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Comparisons Between Cross-Measure Boreholes and Surface Gob Holes

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UNITED STATES DEPARTMENT OF THE INTERIOR

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CONTENTS

ILLUSTRATIONS

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter	kPa	kilopascal
deg	degree	lb/ft^3	pound per cubic foot
d/wk	day per week	m	meter
ft	foot	m^3	cubic meter
ft/s	foot per second	m^3/s	cubic meter per second
ft/s^2	foot per square second	pct	percent
ft^3/min	cubic foot per minute	rad	radian
h	hour	st/d	short ton per day
in	inch		
in Hg	inch of mercury (pressure)		

COMPARISONS BETWEEN CROSS-MEASURE BOREHOLES AND SURFACE GOB HOLES

By T. W. Goodman[1] and J. Cervik[2]

ABSTRACT

The Bureau of Mines conducted studies to compare the effectiveness of the cross-measure borehole system with that of surface gob holes on two successively mined retreating longwalls in the Lower Kittanning Coalbed. Only the cross-measure system was in operation on panel A; on panel B, both systems were in operation. In addition, the cross-measure boreholes on panel B were drilled parallel to the face, whereas those on panel A were drilled at a 45° angle with respect to the longwall axis.

The studies show that the cross-measure system captured 71 pct of the methane generated by longwall mining on panel A. On panel B, the surface gob hole dominated over the cross-measure system for about 700 ft (213 m) after it was intercepted. Beyond that point, the cross-measure system dominated. About 93 pct of the methane generated on panel B was captured by the two systems.

Cross-measure boreholes that were drilled parallel to the face were as effective as boreholes oriented 45° with respect to the longwall axis. In addition, they are shorter and require less drilling time. Comparison between observed gas pressure differentials in boreholes and calculated values indicate that boreholes can be shortened further to 140 ft (43 m). Additional studies are needed to verify these calculations.

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INTRODUCTION

The methods of controlling methane during longwall mining in the United States are ventilation and surface gob holes. Generally, three to four surface gob holes are drilled over a 5,000-ft (1,524-m) panel. Gob holes cannot always be drilled because of rough topography and/or right-of-way problems, or because mining may be under populated areas.

The cross-measure system has been indispensable in degasifying longwall gobs in Europe since Germany first introduced methane drainage using piping systems in 1943 (1).[3] The European coal basins tend to be deeper and steeper dipping, and more frequently are located under populated areas than are those in the United States (2). The single-entry longwalls in Europe are usually advanced, in contrast to the predominantly retreated longwalls in the United States. This prevents immediate technology transfer and generates the need for research in this area.

The Bureau of Mines conducted several studies structured to develop design criteria for the cross-measure technique. Two of the preliminary studies (3-4) were sited in the Upper Kittanning Coalbed, where the European technology underwent feasibility tests. Adaptations, experimentally determined in those tests, have been introduced in two studies conducted on adjacent panels in the Lower Kittanning Coalbed. The objectives of the studies in the Lower Kittanning Coalbed were to compare the effectiveness of the cross-measure technique and surface gob holes in controlling gob gas during retreat longwall mining and to further modify European procedures to meet the needs of the U.S. mining industry.

ACKNOWLEDGMENTS

Special thanks are due to the following officials of BethEnergy Mines Inc., Cambria Division, for their cooperation and help in this study at the Cambria 33 Mine, Ebensburg, PA: E.J. Korber, manager; R. F. Dobson, general superintendent; D. Weaver, geological engineer; N. Carpinello, mine foreman; G. W. Moyer, general assistant; and W. Miller, longwall foreman.

STUDY AREA

The studies were conducted in the Lower Kittanning Coalbed, which is about 48 in (1.2 m) thick. The stratigraphic column shows there are three coal groups located about 15, 85, and 125 ft (5, 26, and 38 m) above the roof of the Lower Kittanning Coalbed (fig. 1). A total of 9 ft (2.7 m) of coal lies within the first 130 ft (40 m) above the roof. These coalbeds are known sources of methane. Overburden is about 645 ft (197 m).

The test retreating longwalls are located between 16 Right and 18 Right off F West in BethEnergy Mines, Inc., Cambria 33 Mine (fig. 2). A detailed view of the test panel is shown in figure 3. All the cross-measure boreholes were drilled from the center entry and connected to an underground pipeline. A surface borehole was drilled between 16 Right and 17 Right to bring the gas to the surface. The center entries were supported with cribs to protect the underground pipelines and to prevent caving so that access to the pipelines and cross-measure boreholes could be maintained during the lives of the panels.

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

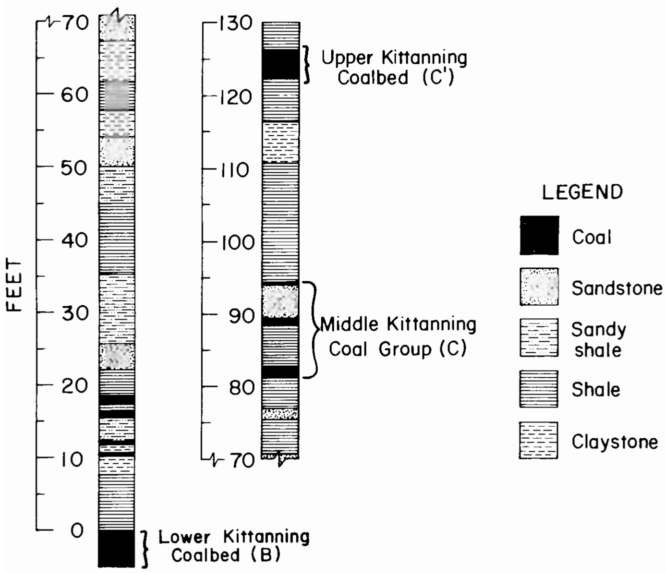

FIGURE 1. - Stratigraphic column above Lower Kittanning Coalbed.

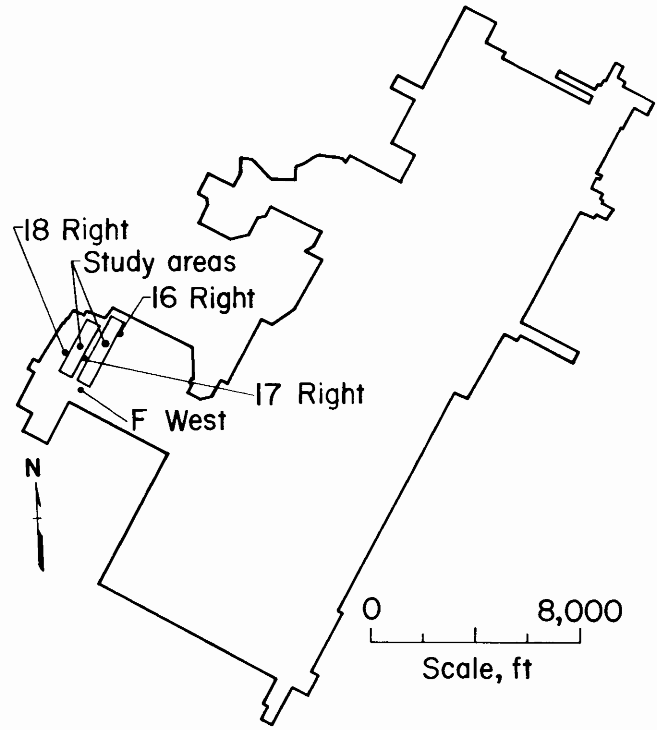

FIGURE 2. - BethEnergy Mines Inc., Cambria 33 Mine.

