RI 8644

Bureau of Mines Report of Investigations/1982

Underground Gob Gas Drainage During Longwall Mining

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UNITED STATES DEPARTMENT OF THE INTERIOR

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This publication has been cataloged as follows:

Schatzel, Steven J

Underground gob gas drainage during longwall mining.

(Report of investigations / United States Department of the Interior, Bureau of Mines ; 8644)

Includes bibliographical references.

Supt. of Docs. no.: I 28.23:8644.

1. Coal Mines and mining—Safety measures. 2. Mine gases. 3. Methane. I. Finfinger, Gerald L. II. Cervik, Joseph. III. Title. IV. Series: Report of investigations (United States. Bureau of Mines) ; 8644.

TN23.U43 [TN295] 622s [622'.8] 81-607572

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UNDERGROUND GOB GAS DRAINAGE DURING LONGWALL MINING

by

Steven J. Schatzel,[1] Gerald L. Finfinger,[2] and Joseph Cervik[3]

ABSTRACT

Gas drainage through surface boreholes has been the conventional means of methane control for U.S. longwall gobs. However, these vertical boreholes are becoming so costly, and the surface rights so difficult to obtain, that the Bureau of Mines is developing underground gob gas drainage as an alternate means of methane control for U.S. longwalls. Holes are drilled into the roof over the panel and on retreating longwalls, towards the working face from a location inby the face. As the longwall retreats, an increasing portion of the hole intercepts the fracture system over the caved gob. A surface exhauster maintains a vacuum on a pipeline parelleling the panel and draws the methane mixture out of the mine.

Auxiliary systems of gob gas drainage during longwall mining will be essential for an increasing number of coal mines. Deep and gassy mines often find ventilation insufficient for adequate dilution of methane in bleeder entries. Although this cross-measure method of degasification has been used successfully in Europe, some of the European techniques cannot be directly applied to U.S. mines. This is the first study of its kind in this country.

INTRODUCTION

Conventional U.S. gob gas control consists in ventilation of gob areas and drainage through surface boreholes. However, the mining of deeper coalbeds and the scarcity of suitable surface locations has increased the cost of surface boreholes. Irregular topography and the inavailability of surface rights can force some mines to rely on the normal ventilation system as the only means of reducing methane concentrations. However, since this may not be sufficient to adequately dilute methane in bleeder entries, the Bureau is exploring gob gas drainage from underground locations as an alternate method of methane control of U.S. longwalls.

Underground drainage of gob gas has been used extensively in Europe, where coal basins tend to be deeper than those in the United States.[4] Generally, European coalbeds are steeply dipping with a high degree of tectonic disturbance. Outbursts of coal, methane, and rock are a serious problem. The first large-scale underground methane drainage and piping

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[4]Cervik, J. Methane Control on Longwalls--European and U.S. Practices. SME-AIME Ann. Meeting, New Orleans, La., Feb. 18-22, 1979; SME-Preprint COAL 79-06, 10 pp.

systems were introduced in 1943 by the Germans. Since that time, degasification during longwall operations has become the most important methane drainage technique throughout Europe. Cross-measure boreholes are drilled into the roof over the panel and sometimes into the floor beneath the longwall. Cribbing prevents full caving on single-entry advancing longwalls commonly used in European coal mines. In Poland and Czechoslovakia, over 90 pct of the gas is recovered and used.[5]

The multiple-entry retreating longwalls used in the U.S. require certain changes in the European approach. In particular, the main methane pipeline connecting the cross-measure boreholes to the surface borehole cannot be adjacent to the full caving gob. The present report describes an initial attempt to assess the feasibility of adapting European technology to U.S. mining conditions.

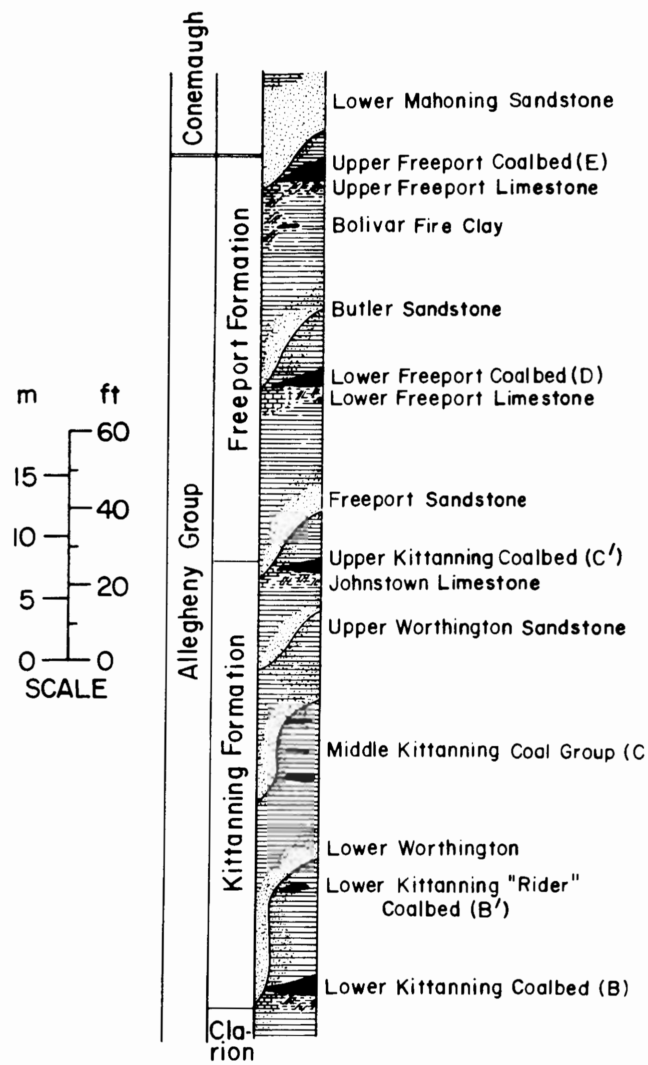

FIGURE 1. - Generalized stratigraphic column of Freeport and Kittanning Formations.

ACKNOWLEDGMENTS

The authors thank the Central Mining Institute of Poland and the following personnel from Bethlehem Mines Corp.'s Cambria Division and Cambria 33 Mine: E. J. Korber, Manager; F. A. Burns, General Superintendent; Dan Weaver, Mining Engineer; and Bill Radabaugh, Mine Foreman.

LOCAL GEOLOGY

The Kittanning and Freeport Formations of Pennsylvanian age were the subject of this study (fig. 1). Deposition of these formations is thought to have taken place in a deltaic environment. The low accumulation rate of detrital sediment allowed vast swamp marshes to develop.[6] The complexity of the depositional environment produced lithologic gradations and discontinuities. The Lower Kittanning Coalbed is generally thicker than the Upper Kittanning, but both are minable. Bethlehem Mines Corp.'s Cambria 33 Mine operates in both coalbeds simultaneously. On the study panel, the Upper Kittanning (C' Coalbed) varies from 29 to 45 in (74 to 114 cm) in

[5]Matuszewki, J., and W. Sikore. Report on the Technology of Degasification of Mines in Poland and Other European Countries. BuMines Project 14-01-0001-1447, January 1978, 117 pp.; available for consultation at Pittsburgh Research Center, Bureau of Mines, Pittsburgh, Pa.

[6]Puglio, D. G., and A. T. Iannacchione. Geology, Mining and Methane Content of the Freeport and Kittanning Coalbeds in Indiana and Surrounding Counties, Pa. BuMines RI 8406, 1979, pp. 20-25.

height. The Middle Kittanning is the least continuous of the Freeport and Kittanning coal groups. The cross-measure boreholes were drilled into the immediate roof rock of the Upper Kittaning horizon. Cores retrieved from the first 20 ft (6.1 m) of each hole revealed a shale and sandstone roof, with the percentage of sandstone increasing with the hole depth into the immediate roof.

STUDY AREA

This experiment was conducted on the panel between sections 1 and 2 Left adjacent to 1 West in Bethlehem Mines Corp.'s Cambria 33 Mine (C' Coalbed) in Ebensburg, Pa. (fig. 2). Federal regulations require underground methane pipelines to be in return air. Entries 1 and 2 are returns, entry 3 is an intake, and the beltline is located in entry 4 (fig. 3). The pipeline was placed in the No. 2 entry, leaving the intake and one return escapeway unobstructed. With 160 ft (49 m) separating the panel from the No. 2 entry and double posts along the length of the return, there is no danger of the collapsed gobs interfering with the pipeline.

