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UNITED STATES DEPARTMENT OF THE INTERIOR

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# METHANE DRAINAGE STUDY USING AN UNDERGROUND PIPELINE, MARIANNA MINE 58

by

L. J. Prosser, Jr.,[1] G. L. Finfinger,[2] and J. Cervik[3]

## ABSTRACT

The Bureau of Mines has completed an underground degasification project in which an underground piping system was used to transport methane from the coalbed to the surface. In a 10-month period four horizontal holes were drilled to an average depth of 1,450 feet. All four holes were surveyed vertically and azimuthally. In 991 days of degasification, 255 MMcf of gas was drained from the coalbed. The underground piping system proved to be a safe and effective means of transporting methane from the coalbed to the surface.

## INTRODUCTION

Methane in coalbeds constitutes a serious hazard when it is released into the mine atmosphere. To provide a safe working environment, the concentration of methane in mine air must be maintained at a level well below the lower explosive limit. Traditionally, ventilation air has been used to dilute methane to nonexplosive levels. However, increased production, due to modern mining techniques, can produce situations in which methane emission rates exceed the capacity of the ventilation system. When this occurs, mining must be halted until a safe methane level is reached; such situations increase the hazards from ignitions and explosions and adversely affect production (7).[4]

Drainage of methane in advance of mining is inherently a safe method for controlling methane emissions during mining and contributes to efficient use of mining equipment. The Bureau of Mines has demonstrated that drainage of methane through horizontal holes drilled from a shaft bottom is a successful method of removing methane in advance of mining (5). Over a 3-year period, approximately 802 MMcf of methane was removed from the Pittsburgh coalbed, and mine entries driven into the degasified zone experienced a 70-pct reduction in

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[1] Geologist, Eastern Field Operations Center, Bureau of Mines, Pittsburgh, Pa.
[2] Supervisory geologist, Pittsburgh Research Center, Bureau of Mines, Pittsburgh, Pa.
[3] Supervisory geophysicist, Pittsburgh Research Center, Bureau of Mines, Pittsburgh, Pa.
[4] Underlined numbers in parentheses refer to items in the list of references at the end of this report.

methane emissions during mining. Emissions began to decline when mine entries were 3,500 feet from the shaft.

Degasification from mine workings requires underground pipelines to transport methane to the surface where it can be sold or utilized at the mine site. Piping methane from underground locations to the surface was first attempted in Great Britain about 200 years ago (1). Large-scale operations were initiated in the 1940's at many collieries in the Ruhr, the Saar, Belgium, France, and Great Britain. However, in the United States no large-scale operations were undertaken until recently. The first methane drainage and underground pipeline integrated in the production cycle is located in Mid-Continent Coal and Coke Co.'s Dutch Creek No. 1 Mine (10). This installation is similar to European advancing longwall drainage systems where holes are drilled into overlying strata and vacuum pumps draw methane from the fracture zone above the mine coalbed (3).

The present paper describes a degasification project conducted by the Bureau of Mines at Marianna Mine 58, Marianna, Pa. The project utilized an underground pipeline for transporting methane from the mine to the surface. Gas emissions were reduced, and a methane-monitoring system provided a continuous check on the integrity of the pipeline system.

## ACKNOWLEDGMENTS

The cooperation of Bethlehem Mines Corp. during this study is greatly appreciated. The authors wish to thank D. Sparks, manager; C. McGlothin, mine superintendent; D. Patterson, chief engineer; L. Sprague, assistant chief engineer; and George Concilio, engineer, for assistance in planning and conducting the work described in this report.

## TEST SITE

The degasification program at Bethlehem Mines Corp.'s Marianna Mine 58, Marianna, Pa., was conducted in a section which was advanced about 5,000 feet into virgin coal (Pittsburgh coalbed) (fig. 1). Four horizontal holes were drilled ranging in length from 982 to 2,505 feet. Two holes were drilled on the left side and two holes on the right side of the section (fig. 1). A fifth hole in the middle of the section is 200 feet long and is used to monitor gas pressure in the coalbed.

A 6-inch-diameter steel pipeline (schedule 40) transports methane from underground locations to the surface (fig. 2). Total length of the pipeline is 1,150 feet, and pipe sections are joined with compression couplings. Cribbing blocks on 5-foot centers are used to protect the pipeline from roof falls as well as supporting the pipeline (fig. 3).

Gas flowing through the underground pipeline contains water vapor which condenses as it travels to the surface through the vertical borehole. Consequently, the underground pipeline is connected to the vertical borehole through a gas-water separator which drains water from the system (fig. 4). Gas produced during and after drilling is vented at the surface. The pipeline is grounded, and the surface venting facility is equipped with an approved flame arrester (fig. 5).

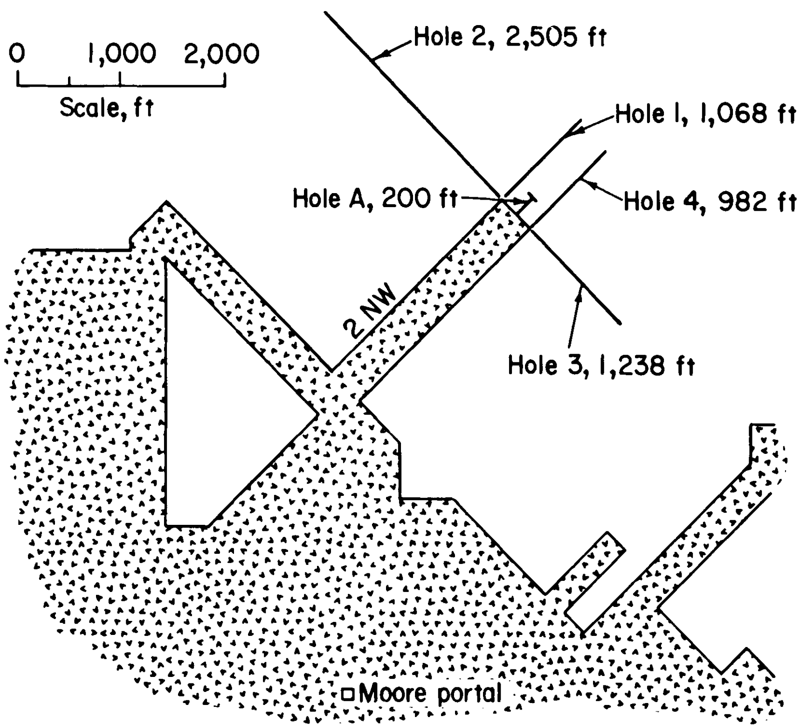


FIGURE 1. - Location of test site.

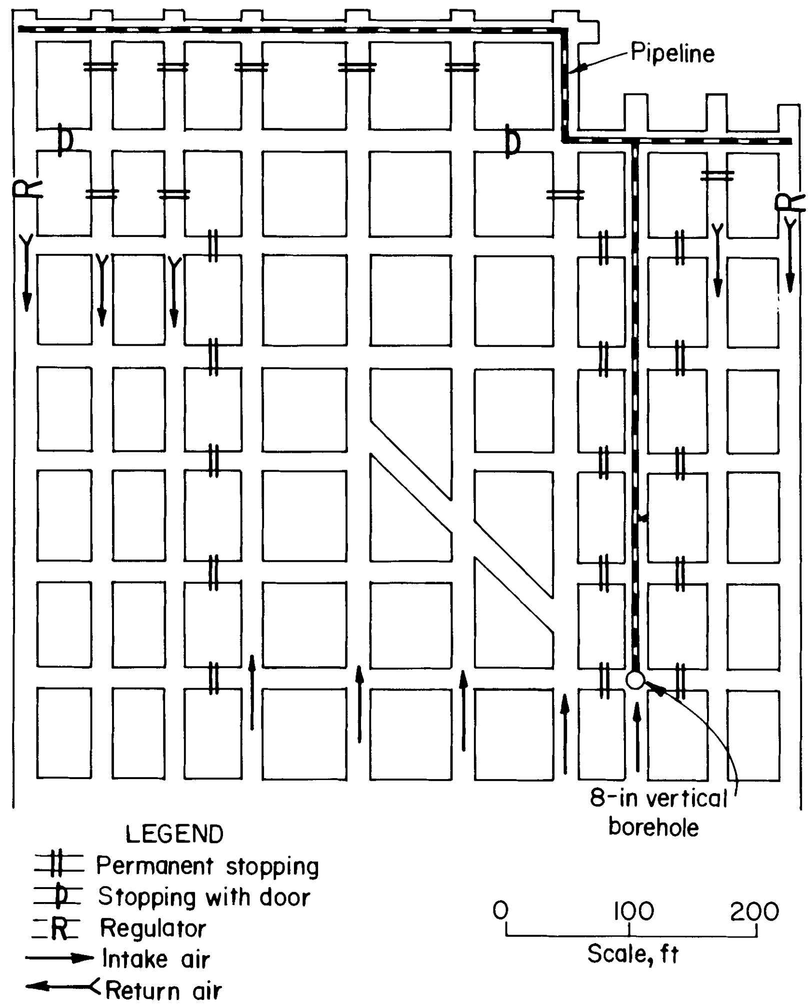


FIGURE 2. - Location of underground pipeline and vertical borehole.

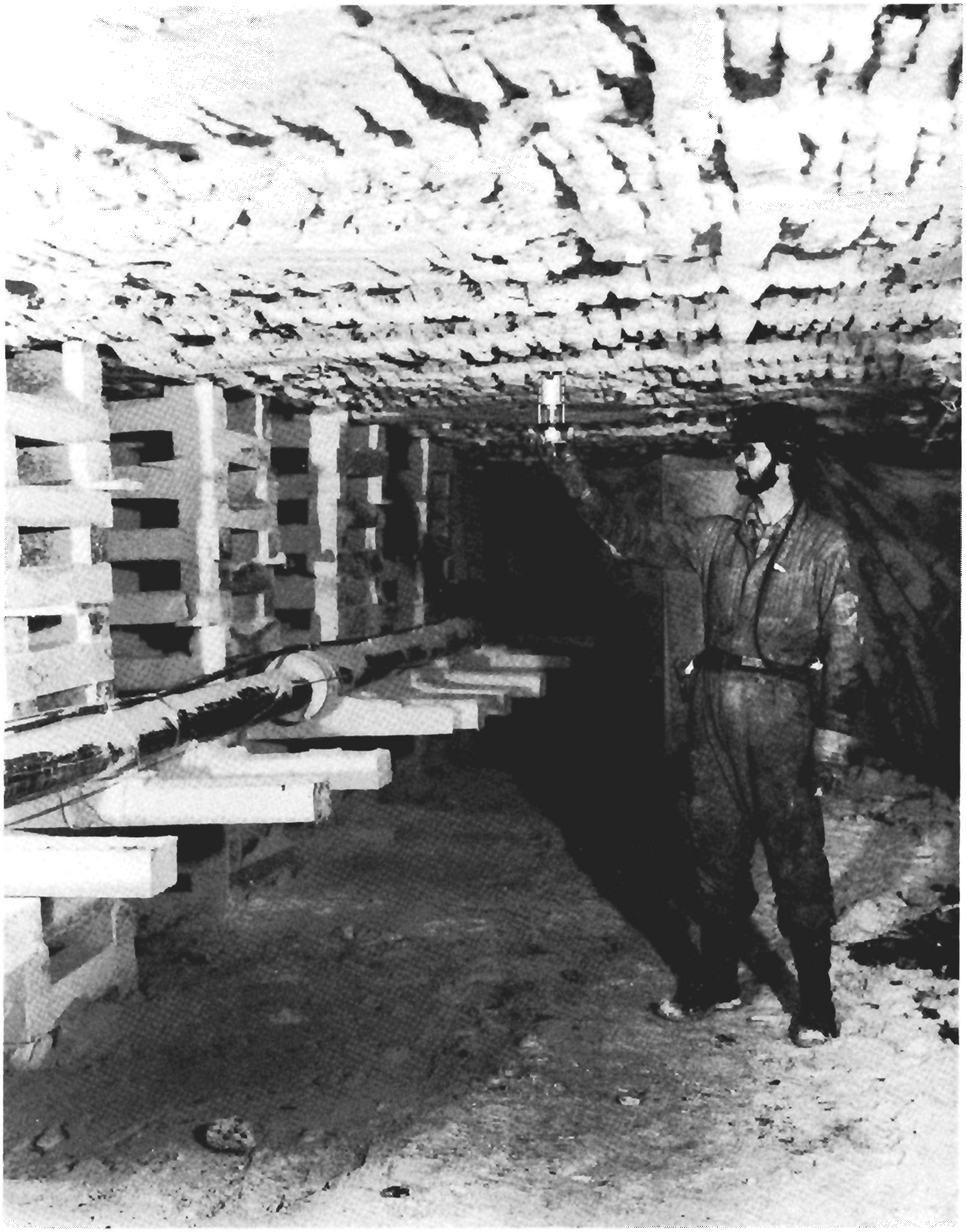

FIGURE 3. - Steel pipeline and cribbing blocks.

