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METHANE CONTROL PROGRAM

GAS MIGRATION CHARACTERISTICS OF COALBEDS

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U.S. DEPARTMENT OF THE INTERIOR

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ILLUSTRATIONS

GAS MIGRATION CHARACTERISTICS OF COALBEDS

by

J. D. Hadden[1] and Albert Sainato[2]

ABSTRACT

The Bureau of Mines conducted drilling studies in the Pocahontas No. 3, the Pittsburgh, and a western coalbed to establish the gas migration characteristics for each. Gas pressures in the Pittsburgh coalbed were about 260 lb/in^2 and in excess of 550 lb/in^2 in the Pocahontas No. 3. Caving in drill holes prevented pressure measurements in the western coalbed. The Pittsburgh coalbed contained intersecting "clay veins" which formed gas pressure cells. Although these geological features hamper mining, they can be used to control the flow of methane into a mine working. Methane control techniques are proposed for the Pittsburgh and Pocahontas No. 3 coalbeds.

INTRODUCTION

A comprehensive methane control research program is being conducted by the Bureau of Mines to establish the geological structural controls that govern the migration and retention of methane in coalbeds; determine the physical properties of methane and of the coal and other strata with which methane is associated; devise methods by which methane may be removed from, or controlled in, coalbeds prior to and during coal extraction; develop mechanical equipment and instrumentation needed to control methane; and conduct field trials of the methane control techniques developed. This is one of a series of reports on specific aspects of the program.

The flow of gas through coalbeds conforms with established laws.[3] This paper is concerned with compressed gas that exists in the fracture system of coalbeds and the movement of this gas, which is governed by Darcy's law:

$$q = - \frac{kA}{\mu} \frac{dP}{dl},$$

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[3] Cervik, Joseph. An Investigation of the Behavior and Control of Methane Gas. Min. Cong. J., v. 53, No. 7, July 1967, pp. 52-57.

where

q = volume rate of flow (cm^3/sec);

k = fracture permeability (darcy);

A = cross section area (cm);

μ = gas viscosity (cp);

P = gas pressure (atm);

l = unit of length (cm).

This law means that a gas pressure must exist in the coalbed and that the amount of gas entering a mine opening is related directly to the pressure gradient (dP/dl) that exists around the opening.

Coalbeds may contain obstructions to gas flow such as faults, clay veins, and want areas. Pressure gradients and, therefore, gas flows into mine workings are affected by these geological structures.

DRILLING STUDIES IN THE POCAHONTAS NO. 3 COALBED

The objectives of the studies conducted in the Pocahontas No. 3 coalbed were to determine pressure gradients in the coalbed and the magnitude of the pressure gradient near an active face and one near an inactive face, and to establish the existence of gas pressures in coal pillars.

To determine pressure gradients, three horizontal holes were drilled into virgin coal near an active face to depths of 30, 60, and 150 feet. The holes were then sealed and the gas pressures measured as follows: The maximum pressure in the 30-foot hole was 205 lb/in^2; in the 60-foot hole 420 lb/in^2; and in the 150-foot hole 500 lb/in^2. Figure 1 shows the curve of the measured pressure versus the depth drilled. This curve is typical for a coalbed containing no obstruction, and will be referred to as a normal gradient curve.

An area that had been developed for 6 months was selected to compare the pressure gradient at an older section of the mine with the pressure gradient that exists near an active face. A hole was drilled into the coal in this area and pressure measurements were made at five different depths. This hole was drilled 250 feet deep and the gas pressure measured at this distance was 105 lb/in^2. Figure 2 shows the gradient for these five measurements.

From the data on these holes, the pressure gradient near the active face area is 420 lb/in^2 per 60 feet, or 7 $lb/in^2/ft$. The gradient from the developed area is 105 lb/in^2 per 250 feet, or 0.42 $lb/in^2/ft$, which is substantially lower than the gradient near the active face. According to Darcy's law, gas flows will be greater at active face areas than inactive areas.