Mining on the panel began on Mar. 24, 1980. Drilling began on May 22. Figure 2 shows the face location on May 21, 1980.

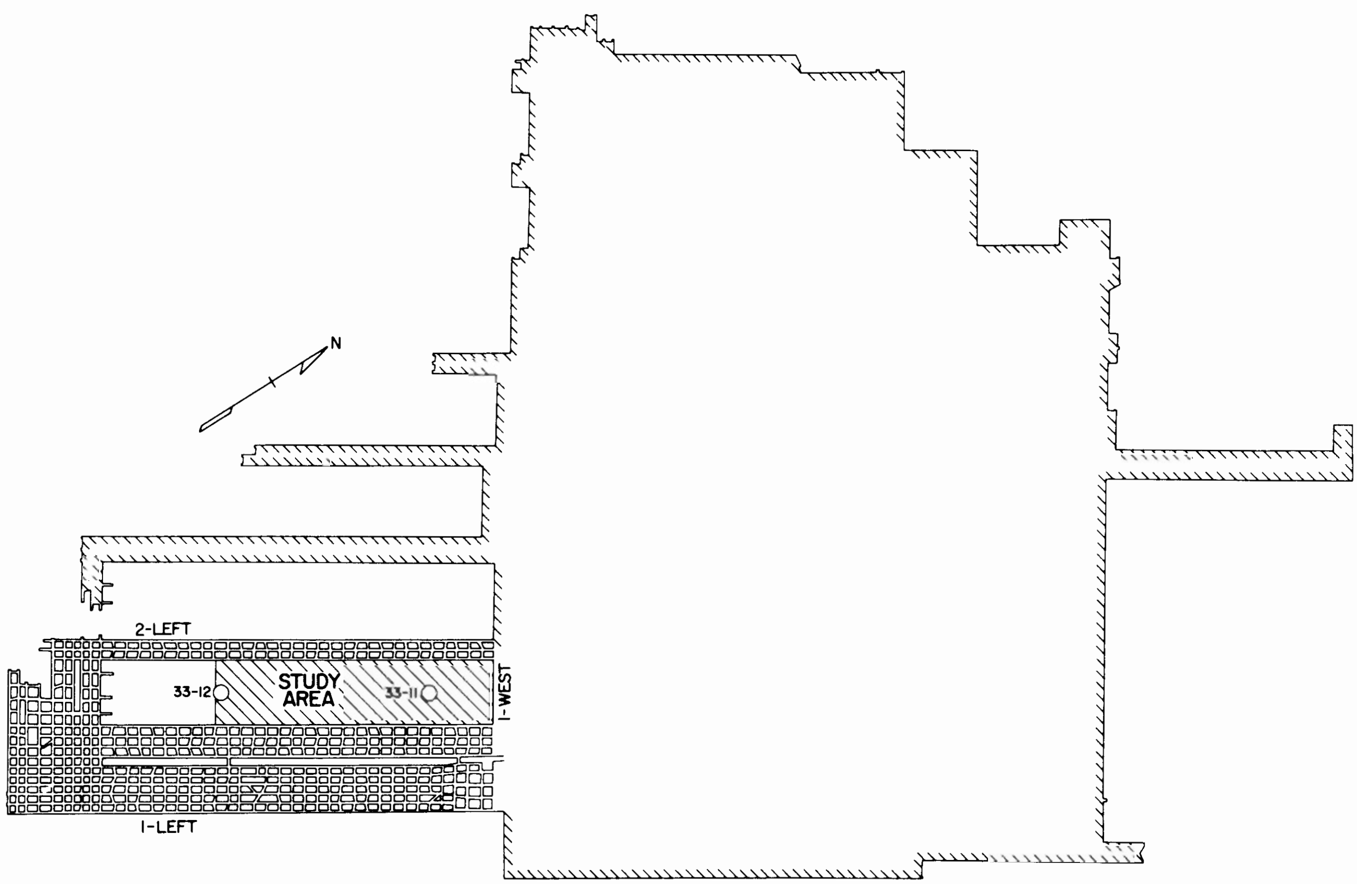

FIGURE 2. - Bethlehem Mines Corp.'s Cambria 33 Mine (C'Coalbed) in Ebensburg, Pa.

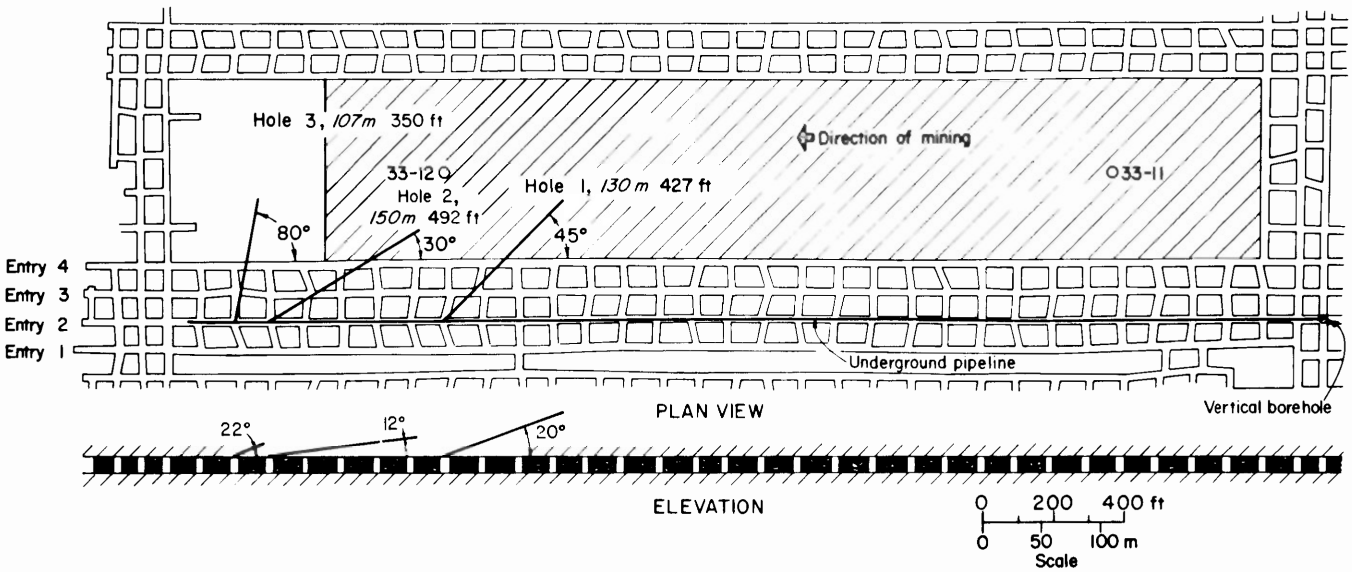

FIGURE 3. - Study panel, cross-measure boreholes, underground pipeline, and vertical boreholes.

DRILLING EQUIPMENT AND PROCEDURE

Two sets of hole parameters were established before the start of the study; a third set was based on preliminary data yielded by the first two holes. The parameters included hole length, inclination, and azimuth (the acute angle made by hole and the long axis of the longwall). All holes were drilled towards the face from a location inby the face.

With holes oriented in this manner, the duration and volume of gob gas flows can be maximized. The fracture system first encounters the back of each hole. As the longwall retreats an increasing portion of the hole intercepts the fracture system, producing increased flows. With all other conditions remaining constant, relatively long holes increase the surface area for methane capture. Acute azimuth angles increase the component of the hole paralleling the axis of the longwall, thus increasing the duration of flow with respect to the progression of the working face. Also, acute azimuth angles mean that a large portion of hole is used in traversing the entries adjacent to the longwall where mine air might be captured. Large angles of inclination allow the holes to communicate with a large number of potential methane-bearing strata, while decreasing flow as the methane is transported through small, extensive fractures. In general, hole trajectories are designed to pass over the panel at a minimum of five times the height of the coalbed. All holes in this study achieved enough height over the panel to at least penetrate the Lower Freeport horizon.

Since surveying was not incorporated into the drilling cycle, true hole parameters were only approximated until a survey could be done once terminal length had been reached. Hole 1 maintained the 20° (0.35 rad) inclination at the collar; hole 2 dropped below the initial 12° (0.21 rad) inclination; and hole 3, started at 22° (0.38 rad) above the horizontal, turned upward (table 1). Hole 3 parameters were selected to compare U.S. and European coalbed characteristics with respect to abutment pressures and gas flows. Holes 1 and 3 intercepted a water-bearing horizon, the Mahoning Sandstone (fig. 1).

