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Drainage of Methane From the Overlying Pocahontas No. 4 Coalbed From Workings in the Pocahontas No. 3 Coalbed

UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 8359

Drainage of Methane From the Overlying Pocahontas No. 4 Coalbed From Workings in the Pocahontas No. 3 Coalbed

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UNITED STATES DEPARTMENT OF THE INTERIOR
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DRAINAGE OF METHANE FROM THE OVERLYING POCAHONTAS NO. 4 COALBED FROM WORKINGS IN THE POCAHONTAS NO. 3 COALBED

by

Gerald L. Finfinger[1] and Joseph Cervik[2]

ABSTRACT

The Bureau of Mines conducted an experimental degasification project in Island Creek Coal Co.'s Virginia Pocahontas No. 5 mine. Methane from the overlying Pocahontas No. 4 coalbed was entering mine workings in the Pocahontas No. 3 coalbed through fractures in the roof rock. Small-diameter (1-5/8-inch) holes were drilled into the overlying coalbed to reduce the gas pressure and intercept methane flows, which were piped to the surface through an underground 6-inch-diam steel pipeline.

The total methane flow rate from the vertical holes averaged 150,000 ft^3/day for the first month. Methane flows into the mine were reduced by 47 pct, thereby demonstrating the effectiveness of this form of degasification in reducing ventilation requirements and providing a safer working environment.

INTRODUCTION

The Bureau of Mines has been conducting research aimed at removing methane from coalbeds in advance of and during mining. One of the most effective methods of degasification of coalbeds has been the drilling of holes into coalbeds (1).[3] In the Pittsburgh coalbed, methane drainage from horizontal holes reduced methane flows at the working face 70 pct (2-3).

The Virginia Pocahontas No. 5 mine was opened in an area where the Pocahontas No. 3 and the overlying Pocahontas No. 4 coalbeds are separated by 9 to 13 feet of sandstone. However, the interval between the two coalbeds increases in thickness as one moves away from the study area, and the overlying Pocahontas No. 4 coalbed decreases in thickness and in some areas pinches out completely. Gas from the Pocahontas No. 4 coalbed migrates downward through fractures in the sandstone and enteres the mine workings in the

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

underlying Pocahontas No. 3 coalbed. The present report describes a procedure used for controlling methane flows from overlying coalbeds, as well as methods for experimentally determining the efficient spacing of holes drilled into the roof strata.

ACKNOWLEDGMENTS

The cooperation of the management of Island Creek Coal Co.'s Virginia Pocahontas No. 5 mine, Grundy, Va., and management of Occidental Research Corp., Keen Mountain, Va., is greatly appreciated.

PRELIMINARY PREPARATIONS

Because methane levels in the Virginia Pocahontas No. 5 mine's returns were approaching 1 pct, methane from drainage holes could not be discharged into the returns. A 6-inch-diam waterline located in the return ventilation system and extending from the surface to the work area was converted to a methane pipeline. At the surface, the pipeline was extended horizontally about 100 feet from the shaft and then vertically 30 feet. The pipeline was grounded, and flame arresters were installed on the vent stacks (fig. 1). Methane could then be vented to the atmosphere free flow or through an exhauster. The exhauster increased flow from drainage holes and maintained a slight negative pressure in the pipeline.

THE STUDY AREA

The study area consisted of a set of four headings in Pocahontas No. 3 coalbed advancing into virgin coal (fig. 2). Two weeks after the study began, the section was extended southward to intercept the skip shaft. In this area, the thickness of the Pocahontas No. 4 coalbed ranged from about 5 to 8 feet, and the interval between the Pocahontas No. 3 and No. 4 coalbeds ranged from 9 to 13 feet. The interval between the two coalbeds increased to about 60 feet as mining advanced southward toward the skip shaft (fig. 3).

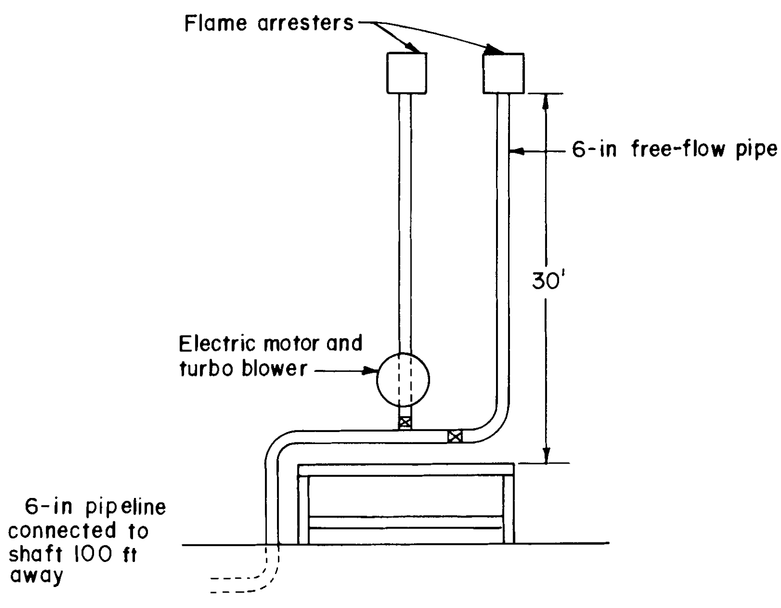

FIGURE 1. - Surface venting facility.

Shortly after an entry is advanced, the sandstone roof fractures with a noise like a thunderclap. These fractures, which may be caused by gas pressure in the Pocahontas No. 4 coalbed, conduct methane from the Pocahontas No. 4 to the entries in the Pocahontas No. 3 coalbed.

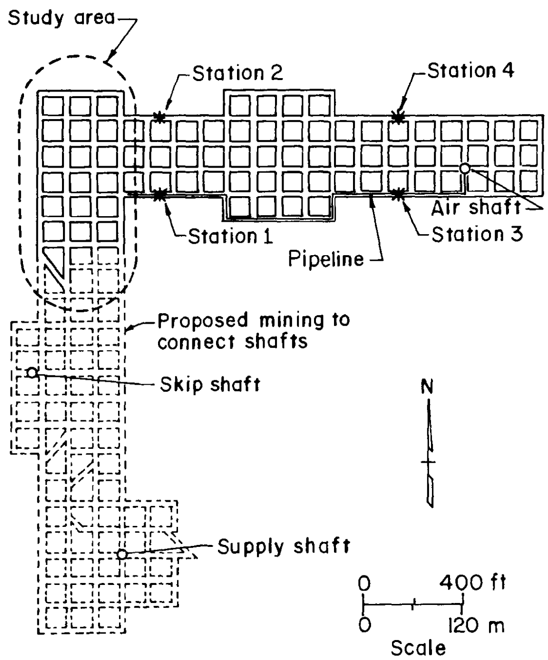

FIGURE 2. - Location of study area.