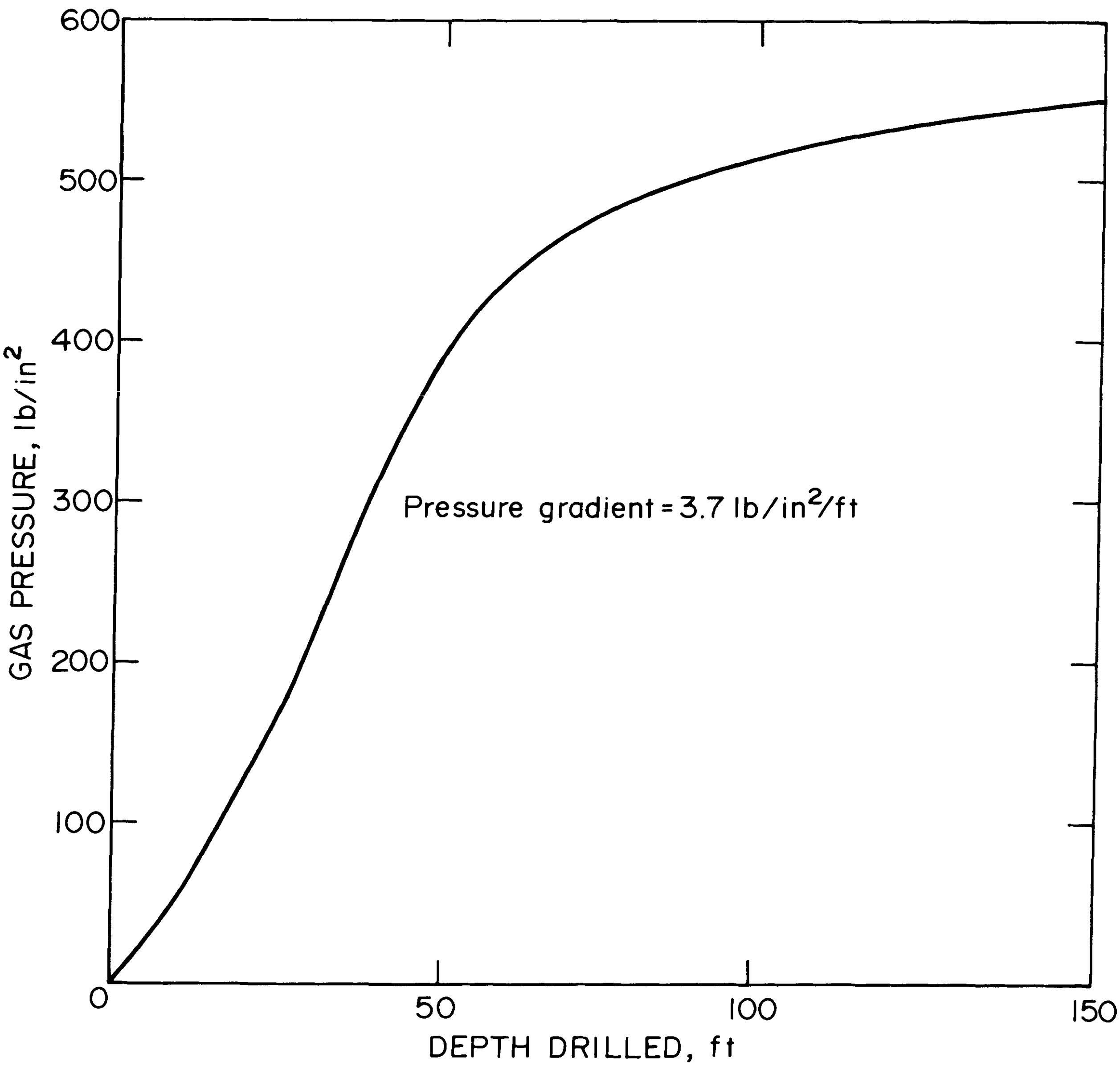

FIGURE 1. - Normal Gradient Near an Active Face.

To establish if coal pillars contained methane under pressure, two 165-foot-long, horizontal bleeder holes were drilled to the centers of two large (330 by 1,000 feet) coal pillars. The gas issuing from the hole in the first pillar contained 95 percent methane at the rate of 20,900 cubic feet per day. When the hole was sealed, the shut-in gas pressure reached 31 lb/in^2. Similarly, gas issuing from the hole in the second panel contained 95 percent methane at a rate of 17,900 cubic feet per day. After the hole was sealed, the shut-in pressure built up to 105 lb/in^2. An additional test was made on a normal-sized (85 by 85 feet) coal pillar by drilling to the center of the pillar. After sealing the hole, no measurable gas pressure was in it.

