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Face Ventilation Measurement With Sulfur Hexafluoride (SF_6)

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

BUREAU OF MINES
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CONTENTS

ILLUSTRATIONS

FACE VENTILATION MEASUREMENT WITH SULFUR HEXAFLUORIDE (SF_6)

by

Robert P. Vinson,[1] Fred N. Kissell,[2] John C. LaScola,[3] and Edward D. Thimons[4]

ABSTRACT

The face ventilation measurement method developed by the Bureau of Mines involves releasing a small volume of tracer gas (SF_6) on the off-curtain side of the working face at the start of the mining cycle. At the same time, gas bottle samples are taken in the immediate return airway. The gas samples are analyzed, and a curve is drawn of SF_6 concentration versus time. From this curve, the percentage of gas removed per time is calculated. A curve showing a high percentage of the tracer gas removed in a short period would represent a well-ventilated face.

The face ventilation measurement method was tested in a full-scale mine entry model. Subsequently it was used underground to evaluate the spray-fan ventilation system and in an MSHA test facility to test machine-mounted scrubbers. The method was shown to be a simple and effective way of evaluating face ventilation systems.

INTRODUCTION

Mine ventilation has always played a vital role in the health and safety of underground miners. The main objectives of mine ventilation are to provide the miners with a clean air supply and to remove hazardous dust and gas from the mine atmosphere. Dust and gas are greatest at the working face where coal is being extracted. It follows that proper ventilation of the working face, especially during mining, is essential for the health and safety of the miners. A method is needed to assess the many variables that affect ventilation in the face area, such as face configuration, curtain-to-face distance, air volume available to the section, and line curtain leakage. When the effect of these variables is understood, intelligent modifications can be made to optimize face ventilation systems with a minimum of effort. Such a method could also be used to evaluate machine-mounted air movers such as diffuser fans, scrubbers, and spray fans.

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Until now, the only way of measuring face ventilation was to measure methane at the face and in the return airway. If no methane was present, face ventilation could not be measured.

The Bureau of Mines has now developed a simple and quick method for measuring ventilation at the working face that eliminates the need of methane; it is called the face ventilation measurement (FVM) method. A small volume of SF_6 tracer gas is released directly behind the cutters on the off-curtain side of the entry at the start of the mining cycle. At the same time, gas samples are taken periodically in the immediate return airway. These samples are analyzed for SF_6 content. A curve is then plotted of SF_6 concentration versus time (fig. 1). The area under this curve represents the volume of SF_6 that passed through the return airway during the test period. The area within each time increment is divided by the total area under the curve to give the fraction of SF_6 removed with each progressive time period. With this information, another curve is plotted showing the percentage of SF_6 removed with respect to time (fig. 2). This curve gives a graphic picture of how well the face is being ventilated. A well-ventilated face will show a high percentage of SF_6 removal in a short time period.

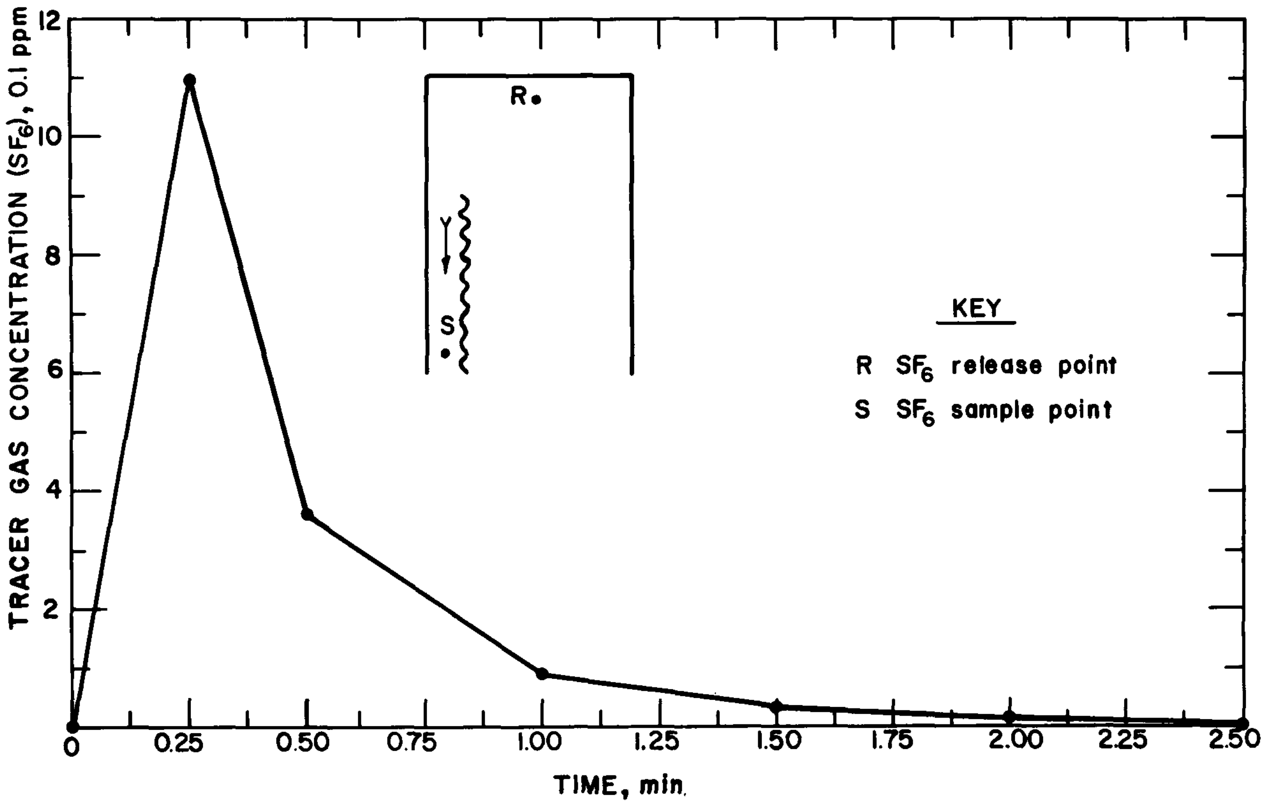

FIGURE 1. - SF_6 concentration with respect to time (6,000 cfm, 10-ft curtain setback).

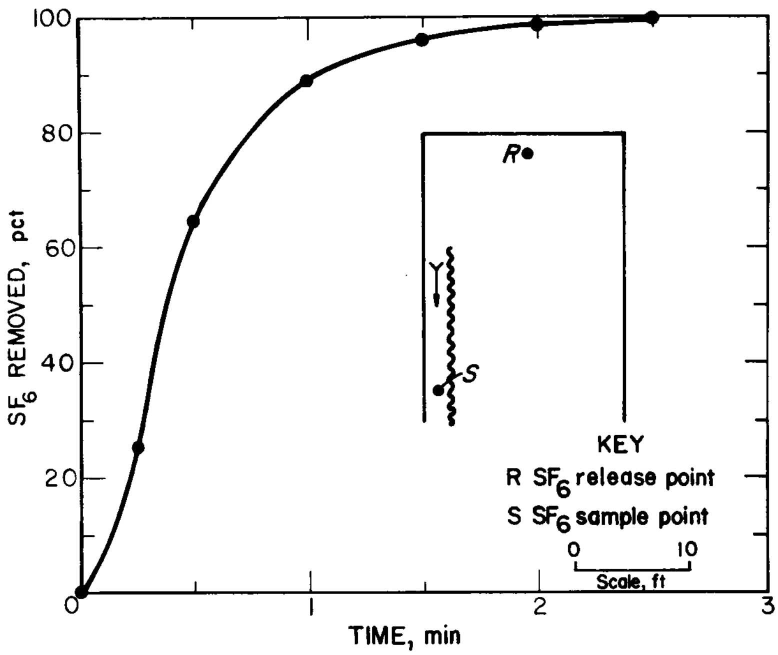

FIGURE 2. - Percent SF_6 removed at 6,000 cfm with 10-ft curtain setback.

