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Degasification of the Mary Lee Coalbed, Brookwood, Ala.

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UNITED STATES DEPARTMENT OF THE INTERIOR

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DEGASIFICATION OF THE MARY LEE COALBED, BROOKWOOD, ALA.

By John H. Perry,[1] Leonard J. Prosser, Jr.,[2] and Joseph Cervik[3]

ABSTRACT

The Bureau of Mines has developed several techniques for draining methane from coalbeds in advance of mining. Drilling long horizontal holes from an underground location is one such technique, which was successfully demonstrated in the Pittsburgh and Sunnyside Coalbeds.

The same technique has now been applied in the Mary Lee Coalbed at Jim Walter Resources, Inc.'s No. 4 Mine, Brookwood, Ala., where two holes were drilled horizontally--one to a depth of 1,010 feet (308 m) and the other to 540 feet (165 m). The 1,010-foot (308-m) hole proved successful in degasifying a portion of the Mary Lee Coalbed. The hole drained methane for 1 year, during which time the initial gas flow of 200,000 ft^3/d (5,663 m^3/d) declined to 65,000 ft^3/d (1,840 m^3/d). Total gas production was 40×10^6 ft^3 (1.1×10^6 m^3). The gas was of commercial quality, with 98 pct methane and a heat rating of 990 Btu/ft^3 (36.89 Mj/m^3). The methane emissions from the faces of the mine section advancing into the degasified zone were reduced by 60 pct. The 540-foot (165-m) hole was terminated prematurely when it became impossible to maintain an open hole. Because of caving, very little gas was drained through this hole.

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INTRODUCTION

The Bureau of Mines has demonstrated that large quantities of methane can be removed from underground coalbeds by means of long horizontal holes drilled into the coalbed. To date, most of this research has been concentrated in the Eastern United States, with some research in the State of Utah (1, 3, 5, 7).[4] Three primary factors determine the amount of gas that can be drained from a coalbed. The volume of methane in the coal, the in situ pressure, and the permeability of the bed. Coalbeds that have relatively high permeability and in situ pressure can be successfully drained of their methane. The Pittsburgh Coalbed, which has an in situ pressure of 275 psig (1,896 kPa), is a prime example. Three demonstration projects in this coalbed have removed more than 1.8×10^9 ft^3 (51×10^6 m^3) of methane; about 700×10^6 ft^3 (19.8×10^6 m^3) of this gas has been sold (3, 5). A single project in Utah removed 35×10^6 ft^3 (991,000 m^3) of methane from the Sunnyside Coalbed (7).

There is a correlation between the volume of gas per ton of coal and the depth of the coalbed. The greater the depth, the more methane there will be in a ton of coal (6). The deepest coal mines in the United States are mining the Mary Lee Coalbed at a depth of 2,000 feet (610 m). The Mary Lee Coalbed is part of the Warrior Coal Basin, which encompasses more than 800 mi^2 (2,072 km^2) of Jefferson, Walker, and Tuscaloosa Counties, Ala. (fig. 1).

The overburden of the Warrior Basin varies from zero to 2,500 feet (762 m). In one area of the basin, the overburden changes 1,500 feet (457 m) within 0.5 mile (0.8 km) (2). The overburden at Jim Walter Resources' No. 4 Mine is about 2,000 feet (610 m) (4).

The face cleat of the Warrior Basin coalbeds is generally oriented between N 53° E and N 68° E. In the No. 4 Mine, the face cleat is about N 60° E, and the coalbed is divided into two benches, separated by an 18- to 24-inch (46- to 61-cm) binder.

The methane content of the Mary Lee Group is estimated to be almost 1×10^{12} ft^3 (28×10^9 m^3). Of this total, 700×10^6 ft^3 (20×10^6 m^3) is held in the Mary Lee Coalbed. Almost 90 pct of this gas is held in the coal where the overburden exceeds 1,000 feet (305 m). In situ gas pressures as high as 800 psig (5,516 kPa) have been measured.

ACKNOWLEDGMENTS

The cooperation of the personnel and management of Jim Walter Resources, Inc.'s No. 4 Mine is greatly appreciated.

LONG-HOLE DRILLING AT NO. 4 MINE

Drill Site

This project was designed to degasify a portion of the Mary Lee Coalbed from the northeast corner of the No. 4 Mine (fig. 2). At this location, the Mary Lee Coalbed is divided into two benches. The upper bench is about 20 inches (51 cm) thick and the lower bench is about 5 feet (1.5 m) thick. The binder separating the two is about 2 feet (0.6 m) thick.

Figure 2 shows the location of the two degasification holes drilled into the lower bench. The first hole was drilled to a depth of 1,010 feet (308 m) in a

