work to date has indicated that the pressure on the directional spray system needs to be closer to 40 psi to enhance the scrubber capture efficiency of dust.

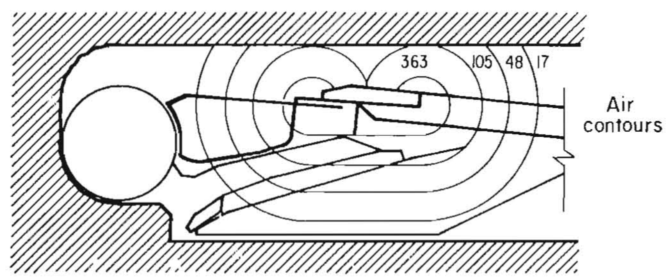

Figure 7.–Zones of air capture of scrubber inlets (courtesy Campbell (*11*)).

Extended advances using remotely controlled mining machines require effective face ventilation for methane control, even if workers are located outby the face dust. The FVE for each mining step in a 38-ft advance cycle was tested to ensure that at no point in the advance, ventilation performance fell below that of the required 10-ft exhaust curtain (FVE 0.27) or the 20-ft blowing curtain

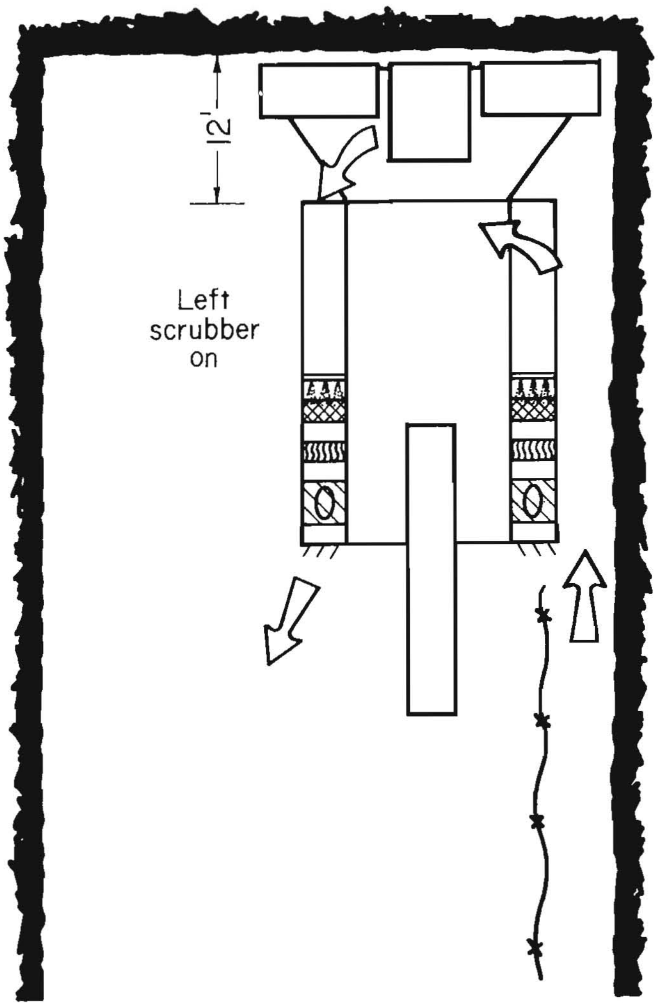

Figure 8.–Airflows to scrubber inlet without sprays.