LABORATORY TESTS

The FVM method was first examined by running a series of tests in a full-scale mine entry model containing a full-scale mining machine (fig. 3). The mine entry had an adjustable face to simulate box cuts to 20 ft, and a movable line curtain for different curtain setback distances. The return airway was connected to an exhaust fan, the flow of which could be varied from 3,000 to 9,000 cfm. The mining machine had rotating cutter drums and a water spray system. To test the FVM method, a section of 1/4-in-diameter plastic tubing was run along the right side (off-curtain side) of the miner from the operator's position to a location directly behind the right-hand cutter. A tee fitting was connected to the tubing at the operator's position. A portable air pump and a syringe containing SF_6 were then connected to the tee fitting. Prior to each test the face configuration was set up, the air volume set, the sprays turned on, and the cutters rotated. The test was initiated by turning on the pump and injecting 50 cu cm of SF_6 into the tubing. The pump pushed the SF_6 out of the tubing behind the right cutter drum. At the same time, air samples

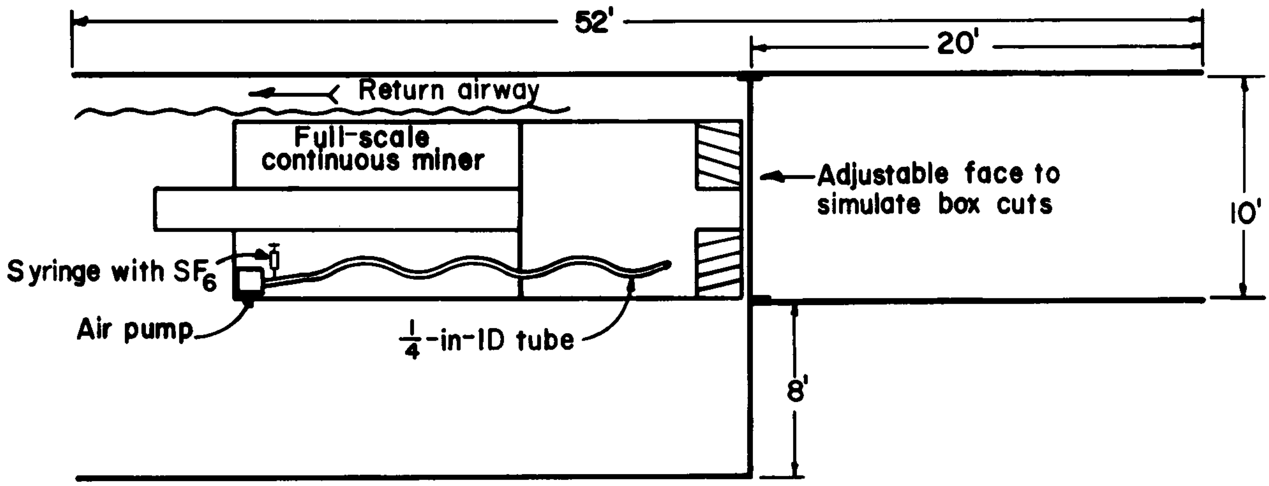

FIGURE 3. - Laboratory test setup for SF_6 studies.

were taken with 10-cu-cm Vacutainers[5] in the immediate return airway and at the miner operator's position, at various preset time increments for 5 minutes. The Vacutainer samples were analyzed for SF_6 content with a gas chromatograph. Graphs were then drawn showing percentage of SF_6 removed per time.

SF_6 concentrations are not listed because the absolute accuracy of the chromatograph calibration curve was poor and gave SF_6 concentrations that were higher than would be expected from the amounts released. However, because the FVM method is used to compare relative differences in the face ventilation, absolute errors do not affect the final results.

The main objective of the laboratory tests was to determine if the FVM method was giving an accurate indication of how the face was being ventilated. This was determined by comparing curves from tests having the same face configuration and airflow, but with different curtain-to-face distances (curtain setback). Studies have shown that face ventilation declines as the curtain-to-face distance is increased.[6] The Mine Safety and Health Administration (MSHA) requires that the curtain-to-face distance be kept within 10 ft.[7] The FVM curves in figure 4 clearly show the effect of curtain setback.

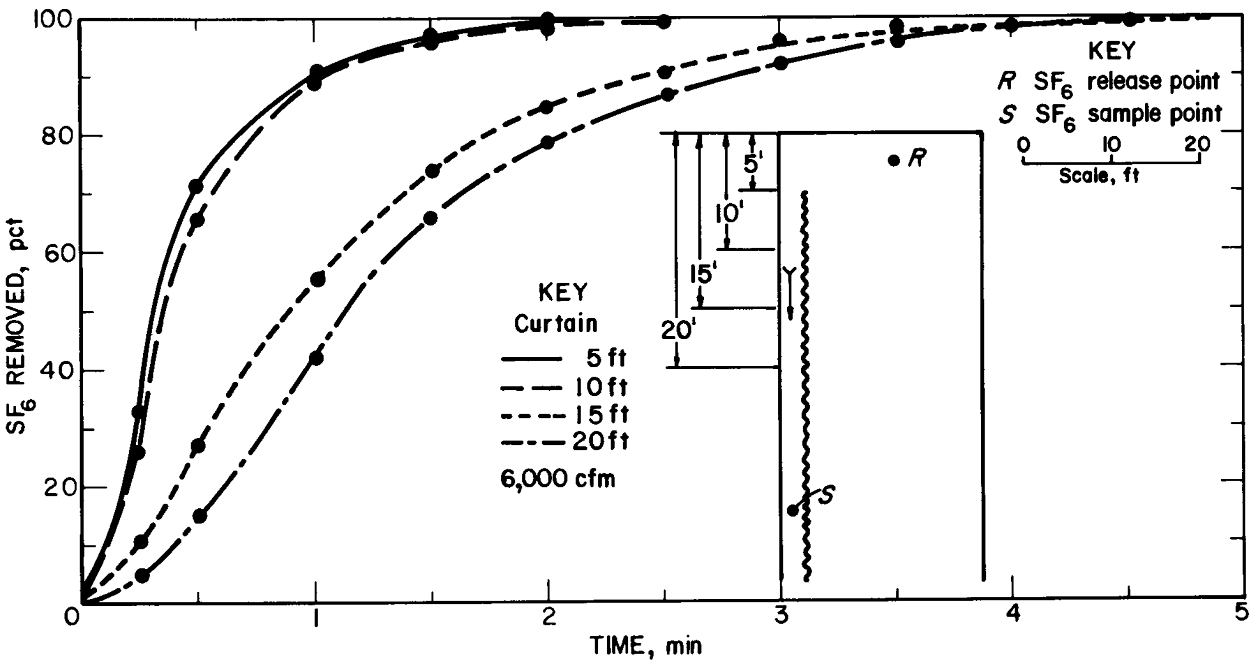

FIGURE 4. - Percent SF_6 removed at different curtain distances.

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

[6]Luxner, J. V. Face Ventilation in Underground Bituminous Coal Mines. BuMines RI 7223, 1969, 16 pp.

[7]U.S. Code of Federal Regulations. Title 30, Mineral Resources; Chapter 1--Mine Safety and Health Administration, Department of Labor; Subchapter O--Coal Mine Health and Safety; Part 75, Mandatory Safety Standards--Underground Coal Mines. Subpart D--Ventilation. Revised annually.

For example, at 1 min about 90 pct of the SF_6 is removed when the curtain setback is 5 ft, whereas only 40 pct of the SF_6 is removed when the setback is 20 ft. Figure 5 shows that as curtain setback is increased, the percentage of SF_6 removed in 1 min decreases. This is a clear indication that the FVM gives an accurate indication of how well the face is being ventilated.

The data from the laboratory tests were also used to see if box depth had any major effect on face ventilation. Curves of three FVM tests are shown in figure 6. Each test used about the same air volume and curtain setback; only the box depth was changed significantly, which had little effect on face ventilation.

During the laboratory studies of the FVM method, air samples were also collected at the miner operator's position. Any SF_6 detection at this location would indicate that air from the working face was recirculating back over the mining machine. In an actual mining situation, this would mean that dust and methane produced at the face were reaching the miner operator. The average SF_6 concentrations at the operator's position are shown in figure 7. In all of the tests except one, SF_6 was detected at the operator's position, with the average SF_6 concentrations always being higher at the lower air volumes (3,000 cfm). These results indicate that higher air volumes reduce the probability of recirculation of contaminated face air.

