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Performance Characteristics of Large-Capacity Face Ventilation Systems for Oil Shale Mining

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

Btu	British thermal unit	in	inch
Btu/h	British thermal unit per hour	L/min	liter per minute
°C	degree Celsius	lb	pound
cm^3	cubic centimeter	m	meter
ft^3/min	cubic foot per minute	m^3/s	cubic meter per second
°F	degree Fahrenheit	min	minute
ft	foot	mol pct	mol percent
ft/min	foot per minute	pct	percent
ft^3	cubic foot	ppm	part per million
hp	horsepower	ppt	part per trillion

PERFORMANCE CHARACTERISTICS OF LARGE-CAPACITY FACE VENTILATION SYSTEMS FOR OIL SHALE MINING

By Edward D. Thimons,[1] Carl E. Brechtel,[2] Marv E. Adams,[3] and Joseph F. T. Agapito[4]

ABSTRACT

The performance of two large-capacity ventilation systems was compared through tests conducted in a large dead-end heading at a pilot oil shale mine in Colorado. Sulfur hexafluoride (SF_6) tracer gas was used to measure the performance of the two systems: a free-standing jet fan and a reversible fan with rigid duct.

The tracer gas was used to simulate the production of mine air pollutants, including blasting pollutants, hot diesel emissions, free methane from surrounding strata, and methane desorbing from muck piles. The test room was 55 ft wide, 30 ft high, and 320 ft long.

The performance of the two fans was similar, but the jet fan used less power. The tests showed that either system could provide effective ventilation during oil shale mining.

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INTRODUCTION

The large openings required for room-and-pillar oil shale mines, coupled with the very large diesel-powered equipment required for production, are expected to create substantial ventilation problems at the working face. Projected rates of air pollutant production indicate that face ventilation capabilities will have to be as large or larger than those required for an entire panel in a typical coal mine. Conventional ventilation equipment is capable of supplying the face airflow rates, but the effects of room dimensions and large-scale turbulence on ventilation effectiveness are not known.

These concerns motivated several oil shale mining companies to sponsor, through the Colorado Mining Association, a design and testing project in conjunction with the Bureau of Mines and the Department of Energy. The primary tasks of the project were to--

- Review current industrial practice to identify data pertinent to the design of face ventilation systems.
- Design and fabricate two test systems with the required air flow capacity.
- Measure the ventilation effectiveness of the two systems in full-size openings in an oil shale mine.

Review of ventilation literature indicated that there were ample design data on the operation of air-moving systems, but little data to describe the motion of air or the pollutant dilution effectiveness of air in large rooms. Analytical techniques to describe air motion and turbulence and their effect on the dilution of air pollutants on a large-room scale are not currently available in the mining industry. Ventilation network models determine average properties of the air stream, such as velocity, temperature, density, or pollutant concentrations, but cannot provide information about the distribution of these properties across the excavation.

SF_6 tracer gas provided a means of quantifying the average performance of the ventilation systems at different locations in the test room. SF_6 has been used in underground ventilation studies by Thimons (7-8),[5] and Matta (6). The gas is inert, does not occur naturally, and is detectable in concentrations as low as 1 ppt. The dilution of the tracer gas provides a direct measure of the action of the ventilation system. Low concentrations can be linearly extrapolated to operational levels of pollutant production so that actual fresh air requirements can be calculated. Different types of pollutant production can be simulated by altering the mode of tracer gas release.

FACE VENTILATION SYSTEMS

Seven conceptual designs for face ventilation systems were generated, based on current ventilation practices. Through comparison and evaluation of the designs, the following two systems were identified as the best approach:

- A free-standing jet fan consisting of a 55-in-diam fan with two-speed, 100-hp motor, mounted on a scissors lift to allow elevation to 17 ft above the floor.
- A reversible fan with rigid duct consisting of a 55-in-diam, two-stage fan with two 125-hp motors, connected to 54-in-diam round steel duct.

Both systems were designed to deliver an airflow of 100,000 ft^3/min, based on the projected operating horsepower during oil shale loading operations. The jet fan system (fig. 1) was ranked very highly because of its operational compatibility and low capital and operating cost. However, it was considered unacceptable under gassy mining conditions, because its operation would cause some reentrainment of exhaust air along the expanding jet. The ducted fan system (fig. 2) was selected for gassy oil shale mining. Rigid duct was chosen because it would

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

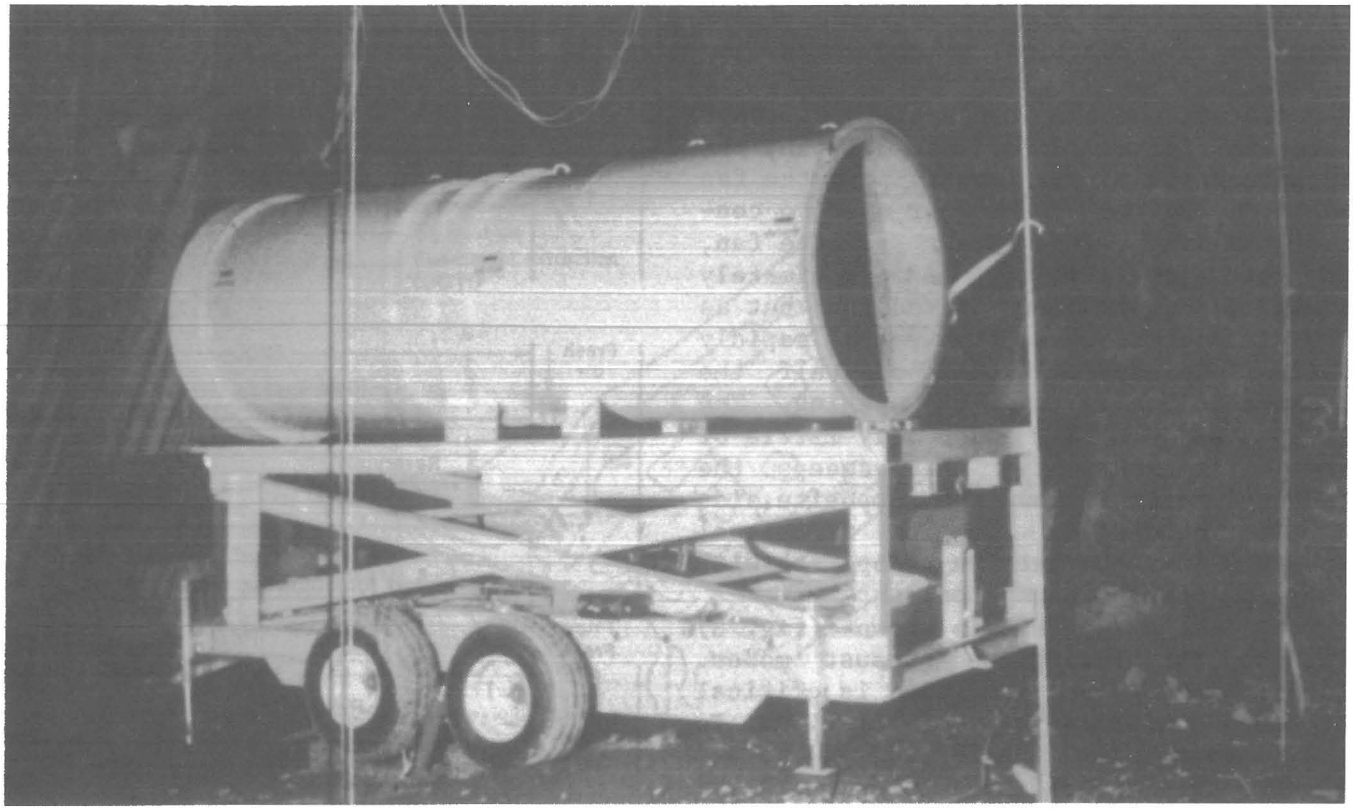

FIGURE 1. - Jet fan.