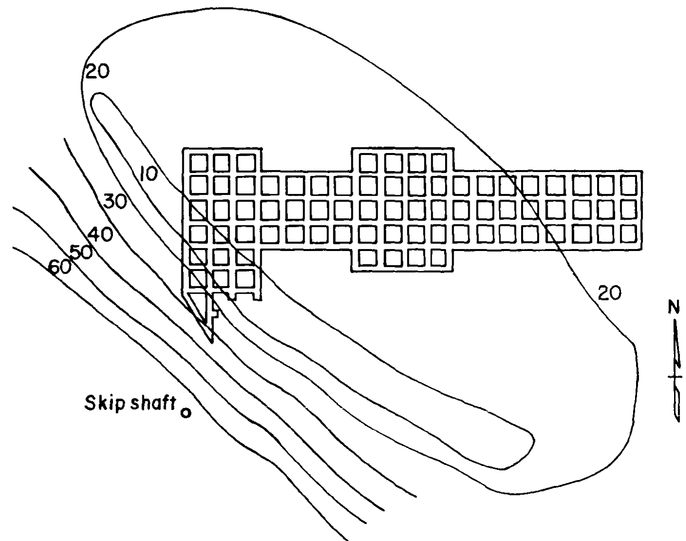

FIGURE 3. - Isopach map of interval between Pocahontas No. 3 and No. 4 coalbeds. Numbers indicated distance in feet.

PRELIMINARY TESTS

A series of three tests was conducted to determine the number and spacing of holes required to effectively reduce methane emissions through fractures in the roof strata. Each test was conducted using three holes that were drilled upward through the Pocahontas No. 4 coalbed (fig. 4), using an air-powered stoper. The first 5 feet of each hole was drilled with a 2-1/4-inch bit, and the remainder of the hole was drilled with a 1-5/8-inch bit.

Each test was conducted in the same way, although the orientation and spacing of the holes varied. In each test, three holes were drilled in a straight line within 5 feet of the rib. The first 5 feet of each hole was packed with a 42-inch-long, inflatable packer that was inflated by hand pump with water to a pressure of 600 psig. The holes were shut in for 24 hours to stabilize the gas pressure. After 24 hours, the two outside holes were opened to flow, and gas pressure at the middle hole was monitored. Methane from each hole was piped to the underground pipeline and vented at the surface. The objective of this test, called an "interference test," was to determine the time required for the drainage radius of the outside holes to reach the center hole. When the drainage radius reaches the middle hole, gas pressure begins to decline; this is called an interference effect. If interference occurs promptly, spacing of holes can be increased, thus reducing the number of holes to be drilled. A similar interference test is conducted for each new spacing, until a spacing is found that minimizes the number of holes to be drilled and for which interference occurs in a reasonable length of time.

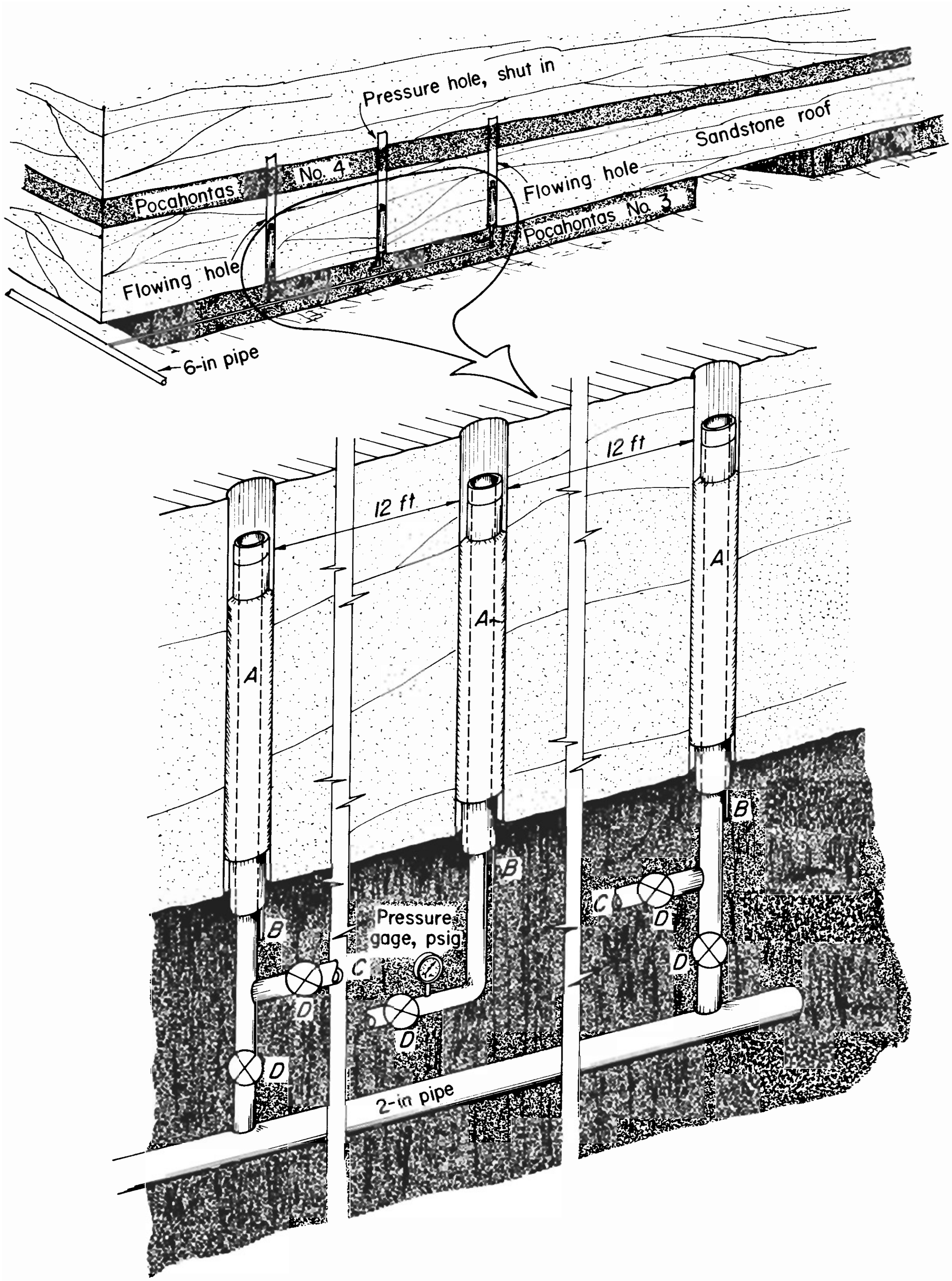

FIGURE 4. - Diagram of test holes. A = inflatable packer; B = packer inflation valves; C = outlet for measuring industrial flow; D = control valves.

