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UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

ILLUSTRATIONS

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm^3	cubic centimeter	min	minute
cfm	cubic foot per minute	pct	percent
ft	foot	psi	pound per square inch
kcfm	thousand cubic foot per minute	s	second
mg/m^3	milligram per cubic meter		

EXHAUST VENTILATION OF DEEP CUTS USING A CONTINUOUS-MINING MACHINE

By Jon C. Volkwein,[1] S. K. Ruggieri,[2] C. McGlothlin,[3] and Fred N. Kissell[4]

ABSTRACT

The Bureau of Mines, Foster-Miller, Inc., and Beaver Creek Coal Co. have evaluated the ability of a new system to ventilate a 40-ft-deep cut. A remote-control continuous-mining machine, in a 7-ft-thick seam, with exhausting brattice was fitted with an improved sprayfan system plus additional forward and reverse pointing sprays. Static and dynamic tests using tracer gas were conducted in a full-scale model and underground to measure the effectiveness of exhaust face ventilation for various deep-cutting mine and spray configurations. When compared to a 10-ft primary ventilation brattice, the extended-cut spray system consistently provided better face ventilation at all configurations up to and including a 40-ft brattice setback.

The system also provided good dust protection and visibility for the machine operator. Another safety advantage is the elimination of the need to set temporary roof supports to maintain the ventilation brattice.

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INTRODUCTION

The need to maintain good ventilation to the mine face is well known and is usually accomplished by hanging brattice or tubing to conduct air to the face. The Bureau of Mines and Foster-Miller, Inc., developed a modified water spray system called a "sprayfan"[5] to provide additional face ventilation to sweep contaminants away from the face toward the brattice or tubing in exhaust ventilation faces.

Based on the success and wide acceptance of the original sprayfan, further research was conducted that resulted in improvement to the original system.[6] Mine tests on the improved sprayfan resulted in Mine Safety and Health Administration (MSHA), U.S. Department of Labor, variances being granted for brattice setbacks up to 20 ft in many mines. Further benefits include improvement of the cutting sequence from 4 to 10 ft to 10- to 20-ft sump and slab cuts.

A unique opportunity arose at a Utah coal mine to test an extended-cutting system on a remote-control continuous miner. The mine uses the machine to make 40-ft cuts between roof-bolting cycles. The mine operators were interested in the sprayfan's effectiveness at ventilating the face with exhaust brattice setback distances of up to 40 ft. Additional laboratory tests resulted in the creation of a modified version of the improved sprayfan called "the extended-cut system," which was capable of effectively ventilating the face area in the test facility at a brattice setback of 40 ft. The knowledge of several previous Bureau of Mines projects were combined to produce the extended-cut system.

The extended-cut system was installed at the mine on a Joy 12 CM[7] hardhead mining machine. It was evaluated underground to determine its ventilation effectiveness under actual mining conditions. The results of this testing showed that the system had the ability to--

1. Ventilate the face at a 40-ft brattice setback more effectively than the primary ventilation did at 10 ft.
2. Maintain excellent levels of performance despite wide variations in system water pressure, primary airflow volume, and system degradation (nozzle plugging).

This report discusses the entire evaluation program, including system description, laboratory results, testing strategy, and underground results. It is important to note that these results are specific to this mine and are not yet refined for general mine use.

ACKNOWLEDGMENTS

The authors greatly appreciate the cooperation of the management and miners of the Beaver Creek Coal Co., whose help and interest in ventilation research was invaluable; and to Mark Poling, who installed, maintained, and coordinated the system hardware. We also wish to thank Bill Wagner of Anaconda Minerals Research, Charles Urban of the Bureau of Mines, and Chip Babbit and Settur Rajun of Foster-Miller, Inc., who performed the field tests.

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[5]Wallhagen, R. E. Development of Optimized Diffuser and Spray Fan Systems for Coal Mine Face Ventilation (contract H0230023, Foster-Miller). BuMines OFR 14-78, 1977, 256 pp.; NTIS PB 277 987.

U.S. Bureau of Mines. Sprayfan Aids in Effectively Controlling Methane. BuMines Technol. News, No. 162, Jan. 1983, 2 pp.

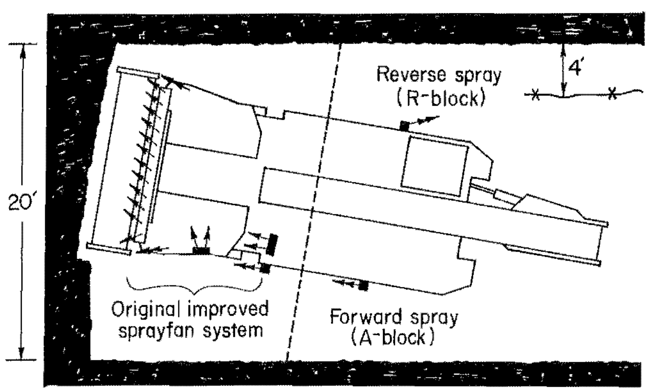
[6]Ruggieri, S. K., D. M. Doyle, and J. C. Volkwein. Improved Sprayfans Provide Ventilation Solutions. Coal Min., v. 21, No. 4, Apr. 1984, pp. 94-98.

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

SYSTEM DESCRIPTION AND LABORATORY RESULTS

The extended-cut system is illustrated in figure 1. Although the figure depicts operation of the system for a right-hand brattice return, a dual system was installed (mirror-image) and plumbed separately for brattice returns on either side. Figure 1 contains a dotted line dividing the miner into two halves. Improved sprayfan components are shown to the left of the line (toward the cutterhead); components to the right of the line comprise additional spray manifolds installed to create the extended-cut system designed for the special 40-ft brattice setback application.

Laboratory testing was conducted in a full-scale model mine. The model contains a full-size mockup of a continuous-mining machine and is capable of (1) releasing methane at the face, (2) sampling gas levels throughout the mine, (3) normalizing the data by computing the methane factor (point concentration divided by return concentration), and (4) producing computer-generated methane maps throughout the simulated entry. Figure 2 shows the methane maps that guided the development of the extended-cut system. Factors held constant were as follows: 40-ft brattice setback, spray pressure at 250 psi, and primary airflow at 8,000 cfm.



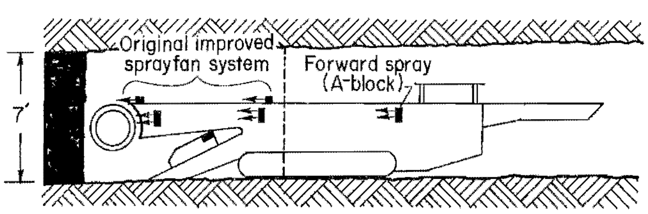


FIGURE 1. - Layout of extended-cut sprayfan system (for right return).

