Ventilating the Box Cut of a Two-Pass 40-ft Extended Cut

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ABSTRACT

On a continuous miner coal face methane concentrations are affected by the quantity of fresh intake air reaching the face. When mining the box cut on a 12.2-m (40-ft) two-pass extended cut face, the continuous miner is always at the point of deepest penetration, and operation of the machine-mounted dust scrubber and water spray system improve the flow of fresh air to the end of the box cut. However, when the continuous miner leaves the box cut to begin cutting the 40-ft slab, little is known about how much ventilation air reaches the end of the box cut. The Pittsburgh Research Laboratory (PRL) of the National Institute for Occupational Safety and Health conducted a full-scale study to answer this question. Tests were run to determine how much ventilation air reaches the end of the box cut with the continuous miner at three locations in the 40-ft two-pass extended cut mining sequence; at the end of the 40-ft box cut, at the start of the 40-ft slab cut, and 6.1 m (20 ft) into the slab cut.

During these tests, methane gas was uniformly released at the end of the 40-ft box cut. Methane concentrations measured 0.3 m (1 ft) from the roof and face of the box cut were used to estimate face airflow quantities. Fresh air flow rates of 1.89 and 4.72 m^3/sec (4,000 and 10.000 cfm), scrubber flow rates of 0, 4,000 and 10,000 cfm, water spray pressures of 0 and 827 kPa (0 and 120 psi), and a blowing curtain setback position of 15.2m (50 ft) were used during these tests.

To improve ventilation to the end of the 40-ft box cut when the continuous miner was starting the 40-ft slab cut and 20 ft into the slab cut, the blowing curtain was advanced from its 50-ft setback to locations 40-ft and then 8.5 m (28 ft) from the face.

KEYWORDS

Face ventilation, Extended cut, Methane, Box cut, Continuous miner, Scrubber

INTRODUCTION

About half of all continuous mining units in the U.S. are using extended cutting, advancing more than 20 ft past the last row of bolts. Most approvals for extended cuts are for cutting depths of approximately 40 ft. The mining sequence will alternate between box and slab cuts. Deep cuts of this length can be taken as two 40-ft cuts, four 20-ft cuts, or some other cutting sequence combination.

Extended cut mining sections generally provide intake air to the face by means of a blowing ventilation curtain, and the continuous miners are equipped with machine-mounted dust scrubbers. Dust scrubbers help to move fresh air to the immediate face area, and to remove the methane laden air from the face area to the rear of the continuous miner. Properly oriented water sprays, used on all continuous miners for dust control, can also improve face airflow.

Previous studies [Taylor et al., 1997; Volkwein and Wellman, 1989] show how operation of scrubbers and water sprays improve face ventilation during extended cut mining. What happens to the ventilation of the 40-ft box cut when the continuous miner backs out of the box cut to begin the slab cut is of particular concern when a two-pass 40-ft cut is taken because, at the start of the slab cut, the continuous miner is located 40 ft from the point of deepest penetration, the face of the box cut. Until the slab cut is completed, the box cut face is the point of deepest penetration in the entry.

To gain some understanding of the ventilation of the box cut on a two-pass 40-ft extended cut, researchers at the PRL undertook a full-scale study. Tests were conducted to determine how the location of the mining machine and other operating conditions affect the quantity of fresh intake air reaching the box cut face during a 40-ft two-pass extended cut mining sequence. Two series of tests were conducted in the PRL methane test gallery to determine:

* How much fresh intake air reaches the box cut face during various phases of the extended cut mining sequence, and how this is affected by operating conditions, and
* How airflow to the box cut face can be increased.

TEST FACILITY

Test Gallery Configurations

The methane test gallery (Figure 1) simulated a 5.2 m (16.5 ft) wide and 2.3 m (7 ft) high entry during mining of a 40-ft two-pass extended cut. Intake air is drawn into the gallery by an exhaust fan, and the return air exits the building behind a wall constructed on the right side of the entry. A blowing ventilation curtain, attached to a wood frame constructed two feet from the left rib of the entry, directs intake air towards the face. Intake airflow was measured at the inby end of the curtain with a vane anemometer. Two regulator doors were adjusted to provide either 10,000 or 4,000 cfm of fresh intake air.

A full-scale model continuous mining machine with dust scrubber and water spray system was used in this testing (Figure 2). Eleven hollow cone water sprays mounted on top of the boom, were directed 10 degrees clockwise to the right of a line perpendicular to the face. Three additional hollow cone sprays were mounted on the left front of the miner chassis. Two of these sprays were also directed 10 degrees to the right and one about 20 degrees to the left of a line perpendicular to the face aimed toward the left corner of the face. When the water spray system was employed, water pressure and flow rate were kept constant at 120 psi and 1.4 l/sec (22 gpm).

Inlets for the scrubber systems were located on each side of the mining machine approximately 3.5 m (11 ft) from the mining face, near the boom hinge point of the machine. Two fans in the scrubber ducting moved air from the two inlets to the exhaust port at the right rear of the continuous miner. Both fans were needed to obtain a scrubber flow rate of 10,000 cfm; only one was needed for the 4,000 cfm flow rate. Scrubber flow rate was measured about 1.2 m (5 ft) downstream from each fan using a pitot tube and Magnehelic gauge (10 point equal area traverse). When the scrubber was operating, scrubber and intake flow quantities were equal.

A 1.27m (4-ft) wide box was built from floor to roof on the right side of the entry to simulate an uncut slab of coal. The slab was either 40 ft or 20 ft in length to simulate the start of the 40-ft slab cut or 20 ft into the slab cut.

Methane Release

Methane gas was released through four perforated horizontal pipes located across the box cut face equally spaced from floor to roof. The result was a uniform release of methane across the entire face that simulated methane liberation at the face of the box cut. Each 3.8 m (12 ft) long pipe was positioned 45cm (18 inches) from the box cut face. Gas flow was set at 2.35 l/sec (5 cfm) using a rotameter. The 5 cfm flow rate provided methane concentrations in the gallery that were easily recorded by the methane monitoring instrumentation.

Methane Monitoring

Bacharach methane monitors concurrently monitored methane at the three face locations shown on Figure 3. Data from each methanometer were downloaded every two seconds to a personal computer via a Metrabyte A/D conversion board and then to a Lotus spreadsheet for analysis. Monitors were calibrated using 1% calibration gas at the start of each test. Zero settings on the monitors were checked daily.

TEST PLAN

Two series of experiments were run in the full-scale gallery. In the first series of tests, the blowing ventilation curtain was maintained at a 50-ft setback at all times to determine how the amount of fresh air reaching the box cut face was impacted by the position of the continuous miner in the cutting sequence, the amount of fresh air supplied, the operation of the scrubber, and the operation of the water spray system.

The continuous miner was sequentially positioned at three locations in the mining cycle of a two-pass 40-ft extended cut (Figure 3); at the completion of the 40-ft box cut, at the start of the 40-ft slab cut, and 20 ft into the slab cut. For each position, testing was done by setting the blowing ventilation curtain airflow at either 10,000 or 4,000 cfm, with the scrubber flow either matched to the 10,000 or 4,000 cfm curtain flow or the scrubber turned off. Also, for each of the two curtain airflows, the water sprays were either operated at a pressure of 120 psi (water flowrate equal to 22 gpm) or were turned off.

Testing consisted of releasing the gas into the gallery for a period of 10 minutes. The first 5 minutes ensured that the methane levels in the gallery reached steady state. Methane concentration data obtained over the last 5 minutes were used to determine the average methane levels at the box cut face for each test condition.