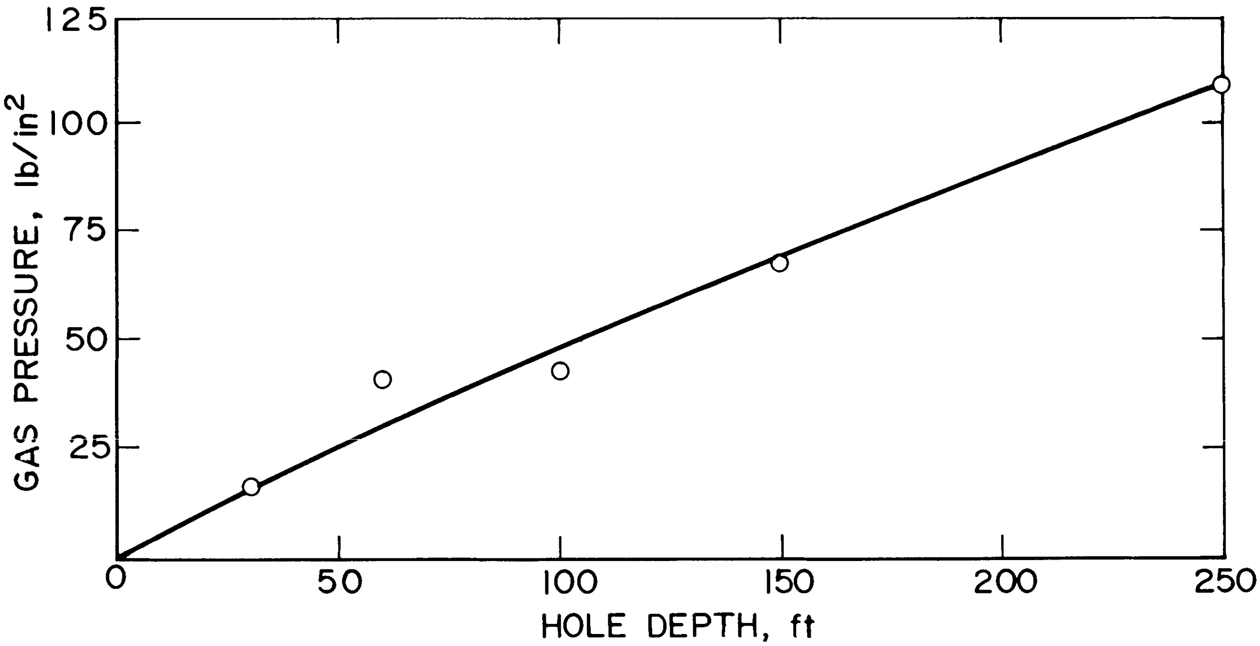

FIGURE 2. - Normal Gradient Near an Inactive Face.

Measurements have shown that roof pressures crush the periphery of large blocks of coal as much as 40 to 60 feet deep, creating an area of reduced permeability. Gas desorbing from solid coal within the block cannot escape, and its pressure builds up within the block. This explains the gas pressure measurements in the two large pillars.

DRILLING STUDIES IN THE PITTSBURGH COALBED

Drilling studies were conducted in the Pittsburgh coalbed in southwestern Pennsylvania to determine the influence of clay veins on the behavior of the gas. This was demonstrated by the pressure measurements taken from one of the horizontal drill holes made in the Pittsburgh bed. Mining in the vicinity of the hole stopped 5 days prior to drilling. The hole was started and advanced 18.5 feet before encountering a clay vein. Before continuing through the clay vein, the hole was tested for gas but none was found. After the 3-foot clay vein was penetrated, the hole was again tested for gas and a pressure of 221 lb/in^2 was measured. Drilling was continued until a second clay vein was encountered at 36 feet. The hole was again sealed to measure the pressure at this depth, and the pressure of 221 lb/in^2 remained. The second 3-foot clay vein was penetrated and sealed with packers. The pressure behind the second clay vein was 263 lb/in^2--an increase of 42 lb/in^2 over the pressure measured in front of the second clay vein. The pressure readings also indicate that the clay veins isolate sections of the coalbed. Figure 3 is a plot of these measurements and this type of curve will be referred to as an abnormal gradient.

Four months later, the area was examined to locate and map the clay veins exposed by mining in the vicinity of this drill hole. The location and thickness of the clay veins, the positions of the faces at the time of drilling,