FIGURE 4. - Gas-water separator.

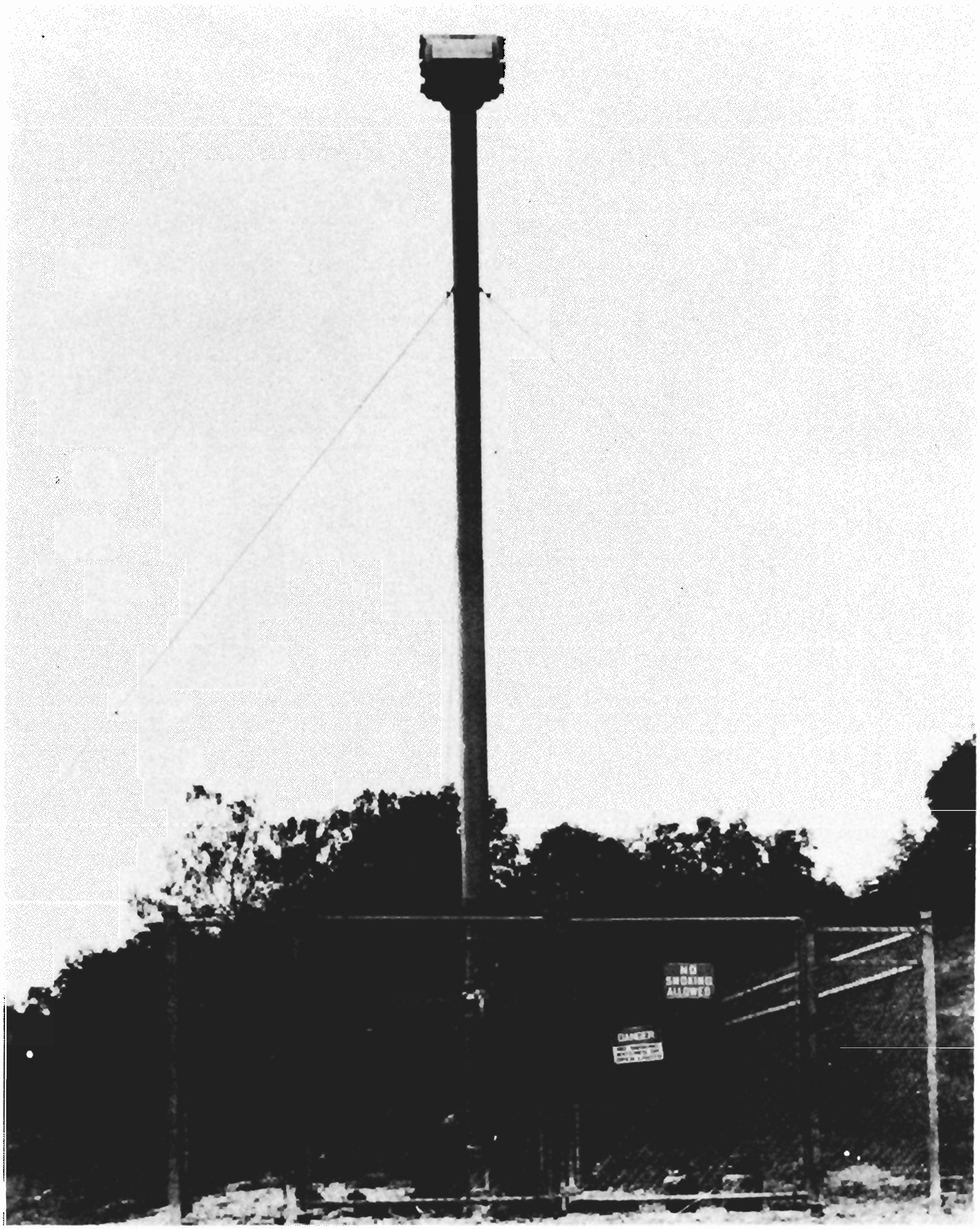


FIGURE 5. - Surface venting facility.

## DRILLING EQUIPMENT AND PROCEDURES

All holes were drilled with a hydraulically operated drill (fig. 6). The power unit for the drill was kept in a fresh air entry and was equipped with a 40-hp, 440-v-ac motor and hydraulic pump. Feed length of the drill unit was 30 inches. The drill string included a 3-5/8- or3-1/2-inch drag bit and two centralizers (3-7/16-inch OD) (fig. 7) separated by an 18-foot NQ drill collar which was 2-3/4 inches in OD and 1-7/8 inches in ID and weighed about 200 pounds. The heavy drill collar stiffened the drilling assembly and added weight to the bottom side of the drag bit.

The path of a bit in the vertical plane is controlled by a combination of bit sizes, bit thrust and rotational speed (rpm), and by location of centralizers on the drill collar (fig. 8). A drilling assembly with a 3-5/8-inch bit tends to wear the bottom side of the hole and arc downward more readily than an assembly with a 3-1/2-inch bit. Therefore, thrust levels must be higher to compensate for the tendency of the 3-5/8-inch bit to arc downward (4).

Previous Bureau experience in drilling the Pittsburgh coalbed in the Fairview, W. Va.,area had revealed marked differences in drilling characteristics of the upper and lower portions of the coalbed (4). The upper 3 to 3.5 feet, which contains numerous streaks and bands of pyrite, appears harder during drilling than the lower part of the coalbed, which is predominately free of impurities and consequently softer. This characteristic of the Pittsburgh coalbed is also in evidence at Marianna Mine 58. Based on this characteristic and other horizontal drilling studies, a 3-1/2-inch bit was initially chosen for drilling at the Marianna Mine 58 site.

Marianna Mine 58 is located about 30 miles north of the Fairview, W. Va., area, where overburden thickness is about 800 feet compared with 500 feet at the Marianna Mine. Comparison of tables 1 and 2 shows that bit penetration rates are greater at the Marianna Mine drill site, with a lower rotational speed (rpm) of the bit at comparable levels of thrust. The lower bit penetration rates in Fairview, W. Va., area may be due to greater overburden pressure on the coalbed.

TABLE 1. - Penetration rates with 3-1/2-inch bit, Fairview, W. Va., area

| Thrust, lb | Bit rotation, rpm | Penetration rate, ipm |
|---|---|---|
| 800 | 700-900 | 4-7 |
| 1,200 | 400-600 | 10 |
| 1,500 or greater | 200-300 | 15 or greater |

TABLE 2. - Penetration rates with 3-1/2-inch bit, Marianna Mine 58

| Thrust, lb | Bit rotation, rpm | Penetration rate, ipm |
|---|---|---|
| 850 | 150 | 8-10 |
| 1,225 | 300 | 12-14 |
| 1,700 | 150 | 16-24 |

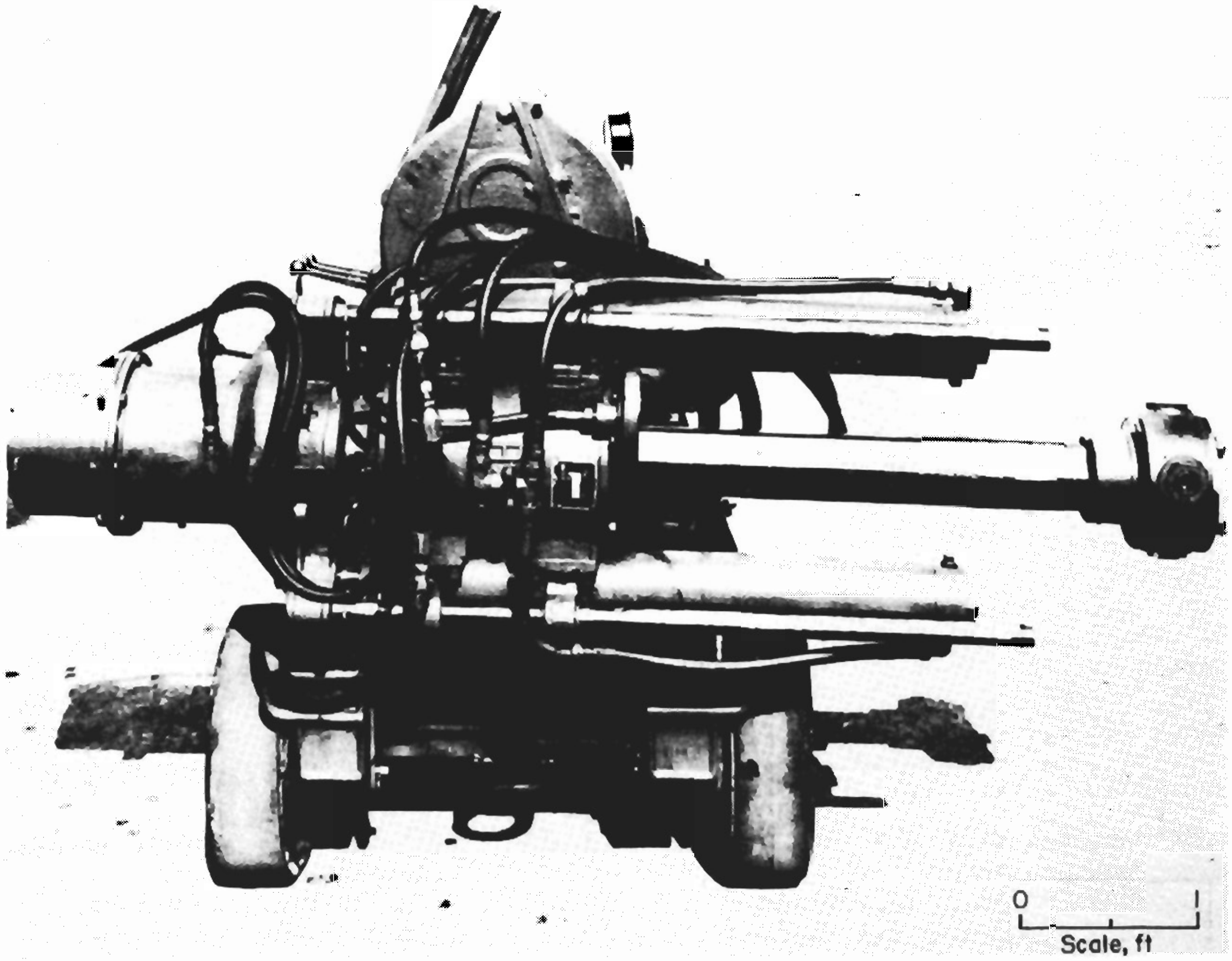


FIGURE 6. - Hydraulic drill.

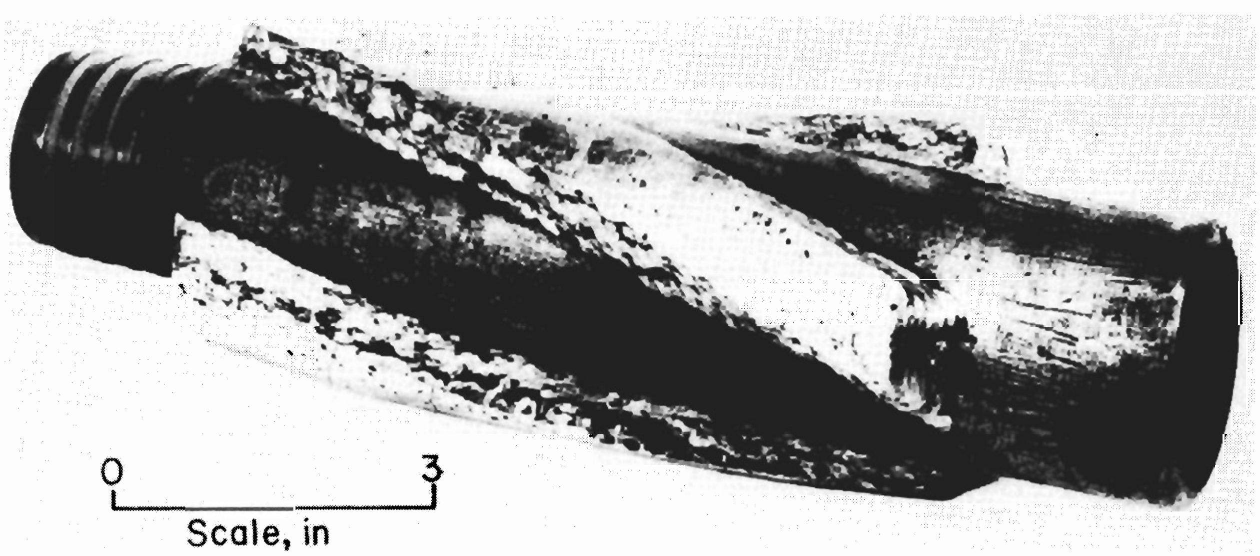


FIGURE 7. - Centralizer.