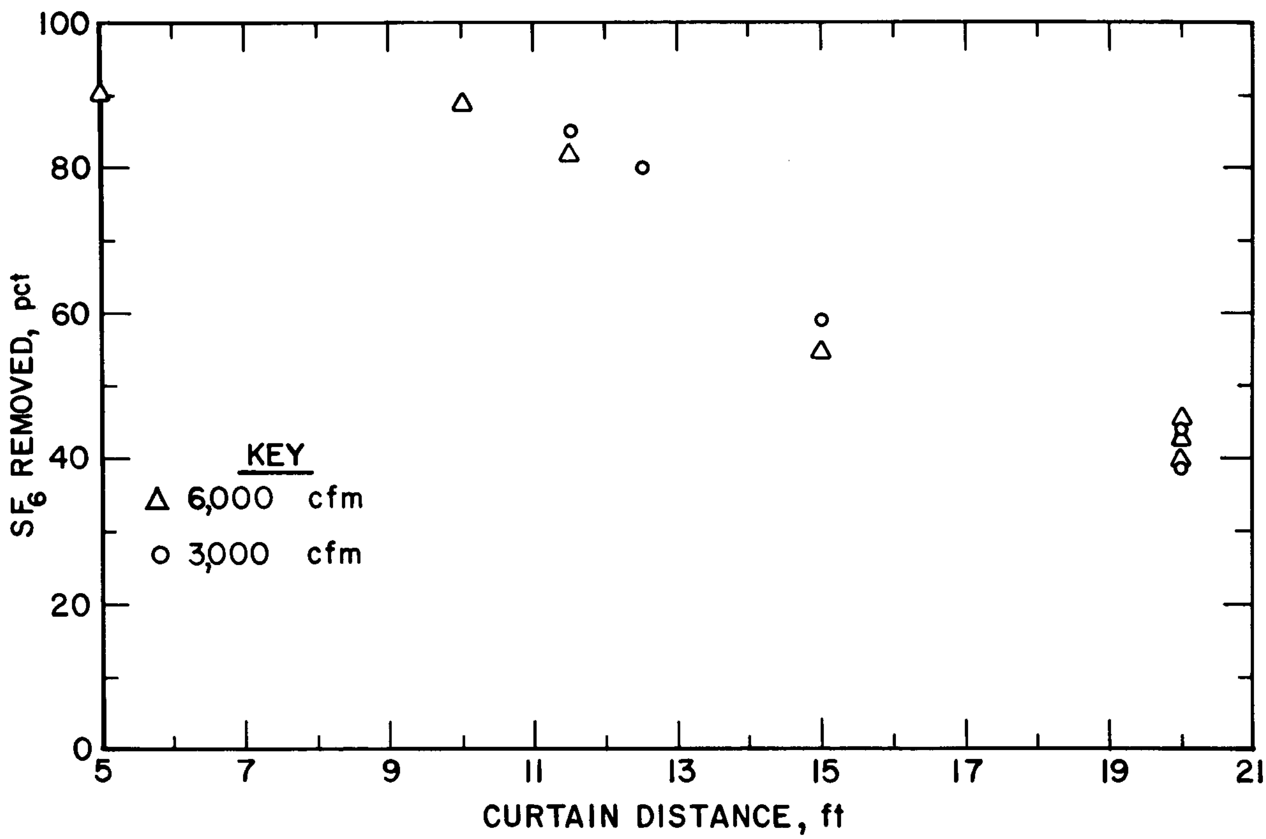

FIGURE 5. - Percent SF_6 removed in 1 min with respect to curtain distance.

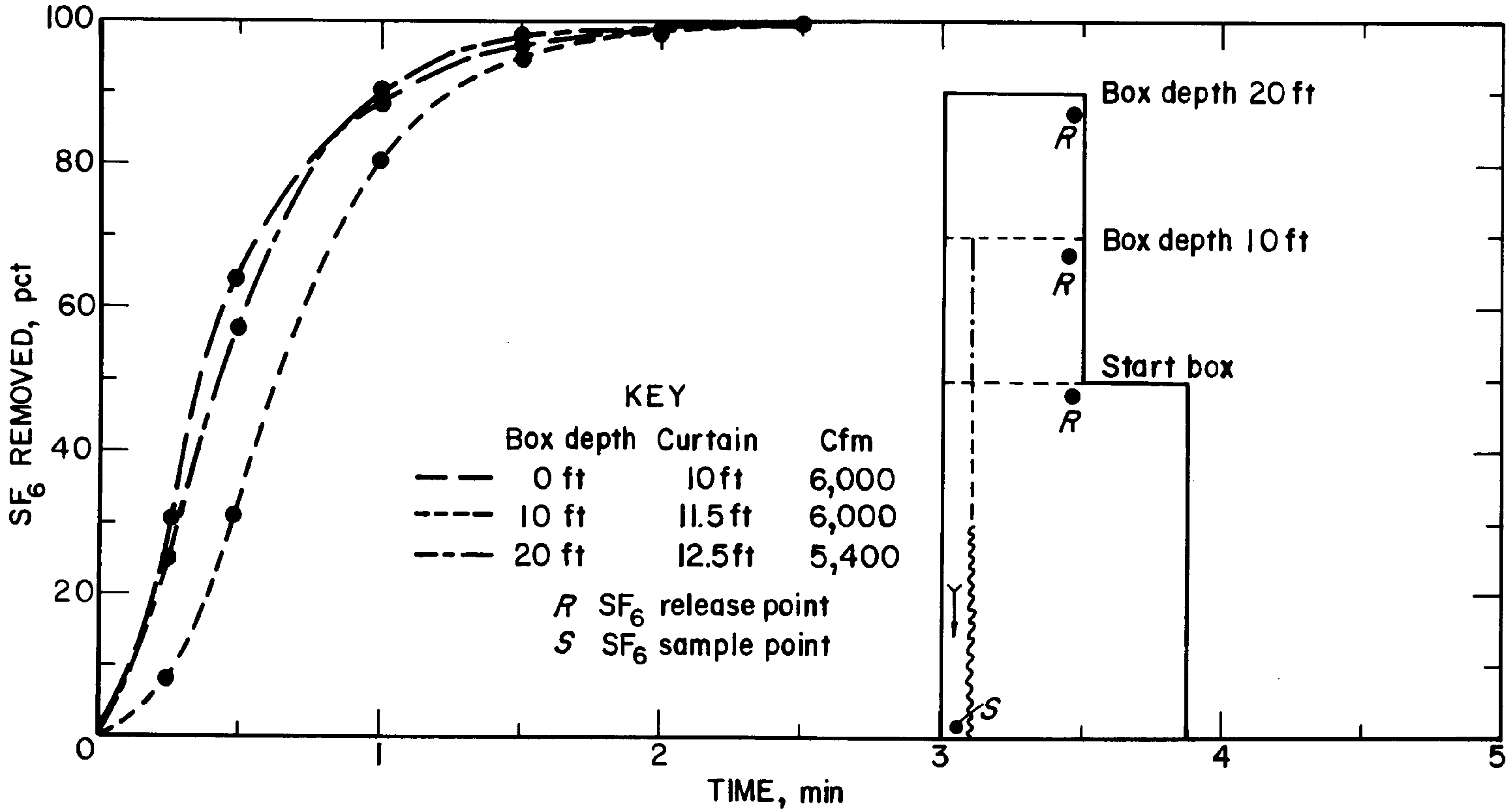

FIGURE 6. - Percent SF_6 removed at different box depths.

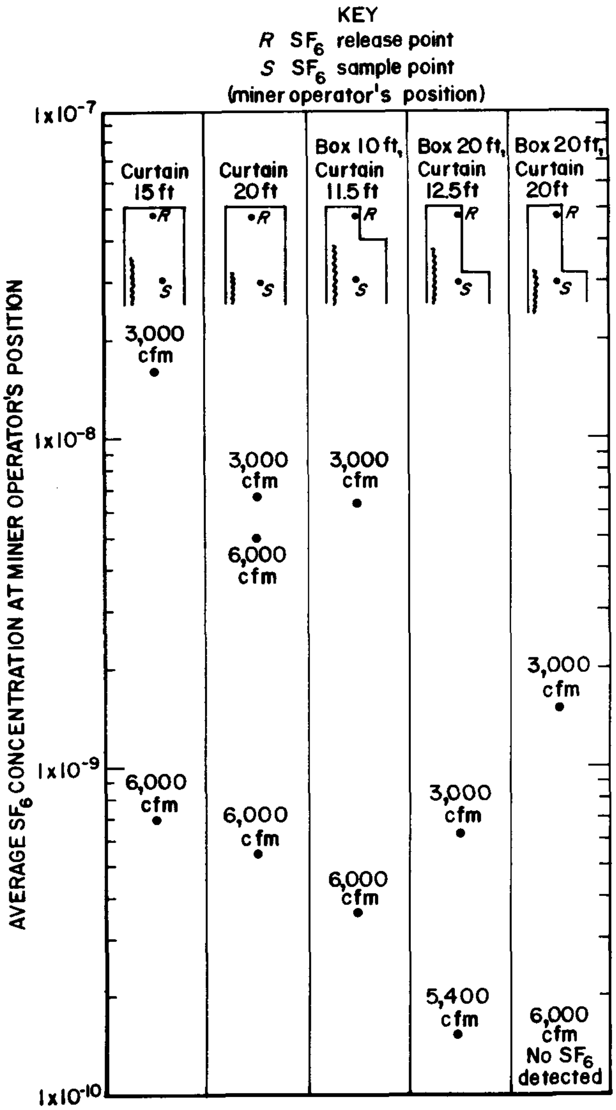

FIGURE 7. - SF_6 detected at miner operator's position.

EVALUATING THE SPRAY FAN

The FVM method was first used underground to compare the spray fan ventilation system with a conventional ventilation system.[8] For this purpose, the laboratory procedure was modified somewhat to fit into the working environment of a coal mine. As in the laboratory tests, a 1/4-in plastic tube was connected to the continuous miner, so that SF_6 could be injected into the tubing at the operator's position and released directly behind the cutterhead on the off-curtain side of the entry. Only 25 cu cm of SF_6 was used for each test. A hand-operated tire pump was used to push the SF_6 through the tubing. Return air samples were taken behind the line curtain airway with 10-cu-cm evacuated tubes. Prior to an FVM test the air volume entering the line curtain, the line curtain setback, and the face configuration were recorded. When the continuous miner began mining coal, the SF_6 tracer gas was ejected directly behind the cutterhead. At the same time, air sampling of the return air started and continued in increments of 15 sec. Samples were taken as long as the miner operated, which was usually from 1.5 to 2 min. The air samples were analyzed on a gas chromatograph for SF_6 content. The resulting SF_6 concentrations were used to construct graphs showing percentage of SF_6 removed versus time.

A series of FVM tests were conducted with the spray fan in use at different face configurations and line curtain setbacks. Comparisons were made with other FVM tests at similar face configurations and curtain setbacks using conventional ventilation (figs. 8-10).