After a satisfactory spacing has been determined, holes are drilled upward through the Pocahontas No. 4 coalbed along the left and right return entries. Each hole develops an interference effect with the adjacent holes. No methane can migrate from virgin coal through the line of holes, and, consequently, flow of methane through fractures into the entries in the Pocahontas No. 3 coalbed declines.

The holes should be drilled immediately following a cut of coal. In the present study, however, the holes were drilled with a stoper, which interfered with the miner's production cycle. Therefore, drainage holes were not drilled at the face following a cut of coal.

In the first test, holes 1, 2, and 3 were oriented north-south and the spacing between holes 1 and 3 was 24 feet (fig. 5). The shut-in gas pressures in holes 1, 2, and 3 stabilized at 50, 45, and 37 psig, respectively. The difference in pressure is probably due to different permeabilities of the joints and fractures in the roof strata at each hole. The initial flows from holes 1 and 3 were 16,300 and 11,500 ft^3/day, respectively. In 30 minutes, gas pressure at the center hole (hole 2) declined to 36 psig (fig. 6). After 5 hours, pressure declined to 31 psig, while the flows from holes 1 and 3 declined to 15,900 and 10,450 ft^3/day, respectively. For the next 19 hours, the pressure at hole 2 remained steady at 31 psig, and the flows from holes 1 and 3 declined to 10,000 and 2,000 ft^3/day, respectively.

In the second test, holes 4, 5, and 6 were oriented east-west (fig. 5) and the spacing between holes 4 and 6 was 24 feet. The stabilized gas pressures in holes 4, 5, and 6 and 37, 45, and 50 psig, respectively. Initial flows were 15,500 ft^3/day from hole 4, and 27,360 ft^3/day from hole 6. The gas pressure in hole 5 declined from 45 to 38 psig in 30 minutes (fig. 7) and to 35 psig in 5 hours. Flows from holes 4 and 6 decreased to 14,460 and 24,500 ft^3/day, respectively. The pressure in hole 5 declined further to 18 psig after 7 days, and gas flows from holes 4 and 6 declined to 5,400 and 15,000 ft^3/day, respectively.

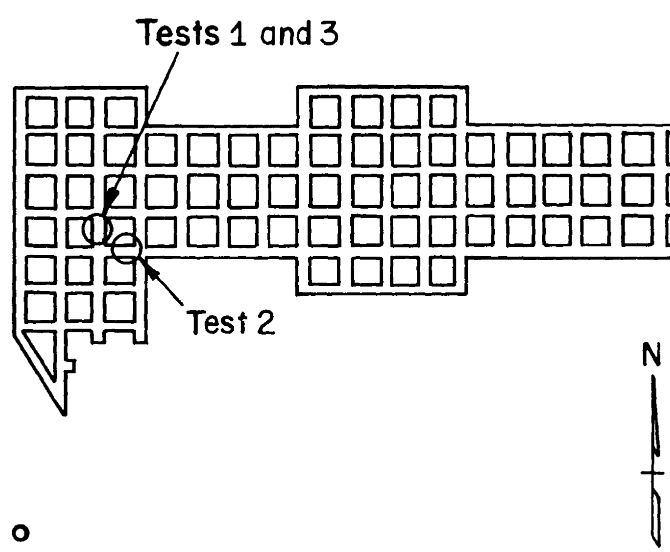

FIGURE 5. - Location of tests.

The third test was conducted in the same location as the first test (fig. 5); the distance between the two outside holes (holes 1 and 7) was 48 feet. Hole 3 was the gas-pressure monitoring hole. The stabilized gas pressures in holes 1, 3, and 7 were 36, 35, and 30 psig, respectively. Initial flows from holes 1 and 7 were 12,500 and 6,300 ft^3/day, respectively;

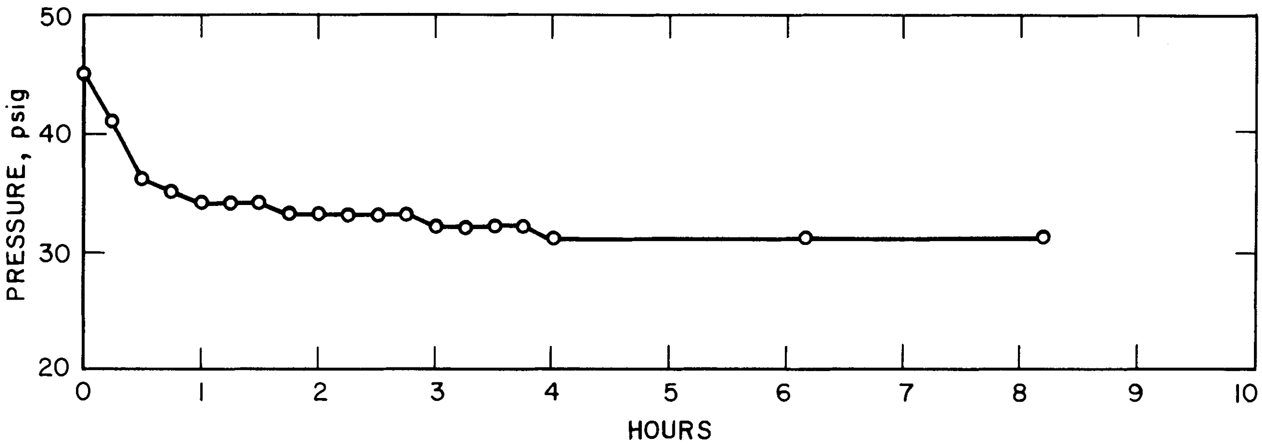

FIGURE 6. - Pressure decline curve–test 1.