Three methane monitoring locations were used at the box cut face (Figure 3). These locations were evenly spaced across the box cut face 0.32 m (1 ft) outby the methane release manifold, and 1 ft from the roof. The average methane concentration at the box cut face was considered to be the average of these three readings. Each test was repeated one time and the average of the two tests was used to calculate the results.

The results of the first series of tests showed little ventilation air was reaching the box cut face when the continuous miner was located at the start of the 40-ft slab cut, with some improvement as the continuous miner advanced 20 ft into the slab cut. A second series of tests was run to determine how advancing the blowing ventilation curtain toward the box cut face impacted box cut ventilation when the slab was being cut.

During the second series of tests, the continuous miner was located either at the start of the 40-ft slab cut or 20 ft into the slab cut. Blowing ventilation curtain flowrates of 10,000 and 4,000 cfm were used. Scrubber flow was always matched to the blowing curtain flow at either 10,000 or 4,000 cfm, and the water spray system was always operated at 120 psi pressure and a total flowrate of 22 gpm. For each of the operating conditions, curtain setback distances of 50, 40 and 28 ft were tested. The 40 ft curtain represents an advance of the curtain during the slab cut to the last row of bolts, while the 28 ft curtain would require the use of a 12-ft extensible curtain beyond the last row of bolts. Figure 4 shows these brattice setbacks with the continuous miner at the two test locations. As in the first series of tests, all tests were repeated once and an average methane face concentration calculated for each set of tests. This information was used, as explained in the following section, to determine how much of the available fresh air from the blowing curtain was reaching the box cut face for each test condition.

CALCULATION OF VENTILATION AIR REACHING BOX CUT FACE

It is possible to calculate the quantity of intake air reaching the box cut (F_v), using the following equation:

$$F_v = C_r / C_f * Q$$

where:

C_r = The average percent methane concentration in the immediate face return. This is the methane concentration that would occur if all methane liberated at the face was thoroughly mixed with all of the available intake airflow. In this research, this was calculated by dividing the face methane liberation rate (5 cfm) by the total available intake airflow measured at the end of the blowing ventilation curtain (10,000 or 4,000 cfm) and multiplying by 100.

C_f = The percent methane concentration at the face. In this research, this was the average of three sampling locations at the face of the box cut. Throughout all of the test this average ranged from a low of 0.1% to 1.2%.

Q = The total available intake airflow, measured at end of the blowing curtain, either 10,000 or 4,000 cfm.

This methodology was used to calculate the volume of ventilation air reaching the box cut face for each test condition as presented in the following results section.

RESULTS

First Test Series

In this test series, the blowing ventilation curtain remained fixed at a 50-ft setback. The curtain flowrate was either 10.000 or 4,000 cfm, the scrubber flow was either set to match the curtain flow or the scrubber was turned off, and the water spray system was either set at 120 psi (22 gpm total water flow) or was turned off. These conditions were varied with the continuous miner in one of three positions in the two-pass, 40-ft extended cut. These were at the completion of the 40-ft box cut, at the start of the 40-ft slab cut, and 20 ft into the slab cut. Tables 1 and 2 show the results of these tests at curtain flowrates of 10,000 and 4,000 cfm, respectively.

From Tables 1 and 2, and from Figures 5 and 6, it can be seen that at the completion of the 40-ft box cut while the scrubber and water sprays are operating, approximately 50% of the available blowing curtain air arrives at the box cut face. This is true for curtain flows of either 10,000 or 4,000 cfm. When the scrubber and water sprays are turned off, the airflow at the box cut face drops significantly. For the 10,000 cfm curtain flow, it drops to 538 cfm (5% of the available curtain air), and for the 4,000 cfm curtain, it drops to 552 cfm (14%).

For both 10,000 and 4,000 cfm curtain flowrates, with the continuous miner positioned to start the 40-ft slab cut, the airflow arriving at the face of the box cut is between 4 to 15% regardless of scrubber or water spray operating conditions. As the miner advances 20 ft into the slab cut, there is an improvement in the ventilation at the box cut sprays. Nineteen to twenty-eight percent of the air arrives at the face of the box cut with the scrubber and water sprays operating.

Figure 7 shows a comparison of a 10,000 cfm blowing ventilation curtain to a 4,000 cfm blowing ventilation curtain in terms of the ventilation provided to the box cut face with the scrubber flowrate matched to the curtain flow, and the water sprays operating. With the continuous miner at the box cut face and 20 ft into the slab cut, more air is provided to the box cut face with the 10,000 cfm curtain. However, with the miner at the start of the 40-ft slab, there is no advantage to the higher curtain flow in terms of airflow to the face of the box cut. In fact, the 4,000 cfm curtain actually provides slightly more air to the box cut face.

Figures 8 and 9 show the effect of the operation of the scrubber on the amount of air reaching the face of the 40-ft box cut for curtain flows of 10,000 and 4,000 cfm, respectively. In all these tests, the water spray system was operated at 120 psi and a total water flowrate of 22 gpm and the curtain setback was at 50 ft. The scrubber system was either turned off or was matched to the curtain flow rate. For the 10,000 cfm blowing ventilation curtain (Figure 8), the operation of the scrubber has a major effect on the airflow reaching the face of the 40-ft box cut when the continuous miner is at the box cut face. Its operation at 10,000 cfm increases the amount of air reaching the face of the box cut from 1,382 to 5,556 cfm (a 333% increase). However, when the continuous miner is at the start of the 40-ft slab cut or 20 ft into the slab cut, the operation of the scrubber has no impact on the amount of air reaching the face of the box cut. In fact, there was a very slight decrease with the scrubber operating under these test conditions. For the 4,000 cfm blowing curtain (Figure 9), the operation of the scrubber at 4,000 cfm has some benefit when the continuous miner is at the face of the 40-ft box cut with the airflow increasing from 1,625 to 2,286 cfm when the scrubber is operating (a 41% increase). With the continuous miner at the start of the 40-ft slab cut or 20 ft into the slab cut, the operation of the 4,000 cfm scrubber actually decreased the amount of fresh air reaching the 40-ft box cut face (about 25 % in both cases).

Tables 3 and 4 and Figures 10 and 11 show the effect of the water spray system on the amount of air reaching the face of the 40-ft box cut for curtain flow rates of 10,000 and 4,000 cfm, respectively. For these tests the scrubber flow was matched to the curtain flow and the curtain was maintained at a setback distance of 50 ft. For each test condition, the water spray system was either operated at a pressure of 120 psi and a total water flow rate of 22 gpm or the water spray system was not operated. For the 10,000 cfm blowing ventilation curtain (Figure 10), use of the water spray system resulted in a slight decrease in air reaching the box cut face when the continuous miner was at the face of the box cut (11% decrease). Some increase in airflow to the end of the box cut occurred with the water spray system operating and the miner at the start of the 40-ft slab cut, the airflow reaching the face of the box cut, even with the water spray system and scrubber operating was still only 549 cfm (less than 6% of the available 10,000 cfm of curtain air). For the 4,000 cfm blowing ventilation curtain (Figure 11), with the continuous miner at the face of the 40-ft box cut, the airflow to the box cut face is greatly impacted by the operation of the water spray system. When the spray systems turned on, the airflow to the face of the box cut increases from 800 to 2,286 cfm (an increase of 186%). With the continuous miner at the start of the 40-ft slab cut and 20 ft into the slab cut, the impact of the water spray system on the quantity of air reaching the face of the box cut is still very low when the continuous miner is at the start of the 40-ft slab cut regardless of water spray system operation (about 14% of the available curtain flow with the water spray system operating).