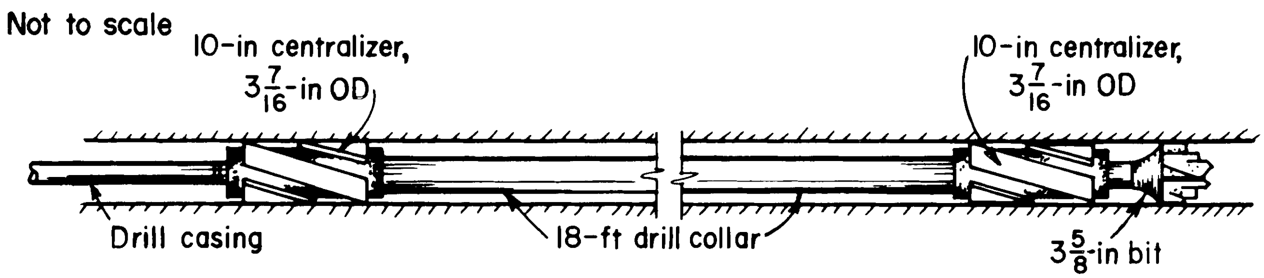


FIGURE 8. - Drilling assembly with two centralizers separated by 18-foot NQ drill collar.

The penetration rate of a drilling assembly (fig. 8) with a 3-5/8-inch bit is greater than that of an assembly with a 3-1/2-inch bit (4). Because of the soft nature of the lower portion of the coalbed at Marianna Mine 58, the drilling assembly with a 3-5/8-inch bit arced into the floor repeatedly and could not be controlled with combinations of bit thrust and rotational speed. Therefore, the rear centralizer was removed, cocking the 18-foot drill collar, front centralizer, and bit about 0.1° upward in the hole (fig. 9). No problems were encountered in controlling this modified drilling assembly at the Marianna Mine 58 site. All holes except hole 1 were drilled with the modified drilling assembly. Table 3 summarizes the effect of bit thrust and rotational speed on bit trajectory and penetration rates. Comparison of tables 1, 2, and 3 shows that penetration rates of the modified drilling assembly are greater by a factor of about two.

TABLE 3. - Penetration rates with 3-5/8-inch bit and modified drilling assembly

| Thrust, lb | Bit rotation, rpm | Effect on bit trajectory | Penetration rate, ipm |
|---|---|---|---|
| 850 | 300 | Downward........... | 12-15 |
| 1,275 | 300 | Held angle......... | 24 |
| 1,700 | 150 | Upward............. | 30-36 |
| 2,500 | 250 | Sharply upward..... | 42-48 |

Table 4 is an analysis of the time spent completing holes 1, 2, and 4. Between 53 and 74 pct of each shift was lost time, which included portal to portal, water supply and electrical problems, equipment failures, etc. Of the

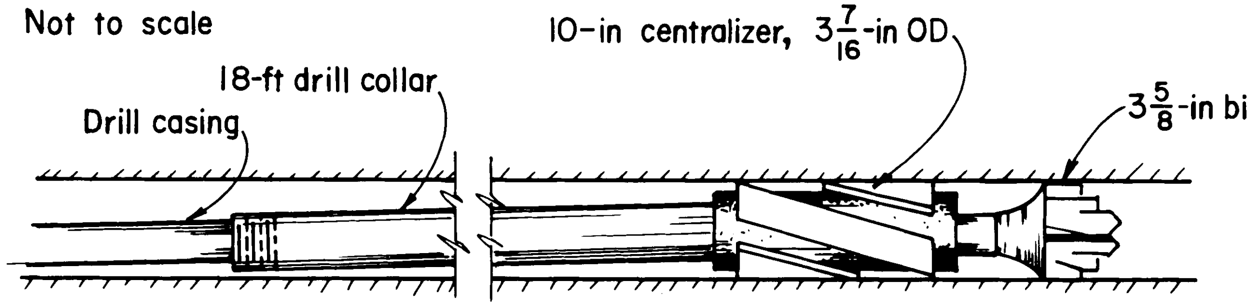


FIGURE 9. - Drilling assembly with rear centralizer removed.

average time available to each shift for drilling and surveying, drilling occupied 67 to 80 pct and surveying 20 to 33 pct.

TABLE 4. - Time study

| | Hole 1 | Hole 2 | Hole 3 | Hole 4 |
|---|---|---|---|---|
| Number of work shifts.................... | 60 | 31 | 39 | 18 |
| Work shift..........................min.. | 480 | 480 | 480 | 480 |
| Time lost per shift (portal to portal, water problems, electrical problems, drill malfunctions, sensor malfunctions)......................min.. | 357 | 259 | (1) | 254 |
| Average time for drilling and surveying per shift..........................min.. | 123 | 221 | (1) | 226 |
| Average drilling time per shift......min.. | 82 | 168 | (1) | 180 |
| Average surveying time per shift.....min.. | 41 | 53 | (1) | 46 |
| Total depth..........................ft.. | 1,068 | 2,505 | 1,238 | 982 |
| Initial bearing of collar................ | N22°W | S67°W | N65°E | N11°W |
| Vertical inclination of coalbed (above or below horizontal)..................deg.. | +0.5 | -0.5 | +0.5 | +0.5 |

[1]No time study data available owing to testing of experimental survey instrument.

## HOLE SURVEYING

Vertical inclination of the hole during drilling was obtained with a Sperry-Sun,[5] single-shot survey instrument (fig. 10). The essential elements (fig. 10C) of the single-shot surveying instrument are the inclination unit, which is in the form of an inverted plumb bob, batteries to furnish electrical power, and a timer which controls the electrical circuits and illuminates the angle unit at a preset time to record the inclination of the bit on a film disk.

Special loading and developing tanks permit handling of the exposed film disk in daylight or without turning off cap lamps underground. When the inclination of the hole is to be determined, the surveying instrument is placed in its protective casing which is then inserted into the drill rod and pumped using water to the end of the hole. At the preset time, the film disk is exposed, after which the instrument is retrieved by a wire line attached to the protective casing. The film disk is removed, developed, and read (4).

The Bureau's experience in horizontal drilling indicates that a hole should be surveyed for vertical inclination at least every 20 feet to insure that projected hole trajectory is maintained. If the hole begins to deviate, then appropriate drilling parameters, such as bit thrust and rotational speed, must be varied to correct hole deviation in the vertical plane. Experience shows that although surveying is time consuming (table 5), maintaining the vertical angle of inclination of the hole within 1° of the projected trajectory

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

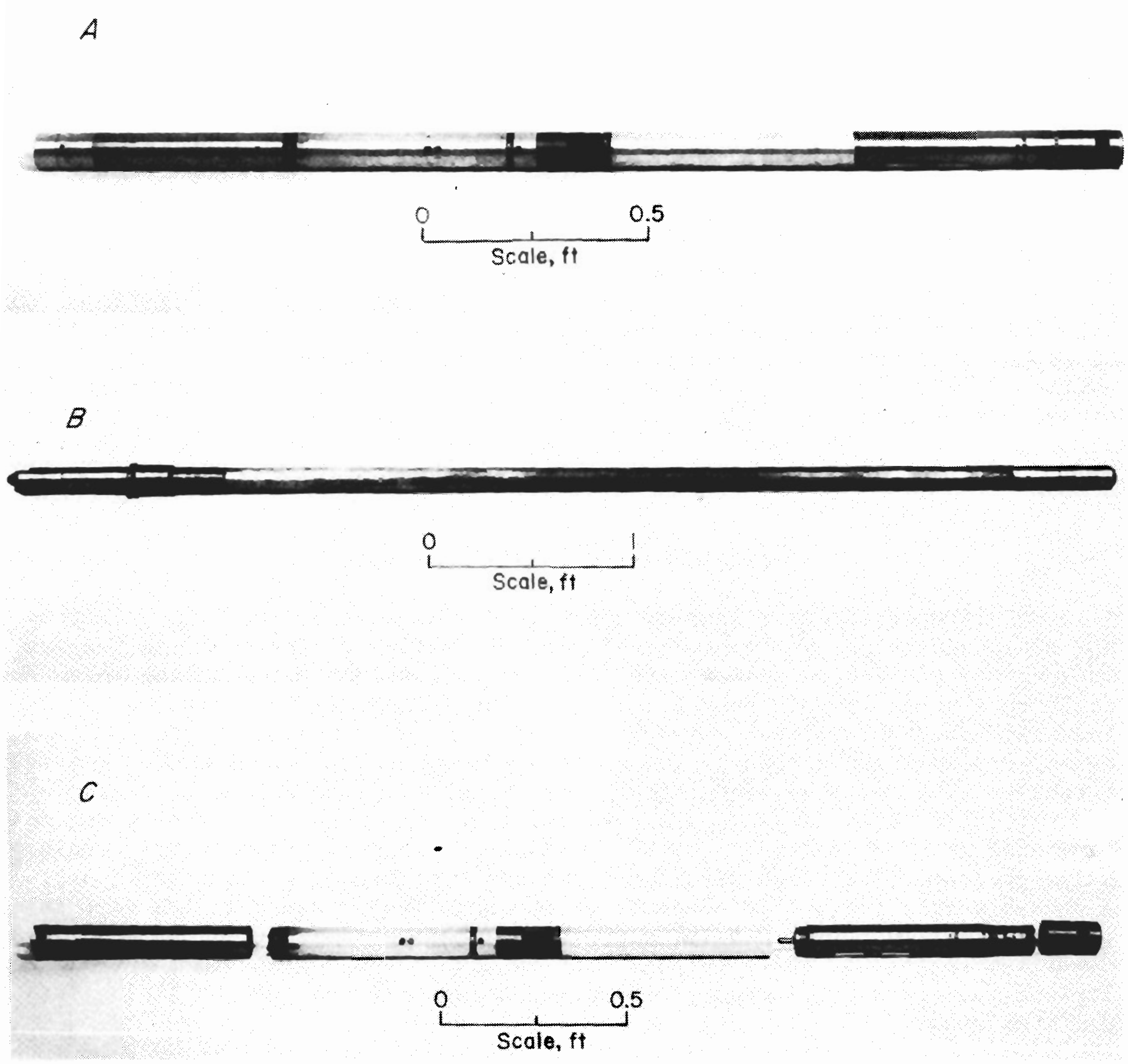


FIGURE 10. - Survey system. *A*, Survey instrument; *B*, protective case; *C*, survey instrument components.

will prevent costly time delays due to loss of control of hole trajectory and subsequent drilling in roof or floor strata. Table 5 shows that the average time per survey is about 16 minutes at hole depths of 1,000 feet. When hole depth is about 2,000 feet, the average time per survey doubles and surveying occupies over 50 pct of the time available for drilling and surveying per shift.

TABLE 5. - Hole depth versus survey time (hole 2)

| Hole depth, ft | Average time survey, min |
|---|---|
| 0-1,150.......... | 16 |
| 1,151-1,600.......... | 21 |
| 1,601-1,900.......... | 26 |
| 1,901-2,450.......... | 34 |

The trajectory of a horizontal hole in the azimuth plane cannot be determined by projecting a line based on the bearing of the hole at or near the collar. The hole must be surveyed to determine its location in the azimuth plane. Experience shows that a hole may turn either to the right or to the left, contrary to the popular belief that a hole will turn to the right because of the clockwise rotation of the bit during drilling. In some cases, a hole may turn to the left and then deflect to the right.