[8]Wallhagin, R. E. (Foster-Miller Associates, Inc.). Development of Optimized Diffuser and Spray Fan Systems for Coal Mine Face Ventilation. BuMines Open File Rept. 14-78, November 1977, 256 pp.; available for reference at Bureau of Mines facilities in Denver, Colo.; Twin Cities, Minn., Bruceton and Pittsburgh, Pa., and Spokane, Wash.; at the Department of Energy facilities in Carbondale, Ill., and Morgantown, W. Va.; at the National Mine Health and Safety Academy, Beckley, W. Va.; and at the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.; and from the National Technical Information Service, Springfield, Va., PB 277 987/AS.

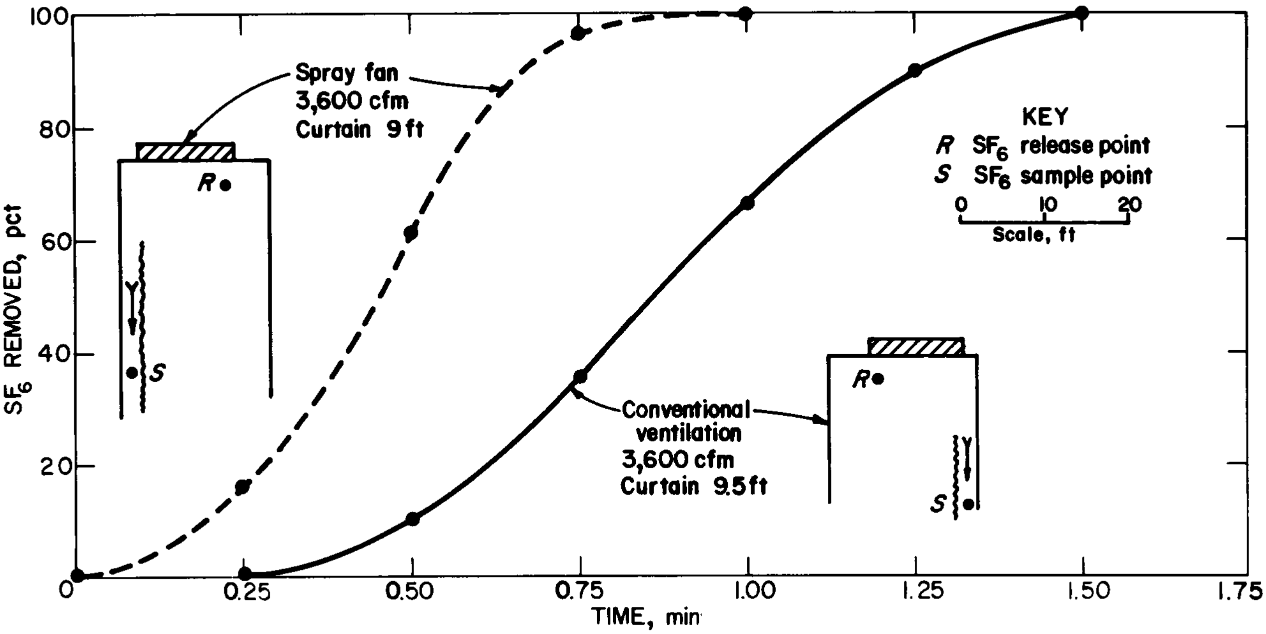

FIGURE 8. - SF_6 spray fan comparison at beginning of a box cut.

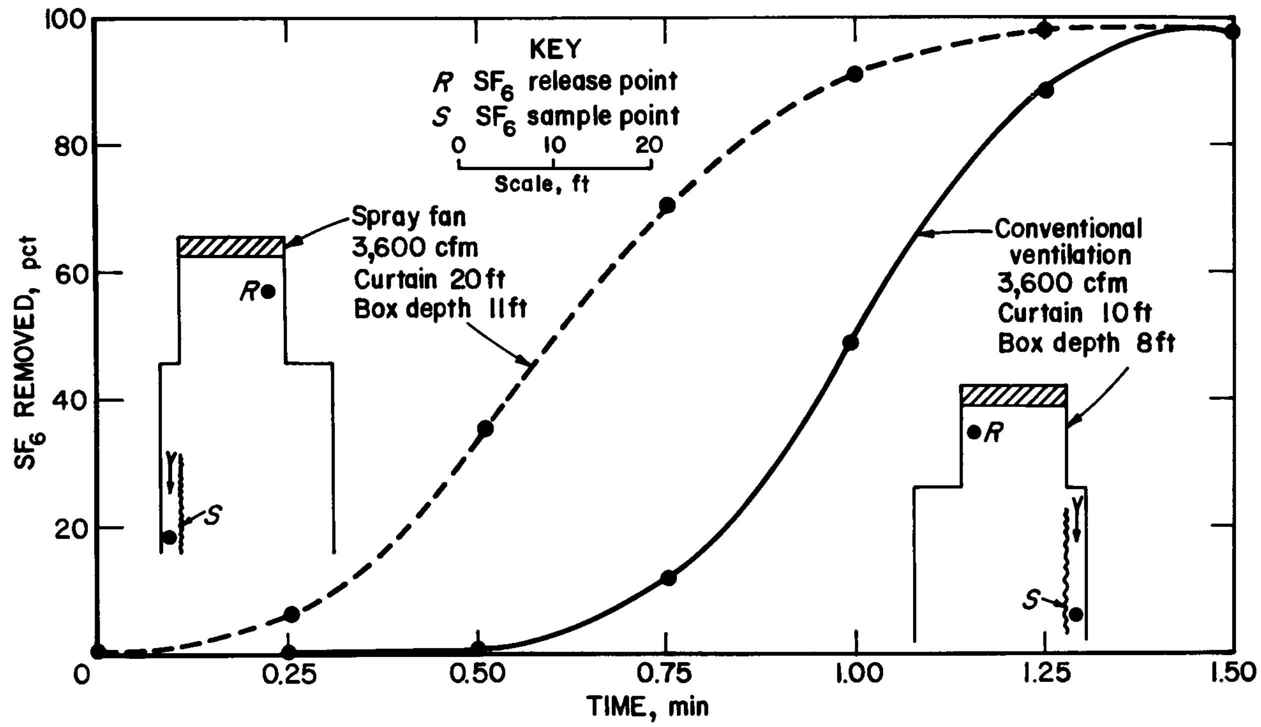

FIGURE 9. - SF_6 comparison of the spray fan with 20-ft curtain setback and conventional ventilation with 10-ft curtain setback.

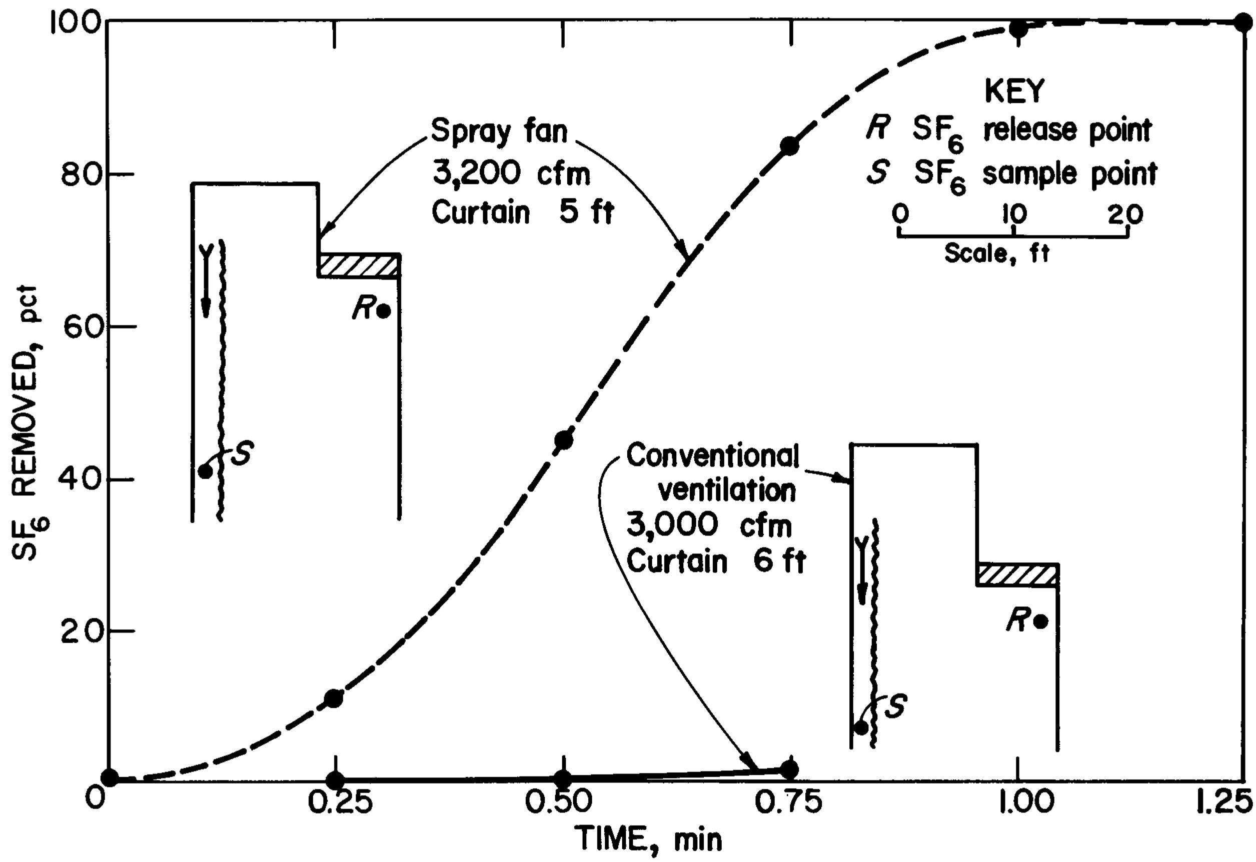

FIGURE 10. - SF_6 spray fan comparison in a slab cut configuration

Figure 8 shows that, as the continuous miner began a box cut, the spray fan removed 60 pct of the SF_6 in 0.5 min, whereas conventional ventilation removed only 10 pct of the SF_6 in 0.5 min. An even more dramatic example of the ability of the spray fan is seen in figure 9, where the spray fan with a 20-ft curtain setback removes the SF faster than conventional ventilation with only a 10-ft curtain setback. The curves show that within 1 min, the spray fan has removed 90 pct of the SF_6 and the conventional system has removed only 50 pct.