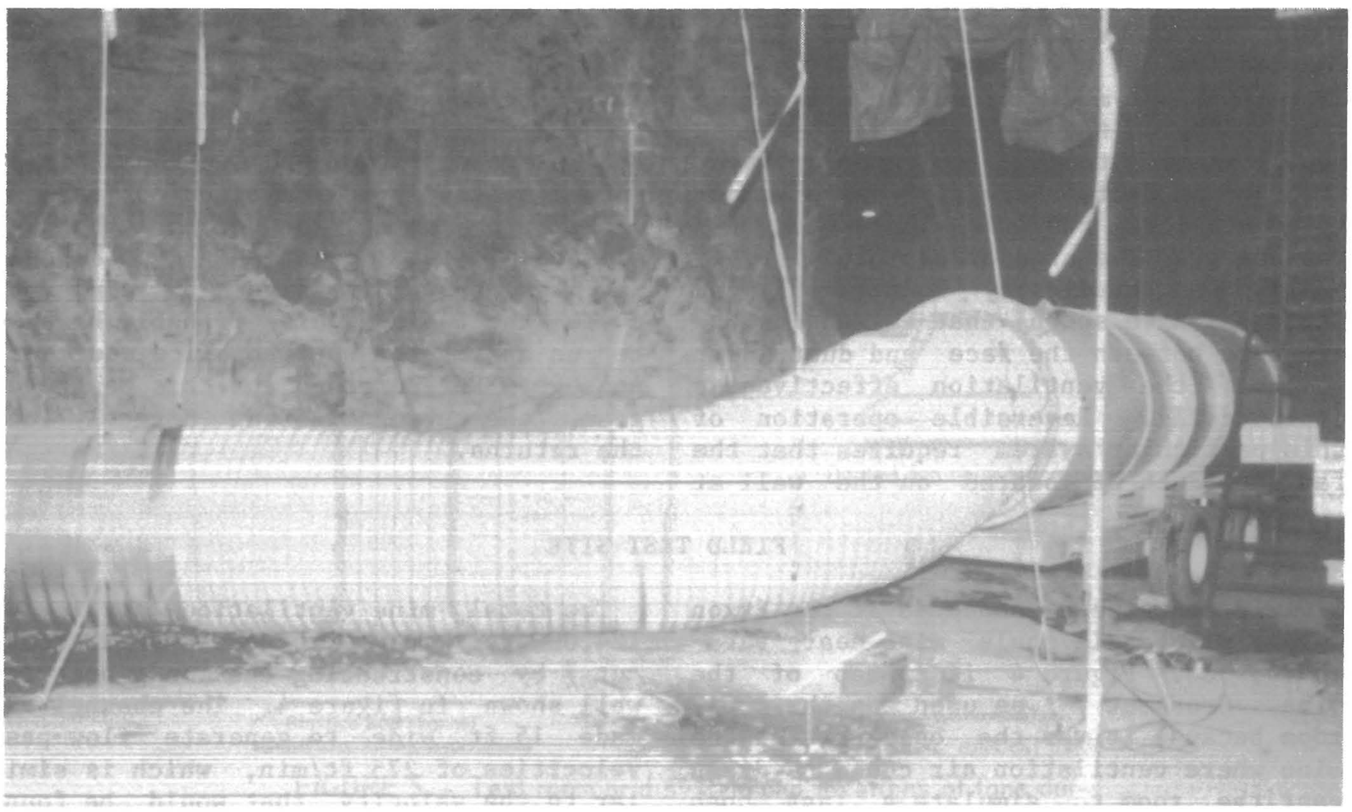

FIGURE 2. - Ducted fan system.

allow comparison of the system's effectiveness in both blowing and exhausting modes.

Operation of the two systems is compared in figure 3. For the jet fan, the turbulent jet of air issuing from the fan outlet forms the channel or duct to conduct the air to the face. Near the fan, the air jet diameter is approximately equal to the diameter of the fan; but as the air jet travels, it expands rapidly until it is approximately one-half the cross-sectional size of the opening. The air reaches the face with very little of its initial velocity, then sweeps the face and returns down the opposite side of the heading. The low frictional losses allow the jet fan to operate with very low power consumption.

The ducted system is shown (fig. 3) in both the blowing and exhaust modes. Positioning of the fan inlet is critical to the elimination of recirculation. In the blowing mode, the fan inlet must be around the corner and upstream in the last open crosscut. Air is carried to the face by the duct and sweeps the face at high velocity. This results in very good mixing of air pollutants in the face area. The exhaust air flows back along the heading to the last open crosscut. In the exhaust mode, fresh air travels up the heading to the face area, and exhaust air flows back to the last open crosscut through the duct. Face air sweep velocities are low, resulting in reduced mixing energy. The area of capture is very small, and studies by Luxner (5) and Haney (3) have shown that increasing the distance between the face and duct inlet reduces the ventilation effectiveness dramatically. Reversible operation of this particular system requires that the fan and duct be located on the wall at the upstream side of the last open crosscut. To avoid recirculation of the exhaust air, the outlet end of the duct must be located downstream of the heading, as shown in figure 3. In most cases, the tubing would probably have to be run up to the roof to allow equipment passage. For purposes of this test program, the tubing was run directly into the returns.

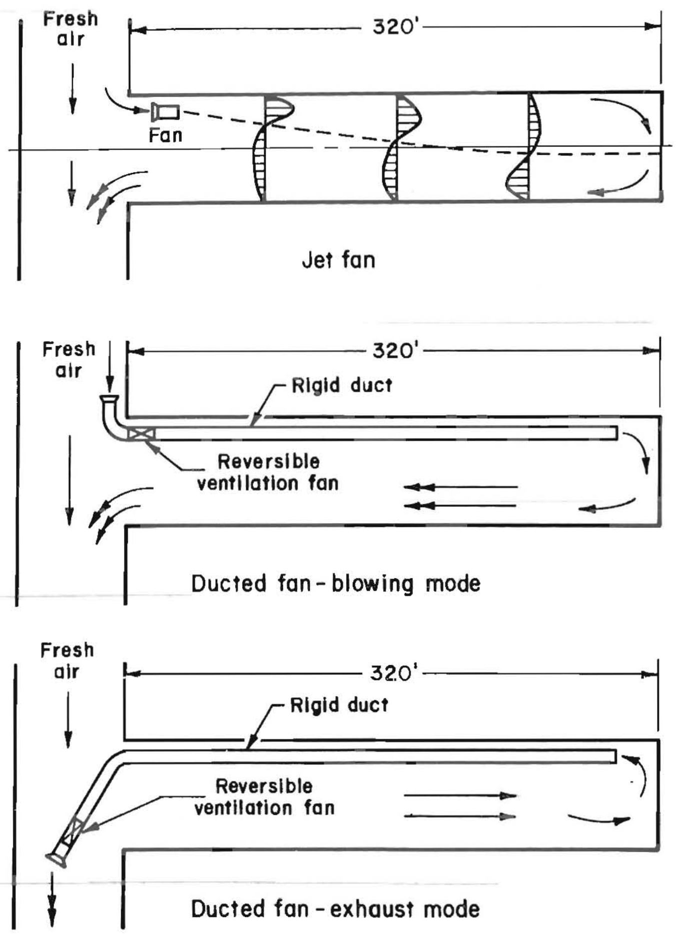

FIGURE 3. - Schematics of fan systems in a dead heading.

