CONTROL OF METHANE IN GOBS AND BLEEDERS BY THE CROSS-MEASURE BOREHOLE TECHNIQUE

Joseph Cervik and Roger L. King

Supervisory Geophysicist — Research Supervisor

Pittsburgh Research Center
U.S. Department of the Interior
Bureau of Mines
Pittsburgh, Pennsylvania

INTRODUCTION

Methane in longwall gobs is controlled in Europe and Great Britain during mining by drilling small-diameter holes into the roof strata (cross-measure boreholes) from underground locations and applying suction to each hole to draw the methane from the roof strata when fractured. Holes are connected to an underground pipeline which transports the gob gas (methane plus air) to the surface. Table 1 clearly demonstrates the importance of gob gas control

TABLE 1. - Gob gas control data for 1975

Location	Methane drained, $10^6 ft^3$	Utilized, pct	Number of boreholes	Total length drilled, miles
Poland.........	7 309	90	2 802	132
Czechoslovakia.	6 992	98	No data	162
West Germany...	21 081	54	3 916	117

during mining in Europe (1)[1/]. The total length of cross-measure boreholes drilled in 1975 ranged from 117 miles in West Germany to 162 miles in Czechoslovakia. In Poland and Czechoslovakia, 90 pct or more of the drained gob gas is utilized, and 54 pct is used in West Germany. The gob gas, which averages 60 pct methane, is used for steam and power generation, for driers in coal preparation plants, and for steel production.

Prior to 1970, ventilation was the primary method of controlling methane in gobs in the United States (fig. 1, A). As mining depth increased, gassier coalbeds and surrounding strata were encountered, and acceptable methane levels in the bleeders could not be maintained by ventilation alone. Consequently, surface gob boreholes were introduced in the 1970's as an auxiliary gob gas control method (fig. 1, B). The method proved highly effective and is commonly used today by the mining industry.

Surface gob boreholes cannot always be drilled because mining may be under populated areas, topography may be too severe, or access to private property may be denied. An alternative method of controlling gob gas is needed that is independent of the mine ventilation system and surface right-of-way problems. The cross-measure borehole technique appears to satisfy these criteria.

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

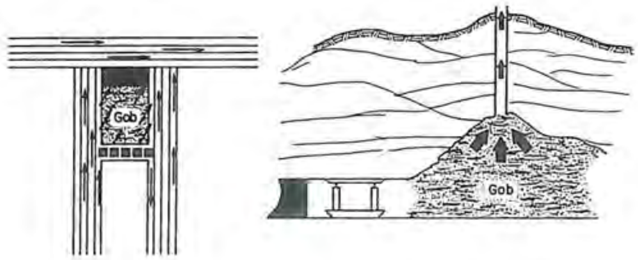

Figure 1. - Methods of gob gas control.

Longwall is the predominant mining system in Europe and Great Britain. Both advancing and retreating longwalls are used, and the proportion varies. For example, 82 pct of Great Britain's longwalls are advancing systems (3), and 73 pct in West Germany (4). This paper describes joint efforts by the Bureau of Mines, U.S. Department of the Interior, and the mining industry to adapt European cross-measure borehole technology to multiple-entry retreat longwall mining in the United States.

CROSS-MEASURE BOREHOLE DESIGN FACTORS

Borehole length and angles (vertical and horizontal), location of methane-bearing strata, pipeline diameter, and operating parameters of the surface pumping facility are factors that need to be considered in designing a cross-measure borehole system. Trial and error is the only method at present to determine optimum design factors in a given geologic setting.

Methane Source Beds in Roof Strata

Coalbeds and dark shales that are rich in organic matter are known source beds for methane. Sandstone beds may or may not contain methane. Generally, the methane-bearing strata are overlain and underlain by impermeable shale beds which prevent methane migration between beds. Longwall mining, which fractures and breaks up the overlying strata, releases the methane from these beds. European experience indicates methane enters mine workings from source beds as high as 660 ft above the mined coalbed (2). A reasonable penetration height for the cross-measure boreholes is at least 100 ft. Methane migrating downward will be intercepted by the boreholes, and methane from lower levels in the gob and possibly mine air will be drawn upward toward the borehole.

Vertical and Horizontal Angles of Boreholes

When a coalbed is extracted by longwall mining, the roof strata above the cavity break and cave to a height ranging from about 4 to 8 times coalbed thickness, creating a rubble zone (fig. 2). The strata above the rubble zone fracture and sag but remain more or less intact (6). The sagging strata will eventually produce a subsidence trough on the surface. Because the rubble zone is swept by mine air, the vertical trajectory of the borehole should remain outside the rubble zone when the gob is formed. If the borehole is intercepted by the rubble zone, then mine air will be drawn into the borehole and the effectiveness of the borehole to control gob gas will be reduced.