When making a slab cut, the spray fan proved to be a vast improvement over conventional ventilation (fig. 10). In 0.75 min the spray fan had removed over 80 pct of the SF_6, and the conventional ventilation had not removed even 5 pct.

Figure 11 gives the percent of SF_6 removed in 1 min as a function of curtain setback and clearly shows the superiority of the spray fan, especially at the longer curtain setback distances.

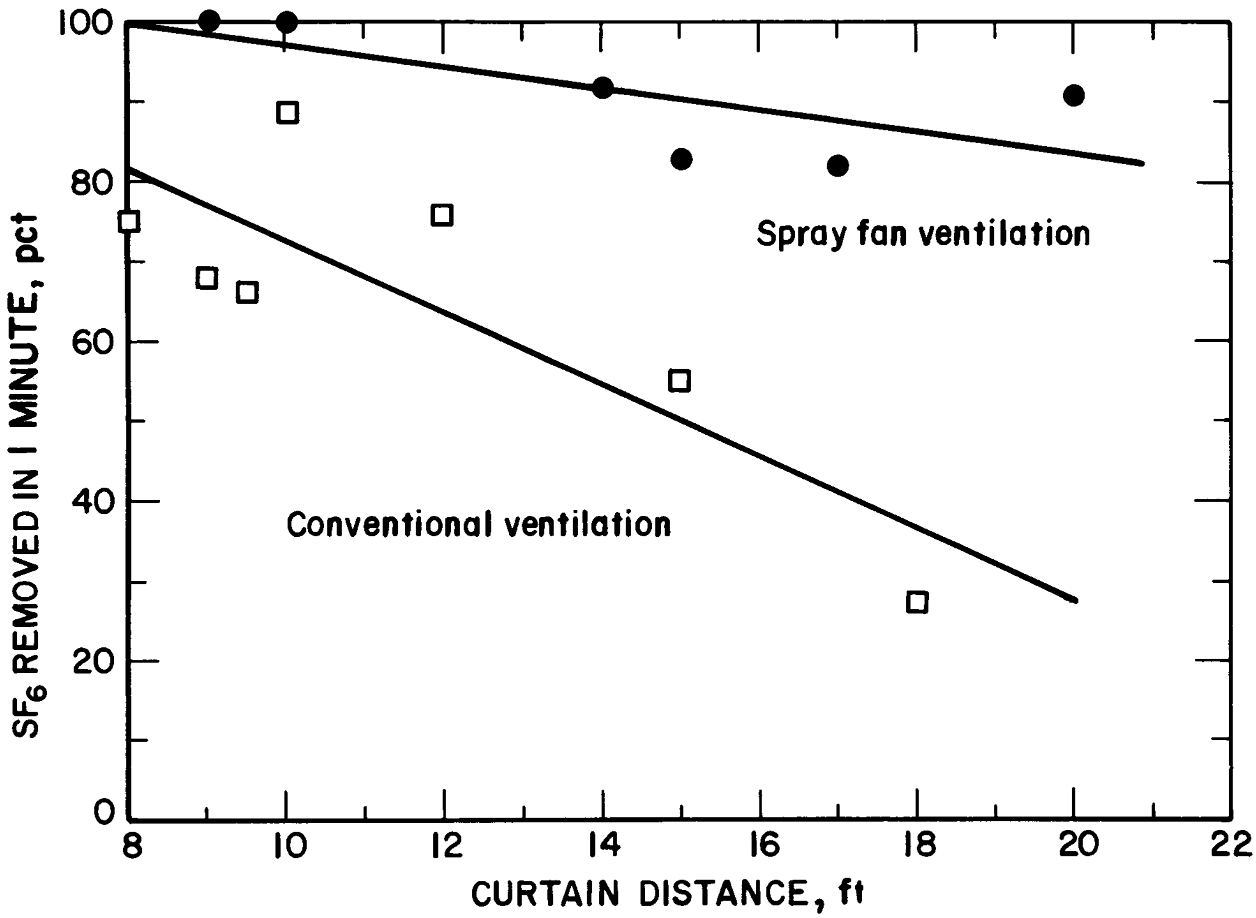

FIGURE 11. - Percent SF_6 removed in 1 min versus curtain distance.

EVALUATING SCRUBBERS

The FVM method was next used to evaluate a dual-scrubber system consisting of two flooded fibrous-bed scrubbers mounted on the right and left side of the cutterhead of a continuous miner. MSHA was conducting a series of studies in the MSHA face ventilation appraisal and testing facility (FVATF) to evaluate different inlet and outlet locations of the scrubber system. The FVM method was used during one phase of the studies, when the inlet and outlet locations of the scrubbers were as in figure 12. The entry was 3-1/2 ft high and 20 ft wide. The width of the entry was narrowed to 16 ft for a box cut configuration. Also shown are the position of the full-scale miner and the inlet and outlet locations of the scrubbers along with the approximate release and sampling locations of the tracer gas. FVM tests were run with each scrubber operating at 2,400 cfm. At each air volume, curtain setbacks of 5, 10, 15, and 20 ft were tested. Identical series of FVM tests were run with the scrubbers turned off for comparison.

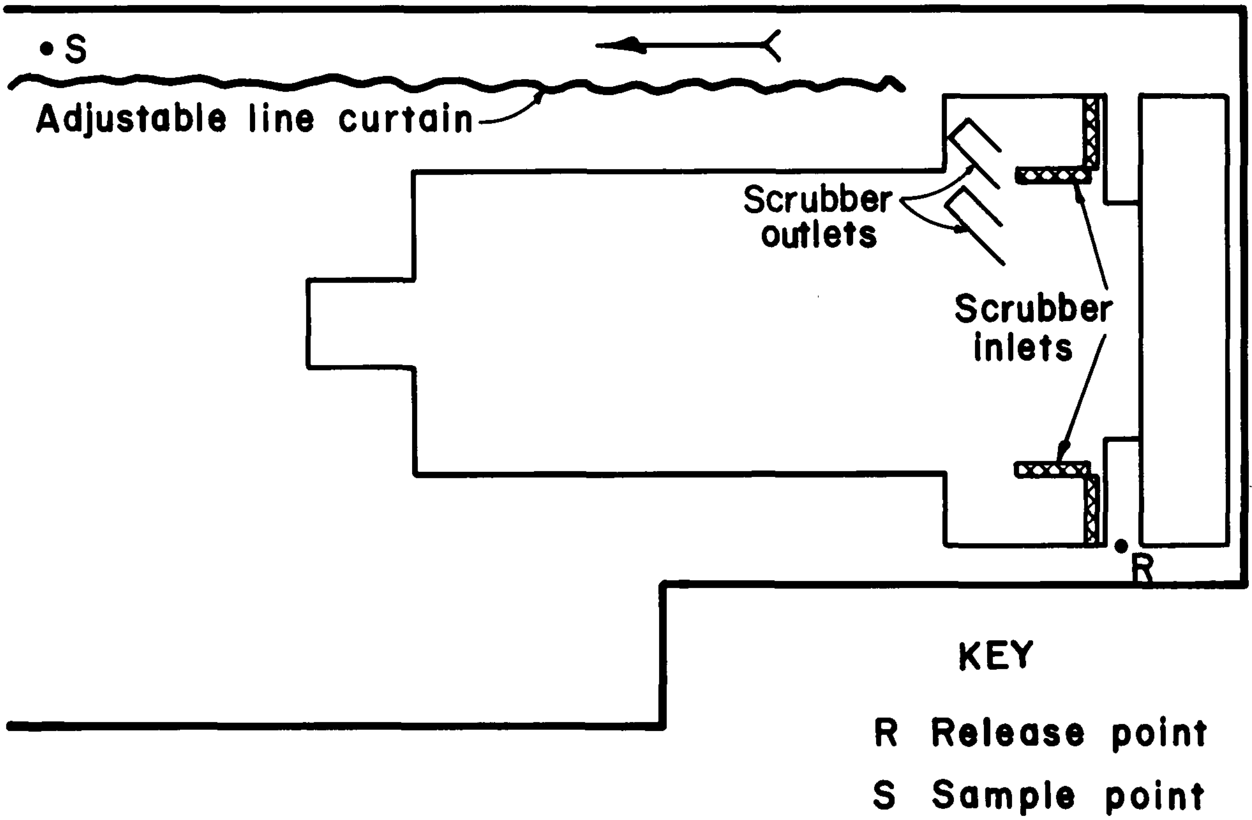

FIGURE 12. - Test configuration for evaluating dual-scrubber system.