FIELD TEST SITE

Field tests were conducted at the Exxon Colony pilot oil shale mine near Parachute, CO. Figure 4 is a map of the mine. Crosscut 7 was used as the test room because it was the only part of the mine where ventilation air could be drawn past the room to simulate a last open crosscut.

The total mine ventilation airflow of 124,000 ft^3/min was channeled past crosscut 7 by constructing the long brattice wall shown in figure 4. The channel was made 15 ft wide to generate flow-past velocities of 275 ft/min, which is similar to the velocity that would be found in an operating oil shale mine. The room

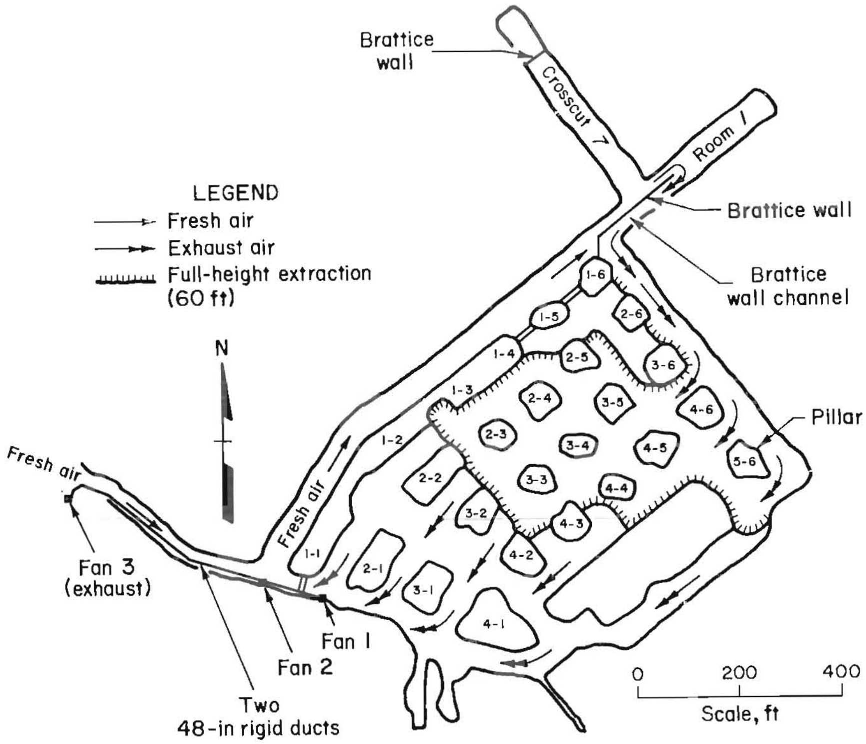

FIGURE 4. - Map of Colony pilot oil shale mine.

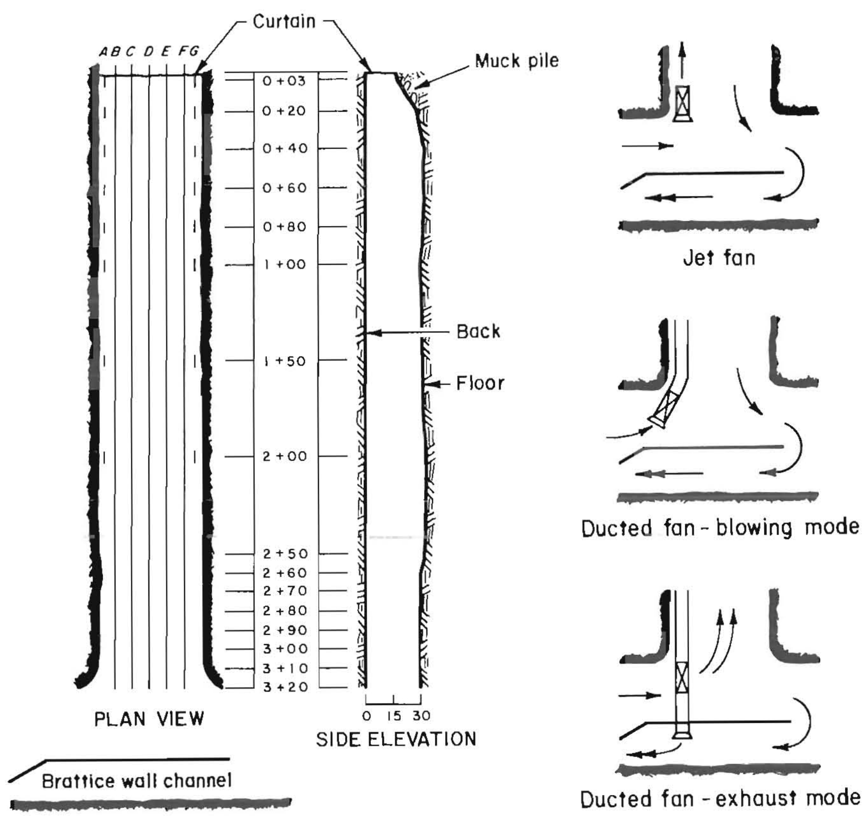

FIGURE 5. - Test room grid system and locations of fans during tracer gas tests.

was closed at a distance of 320 ft by constructing another brattice wall.

A grid system was constructed in the test room so that comparative measurements could be made for both fan systems. Figure 5 shows the layout of the grid system in both plan and side views. At each point in the grid, small pulleys were attached to the roof and floor with a 3/8-in rope traveling through them. Orange plastic streamers were attached to the ropes at 5-ft increments and raised to the desired heights by means of the pulleys, to show the direction of air motion. Air velocity, air direction, and tracer gas sampling were restricted to the grid points.

The locations of the fan systems during testing are also shown in figure 5. Studies of air velocity and airflow direction were used to select the optimum operational position for the tests. Tests of the jet fan at various heights above the floor showed that the fan's ability to project air to the face was reduced by increasing the height. The optimum position was as close to the bottom corner as possible. The ducted fan was placed around the corner for blowing-mode tests. In the exhaust-mode test, the ducted fan outlet passed through the brattice wall so that outlet air was dumped directly into the mine exhaust channel.