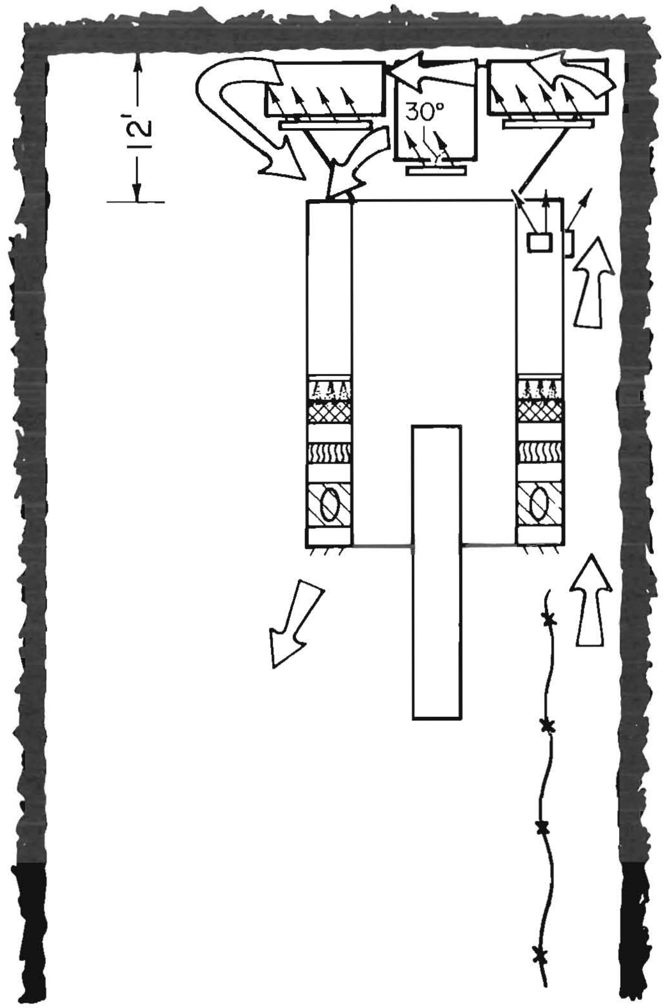

Figure 9.–Sprays move air to face before entering scrubber inlet.

(FVE 0.37). Figure 10 shows the stepwise sequence, the respective engineering parameters, and the FVE values. A 10-ft extensible brattice is used in step 10. At no position did the FVE value drop below the 20-ft blowing value. At the completion of the cut, the mining machine has moved to a new face and the blowing brattice remains at a distance of 30 ft from the face (position 14, fig. 10) until the bolter permanently supported the roof. For comparison, position 15 shows the FVE in a place with a 10-ft exhaust curtain.

Figure 11 shows the FVE values for the situation where the entire 38-ft sump is cut in one lift and the 10-ft extensible brattice is not installed until the sump is complete and the mining machine has moved to the slab side. In practice, the first one or two open face sump cuts create the most dust. This is due to the lack of confinement of the head by the coal, less effective capture efficiency, and more chance for blowby of the sprayfans. Therefore, this single 38-ft sump technique requires the cutting of a single open face cut, resulting in less dust escaping the face area. Of equal importance, is the ability of the scrubber and/ordirectional spray system to maintain good FVE values for this method.