One would expect to find the highest concentrations of methane near the center of the longwall gob. Polish studies, however, show that this is not the case (5). Rubber hoses contained within a 2-in steel pipe laid in the gob directly behind the supports were used to draw gas samples from the gob during mining. The rubber hoses were connected to steel tubes protruding from the 2-in line and inclined toward the gob. Results of the study indicate that the highest concentrations of methane are found near the tailgate side of the longwall (fig. 3) and that this

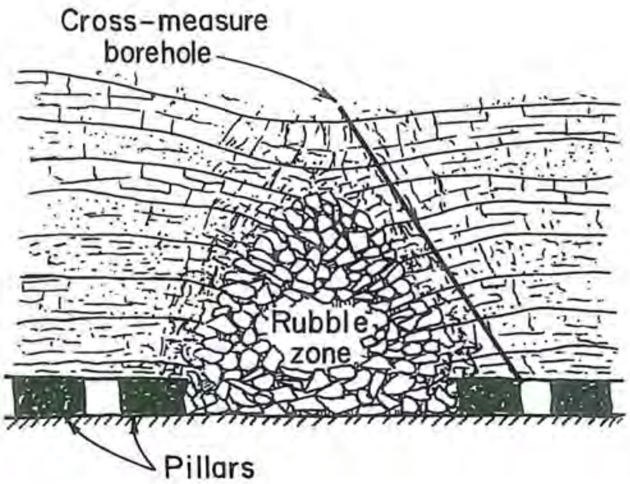

FIGURE 2. - Cross-measure borehole and rubble zone.

characteristic is the result of pressure differentials of the mine ventilation system. Consequently, the penetration of the cross-measure boreholes into the gob should be limited to about 100 ft (horizontal projection of borehole parallel to longwall face).

Single entries are generally used in Europe to develop longwall panels. On retreating longwalls, cross-measure boreholes are drilled 45 deg with respect to the axis of the longwall (fig. 4) (1). The end of a borehole is undermined first and the borehole produces gob gas until the face reaches the collar of the borehole. At this point, the borehole is disconnected from the main pipeline, which is partially main pipeline, which is partially removed because the single entry collapses as the face is retreated further. When mining of the panel is completed, the gob is sealed and drainage is continued through the seals. Best control of gob gas is obtained on an advancing longwall because entries are supported and maintained and methane drainage is possible along the whole length of the longwall.

Mining regulations in the United States require multiple-entry develement of longwall panels and ventila-

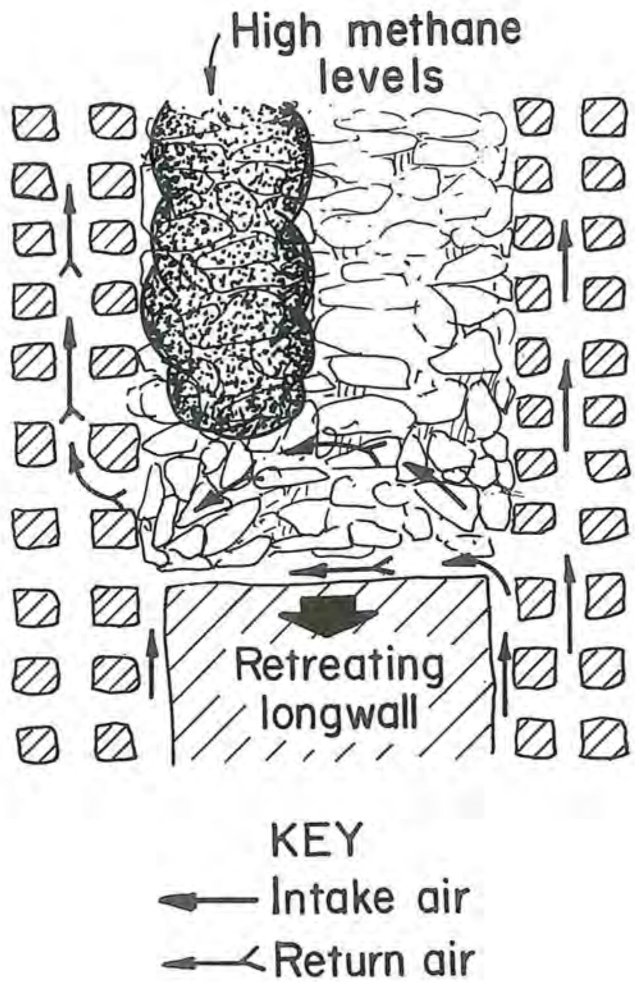

FIGURE 3. - Location of high methane levels in gobs.