TRACER GAS SIMULATIONS

The tracer gas tests were designed to simulate different mechanisms of pollutant production. Oil shale loading operations at the face were expected to be the pollutant source governing face air quantity requirements. Specifically, the combined effect of carbon monoxide and nitrogen oxides was generally thought to be the governing factor. However, reports by Breslin (1) and Daniel (2) have suggested that diesel particulates could be the key design factor. Oil shale dust has been found to contain between 10 and 13 pct respirable quartz and is a potential problem during loading operations. Face blasting in oil shale mining requires the detonation of up to 2,000 lb of ammonium nitrate-fuel oil (ANFO), which produces high levels of gaseous pollutants and dust in the face area. Methane is known to occur as both a free gas in solution with the ground water and in solid solution with the kerogen. Although not expected to be a problem in oil shale mines on the rim of Piceance Creek basin (where the Colony Mine is located), mines in the central Piceance Creek and Unita basins have been classified as gassy during developmental mining operations. Tracer gas tests were designed to simulate each of these potential mine air pollutants. These tests are described in the following sections:

SIMULATION OF BLAST CLEARING

This test was designed to simulate the fans' effectiveness in clearing a heading after blasting. The test room was sealed and SF_6 gas released to give a uniform concentration in the heading of approximately 1,000 ppt. The room seal was removed, and the primary mine ventilation system was then started. The face ventilation fan systems were then turned on to clear the tracer gas from the room, and the SF_6 drawdown rate was measured.

SIMULATION OF HOT DIESEL EXHAUST

This test was designed to simulate the systems' ability to dilute diesel emissions (gaseous and particulates). A 50,000-Btu/h kerosene space heater was placed in the face area with the exhaust routed through a vertical stack that terminated 15 ft above the floor. Tracer gas flowing at a constant rate was mixed in the hot gas stream before the outlet. The space heater generated a stream of hot gases with a buoyancy similar to engine emissions. The mine ventilation and face ventilation systems were started, and the steady-state concentration of SF_6 was measured.

SIMULATION OF METHANE LAYERING

SF_6 was thoroughly mixed with 52.4 mol pct He in air to simulate the density of methane gas, then released from very small holes along a 50-ft-long pipe that was suspended at the roof. The pipe simulated the intersection of a crack that was conducting methane gas into the mine at roof level. The tracer gas was released at a uniform rate for 45 to 60 min, and gas samples were taken to see if the tracer would form a roof layer similar to the layer formed by methane. The fans were then started to test their effectiveness at breaking up the layer.

SIMULATION OF METHANE EMISSIONS FROM A MUCK PILE

In this test, the mixture of air, helium, and SF_6 was released from a group of pipes laid out in the face area to simulate methane desorbing from a freshly blasted muck pile. The tracer gas was released for 45 to 60 min, and then the fans were started. The steady-state concentration was measured to establish the effectiveness of the two systems.

In addition to the tests described above, the inlet recirculation of each fan was measured using SF_6.

TRACER GAS RELEASE AND SAMPLING

The locations of tracer gas release and the tracer gas sampling points are illustrated in figure 6 for each type of test. Automatic, programmable syringe samplers were used to collect tracer gas samples. Each sampler was loaded with nine 25-cm^3 syringes. Both the time to begin sampling and the time interval over which the sample was drawn into the syringe could be programmed. Samplers were suspended at different locations with respect to the roof to provide for measurement of the variations in SF_6 concentration in the vertical as well as the horizontal plane. Tracer gas release was controlled by electronic mass flow meters that were calibrated for the mine air density.

This study employed two types of SF_6 release:

- Steady-state, continuous release of SF_6.
- Release of a fixed quantity of SF_6 and then mixing that quantity uniformly throughout the test room.

DILUTION EFFICIENCY

Analysis of data resulting from both steady-state and fixed release of SF_6 was designed to yield a uniform measure of ventilation effectiveness, which is designated as the dilution efficiency (E_D). E_D is defined as the ratio of the effective quantity of air that is diluting the tracer gas divided by the fan outlet flow rate. A value of 1.00 indicates that all of the air flowing through the fan is being perfectly mixed with the tracer gas. This type of efficiency index was used previously by Haney (3) and called the face ventilation index. In a steady-state release, the following equation would be used to determine E_D:

$$E_D = \bar{C}_{ss}/C_{ideal}, \tag{1}$$

where $\bar{C}_{ss}$ = time-weighted average SF_6 concentration, ppt,

and C_{ideal} = ideal SF_6 concentration assuming perfect mixing with the fan outlet flow rate, ppt.

The ideal concentration is calculated as follows:

$$C_{ideal} = q_{SF_6}/Q_{fan}, \tag{2}$$

where q_{SF_6} = flow rate of SF_6, ft^3/min,

and Q_{fan} = fan outlet flow rate, ft^3/min.