Second Test Series

In the second test series, the curtain setback distance was varied. For each test configuration, the setback distance was set at 50, 40, and 28 ft from the inby end of the box cut. The blowing ventilation curtain flow rate was established at either 10,000 or 4,000 cfm, and the scrubber flow rate was set to match that at the end of the curtain. For all tests, the water spray system was operated at 120 psi and 22 gpm total water flow rate. All testing was done with the continuous miner located either at the start of the 40-ft slab cut or 20 ft into the slab cut.

Figures 12 and 13 show the impact of advancing the blowing ventilation curtain inby on the quantity of fresh air reaching the box cut face for a 10,000 and 4,000 cfm curtain, respectively. For the 10,000 cfm curtain (Figure 12), with the continuous miner at the start of the 40-ft slab cut, advancing the curtain from a 50-ft setback to a 40-ft setback results in a 159% increase in the airflow reaching the face of the box cut. Advancing the curtain from a 50-ft setback to a 28-ft setback by means of an extensible curtain results in an increase in airflow reaching the box cut face from 459 cfm to 3,333 cfm (an increase of 626%). One third of the available fresh air reached the face of the box cut. With the continuous miner 20 ft into the slab cut, advancing the curtain from a 50-ft setback to a 40-ft setback resulted in only a slight increase in airflow to the box cut face, but advancing it to the 28-ft setback, resulted in a 54% increase in the airflow to the box cut face.

For the 4,000 cfm curtain (Figure 13), the findings are somewhat similar to those for the 10,000 cfm curtain. With the continuous miner positioned a the start of the 40-ft slab cut, advancing the curtain from a 50-ft setback to a 40-ft setback results in an increase in airflow to the box cut face of 53%. Advancing the curtain from a 40-ft setback to a 28-ft setback using an extensible curtain, results in an increase in airflow reaching the face of the box cut from 419 to 1,551 cfm (an increase of 270%). Better than one third of the available fresh air (39%) now reaches the box cut face. With the continuous miner 20 ft into the slab cut, advancing the curtain from a 50-ft setback to a 40-ft, and then a 28-ft setback, resulted in increases in airflow to the face of the box cut of 30 and 68%, respectively.

CONCLUSIONS

This study was concerned with the ventilation of the box cut during a 40-ft two-pass extended cut. Testing was done with both 10,000 and 4,000 cfm blowing ventilation curtains. Scrubber system airflows were matched to the blowing ventilation curtain air volumes or the scrubber was turned off. The water spray system was either operated at 120 psi and 22 gpm or it was turned off. For the first series of tests, the continuous miner was located at one of three locations in the cutting sequence; at the face of the 40-ft box cut, at the start of the 40-ft slab cut or 20 ft into the slab cut. For the second test series, it was located at the start of the 40-ft slab and 20 ft into the slab.

The first series of tests was done with the blowing ventilation curtain at a 50-ft setback. For both 10,000 and 4,000 cfm blowing ventilation curtains, as the continuous miner is just completing the40-ft box cut, with the scrubber and water spray systems operating, at least 50% of the available curtain air reaches the face of the box cut. When the scrubber and water spray systems are turned off, the airflow reaching the face of the box cut drops significantly to 5% of the available air for the

10,000 cfm curtain and 14% of the available air for the 4,000 cfm curtain.

For both 10,000 and 4,000 cfm flow rates, when the continuous miner is located at the start of the 40-ft slab cut, the airflow to the face of the 40-ft box cut is low (about 4 and 15%, respectively) regardless of scrubber and water spray system operation. When the miner advances 20 ft into the slab cut, the ventilation to the face of the box cut improves, particularly when the scrubber and water spray systems are operating. For a 10,000 cfm blowing curtain, 19% of the available air reaches the box cut face, and for a 4,000 cfm blowing curtain, 28% of the available air reaches the box cut face.

A comparison was made of the quantity of air reaching the face of the 40-ft box cut as a function of the blowing ventilation curtain flow rate with the water spray system operating and the scrubber flow rate matched to the curtain flow rate. When the continuous miner is at the face of the box cut and 20 ft into the slab cut, more air is provided to the face of the box cut with the 10,000 cfm curtain than with the 4,000 cfm curtain. When the continuous miner is at the start of the 40-ft slab cut, there is no advantage to the higher curtain flow rate in terms of the quantity of air reaching the 40-ft box cut face. As noted earlier, the operation of the scrubber and water spray systems had no significant impact on the air reaching the box cut face when the continuous miner was at the start of the 40-ft slab cut.

The second series of tests analyzed the quantity of air reaching the face of the 40-ft box cut with the continuous miner at the start of the 40-ft slab cut and 20 ft into the slab cut as a function of blowing ventilation curtain setback distance. For these tests, the scrubber flow rate was matched to the blowing ventilation curtain flow rate and the water spray system was operated. Three curtain setback distances, 50, 40, and 28 ft from the inby end of the 40-ft box cut were tested. For a 10,000 cfm blowing curtain, when the continuous miner was located at the start of the 40-ft slab cut, advancing the curtain from 50 ft to 40 ft, and then to 28 ft., resulted in increases in airflow to the face of the box cut of 159 and 626% respectively. With the miner 20 ft into the slab cut, only a small increase in airflow to the face of the box cut resulted for a 40-ft curtain setback, and a 54% increase resulted when the curtain was advanced to a 28-ft setback.

For the 4,000 cfm blowing curtain, with the continuous miner at the start of the 40-ft slab cut, advancing the curtain from 50 ft to 40 ft, and then to 28 ft, resulted in increases in airflow to the face of the box cut of 53 and 270%, respectively. With the miner 20 ft into the slab cut, advancing the curtain to a 40 ft setback, increased airflow to the box cut face by 30%, while advancing it to a 28-ft setback increased airflow to the box cut face by 68%.

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Table 1 - Airflow to Box Cut Face for 10,000 cfm Curtain with 50-ft Setback

Machine Location	Scrubber Flow, cfm	Water Sprays, psi	Box Cut Ventilation, cfm
Box Cut Face	10,000	0	6,250
Start of 40 ft Slab	10,000	0	435
20 ft Into Slab Cut	10,000	0	1,471
Box Cut Face	10,000	120	5,556
Start of 40 ft Slab	10,000	120	549
20 ft Into slab Cut	10,000	120	1,852
Box Cut Face	0	0	538
Start of 40 ft Slab	0	0	435
20 ft Into Slab Cut	0	0	1,136
Box Cut Face	0	120	1,282
Start of 40 ft Slab	0	120	630
20 ft Into Slab Cut	0	120	1,923

Table 2 - Airflow to Box Cut Face for 4,000 cfm Curtain with 50-ft Setback

Machine Location	Scrubber Flow, cfm	Water Sprays, psi	Box Cut Ventilation, cfm
Box Cut Face	4,000	0	800
Start of 40 ft Slab	4,000	0	538
20 ft Into Slab cut	4,000	0	870
Box Cut Face	4,000	120	2,286
Start of 40 ft Slab	4.000	120	583
20 ft Into Slab Cut	4,000	120	1,111
Box Cut Face	0	0	552
Start of 40 ft Slab	0	0	505
20 ft Into Slab Cut	0	0	494

Box Cut Face	0	120	1,500
Start of 40 ft Slab	0	120	776
20 ft Into Slab Cut	0	120	1,625

Table 3 - Airflow to Box Cut Face as 10,000 cfm Curtain is Advanced.