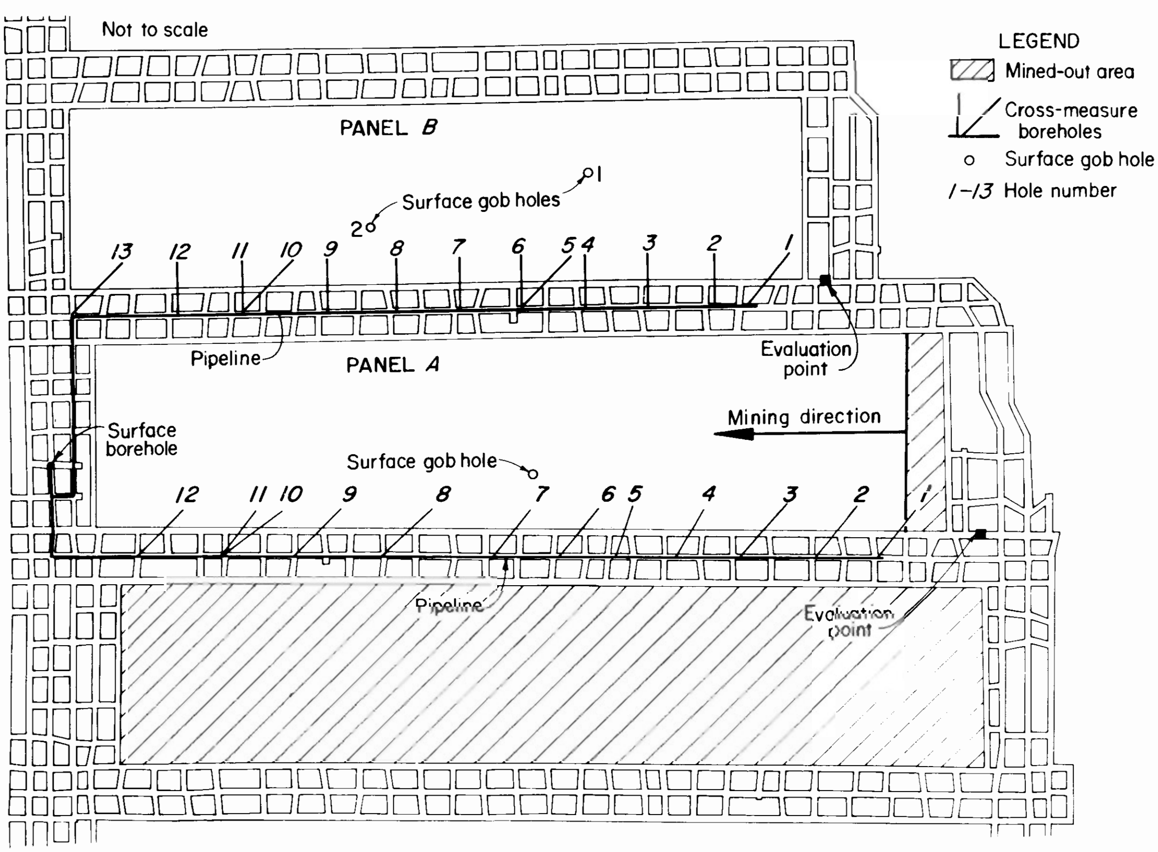

FIGURE 3. - Longwall test panels.

CROSS-MEASURE BOREHOLE SYSTEM

DRILLING EQUIPMENT AND PROCEDURES

The cross-measure boreholes were drilled similarly to those in the Upper Kittanning (4) and the Lower Kittanning Coalbed (5) studies. The first 30 ft (9 m) was cored with a 6-in (15-cm) diamond bit core barrel, and the remainder with a 1.9-in (5-cm) bit. A 4-in (10-cm) diameter 20-ft (6.1-m) plastic pipe was then grouted 18 ft (5.5 m) into the hole. Gas-water separators were used on each hole. Azimuth and declination surveys were made of each hole after the drilling phase was completed.

UNDERGROUND INSTRUMENTATION

Figure 4 shows the connection of a cross-measure borehole to the underground pipeline. Gas flow rates (air plus methane) were calculated from differential pressure measurements with a U-tube manometer across the pressure taps of the venturi. Methane concentration in the gas flow was determined with a hand-held 0- to 100-pct methanometer, and the partial vacuum at each borehole was measured with a manometer at the inlet venturi tap 1. Return air from each longwall was channeled through a single entry (evaluation point) before it entered the main returns (fig. 3). Ventilation surveys were made in these locations using a methane detector and an anemometer. The total gas flows from each test panel were obtained by summing the individual borehole flows.

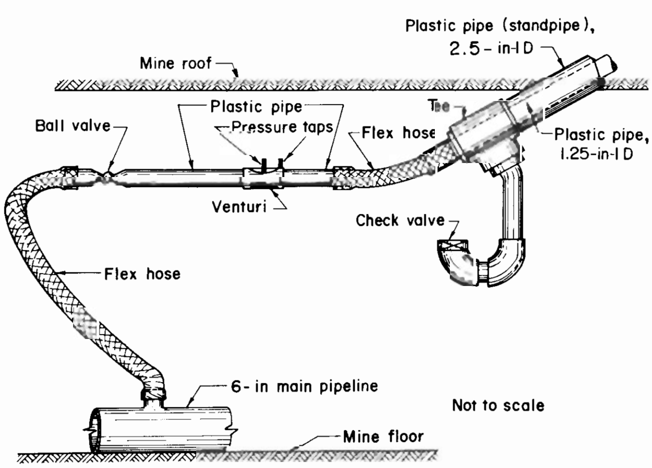

FIGURE 4. - Underground measurement instrumentation.

METHANE REMOVAL

Longwall mining creates a void which eventually begins to cave. Fractures radiate from the caving zone and intercept methane-bearing rock strata and coalbeds in the roof. These fractures conduct methane into the mine opening. Holes drilled into the roof strata intercept the fractures and capture the methane. The holes are connected to an underground 6-in (15-cm) diameter polyethylene pipeline (fig. 4), which transports the methane to the surface through a cased 8-in (20-cm) vertical borehole.