The FVM comparison tests run with the air intake at 3,000 cfm and with 15- and 20-ft curtain setbacks are in figures 13 and 14. Although the FVM tests at 3,000 cfm showed the scrubbers improved ventilation, personnel conducting the scrubber studies do not believe this particular scrubber exhaust configuration (fig. 12) will work under actual mining conditions. The FVM tests at 3,000 cfm showed the scrubbers improved ventilation because the line curtain in the FVATF was tightly secured to the roof and floor and was thus able to contain the return air in spite of a high-pressure zone, produced by the scrubbers' exhaust, at the entrance of the line curtain. Line curtains constructed in mines could not withstand the high-pressure zone but would leak and contaminate the intake air. Also, the high-pressure zone could block intake air.

All of the FVM tests conducted when the intake air was 6,000 cfm showed the influence the scrubbers had on face ventilation. When the curtain setback was 5 ft (fig. 15) the scrubbers actually reduced face ventilation; the scrubbers' exhaust was about 8 ft from the face, and with a 5-ft curtain setback the air exhausting from the scrubbers struck the line curtain rather than entering the return airway. The scrubbers improved face ventilation once the line curtain was set outby the scrubbers' exhaust at 10, 15, and 20 ft (figs. 16-18).

In figures 19-21, the FVM curves show that the scrubbers had little or no effect on face ventilation when the incoming air was 9,000 cfm.

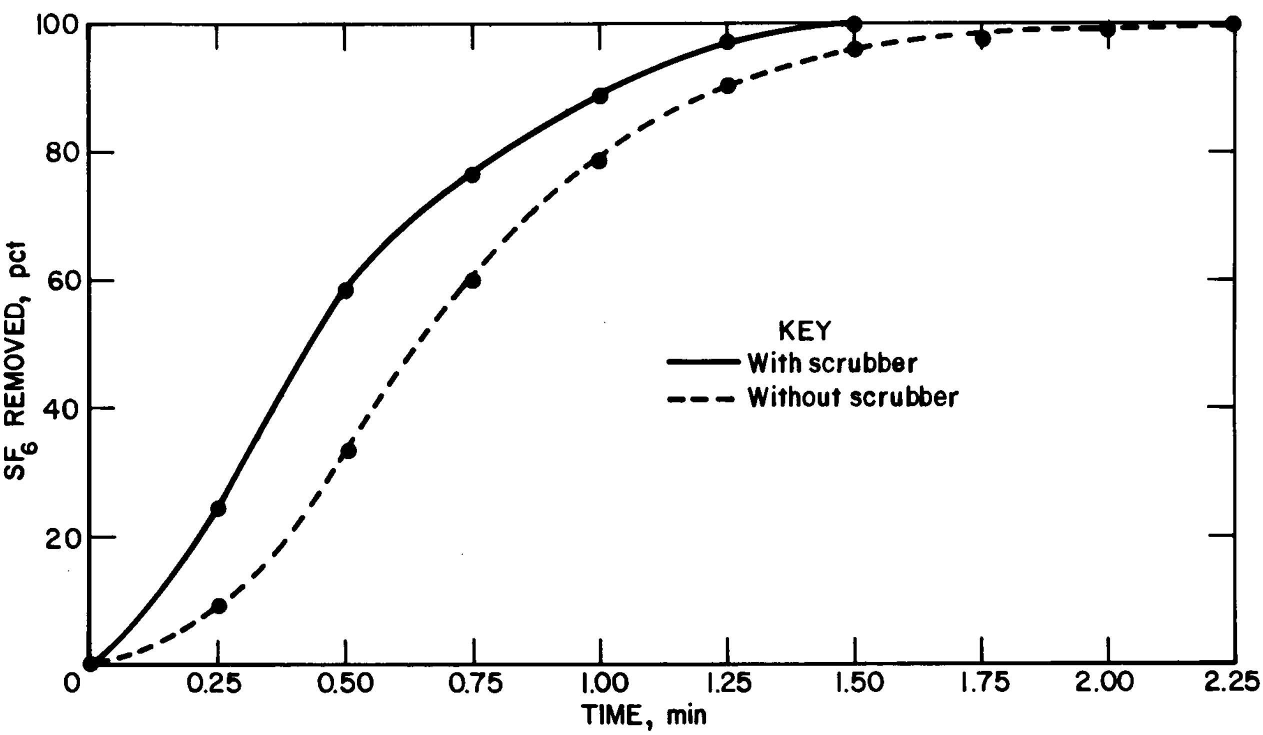

FIGURE 13. - SF_6 scrubber comparison at 3,000 cfm with 15-ft curtain setback.

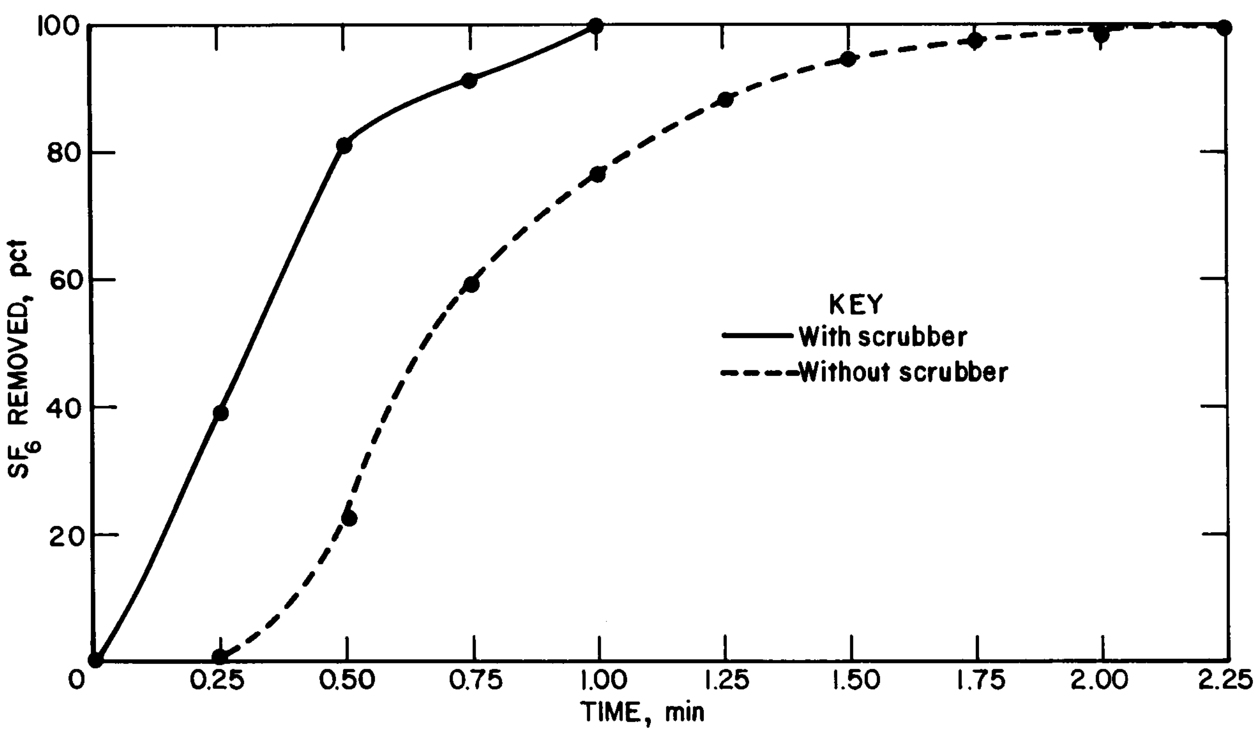

FIGURE 14. - SF_6 scrubber comparison at 3,000 cfm with 20-ft curtain setback.

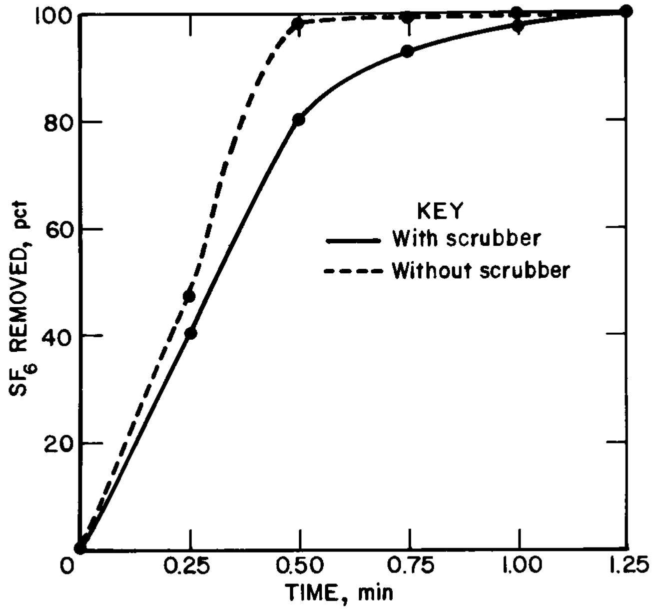

FIGURE 15. - SF_6 scrubber comparison at 6,000 cfm with 5-ft curtain setback.