Machine Location	Curtain Setback, ft	Scrubber Flow, cfm	Water Sprays, psi	Box Cut Ventilation, cfm
Start of 40 ft Slab	50	10,000	120	459
Start of 40 ft Slab	40	10,000	120	1,190
Start of 40 ft Slab	28	10,000	120	3,333
20-ft Into Slab Cut	50	10,000	120	2,273
20-ft Into Slab Cut	40	10,000	120	2,500
20-ft Into Slab Cut	28	10,000	120	3,505

Table 4 – Airflow to Box Cut Face as 4,000 cfm Curtain is Advanced

Machine Location	Curtain Setback, ft	Scrubber Flow, cfm	Water Sprays, psi	Box Cut Ventilation, cfm
Start of 40 ft Slab	50	4,000	120	419
Start of 40 ft Slab	40	4,000	120	640
Start of 40 ft Slab	28	4,000	120	1,551
20-ft Into Slab Cut	50	4,000	120	2,000
20-ft Into Slab Cut	40	4,000	120	2,600
20-ft Into Slab Cut	28	4,000	120	3,368

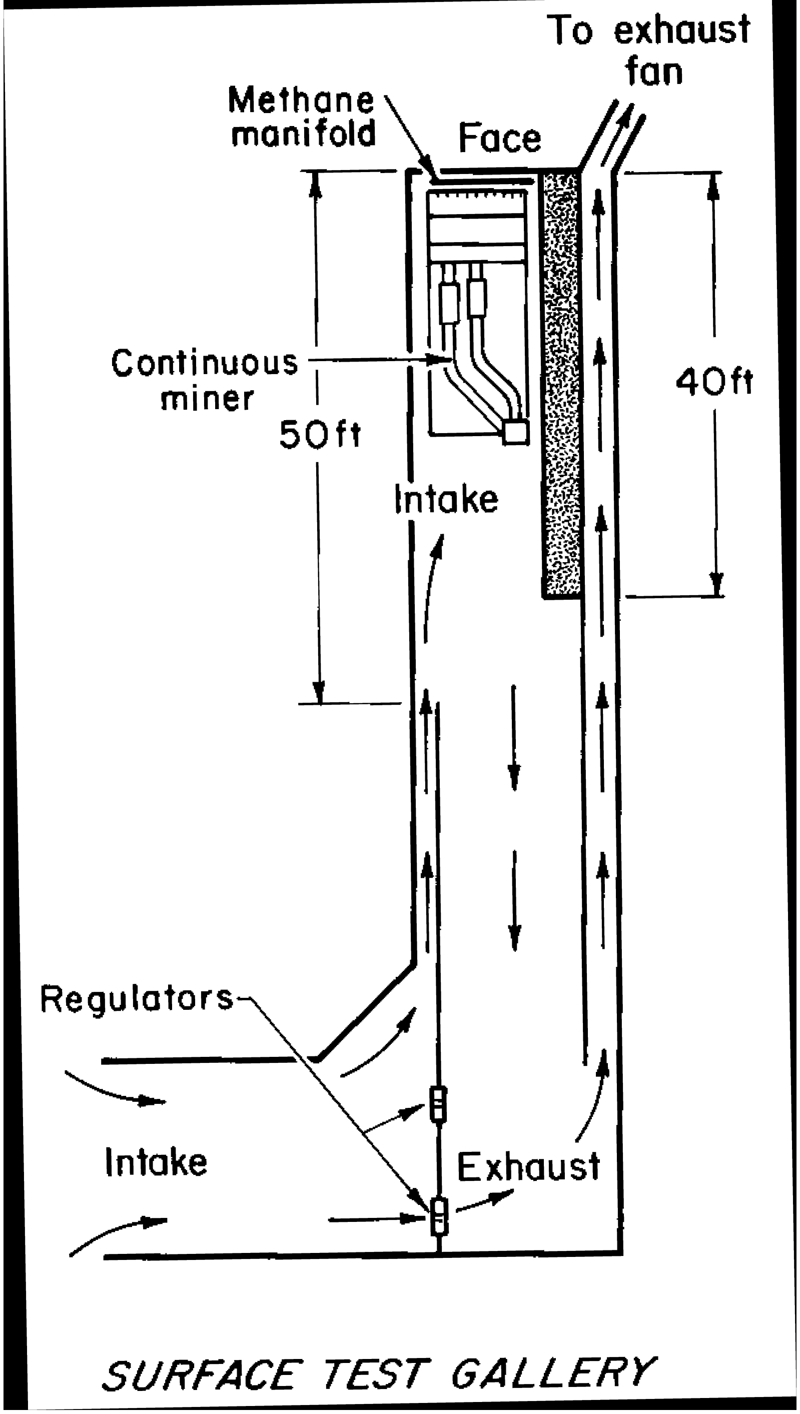

Figure 1 - Full-scale test gallery.

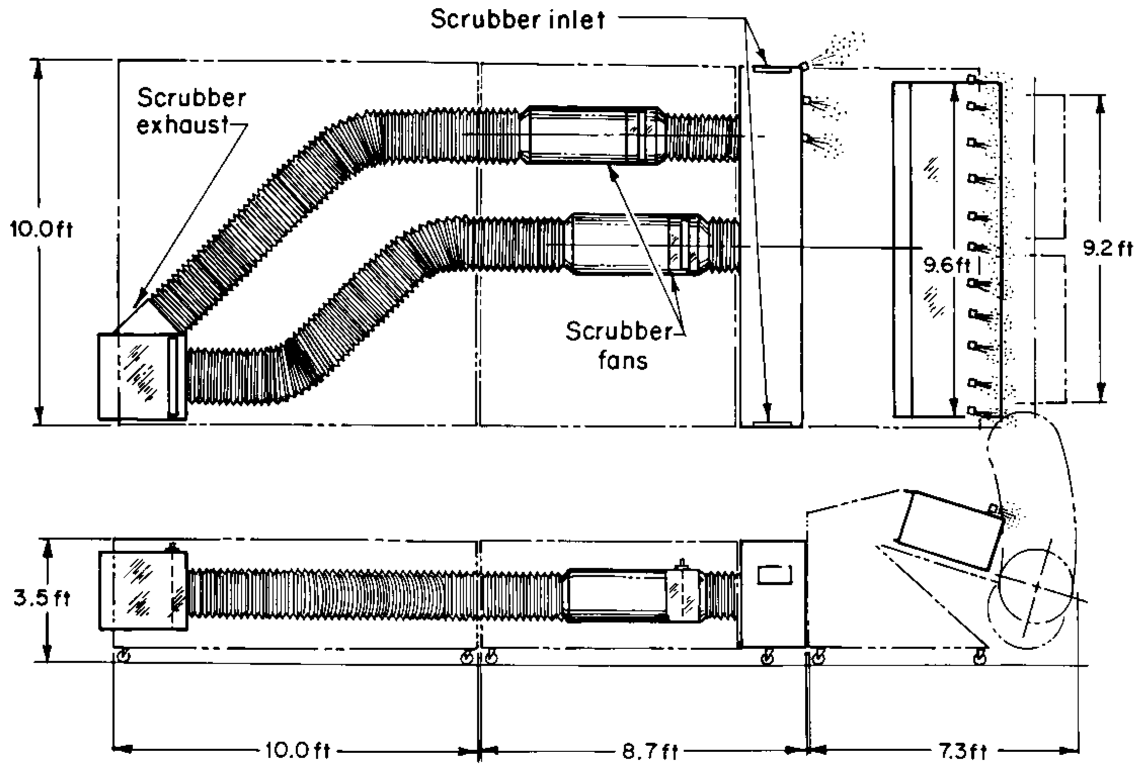

Figure 2- Full-scale model continuous miner with dust scrubber and water spray system.