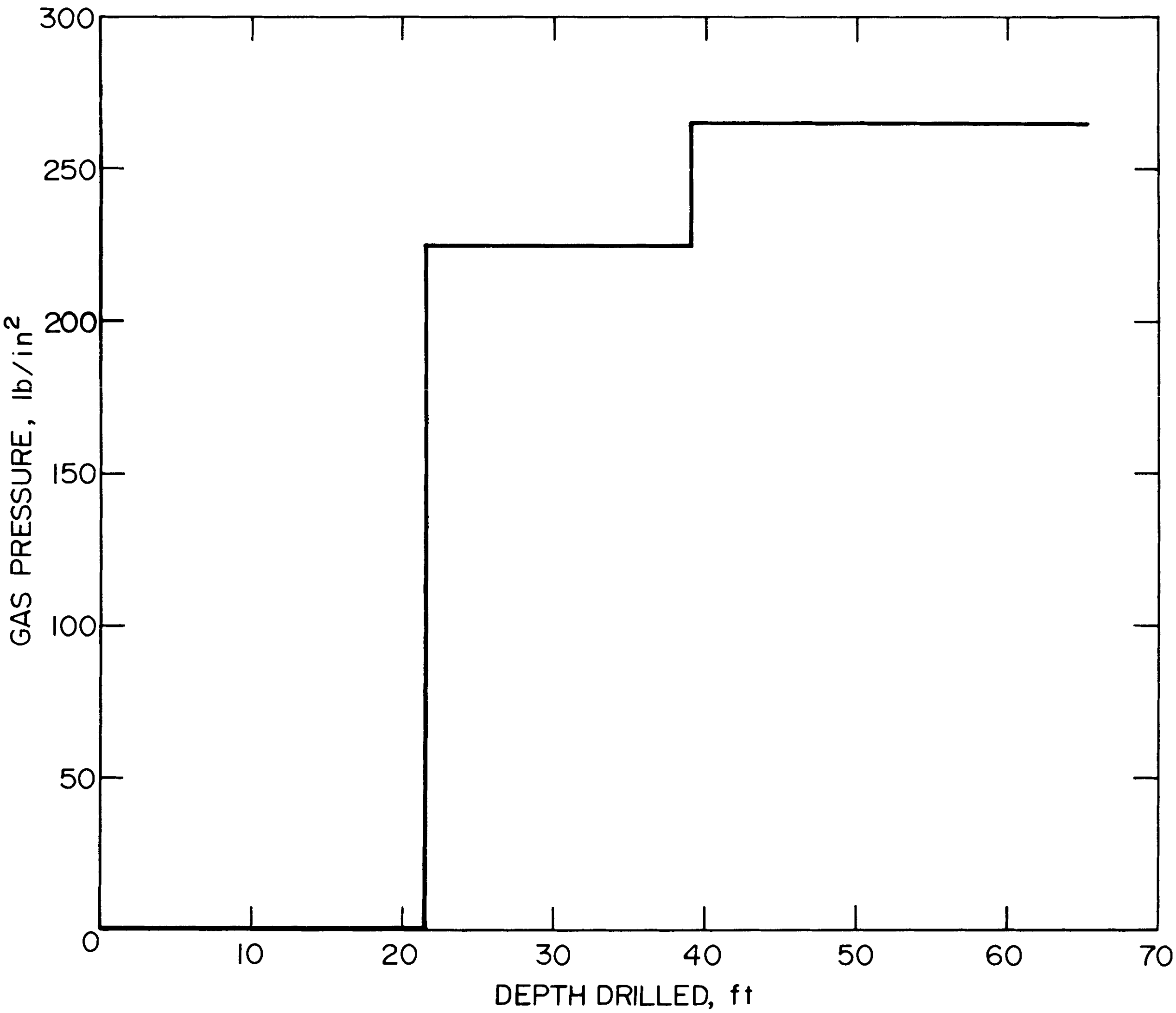

FIGURE 3. - Abnormal Gradient.

and the location of the drill hole (No. 3) are shown in figure 4. This figure shows that clay veins intersect to form closed cells. The pressure readings for these cells indicate that each cell has characteristics independent of cells surrounding it.

The term "clay vein" is a misnomer. These so-called "clay veins" are lithified clay fracture fillings and, therefore, sparks can be produced by the action of bits during mining. Complete penetration of a clay vein is accompanied by a large flow of methane and presents a high potential for an ignition.