TABLE 1. - Hole parameters

Hole	Length		Inclination		Azimuth	
	ft	m	deg	rad	deg	rad
1..............	427	130	20°	0.35	45°	0.79
2..............	492	150	12°	.21	30°	.52
3..............	350	107	22°	.38	80°	1.40

A post-mounted electrohydraulic drill was used for this study (fig. 4). The drill's hydraulic motor and pistons receive fluid from a 20 hp, 460-V electric motor. Because of space limitations at the drill sites, the standard Bureau stuffing box was replaced with a 4-in (10-cm) tee screw-fastened to a section of grouted steel casing. Water and gas were drawn off through a single opening and separated at another location. The drill was situated in the No. 2 entry. Hydraulic hoses carried fluid from the intake air of the No. 3 entry to the drill unit (fig. 3).

Each of the three holes was started with a core bit 4 in (10 cm) in diameter mounted on a 2-ft (0.6-m) core barrel. The holes were drilled to a depth of about 23 ft (7 m). The first 3 ft (0.9 m) were then reamed to 6 in (15 cm) with a drag bit. A 3-ft (0.9-m) length of steel casing was grouted in place and allowed to set. The remainder of the hole was drilled with a smaller core bit, about 2.3 in (5.8 cm) in diameter, mounted on a 4-ft (1.2-m) core barrel. The small surface area of this synthetic diamond bit produced the greatest penetration rate of available drill bits.

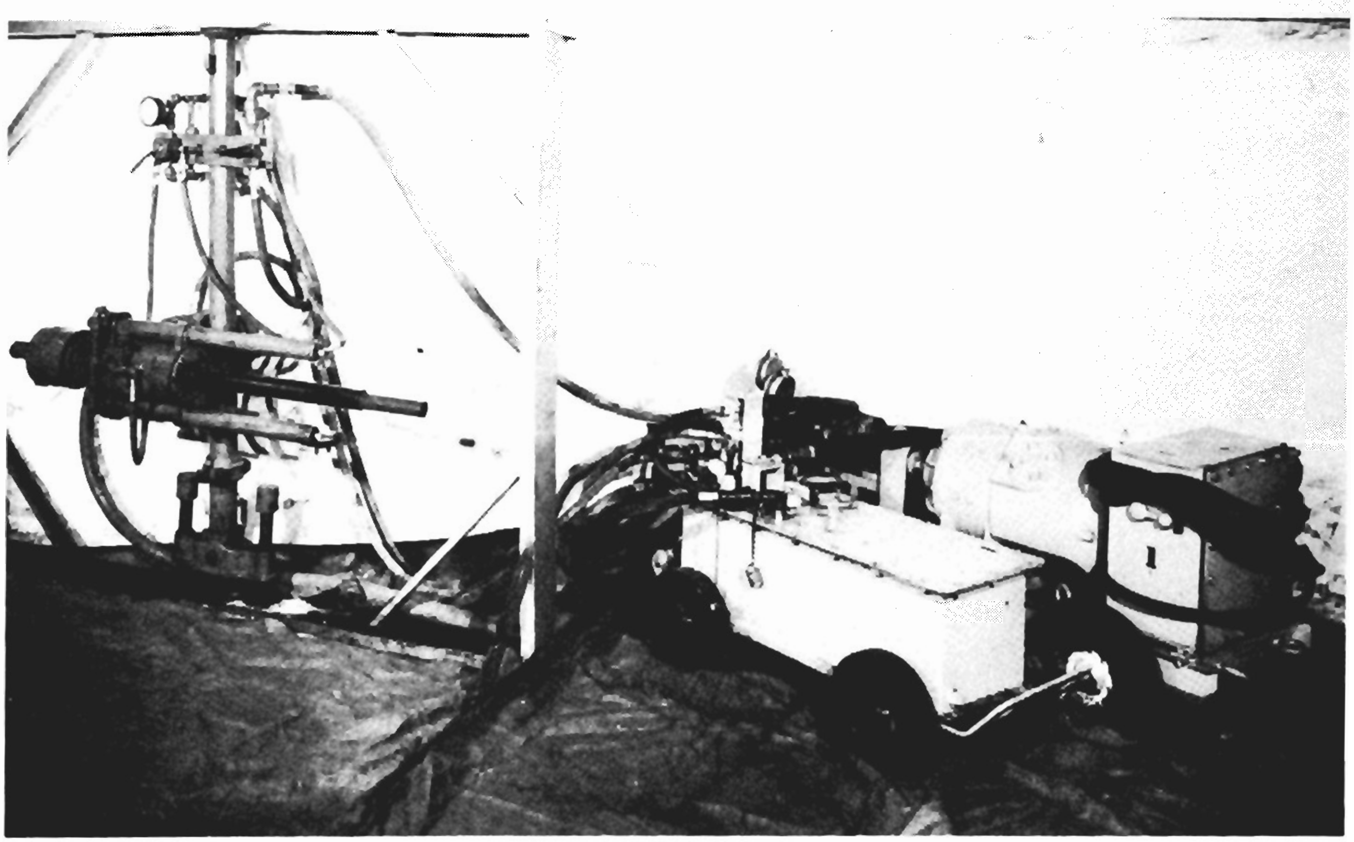

FIGURE 4. - Post-mounted, electrohydraulic drill.

Behind the core barrel, a combination of BX and EW flush joint casing in 5-ft (1.5-m) lengths made up the drill string.

Normally, a core retriever with attached wire line must be inserted in the drill rod and driven by water pressure to the rear of the core barrel after each 4-ft (1.2-m) interval drilled. However, with careful application of thrust, 40 ft (12 m) could be drilled as portions of the core would break off and slip down the rods. When, eventually, the core became lodged against the inner walls of the drill rod or when the weight of the core interfered with drilling, the crew pulled tools and removed the core. Using this technique and with two shifts of drilling per day, each hole was completed in no more than 13 days.

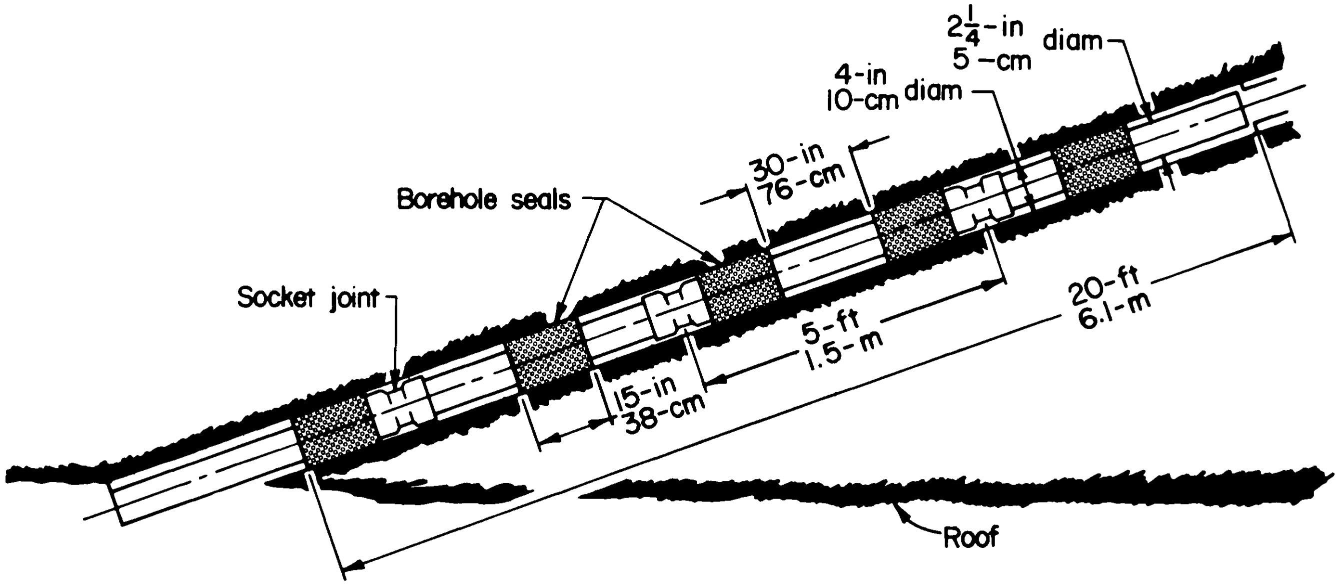

FIGURE 5. - Plastic standpipe with borehole seals.