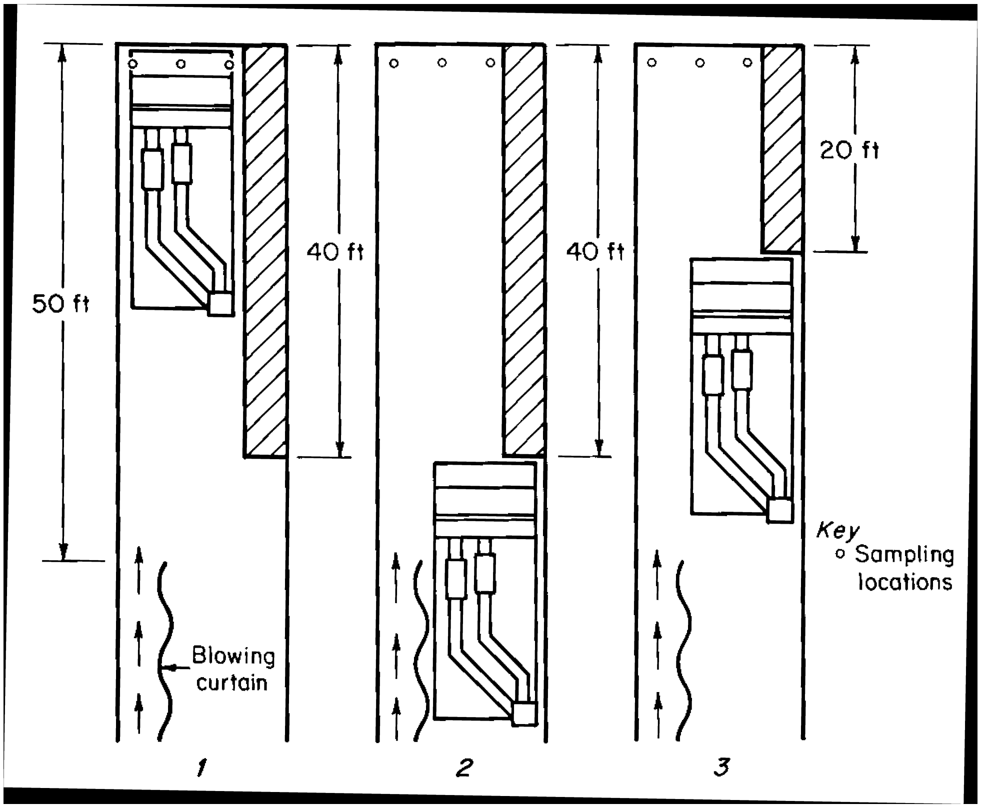

Figure 3 - First tests series: continuous miner locations wit 50-ft brattice setback distance.

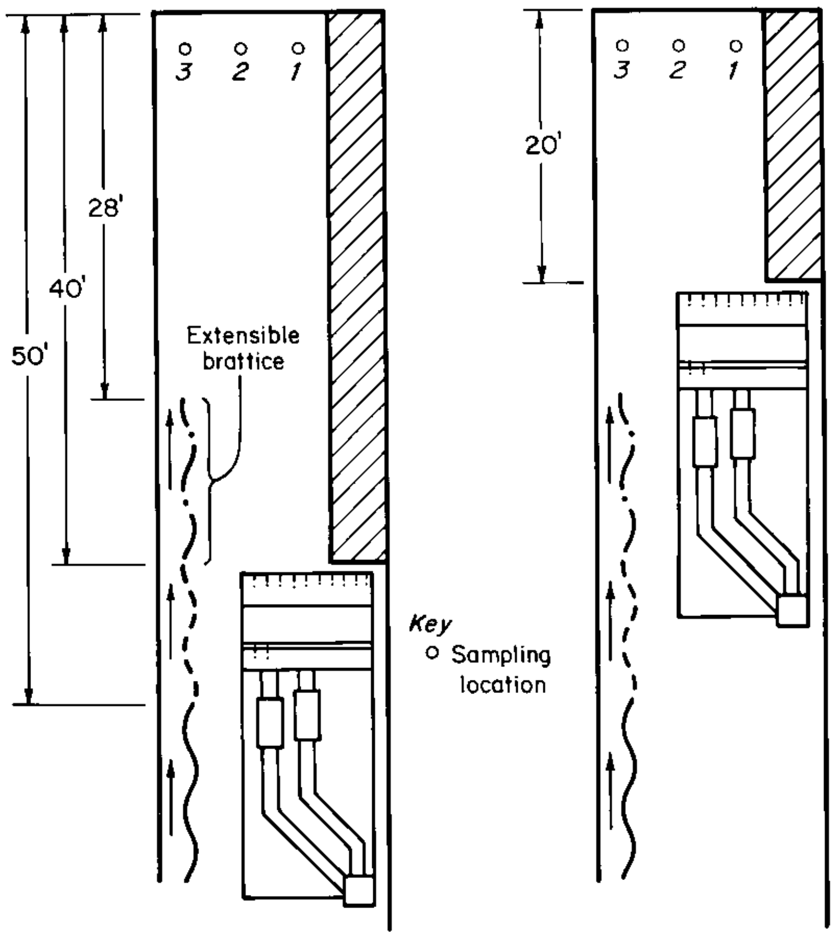

Figure 4 - Second test series: continuous miner locations with 50, 40, and 28-ft brattice setback distances.

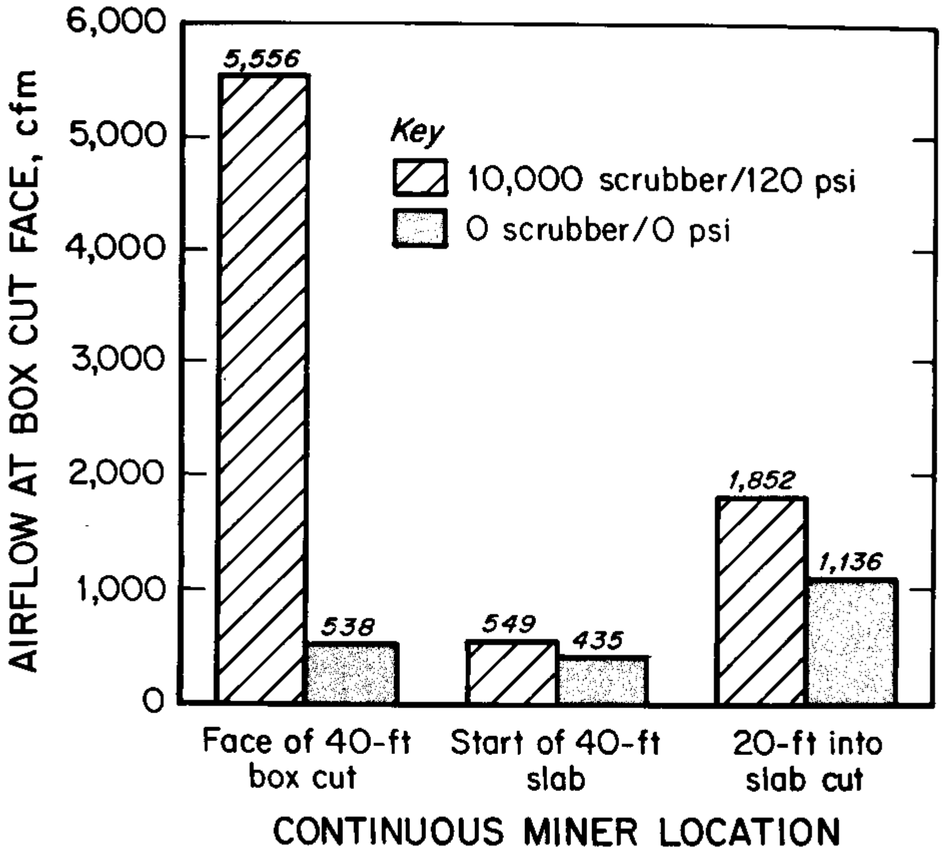

Figure 5 - Effects of scrubber flow and water sprays (10,000 cfm intake).