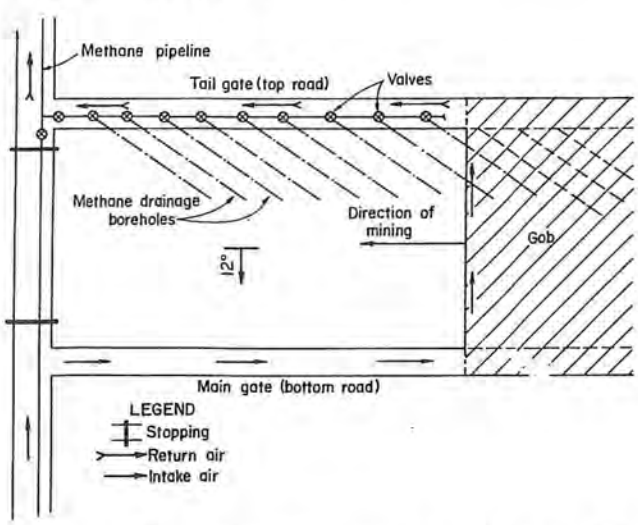

FIGURE 4. Cross-measure boreholes on European single-entry retreating longwall.

tion of the gob. Consequently, if an entry can be supported and maintained to protect the main underground pipeline, drainage of gob gas is possible during the life of the retreating panel. Further improvement can be made by drilling the boreholes parallel to the face line instead of 45 deg. Because the holes are shorter, drilling costs will be reduced.

Surface Pumping Facility and Underground Pipeline

Cross-measure boreholes when undermined do not generally produce methane until suction is applied to the borehole. Gas flow (methane plus air) is directly proportional to the negative pressure applied. The quantity of methane that can be captured by a cross-measure borehole system is determined primarily by the gassiness of the overlying strata and secondly by the capacity of the surface pump or exhauster. Cross-measure borehole technology is well developed in Europe, and models have been developed to predict methane flow into mine workings during longwall mining (2, 8). These prediction models are based on measurement of the gas content of the shales, sandstones, and coalbeds surrounding the mined coalbed. Because cross-measure borehole technology is new in this country and prediction models have not been developed, best estimate of the methane flow from a proposed longwall can be obtained by measuring methane flow from a pillar section or from longwalls in other mines in the area. This estimate then determines the pump capacity and size of the underground pipeline. The other important pump parameter is the negative operating pressure of the pump. Because gas flow from a borehole is proportional to the applied negative pressure, the pump should be capable of applying up to 9-in mercury negative pressure at a borehole after overcoming the pressure drop in the main pipeline. The pressure drop in the pipeline due to frictional flow effects is governed by volume flow and pipeline diameter.

Borehole Spacing

Borehole spacing depends upon the permeability of the fractured strata and operating parameters of the pump. Because little is known about gob permeability, which may be affected by local geologic conditions and overburden thickness, borehole spacing is best determined from underground tests.

The primary purpose of a cross-measure borehole system is to create a continuous low-pressure zone above the mined coalbed (fig. 5, A). Methane migrating downward through the fractured strata is intercepted by the low-pressure zone and captured by the cross-measure boreholes. Methane and mine air are pulled upward into the low-pressure zone. If the boreholes are spaced too far apart, then the low-pressure zone is not continuous and methane can migrate between boreholes into the mine opening (fig. 5, B). A borehole spacing of 200 to 250 ft is a reasonable starting point.

Water Production From Boreholes

Cross-measure boreholes may penetrate several water-bearing horizons in the roof strata. Consequently, provisions must be made to separate gas from water and to prevent the water from entering and blocking the underground pipeline. If the main pipeline can be sloped so that the water flows freely to one end of the pipeline, then individual gas-water separators on each borehole are not necessary. The water can be discharged directly into the main pipeline and subsequently removed at a convenient location.

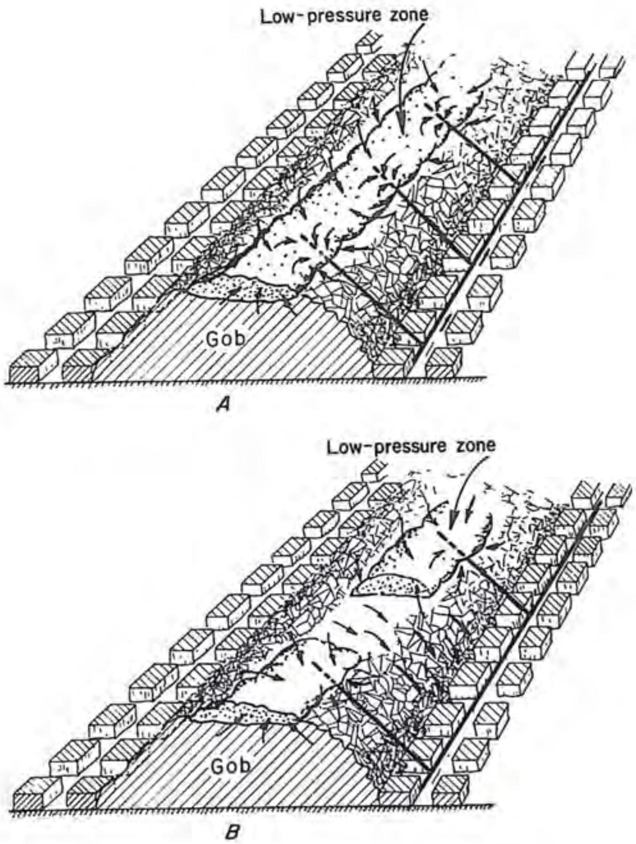

FIGURE 5. - Low-pressure zone in gob.