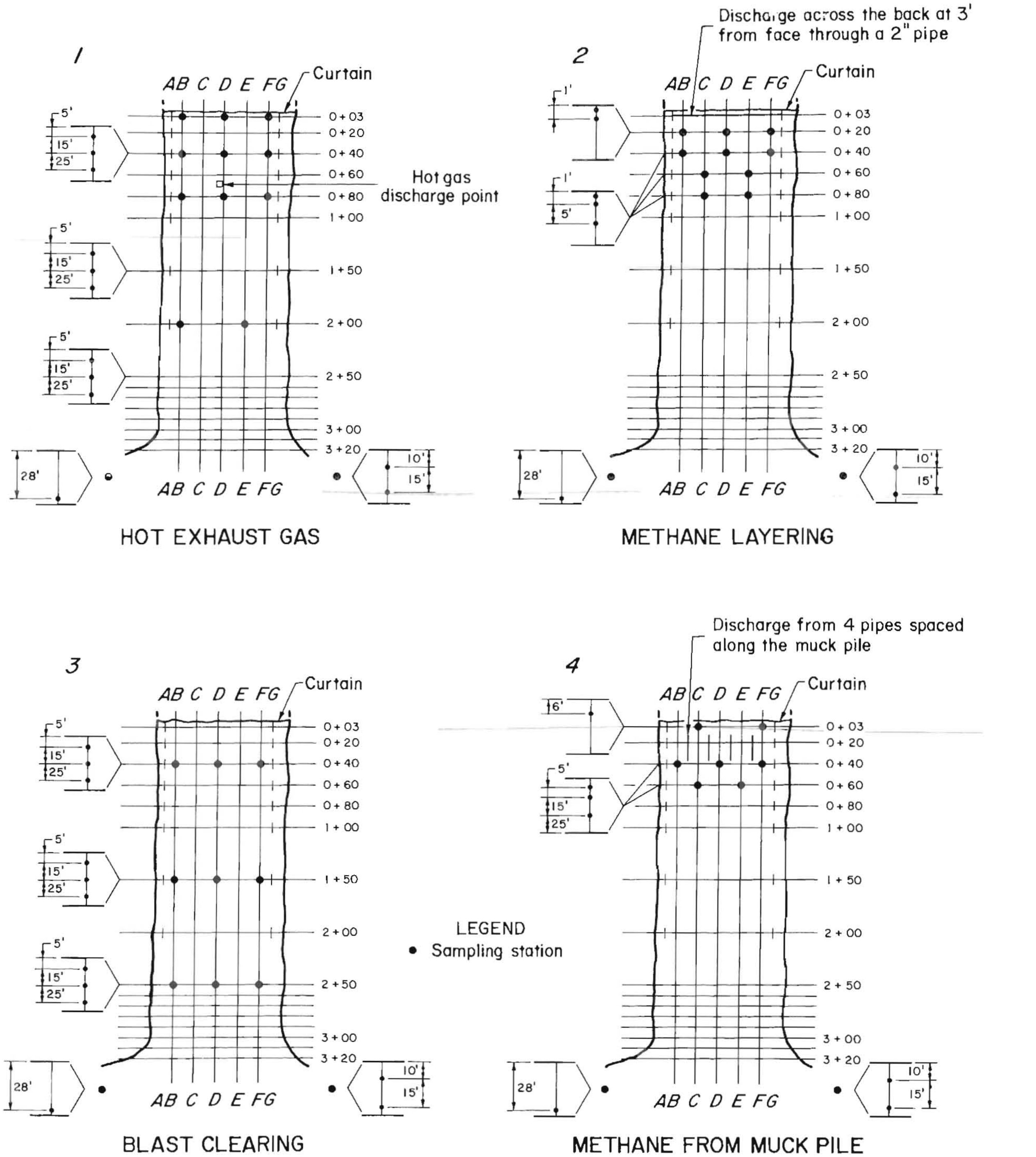

FIGURE 6. - Schematics of tracer gas release points and sampling locations (overhead view).

When uniformly mixed tracer gas is diluted in a room of a given volume (V), Matta (6) provides the following equation to determine the effective flow rate of air:

$$Q_E = V \frac{(\ln C_o - \ln C)}{t_2 - t_1}, \qquad (3)$$

where Q_E = effective airflow rate, ft^3/min,

V = room volume, ft^3,

C_o = initial SF_6 concentration at time t_1, ppt,

C = SF_6 concentration at time $t_2 < t_1$, ppt,

and t_2, t_1 = time, min.

E_D is then calculated as follows:

$$E_D = Q_E/Q_{Fan} \quad (4)$$

Fan inlet recirculation was measured by releasing the tracer gas at a constant rate at the fan inlet and measuring the concentration in the outlet air. The equation below was then used to determine the recirculated flow.

$$Q_R = \frac{Q_{Fan}\, C_{OT} - q_{SF_6}}{C_R}, \quad (5)$$

where Q_R = flow rate of air being recirculated, ft³/min,

Q_{Fan} = fan outlet flow rate, ft³/min,

C_{OT} = SF_6 concentration in outlet, ppt,

q_{SF_6} = flow rate of SF_6 injected into fan inlet, ft³/min,

and C_R = average SF_6 concentration in air around fan inlet, ppt.

Q_R divided by Q_{Fan} is the proportion of air being recirculated at the inlet.

TRACER GAS RESULTS

BLAST CLEARING TEST

In the blast clearing tests, the test room was closed by sealing the brattice wall channel. Release gas containing 101 ppm SF_6 was released at a rate of 0.177 ft³/min for 30 min. In the blowing-mode tests, the fan was then used to mix the air throughout the room, resulting in an average concentration of 947 ppt. The samplers were allowed to take a background sample, then the brattice wall channel was opened and the main mine fans were activated. Samples were taken for several minutes to determine the dilution due to the primary airflow in the last open crosscut, then the face ventilation fan system was turned on, and the dilution rate resulting from its operation was measured. Figure 7 shows the time-concentration data for the nine samplers located at the left, center, and right of section 0+40[6] during the jet fan testing at a flow rate of 88,400 ft³/min. The curves are typical of all the blast clearing tests. Dilution efficiencies for the different tests are compared in table 1.

The E_D values in all of the tests were high and showed that the systems delivered between 71 and 100 pct of the fan outlet volume to the immediate face area. The ducted system achieved the highest efficiency in the blowing mode and showed

[6]For locations of test room cross sections identified as "section 0+40, etc., see figures 5-6.

TABLE 1. - Comparison of dilution efficiencies in blast clearing tests

Fan tested	Fan flow rate, ft³/min	Dilution efficiency[1]			
		0+40	1+50	2+50	Average
Jet fan..........	88,400	0.77	0.65	0.83	0.75
	60,000	1.00	1.00	1.00	1.00
Ducted fan:					
Blowing........	90,700	1.00	.94	.97	.98
Exhausting......	73,000	.71	.78	.88	.79

[1]"0+40," "1+50," and "2+50" indicate locations of test room cross sections, as shown in figures 5-6.

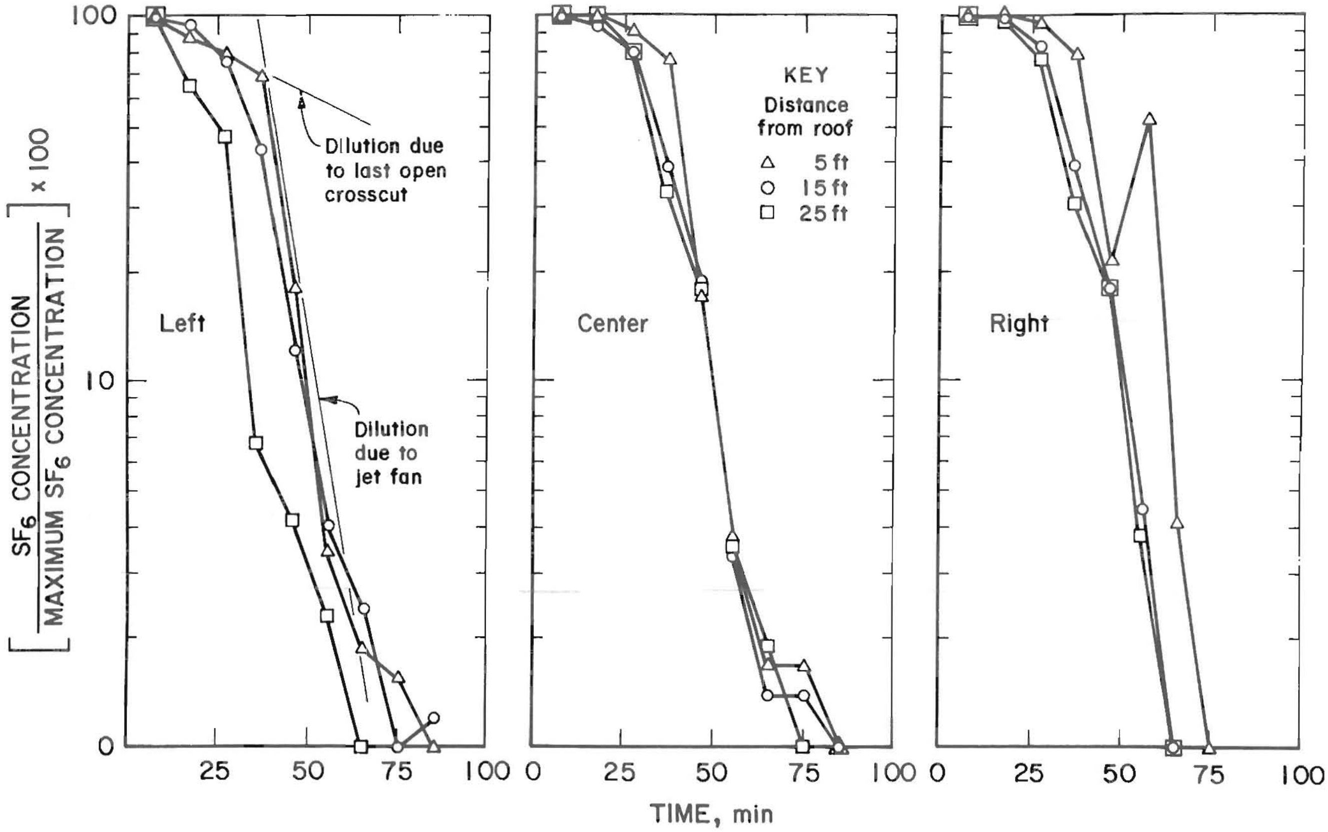

FIGURE 7. - SF_6 concentration versus time during blast clearing test at cross section 0+40 for jet fan. (Results are shown for three positions within the cross section.)