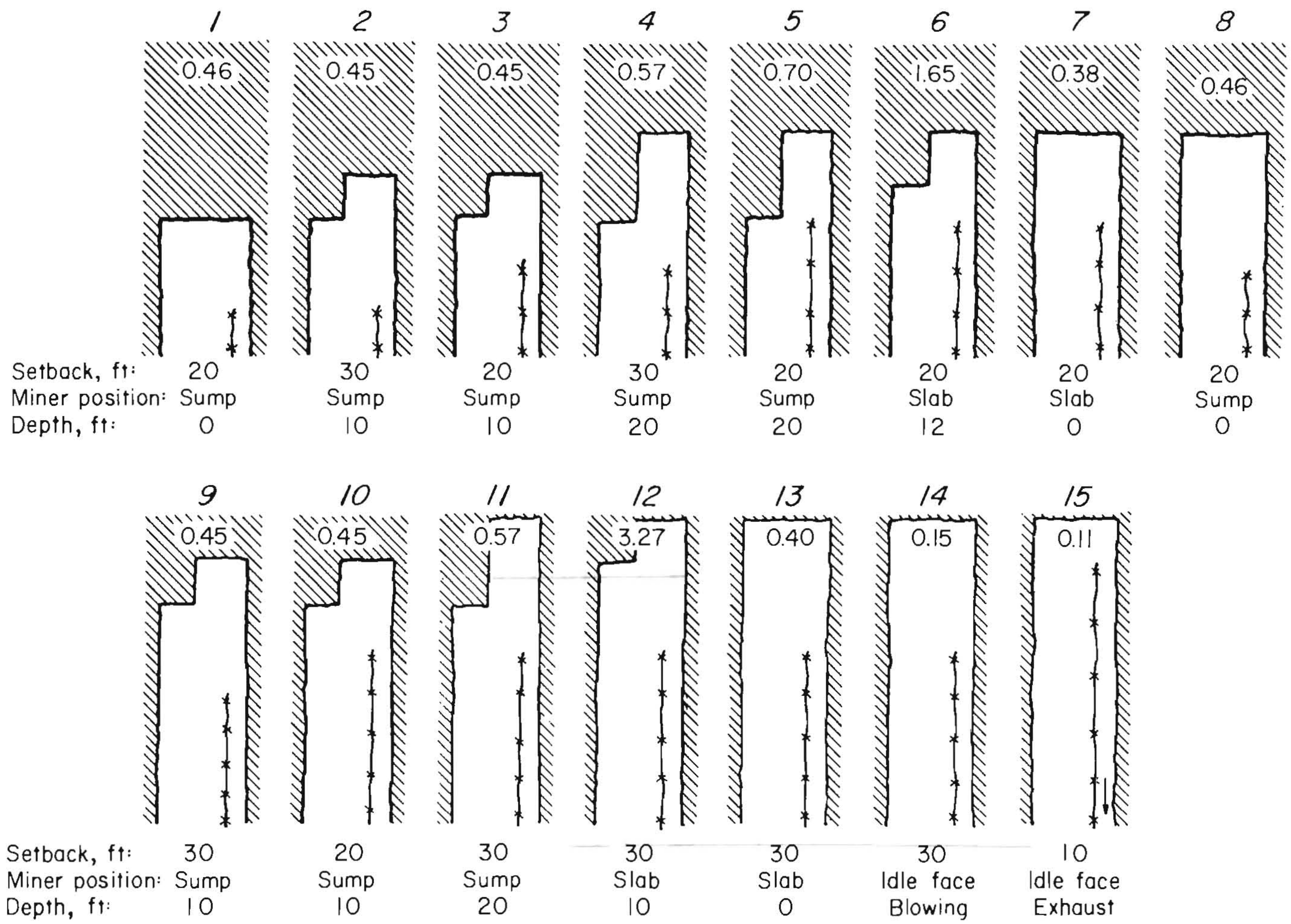

Figure 10.–Cut and curtain sequences and their respective FVE values taking two 20-ft alternating box and slab cuts.

Data for the scrubber operating with the directional sprays were also grouped according to brattice setback and sump or slab side mining machine positions. FVE values were 0.87 and 0.77 for 20-, and 30-ft brattice setbacks for all depth of cuts and mining machine positions, respectively. The difference between sump and slab side miner positions was somewhat greater at 0.73 for sump FVE's and 1.18 for slab side FVE's. These FVE values are the averages of 10 or more individual tests. The setback values are consistent with previous work where FVE values remained relatively constant with brattice setback. Improvement in FVE values from sump to slab side are also consistent with past work except the magnitude of the improvement from sump to slab is about a 38-pct improvement as opposed to 17 pct. The improved sweeping action of the directional sprays in the slab position is a likely reason for this observation.