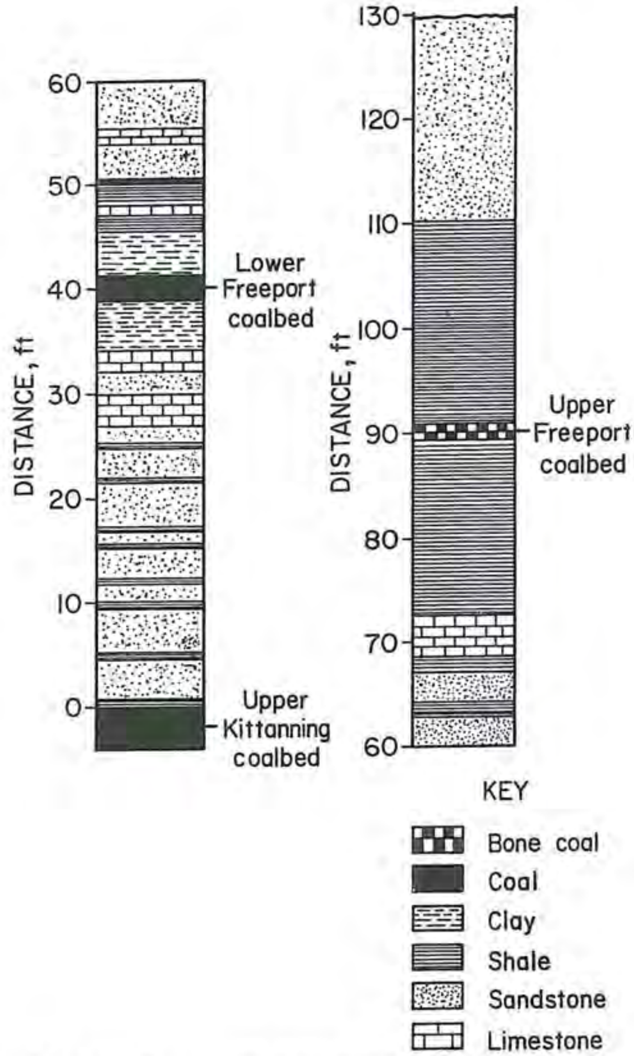

FIGURE 6. - Stratigraphic column above Upper Kittanning Coalbed.

CASE STUDIES

Upper Kittanning Coalbed Study

A test was conducted on a retreating longwall in the Upper Kittanning Coalbed (Bethlehem Mines Corporation) under 550 ft of cover. The stratigraphic column for this site shows the overlying strata are predominantly alternating sandstone and shale beds (fig. 6). The Lower Freeport (thickness 1.5 ft) and the Upper Freeport (thickness 2.4 ft) coalbeds are 40 and 90 ft respectively above the Upper Kittanning coalbed. Both are expected to contribute to the methane flow into the mine workings.

Test Panel. Twelve cross-measure boreholes were drilled over the test panel from the center entry in the return side of the longwall (fig. 7). They were drilled over pillars which protected the collars of the boreholes when the longwall face passed. The first 25 ft of each borehole was drilled with a 4-in diameter diamond bit core barrel and the remainder with a 2-in bit. A 20-ft plastic standpipe was then grouted into the collar of each borehole.

Each borehole connection to the main pipeline contained a valve to control the negative pressure on the borehole and to shut in the borehole when the methane concentration in the gas flow (methane plus air) fell below 25 pct. A venturi was used to monitor gas flow from each borehole.

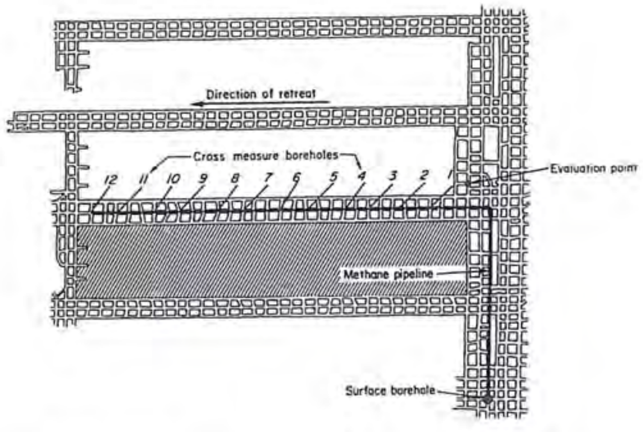

FIGURE 7. - Longwall test panel - Upper Kittanning Coalbed.