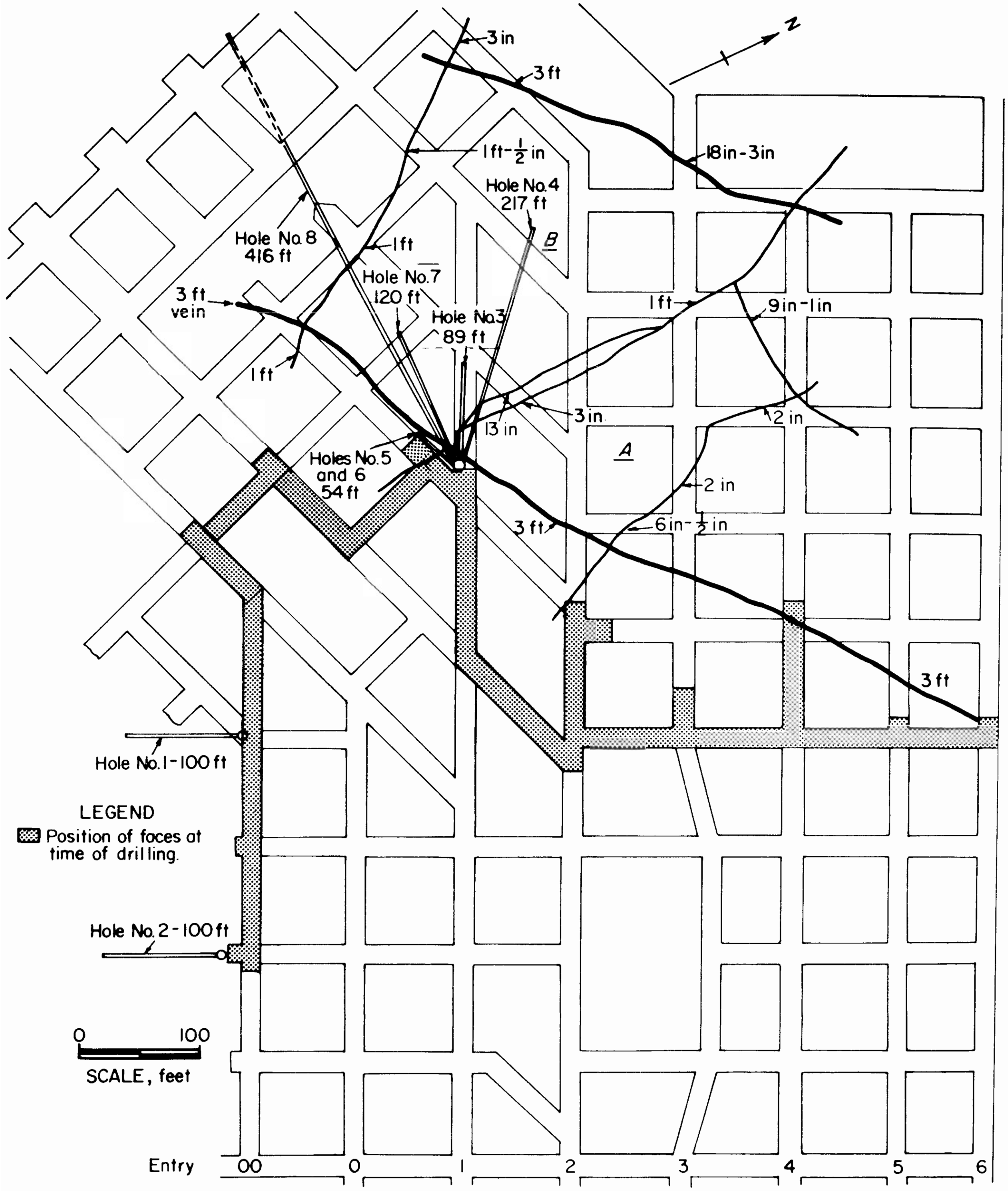

FIGURE 4. - Drill Site Location in the Pittsburgh Coalbed.

DRILLING STUDIES IN A WESTERN COALBED

Studies were conducted in a western coalbed to measure reservoir pressure and pressure gradients. The studies were hampered because of hole caving which was caused by severe overburden pressures.

The first attempts at drilling in the coalbed were made using flush-jointed drill casing. Various 2-inch bits were tried with EX casing (1-13/16-inch outside diameter) and special E casing (1-3/8-inch outside diameter). None of the combinations was successful in drilling deep holes consistently. Holes would cave and seize the drill casing. Flushing with water would not remove the caved material.

Using hollow extensible auger steel (1-3/4-inch-diameter), a hole was drilled 165 feet deep in virgin coal before striking bottom rock. The circulation of flushing water, combined with action of the auger flights, removed caved debris from the hole.

Gas emission from this hole was 27,000 cubic feet per day but after 4 days was reduced to 5,000 cubic feet, indicating that the coal around the hole has a low permeability. More work must be done to determine why the coal has a low permeability and how to degasify the coalbed.

Pressure measurements could not be made in the oversize hole using inflatable packers. Before more drilling is done in this coalbed, a method will be developed for sealing oversized holes.

PROPOSED METHANE CONTROL TECHNIQUES

Coalbeds With Normal Pressure Gradients

A method of degasification conducted at Christopher Coal Company's Humphrey No. 7 Mine in 1959 and 1960[4] required drilling long horizontal holes into ribs from the outside entries (fig. 5). The holes were drilled in advance of the face at an angle of 15° from the centerline of the outside entry. The depth of the hole was determined by the rate of development and time required to degasify the area in advance of the face. As an example, if a section advanced 100 feet per week and control holes degasified the virgin area in a few days, then holes drilled 100 feet in advance of the section would be sufficient. On the other hand, if the section advanced more rapidly and more time was needed to degasify the virgin area, deeper holes would be drilled. This method required development by driving the outside entries first, drilling the control holes from these entries, and allowing the holes to degasify the virgin area while the inside entries were advanced. Split ventilation was required to permit the gas emitted from the control holes to drain directly into the outside entries that were the return airways for the section.