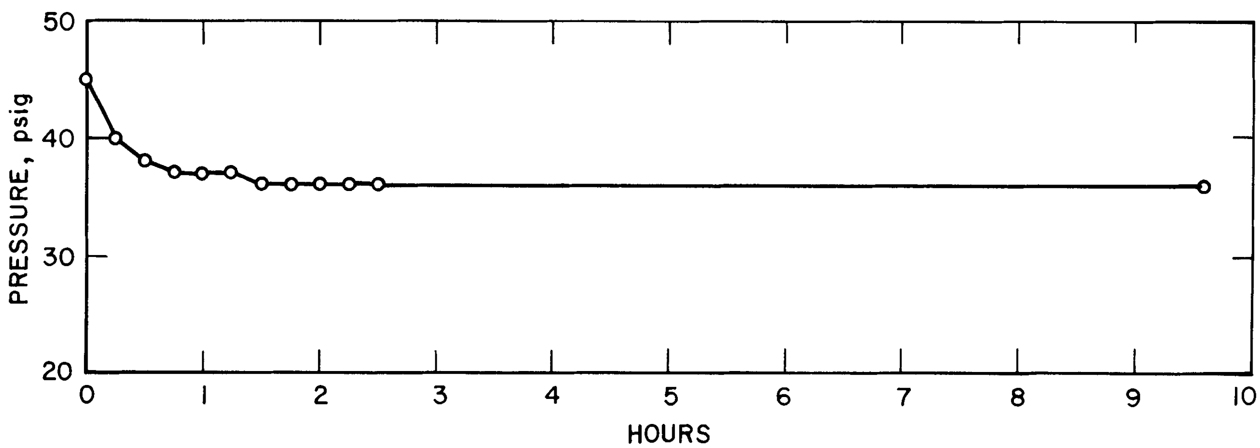

FIGURE 7. - Pressure decline curve–test 2.

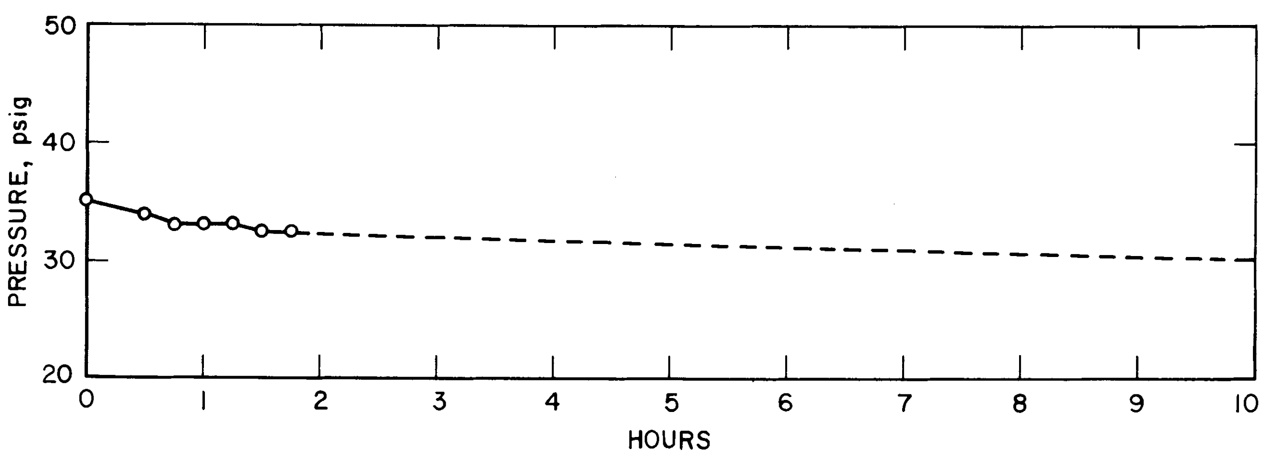

FIGURE 8. - Pressure decline curve–test 3.

they declined to 12,000 and 5,400 ft^3/day after 2 hours. Gas pressure in hole 3 declined to 34 psig in 30 minutes (fig. 8) and to 32.5 psig in 2 hours. Over a 5-day period, the flows from the outside holes became negligible, and gas pressure (hole 3) declined to 22.5 psig.

Tests 1 and 2 indicate no large permeability variations between north-south and east-west directions. Gas pressures in the center holes of both tests declined immediately after the outside holes were opened to flow. Test 3 showed that an interference effect between holes 48 feet apart occurred within a few hours after the holes were opened to flow. Accordingly, a spacing of 50 feet or less was used in the hole drilling program.

DEGASIFICATION PROGRAM

Holes were drilled from the working section (fig. 9) to intercept methane flows from virgin coal areas of the Pocahontas No. 4 coalbed and prevent methane from entering the mine atmosphere of the Pocahontas No. 3 coalbed through fractures and joints in the sandstone roof strata. Drainage holes were connected to the underground pipeline which vented the methane at the surface.