*	A	B	C	D	E	F	G	H
1	28	48	248	97	46	90	153	27
2	28	42	283	135	64	90	187	261
3	26	53	288	125	49	127	156	544
4	31	56	258	133	58	103	124	776
5	25	56	288	122	45	136	146	1,044
6	31	64	258	133	53	119	97	1,303
7	25	48	288	122	50	114	175	1,525
8	21	58	258	92	36	124	128	1,762
9	24	47	288	117	49	112	179	2,031
10	33	54	258	141	64	95	127	2,273
11	26	53	288	126	49	127	156	2,554
12	28	54	258	121	53	104	134	2,776

KEY

* Cross-measure borehole number
A Inclination, degrees
B Horizontal angle, degrees
C Hole length, feet
D Terminal height of hole, feet
E Height of hole at end of supported length, feet
F Penetration over longwall panel, feet
G Distance from endpoint to origin of hole, feet
H Distance from start of panel to endpoint of hole, feet

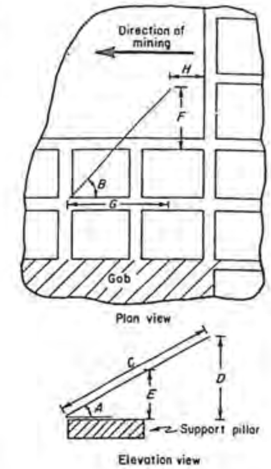

FIGURE 8. - Cross-measure borehole design parameters in Upper Kittanning Coalbed.

A 6-in polyethylene pipeline was used to transport the gas to the bottom of a cased 8-in surface borehole. An exhauster on the surface was employed to produce a negative pressure in the underground pipeline and at each borehole. The exhauster had a capacity of 200 ft^3/min and could produce negative pressures up to 3.5 in mercury. Gob gas was discharged into the atmosphere from a stack which was protected with lightning and flame arrestors.

Borehole Design Parameters. The design parameters for the borehole system were based on experience gained from a prior Bureau study (7). The spacing between the ends of the boreholes was 250 ft, and borehole inclinations ranged from 21 to 33 deg (fig. 8, A). Each borehole penetrated at least the Upper Freeport Coalbed. Horizontal angle of the boreholes ranged from 42 to 64 deg, and each borehole penetrated at least 90 ft into the gob (fig. 8, B and F). Borehole length ranged from 248 to 288 ft (fig. 8, C).

Data Collection. The total methane flow from the longwall mining operation was obtained by measuring the methane flow in the return air from the longwall and the methane flow from the cross-measure boreholes. Return air from the longwall was channeled through a single entry before it entered the main returns (fig. 7 - Evaluation point). Periodically, the volume of air was measured with an anemometer at the evaluation point. Gas bottle samples were also taken simultaneously and analyzed with a gas chromatograph to determine methane concentration in the return air at the evaluation point.

Gas flow from individual boreholes was calculated from pressure drop measurements with a U-tube manometer across a venturi. Gas bottle samples were analyzed with a gas chromatograph to determine methane concentration in the gas flow.

Data Analysis. No gas flow occurred from any cross-measure borehole until a negative pressure was applied. Generally, gas production started when the longwall face was 75 to 100 ft outby the end of the borehole and before the face passed the collar of the borehole. The initial methane concentration in the gas flow was 80 pct or greater.

Methane flows from the boreholes are shown on figure 9. All boreholes produced methane except hole 1, which was drilled close to the starting point of the panel (fig. 8, H).

Apparently, no fracturing occurred around hole 1 and the borehole produced neither air nor methane. Gas production life of boreholes ranged from about 15 to 140 days. Borehole inclination (fig. 8, A) and penetration into the gob (fig. 8, F) were two important parameters that appear to affect gas production life of boreholes. Figure 10 shows borehole life is greater for inclinations ranging from 28 to 33 deg than for inclinations of 21 to 26 deg. Boreholes with higher inclination angles also tend to produce gob gas with higher concentrations of methane. Figure 11 shows borehole life is inversely proportional to borehole penetration into the gob. The Polish studies (5), which showed that at floor level the highest methane concentrations are found near the tailgate of the longwall, also appear to be valid for a distance of at least 100 ft above the mined coalbed.

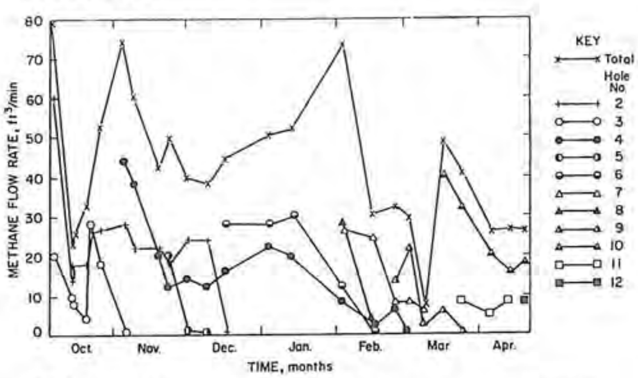

FIGURE 9. - Cross-measure borehole methane flow rates.

Figure 12 shows that methane flow in the return air from the longwall increases by a factor of over 2 when the cross-measure borehole system is not in operation. These data clearly demonstrated the effectiveness of the boreholes in controlling methane in the gob. About 50 pct of the total methane produced by the mining operation was captured by the cross-measure borehole system.