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

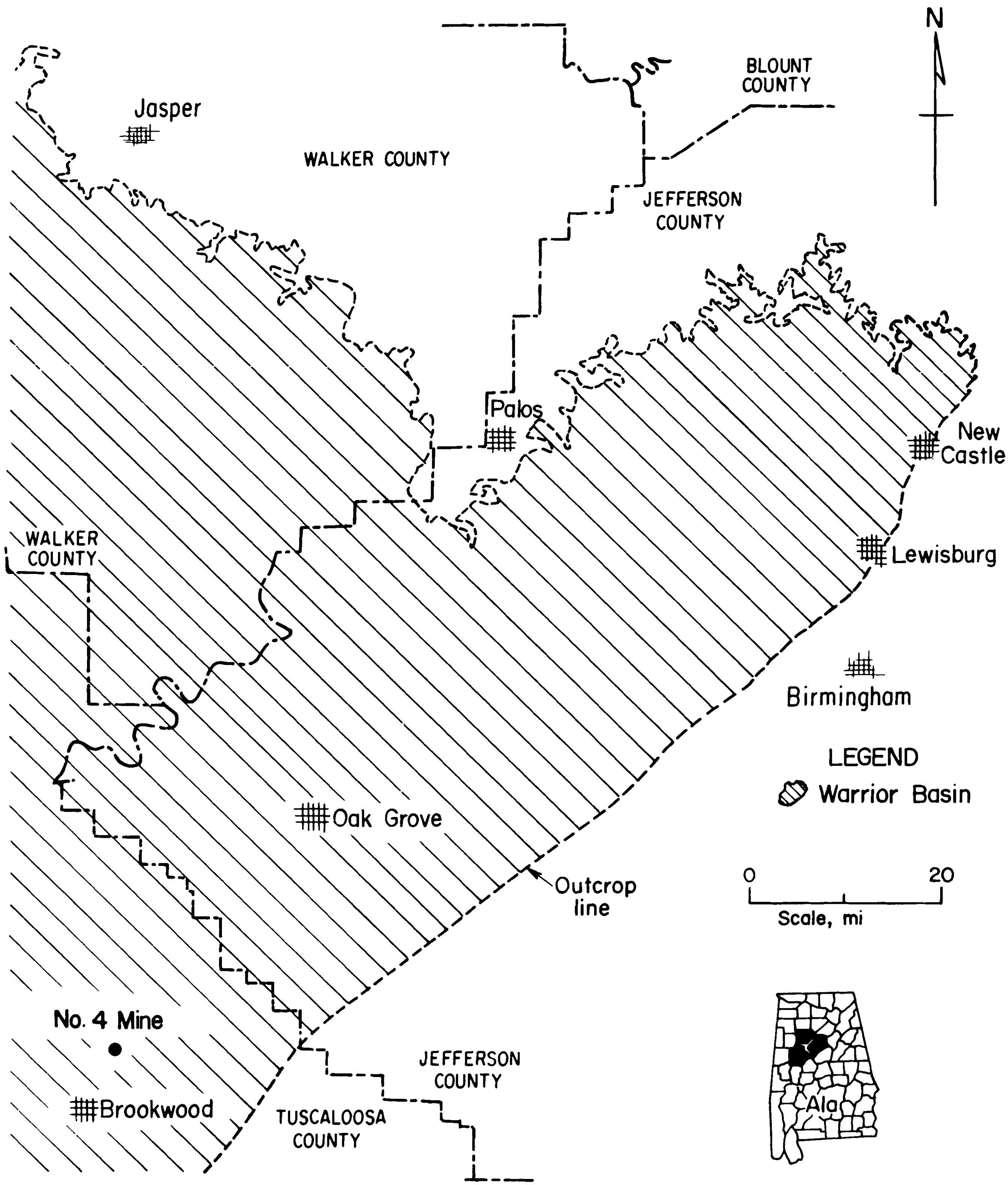

FIGURE 1. - Warrior Basin, Ala.

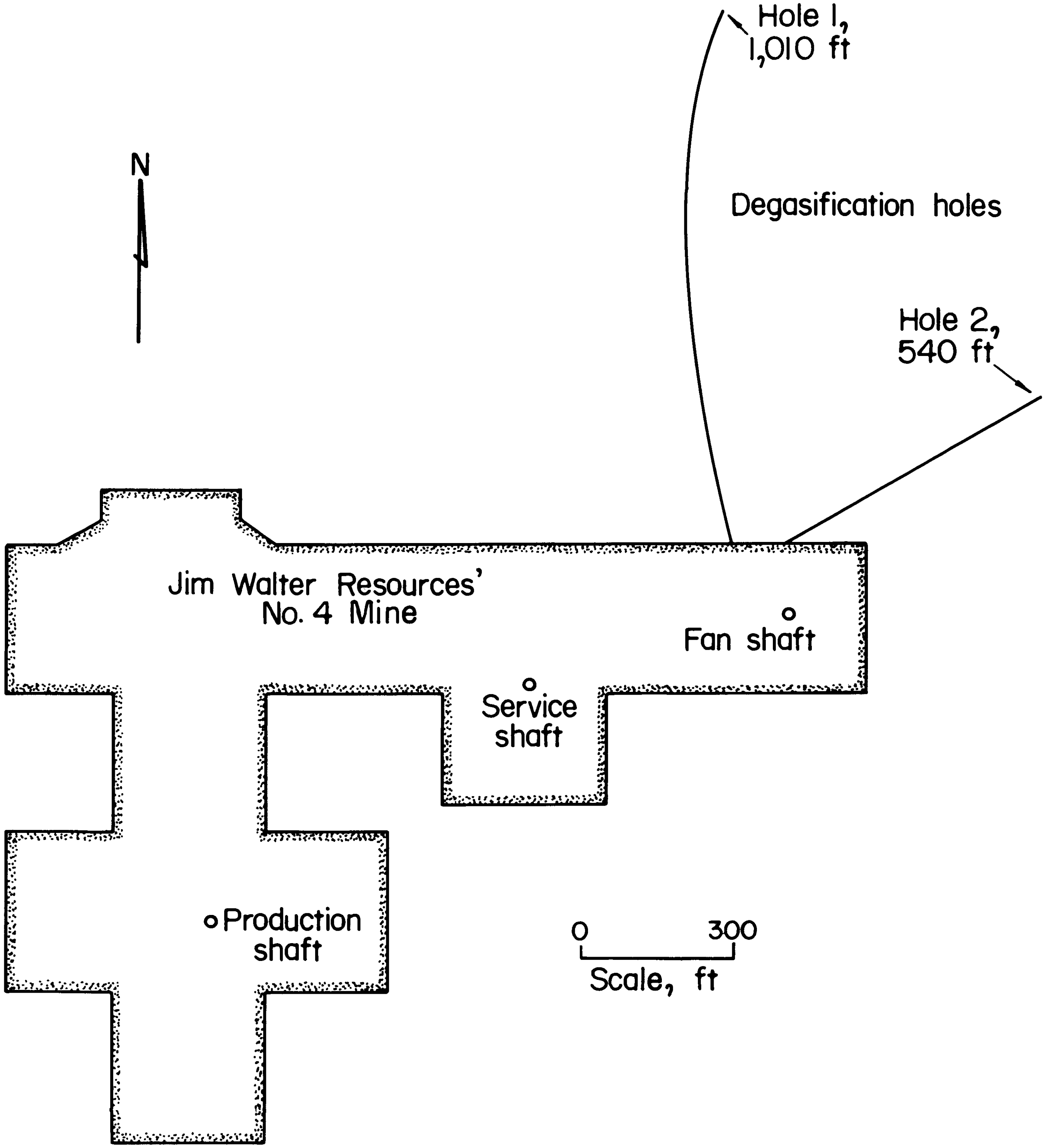

FIGURE 2. - Drill site at No. 4 Mine.

N 15° W direction and crosses the face cleat. The second hole was drilled to a depth of 540 feet (165 m) parallel to the face cleat direction.