19 pct less efficiency in the exhaust mode. The jet fan system was effective at delivering 77 pct of its outlet flow at a distance of 320 ft from the fan outlet. The efficiency increased when the outlet flow rate was reduced to 60,000 ft^3/min. In fact, the tracer gas measurements indicated that the jet fan delivered as much air to the face at the lower flow rate as it did at the higher flow rate. This suggests some interaction between the jet stream and room dimensions that is not currently defined. Similar results were reported by Volkwein (9) in measurements of jet fan effectiveness at Union Oil Co.'s Parachute Creek oil shale project.

The distance air will circulate into the test room as a result of flow from the last open crosscut was measured during these tests. Air flow was detected as far as section 1+50, with flow rates of 17,500 and 11,300 ft^3/min measured at sections 2+50 and 1+50, respectively.

DIESEL EXHAUST SIMULATION

Diesel exhaust emissions were simulated by releasing a steady stream of release gas containing 101 ppm SF_6 into a 50,000-Btu kerosene space heater connected to a 15-ft vertical stack. The release gas was injected at a rate of 0.192 ft^3/min. The exhaust stream temperature was 300° F, well below the temperature at which SF_6 begins to break up.

The mine fans and face ventilation system were in steady operation for 20 min before the tracer gas release began. Figure 8 shows the time-concentration curves for samples at section 0+40 during the ducted fan test in the blowing mode. The SF_6 concentration reached a steady-state value within 40 min. Time-weighted average concentrations were calculated for the last three sample points and used to determine the E_D values in table 2.

The space heater was used to increase the buoyancy of the exhaust stream, as

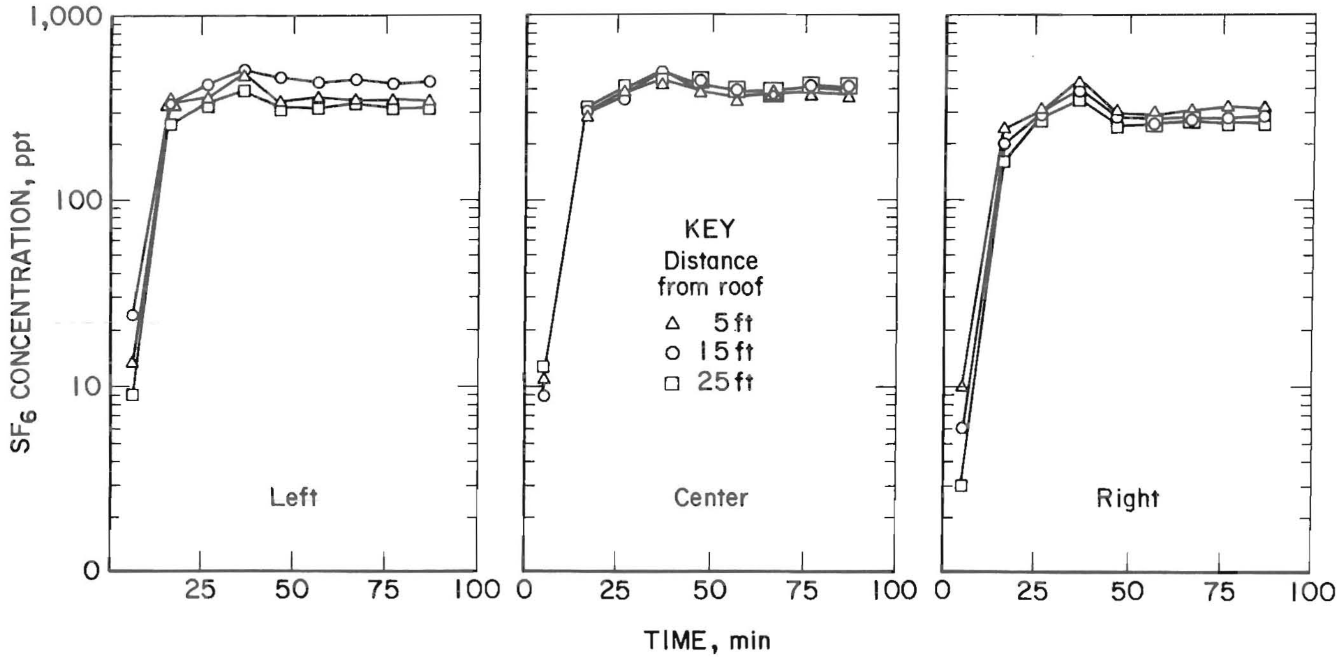

FIGURE 8. - SF_6 concentration versus time in hot exhaust test at cross section 0+40 for ducted fan (blowing). (Results are shown for three positions within the cross section.)

TABLE 2. - Comparison of dilution efficiencies in hot exhaust tests

Section[1]	Distance from roof, ft	Dilution efficiency	
		Jet fan at 88,400 ft^3/min	Ducted fan blowing at 90,700 ft^3/min
0+30..................	6	0.76	0.97
0+40..................	5	.69	.63
	15	.70	.59
	25	.71	.67
0+80..................	5	.76	.74
	15	.83	.75
	25	.83	.77
Overall average..	NAp	.78	.74

NAp Not applicable.
[1]Test room cross section as shown in figures 5-6.

was done in the diesel emissions test. This produced a small stratification of the tracer gas, with the SF_6 concentration averaging 7.5 pct higher at 5 ft from the roof than at 25 ft from the roof. This was significantly less than stratifications measured during actual loading operations, when concentrations were between 36 and 72 pct higher near the roof.

In this test, the jet fan was marginally more effective than the ducted fan in the blowing mode with an average 7 pct higher E_D at the face.

METHANE LAYERING SIMULATION

Methane layering occurs because methane bleeding from fissures in the roof is less dense than air. The density contrast causes most of the methane to float near the roof and makes dilution of the methane more difficult. In order to correctly simulate this phenomenon and make a realistic measurement of the fan systems' capability to break up a methane layer, a release gas mixture of 52.4 mol pct He in air with 1.09 ppm SF_6 was employed.

The gas was released from a 50-ft-long pipe suspended at the roof at cross section 0+30. Small holes were drilled in the pipe at 1-ft spacing so the gas would be released uniformly along the roof line. Gas was released at a rate of 0.833 ft^3/min for 120 min to develop the layer. The gas was then left flowing and the fan system started.