## METHANE CONTROL DURING DRILLING

Gas flow during drilling was controlled with a Bureau-designed stuffing box which separated gas from water and drill cuttings. The stuffing box was attached to a 4-inch-diameter pipe fitted with a 4-inch valve so the hole could be shut-in if necessary (fig. 11). The 4-inch-diameter pipe was 21 feet long and grouted in place. Gas was ducted from the stuffing box to the 6-inch-diameter pipeline and then to the surface through the 8-inch-diameter vertical borehole. The vertical flow through the 8-inch-diameter borehole created a natural draft which maintained a negative pressure in the vent tubing and prevented methane leakage from the stuffing box into the mine entry. The negative pressure (-0.5 inch water gage) in the vent tubing was monitored with a pressure gage (fig. 12). Because of the negative pressure in the vent tubing, some air is drawn into the stuffing box through small openings where the drill rod enters the stuffing box. The methane concentration in the vent tubing was monitored continuously and varied between 80 and 100 pct during the drilling phase.

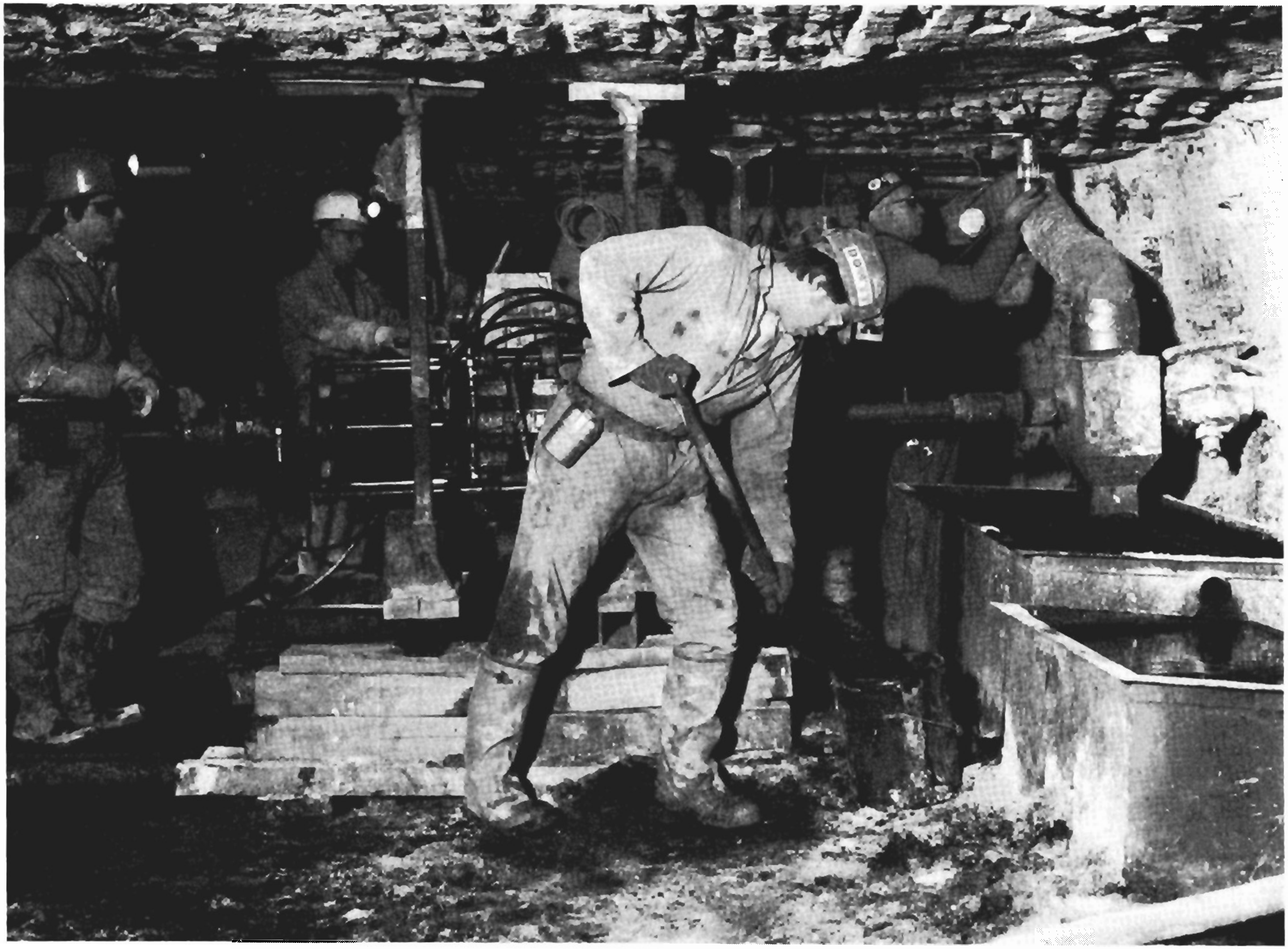

FIGURE 11. - Stuffing box and 4-inch valve.

FIGURE 12. - Pressure gage and vent tubing.

## PIPELINE SAFETY CONTROLS

Methane sensors are installed every 500 feet in the entries containing the pipeline. The power supply for the sensor system operates on 110 v ac and is located in a fresh air entry (fig. 13). The sensors are intrinsically safe and approved for use in coal mines.

A 3/4-inch polyvinyl chloride (PVC) plastic pipe is strapped to the top of the pipeline along its entire length (fig. 14). This plastic pipe is connected to the pneumatic valves which are installed on each hole after drilling has been completed (fig. 15). The valves are spring-loaded and held open by air pressure (55 psig) supplied by a small nonpermissible air compressor rated at 1.05 cfm, 80 psig. This unit is located in a fresh air entry near the control panel and is wired to the methane sensor control panel.

The methane sensors control the pneumatic valves on each horizontal hole and will close them automatically if a sensor ceases to function, if the electrical line to a sensor is broken, or if the methane concentration in the pipeline entry exceeds 1 pct. If any of these conditions exist, a relay in the control panel powers a solenoid which vents the compressed air in the PVC line. Power to the compressor is automatically cut off when air pressure in the plastic line drops below 50 psig. The PVC pipe is brittle and shatters on impact. A roof fall that severs the main pipeline will also shatter the PVC pipe. When this occurs the pneumatic valves will close as air pressure in the line decreases.

## DISCUSSION OF FLOWS

### Gas Flows During Drilling

Gas flows were monitored during drilling of each hole. These flows were determined from velocity measurements taken with an anemometer inside the ducting which connected the gas-water and drill cutting separator to the underground pipeline. The measured velocity was corrected for ducting diameter, and methane flows were monitored throughout the drilling phase. The correction for ducting diameter was determined in the laboratory.

The Pittsburgh coalbed in the area of Marianna Mine 58 contains a sandstone channel and clay veins (8) which can form cells that limit the drainage area of a horizontal hole. Clay veins are generally associated with fractured roof strata and produce abnormal methane flows when penetrated by mining or a horizontal hole.

The drill site at Marianna Mine 58 is in a section where mining was abandoned because of severe gas problems. When the study began, the section had been idle for about 2-1/2 years. Consequently, gas flows from holes could be expected to be much lower than flows from holes drilled in an active section.

Hole 3 was drilled to 1,238 feet at a fairly constant rate, and gas flows during drilling increased linearly at a rate of 89 cfd/ft of hole drilled (fig. 16). Gas flows from hole 4 increased at a rate of 86 cfd/ft to 420 feet

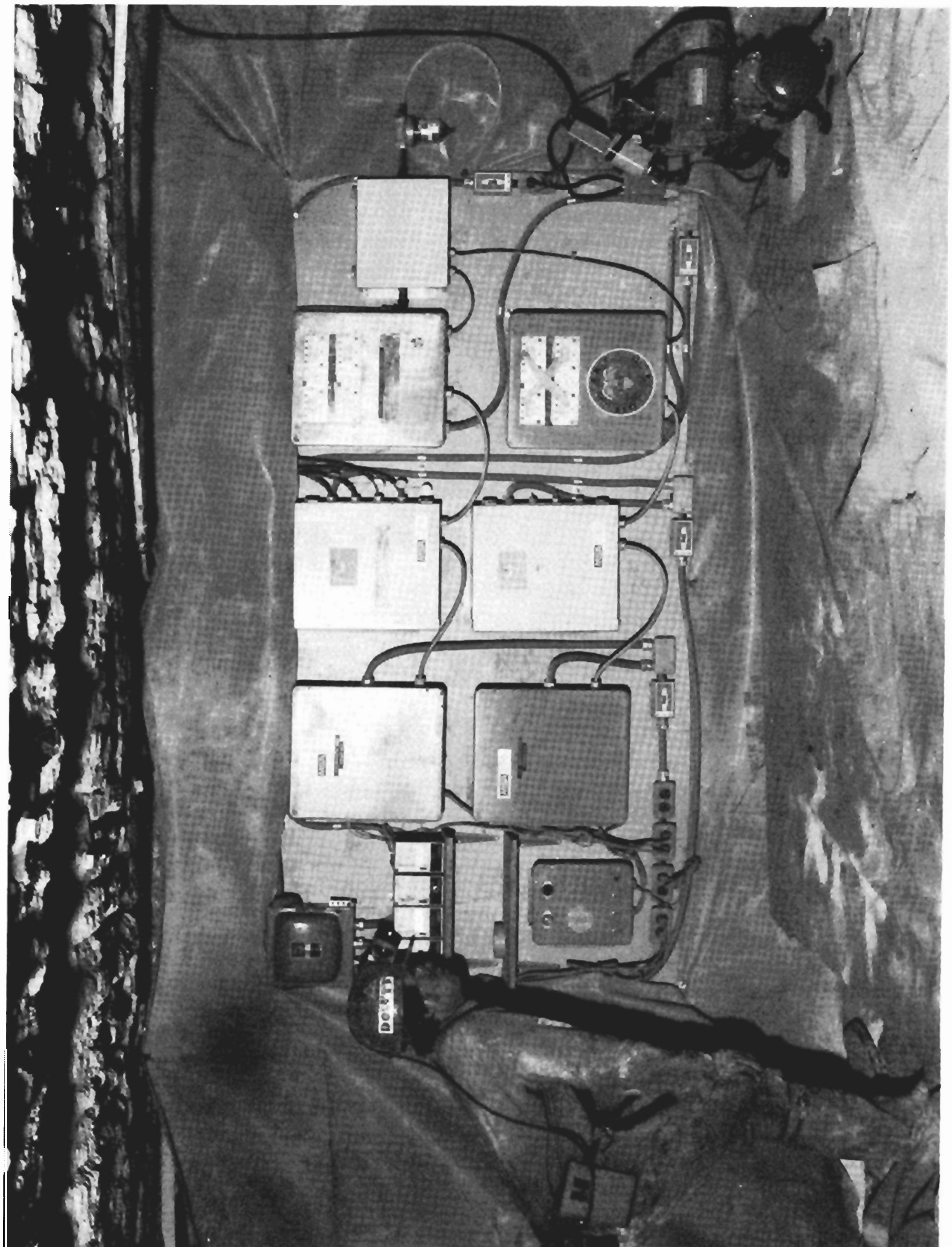

FIGURE 13. - Methane pipeline control system.