Drill Operations

A horizontal drill unit, powered by an electrically driven hydraulic pump, was used for drilling. The power head was equipped with a 3-foot (915-mm) feed length. Initially, the standard long-hole drill string was used (fig. 3). It consisted of a 3-1/2-inch (88.9-mm) drag bit, two 3-7/16-inch (87.3-mm) OD centralizers separated by an 18-foot (5.5-m) NQ drill collar, and a BQ drill rod 2-3/16 inches (55.6 mm) OD. The NQ drill collar was 2-3/4 inches (69.9 mm) OD and 1-7/8 inches (47.6 mm) ID, and weighed about 200 pounds (90.6 kg).

This standard drill string caused problems. After drilling 120 feet (37 m), the drill tools became wedged in the hole because of the collapsing and/or squeezing of the hole. Hole collapse is evident when drilling produces excess coal cuttings and large fragments of coal. These coal fragments from the resulting oversized hole wedge the bit, drill collar, and centralizers in place. Normally, water is used to flush the coal cuttings from the hole, but when collapse occurs, the large coal fragments and cuttings wedged around the drill string prevent flushing, and the tools become jammed. Hole collapse occurs predominantly in softer coalbeds, such as the Mary Lee. Hole squeezing is attributable to overburden pressure. In this case, the hole flattens because of stresses, and the drill string becomes jammed in the undersized hole. It is possible for squeezing and collapse to occur in the same hole. The Mary Lee is both soft (friable) and deeply deposited (2,000 feet (610 m)).

Because of this situation, alternative drill strings were employed in the Mary Lee Coalbed. A string consisting of only a 3-inch (76.2-mm) drag bit and BQ rod was used (fig. 4). The smaller diameter bit produces fewer cuttings. Removal of the drill collar and centralizer allows more area around the drill rod for the cuttings to be flushed. Also, as the hole increases in depth, it is further outby the mine opening, which decreases the risk of hole squeezing.

Control During Drilling

With the standard drill string (fig. 3), the path of the bit in the vertical plane is controlled in three ways: By the thrust applied to the bit, by the rotational speed of the bit (revolutions per minute), and by centralizers on the heavy NQ drill collar. The drill collar stiffens the drilling assembly and adds weight to the bottom side of the drag bit. A drilling assembly with a

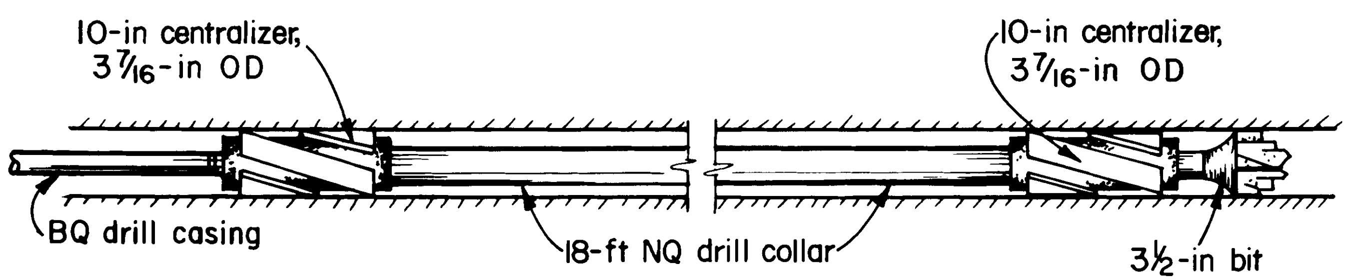

FIGURE 3. - Standard long-hole drill string.

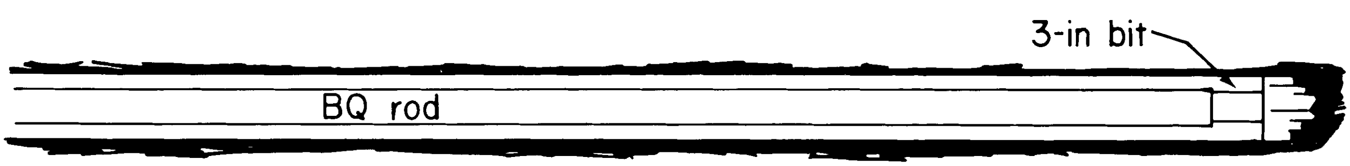

FIGURE 4. - Modified drill string with 3-inch bit.

3-5/8-inch (92.1-mm) bit tends to wear the bottom side of the hole and arc downward more readily than one with a 3-1/2-inch (88.9-mm) bit, and thrust levels must be higher to compensate for this tendency. Because the drilling of the Mary Lee required removing the drill collar and centralizers and using a 3-inch (76.2-mm) bit, the normal control techniques were not applicable.

Hole 1 was drilled in the return to a depth of 1,010 feet (308 m) (fig. 2). The final 890 feet (271 m) were drilled using only a 3-inch (76.2-mm) bit and BQ rod. Controlling the bit in a vertical plane was attempted by adjusting bit thrust and rotational speed, but without the drill collar and stabilizers, control was not obtained. However, because of the softness of the coal and the hardness of the floor rock, the hole trajectory naturally followed the bottom of the coalbed for its entire length (fig. 5).

Table 1 shows control parameters for a standard drill string. These can be compared with the drilling parameters in table 2 for the modified drill string consisting of a 3-inch (76.2-mm) bit and BQ rod. Increasing thrust and lowering rotational speed normally tends to bring the standard drill string upward (table 1); no response was experienced with the modified drill string (table 2), regardless of thrust and rotational speeds.

TABLE 1. - Drilling parameters for standard drill string

Thrust		Bit rotation,	Bit angle
lb	N	rpm	trajectory
800	3,559	700-900	Downward.
1,200	5,378	400-600	Holding.
1,500	6,672	200-300	Upward.

TABLE 2. - Drilling parameters for modified drill string

Thrust		Bit rotation,	Bit angle
lb	N	rpm	trajectory
1,275	5,671	50	No change.
2,125	9,452	75	Do.
2,550	11,342	75	Do.
2,975	13,233	75-100	Do.
3,400	15,123	100	Do.
7,250	32,248	175	Do.