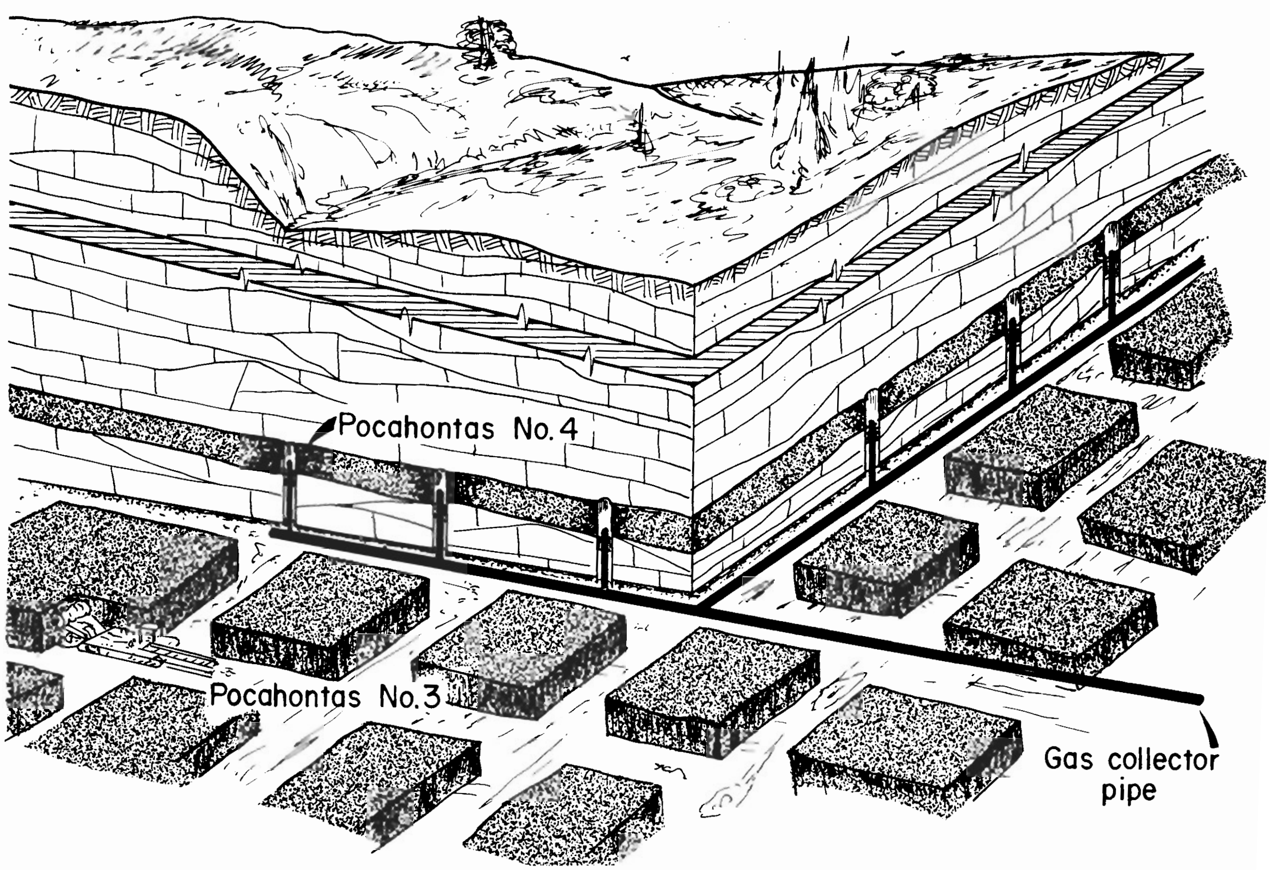

FIGURE 9. - Diagram of degasification system.

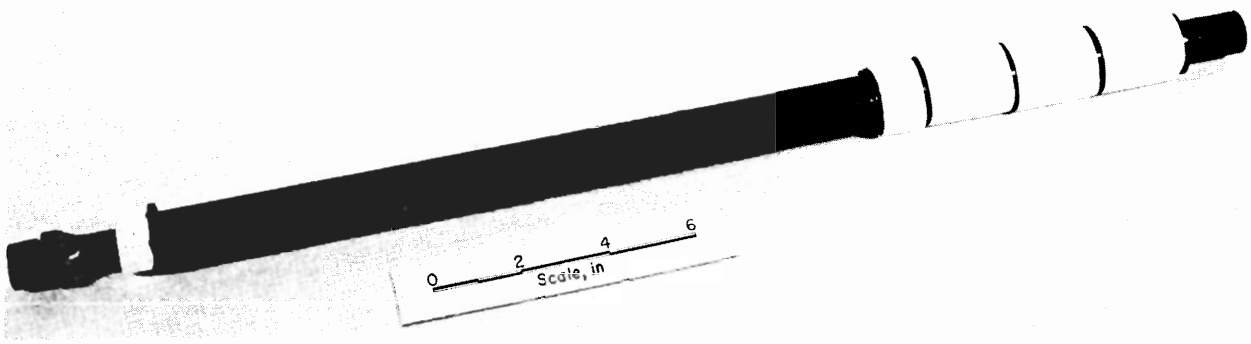

FIGURE 10. - Mechanical packer, released.

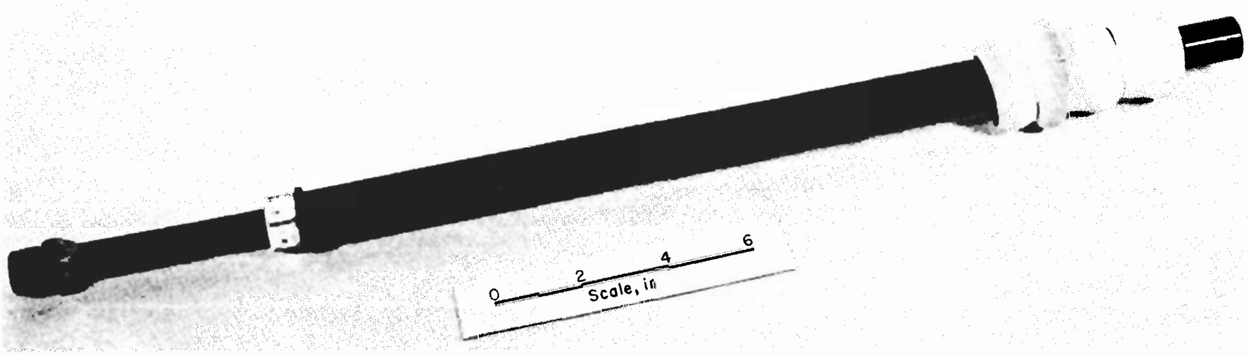

FIGURE 11. - Mechanical packer, compressed.

Drainage holes were drilled upward with an air-powered stoper to the top of the Pocahontas No. 4 coalbed. Holes were drilled with a 1-5/8-inch bit and sealed with mechanical packers fabricated by the mine's machine shop (appendix A). These packers are relatively inexpensive, easily constructed, and simpler to use than inflatable packers (figs. 10-11).

Holes were connected to the main underground pipeline with plastic pipe. Holes 8 through 17 required a gas-water separator. Initial waterflow from these holes was 3 gal/hr and declined to about 0.1 gal/hr within 24 hours. Holes 18 through 37 produced no water and were connected directly to the pipeline. Gases from both the Pocahontas No. 3 and No. 4 coalbeds contain a high percentage of methane (table 1).