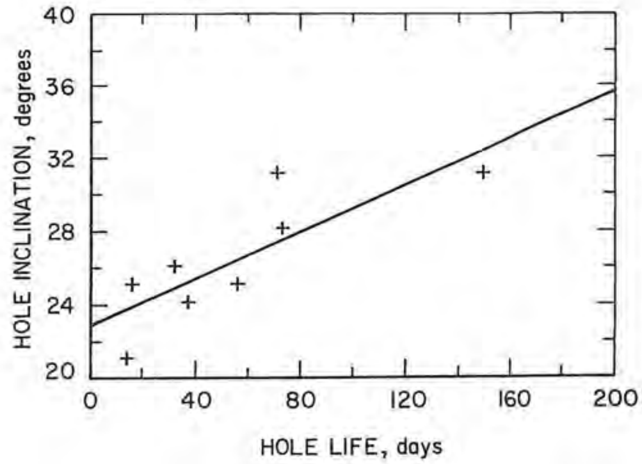

FIGURE 10. - Hole life versus inclination.

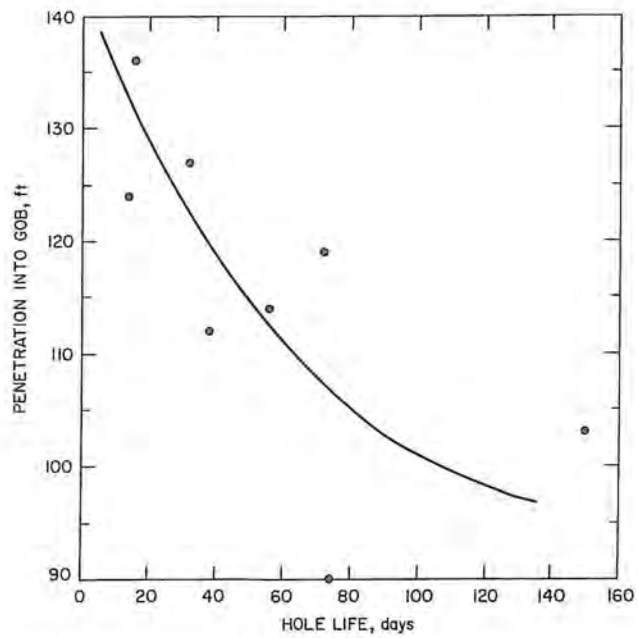

FIGURE 11. - Hole life versus penetration.

Pittsburgh Coalbed Study

A concurrent study in the Pittsburgh Coalbed (Consolidated Coal Co. and Conoco Coal Research Division) was conducted in a similar manner to the Upper Kittanning study. Overburden thickness is about 750 ft, and the overlying strata are predominantly limestone and shale (fig. 13). The Redstone (thickness 1.2 ft) and the Sewickley (thickness 3.8 ft) Coalbeds are 30 and 90 ft respectively above the Pittsburgh Coalbed.

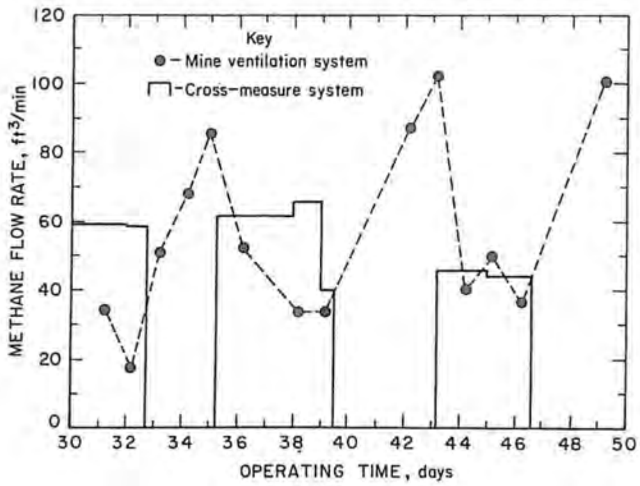

FIGURE 12. - Effect of cross-measure system on the mine ventilation system.

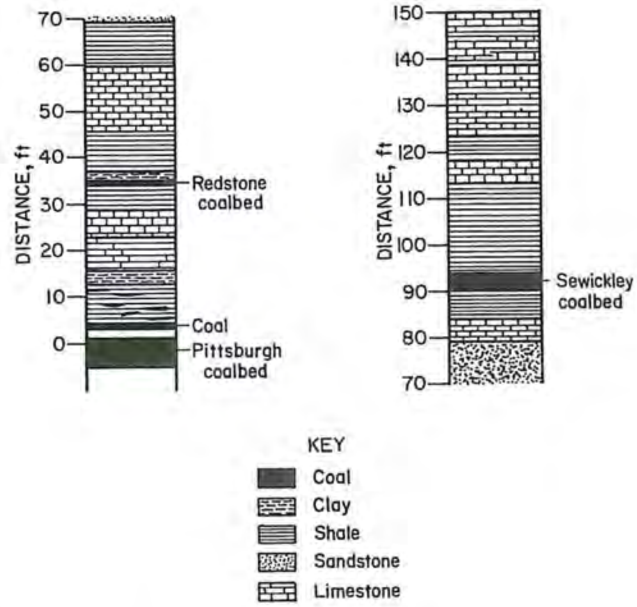

FIGURE 13. - Stratigraphic column above Pittsburgh Coalbed.