Gas flow occurs into a cross-measure borehole after undermining of the hole and application of a partial vacuum by an exhauster or vacuum pump on the system. In this study, two exhausters were used (fig. 5). The capacity of the smaller exhauster, used initially until the gas flow from the undermined cross-measure boreholes reached about 400 ft^3/min (0.19 m^3/s), ranged to 450 ft^3/min (0.21 m^3/s) with partial vacuums up to 8.65 in Hg (29 kPa). The larger exhauster, used thereafter, requires a minimum flow of 350 ft^3/min (0.17 m^3/s). Maximum capacity is 1,300 ft^3/min (0.61 m^3/s) with partial vacuums up to 12.6 in Hg (42 kPa).

GAS-WATER SEPARATOR

Each borehole was equipped with a Bureau-designed gas-water separator (6). Figure 6 shows the design of the separator used on each borehole on panel A. In some instances, water blocking problems developed when rock particles washed down the hole and accumulated in the annulus between the gas drainage pipe and the standpipe or in the pipe extension near the one-way check valve. When this occurred, the water accumulated in the annulus until the slot in the gas drainage pipe was reached and then discharged into the underground pipeline. To circumvent this problem, the first 30 ft (9 m) of each cross-measure

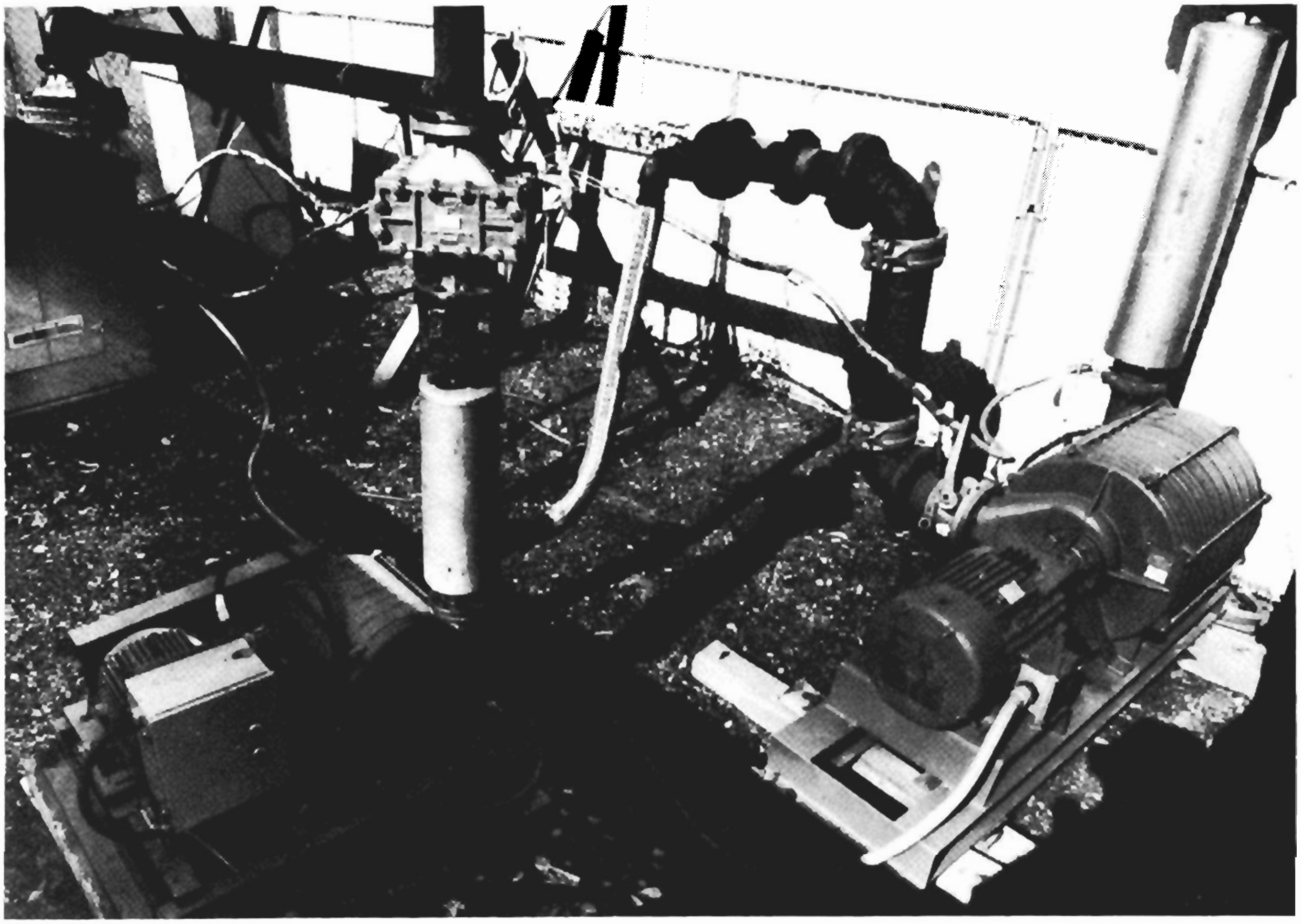

FIGURE 5. - Surface exhausters.

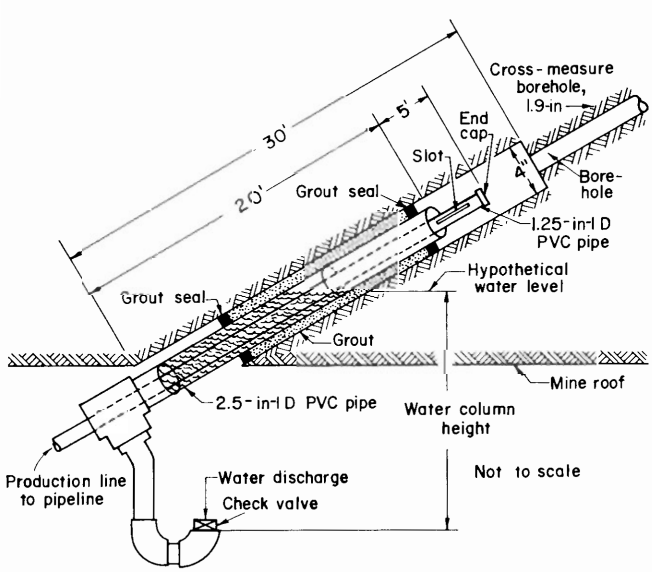

FIGURE 6. - Gas-water separators.

borehole on panel B was enlarged from 4 to 6 in (102 to 152 mm) so that the standpipe diameter could be increased from 2.5 to 4 in (64 to 102 mm) and the gas drainage pipe diameter from 1.5 to 2 in (38 to 51 mm). Thus the annulus size was increased by a factor of 2 over the holes on panel A. No debris accumulated in the annulus of boreholes on panel B, and little downtime occurred due to water bypassing the separator. The separators, however, should be checked periodically to ensure that no rock particles are accumulating in the pipe extension near the one-way check valve.