TABLE 1. - Comparison of gas compositions from the Pocahontas No. 3 and No. 4 coalbeds

	Composition, pct	
	Pocahontas No. 3	Pocahontas No. 4
Ethane (C_2H_6)...........	1.3	0.14
Carbon dioxide (CO_2)....	.26	1.6
Oxygen (O_2).............	.18	.12
Nitrogen (N_2)...........	1.0	.46
Methane (CH_4)...........	97.2	97.7

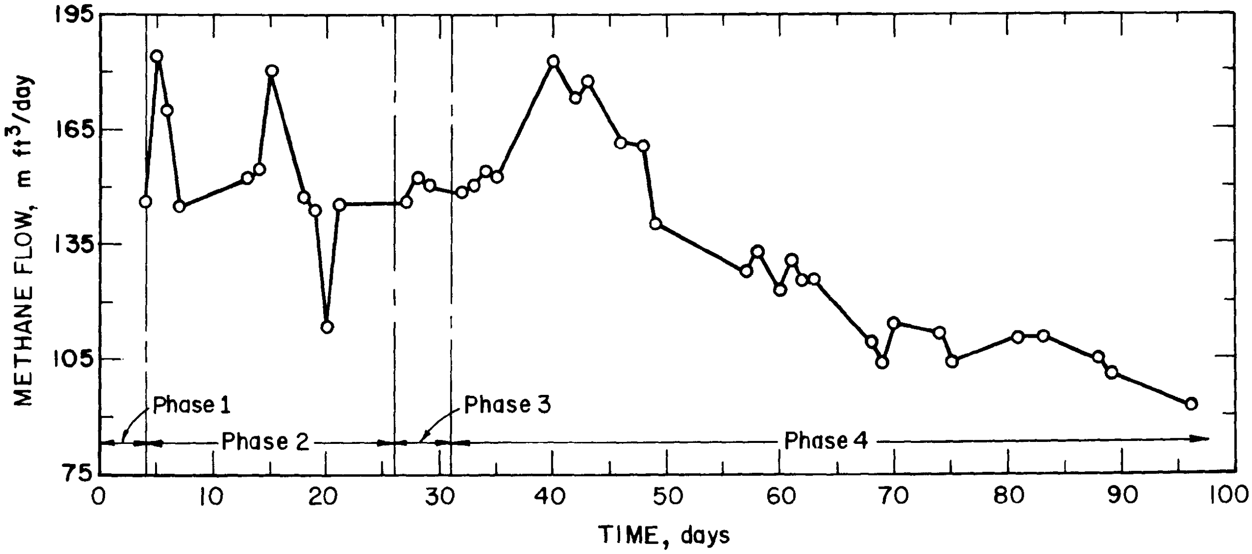

FIGURE 12. - Daily methane flows from degasification holes.

Figure 2 shows the location of the underground, 6-inch-diam, steel pipeline. The length of the underground segment is 1,700 feet, followed by a segment of about 1,600 feet rising vertically in the return air shaft. When methane flow through the pipeline was 150,000 ft^3/day, gas pressure in the pipeline near the working face was -5.2 inches water gage. Negative pressure is due to buoyancy of methane as it rises in the vertical section of the pipeline. However, as the section advanced, the pipeline was extended horizontally 500 feet with 2-inch-diam plastic pipe. Because of frictional resistance to flow in the plastic line, gas pressure in the line became positive and some methane began flowing through fractures in the roof strata. An exhaust fan, installed on the pipeline at the surface, eliminated the positive pressure underground and increased the flow of methane from the drainage holes.

Daily flow measurements were made at the end of the 6-inch pipeline on the surface (fig. 12) using an anemometer and converting to a volume flow. Laboratory tests with air flowing through a 6-inch pipe showed that the velocity measured with an anemometer at the end of the pipe is about 24 pct higher than the true average velocity, which was determined with a venturi. Because the anemometer is calibrated for air measurements, the pipeline flow measurements were also corrected for density of methane (4). Over 12 million cubic feet of methane was drained from the Pocahontas No. 4 coalbed over 96 days.

RESULTS AND DISCUSSION

Methane surveys were conducted in the section before the drilling and drainage phases started for use as a comparison basis. Air velocities were measured with anemometers. Methane levels were determined in the laboratory from bottle samples. Stations 1 and 2 are located in the immediate returns from the working faces, and stations 3 and 4 are located in returns about

1,000 feet outby the working faces (fig. 2). Because a split system of ventilation is employed on the section, the methane flow from the faces of the section and the methane entering the intake air entries through fractures and joints in the roof strata are determined by adding the methane flows measured at stations 1 and 2. The total methane flow from roof strata, working faces, and the two outside ribs is determined by adding the methane flows at stations 3 and 4.

The effects of the roof hole drilling and drainage program on methane flows in the returns are shown in figure 13, which is divided into four phases. Curves A and B show methane levels in the return at the inby (stations 1 plus 2) and outby (stations 3 plus 4) locations, respectively. Base level of methane in the immediate return was 1,700 ft^3/min and about 2,350 ft^3/min at the outby station (phase 1). During phase 1, holes were drilled into the roof strata; however, these holes were shut in (fig. 14, phase 1).

During phase 2, the 23 holes drilled and shut in during phase 1 were connected to the underground pipeline and opened. Five additional holes were drilled during the 22-day period (fig. 14 phase 2). Curves A and B (fig. 13) show a steady decline in methane levels in the returns over 22 days; curve A shows a 47-pct reduction and curve B shows a 43-pct reduction in methane flows.

Phase 3 corresponds to a 5-day period during which no degasification holes were drilled although the section was advanced (fig. 15, phase 3). Both curves A and B (fig. 13) show an increase of methane levels in the returns.