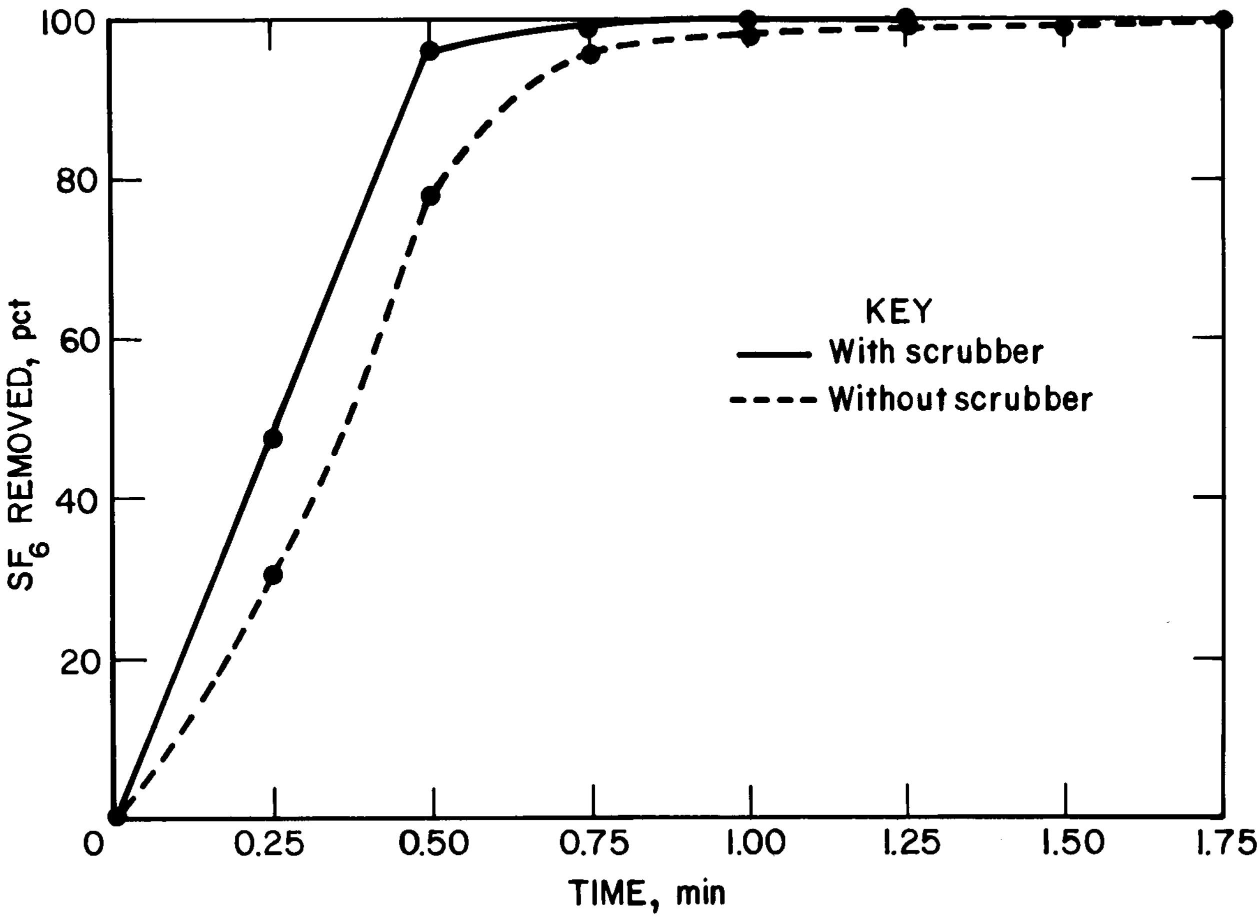

FIGURE 16. - SF_6 scrubber comparison at 6,000 cfm with 10-ft curtain setback.

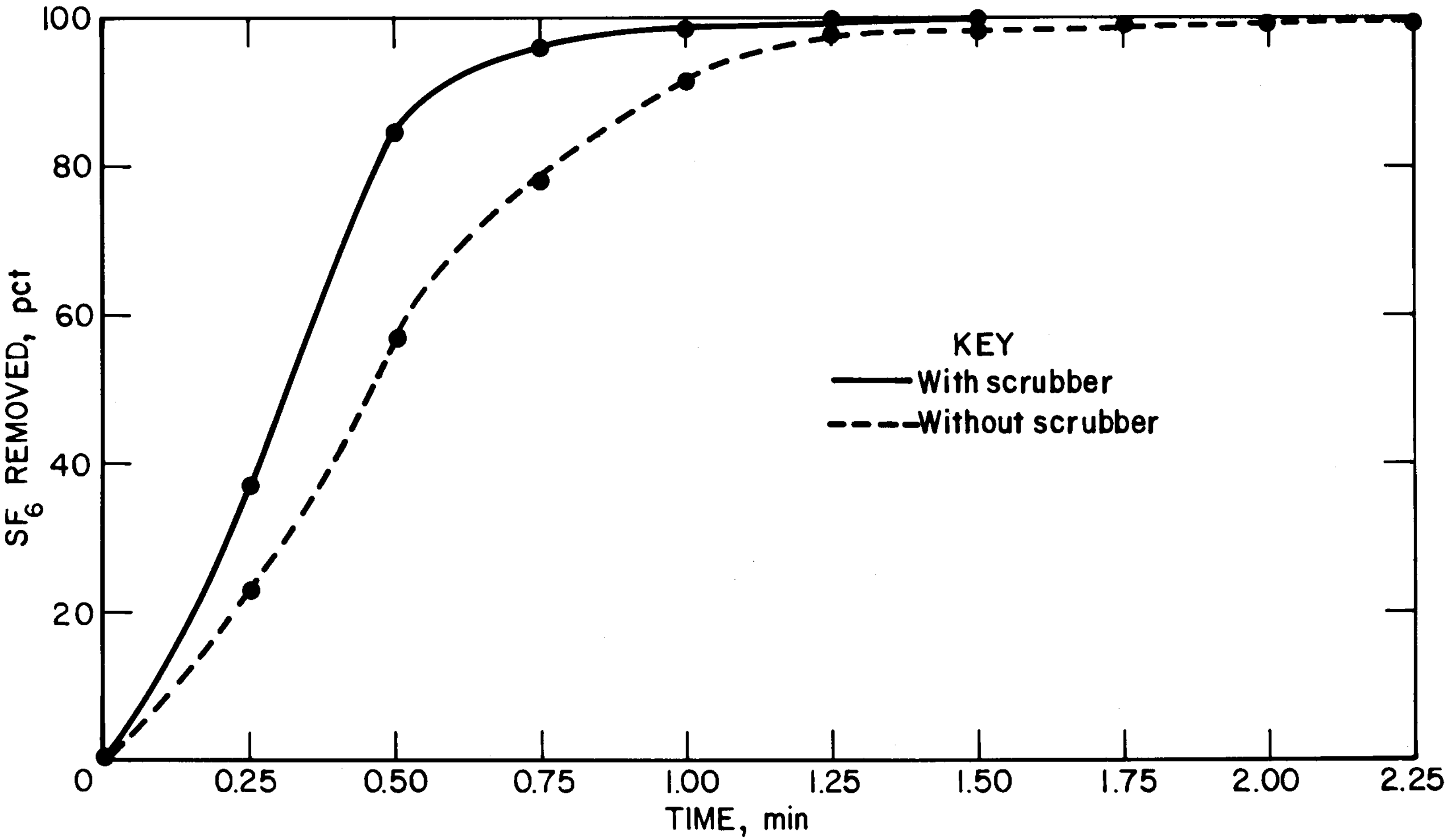

FIGURE 17. - SF_6 scrubber comparison at 6,000 cfm with 15-ft curtain setback.