CROSS-MEASURE BOREHOLE DESIGN

The design parameters for the cross-measure boreholes on panel A are similar to the design used in earlier Bureau studies (3-4). These boreholes were

TABLE 1. - Design parameters for cross-measure boreholes

Borehole parameters	Panel A	Panel B
Angle, deg:		
Vertical	28	35
Horizontal	45	90
Length...ft..	280	225
Terminal height...ft..	130	130
Spacing, ft:		
1st half of panel	200	200
2d half of panel	300	300

drilled 45° with respect to the axis on the longwall, which is a common practice in Europe. On panel B, the cross-measure boreholes were drilled perpendicular to the axis on the longwall. This is a departure from the European design, where the holes must be drilled diagonally to reach the gas ahead of the face in advancing longwall systems. In European retreating systems, the holes must be dismantled when the face reaches the collar of the hole owing to caving of the single entry.

Table 1 summarizes the design parameters for the two panels. All boreholes terminate about 130 ft (40 m) above the mined coalbed, and even though the boreholes of panel B are 55 ft (17 m) shorter than those of panel A, the penetration depth of the boreholes into the gob is about the same for the two panels. (The penetration depth is the horizontal projection of the hole parallel to the line of the face.) All holes were surveyed after completion of drilling to determine the actual path of the bit through the roof strata. In general, the surveys showed that the holes turned upward more steeply and to the right because of clockwise rotation of the bit.

SURFACE GOB HOLES

Surface gob holes have been used at the Cambria 33 Mine since 1968. A typical borehole plan is shown in figure 7. The first gob hole is located about 400 ft (122 m) from the starting face, and others are spaced equidistant along the remainder of the panel.

The surface gob hole fan is energized after the hole is undermined by the longwall miner. When the concentration of the methane drops below 25 pct, the hole is shut in. Methane concentration and flow readings are made daily during mining of the longwall panel, using a methane detector and anemometer.

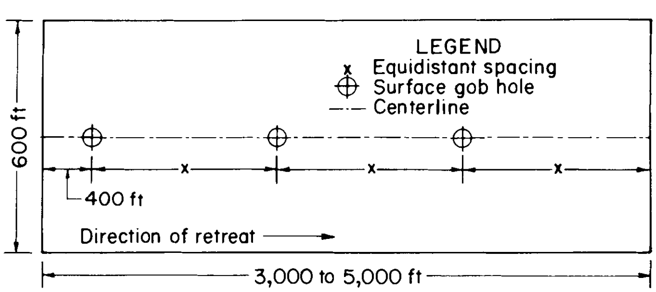

FIGURE 7. - Surface gob hole location plan.

For panel A, only one surface gob hole could be drilled because of a populated area on the surface (fig. 3). It was drilled about 1,300 ft (396 m) from the start of the panel. Even this borehole had to be displaced about 75 ft (23 m) from the centerline toward the return side of the longwall to avoid surface structures. Panel length is 2,700 ft (823 m). For panel B, two surface gob holes were drilled 650 and 1,350 ft (198 and 411 m) from the start of the panel. Both surface gob holes were displaced from the centerline of the panel because of surface right-of-way problems. Panel B is 2,340 ft (713) long.

DATA ANALYSIS

PANEL A

Panel A was worked three shifts per day but on a predominantly 3-d/wk schedule because of the low demand for coal (fig. 8). The panel was completely mined in 69 working days, which were spread over a 240-day interval and included three idle periods of 73, 32, and 10 days.

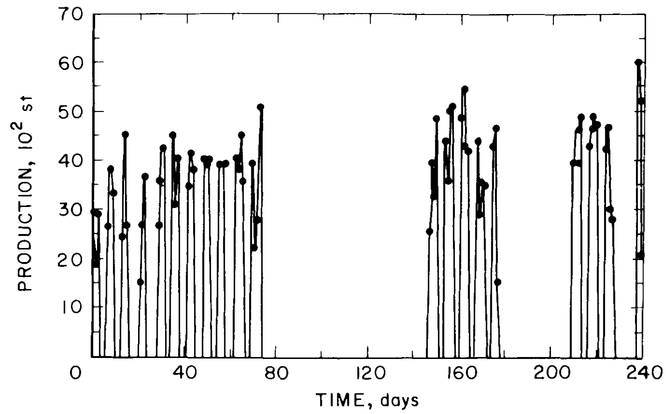

FIGURE 8. - Daily longwall coal production (panel A).

Cross-Measure System--Gas Production

Most boreholes did not produce gas until a partial vacuum was applied and the longwall face passed 75 to 100 ft (23 to 30 m) beyond the end of a borehole (but before the face reached its collar). Holes 5 and 10 were exceptions. A free flow of methane [60 ft^3/min (0.028 m^3/s)] was measured from hole 5 before the face reached its collar. After the face passed beyond the collar, the free flow stopped and a partial vacuum was required to maintain flow. Gas production occurred from hole 10 only after the face passed well beyond its collar.

The methane flow from the cross-measure system is shown in figure 9. Also shown are the times when each borehole started methane production, which is greatest when the borehole first goes on production. Methane flow from the cross-measure system gradually increased as the number of boreholes undermined increased. That methane flow rates are dependent on whether coal is actively being mined is clearly demonstrated by the much lower flow rates during prolonged idle periods. During the first idle period (73 days), methane flow declined from 400 to 100 ft^3/min (0.19 to 0.05 m^3/s); when mining resumed, the flow increased and returned to about 400 ft^3/min (0.19 m^3/s). These data indicate that about 75 pct of the methane in the gob comes from the newly fractured roof strata near the face.

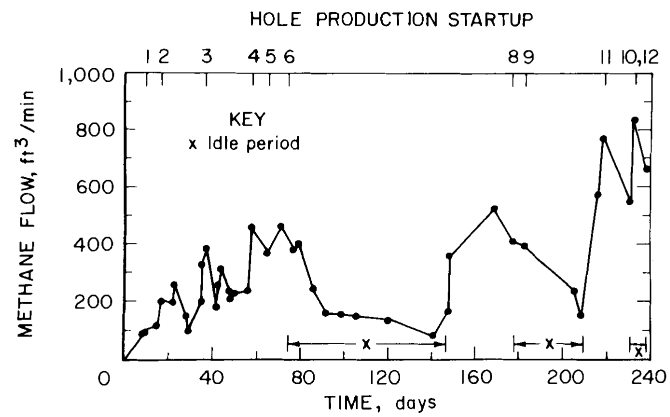

FIGURE 9. - Methane flow from cross-measure system (panel A).