Because the modified drill string with the 3-inch (76.2-mm) bit could not be controlled, the bit diameter was reduced to 2-5/8 inches (66.7 mm) in an attempt to prevent the bit from undercutting the hole and arcing downward. Hole 2 was drilled with the 2-5/8-inch (66.7-mm) bit, but the hole trajectory still could not be controlled. The bit arced toward the floor and followed the bottom of the coalbed. Drilling was stopped at 330 feet (101 m), and a 2-1/2-inch (63.5-mm) diameter centralizer was added directly behind the bit

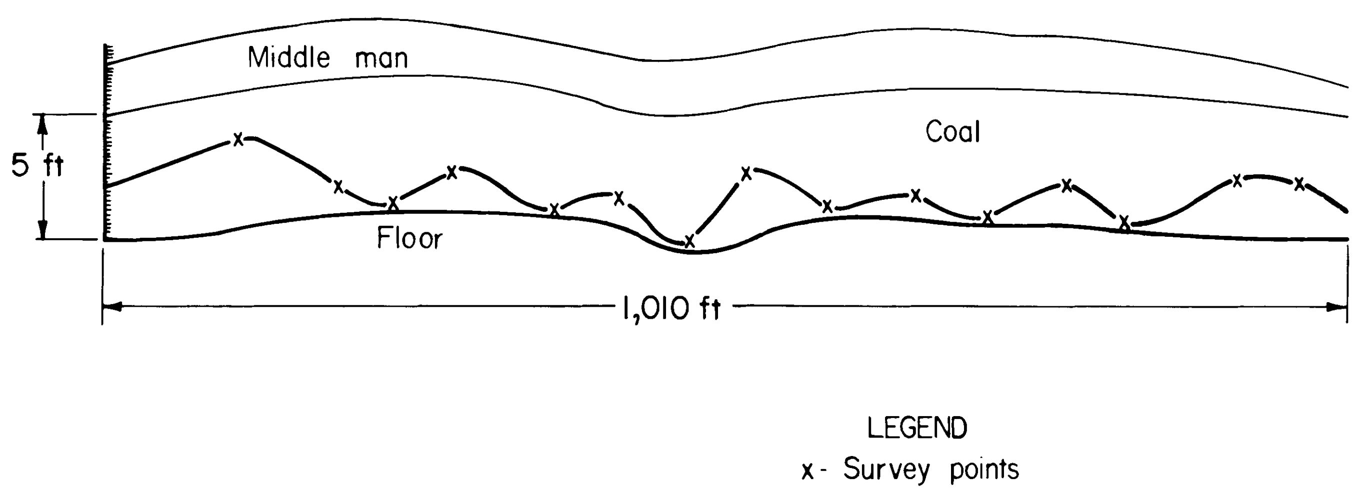

FIGURE 5. - Plot of hole 1.

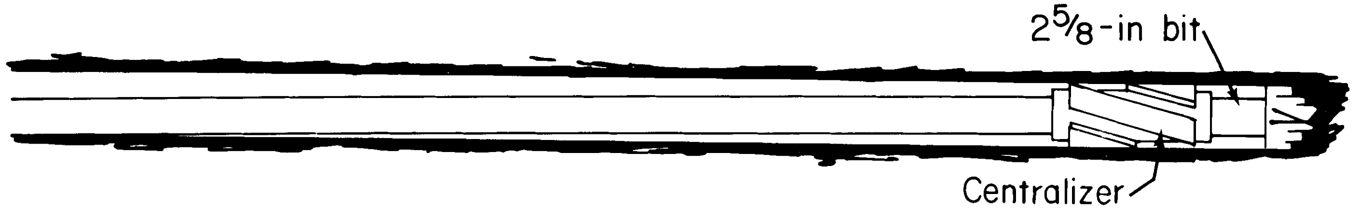

FIGURE 6. - Upwardly cocked drill assembly.

(fig. 6). The centralizer cocked the drilling assembly (bit, centralizer, and BQ rod) about 0°54' upward. Table 3 shows the results of bit thrust and rotational speed on hole trajectory during drilling from 330 to 480 feet (101 to 146 m). Some control over bit trajectory was exercised. However, the data are inconclusive because the test terminated when the hole collapsed or squeezed at 540 feet (165 m).

TABLE 3. - Drill log of hole 2

Depth		Vertical inclination, deg.	Thrust		Bit rotation, rpm
ft	m		lb	N	
380	116	89.8	2,975	13,233	62
430	131	91.5	3,400	15,124	75
440	134	NAp	3,400	15,124	75
450	137	NAp	2,550	11,343	100
480	146	89.5	2,550	11,343	100

SURVEYING

A Sperry Sun[5] single-shot survey instrument was used to survey during drilling. In most drilling operations, the inclination of the bit and length of the hole are used to compute the location of the hole within the coalbed. From this information, the drilling parameters are determined to better keep the hole within the coalbed. However, since the horizontal hole trajectory naturally followed the Mary Lee Coalbed, the survey information was used in this case to determine the contour of the coalbed.

The Sperry Sun has a magnetic compass to determine the azimuth of the hole. This is used to plot the location of the hole with respect to the mine projections. It is important to know the location of the hole, so that it will not be inadvertently mined through. The uncontrolled gas flow from such a situation could present a hazard to mining.

Usually, a 1,000-foot (305-m) hole can be plotted with an accuracy of ±5 feet (1.5 m). However, this was not the case here. Mine section 3 was about 20 feet closer to hole 1 than anticipated, and the hole was mined into just as grouting had started. There are two plausible explanations for this. Either the magnetic correction was not 3° at the underground drill site, or the survey instrument was off by 3°. However, there is no evidence to support these assumptions. The error was not recognized until every point of the section intercepted by the hole was surveyed. Figure 7 shows the hole as projected by the Sperry Sun and its actual location.

GAS FLOW AND PRESSURE MEASUREMENTS FOR HOLE 1

Hole 1 was shut in so that an in situ pressure monitoring hole could be drilled 100 feet (30.5 m) to the west. This hole was drilled to a horizontal were allowed to reach equilibrium pres- depth of 100 feet (30.5 m) and grouted, so that the in situ pressure at that depth could be monitored. Both holes