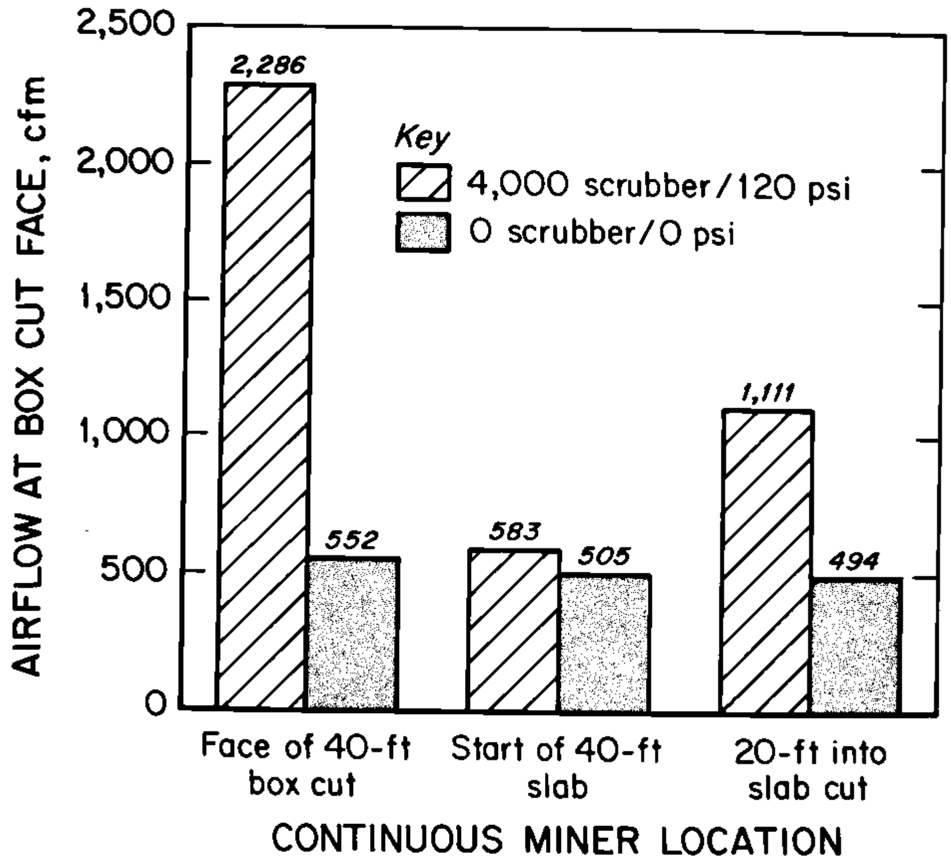

Figure 6 - Effects of scrubber flow and water sprays (4,000 cfm intake).

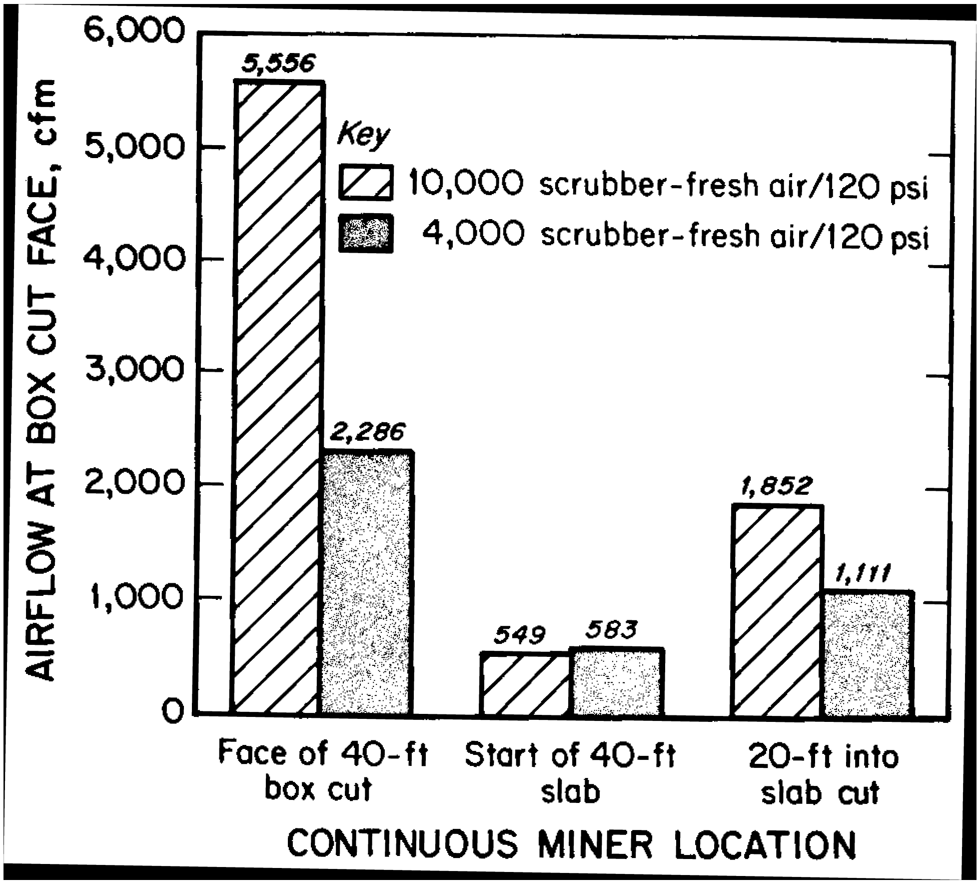

Figure 7 - Effects of intake airflow (scrubber and water sprays operating).