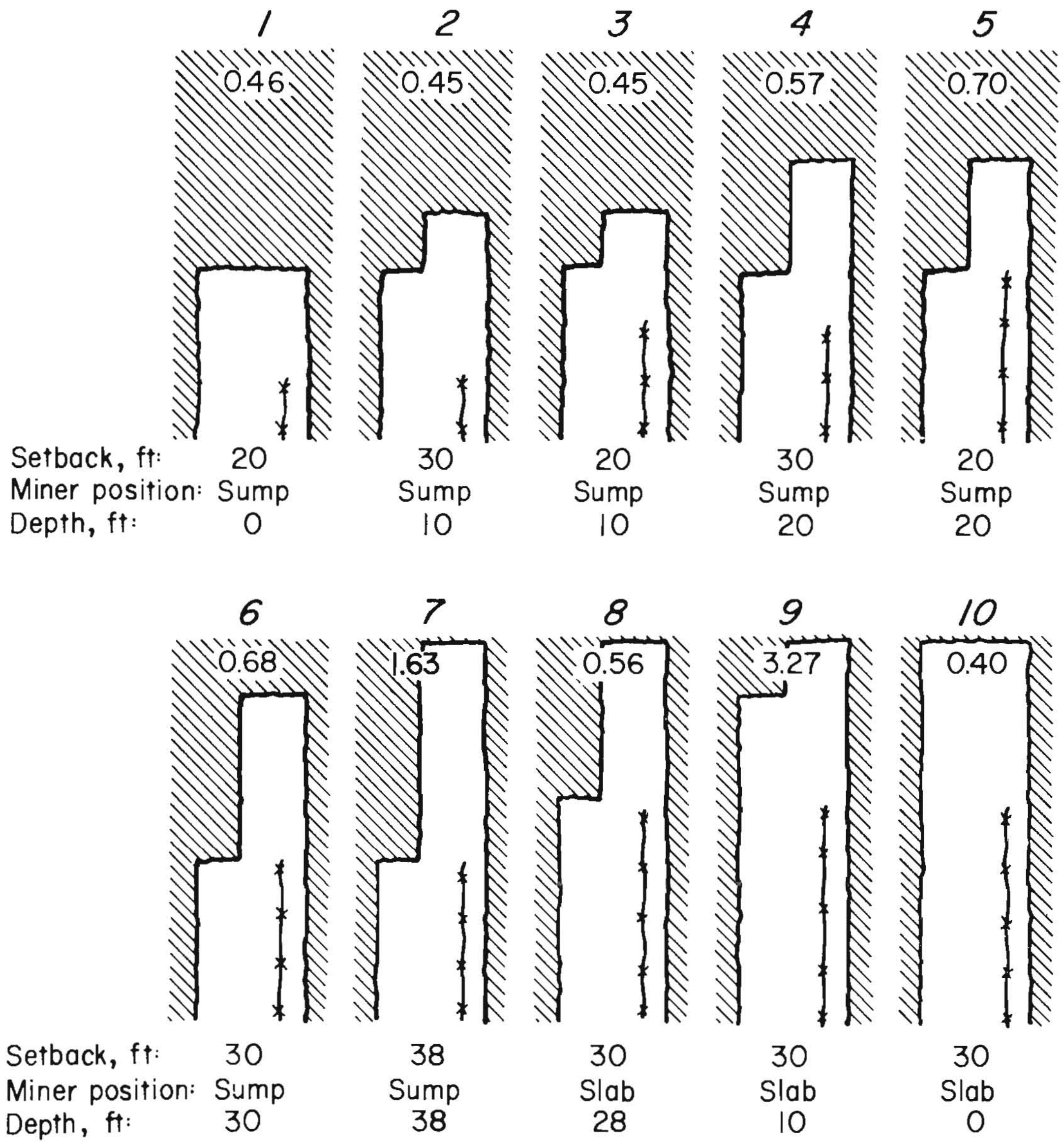

Figure 11.–Cut and curtain sequences and their respective FVE values taking 38-ft-box and 38-ft-slab cut.

CONCLUSIONS

Past work has shown that water sprays can move tremendous quantities of air. The mine ventilation engineer can use this fact to improve dust and methane control. This study specifically looked at the ability of directional sprays to help ventilate the face when a single scrubber inlet was located 12 ft from the face, much like a fixed exhaust tube. The impact of the water spray systems on FVE of dust scrubbers is far greater than previously thought. This work has shown that water sprays alone improve ventilation effectiveness of the scrubber by a factor of 2 to 3.

The use of a scrubber evens out return gas concentrations, minimizing peak heights. FVE values were comparable to, or better than, previous work on the scrubber alone. The use of directional sprays appears to improve scrubber ventilation of the slab cut.

The novel use of a directional water spray system and a single-sided dust scrubber on a low-seam continuous mining machine was effective. Little difference in FVE values was seen when four alternating 20-ft box and slab cuts were taken versus two single 38-ft box and slab cuts.

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