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

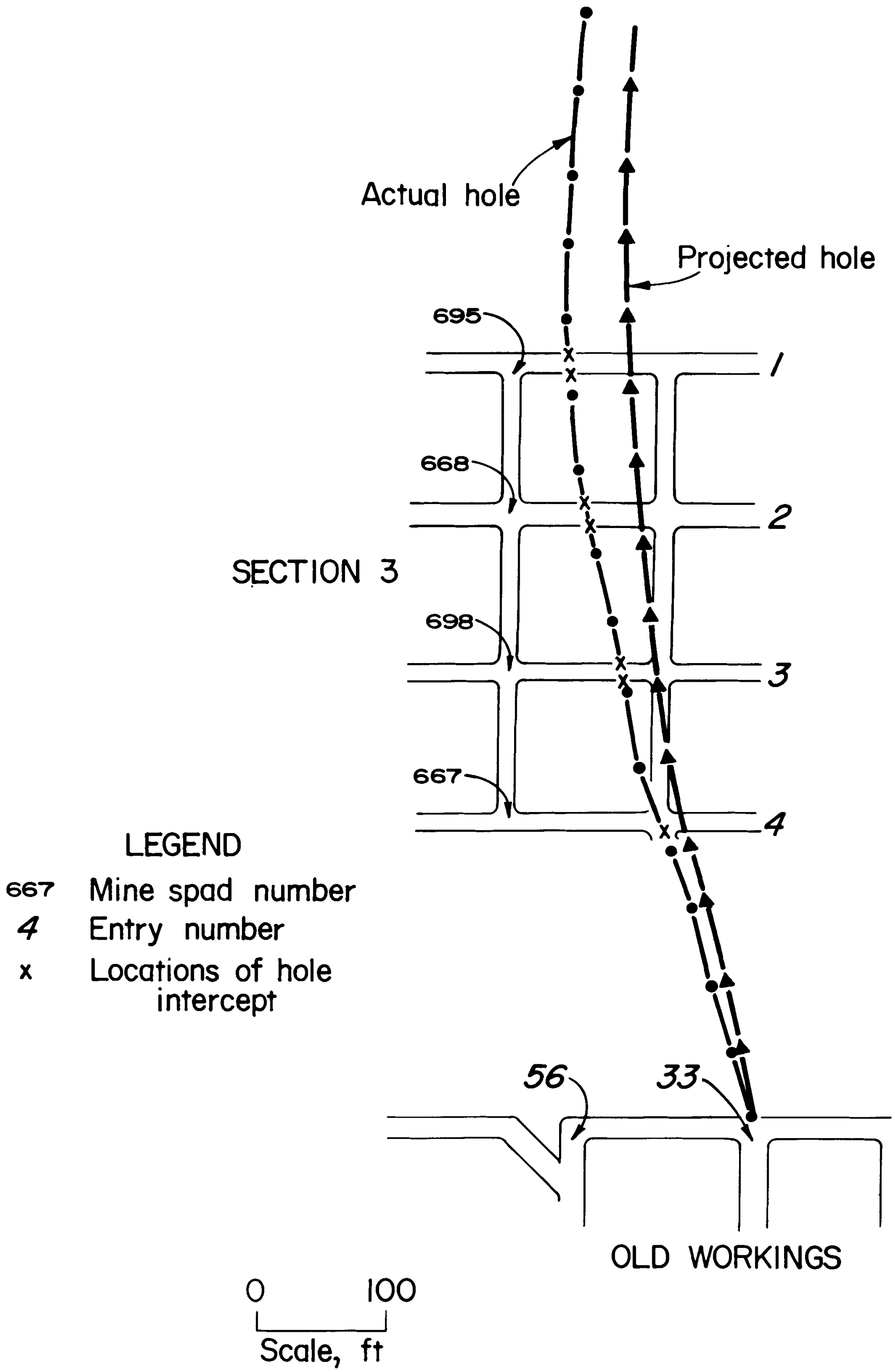

FIGURE 7. - Plain view–hole 1.

were allowed to reach equilibrium pressure. The long hole reached a steady pressure of about 70 psig (483 kPa) and the in situ pressure hole leveled off at 22.5 psig (155 kPa).

When the long hole was reopened, its flow-rate and the in situ pressure began declining rapidly. In 18 days, the gas flow dropped from an initial value of 200,000 to 155,000 ft^3/d (5,663 to 4,389 m^3/d), and the in situ pressure dropped from 22.5 to 9 psig (155 to 66 kPa). Both the pressure and flow continued to decline slowly for the next 6 months. The in situ pressure declined to 1.7 psig (12 kPa). The gas flow was 62,000 ft^3/d (1,752 m^3/d) when section 3 was 500 feet (152 m) from the hole. The flow reading taken the day before the hole was mined through and then grouted was 68,000 ft^3/d (1,926 m^3/d). Figure 8 shows the flow and pressure data for hole 1. Total gas flow from the hole for a year was 40×10^6 ft^3 (1.1×10^6 m^3). The percentage of methane in the gas was between 98 and 99 pct. The gas was analyzed to have a heat rating of 990 Btu/ft^3 (3,689 Mj/m^3).

REDUCTION OF FACE EMISSIONS

Ventilation surveys were made of section 3 after it turned east and started to mine toward the 1,010-foot (308-m) degasification hole, to determine the benefit of degasification to mining. All methane and air readings were made approximately 150 feet (46 m) back of each return from the last open crosscut. Wherever possible, continuous-recording methanometers were set at each location. Methane surveys were taken each month from June 1979 to January 1980, with the exception of December 1979. Each monthly survey lasted about 4 days.

The recording methanometers were used to measure the methane peak concentrations that occurred briefly as the mining machine sumped into the coal face. There was a marked increase in these peaks after the section had advanced through the degasification zone. Figure 9 shows typical methane concentration recordings taken during the August 1979