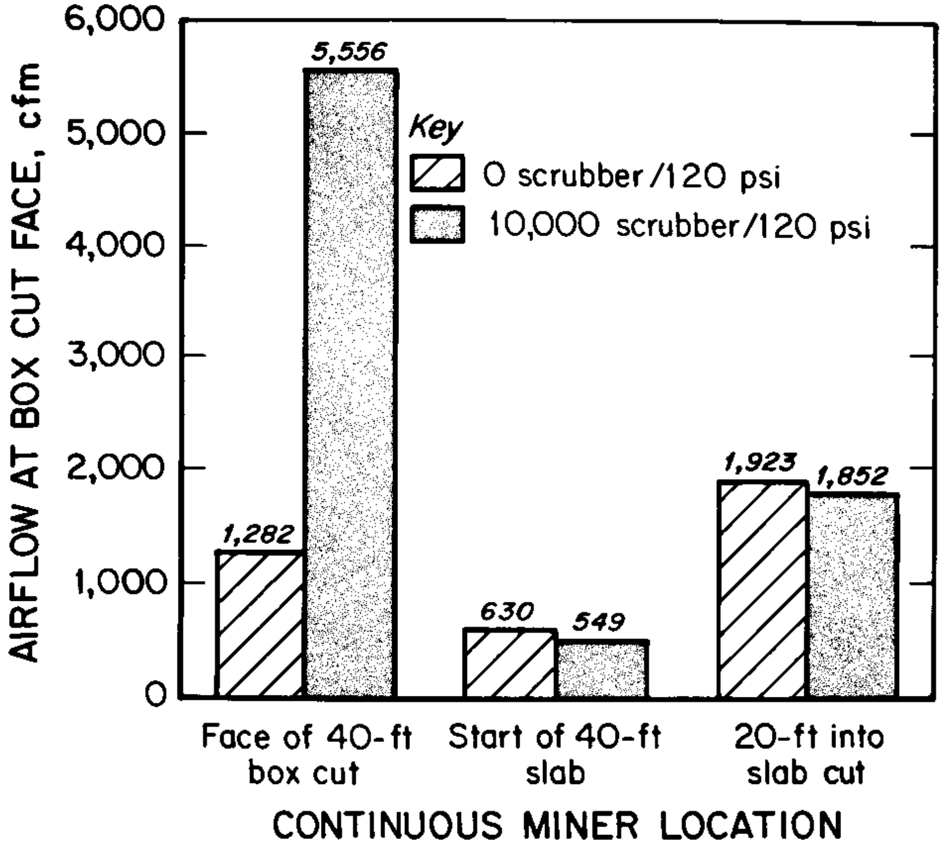

Figure 8 - Effects of scrubber flow (10,000 cfm intake)

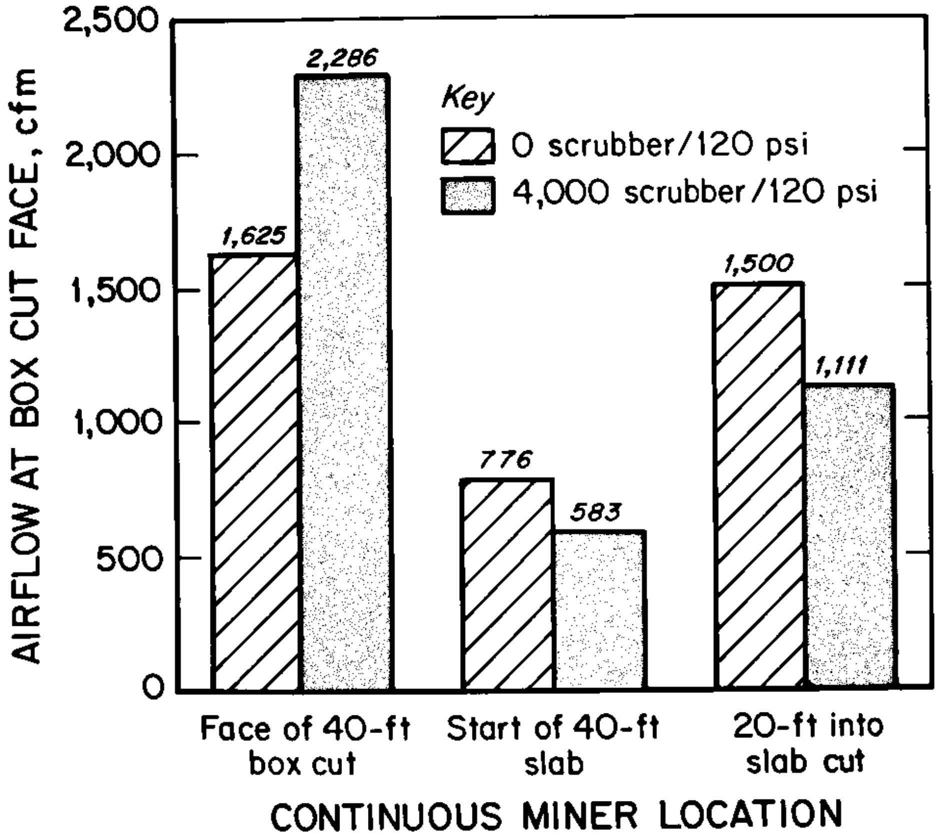

Figure 9 - Effects of scrubber flow (4,000 cfm intake).

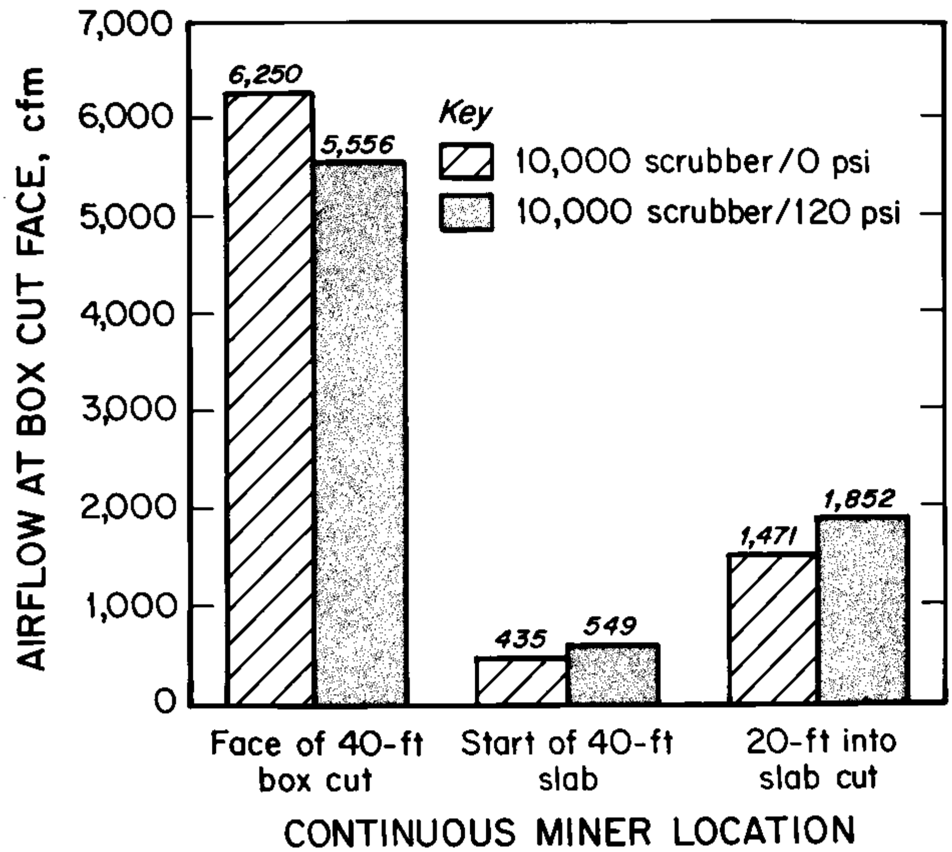

Figure 10 - Effects of water sprays (10,000 cfm intake).