Figure 10 shows the variations in methane concentration in the gas flow from hole 2; they are typical of the methane concentration variations in gas flow from

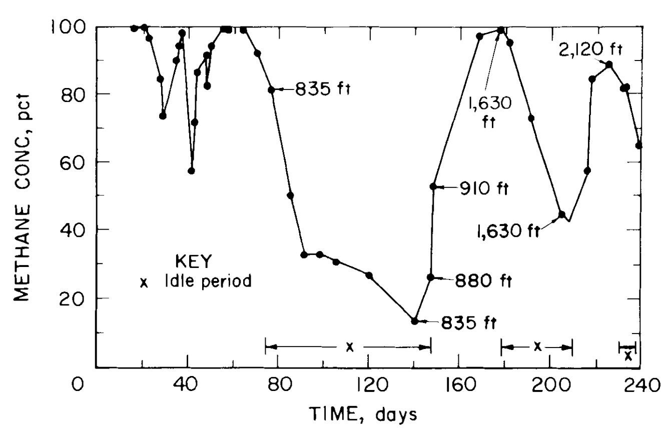

FIGURE 10. - Methane concentrations in gas flow from hole 2 (panel A).

other cross-measure boreholes. The methane concentration averaged about 90 pct but dropped to about 30 pct in 20 days during the first idle period. The distance between hole 2 and the longwall face was 835 ft (255 m) at this time. When mining resumed on day 140, the methane concentration in the gas flow began to increase and reached 100 pct on day 178, when the longwall face was 1,630 ft (497 m) from hole 2. During the second idle period (day 180 to 210), the methane concentration again declined, but it increased after mining resumed and reached 90 pct. At this time, the distance between the longwall face and hole 2 was 2,120 ft (646 m). These data clearly indicate the gob is quite permeable and that methane migrates easily through the gob for distances of at least 2,120 ft (646 m).

The effectiveness of the cross-measure system in controlling methane in the return air from the longwall is shown in figure 11. The point in time when each borehole started to produce gas is shown along the top on the graph. Methane flows in the return air gradually decreased from 250 to 100 ft^3/min (0.12 to 0.05 m^3/s) as the number of the boreholes producing gas increased. The effect of each borehole on methane flow in the return air is clearly demonstrated by the large decrease in flow in the return air immediately after each borehole started gob gas production. These peak flows ranged from about 200 to 450 ft^3/min

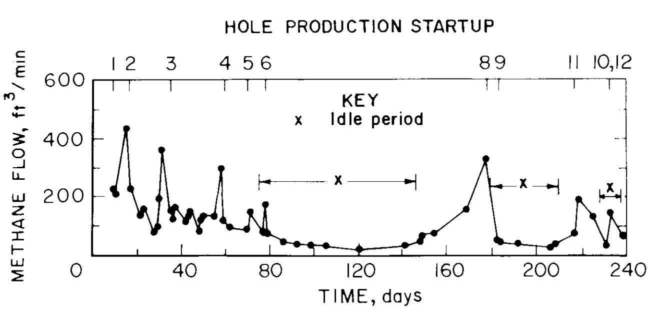

FIGURE 11. - Methane flow in return air (panel A).

(0.09 to 0.21 m^3/s), suggesting that the 200-ft (61-m) spacing should be reduced.

The first large roof fall after mining of the panel was started, was accompanied by large flows of methane, and mining was suspended for short periods because sufficient air was not available to maintain methane concentrations in the returns at permissible levels. Generally, only one borehole was on production at this time, and the quantity of the gob gas that can be drawn through a 2-in (51-mm) diameter borehole is small in comparison to the tremendous quantities generated in the gob. Consequently, gob gas began to spill into and overload the return air system. Additional boreholes drilled between holes 1 and 2 and between holes 2 and 3 would prevent large peak flows and would lower the general level of methane flow in the returns. Therefore, boreholes should be spaced 100 ft (30 m) apart along the first 600 ft (183 m) of the longwall and thereafter 200 ft (61 m) apart.

Surface Gob Hole--Gas Production

The surface gob hole produced gob gas for about 6 days and was finally shut in because of low methane concentrations in the gas flow. The hole vented about 1,000,000 ft^3 (28,300 m^3) of methane during its short productive life. Gas production started on day 156, and no indications exist that the gob hole affected methane flows in the return air, despite the fact that hole 7, which was undermined around day 160 and produced no gas, is in the same area as the surface gob hole. The large peak methane flow around day 180 (fig. 11) was caused by a partially blocked pipeline; this may have masked the effect of the surface gob hole.

Table 2 shows that the cross-measure borehole system captured 70.7 pct of the methane produced by the mining operation. About 28.7 pct of the methane entered the mine ventilation system, and only 0.6 pct was captured by the surface gob hole.

TABLE 2. - Panel A and B capture ratios

System	Methane, 10^6 ft^3	Capture ratio, pct
PANEL A		
Cross-measure boreholes	118	70.7
Return air.............	48	28.7
Surface gob hole.......	1	.6
Total.............	167	100.0
PANEL B (DAYS 37-59)		
Cross-measure boreholes	8	28.0
Return air.............	2	7.0
Surface gob hole.......	19	65.0
Total.............	29	100.0
PANEL B (DAYS 60-121)		
Cross-measure boreholes	28	62.0
Return air.............	3	7.0
Surface gob holes......	14	31.0
Total.............	45	100.0

PANEL B

The panel was completely extracted in 61 working days, which were spread over a 121-day interval and included two idle periods of 11 and 25 days (fig. 12).

Cross-Measure and Surface Gob Holes--Gas Production

All boreholes produced gas continuously after they went on production, except hole 10, which produced for only 3 weeks. Gas flows began after mining moved 75 to 100 ft (23 to 30 m) past the boreholes, which are oriented parallel to the longwall face. For boreholes oriented at 45° (0.79 rad) with the longwall axis, gas production started after the longwall face passed 75 to 100 ft (23 to 30 m) beyond the end of the borehole but before the face reached its collar.

Figure 13 shows that the partial vacuum of the surface pump ranged from 8 to 10 in Hg (27 to 34 kPa) during the study. The partial vacuum, however, on individual boreholes generally decreases with time. During the early life of the panel, the capacity of the surface pump is distributed over a few holes, and the partial vacuum is high. Addition of boreholes to the system causes the partial vacuum on the older boreholes to decrease.

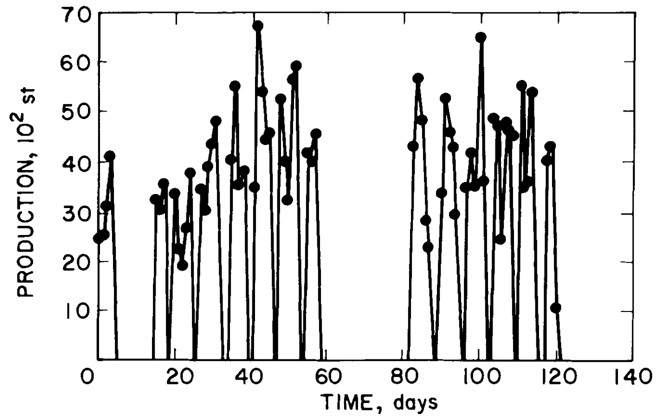

FIGURE 12. - Daily longwall coal production (panel B).