Fourteen cross-measure boreholes were drilled about 200 ft apart along the test panel (fig. 14). The main underground pipeline is located in the entry adjacent to the panel, and the cross-measure boreholes were drilled from crosscuts adjacent to the panel. This was not the ideal situation, but prevailing mining conditions precluded other options. Steel casing was grouted 10 ft into the collar of each borehole except holes 1, 2, and 3, which were 5 ft. These latter three factors were the chief differences between the studies in the Upper Kittanning and Pittsburgh Coalbeds. In the Upper Kittanning study, the borehole collars and pipeline were located in the center entry (fig. 7), and standpipe length was 20 ft.

Vertical gob holes are routinely used to control methane in the gob, and one was drilled about 700 ft from the start of the panel (fig. 14). It was put on production when intercepted. An exhauster was not used to assist in removing gob gas through the vertical gob hole.

Figure 15 shows the methane flows in the return at the evaluation point (curve 1), through the vertical gob hole (curve 2), and through the cross-measure borehole system (curve 3) during mining of the longwall. Methane flow in the returns ranged from about 300 to 370 ft^3/min compared with about 40 ft^3/min through the cross-measure borehole system and about 100 ft^3/min through the vertical gob hole. Thus, the cross-measure borehole system and the vertical gob hole captured about 8 and 23 pct, respectively, of the total methane produced by the mining operation. The methane flow increase in the returns during September and October and the subsequent decline in November (fig. 15, curve 1) are directly related to mining rates, which reached a maximum in October and then declined (table 2).

TABLE 2. - Longwall Mining Rates

Month	Longwall advance, ft
July............	490
August..........	530
September.......	680
October.........	800
November........	630

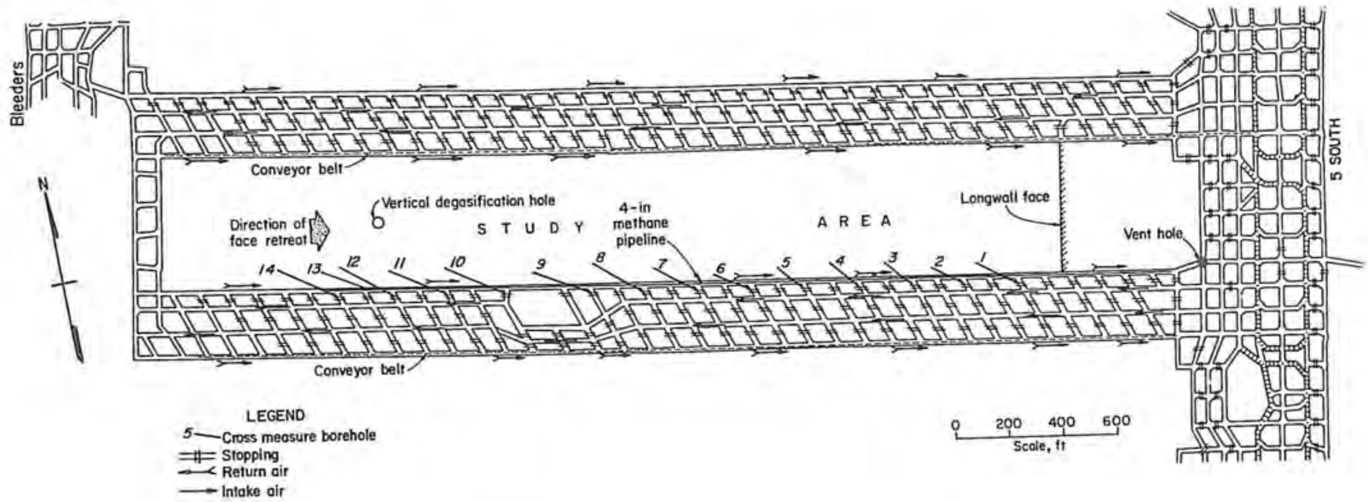

FIGURE 14. - Longwall test panel in Pittsburgh Coalbed.

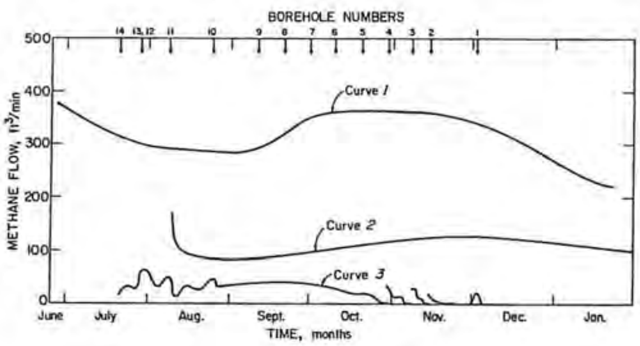

FIGURE 15. - Methane flows during longwall mining in the Pittsburgh Coalbed.