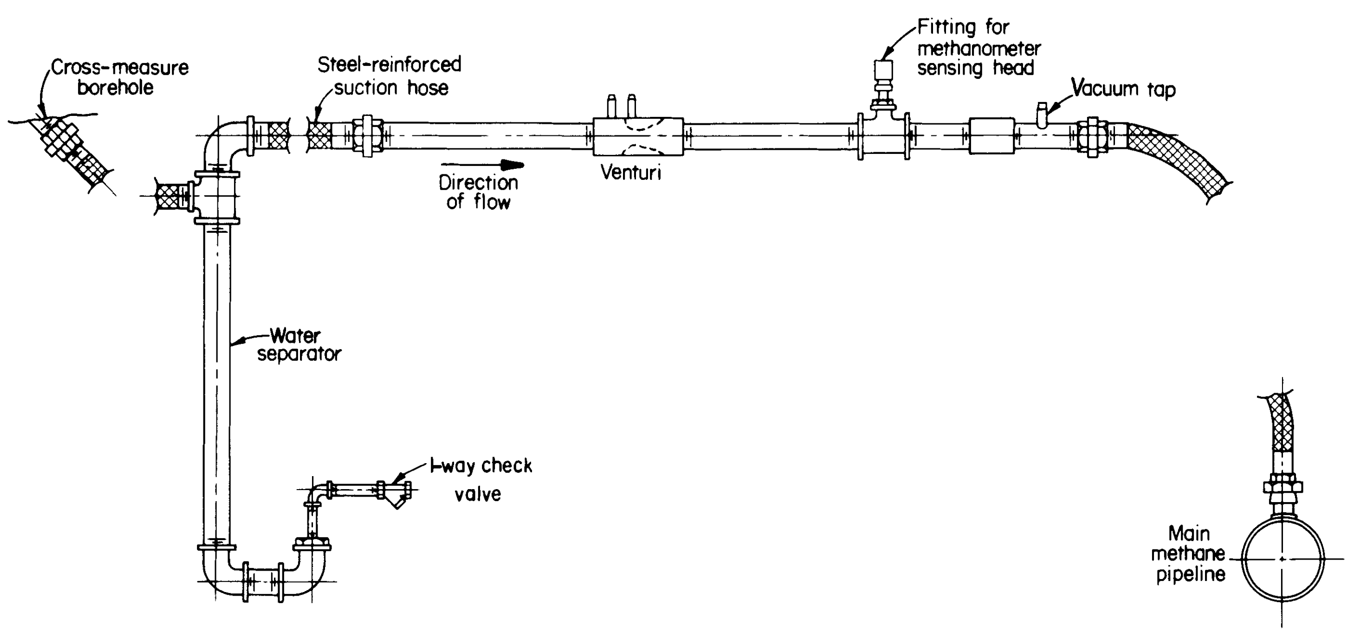

FIGURE 6. - Underground data acquisition pipeline.

With this procedure, after completion of drilling, the steel casing is removed and replaced by a 20-ft (6.1-m) plastic standpipe. Borehole seals 4 in (10 cm) in diameter are placed at regular intervals along the standpipe. One-half inch (13-mm) plastic tubing carries a grout mixture from a pneumatic pump to each borehole seal (fig. 5). Steel-reinforced 2-in (5-cm) suction hose is fastened to the standpipe. The methane mixture then passes through 10 ft (3.0 m) of 2-in (5 cm) schedule 40 steel pipe. A suction hose connects the steel pipe to saddle fittings located every 100 ft (30.5 m) on the main pipeline. This pipe contains all the equipment and fittings required for the acquisition of data presented in this report (fig. 6).

METHANE MONITORING AND SAFETY SYSTEM

Three permissible methane monitors are positioned along the underground pipeline (fig. 3). The concentration of methane detected by these sensors is electronically transmitted to the sensor board located in intake air (fig. 7). Here these signals are displayed as instantaneous methane levels at each sensor. A continuous concentration plot is produced by chart recorders. Near the sensor board, a 100-V ac air compressor maintains a 50- to 80-psi (3.5- to 5.6-kg/cm^2) pressure in a 3/4-in (19-mm) PVC pipeline. This pipe is fastened to the top of the main pipeline and runs its entire length.

Normally closed control valves on each of the three holes are attached to the PVC pipe. If methane concentrations of 1 pct or more occur in the pipeline entry, the sensors trigger a warning

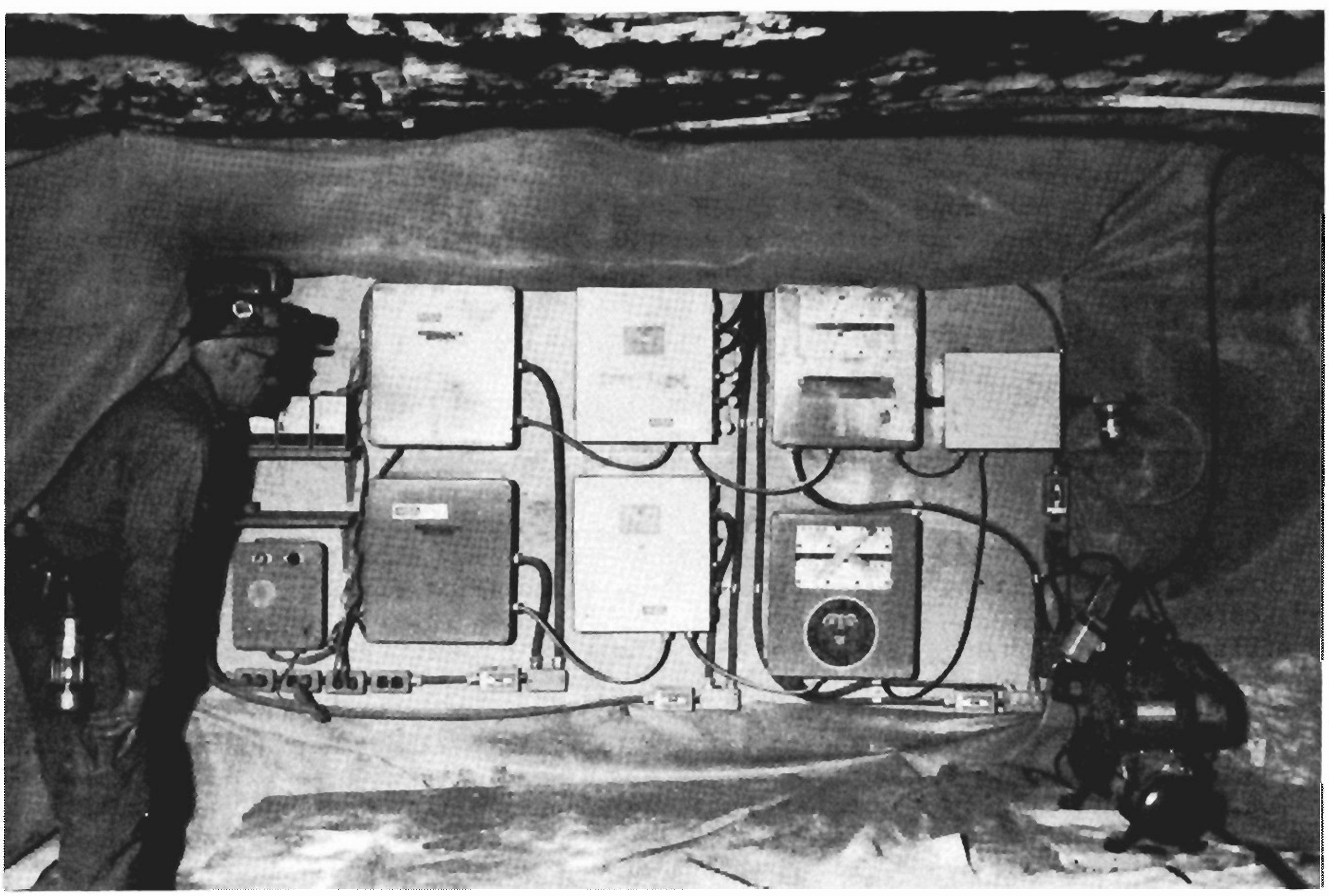

FIGURE 7. - Monitoring and safety system.

display on the sensor board. At 1.2 pct methane, the sensors transmit an alarm signal. At the sensor board, a valve in line with the PVC opens evacuating the 3/4-in (19-mm) pipeline. All control valves close, shutting in the cross-measure boreholes. The alarm is also activated in the event of a power outage at the mine. A roof fall over the pipeline large enough to fracture the PVC will shut in the boreholes.