Laboratory testing showed that at brattice setback distances greater than 22 ft, the improved sprayfan needed additional power along both sides of the continuous miner to induce an adequate airflow split to reach the face area and to effectively channel contaminated air into the return. An additional spray manifold (known as A-block) was installed on the off-curtain side of the continuous miner located as far outby as practical. This manifold, containing two sprays, begins the airsplit process and pushes clean air up into the hingepoint region where the improved sprayfan system continues to move the air up to and across the face.

To prevent the airsplit from "dying out" after sweeping the face area, a rereverse spray manifold (known as R-block) was installed on the curtain side of the continuous miner aimed toward the curtain mouth. Again, the manifold was located as far outby as practical. This manifold provides a final "boost" of the contaminated air into the return. The R-block design was the result of earlier work done by the Bureau of Mines in which reverse sprays were used to control airborne dust caused by continuous-mining machines.[8] During this work, improvements in face methane control were seen for both low- and high-coal testing. The effectiveness of the reverse spray was found to depend on the relationship between the spray and brattice mouth.

The mine modified the original R-block design shortly after delivery of the continuous miner to the underground section. The manifold had consisted of two sprays oriented at an outward angle of 15° to the continuous miner. During mining of the on-curtain side of the entry, the

[8]Foster-Miller, Inc. Development of Optimal Water Sprays and Scrubber Ventilation Systems for Dust and Methane Control in Underground Coal Mines (BuMines contract H0199070). Tech. Prog. Rep. 23, Aug. 1981; 25, Oct. 1981; 33, June 1982. Available upon request from N. I. Jayaraman, BuMines, Pittsburgh, PA.

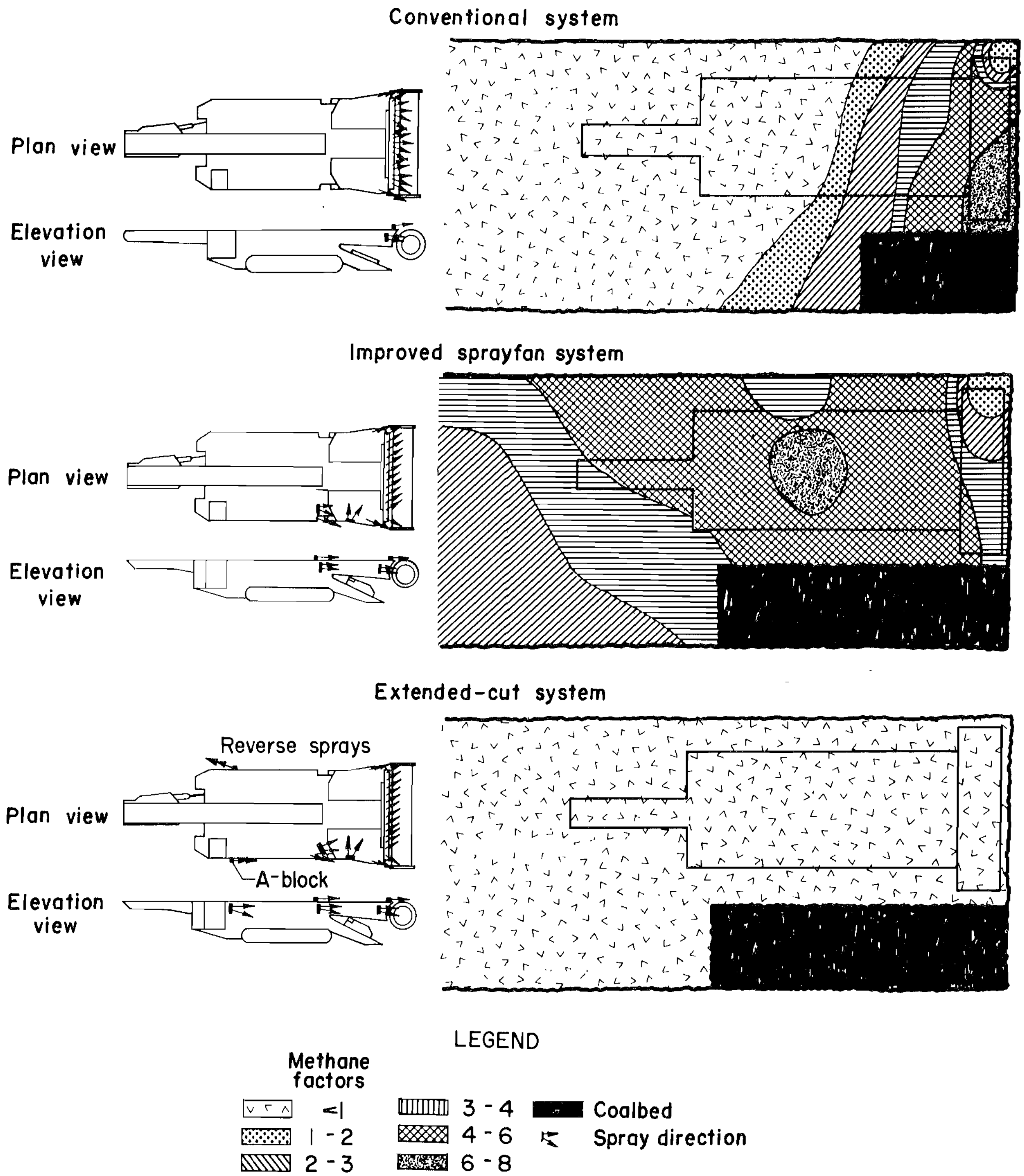


FIGURE 2. - Diagram of laboratory test results.

R-block prematurely impinged on the rib and caused some recirculation in front of the curtain mouth. Conversely, when mining the off-curtain side of the entry, the outward spray angle of 15° was not adequate to push contaminated air across the entry to the curtain mouth. Contaminated air was pushed backward toward the fresh air side of the curtain mouth resulting in some recirculation. The mining company designed and installed a new R-block with two separate sets of two sprays each:

1. One set with an outward angle of 10° to be operated when cutting the *on-curtain* side of the entry.
2. One set with an outward angle of 45° to be operated when cutting the off-curtain side of the entry.

Each set of sprays was valved separately to allow independent use.

Throughout the evaluation testing, use of the appropriate R-block spray set followed the procedure described above. Specific tests to compare the 10°-angled sprays against the 45°-angled sprays were not conducted. However, smoke tests and visual observations showed the procedure to provide excellent control of face ventilation near the curtain mouth.

The extended-cut system was operated as follows:

1. At brattice setback distances of 20 ft or less, the improved sprayfan and A-block were on. R-block had been turned off to prevent wetting operators.
2. At brattice setback distances greater than 20 ft, up to 40 ft, the entire extended-cut system was in operation (R-block 10° or 45° on).