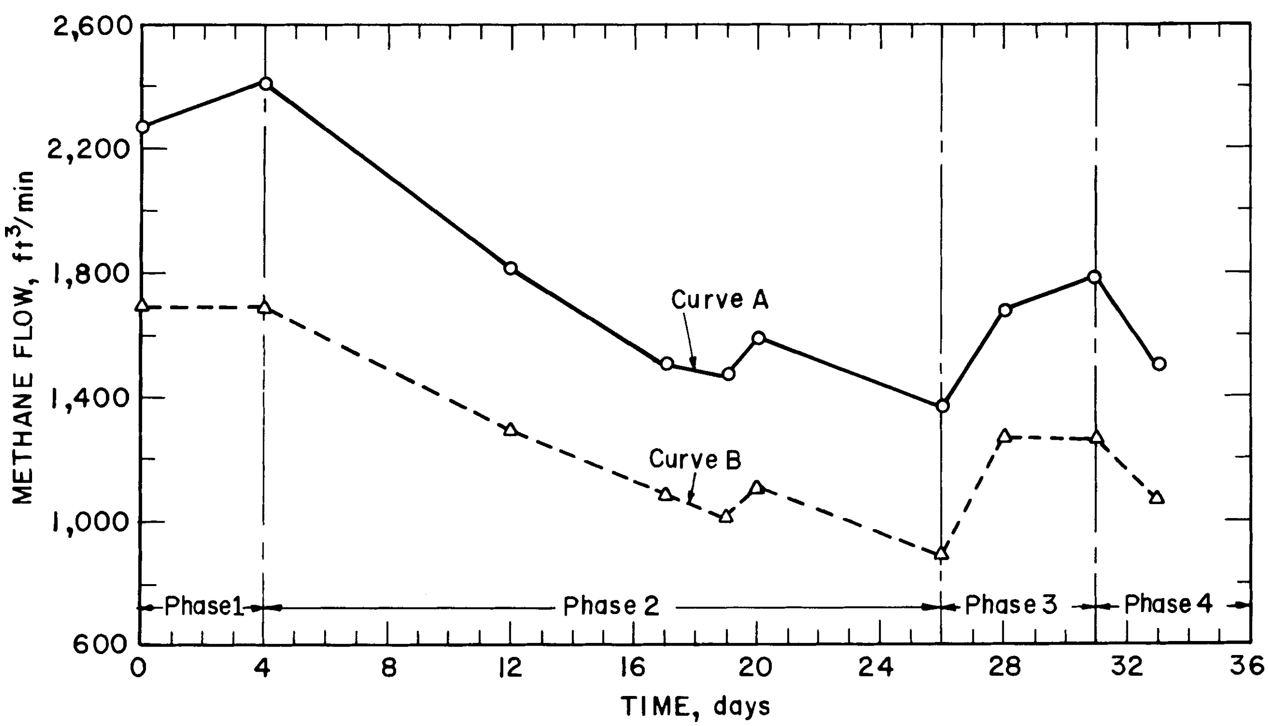

FIGURE 13. - Methane volume in the returns.

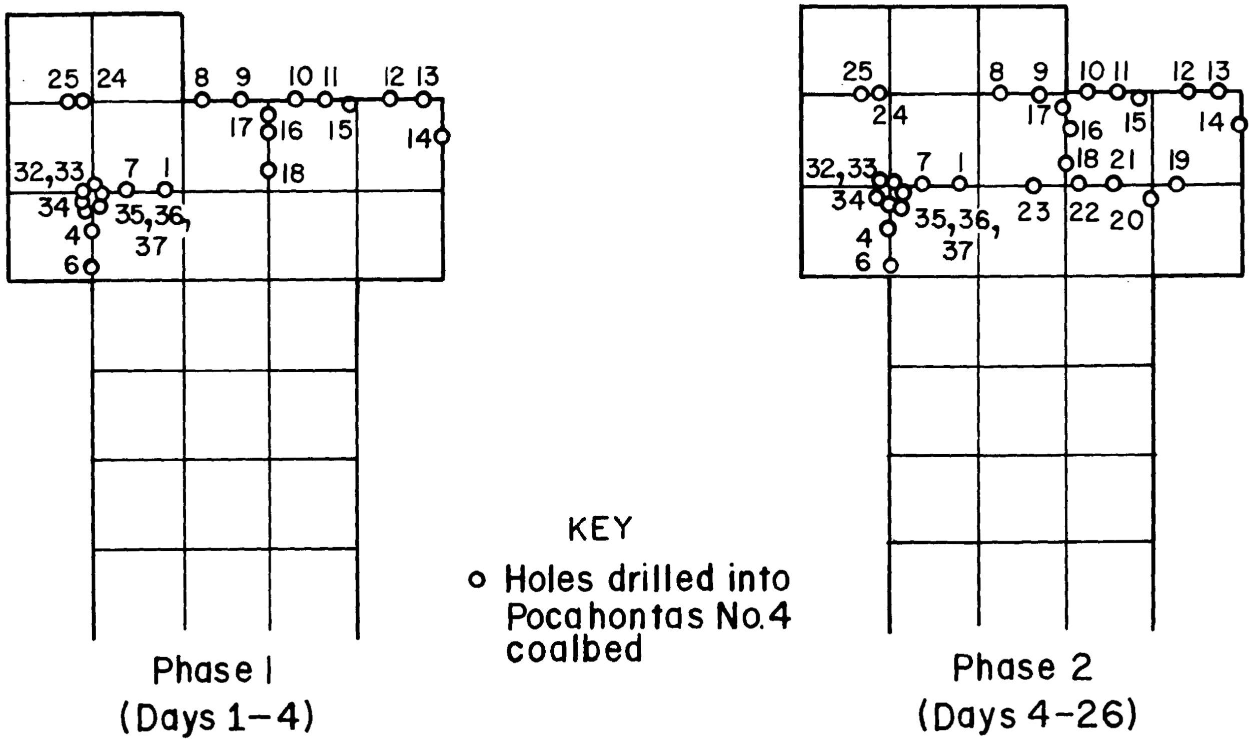

FIGURE 14. - Locations of degasification holes in the working section (phases 1 and 2).