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[4]Merritts, William M., W. N. Poundstone, and B. A. Light. Removing Methane (Degasification) From the Pittsburgh Coalbed in Northern West Virginia. BuMines Rept. of Inv. 5977, 1962, 39 pp.

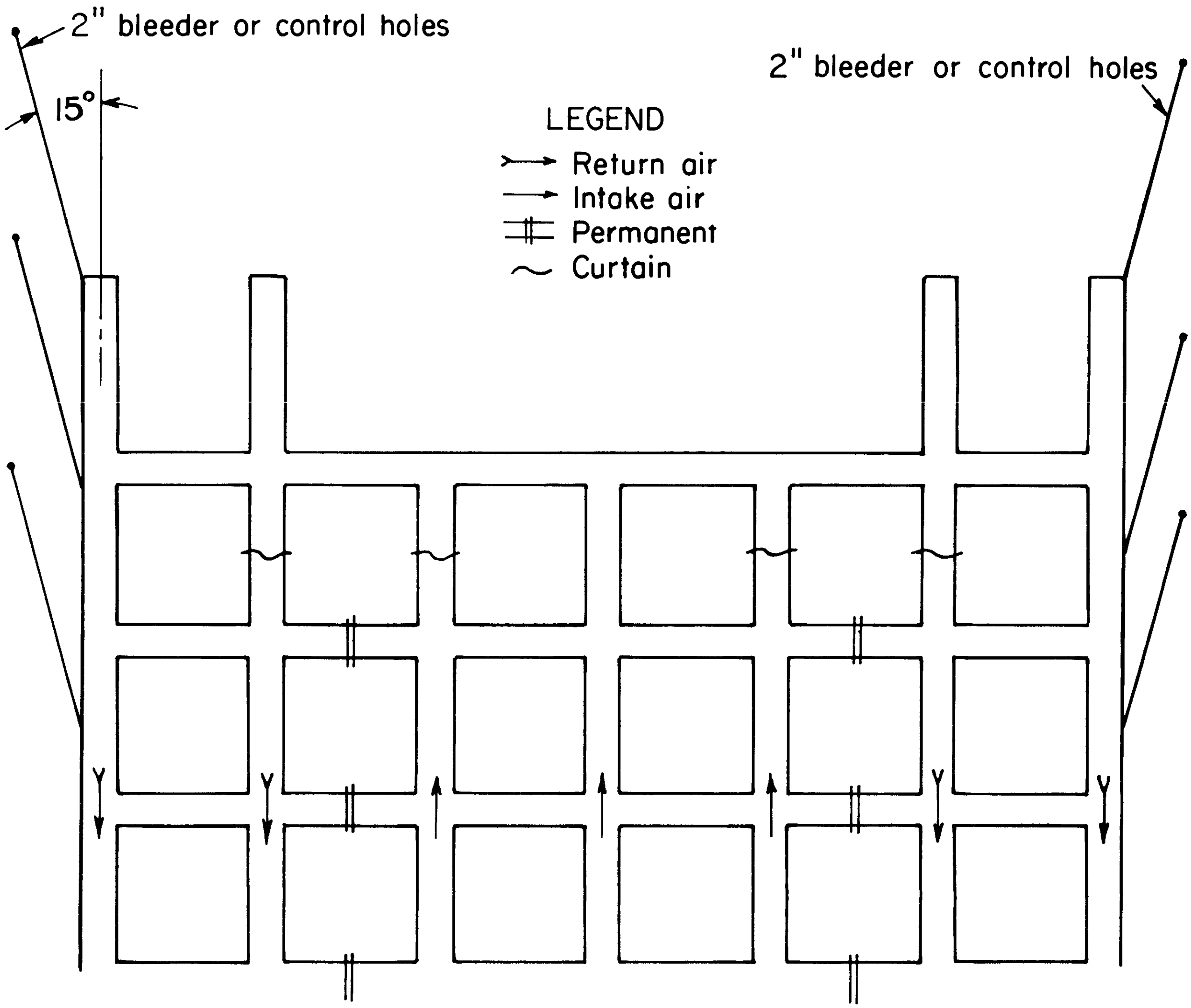

FIGURE 5. - Proposed Methane Control by Horizontal Drilling Into Outside Ribs.

Another control technique was to infuse the coalbed with water to form a barrier which isolated the area to be mined from the gas reservoir. To form the barrier, horizontal holes were drilled across the face of an advancing coal section and the coal was infused through these holes. The holes were spaced to permit the area infused by one hole to overlap the infused areas of the holes on either side. In this manner, a water barrier was formed in the coal ahead of the working face. Control holes were angled from the outside ribs into the coal on each side of the barrier. These holes were the escape routes for the gas displaced from the area during water infusion. The idealized method is shown in figure 6.