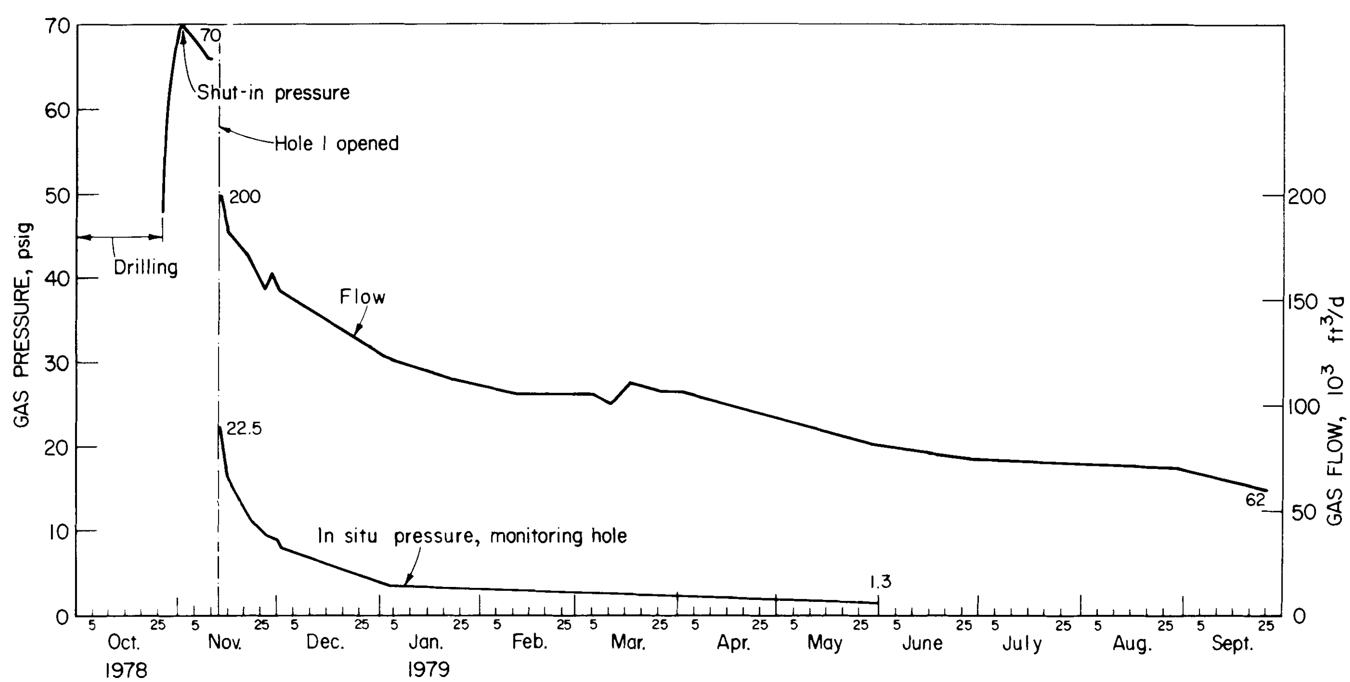

FIGURE 8. - Flow and pressure data for hole 1.

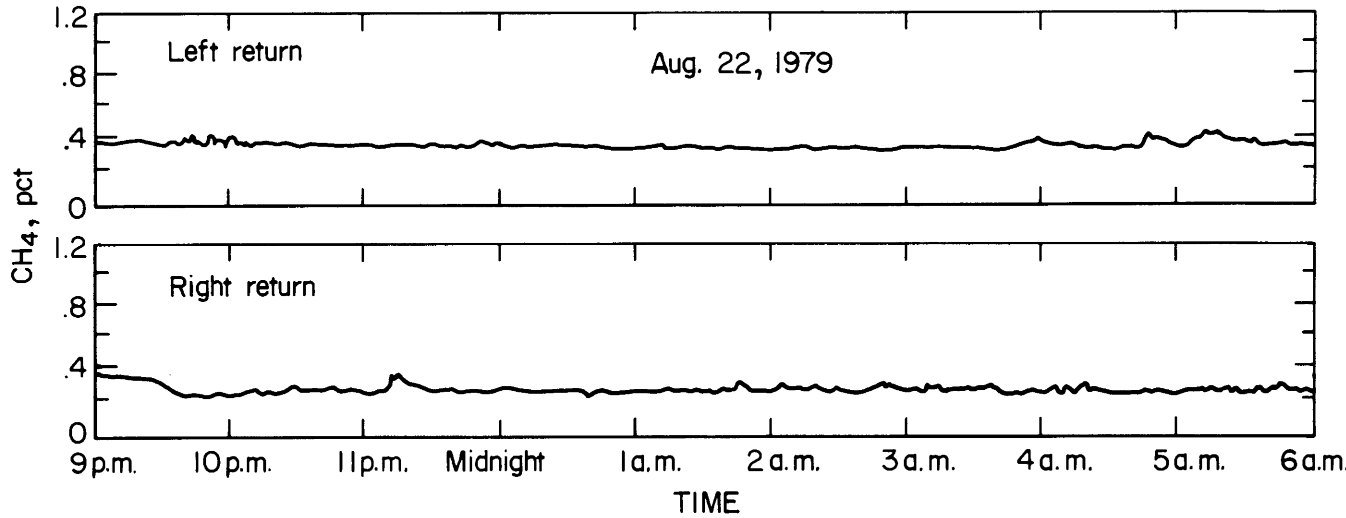

FIGURE 9. - Methane recordings, August 1979, in the degasified zone.

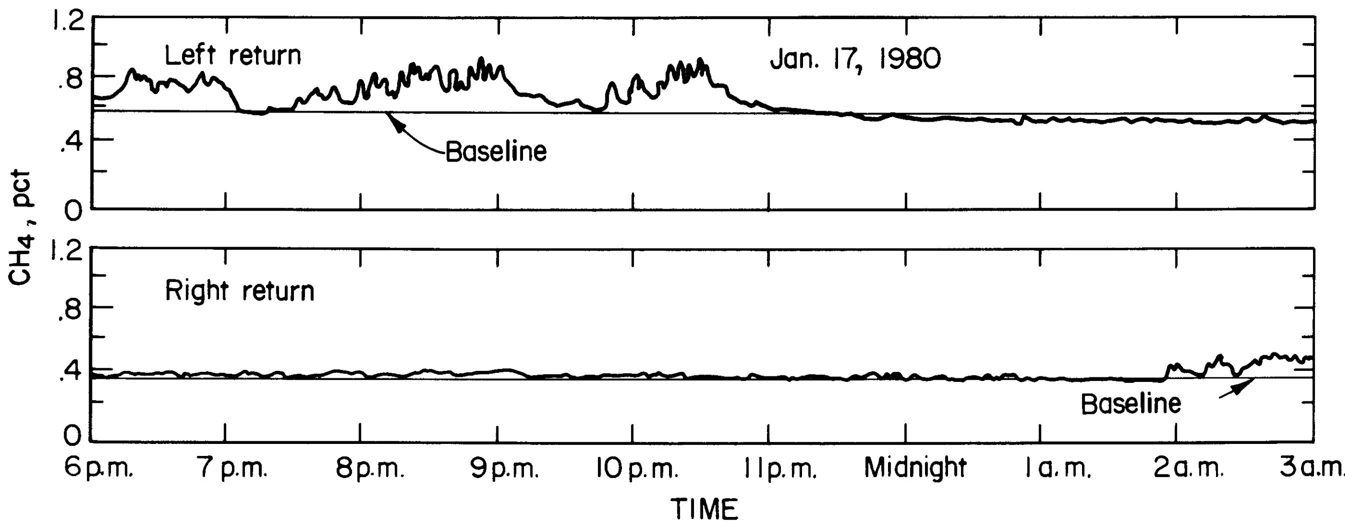

FIGURE 10. - Methane recordings, January 1980, beyond the degasified zone.

survey. Section 3 had advanced to within 500 feet (152 m) of the degasification hole and was in the degasified zone. The baseline readings for the left and right returns were 0.38 and 0.22 pct, respectively. The methane peaks (Δ%) were only 0.07 and 0.16 pct above the baselines. This compares favorably with the recordings taken during the January 1980 survey when the section had advanced 700 feet (213 m) beyond the hole (fig. 10). The methane peaks recorded in the left return increased 0.32 pct, from a baseline of 0.58 to 0.9 pct. To determine the overall methane reduction due to degasification, handheld methanometer, air, and baseline methane recordings were calculated and averaged for each monthly survey and compared. Bottle samples were also taken to check the methanometer.