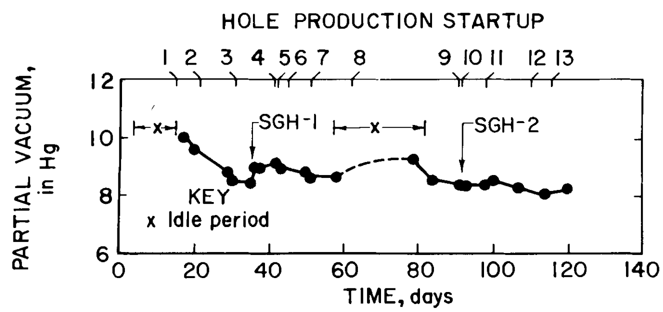

FIGURE 13. - Partial vacuum measured at surface pump (panel B).

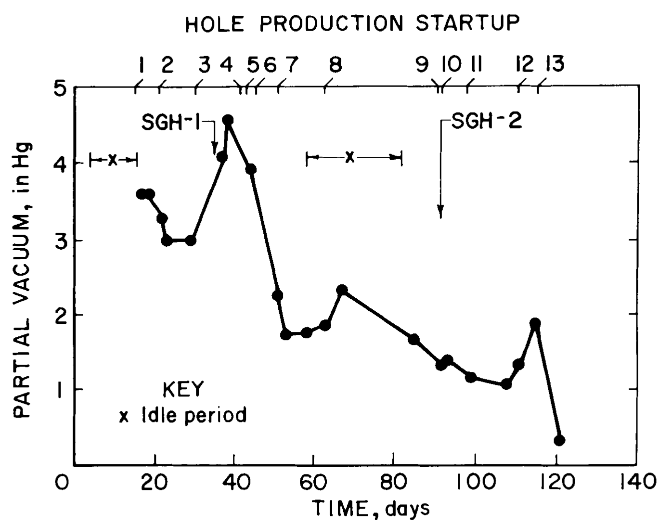

FIGURE 14. - Partial vacuum measured at hole 1 (panel B).

Figure 14 shows the partial vacuum curve for hole 1, which is typical for other boreholes. The partial vacuum decreased from about 4 in Hg (14 kPa) when only 2 boreholes were producing to about

1 in Hg (3.4 kPa) when 13 boreholes were producing. The increase in partial vacuum on hole 1 around day 37 was caused by the start of gas production from surface gob hole 1 (SGH-1), which caused the surface exhauster to work harder to maintain flow through the cross-measure system. SGH-2, which was intercepted on day 92, is too far from hole 1 to have had any effect.

Generally, gas flow (methane plus air) and methane flow (fig. 9) from the cross-measure system on panel A increased as the number of boreholes undermined increased. On panel B, gas and methane flows increased when holes 1 to 3 were undermined (fig. 15). The differences between the two curves represent the amount of air drawn into the cross-measure system. When SGH-1 was undermined, both gas and methane flows decreased. Gas flow recovered more quickly than methane flow and exceeded the gas flow that existed before SHG-1 was intercepted; the methane flow did not fully recover. These data indicate that the cross-measure system was drawing more mine air into the system to make up for the loss of methane to SGH-1. Methane flow was about 1,800 ft^3/min (0.85 m^3/s) when SGH-1 started production, and declined over a 7-day period to about 500 ft^3/min (0.24 m^3/s) (fig. 16). The high methane flow from SGH-1 caused the declines in both gas and methane flows from the cross-measure system. Because the flow from SGH-1 declined rapidly, both methane and gas flows from the cross-measure system increased again. For the next 23 days, both methane and gas flows remained constant even though holes 4 to 8 were undermined. After day 80, gas and methane flows began to increase again as holes 9 to 13 were undermined. These data indicate that the zone of influence of SGH-1 extended about 700 ft (211 m). Beyond that distance, flows from the cross-measure system increased as additional boreholes were undermined. SGH-2 caused a slight decrease in flow from the cross-measure system, but its effect was not as great as that of SGH-1 (fig. 15).

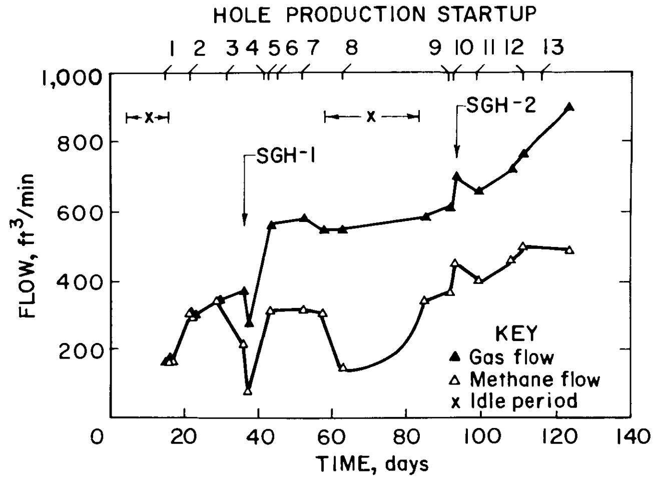

FIGURE 15. - Gas and methane flows from cross-measure boreholes (panel B).

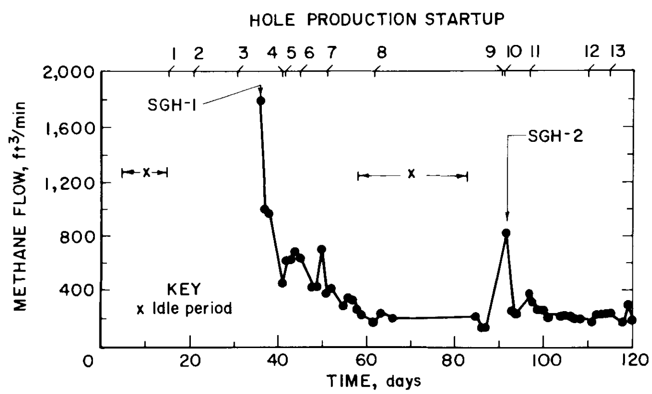

FIGURE 16. - Methane flow from surface gob holes (panel B).

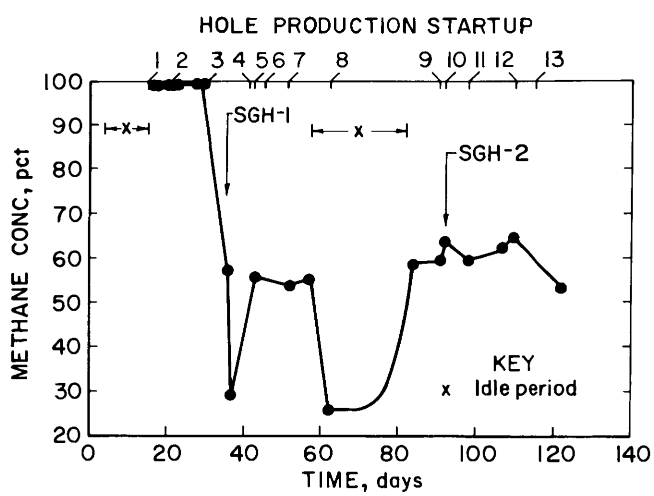

FIGURE 17. - Methane concentration in gas flow from the cross-measure system (panel B).