The operation of A-block proved to have a negligible effect on system performance at brattice setback distances of less than 20 ft. This was consistent with laboratory test results: A-block (a component of the original sprayfan system) was eliminated from the improved sprayfan because of its negligible effect on performance.

EVALUATION STRATEGY

The basic strategy for testing the performance of the extended-cut system underground was to determine the speed and effectiveness with which it was capable of sweeping contamination out of the face area and into the return under a variety of different face conditions. Generally, such testing is conducted by monitoring actual face methane (CH_4) concentrations at several points on the continuous miner and also in the return. However, since methane was not present at this mine in quantities sufficient for practical test procedures, the tracer gas sulfur hexafluoride (SF_6) was used to evaluate extended-cut effectiveness.

The SF_6 gas was released on the off-curtain corner of the mining-machine boom. Bottles were used to collect gas samples in the immediate return; the time required to remove two-thirds of the gas from the face was used as the ventilation effectiveness criterion.

The basic method used was described in a Bureau of Mines publication.[9] Prior to the start of testing in a given cut, air-velocity and volume measurements were made at the mouth of the line curtain and at the return sampling position. In addition, the layout and configuration of the cut as well as the distance from the curtain mouth to the return position were documented.

Two categories of testing were performed during the evaluation: static and dynamic. Static tests were conducted over two idle shifts with the mining machine positioned at the face of a straight squared-off cut. The standard SF_6 testing procedure was used with key face variables accurately controlled. Dynamic tests were conducted during actual mining and provided a measure of system effectiveness during the constantly changing active mining process. Dynamic test results were obtained over a range of brattice setback, sump depth and sump cut versus slab cut conditions.

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[9] Divers, E., N. Jayaraman, and J. Custer. Evaluation of a Combined Face Ventilation System Used With Remotely Operated Mining Machine. BuMines IC 8899, 1982, 7 pp.

The evaluation was conducted in a section in which a major rock fault was encountered. Since the mine operators elected not to traverse it, pillar retreat mining was begun just prior to the evaluation start date. A pillaring section does not provide an ideal test site for measuring the effectiveness of methane and dust control techniques, which are dependent on airflow patterns. However, to provide a reasonable facsimile of normal section development, the usual pillar-mining sequence was altered as illustrated in figure 3. The sequence was as follows:

1. A 10-ft backside cut was taken on a fresh pillar during mining of the previous row of pillars.
2. A full-width, squared-off 20-ft cut was made in the pillar prior to SF_6 testing.
3. The continuous miner was withdrawn, two timbers were installed, and the line curtain was extended into the cut by approximately 8 ft.
4. Mining continued, generally beginning with an on-curtain sump; care was taken to avoid holing through to cut 1.
5. An off-curtain slab cut was allowed to hole through to cut 1. SF_6 testing generally began after ventilation had been established into the pillar split. The discussion of dynamic test results in the next section is based upon this altered pillaring sequence.

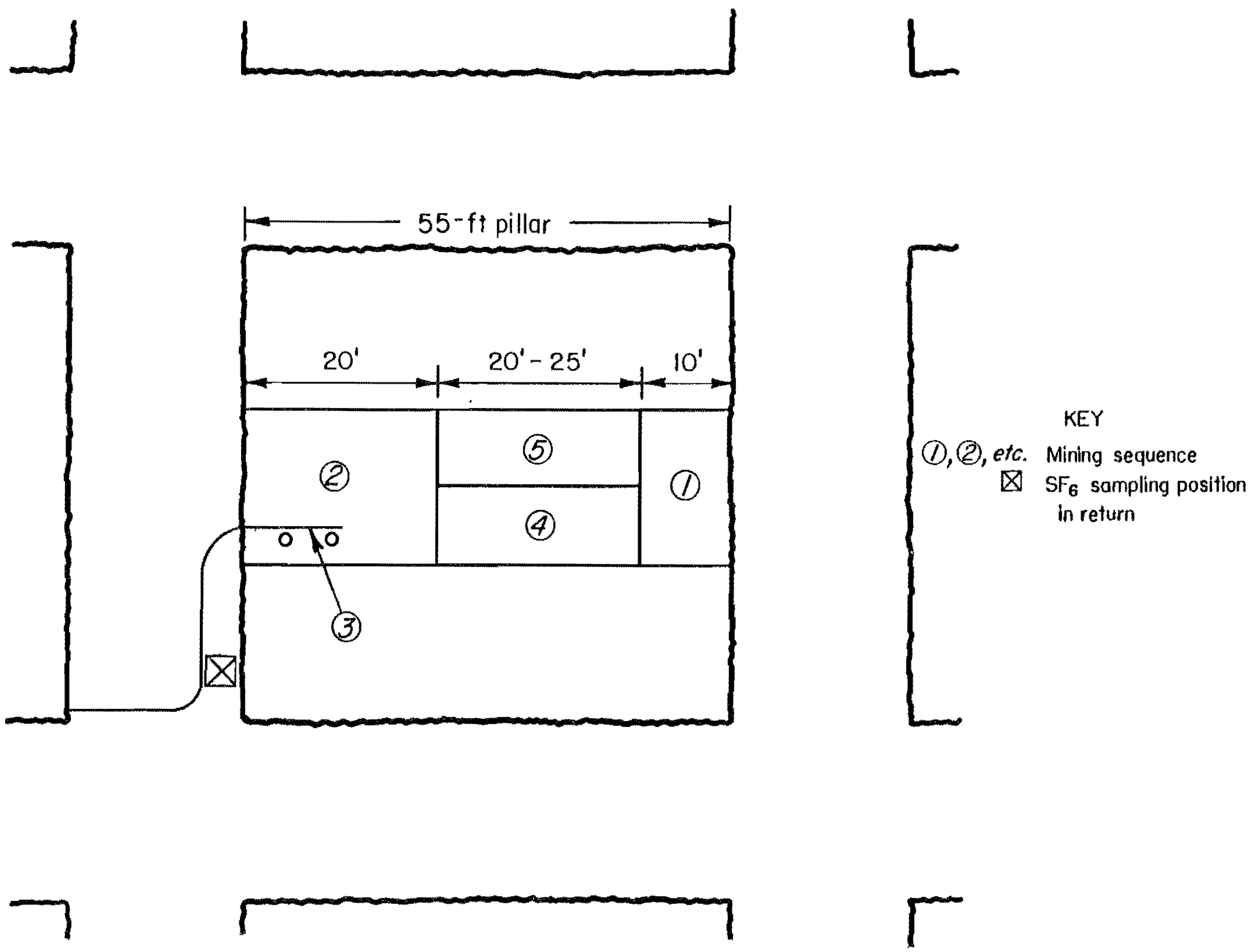

FIGURE 3. - Modified pillaring plan to simulate development mining.