Time-weighted average concentrations were calculated during the build-up period to evaluate the extent of the layer. Figure 9 shows the extent of layering developed in the test of the ducted fan. After 120 min of tracer gas release, the fans were started and the times required to break up the layer and then to reach steady-state concentration were determined. Time-concentration curves for cross section 0+20 during the jet fan test are presented in figure 10. Table 3 lists the E_D values.

The ducted fan system in the blowing mode showed very high efficiency in this test because it delivered its full flow of air directly at the tracer gas release point. If the gas release point were moved, the effectiveness would probably drop to near the level of the jet fan. Both systems broke up the layering effectively in a period of 40 min.

METHANE FROM MUCK PILE SIMULATION

The release gas with 52.4 mol pct He was used to simulate methane desorbing from a freshly blasted muck pile. The gas containing 1.09 ppm SF_6 was released at a rate of 0.833 ft^3/min for 40 min to build a tracer gas cloud in the face. The gas was released from four pipes laid out in the configuration of a muck pile. Small holes were drilled in the pipes at 1-ft spacings to allow uniform release over the face area. The fan being tested was started after 40 min and the steady-state concentration measured.

TABLE 3. - Comparison of dilution efficiencies in methane layering tests

Section[1]	Distance from roof, ft	Dilution efficiency	
		Jet fan at 88,400 ft^3/min	Ducted fan blowing at 90,700 ft^3/min
0+20....................	0	0.40	1.00
	1	.41	1.00
0+40....................	0	.57	.77
	1	.54	.77
	5	.64	.83
Overall average.....	NAp	.59	.83

NAp Not applicable.

[1]Test room cross section as shown in figures 5-6.

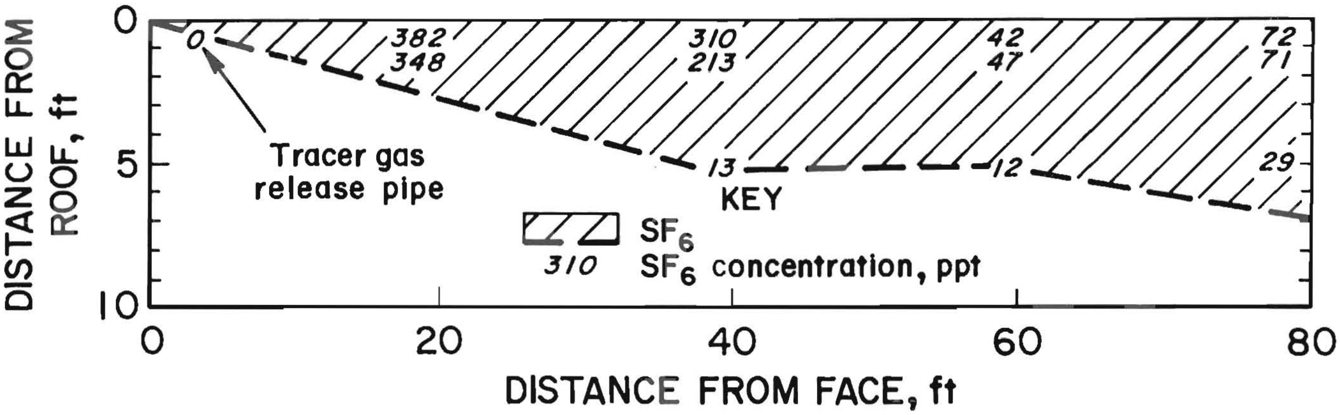

FIGURE 9. - SF_6 layering produced during methane layering test for ducted fan.

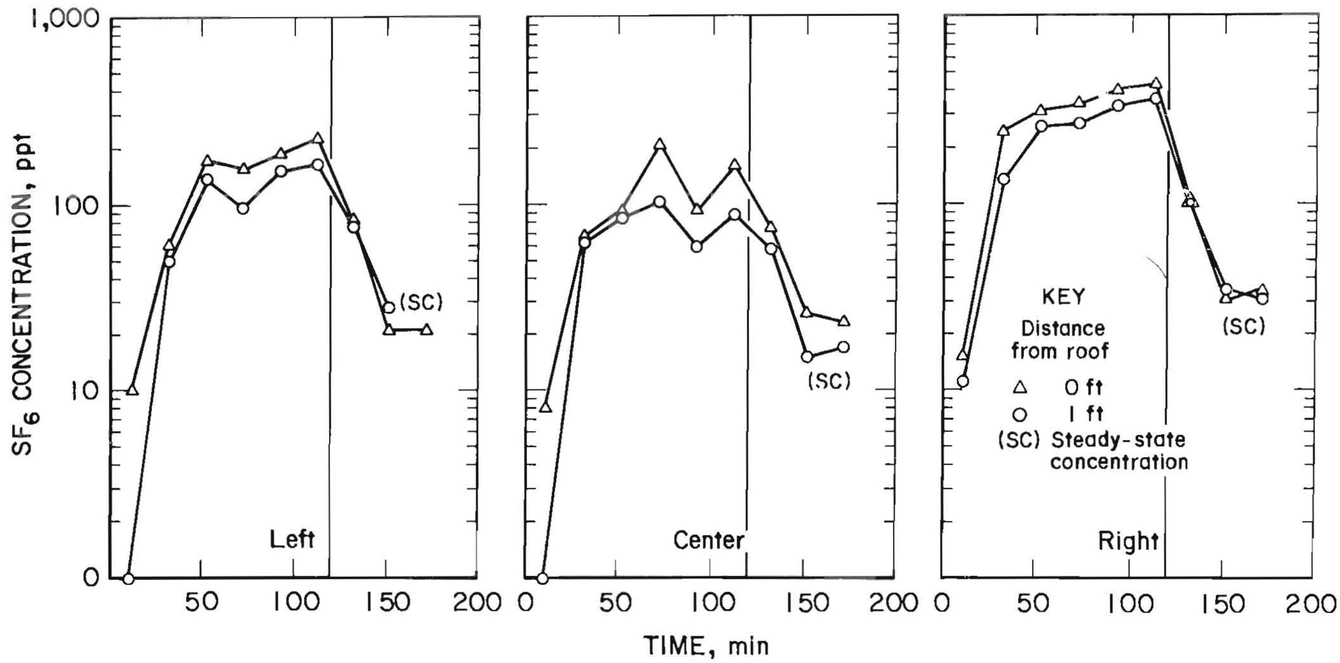

FIGURE 10. - SF_6 concentration versus time in methane layering test at cross section 0+20 for jet fan. (Results are shown for three positions within the cross section.)

Time-concentration data for cross section 0+40 in the ducted fan test are shown in figure 11. The curves show the buildup of SF_6 and that the tracer gas is being transported up through the still air because of the lower density of the release gas mixture. The SF_6 concentration 25 ft from the roof averaged 20 pct of the concentration at 5 ft from the roof.

The fans were then started and the SF_6 concentration quickly reduced to steady-state values. E_D values calculated from the steady-state values are compared in table 4.

FAN INLET RECIRCULATION MEASUREMENTS

Tracer gas measurements of fan inlet recirculation were made for both systems in the blowing mode. Recirculation of the fans was 24 and 28 pct of the outlet flow for the jet fan and ducted fan, respectively. This was surprisingly high for the ducted fan; the high value was due to the location of the fan and the restriction of flow area by the brattice wall channel. Elimination of the recirculation would improve the E_D of the ducted fan to a range of 0.81 to 1.0.