The concentration of methane in gas flow from the cross-measure system was close to 100 pct before SGH-1 was intercepted (fig. 17). The concentration dropped to about 30 pct for a few days after SGH-1 was intercepted and recovered to about 55 pct. These measurements reinforce the gas and methane flow (fig. 15) data, which demonstrate the tremendous influence of SGH-1 on the cross-measure system. Except for the 25-day idle period when the concentration dropped to 30 pct and then increased again when mining resumed, the concentration changed only a few points for the remainder of the study. The effect of SGH-2 on methane concentration in the gas flow from the cross-measure system was negligible.

Methane flow in the return air from the longwall showed characteristics similar to those noted in the panel A study (fig. 11). It decreased dramatically after hole 2 was intercepted, began to build up again during mining, and then decreased again when hole 3 was intercepted (fig. 18). Shortly after hole 3 went on production, SGH-1 was intercepted and the methane flow in the return dropped to 50 ft^3/min (0.023 m^3/s) or less for the remainder of the study. The peak methane flows that occurred during the early life of the panel suggest that the boreholes were spaced too far apart. A closer spacing of holes would eliminate the peak flows and lower the general level of methane in the returns.

Capture Ratios

Figure 16 shows the combined methane flow from SGH-1 and SGH-2. Methane flow from SGH-1 declined from 1,800 to 200 ft^3/min (0.85 to 0.09 m^3/s) in about 22 days (day 37 to 59); during this time interval, the hole captured 65 pct of the methane generated by the mining operation (table 2). The cross-measure system captured 28 pct, and the other 7 pct entered the mine ventilation system. However, for the remainder of the panel (days 60 to 121), when the combined flow from SGH-1 and SGH-2 averaged 200 ft^3/min (0.09 m^3/s), the cross-measure boreholes were the dominant system controlling

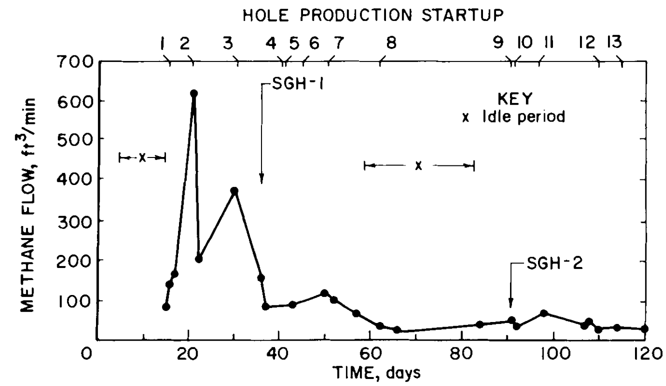

FIGURE 18. - Methane flow in return air (panel B).

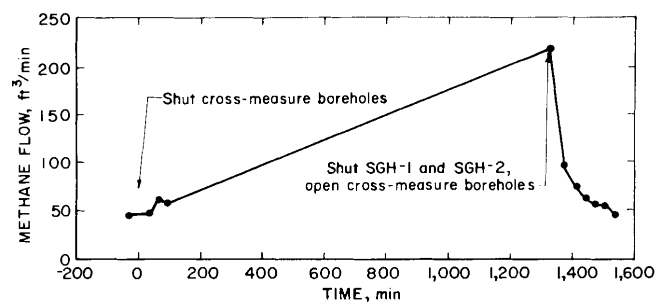

FIGURE 19. - Effectiveness of cross-measure system and surface gob holes (panel B).

methane. Table 2 shows that the cross-measure system captured 62 pct of the methane, compared with 28 pct for the two surface gob holes during this period.

The capture ratios for the two systems might have been much higher than indicated in table 2 had only the surface gob holes or the cross-measure system been in operation on panel B. The surface gob holes did affect the performance of the cross-measure system, and undoubtedly the cross-measure system affected the performance of the surface gob holes. On panel A, the methane concentration in the gas flow from the cross-measure system averaged 80 pct or greater during mining. On panel B, the concentration dropped from 100 to about 60 pct after SGH-1 was intercepted (fig. 17). Tests conducted on panel B during the second idle period (day 62) indicate that no change occurred in the methane flow in the return air over a 20-h period when the cross-measure system was closed and the surface gob hole was operating. The test showed that the surface gob hole alone could control methane flow in the return air. However, in a later test on day 109, methane flow in the return air increased from 50 to 220 ft^3/min (0.02 to 0.10 m^3/s) over a 22-h period when the cross-measure system was not operating and the two surface gob holes were producing methane (fig. 19). When the situation was reversed--that is, the surface gob holes were shut in and the cross-measure system was in operation--the methane flow in the return air decreased rapidly from 220 to 50 ft^3/min (0.10 to 0.02 m^3/s) in about 3.5 h. During the period when the cross-measure system was not in operation, over 50 pct of the methane produced by the mining operation entered the mine ventilation system. The test was terminated to avoid exceeding the permissible methane level in the return air.

Table 2 shows that about 93 pct of the methane generated by the longwall operation on panel B was captured by the combined effects of the cross-measure system and the two surface gob holes. On panel A, where only the cross-measure system was in operation, about 71 pct of the methane was captured.

Gas flows from the boreholes drilled parallel to the face on panel B were comparable to flows from boreholes drilled at a 45° angle to the axis of the longwall on panel A. No discernible difference was observed. Both SGH-1 and SGH-2 affected the concentration of methane in the gas flow from the cross-measure system and prevented further comparisons.

GOB GAS MIGRATION INTO A BOREHOLE

Gas pressure differentials associated with flow of gas from a cross-measure borehole were calculated for three cases and then compared to observed values for the boreholes along panel B. In the first case, gob gas is assumed to flow into the borehole near the pillar line (fig. 20*A*) with the remainder of the borehole in the gob nonproductive. In the second case, gob gas is assumed to flow into the borehole uniformly along the length of the borehole in the gob (fig. 20*B*). In the third case, gob gas is assumed to flow into the borehole over the pillar with the remainder of the borehole nonproductive (fig. 20*C*). The following equation was used to compute the gas pressure differentials for the three cases (7):

$$p = \frac{\psi\ \lambda}{70.7}\ \frac{L\rho\ \bar{V}^2}{2dg}$$

where p = pressure differential (in Hg),

ψ = 1 for case 1 (fig. 20*A*) and 1/3 for cases 2 (fig. 20*B*) and 3 (fig. 20*C*),

λ = coefficient of resistance (dimensionless),

L = pipe or hole length (ft),

d = pipe or hole diameter (ft),

ρ = gas density (lb/ft^3),

$\bar{V}$ = average gas velocity (ft/s),

and g = accelerations of gravity (ft/s^2).