EVALUATION RESULTS

The evaluation of the extended-cut system was completed over eight operating shifts and two idle shifts. A total of 39 static tests, representing a variety of different face conditions, were conducted during the idle shifts. Dynamic testing during active mining consisted of 40 separate SF_6 tests performed over 16 cuts. A representative cross section of the static and dynamic test results was chosen for inclusion in this report.

During the evaluation and subsequent data analysis, the greatest emphasis was placed on the results of static testing. Only through the stable face geometry of a static test site was it possible to accurately control the parameters that influence system performance. Face variables, which were changed and examined through static SF_6 testing, included the following:

1. Brattice setback distances (10, 20, 30, and 40 ft).
2. Selective use of A-block and R-block spray manifolds (operating versus not operating).
3. Spray water pressure (full pressure of approximately 170-psi; pressure reduced by 50 pct to approximately 80 psi).
4. Airflow volume (full volume of approximately 13,000 cfm; volume reduced by 50 pct to approximately 6,500 cfm; volume reduced by 72 pct to approximately 3,650 cfm).
5. Spray maintenance (all sprays operating, sprays approximately 30 pct plugged).

A series of tests was also repeated with the system turned off to determine the ability of the primary ventilation airflow to remove SF_6 from the face. This "baseline" testing allowed a direct measurement of the sprayfan's effectiveness at redirecting and better utilizing the primary airflow patterns.

The results of dynamic testing, under roughly similar face conditions as specific static tests, were used as backup to the static test results. During dynamic testing, SF_6 was injected and sampled according to the procedure described earlier. The test sequence was repeated for every second or third shuttle car as mining progressed. This provided test results under a range of brattice setback and sump distances.

Through the static and dynamic SF_6 test strategy, it was possible to directly quantify and compare the effectiveness of the modified sprayfan at removing face contaminants under a variety of mining conditions. The data analysis technique involved calculating and plotting the percent of SF_6 captured at the return sampling station versus time. At the start of each test, 10 cm^3 of SF_6 was injected at the face. The total amount of SF_6 actually accounted for in the return samples varied from test to test because an exact mass balance of tracer gas released versus that collected is only possible under highly controlled conditions not possible underground. Consequently, to make valid comparisons, all data were "normalized" to represent a capture of 100 pct of the SF_6.

A variety of plots, representing comparisons of system effectiveness under many different face conditions, are presented in the following subsections. When comparing plots qualitatively, emphasis has been placed on an analysis of the trends of the curves:

1. The time delay (from time zero) before the rapid increase of SF_6 capture began, providing a direct measure of the speed with which SF_6 removal from the face was initiated.
2. The slope of the curve over the portion of rapidly increasing SF_6 capture, providing a measure of the efficiency with which SF_6 was removed from the face.

To provide a simple quantitative measure of effectiveness by which to compare face ventilation at different conditions, three data points were selected:

1. Time required to capture two-thirds (66.7 pct) of SF_6.
2. Percent of SF_6 capture after 30 s.
3. Percent of SF_6 capture after 1 min.

Table A-1 in the appendix summarizes these three quantitative data points for each static comparison presented in this report. The time duration for 66.7 pct of SF_6 capture was selected as the measure of effectiveness used in the discussions of test results in the following subsections.

Except where noted, all tests up to 20-ft setback were performed with the improved sprayfan operating and all 20- to 40-ft setback tests were performed with the extended-cut system operating (A- and R-blocks on).

EFFECT OF BRATTICE SETBACK DISTANCE--EXTENDED CUT VERSUS PRIMARY VENTILATION

The first test series conducted during the evaluation involved determining the effectiveness of extended-cut system face ventilation at the four brattice setback distances of 10, 20, 30, and 40 ft. To provide a basis for comparison, the following static tests were completed:

1. Primary ventilation tests (all sprays off) at setback distances of 10 and 40 ft.
2. Improved sprayfan (R-block off) operating at setback distances of 10 and 20 ft.
3. Extended cutting (A- and R-blocks on) operating at setback distances of 30 and 40 ft.

Figure 4 contains plots of percent of SF_6 captured versus time for primary ventilation at 10- and 40-ft setback distances. Face ventilation effectiveness at the 10-ft setback distance indicated a time duration of 51 s for 66.7 pct of capture of the SF_6. At a 40-ft setback, however, ventilation effectiveness was reduced to 78 s required for 66.7 pct capture. In addition, trace amounts of SF_6 continued to be detected after a total time duration of 7 min.

Figure 5 contains plots of percent of SF_6 captured versus time for the extended-cut system operating at the four setback distances. Repeated is the plot of primary ventilation at the "best case" condition of 10-ft brattice setback. All four graphs of system performance are very similar: the plots "track" each other very closely regardless of brattice setback distance. The four graphs also represent a face ventilation effectiveness substantially better than that of the 10-ft primary ventilation test: average system time duration for 66.7 pct capture was 35 s versus 51 s for the primary ventilation test (a reduction of 31 pct).

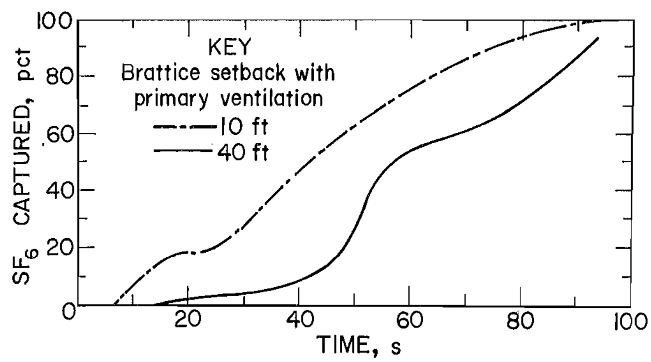

FIGURE 4. - Percent of sulfur hexafluoride captured versus time for primary ventilation.

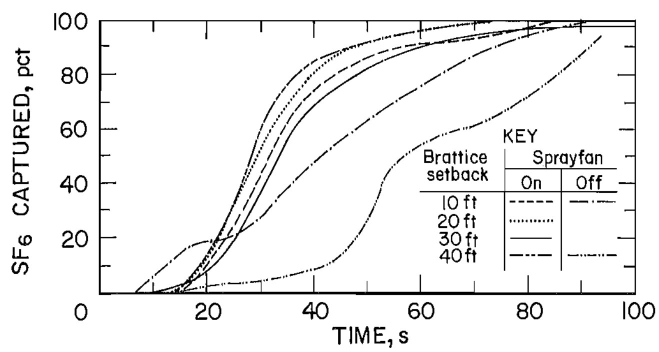

FIGURE 5. - Percent of sulfur hexafluoride captured versus time for different curtain setback distances (static testing).