Coalbeds With Abnormal Pressure Gradients

Clay veins forming closed cells provide an ideal condition for controlling the flow of gas during mining. The clay veins form natural barriers

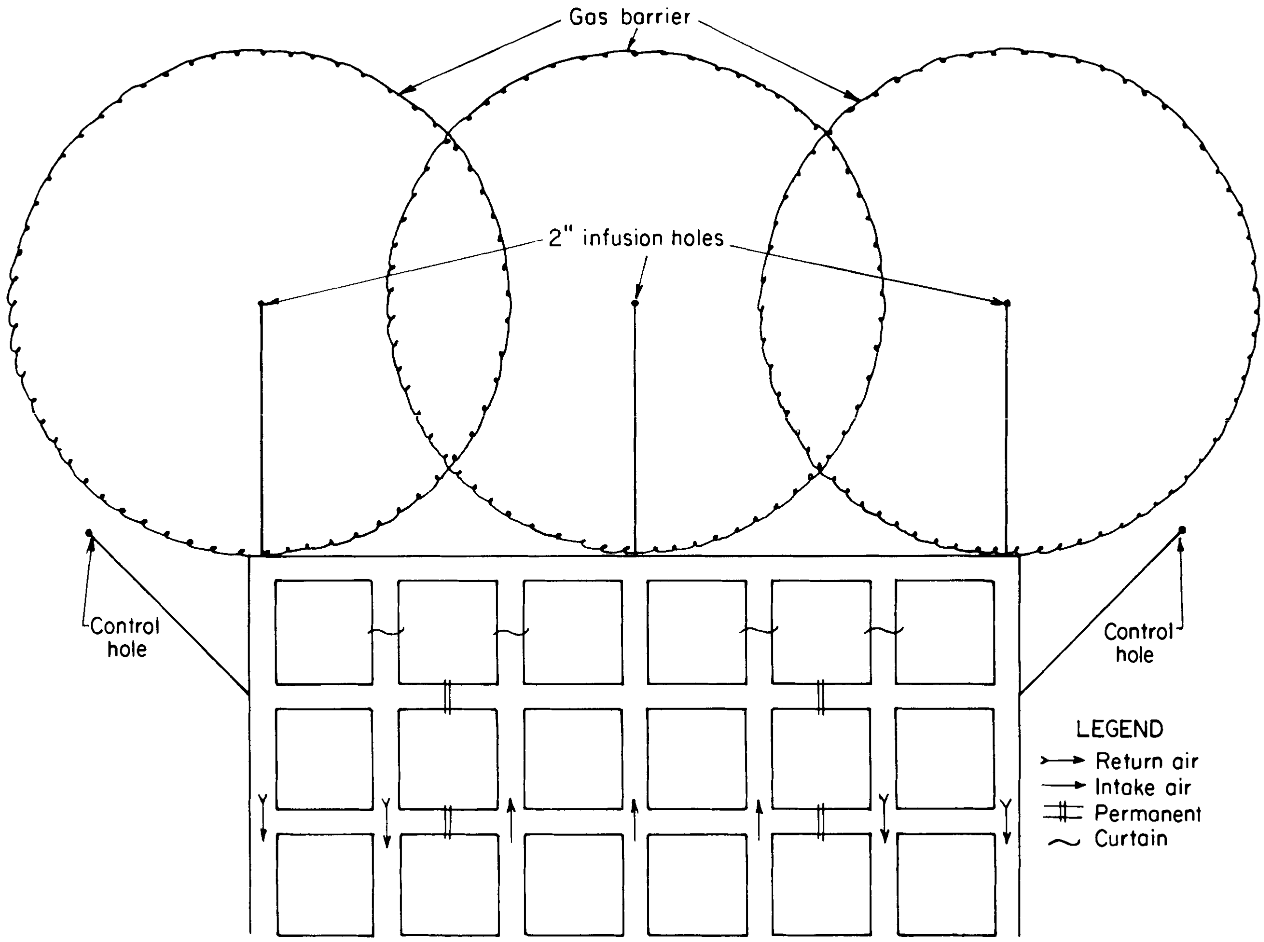

FIGURE 6. - Proposed Methane Control by Water Infusion.

that stop the flow of gas into the face areas from the main gas reservoir of the coalbed. Figure 7 shows a proposed method of methane control where clay veins are present. This method requires a split ventilation system that uses the outside entries for the return airways. This permits the gas from the bleeder or control holes to enter directly into the return airways without passing over other working places at the face.