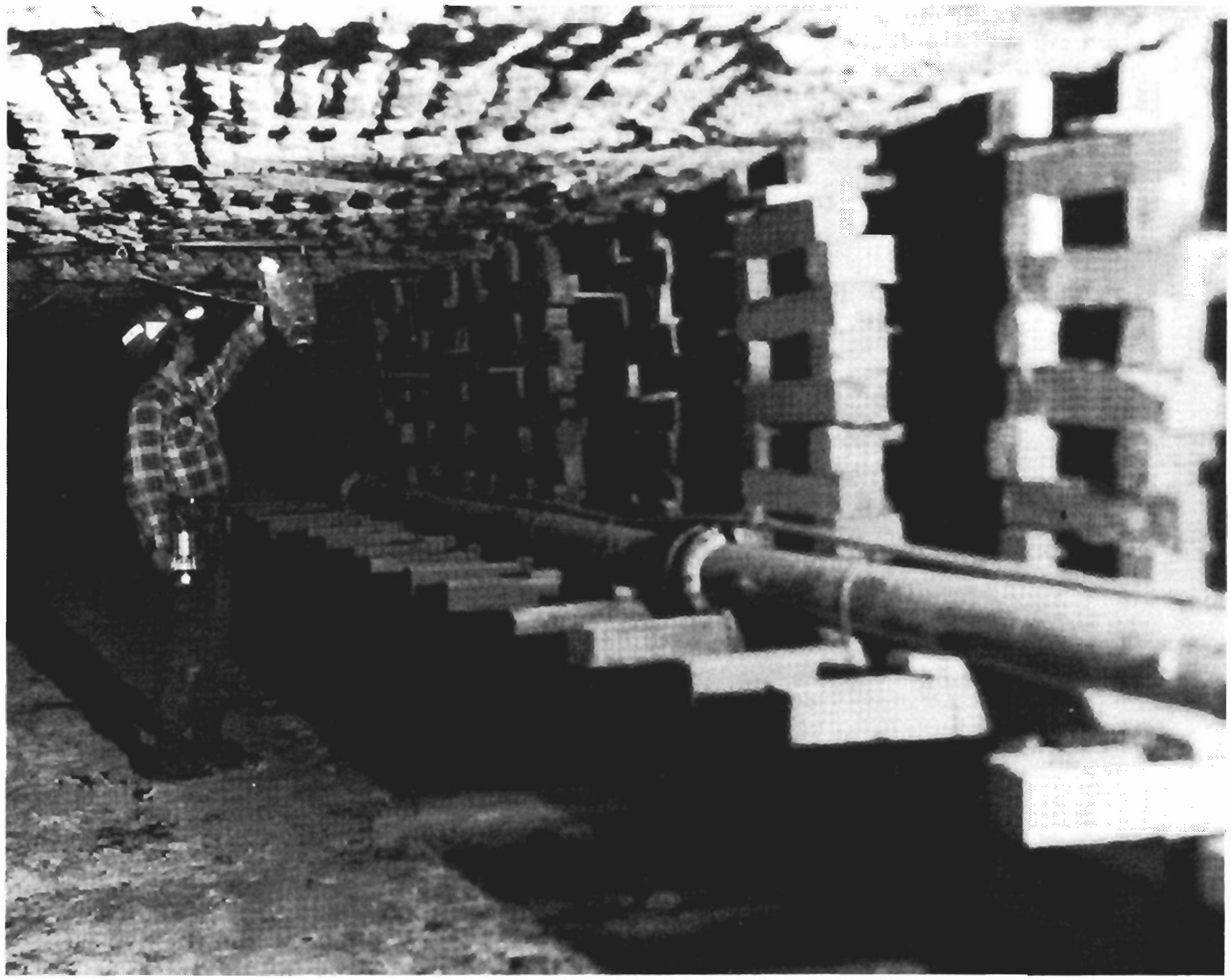

FIGURE 14. - PVC plastic pipe and pipeline.

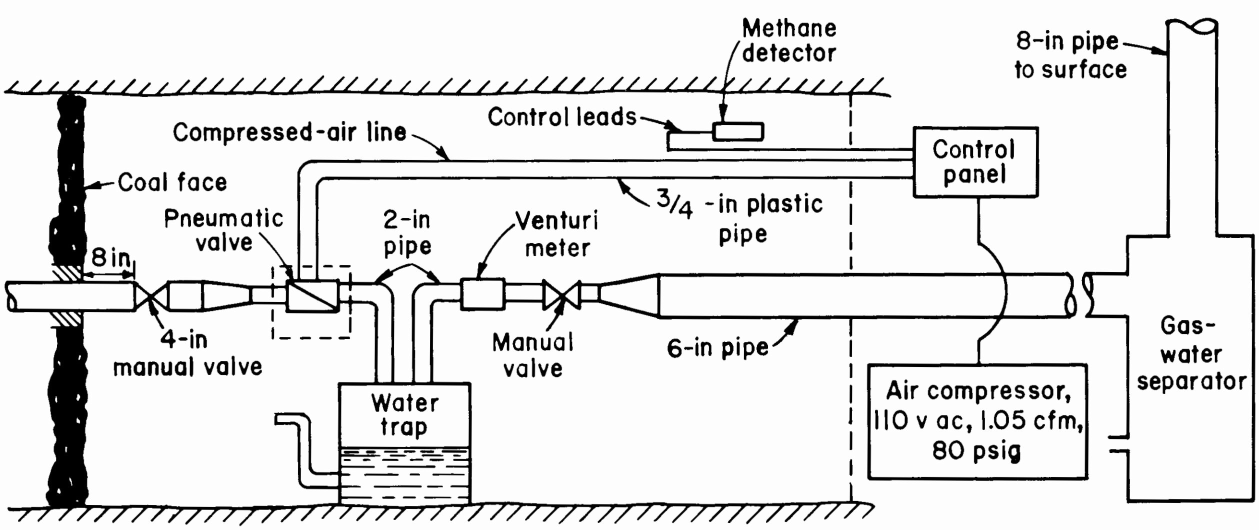


FIGURE 15. - Location of pneumatic shutoff valve in methane drainage pipeline system.

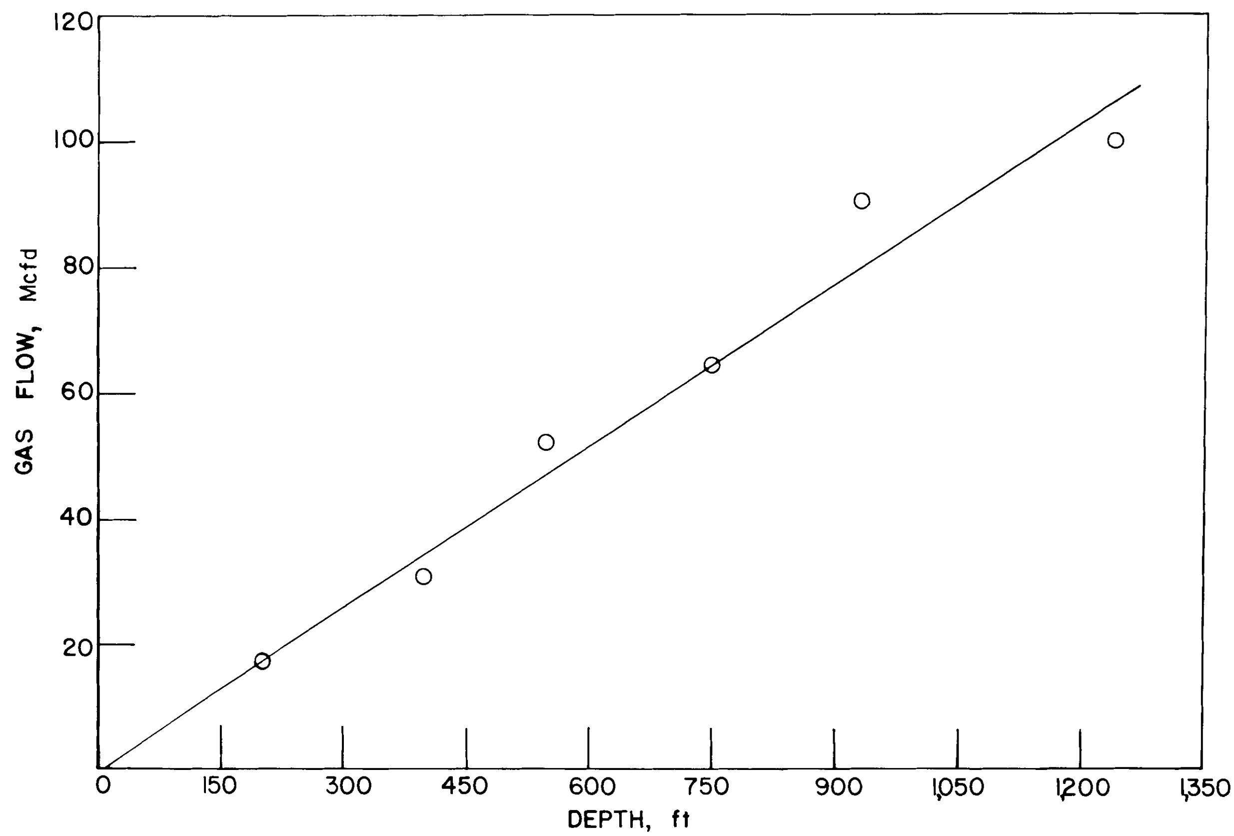


FIGURE 16. - Hole 3 gas flow rates during drilling.

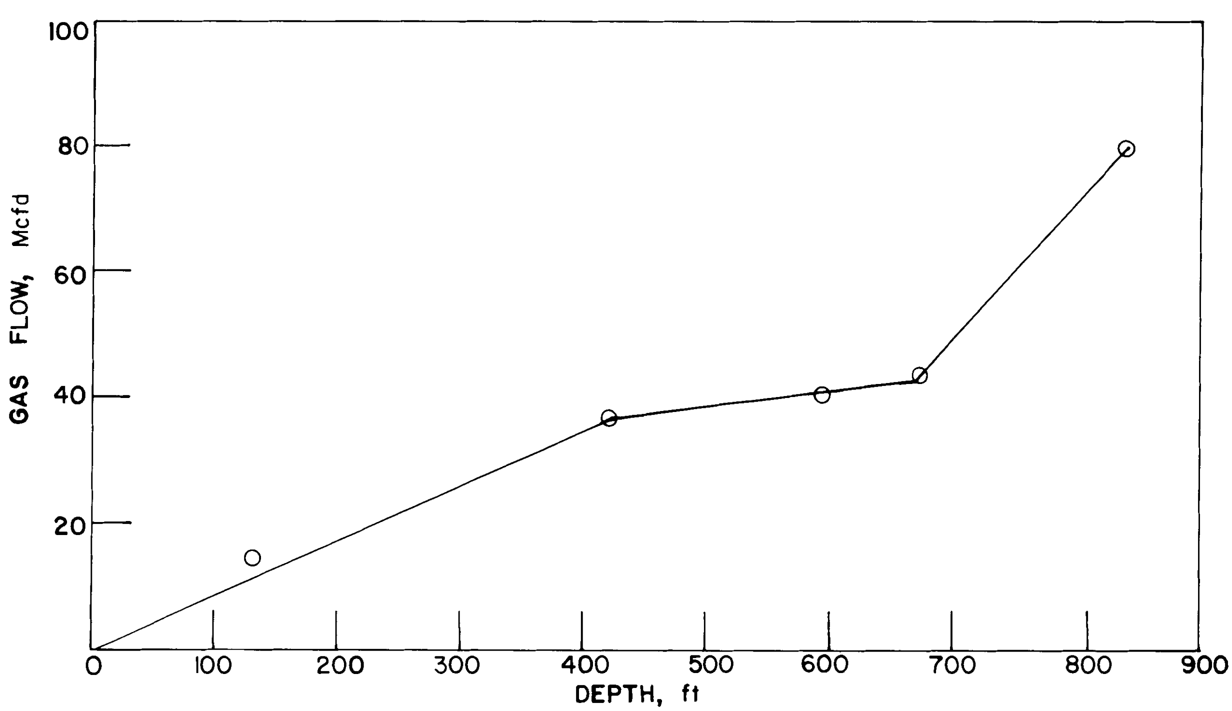


FIGURE 17. - Hole 4 gas flow rates during drilling.

and then the rate declined to about 35 cfd/ft between 420 and 740 feet (fig. 17). Between 740 and 840 feet gas flow rose from 47,000 to 80,000 cfd. This sharp increase in flow (330 cfd/ft) resulted from interception of a thin clay vein. The lower gas flow rate between 420 and 740 feet was probably due to a clay vein which shielded the hole and prevented free migration of gas to the hole. Hole 4 first hit rock at 840 feet. Attempts were made to drill through the rock at two other levels in the coalbed. However, both probe holes intercepted rock and were terminated at 910 and 982 feet (fig. 18). Hole 1 hit rock at 950 feet; drilling was continued for an additional 118 feet in rock before the hole was abandoned.