Following is a summary of the conclusions drawn from the static test results:

1. Through use of the extended-cut system, effective face ventilation was maintained at brattice setback distances of up to 40 ft despite greatly reduced primary ventilation capabilities. The extended-cut system was capable of ventilating the face at 30- and 40-ft setback distances as effectively as the original improved sprayfan was at 10- and 20-ft setback distances.
2. The extended-cut system was capable of ventilating the face better at all brattice setback distances than primary ventilation airflow was at a 10-ft setback distance.

These conclusions were confirmed through dynamic testing. Figure 6 contains plots of percent of SF_6 captured versus time for three brattice setback distances with the extended-cut system operating during mining of slab cuts. As observed in the static test results, the graphs are very similar, indicating comparable face ventilation effectiveness regardless of setback distance. Differences between the static and dynamic test results of system performance, when comparing the plots of figures 5 and 6, include the following:

1. The dynamic tests contained an additional time delay of approximately 10 s before the start of significant SF_6 capture.
2. The time delay contributed to a higher average time duration for 66.7 pct capture (35 s during static testing versus 47 s during dynamic testing).

Altered airflow patterns during dynamic mining conditions and the back-mixing volume of the sump during a slab cut explain the differences.

As an additional measure of system effectiveness, a special SF_6 static test was conducted by a procedure differing somewhat from that described above. The procedure is illustrated in figure 7. SF_6 was injected in the traditional manner in the off-curtain corner of the face behind the cutter head. Instead of sampling in the return behind the brattice, samples were simultaneously drawn from the face area through two sampling lines: one each located on the off-curtain side and the on-curtain side of the mining machine behind the cutter head. Samples were collected in evacuated containers according to the same procedure and time intervals as previously discussed.

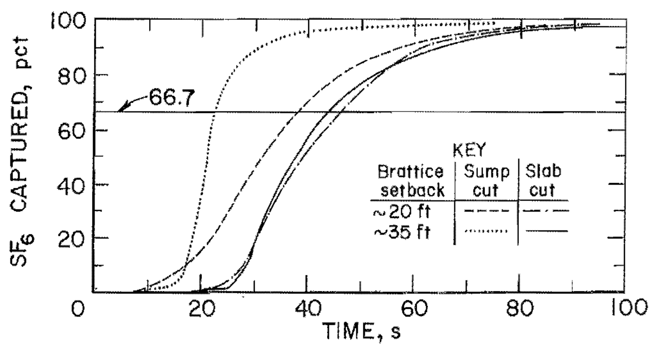

FIGURE 6. - Percent of sulfur hexafluoride captured versus time for actual mining (slab cuts).

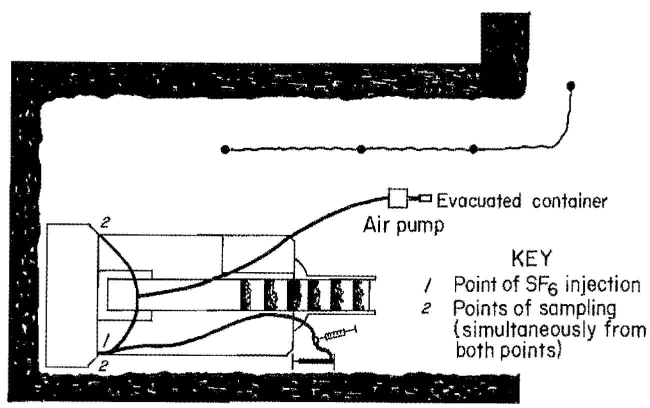

FIGURE 7. - Tracer gas setup for special face-area testing.

The test was conducted at a brattice setback distance of 20 ft with the system operating (R-block off). The result is illustrated in figure 8 and represents the percent of SF_6 remaining in the face area versus time. Also shown in figure 8 is a repeat of the plot of SF_6 captured in the return versus time for the extended-cut system operating at a 20-ft setback (fig. 6). Ideally, the sum of the percent remaining plus the percent captured should be 100 pct at each time interval, and the two curves should cross at 50 pct. However, the time required for the SF_6 to move from the face to the return results in the plot of SF_6 captured in the return being "time-shifted" to the right. Shifting of the percent captured curve back to the left, until the curves cross at 50 pct, normalizes for the travel time. This procedure indicated a travel time of approximately 8 s and is consistent with the delay time for SF_6 arrival that was noted at the return sampling position.

IMPROVED SPRAYFAN VERSUS EXTENDED-CUT SYSTEM

Laboratory testing demonstrated the need for the additional spray power delivered by the A- and R-blocks at brattice setback distances greater than 20 ft. To confirm those results underground, both static and dynamic testing was conducted with A- and R-blocks on versus off at brattice setback distances of approximately 20 and 40 ft. An additional 20-ft setback static test was performed with A-block on and R-block off.

Static test results are presented in figure 9. The trends in the plots of percent of SF_6 captured versus time are as follows:

1. The most effective system performance occurred at a 20-ft brattice setback with A- and R-blocks on. Only a minimal decrease in effectiveness resulted when the A- and R-blocks were turned off (26 s versus 35 s for 66.7 pct capture). No change in effectiveness was noted when A-block was then turned back on.
2. The role of A- and R-blocks was critical at a 40-ft brattice setback: a significant decrease in effectiveness resulted when the A-and R-blocks were turned off (31 s versus 48 s for 66.7 pct of SF_6 capture).

These results were also confirmed through the dynamic testing. However, when the dynamic tests were compared to the static tests, the dynamic tests again exhibited small time delays before the start of significant SF_6 capture and higher time durations for 66.7 pct of capture. This phenomenon was discussed in the previous section.

The general result of this test series demonstrated the importance of using the modified system A- and R-blocks at brattice setback distances greater than 20 ft. From the standpoint of face ventilation effectiveness, the entire extended-cut system could be used at setback distances of less than 20 ft if desired. However, practical problems may result with R-block spraying into the curtain.

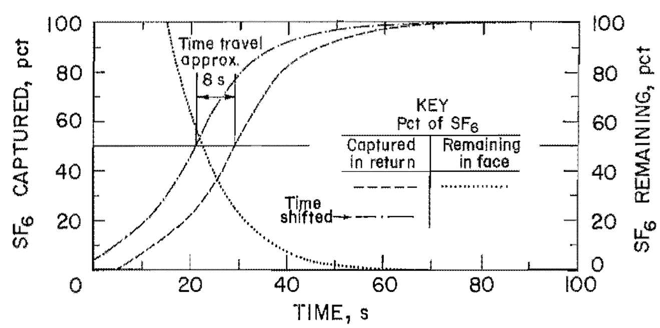

FIGURE 8. - Time shifting of test results.