When the section was 840 feet (256 m) from the hole, there was a 172-ft^3/min (4.9-m^3/min) flow from the faces (fig. 11). At a distance of 40 feet (12 m), the flow was 67 ft^3/min (1.9 m^3/min), a reduction of 60 pct. When the section passed 700 feet (213 m) beyond the hole, the methane coming from the faces was 230 ft^3/min (6.5 m^3/min).

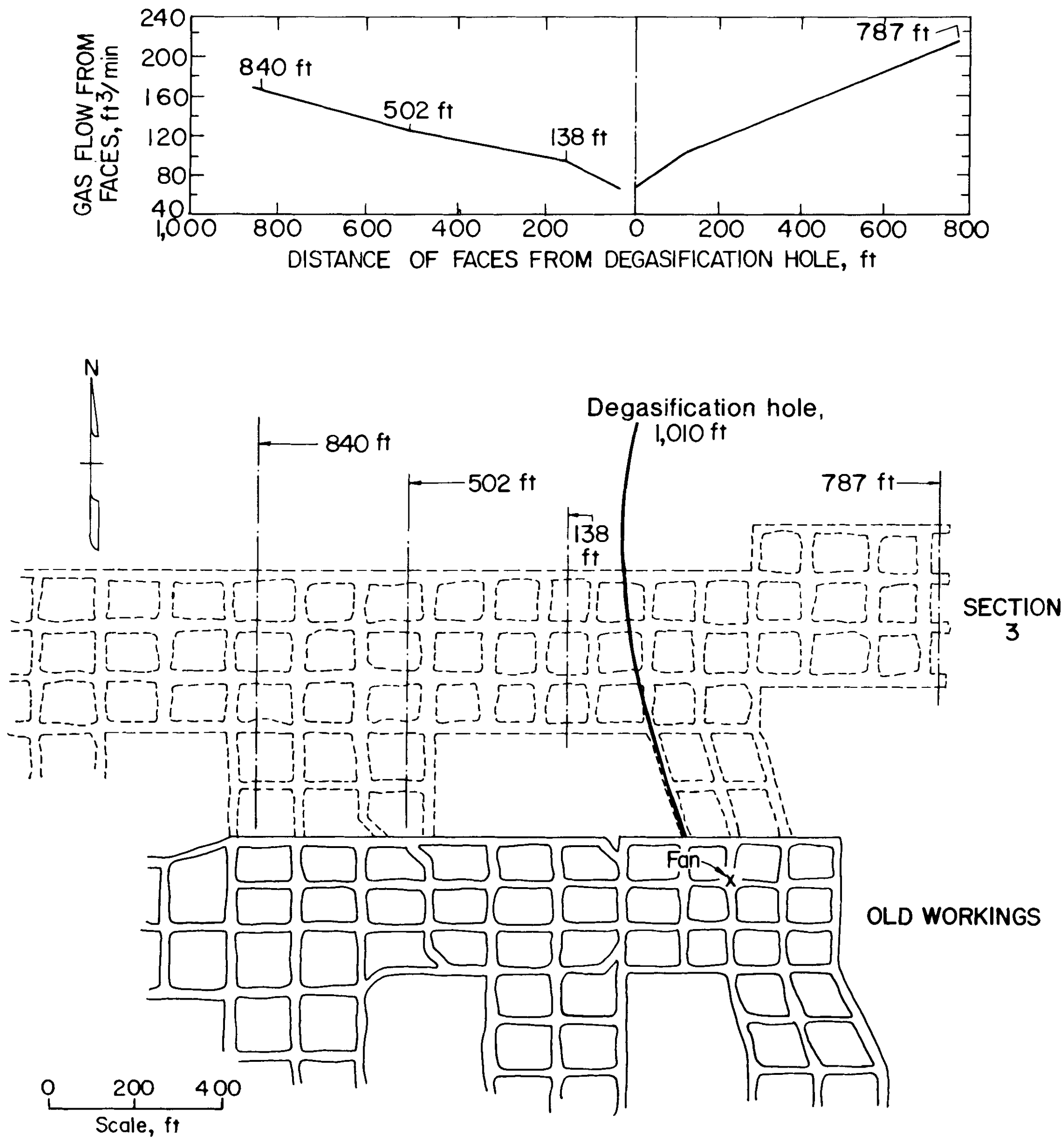

FIGURE 11. - Methane history of degasified section.

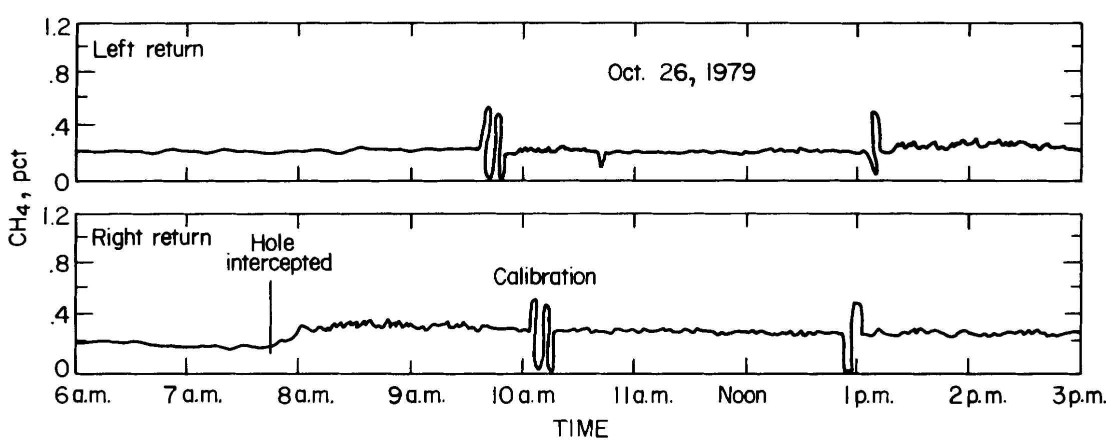

FIGURE 12. - Methane recordings, October 1979.