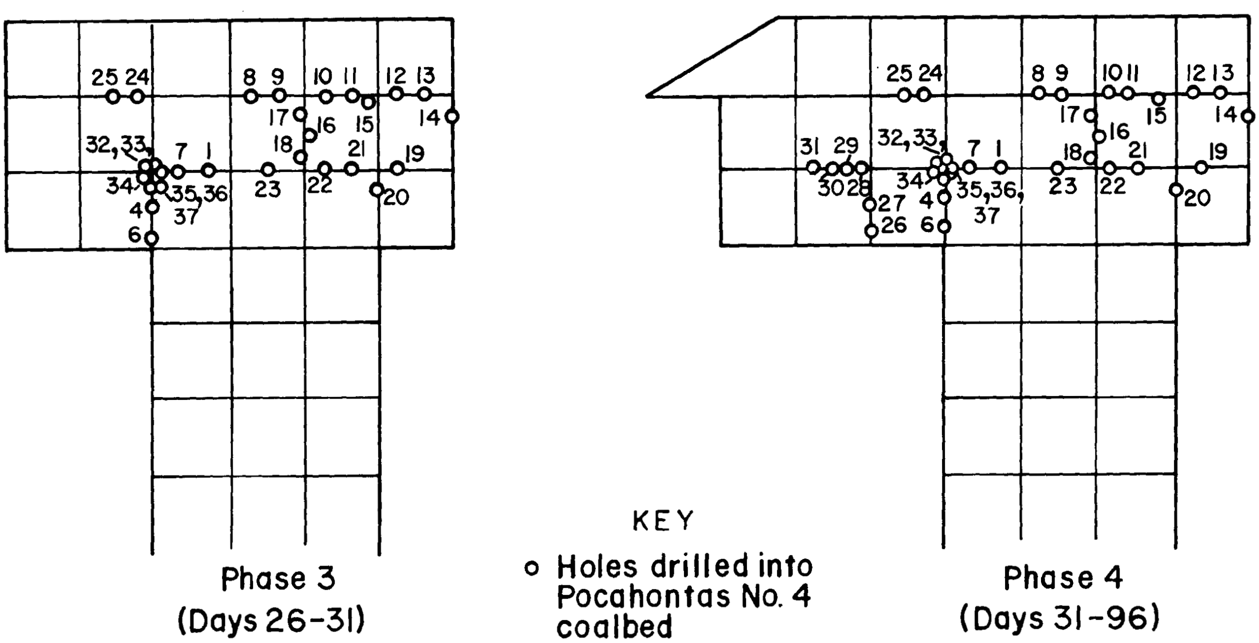

FIGURE 15. - Locations of degasification holes in the working section (phases 3 and 4).

Phase 4 is a 3-day period during which six degasification holes (fig. 14, phase 4) were drilled. The effect of these holes was an abrupt decrease of methane levels in the returns (fig. 13).

CONCLUSIONS

This investigation showed that roof hole drilling and drainage is an effective method of controlling methane flows from overlying coalbeds. Methane levels were reduced significantly (47 pct) in the immediate returns from the section in the underlying mine and, more importantly, intake-air methane levels were also reduced. Generally, safety conditions were improved throughout the mine. In addition, the mine's existing ventilation system was extended and a costly shutdown of the mine was avoided.

This method of methane control is applicable to any gas-bearing stratum that discharges methane into an underlying mine opening. Holes are drilled through the gas-bearing stratum, and packers are set immediately below the stratum. These packers seal against the wall of the hole and conduct the gas to the underlying mine opening where it is discharged into an underground pipeline and piped to the surface.

Gas pressure in overlying roof strata is suspected to be the cause of roof instability in some cases, but documented case studies could not be found in the published literature. The technique presented in this study can be used to reduce gas pressure and perhaps alleviate roof instability.

Strata overlying coalbeds may contain methane under pressure in the pore system. If the pore system is not interconnected, the strata lack permeability and, consequently, roof drilling and drainage will not be effective.

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APPENDIX--CONSTRUCTION OF MECHANICAL PACKERS

A method of directing the gas flow from drainage holes to the pipeline was needed to insure that no methane would be emitted into the mine workings. A mechanical packer was used because of the low cost and relative ease of fabrication. Figure A-1 shows a cutaway view of the packer.

The only special part needed for the construction of the packer is the rubber hose that forms the sealing element. The hose was purchased in a 60-foot length. The outside and inside diameters of the hose were matched to the bit size and mandrel size, respectively. The diameter of the packer can be varied to match the diameter of the hole drilled.

The following is a list of materials needed to construct a mechanical packer for sealing holes from 1-5/8 to 2-1/4 inches in diameter (pipe length varied as needed):

4 Rubber seals (2 inches in length)

6 Steel washers (5/8 inch ID, 1-3/8 inches OD)

1 Standard black pipe (1/2 inch, one end pipe threads, one end bolt threads

1 Standard black pipe (1 inch, no threads)

1 Standard black pipe coupler (1/2 inch)

1 Standard black pipe bushing (1/2 inch by 1 inch welded to 1/2-inch pipe)

1 Nut

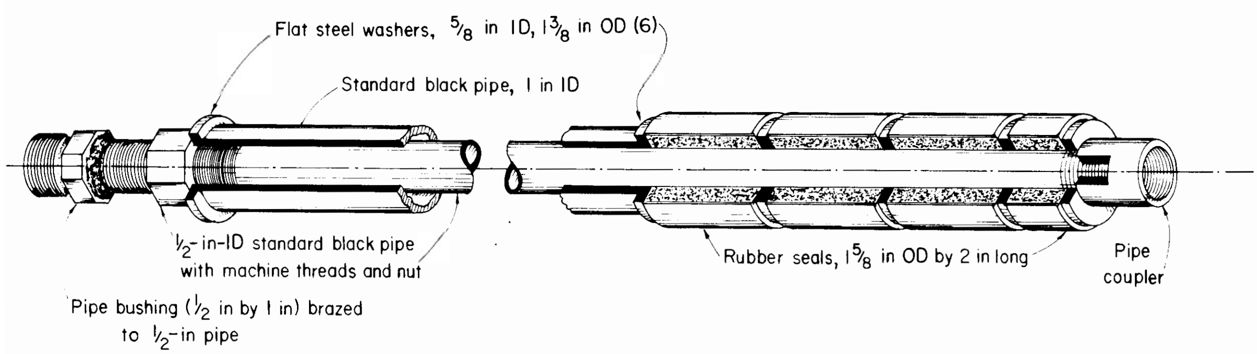

FIGURE A-1. - Cutaway view of mechanical packer.

The packer is constructed as follows (fig. A-1):

1. Cut approximately 4 inches of standard bolt thread on one end of the 1/2-inch pipe and 2 inches of pipe thread on the other end. Screw the matching nut onto the bolt threaded end.

2. Weld or braze the pipe bushing on the bolt threaded end of the 1/2-inch pipe.

3. Slip a washer over the other end of the 1/2-inch pipe.

4. Slip the 1-inch pipe over the 1/2-inch pipe.

5. Alternately add washers and rubber seals to the 1/2-inch pipe until the pipe threads are reached.

6. Screw the pipe coupler onto the 1/2-inch pipe.

The packer can now be expanded by tightening the nut which compresses the rubber seals.

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