GAS AND WATER FLOWS

Only during the operation of the surface exhauster could gas be extracted from the cross-measure boreholes (fig. 8). The underground boreholes were manually shut-in at the collar of each hole after every test run. During most test runs, enough locations were monitored to determine the total volume of gas given off by, and removed from, the study panel.

Gas production from the underground degasification system began on June 11, 1980. While connecting hole 1 to the main pipeline, a vacuum into the gob was noted. A vacuum of 5.3 in (13 cm) H_2O was measured, producing a flow of 27 cfm (0.76 m^3/min). A standing wave of water at the collar of the hole was held in place by the vacuum. On this date, a test run of 1 hour produced 2,200 ft^3 (62 m^3) of pure methane at an average concentration of 34 pct methane. The negative pressure at the hole averaged 2.7 in (6.9 cm) Hg. Subsequently, water flowing freely from hole 1 choked the main pipeline. A water separator built to operate under a vacuum was designed

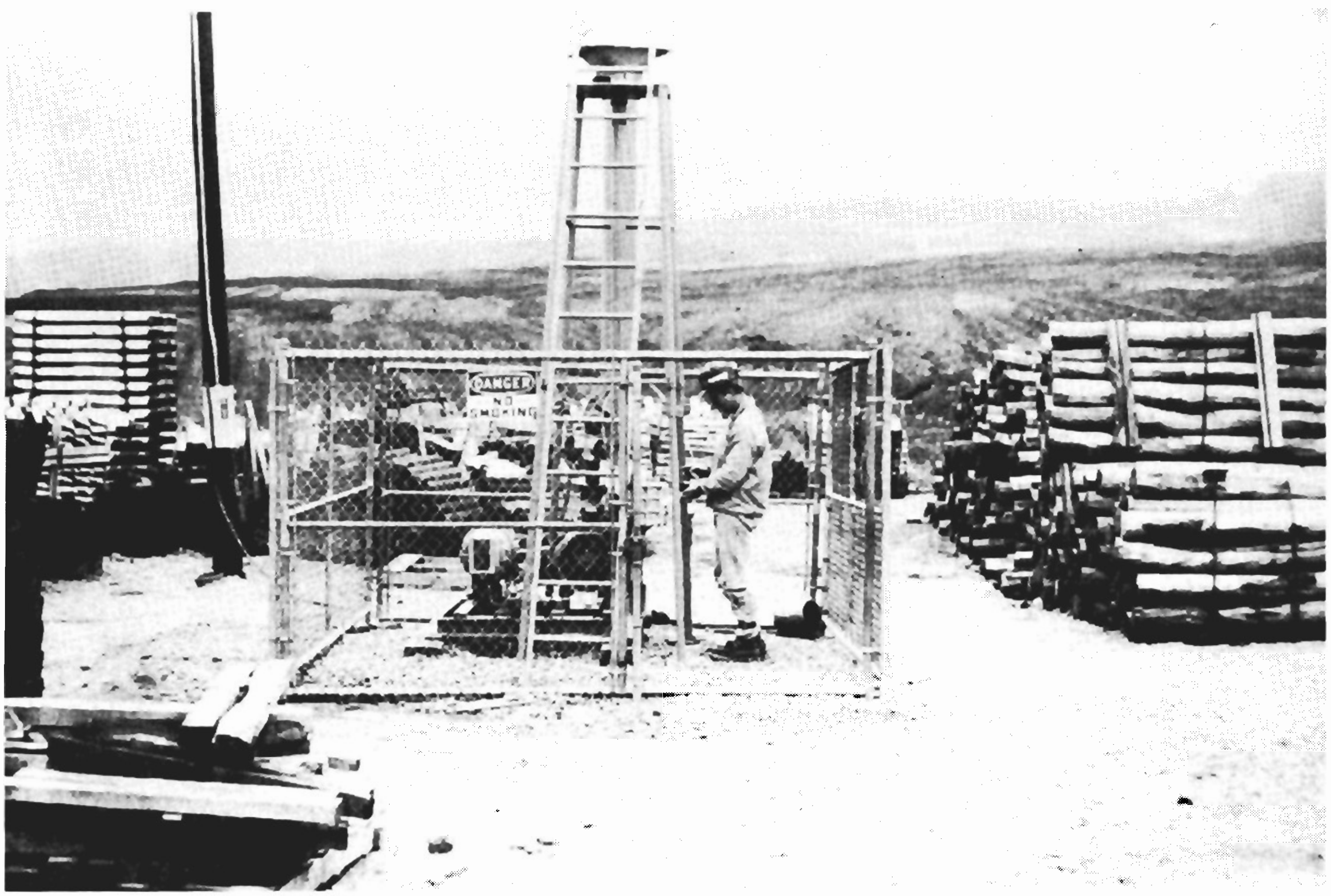

FIGURE 8. - Bureau of Mines vertical borehole and surface sight.

and fabricated by Bureau personnel. Water flows of 3 gpm (11.3 l/min) were measured on hole 1 during this period. The pipeline was drained, and the water separators were installed on holes 1 and 2.

Day 16 was the first day of gas production on hole 2. Only hole 2 was on stream during this test with borehole 33-12 operational. Cross-measure borehole 2, surface borehole 33-12, the Bureau's surface borehole, and the evaluation point were monitored (fig. 3). The relatively low volume of methane extracted during this test does not conclusively establish the effectiveness of underground gob gas drainage during longwall mining (fig. 9). The negative pressure at hole 2 was gradually changed from 3.0 in (7.6 cm) Hg at the beginning of the test to 0.4 in (1.0 cm) Hg near the end of the test.

On day 17, holes 1 and 2 were on stream and borehole 33-12 was shut-in. The lowest volume of methane at the evaluation point corresponds to the peak methane production from the Bureau's surface borehole (fig. 10). Under a negative pressure of 2.5 in (6.4 cm) Hg, 100×10^3 cfd (2.8×10^3 m^3/day) of 100 pct methane were produced on day 17. Methane concentrations were no problem, although borehole 33-12 was shut-in.

With boreholes 33-12 shut-in and holes 1 and 2 producing gas on day 22, the bleeders again were essentially free of methane. Concentrations of methane at the evaluation point never exceeded