Both holes 1 and 4 originally terminated in rock within the projected coalbed horizon (fig. 18). Some time later, hole 1 was extended over 782 feet and penetrated through the sandstone rock. When the coalbed was penetrated on

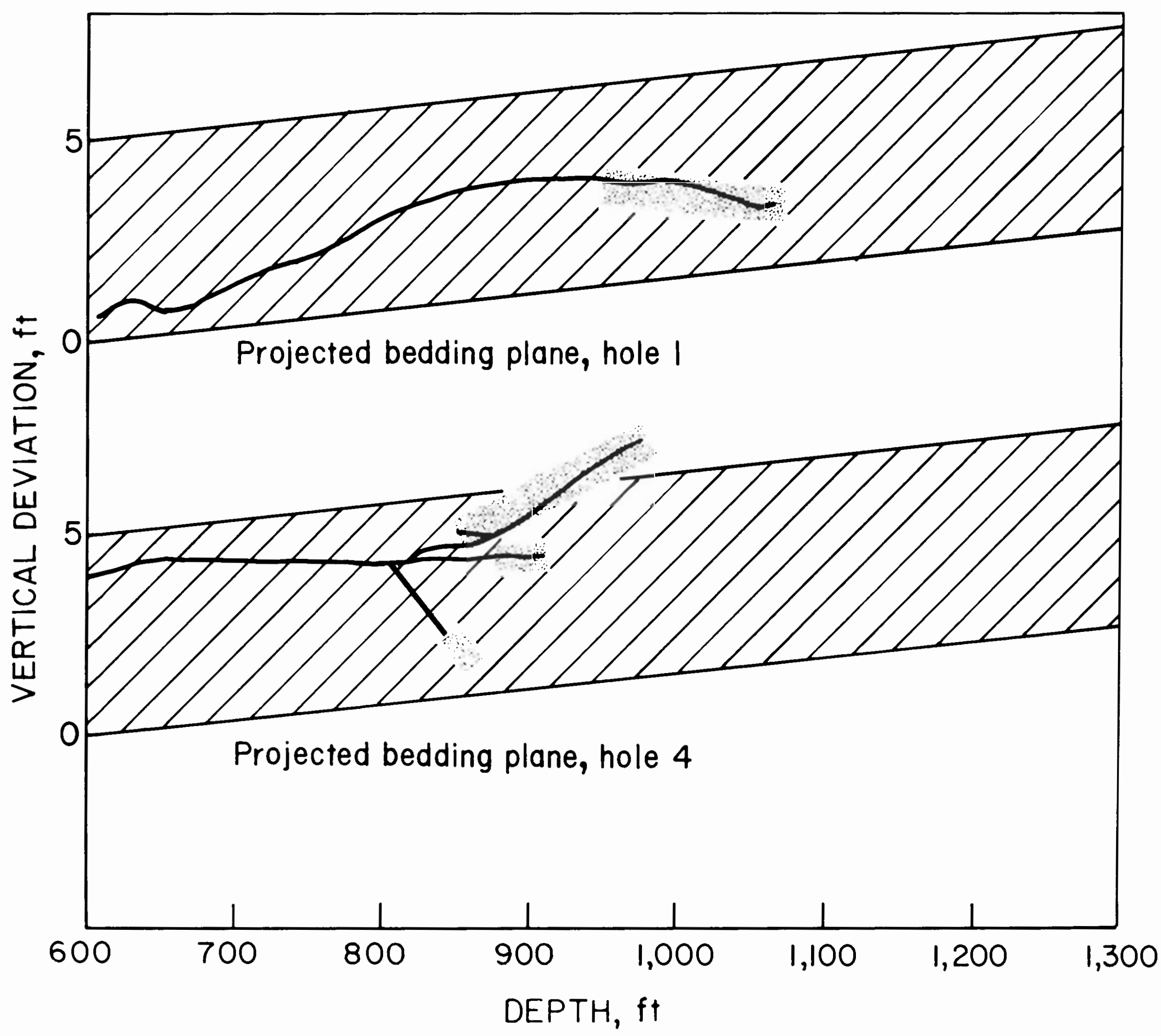


FIGURE 18. - Trajectories of holes 1 and 4. Dotted pattern indicates rock.

the far side of the sandstone, gas flow from the hole increased by 50,000 cfd. Based on this drilling and information from core hole logs, the discontinuity was assumed to be a sandstone channel.

Hole 1 was not drilled at a constant rate; consequently, the flow data are difficult to interpret. The gas flow rates during drilling of hole 2 were 168 cfd/ft to 440 feet and 41 cfd/ft between 440 and 2,150 feet (fig. 19). At 2,220 feet, gas flow increased to 214,000 cfd from 144,000 cfd at 2,150 feet, indicating that a clay vein had been intercepted. Drilling terminated in the floor at 2,505 feet. The lower gas flow rate between 440 and 2,150 feet was again probably due to a clay vein that shielded the hole and prevented free migration of gas to the hole.

The bearings of the clay vein intercepted by holes 2 and 4 were determined by observing interference effects between holes. All holes were shut-in for about 24 hours. Gas pressure at the pressure-monitoring hole (hole A) increased from 8.4 to 11.2 psig (fig. 20). Then hole 1 was opened and gas pressure at hole A immediately began to decline, indicating an interference effect. If a clay vein, which obstructs flow, had been located between holes 1 and A, no gas pressure change would have been observed at hole A. Subsequently, hole 4 was opened and a further decrease in gas pressure was immediately observed at hole A (fig. 20). This test indicated that there probably were no clay veins to obstruct flow laterally between holes 1 and 4.

The gas pressure buildups for holes 1 and 2 are shown in figure 21. After about 23 hours, shut-in gas pressure at holes 1 and 2 were 6.4 and 7.7 psig, respectively. When hole 1 was opened, no change in gas pressure was observed at hole 2. The holes are 12 feet apart at the collars. This indicates the clay vein intercepted by hole 2 at 2,220 feet is probably located between holes 1 and 2 (fig. 22). Similarly, the gas pressure buildups for holes 3 and 4 were 4.7 and 4.4 psig, respectively. When hole 4 was opened, no pressure change occurred at hole 3. The holes are 37 feet apart at the collars. This indicates that the clay vein intercepted by hole 4 at 740 feet is probably located between holes 3 and 4 (fig. 22).

Two clay veins were mapped in the section near the drill site (fig. 22). A thick clay vein (2-1/2 to 3 feet) crosses the section about 1,000 feet outby the face area, and a thin vein (1 to 2 inches) crosses the right side and terminates near the middle of the section about 500 feet outby the face (fig. 22).

Shut-in gas pressures of horizontal holes generally decrease because of the large quantities of methane drained from the coalbed. Initial shut-in gas pressure of holes 1 and 2 measured after the completion of drilling were 11 and 13.1 psig, respectively (fig. 23). After 660 days of degasification the shut-in gas pressure declined to 6.4 and 7.7 psig, respectively (fig. 21), or about 40 pct for both holes.

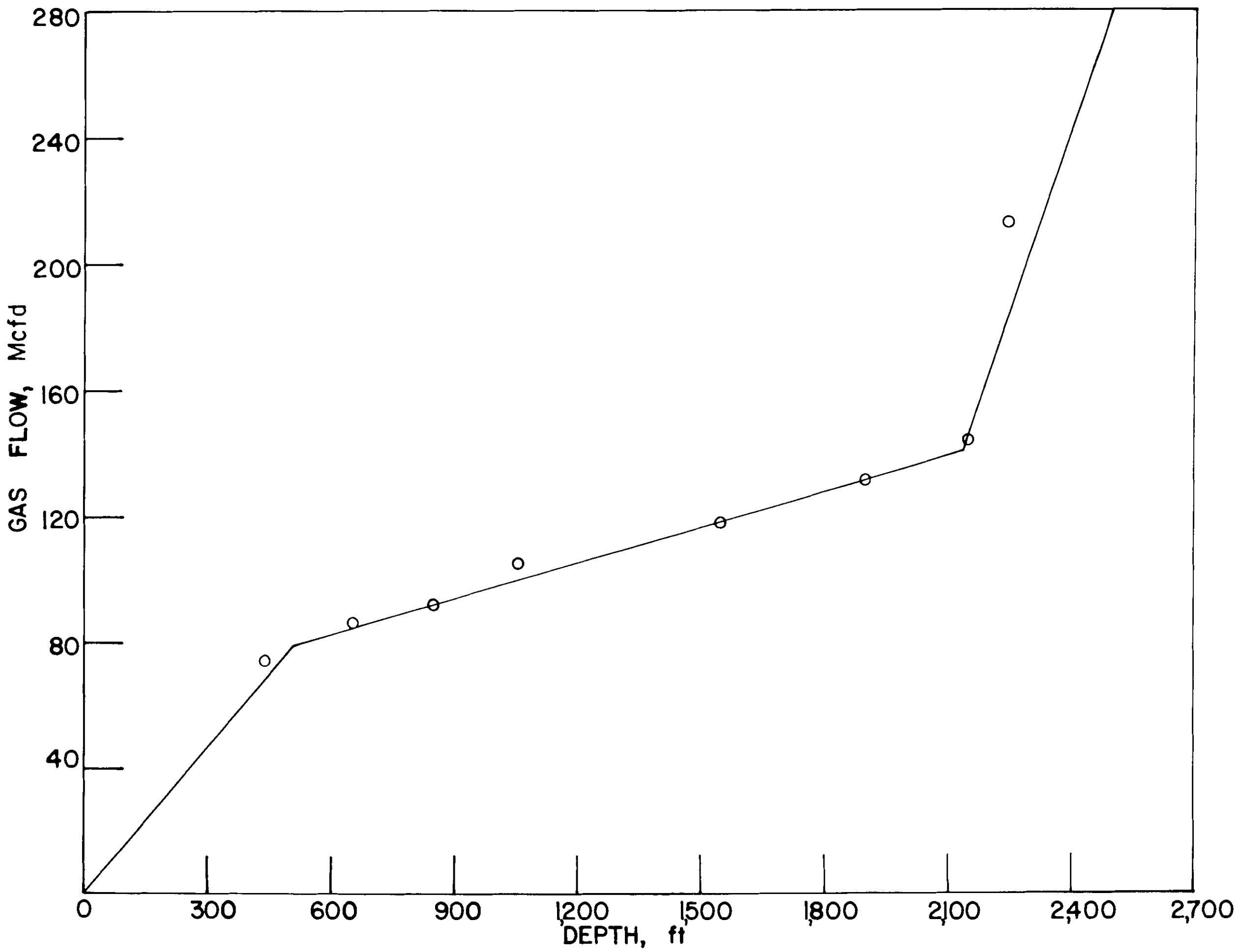


FIGURE 19. - Hole 2 gas flow rates during drilling.

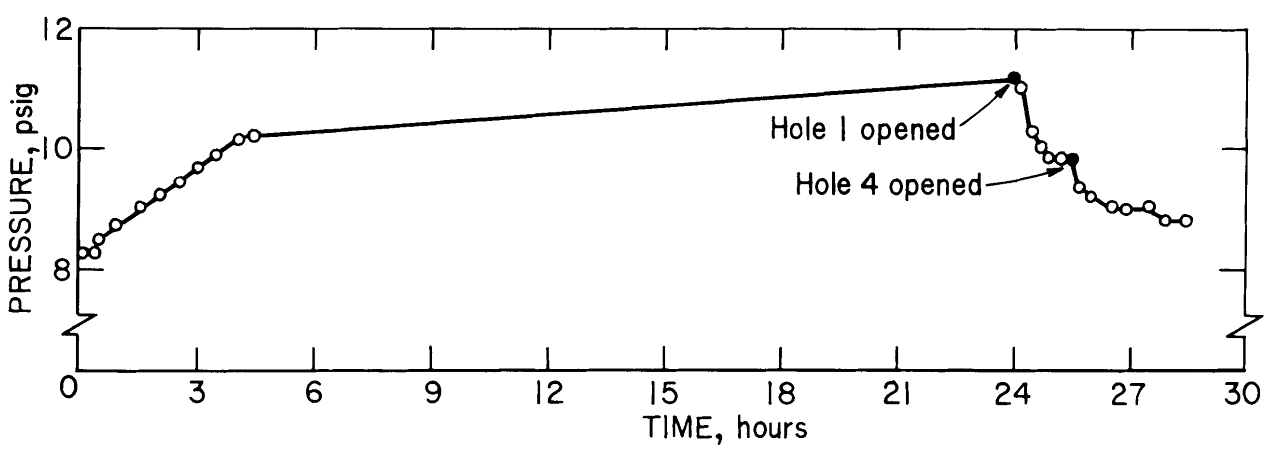


FIGURE 20. - Gas pressure buildup at control hole A.