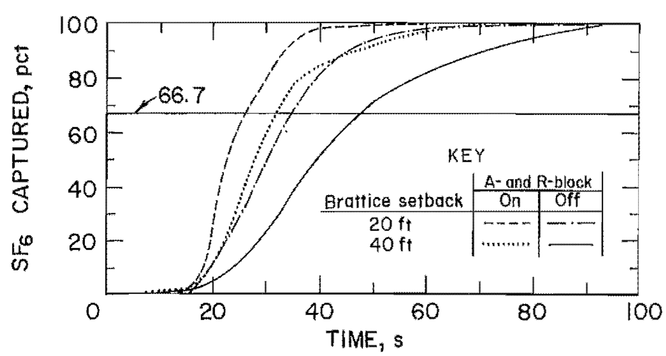

FIGURE 9. - Effect of A- and R-block on system performance.

EFFECTS OF REDUCED WATER PRESSURE ON PERFORMANCE OF EXTENDED-CUT SYSTEM

Laboratory development of the system consistently showed the importance of properly balancing dynamic spray water pressure against primary face airflow. Too high a spray pressure can overpower low face ventilation airflow patterns and result in recirculation. Too low a spray pressure can result in inadequate development of a clean airsplit to ventilate the immediate face area, with much of the primary airflow short-circuiting to the curtain mouth. To quantify the phenomenon underground, the following static tests were conducted at both 20- and 40-ft brattice setback distances:

1. Full available water pressure (170 psi).
2. Water pressure reduced to 80 psi by turning onboard booster pump off.

The results are presented in the plots of percent of SF_6 captured versus time shown in figure 10. As discussed previously, system effectiveness at 20- and 40-ft setback distances was very similar (at the "normal" water pressure of 170 psi). At a reduced water pressure of 80 psi, however, a greater decrease in system effectiveness was noted at the 20-ft setback than at the 40-ft setback increases of 22 s versus 10 s, respectively, for 66.7 pct of SF_6 capture). Nonetheless, sprayfan effectiveness at 80 psi at a 20-ft setback was comparable to the effectiveness of primary ventilation at a 10-ft setback. (Refer to discussion of figure 4.)

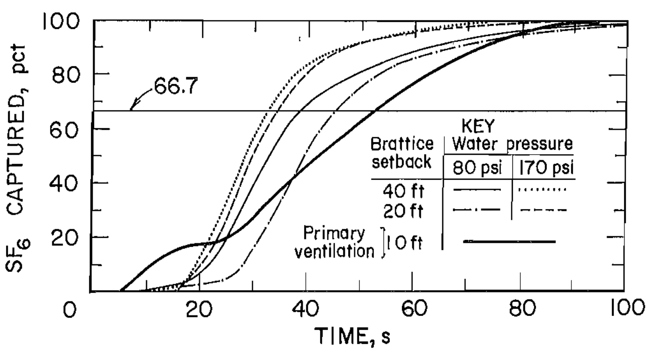

FIGURE 10. - Effect of water pressure on system performance.

With regard to the effects of improved sprayfan versus extended-cut system, the previous section discussed the importance of the A- and R-blocks at setback distances greater than 20 ft. The additional use of A- and R-block sprays during the 40-ft setback test at 80 psi water pressure helps to explain the relatively small reduction in ventilation effectiveness. The low water pressure of 80 psi tended to inhibit the ability of the improved sprayfan (R-block off) to create a clean airsplit to the face at a 20-ft setback. Use of A- and R-blocks during the 40-ft setback test helped to offset that tendency. The R-block was not tested during the 20-ft setback test, and the benefit of its ability to help maintain the airsplit was not available.

It should be cautioned, however, that placement and use of additional water sprays to compensate for inadequate water pressure should not be attempted. The importance of achieving and maintaining a spray water pressure properly balanced to the primary face ventilation cannot be overstated.

EFFECTS OF REDUCED FACE AIRFLOW ON PERFORMANCE OF EXTENDED-CUT SYSTEM

A significant change in face airflow can also upset the system's water pressure-to-airflow balance. To quantify the effect of a significant reduction in airflow on system effectiveness, the following static tests were conducted at both 20- and 40-ft brattice setback distances:

1. Full available face airflow volume (approximately 13,000 cfm measured behind curtain).
2. Face airflow volume reduced to approximately 6,500 cfm.

The results are shown in figure 11, containing plots of percent of SF_6 captured versus time. The results closely follow and confirm those tests conducted at reduced water pressure:

a. System effectiveness at both 20- and 40-ft setback distances was very similar at the full airflow of 13,000 cfm.

b. At the reduced airflow, a slightly greater decrease in system effectiveness was noted at the 20-ft setback than at the 40-ft setback (increases of 11 s versus 7 s for 66.7 pct of SF_6 capture respectively). Nonetheless, at both setback distances system effectiveness was greater than that of primary ventilation at a 10-ft setback.

c. The use of A- and R-blocks during the 40-ft setback test at reduced airflow again helped to better maintain the clean airsplit to the face.

In general, the reduction in effectiveness was more noticeable at reduced spray water pressure than at reduced face airflow. This confirmed laboratory test results: although the system, is very accommodating and maintains its effectiveness under a variety of conditions, it is more affected by fluctuations in water pressure than by fluctuations in primary airflow. However, it should be emphasized that the system cannot be used to correct for insufficient primary airflow.

SYSTEM BALANCING

The two previous sections introduced the need for properly balancing water pressure against face airflow for the extended-cut system. To further illustrate and quantify this relationship, the following static tests were conducted at a 30-ft brattice setback distance (A- and R-blocks were operating):

1. Full available spray water pressure (170 psi) and face airflow volume (13,000 cfm).
2. Spray water pressure remaining at 170 psi; face airflow volume reduced by 72 pct to approximately 3,650 cfm.
3. Face airflow volume reduced to 3,650 cfm and spray water pressure reduced to 80 psi.

The results are shown in the plots of percent of SF_6 captured versus time shown in figure 12. A substantial decrease in effectiveness occurred when the water pressure remained at 170 psi and the airflow was reduced to 3,650 cfm: 39 s for 66.7 pct of SF_6 capture at full water pressure and airflow compared with 53 s at full water pressure and the reduced airflow of 3,650 cfm. This decrease in ventilation effectiveness was due to spray pressure overpowering the airflow, leading to recirculation in the face area inby the curtain mouth. Despite this phenomenon, the ventilation effectiveness was still comparable to that of primary ventilation at a 10-ft setback distance.