One factor affecting the performance of the cross-measure borehole system was the location of the collars, which in each case was a crosscut adjacent to the panel (fig. 14). Roof fracturing and in some cases roof falls occurred around the collars of boreholes when the longwall approached the crosscut. Mine air then short-circuited through the fractured roof strata into the borehole and reduced its effectiveness to draw methane from the gob. In addition, standpipes 10 ft long or less may have allowed boreholes to draw mine air when roof strata fractured. The main pipeline was under fallen rock outby the longwall face, and access to the individual boreholes was not possible because of fractured roof and falls.

Lower Kittanning Coalbed Study

Tests were recently completed on a retreating longwall in the Lower Kittanning Coalbed at a depth of 650 ft (Bethlehem Mines Corporation). The test setup was similar to that for the study in the Upper Kittanning Coalbed except for two factors: The capacity of the exhauster was increased to about 1000 ft^3/min, and the exhauster could produce negative pressures up to 11 in mercury. About half the cross-measure boreholes were spaced 200 ft short and the other half were 250 ft short. Preliminary analysis of the data indicates that about 80 pct of the methane produced by the mining operation was captured by the cross-measure borehole system. Tests on adjacent cross-measure boreholes showed that when a borehole was shut-in, production of gas from the adjacent borehole produced a negative pressure on the shut-in hole, indicating communication between boreholes. Thus, a continuous low-pressure zone is created in the gob which results in a high capture ratio for the cross-measure borehole system.

SUMMARY AND CONCLUSIONS

The cross-measure borehole technique is a viable method of controlling gob gas on retreating longwall faces, provided access to the main pipeline and individual borehole can be maintained during the life of the panel. Terminal height and depth of penetration into the gob gob of a borehole are two important borehole parameters that affect the quality and quantity of gob gas produced. At least 50 pct of the methane produced by the longwall mining operation can be captured by the cross-measure borehole system.

REFERENCES

1. Cervik, J., "Methane Control on Longwalls - European and U.S. Practices," chapter in "Longwall-Shortwall Mining, State-of-the-Art," SME/AIME, New York, NY, 1981, pp. 75-80.

2. Curl, S. J., "Methane Prediction in Coal Mines," IEA Coal Research, Report No. ICTIS/TR 04, 1978, London.

3. Fennelly, S. D., "Face-ends, A Challenge for the 1980's," Colliery Guardian, vol. 288, No. 11, November 1980, 498 pp.

4. Heising, C. and Becker, H., "Dust Control in Longwall Workings," Proc. Second International Mine Ventilation Congress, Reno, NV, November 4-8, 1979, Society of Mining Engineers, New York, NY, 1980, pp. 604-607.

5. Matuzewski, J. and Lunarzewski, L., "Control of Dangerous Methane Accumulations," Proc. Second International Mine Ventilation Congress, Reno, NV, November 4-8, 1979, Society of Mining Engineers, New York, NY, 1980, pp. 384-393.

6. Peng, S. S. and Cheng, S. L., "Predicting Surface Subsidence for Damage Prevention," Coal Mining and Processing, vol. 18, No. 5, May 1981, pp. 84-95.

7. Schatzel, S. J., Finfinger, G. L., and Cervik, J., "Underground Gob Gas Drainage During Longwall Mining," BuMines RI 8644, 1982, 14 pp.

8. Thakur, P., "Methane Control for Longwall Gobs," chapter in "Longwall-Shortwall Mining, State-of-the-Art," SME/AIME, New York, NY, 1981, pp. 81-86.

PROCEEDINGS
OF THE
FOURTEENTH ANNUAL INSTITUTE ON COAL MINING HEALTH, SAFETY AND RESEARCH

BLACKSBURG, VIRGINIA
AUGUST 23-25, 1983

SPONSORING ORGANIZATIONS:

DEPARTMENT OF MINING & MINERALS ENGINEERING
VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY

MINE SAFETY AND
HEALTH ADMINISTRATION
U.S. DEPARTMENT OF LABOR

BUREAU OF MINES
U.S. DEPARTMENT OF THE INTERIOR

EDITED BY:

Michael Karmis
Department of Mining and
Minerals Engineering
Virginia Polytechnic Institute
and State University

Joseph L. Patrick
Bureau of Mines
U.S. Department of the Interior

J. Richard Lucas
Department of Mining and
Minerals Engineering
Virginia Polytechnic Institute
and State University

William H. Sutherland
Mine Safety and Health
Administration
U.S. Department of Labor

Gavin J. Faulkner
Department of Mining and
Minerals Engineering
Virginia Polytechnic Institute
and State University

Published by the Department of Mining and Minerals Engineering
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061