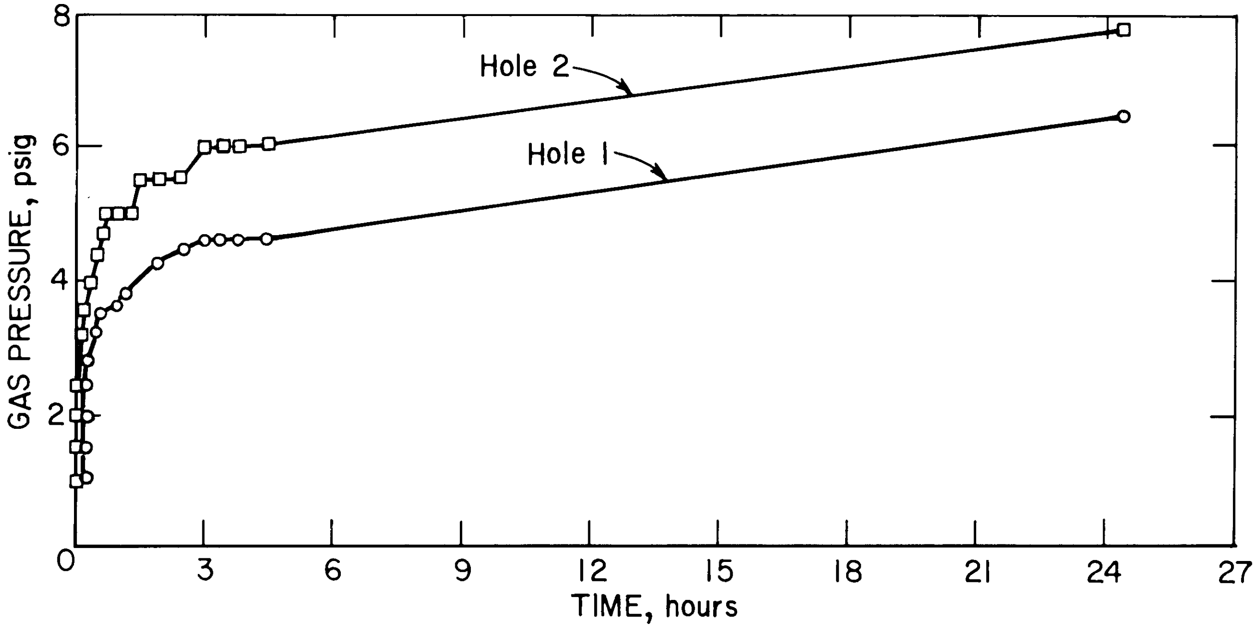


FIGURE 21. - Gas pressure buildup—holes 1 and 2.

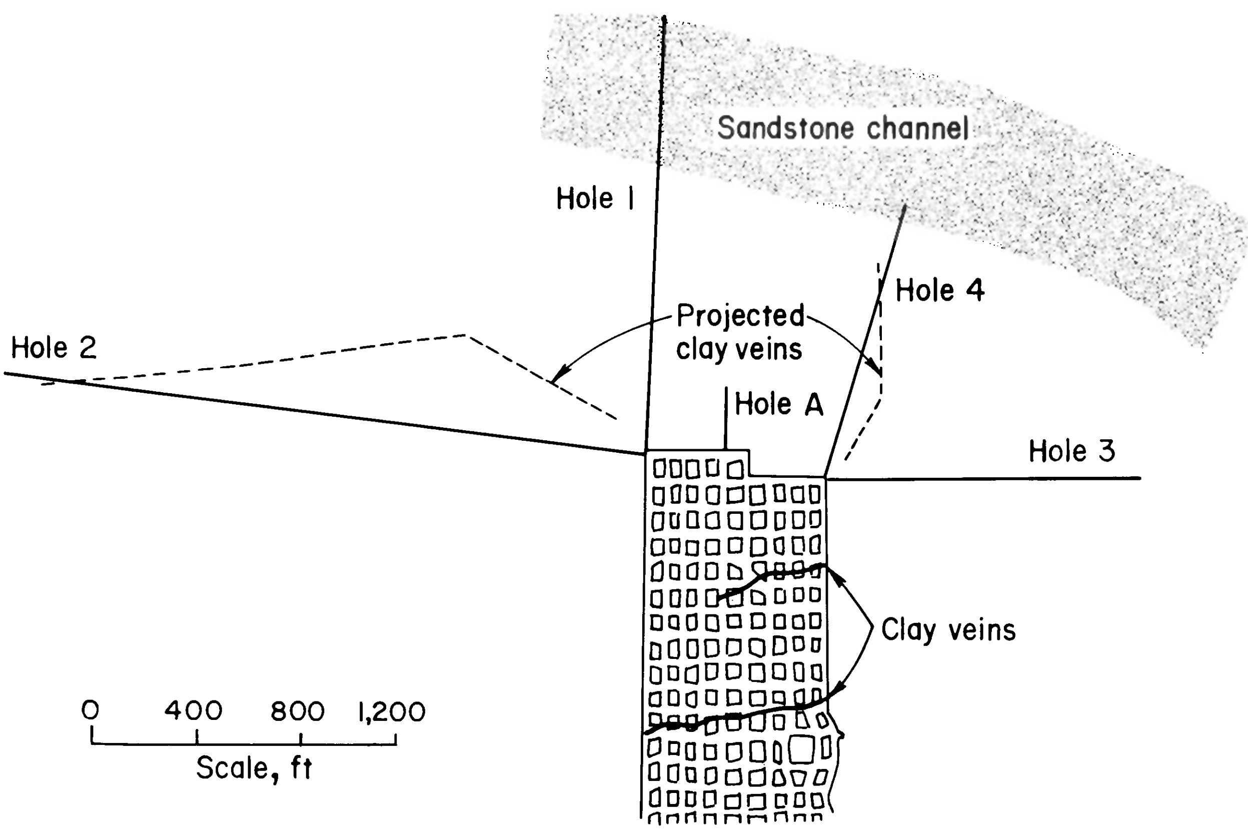


FIGURE 22. - Sandstone channel and clay veins.

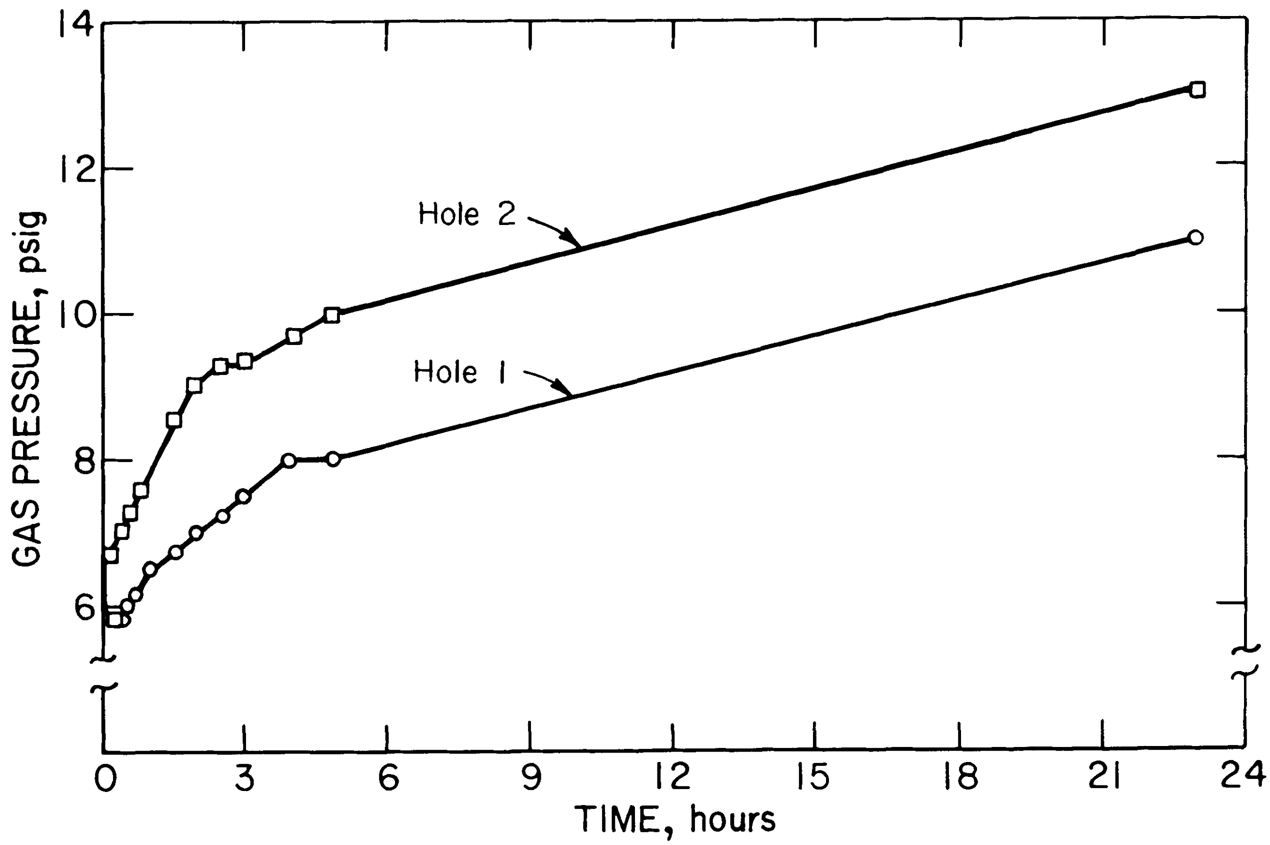


FIGURE 23. - Initial shut-in gas pressures—holes 1 and 2.

## Gas and Water Flows After Drilling

After drilling is completed, the hole is connected to the 6-inch-diameter underground pipeline. The following equipment is installed between the collar of the hole and pipeline (fig. 15): 4-inch-diameter manual valve, pneumatic valve, gas-water separator, venturi meter, 2-inch diameter steel pipe, and 2-inch-diameter manual valve.

The pneumatic valve, which is controlled by the methane sensor system, was discussed previously. Generally, holes drilled into coalbeds produce water and methane, which are separated at the gas-water separator. Water level in the separator is controlled by a float valve on the outside of the tank. The venturi is used to monitor methane flows by measuring a gas pressure differential across the venturi. Finally, the hole is connected to the main pipeline with 2-inch-diameter steel pipe. Manual valves are located at the collar and main pipeline for safety. These valves isolate the equipment between the collar and main pipeline for cleaning, repair, or replacement.

Initial gas flow from horizontal holes in other areas of the Pittsburgh coalbed is about 250 cfd/ft of hole length (2). The initial gas flows from holes 1 through 4 at Marianna Mine 58 were much less (table 6) and ranged from 81 to 126 cfd/ft of hole. The lower flows are due to clay veins and a sandstone channel which isolate large blocks of coal (8). Degasification is confined to those large blocks of coal outlined by the clay veins and sandstone channel and subsequently penetrated by a drainage hole. In addition, the section was abandoned for about 2-1/2 years, allowing gas to bleed from the coalbed fracture system to the mine opening before the drilling program started.

TABLE 6. - Initial gas flows of holes 1, 2, 3, and 4

| Hole | Hole length, ft | Initial gas flow, cfd | Initial gas flow, cfd/ft |
|---|---|---|---|
| 1 | [1]950 | 120,000 | 126 |
| 2 | 2,505 | 280,000 | 112 |
| 3 | 1,238 | 100,000 | 81 |
| 4 | [1]840 | 80,000 | 95 |

[1]Depth at which hole initially hit rock.

When a hole is shut-in, methane leaks around the 21-foot steel pipe and enters the mine opening through the coalbed. Tests conducted to determined methane leakage rates into the mine opening when all holes were shut-in showed the leakage rates were significant. Holes 1 and 2 are located in the left return and holes 3 and 4 in the right return. Before the holes were shut-in, combined flow of holes 1 and 2 was 169,000 cfd (117.2 cfm), compared with 80,000 cfd (56 cfm) for holes 3 and 4. The flow of methane from face and ribs was 17,700 cfd (12.3 cfm) in the left return immediately outby holes 1 and 2 and 18,100 cfd (12.6 cfm) in the right return immediately outby holes 3 and 4.

Twenty-four hours after all holes were shut-in, methane flows from face and ribs in the left and right returns increased to 145,200 cfd (100.9 cfm) and 91,300 cfd (63.3 cfm), respectively. The combined leakage rate is 127,500 cfd (89.3 cfm) for holes 1 and 2 and 73,200 cfd (51.2 cfm) for holes 3 and 4. Consequently, 80 pct of the total flow from all holes leaks into the mine opening when holes are shut-in.

Daily methane flows for each hole are shown in figure 24. In each case when the hole was reopened after being shut-in, methane flows had declined considerably, which substantiates the leakage rate measurements discussed in the previous paragraph. Flows after about 660 days of degasification are about one-half initial flow rates.