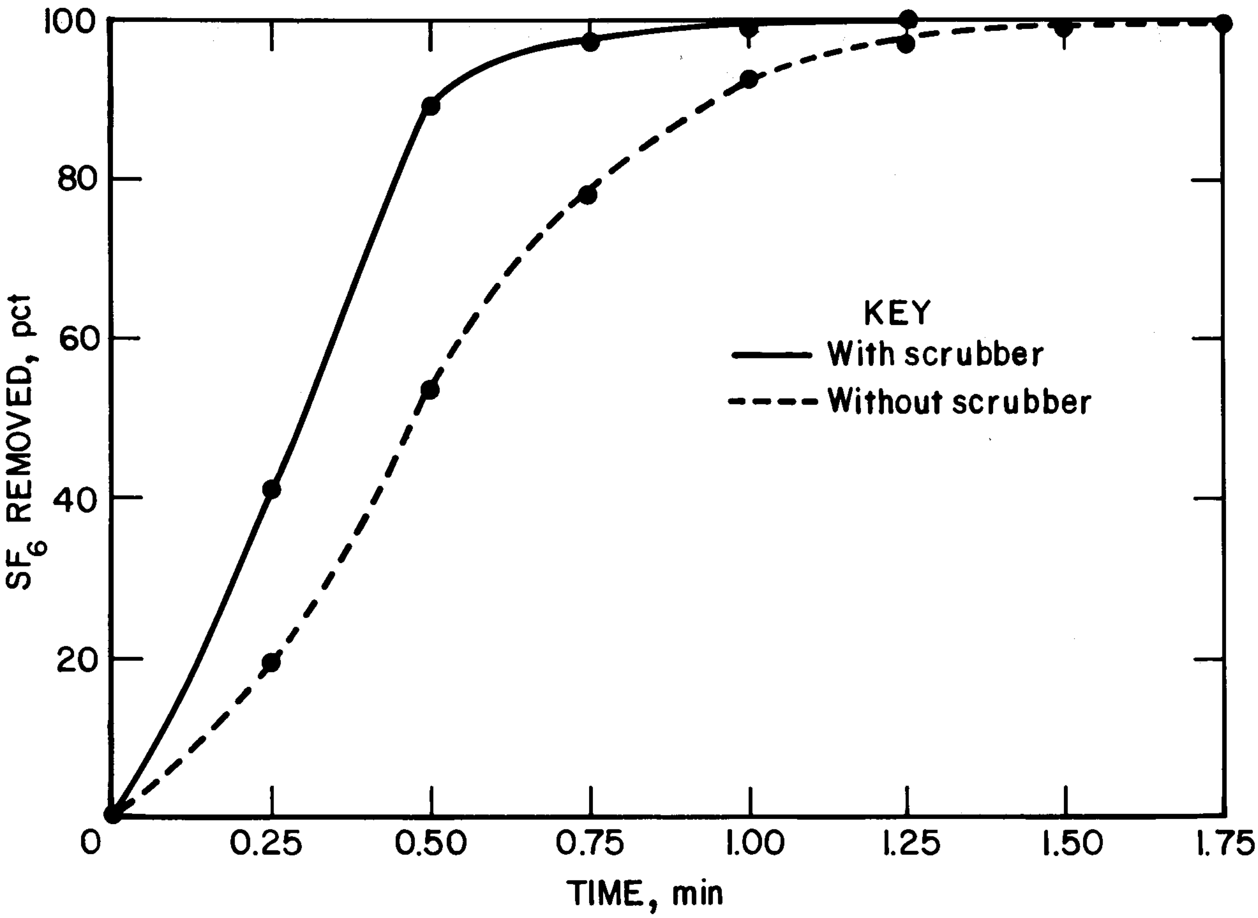

FIGURE 18. - SF_6 scrubber comparison at 6,000 cfm with 20-ft curtain setback.

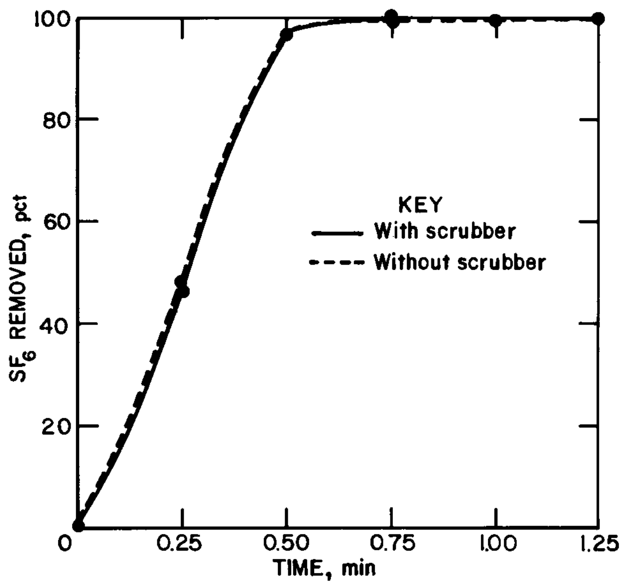

FIGURE 19. - SF_6 scrubber comparison at 9,000 cfm with 10-ft curtain setback.

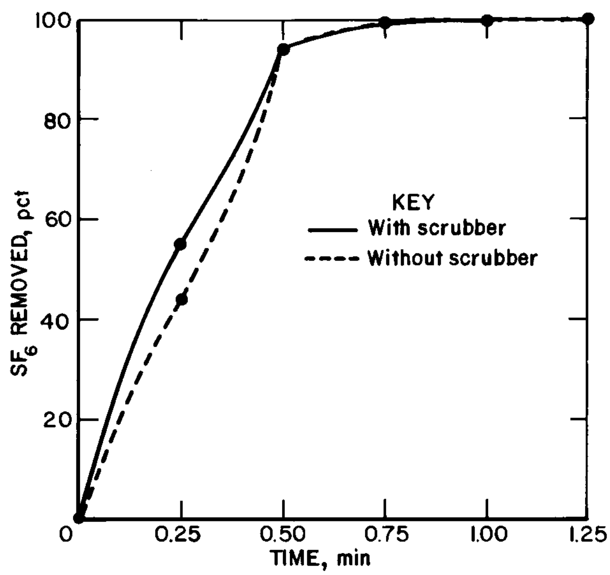

FIGURE 20. - SF_6 scrubber comparison at 9,000 cfm with 15-ft curtain setback.

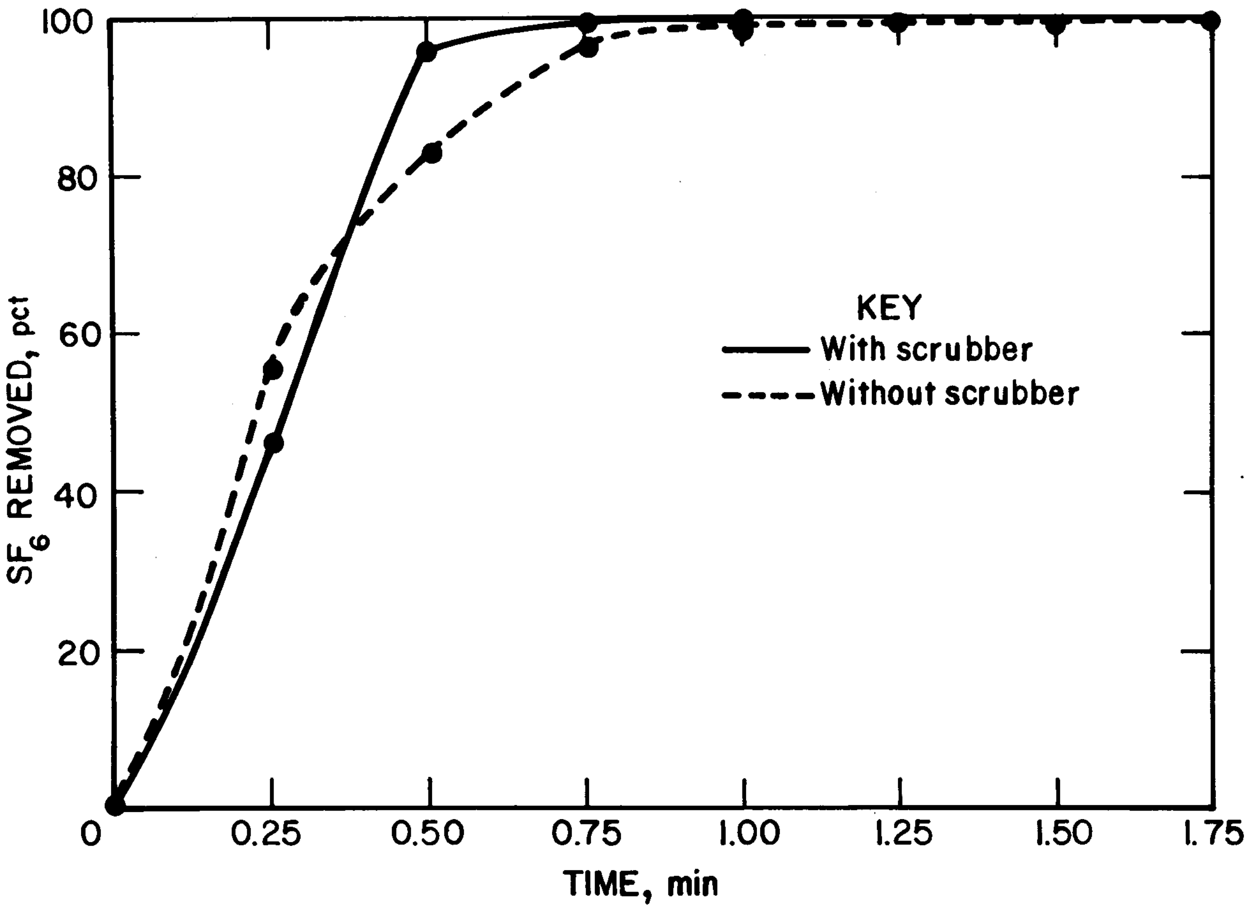

FIGURE 21. - SF_6 scrubber comparison at 9,000 cfm with 20-ft curtain setback.

CONCLUSIONS

The face ventilation measurement (FVM) method developed by the Bureau of Mines is a quick and simple means of measuring face ventilation. It requires easy-to-use equipment, several tests can be run in a short time, and most important it does not interrupt the mining cycle. The only complicated equipment is a gas chromatograph for analyzing the air samples for SF_6.

The FVM method has been used successfully underground to evaluate the spray fan, and to evaluate a machine-mounted scrubber system in MSHA's face ventilation appraisal and testing facility.