Degasification could then be considered to have reduced face emissions by 71 pct.

As already mentioned, the hole was intercepted before it could be grouted. There was concern that this would gas off the section, but when the hole was mined into, the methane in the return air increased by only a few hundredths of a percent, from 0.20 pct to about 0.39 pct (fig. 12). This was much less than the 0.32-pct increase when the mine sumped into nondegasified virgin coal (fig. 10).

GROUTING

When the hole was intercepted as grouting began, all the grouting equipment had to be moved to the point where interception occurred. The point of interception was at a hole depth of about 300 feet (91 m), at entry 3 of section 3 (fig. 7).

Grouting of the remaining 600 feet (183 m) of hole required 30 sacks of class A portland cement. Each 96-pound (43.5-kg) sack of cement was mixed with 5 gal (19 liters) of water and about 2 pounds (0.9 kg) of fluidifier. The grout mix was pumped to the back of the hole through the remaining 600 feet (183 m) of plastic pipe, and returned through the annulus between the pipe and coal. An air-driven moyno pump was used.

This grout mixture proved to be very successful. Grouting was started by

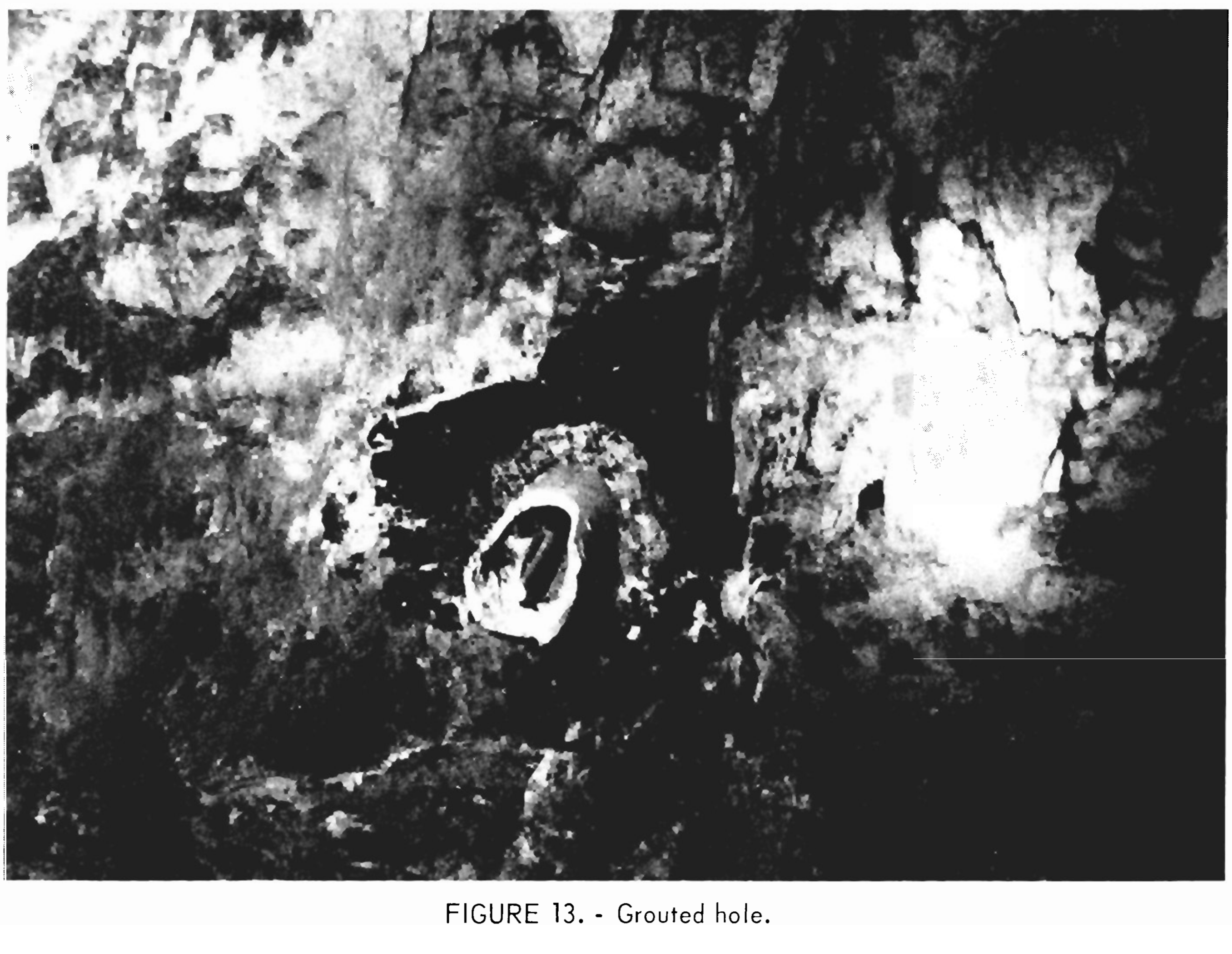

FIGURE 13. - Grouted hole.

thoroughly mixing four stacks of cement, water, and fluidifier in a 55-gal (2,08 liter) drum. The grout was dipped from the drum with a bucket and poured into the hopper of the moyno grout pump. As the mix in the drum decreased by the equivalent of one sack of cement, the corresponding amounts of cement, water, and fluidifier were added. By continually repeating this procedure, the grout pump could be run continuously, which reduced the probability of the grout setting. Mixing was continuous during the grouting, which took 1.5 hours to complete. Once grouting was completed, only a slight amount of methane was perceptible coming from the hole.

A check of the grouted portions of the hole that were later mined through showed the annulus between the pipe and coal to be completely filled (fig. 13).

CONCLUSIONS

The Mary Lee Coalbed can be successfully degasified using long horizontal holes. The 1,010-foot (308-m) hole removed 40×10^6 ft^3 (1.1×10^6 m^3) of methane from the coalbed in 1 year. The methane face emissions of the mine section being driven through the degasified zone were reduced by 60 pct.

Long horizontal holes can be drilled quickly in the Mary Lee Coalbed. Because of the softness of the coal and the hardness of the floor rock, the bit bounces off the rock, staying in the hole as it is drilled. Only a 3-inch (76.2-mm) diameter drag bit and BQ rod should be used, because experience has shown that when centralizers are used, they become wedged in the hole.

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