In an attempt to "rebalance" spray water pressure with the lower airflow of 3,650 cfm, the water pressure was reduced from 170 to 80 psi. As shown by the plot in figure 12, the result was a return to a level of effectiveness similar to that of the full water pressure and full airflow test. It is important to note, however, that the plots illustrated in figure 12 only represent the efficiency with which the test tracer gas was swept away from the face. They do not take into

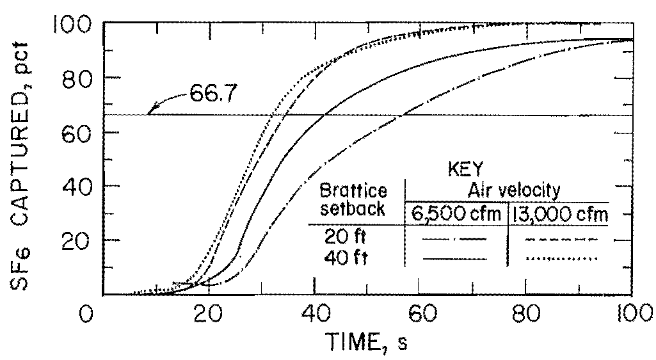

FIGURE 11. - Effect of primary face airflow on system performance.

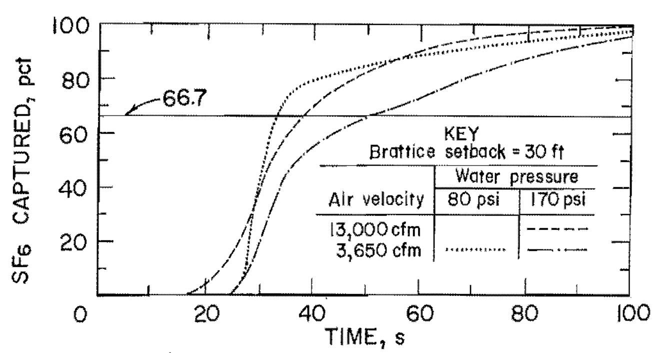

FIGURE 12. - Importance of balancing face airflow with water pressure.

account the greatly differing quantities of total air and water available for dilution and suppression of face contaminants (such as dust and diesel fumes).

EFFECTS OF NOZZLE DEGRADATION ON SYSTEM PERFORMANCE

Extensive laboratory and field testing to develop waterspray systems for a variety of methane and dust control applications has shown the detrimental effects of nozzle plugging. Poor filtration of the water supply leads to nozzle plugging, which leads to an inevitable decline in spray system effectiveness.

Natural plugging of nozzles was not a problem during the 2-week evaluation. However, to test the effects of the plugging on system effectiveness, a series of static tests was conducted with approximately 30 pct of the nozzles artificially plugged. Figure 13 illustrates the extent of nozzle plugging. The test series compared normal system operation against system operation with nozzles plugged at 20- and 40-ft brattice setbacks.

The test results are presented in figure 14. Following is a synopsis of the results and conclusions:

1. Nozzle plugging during the 20-ft-setback test increased the time duration for 66.7 pct capture of SF_6 from 34 s (normal operation, no plugging) to 43 s.
2. Nozzle plugging during the 40-ft-setback test increased the time duration from 31 to 50 s.
3. Nozzle plugging had a greater effect at the 40-ft setback due to the reduced ability of the A- and R-blocks to help maintain the clean airsplit to the face.
4. The reduction in system effectiveness due to plugging was limited to an extent by a resultant increase in spray water pressure to the remaining sprays (from 170 to 230 psi).
5. Despite nozzle plugging, sprayfan effectiveness in both cases was maintained comparable to or better than primary ventilation at a 10-ft setback distance.

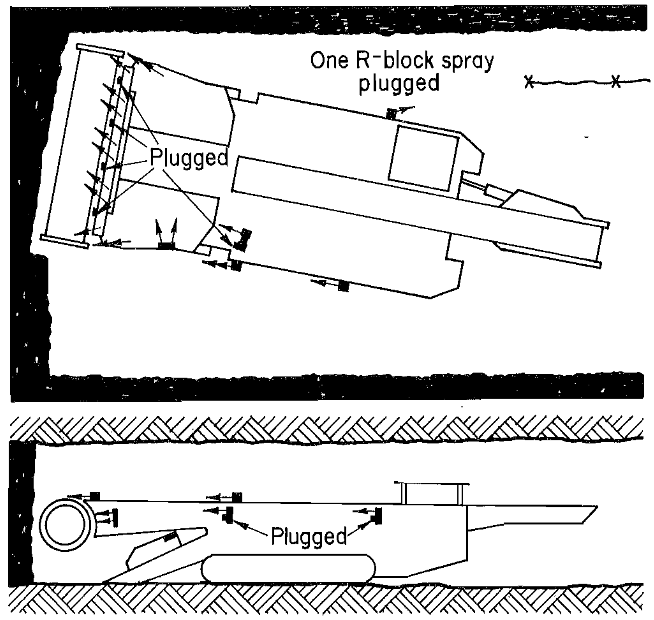

FIGURE 13. - System tests with plugged nozzles.

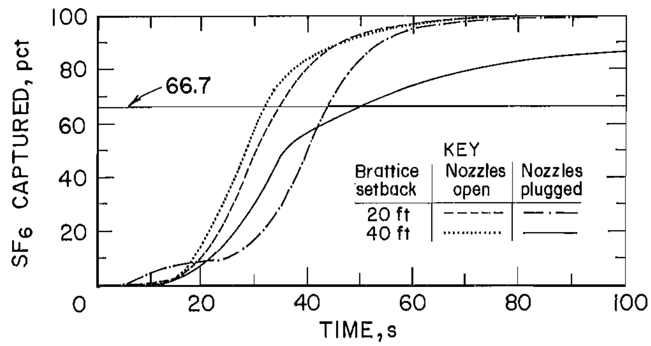

FIGURE 14. - Results of plugged-nozzle tests.

The effects of nozzle degradation from plugging, though not severe, were substantial and confirm the importance of effective filtration and routine system maintenance.

EFFECTS OF SUMP CUTS VERSUS SLAB CUTS IN DYNAMIC MINING

Laboratory development of the system tested under simulated conditions of sump and slab cutting revealed the following: The system provides more effective face ventilation in sump cuts than in slab cuts, and ventilation effectiveness increases with increasing sump depth (up to the 20-ft maximum depth tested).

This phenomenon is a function of the mechanics of sprays as air movers. A spray will move air at higher "sweeping" velocities the more confined the space around the sprays. When the continuous miner is positioned deep within a sump cut, the available free space around the head of the machine is very limited. The confined space acts as a duct through which the system is capable of moving air at a very high sweeping velocity, providing effective face ventilation. At shallow depth sump cuts, only a portion of the sprays are within the cut: Airflow patterns are not as well established and the sweeping velocity is not as great.