TABLE 4. - Comparison of dilution efficiencies in methane from muck pile tests

Section[1]	Distance from roof, ft	Dilution efficiency	
		Jet fan at 88,400 ft^3/min	Ducted fan blowing at 90,700 ft^3/min
0+30.....................	5	0.45	0.69
	5	.74	.71
0+40.....................	15	.79	.59
	25	.69	.52
Overall average......	NAp	.79	.60

NAp Not applicable.
[1]Test room cross section as shown in figures 5-6.

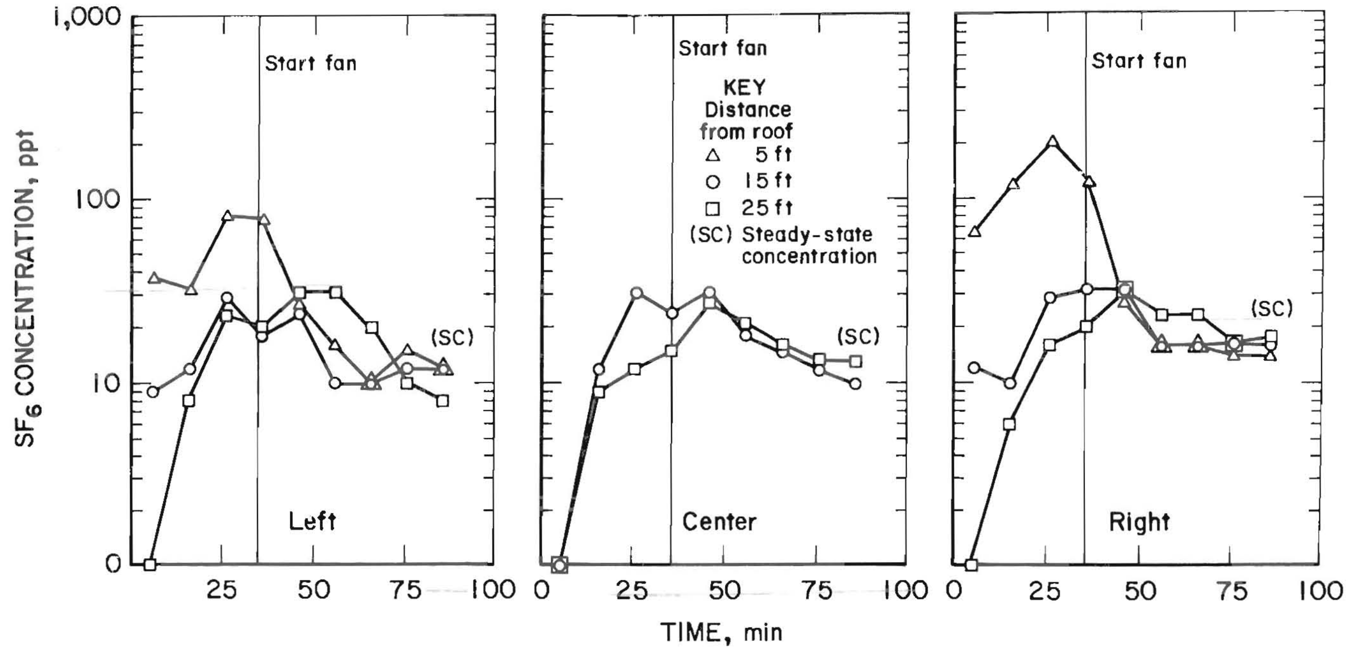

FIGURE 11. - SF_6 concentration versus time in methane from muck pile test at cross section 0+40 for ducted fan (blowing). (Results are shown for three positions within the cross section.)

DISCUSSION

The tracer tests indicated that both of the systems are capable of providing effective face ventilation during oil shale mining operations. The jet fan gives similar levels of ventilation effectiveness at lower power consumption compared with the ducted system, because it eliminates the use of ducting and resulting friction losses. If properly used, the jet fan has many advantages over the ducted system for oil shale mining, including--

- low capital and operating cost,
- ease of movement and positioning, and
- higher air velocities throughout the heading.

Present Mine Safety and Health Administration (MSHA) regulations prohibit the use of the jet fan in gassy situations because of recirculation. Inlet recirculation could be eliminated by attaching ducting to the inlet and drawing air into the fan from upstream in the last open crosscut. Studies of controlled recirculation reported by Leach (4) indicate that recirculation by entrainment along the jet will not increase the methane concentration as long as the inlet fresh air quantity remains constant.

The results of the fan tests are highly dependent upon fan inlet location, recirculation, room dimensions, fan outlet location, and airflow in the last open crosscut. These tests have sought to characterize the fans in what was considered to be simulations of normal operation. The tests were successful in that they showed the fans were able to provide effective ventilation under field conditions.

CONCLUSIONS

Primary conclusions resulting from this work include the following:

- SF_6 tracer gas testing is an effective method of characterizing face ventilation performance.
- The results of the tests performed in this study are dependent upon recirculation, fan inlet and outlet location, pollution source, room dimensions, and flow in last open crosscut.

- Recirculation reduced the dilution efficiencies measured in this study by 17 to 27 pct.
- Both systems showed high dilution efficiencies and were effective in ventilating the face at a distance of 320 ft.
- The jet fan delivered similar performance at significantly less power consumption compared with the ducted system.

REFERENCES

1. Breslin, J. A., A. J. Strazisur, and R. L. Stein. Size Distributions and Mass Output of Particulates From Diesel Exhaust Engines. BuMines RI 8141r, 1976, 10 pp.
2. Daniel, J. H. Diesels in Underground Mining - A Review and An Evaluation of An Air Quality Monitoring Methodology. BuMines RI 8884, 1984, 36 pp.
3. Haney, R. A., S. J. Gigliotti, and J. A. Banfield. Face Ventilation Systems Performance in Low Height Coal Seams. Paper in Proceedings of the First Mine Ventilation Symposium (Tuscaloosa, AL, 1982). Soc. Min. Eng. AIME, 1982, pp. 55-62.
4. Leach, S. J., and A. Slack. Recirculation of Mine Ventilation Systems. Paper in Proceedings of Colloquium on Firedamp Measurement and Control (Isleworth, England, 1969). SMRE, 1969, pp. 218-228.
5. Luxner, J. V. Face Ventilation in Underground Bituminous Coal Mines. BuMines RI 7223, 1969, 16 pp.
6. Matta, J. E., E. D. Thimons, and F. N. Kissell. Jet Fan Effectiveness as Measured With SF_6 Tracer Gas. BuMines RI 8310, 1978, 14 pp.
7. Thimons, E. D., R. J. Bielicki, and F. N. Kissell. Using Sulfur Hexafluoride as a Gaseous Tracer To Study Ventilation Systems in Mines. BuMines RI 7916, 1974, 22 pp.
8. Thimons, E. D., and F. N. Kissell. Tracer Gas as an Aid in Mine Ventilation Analysis. BuMines RI 7917, 1974, 17 pp.
9. Volkwein, J. C. Private communication to Larry Pyeatt of Union Oil Co. of CA, 1982; available upon request from J. C. Volkwein, BuMines, Pittsburgh, PA.

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