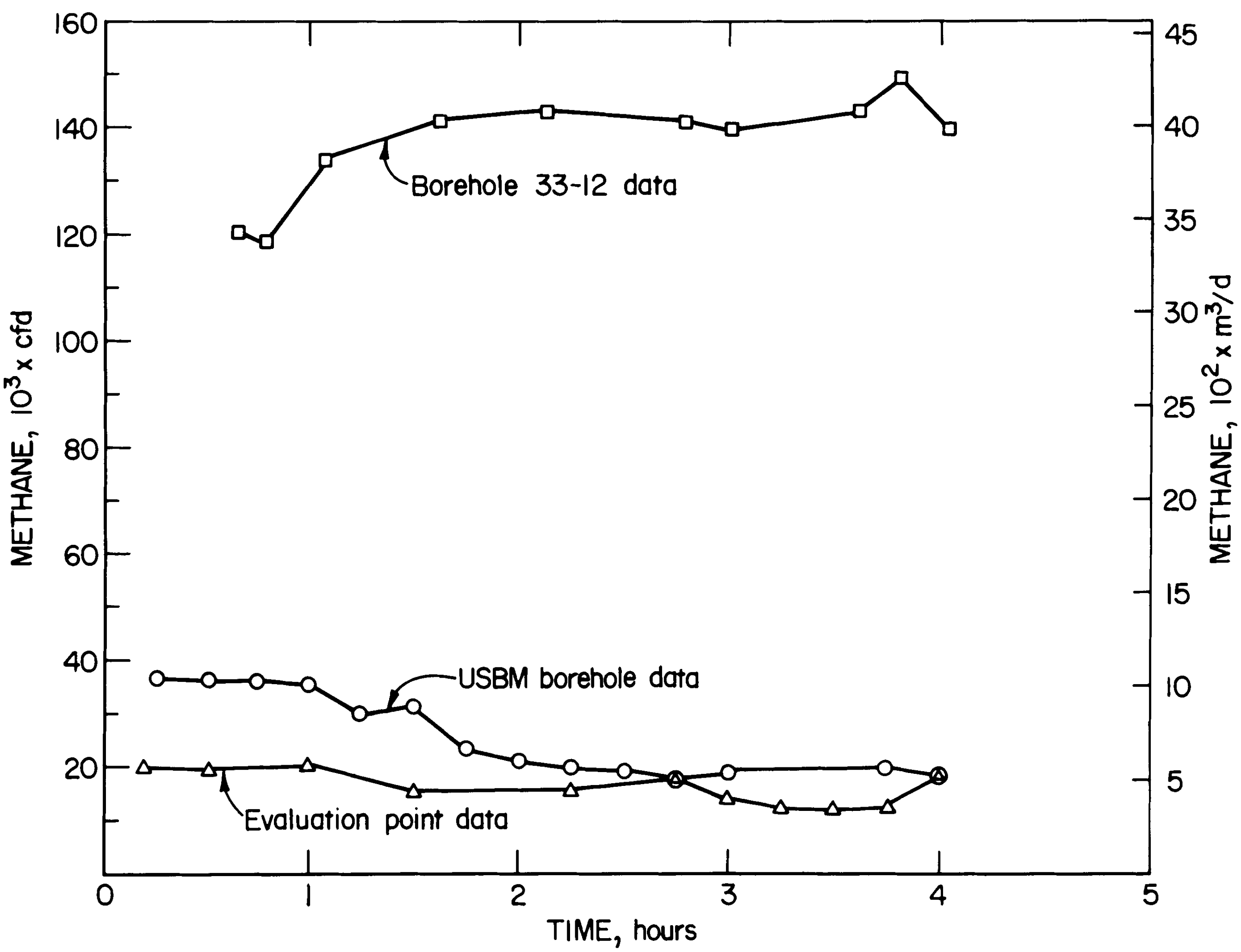

FIGURE 9. - Methane production for day 16.

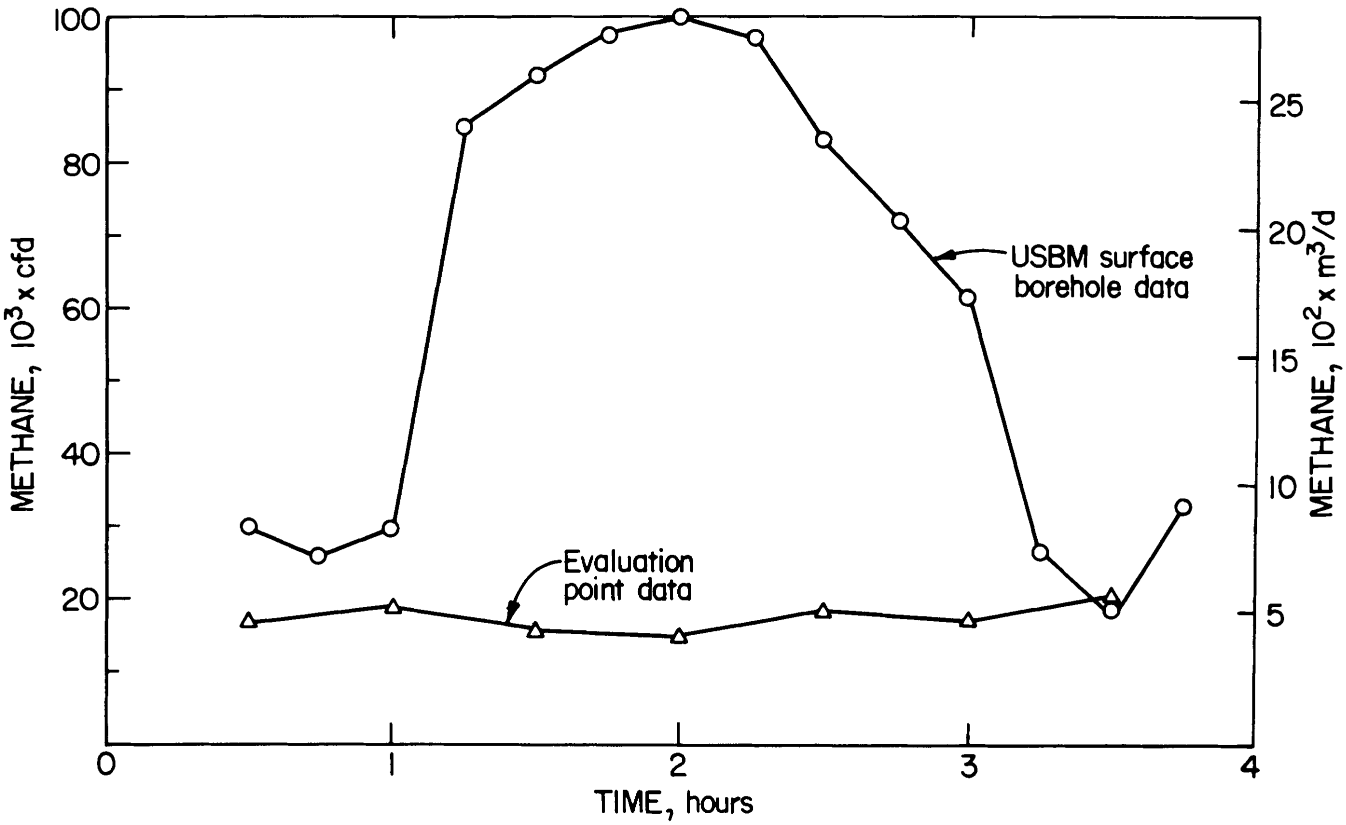

FIGURE 10. - Methane production for day 17.

0.2 pct anywhere in the mouth of the entry. Note the correspondence between the peak production measured on the surface at 1.75 hours and the lowest methane volume underground at 1.85 hours (fig. 11).

The gas being removed by the holes drilled into the roof is either derived from or added to the gas released from the caved area. The holes communicate with gob gas through the gob fracture system, but the holes also penetrate methane-bearing horizons. Before turning off the Bureau's borehole exhauster at 6.25 hours, the 33-12 borehole exhauster was restarted corresponding to a reduced amount of methane at the evaluation point.

A continuous 40-hour test was begun at 8:00 a.m. on day 29. Again, borehole 33-12 was shut-in and holes 1 and 2 were on stream (fig. 12). The partial vacuum at each hole was held constant at about 2.6 in (6.6 cm) Hg. Methane at each hole underground and at the surface did not change appreciably (fig. 13). During test hour 28, holes 1 and 2 were shut-in underground to drain water from the main pipeline. With borehole 33-12 shut-in, the volume of methane at the evaluation point rose steadily until hour 30 of the test, when flow was restored. It can be seen from figure 13 that there was little change in concentration during the nonproducing period. The temporary shut-in of the holes underground was unsuccessful at removing water and increasing pipeline flow. Therefore, the fluctuations in methane production at the surface and methane volume underground between hours 28 and 33 are a function of changes in the volume of the gas reservoir near the gob.