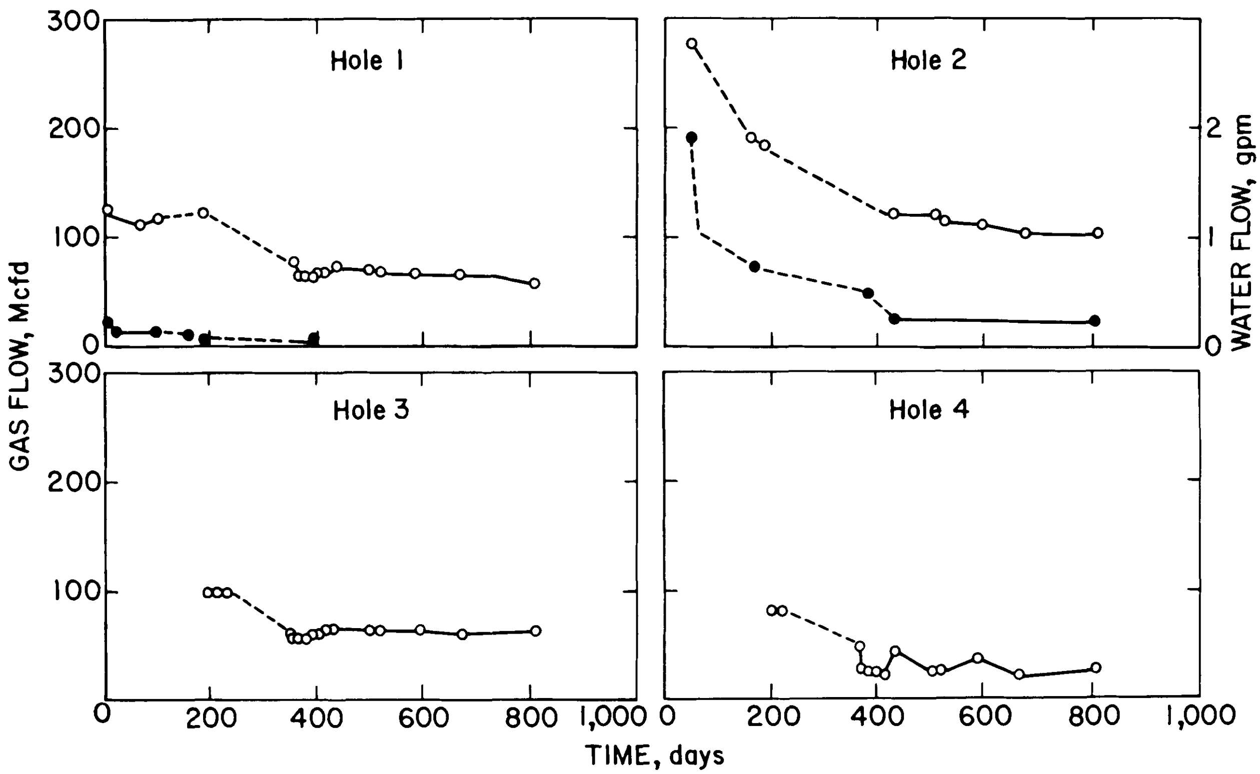


FIGURE 24. - Daily methane flows—holes 1, 2, 3, and 4. Dashed portions of curves represent interval when hole was shut-in; dark symbols indicate water flow.

Holes 3 and 4 did not produce water. Daily flow rates for holes 1 and 2 are shown in figure 24. Waterflow from hole 1 declined to zero flow after about 400 days of degasification. Total daily methane and water flow rates are shown in figure 25. Cumulative production after 991 days of operation is 255 MMcf of methane (fig. 26).

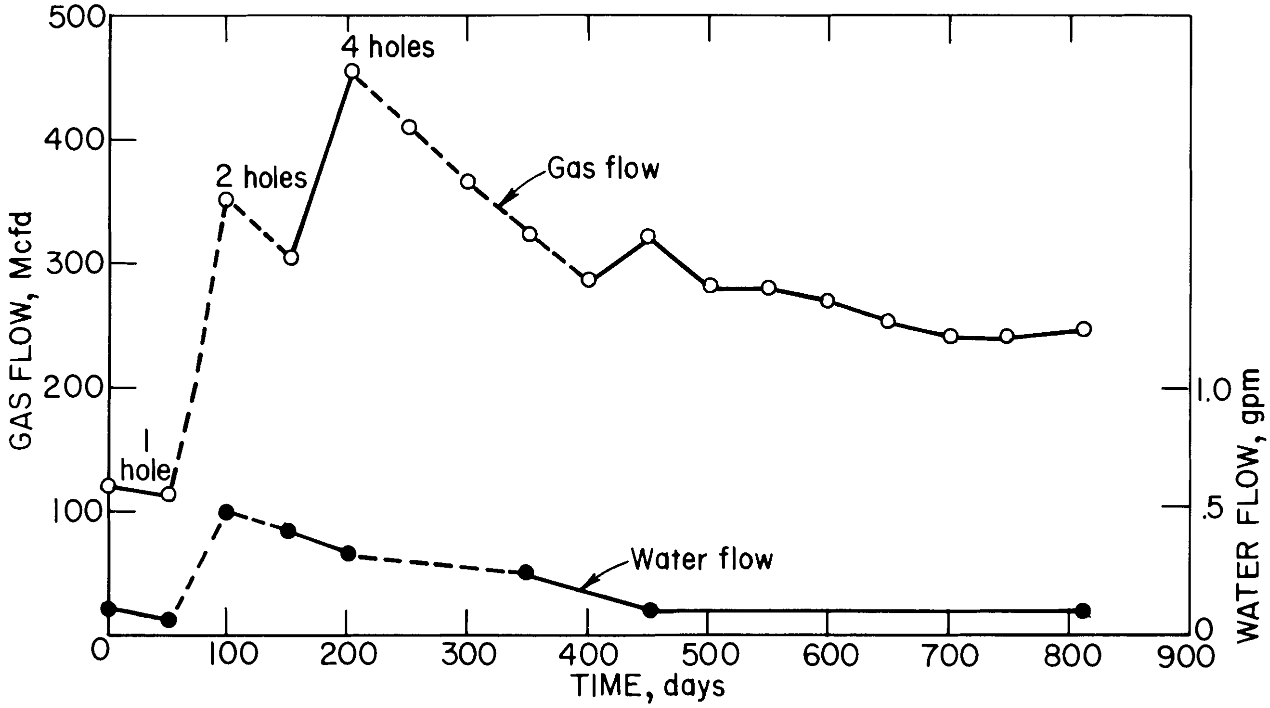


FIGURE 25. - Total daily methane and water flow rates. Dashed portions of curves represent interval when hole was shut-in; dark symbols indicate water flow.

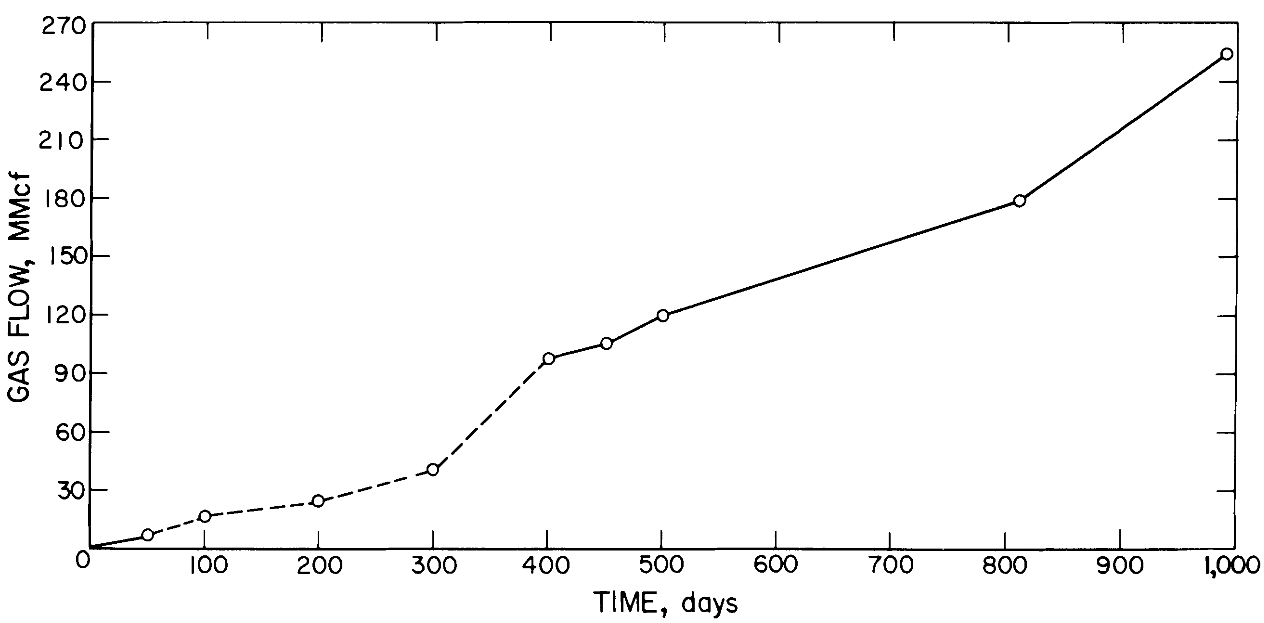


FIGURE 26. - Cumulative methane production. Dashed portion of curve represents interval when hole was shut-in.

## Gas Utilization

The composition and heating value of gas in coal are very similar to those of natural gas (6), as shown in table 7. The analysis shows the gas drained from this portion of the Pittsburgh coalbed is interchangeable with natural gas or is suitable for utilization.

TABLE 7. - Composition and heating value of coalbed gas and natural gas, pct

| | $CH_4$ | CH[1] | $H_2$ | Inerts[2] | $O_2$ | Btu/scf |
|---|---|---|---|---|---|---|
| Pittsburgh (Marianna)........ | 97.75 | 0.05 | ND | 2.12 | 0.09 | 1,000 |
| Pocahontas No. 3............. | 96.87 | 1.40 | 0.01 | 2.09 | .17 | 1,059 |
| Kittanning................... | 97.32 | .01 | ND | 2.44 | .24 | 1,039 |
| Lower Hartshorne............. | 99.22 | .01 | ND | .66 | .10 | 1,058 |
| Mary Lee..................... | 96.05 | .01 | ND | 3.45 | .15 | 1,024 |
| Natural gas (9).............. | 94.40 | 4.90 | ND | .40 | ND | 1,068 |

ND Not detected.
[1]Other hydrocarbons.
[2]$N_2$, $CO_2$, and He.

Effective horizontal drainage technology requires an underground pipeline and a vertical borehole to the surface to remove the methane from the mine. Since many horizontal holes can be connected to the underground pipeline and vented at a single location on the surface, the methane can be utilized without a complex and expensive gathering system. The Bureau of Mines cooperated with Bethlehem Mines Corp. and the Department of Energy on a demonstration project at Marianna Mine 58 for generating electricity from the methane gas being captured from the four horizontal drainage holes. A turbine generator has been installed at a surface location of the Marianna Mine 58 property. Methane from the horizontal holes is piped to the turbine generator, which converts it to electricity for operation of a mine ventilation fan. A total of 20 MMcf of methane has been utilized during the demonstration project, and a total of 255 MMcf of methane has been removed from the mine by the four horizontal drainage holes.

## SUMMARY

Four horizontal drainage holes were drilled ranging from 982 to 2,505 feet. Initial methane flow from the holes was 580,000 cfd. The methane is piped to the surface through an underground 6-inch steel pipeline 1,150 feet long.

All holes are equipped with pneumatic valves which are held open with compressed air (55 psig). Methane sensors, which are located every 500 feet along the pipeline, control the pneumatic valves. If an abnormal methane concentration (1 pct) is detected, the sensor sends a signal to the control panel, and the compressed-air line to the pneumatic valves is vented, closing the holes.

Clay veins and a sandstone channel were located during the drilling phase. The sandstone channel extends over 420 feet along the projected coalbed horizon

(in hole 1). Methane flows from the horizontal holes were much less than flows observed in other areas of the Pittsburgh coalbed. The clay veins and sandstone channel isolate large blocks of coal, which limits drainage to the isolated blocks of coal penetrated by the horizontal holes.

Because of the soft nature of the Pittsburgh coalbed at Marianna Mine 58, all holes except hole 1 were drilled with a modified drilling assembly which consisted of a 3-5/8-inch bit, centralizer, and 18-foot drill collar. Removal of the rear centralizer cocked the assembly 0.1° upward in the hole.

## CONCLUSIONS

Degasification of the Pittsburgh coalbed has been successfully demonstrated at Marianna Mine 58. Horizontal drainage holes drilled into virgin coal in advance of mining have captured a significant amount of methane before it could enter the mine's ventilation system. The initial combined gas flow of 580,000 cfd of methane decreased to 234,000 cfd after 991 days, with a total gas production of 255 MMcf.

Horizontal holes are an effective method for identifying and locating discontinuities in a coalbed in advance of mining. At Marianna Mine 58 clay veins and a sandstone channel have been located and penetrated by horizontal drilling in virgin areas. Gas flows from horizontal holes are significantly reduced in areas of coalbeds in which discontinuities are present.

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