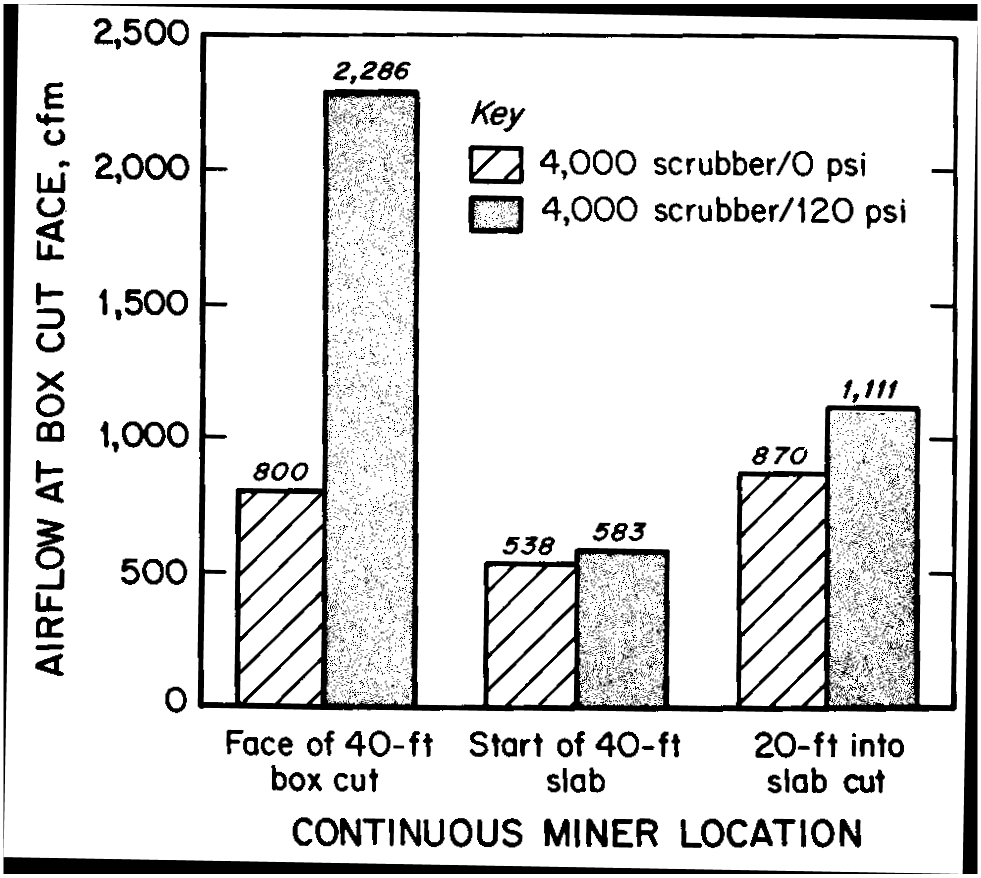

Figure 11 - Effects of water sprays (4,000 cfm intake).

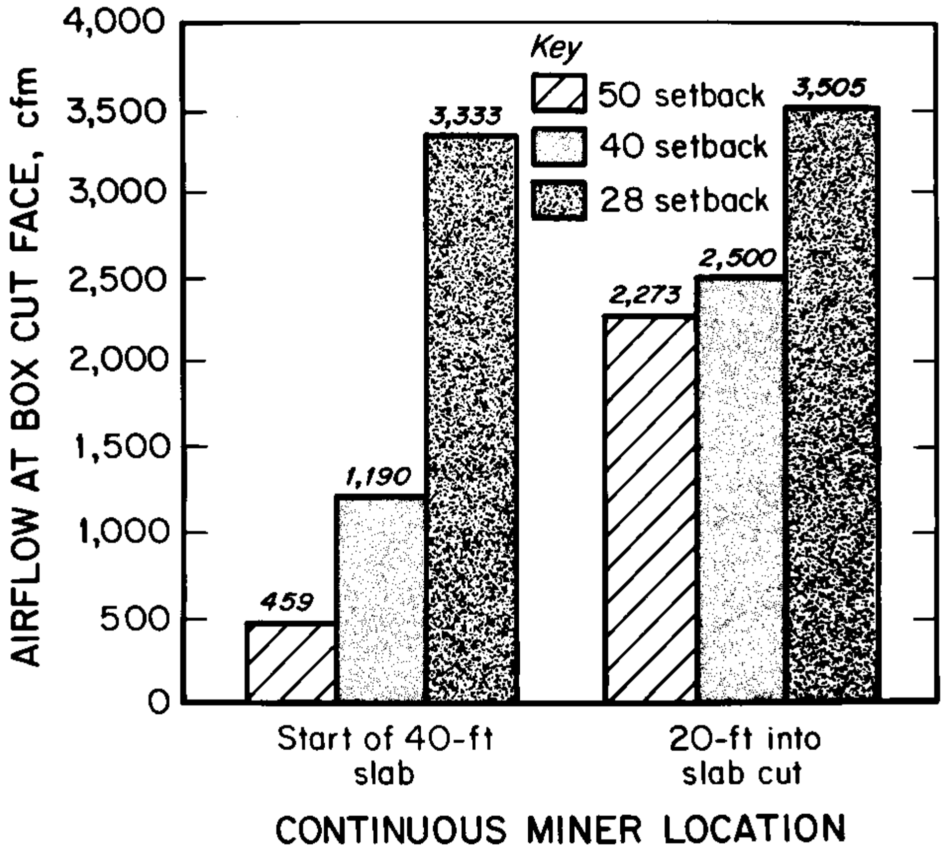

Figure 12 - Brattice setback effect (10,000 cfm intake/scrubber flow and 120 psi water pressure)

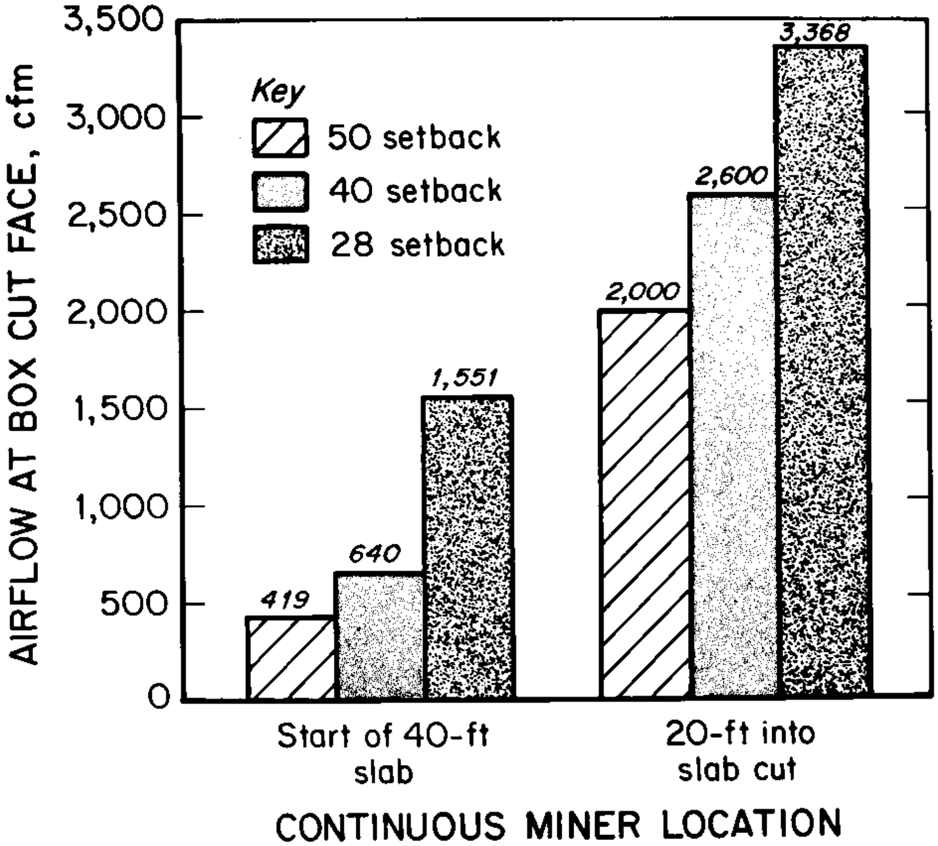

Figure 13 - Brattice setback effect (4,000 cfm intake/scrubber flow and 120 psi water pressure)