During slab cuts, only one side of the miner is closely confined, and the previously cut sump acts as a backmixing volume. Contaminants are pushed into the sump volume and "stored" there for a period of time. Hence, face ventilation effectiveness is reduced during slab cutting.

The results of dynamic testing conducted during the evaluation supported these laboratory findings. Figure 15 illustrates percent of SF_6 captured versus time during sump and slab cutting at the various depths and brattice setback distances. The most effective sprayfan face ventilation performance occurred during the deeper sump cut. All conditions were ranked best to worst as follows:

1. Sump cut: 23-ft sump, 35-ft brattice setback; time duration of 22 s for 66.7 pct SF_6 capture.
2. Sump cut: 8 ft sump, 20-ft brattice setback; time duration of 39 s for 66.7 pct SF_6 capture.
3. Slab cut: 23-ft cut depth, 35-ft brattice setback; time duration of 43 s for 66.7 pct SF_6 capture.
4. Slab cut: 8-ft cut depth, 20-ft brattice setback; time duration of 47 s for 66.7 pct SF_6 capture.

SPECIAL SURVEY OF DUST CONCENTRATIONS

During active mining on one production shift, respirable dust concentrations were monitored at the following locations using a GCA RAM-1 instantaneous dust monitor:

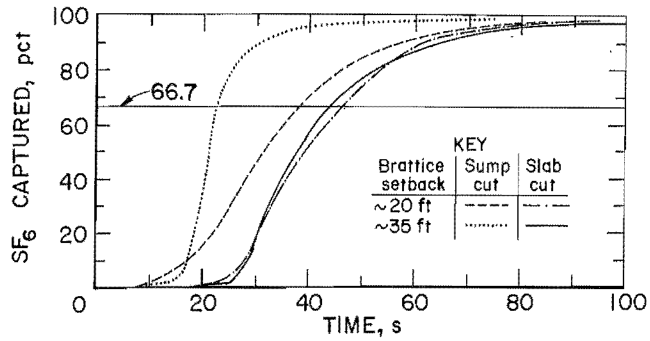

FIGURE 15. - System performance during sump and slab cuts.

1. Remote mining-machine operator's control position.
2. Shuttle car operator's control position.
3. Intake airstream outby the shuttle car operator's position.
4. Return airstream downstream of the cut.

Monitoring was conducted by positioning the RAM-1 at the subject location for an extended period of time and recording dust levels at approximate 15-s intervals during coal cutting and loading.

Dust concentrations presented in table 1 reflect instantaneous dust readings taken only while the continous miner was cutting and loading coal. They cannot be compared to full-shift compliance samples.

TABLE 1. - Dust concentration, milligrams per cubic meter

Cut No.	Remote mining-machine operator	Shuttle car operator	Intake air	Return air
1........	1.48	1.51	1.5	NA
2........	1.52	1.51	[1]1.5	5.16
3........	1.75	NA	NA	NA
4........	1.90	NA	1.35	NA
Average	1.66	1.51	1.45	5.16

NA Not available.

[1]During a period of extensive production downtime, intake concentrations dropped to an average of 0.58 mg/m^3.

The results, shown in the overall averages of table 1, indicated that only a minute amount of dust generated by the mining machine during cutting and loading migrated to the remote mining-machine operator's position (located approximately 15 ft outby the mouth of the cut). Very little dust from any source other than intake sources affected either the remote machine operator or the shuttle car operators. Average concentrations at the shuttle car operator were only 4 pct higher than the intake, and average concentrations at the remote mining-machine operator were only 10 pct higher than at the shuttle car operator. Intake contamination was the predominant face contamination source.

A combination of the following factors indicates a high qualitative measure of dust control effectiveness.

1. The lack of mining machine-generated dust measured at the remote operator's position.
2. Observations from the remote operator's position during cutting that showed cutter head to be clearly visible even at brattice setback distances of 40 ft.
3. Feedback from the mining-machine operators (and all section personnel) that indicated a very high regard for the system's ability to keep the face cleared of contaminants.

CONCLUSIONS AND RECOMMENDATIONS

The following is a summary of the conclusions and recommendations based on results at this particular mine evaluation:

1. The extended-cut system was capable of ventilating the face significantly better at all setback distances than was primary ventilation alone at a 10-ft setback distance.
2. Use of the complete extended-cut system (A- and R-blocks operating) is very important at brattice setback distances greater than 20 ft. From the standpoint of face ventilation effectiveness, the complete system could also be used at setback distances under 20 ft. However, discomfort to personnel from the back-blowing of spray mist would probably preclude the use of R-block at setback distances under 20 ft. An acceptable alternative is to operate A-block at all times and alternating the use of R-block.
3. The importance of properly balancing water pressure against primary face airflow was demonstrated through variable-pressure and airflow tests.
4. The results of the balancing tests indicated that additional water pressure above the maximum 170 psi encountered during the evaluation should further improve performance at "normal" airflow levels. A simple fire extinguisher test of face airflow patterns should be conducted to confirm the effectiveness of the higher pressure.
5. The effects of nozzle plugging produced slight but measurable reductions in system performance and confirmed the importance of effective water supply filtration and system maintenance.
6. Throughout all special system degradation tests (reduced water pressure and face airflow, nozzle plugging, lack of A- and R-blocks operation, etc.), the sprayfan system ventilated the face in a manner comparable to or better than primary ventilation at a brattice setback distance of 10 ft.

This particular ventilation system was moderately complex to operate since various combinations of right and left returns, R-block on and off, and slab and sump R-block spray angles all must be operating at the appropriate times. For this reason, the system described in this report is still in the research stage and should not be applied to general mine use without careful study or simplification.

APPENDIX

TABLE A-1. - Summary of static SF_6 test results

Brattice setback, ft	Test conditions										Percent of SF_6 captured at--		Time span 66.7 pct of SF_6 captured, s
	A- and R-blocks		Water pressure, psi			Airflow, kcfm			Nozzle condition		30 s	60 s	
	On	Off	230	170	80	13	6.5	3.65	Open	Plugged			
10......	Primary ventilation					X			NS	NS	28	76	51
10......		X		X		X			X		42	92	36
20......		X		X		X			X		52	97	34
20......	X			X		X			X		81	99	26
20......		X	X			X				X	17	94	43
20......		X			X	X			X		19	71	56
20......		X		X			X		X		25	86	56
30......	X			X		X			X		36	91	39
30......	X			X				X	X		26	73	53
30......	X				X			X	X		44	89	32
40......	Primary ventilation					X			NS	NS	4	54	78
40......	X			X		X			X		60	96	31
40......		X		X		X			X		24	81	48
40......	X		X			X				X	30	74	50
40......	X				X	X			X		38	85	41
40......	X			X			X		X		40	89	38

NS No sprays used.