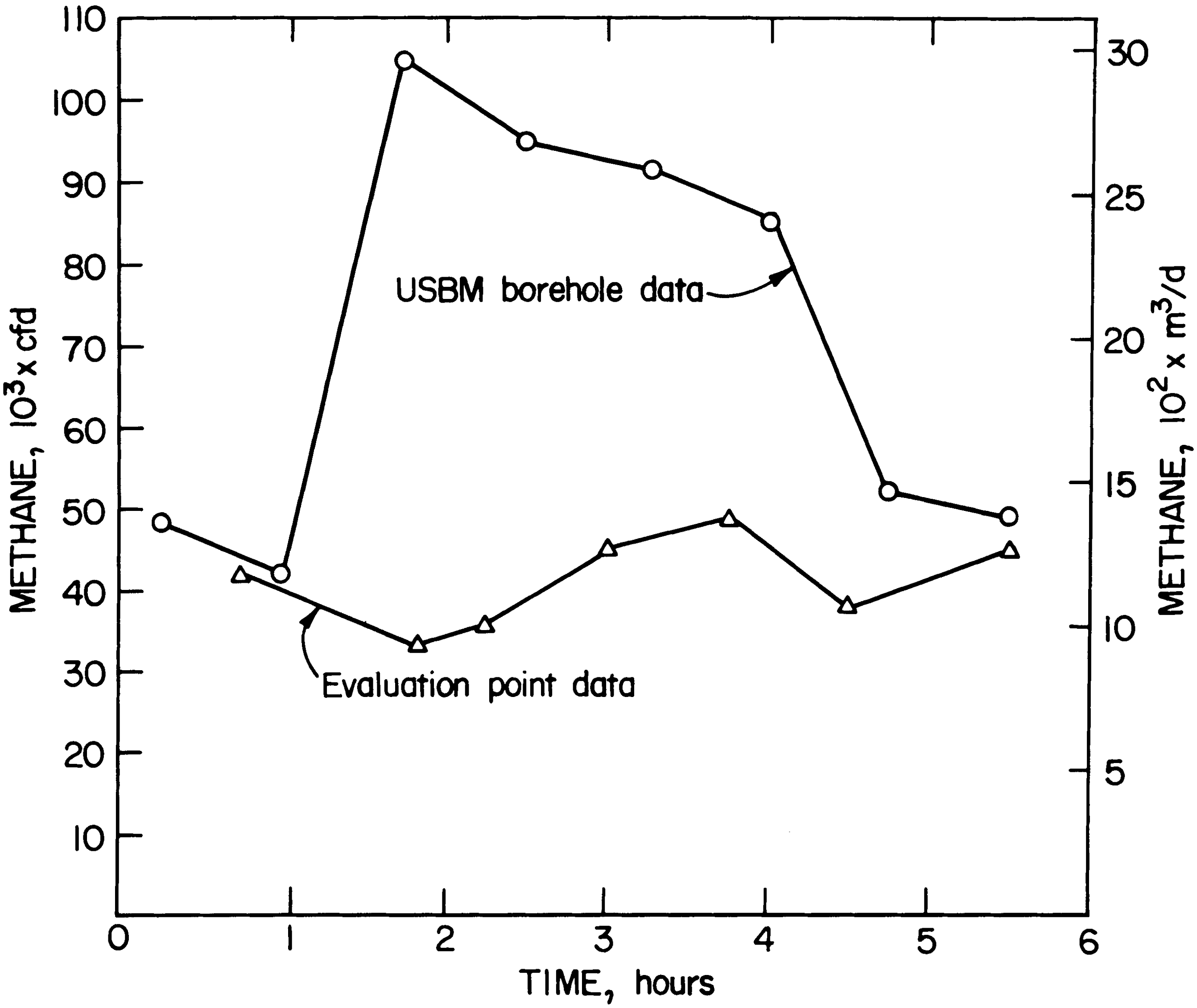

FIGURE 11. - Methane production for day 22.

Interference tests were conducted to quantify communication between holes. No discernible diversion of methane flow could be made. Also, sulfur hexafluoride (SF_6) tracer gas was released into borehole 1. While liberating the gas, hole 2 was on stream at full vacuum in an attempt to pull the tracer through the gob into hole 2 and through the main pipeline. Sampling was conducted at the surface site and at borehole 33-12 for 3 hours following the release of the tracer. Although SF_6 is detectable in concentrations of 1 ppb, no tracer was found in any of the gas bottle samples.

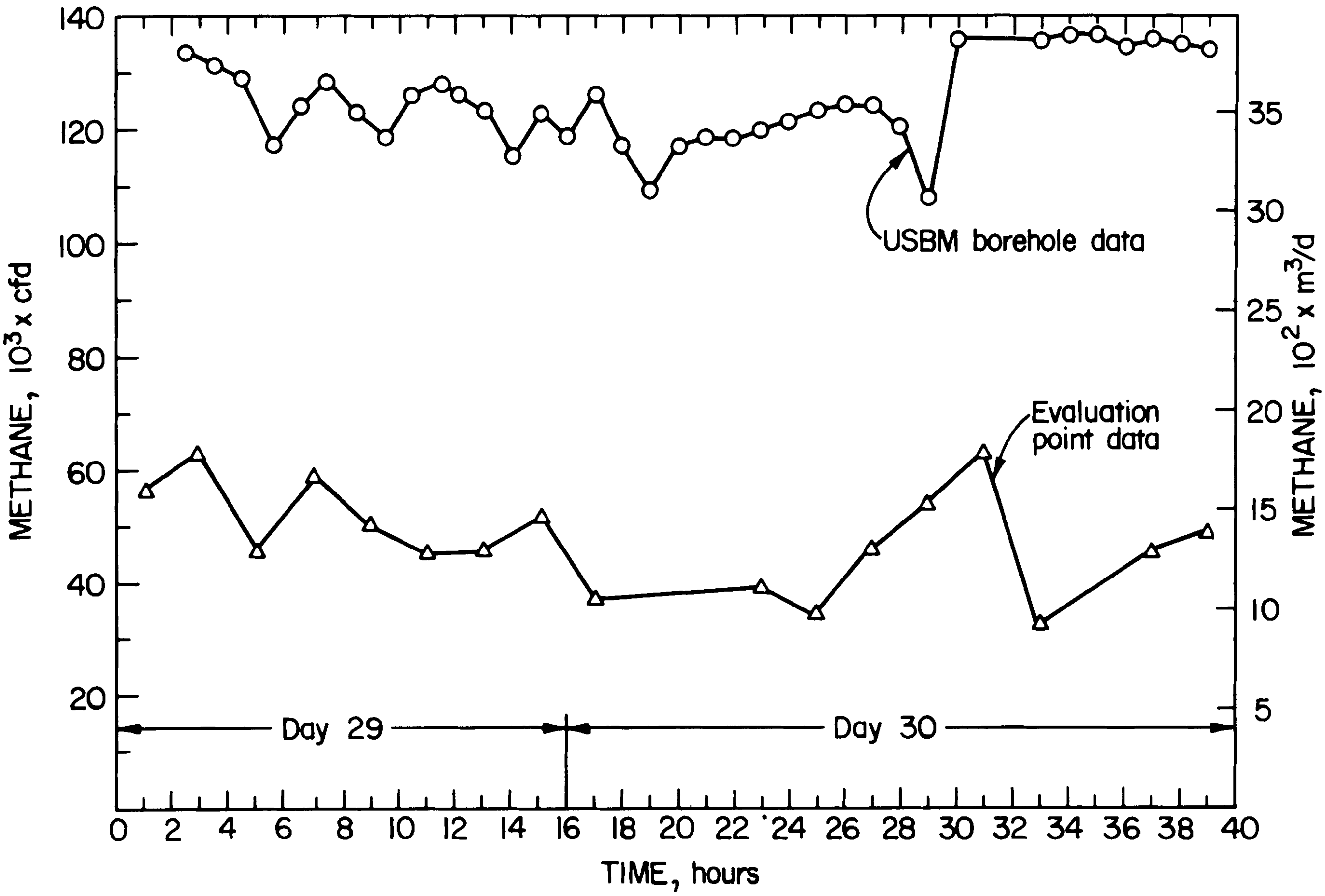

FIGURE 12. - Methane production during a continuous 40-hour test on days 29 and 30.