In most instances, the calculated gas pressure differentials agree with observed values for the case where gas enters the boreholes close to the pillar line (fig. 20*A*). In a few instances, the case where the gas flowed into the borehole over the pillar (fig. 20*C*) fit observed values more closely. Figure 21

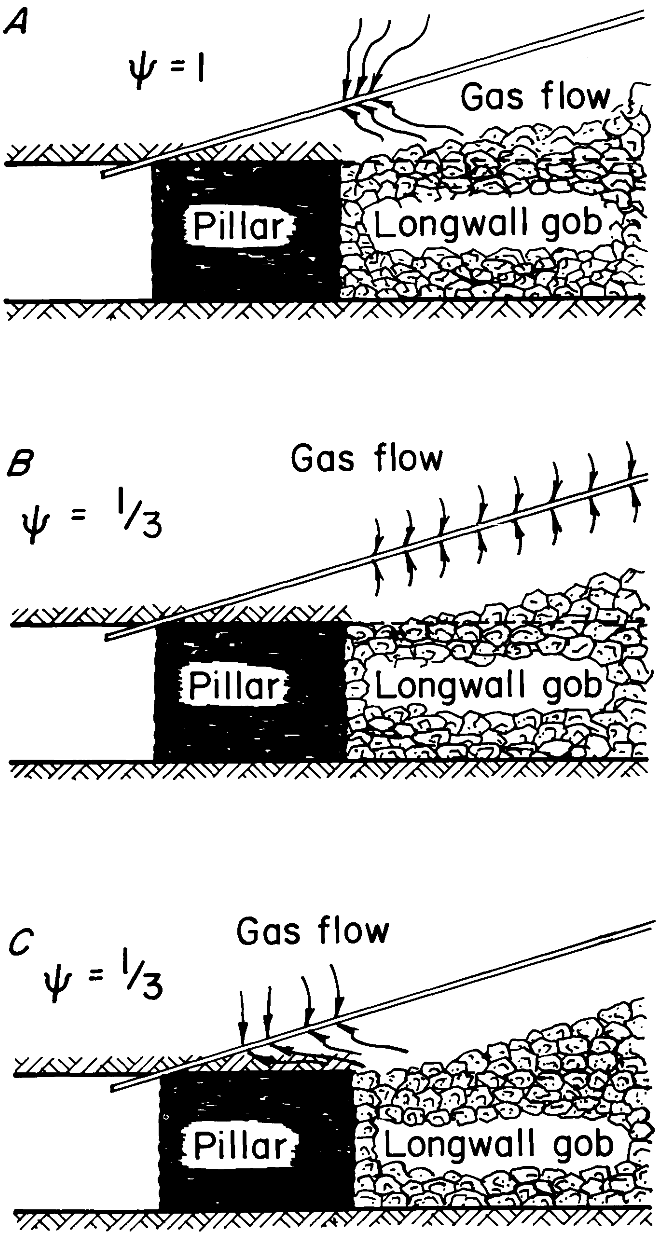

FIGURE 20. - Migration of gas into a borehole.

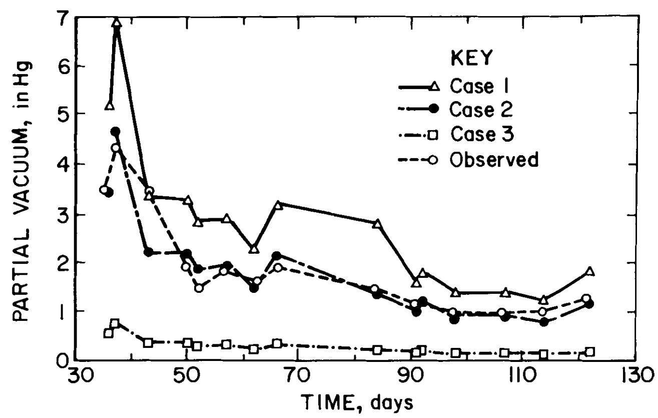

FIGURE 21. - Comparison of observed and calculated partial vacuums on hole 3 (panel B).

shows the calculated values for the three cases compared to the observed values for hole 3, which are typical for most of the boreholes. Good agreement exists for the case where gas enters the borehole close to the pillar line. Comparisons between calculated and observed values for boreholes along panel A yielded similar results (5). Thus, boreholes drilled at a 45° angle with respect to the axis of the longwall behave in a manner similar to boreholes drilled parallel to the face. These calculations also indicate that the boreholes can be shortened considerably, which will make the cross-measure system more cost effective. Cross-measure borehole length is 280 ft (85 m) on panel A and 225 ft (69) on panel B. These calculations show that borehole length can be reduced to about 140 ft (43 m) without affecting the performance of the system. Additional experimentation is necessary to verify these calculations.

SUMMARY AND CONCLUSIONS

The cross-measure system is a viable method of controlling gob gas on retreating longwall faces, provided access to the main pipeline and individual boreholes can be maintained during the life of the panel. On panel A, where only the cross-measure system was operating, about 71 pct of the methane produced by the mining operation was captured. On panel B, where both the cross-measure and surface gob holes were in operation, 93 pct of the methane was captured.

Methane flows in the return air on both panels indicate that borehole spacing should be limited to 200 ft (61 m), except on about the first 600 ft (183 m) of the longwall, where spacing should be reduced to 100 ft (30 m). More cross-measure boreholes are necessary near the start of the longwall to capture the large quantities of methane that are released when the first large roof fall occurs.

During prolonged idle periods, methane in the gob was depleted by the cross-measure system; consequently, the methane concentration in the gas flow from the cross-measure system dropped from 80 pct or more to 30 pct. When mining resumed, the concentration increased again to 80 pct or more even in boreholes located over 2,000 ft (610 m) from the face. These data indicate that the gob is permeable and that methane generated by the breakup of roof strata near the face will migrate through the gob for distances of over 2,000 ft (610 m). About 75 pct of the methane in the gob during mining emanates from newly fractured roof strata near the face.

Gas flows from boreholes drilled parallel to the face on panel B were comparable to flows from boreholes drilled 45° to the axis of the longwall on panel A. No discernible difference was observed. Both sets of holes terminated at the same height above the mined coalbed and penetrated about the same distance into the gob. Penetration into the gob is defined as the horizontal projection of the borehole parallel to the face. Boreholes drilled parallel to the face are recommended because they are shorter and require less drilling.

SGH-1 was very effective in controlling methane in the gob. Its influence extended about 700 ft (213 m). Beyond that point, the cross-measure system controlled gob gas. SGH-2 was not as effective as SGH-1. Both surface gob holes were offset from the centerline of the panel because of right-of-way problems. This may have affected their performance.

Comparisons between measured and calculated gas pressure differentials in boreholes on both panels indicate that gob gas entered the boreholes close to the pillar line, which was about 140 ft (43 m) from the collar of the borehole. The remainder of the borehole was nonproductive. Reducing borehole length to 140 ft (43 m) would lower drilling costs and make the cross-measure system more cost effective. Additional experimentation is necessary to verify the calculations.

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