The sequence of mining would be as follows:

1. Advance outside entries.

2. Retreat and develop the inside entries.

3. Fan out degasification holes from the outside entries while mining the inside entries.

Holes at the outside entries may be drilled in a 45° pattern and deep enough to penetrate clay veins. These holes will have time to bleed down while mining the inside entries. A 45° pattern was chosen to permit a maximum coverage with a minimum number of holes.

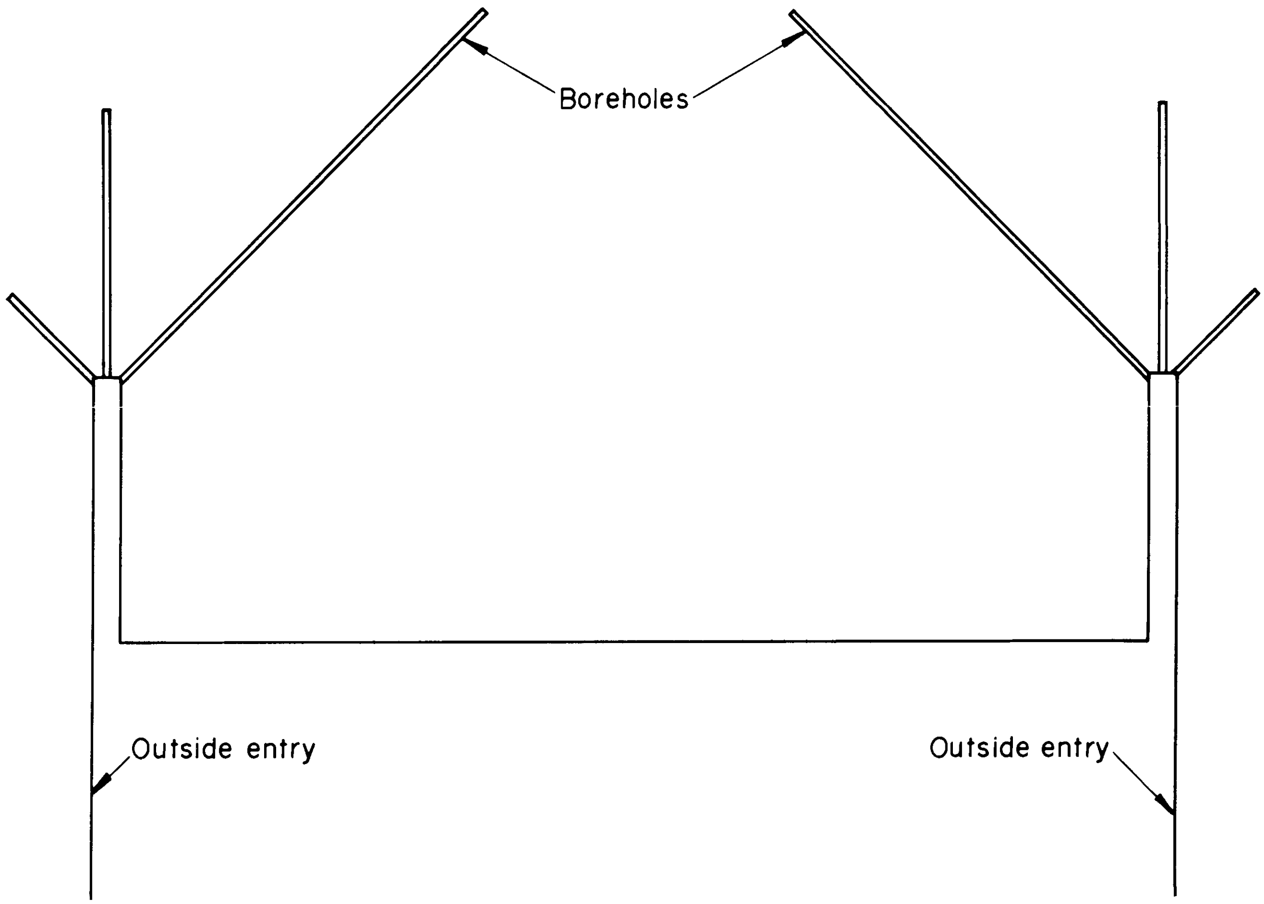

FIGURE 7. - Proposed Location of Degasification Holes for a Multiple Entry System.

CONCLUSIONS

The flow of gas in U.S. coalbeds is governed predominantly by Darcy's law. Therefore, control measures and degasification techniques are aimed primarily at reducing pressure, reducing permeability, or filling of the fracture pore volume with a more viscous liquid.

Where the mining of deeper coalbeds requires smaller mine openings, this will place practical limitations on the quantity of air supplied to active areas of the mine. Since deeper coalbeds tend to be more gassy, the use of ventilation as a means of controlling methane concentrations at active face areas and in the returns is severely limited. Consequently, methane control techniques as described may become mandatory.

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