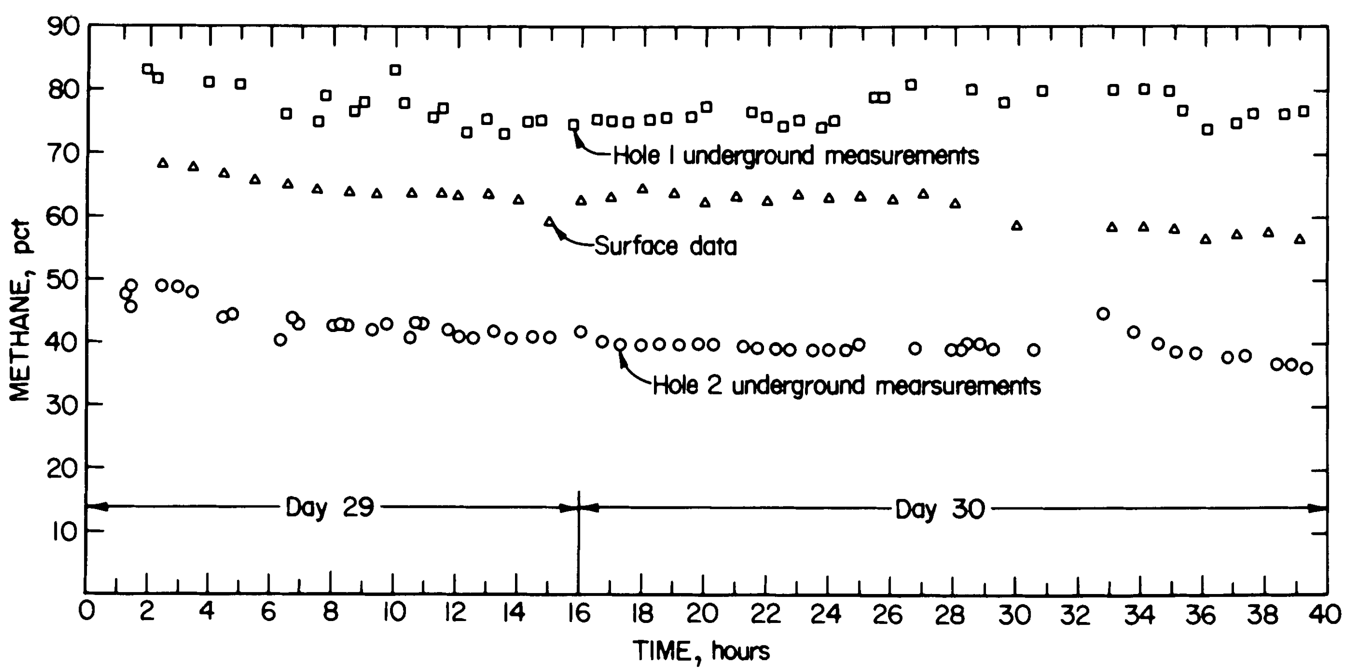

FIGURE 13. - Methane concentration during a continuous 40-hour test on days 29 and 30.

Cumulative Flow Data

Table 2 shows the total volume of methane removed from each hole during this study. Hole 3 produced gas on one day only (day 29).

Following the initial surge of 12 qt/min (11.32 l/min), water flow from hole 1 remained fairly consistent at 4 to 6 qt/min (figs. 14 and 15). On day 36, hole 3 showed a trace of water too small to be accurately measured, less than 0.5 qt (0.47 l) per 5 minutes. Flows from holes 1 and 3 were comparable between days 85 and 90, after which hole 3 flows dropped steadily. Cumulative water flows are given in table 2. Hole 2 produced no water because it did not penetrate the Mahoning Sandstone.

TABLE 2. - Cumulative methane and water flows

	Cumulative methane production		Average methane concentration, pct	Cumulative time of production, hours	Cumulative H_2O production	
	ft^3	m^3			gal	ℓ
Hole 1.......	274,450	7,766	79	69.33	180,100	682,000
Hole 2.......	311,850	8,825	44.5	114.8	0	0
Hole 3.......	1,700	48.1	66	1	36,600	138,500

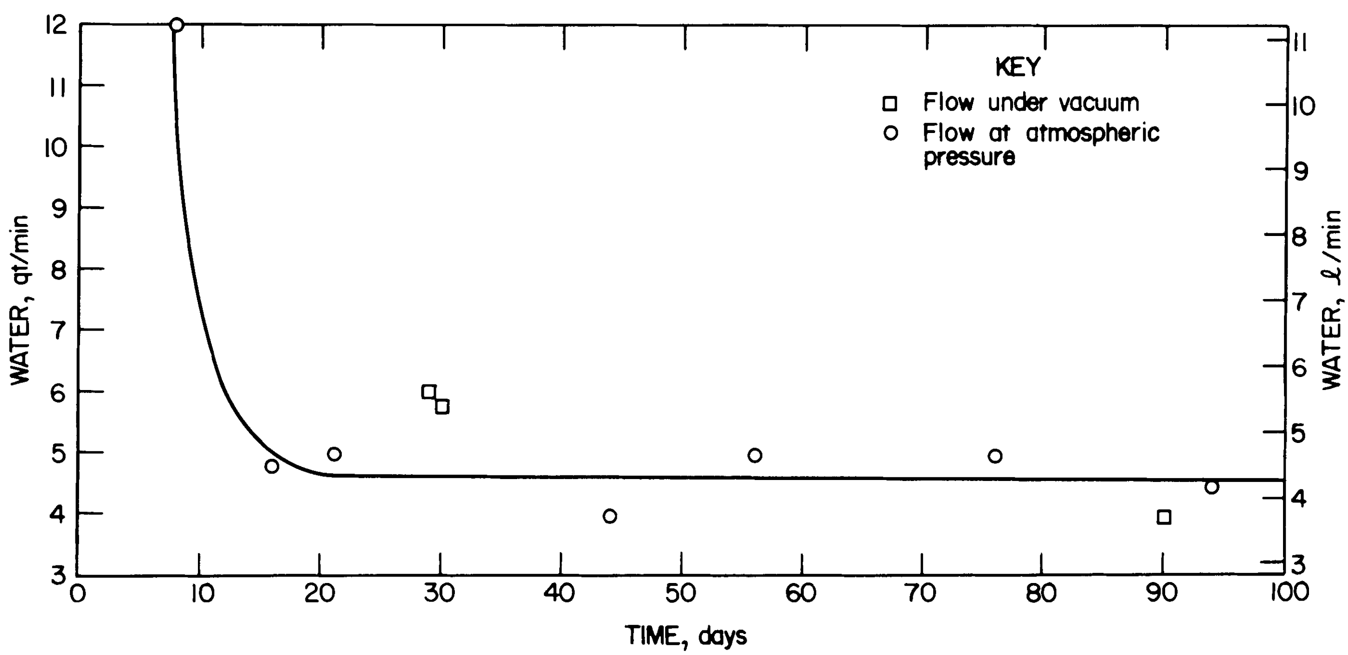

FIGURE 14. - Water production for hole 1.

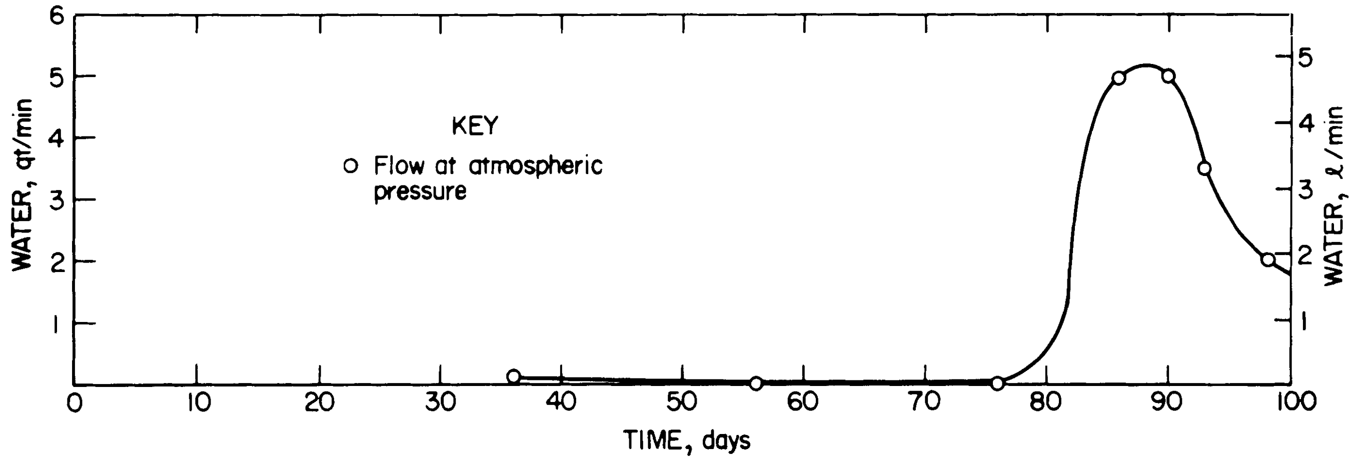

FIGURE 15. - Water production for hole 3.

CONCLUSIONS

Underground gob gas drainage during longwall mining can make invaluable contributions to the U.S. coal mining industry. Future studies may benefit from information that has been presented here. The authors stress that no methane was encountered during drilling; little or no methane was found until the gob fracture system intercepted the cross-measure boreholes, and gas was available from the cross-measure boreholes only when extracted under a negative pressure. Gas production from holes 1 and 2 was more than sufficient to maintain safe methane concentrations in bleeder entries while the conventional means of gob gas drainage was not in use and during longwall mining. Communication between cross-measure boreholes could not be induced with the chosen hole spacing. The concentration of the gas drained was essentially contant over a 40-hour period. A cost analysis will be included in future studies in this field.