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Directional Drilling For Coalbed Degasification

Program Goals and Progress in 1978

By David C. Oyler, William P. Diamond, and Paul W. Jeran

UNITED STATES DEPARTMENT OF THE INTERIOR

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DIRECTIONAL DRILLING FOR COALBED DEGASIFICATION

Program Goals and Progress in 1978

by

David C. Oyler,[1] William P. Diamond,[2] and Paul W. Jeran[3]

ABSTRACT

The Bureau of Mines is cooperating with the U.S. Department of Energy in a directional degasification project at the Emerald mine near Waynesburg, Pa. This project is designed to combine the highly successful underground horizontal degasification technology with surface drilling methods. The objective of this program is to demonstrate that directional drilling can be used as a technique for degasifying coalbeds ahead of mining to reduce the hazards of methane-air explosions in coal mines.

The directional hole at the Emerald mine is designed to start vertically and enter the Pittsburgh coalbed horizontally. A 3-inch-pilot hole entered the Pittsburgh coalbed at a vertical depth of 999 feet. The hole will be reamed to 8-3/4 inches in diameter, and 5-1/2-inch casing will be cemented in place. Three individual 3-inch-diameter, 3,000-foot horizontal gas collection holes will be drilled into the coalbed in a "bird foot" pattern.

A corehole and vertical dewatering hole have been completed at the anticipated coalbed intercept. The dewatering hole was drilled to 130 feet below the Pittsburgh coalbed, a depth of 900 feet, and 880 feet of 7-inch-OD casing was cemented in place. Seven vertical holes for monitoring the extent and progress of degasification have been drilled within the horizontal drilling area.

BACKGROUND AND INTRODUCTION

Since 1964 the Bureau of Mines has conducted an expanded program of research in coalbed degasification. This program has evolved to include degasification through the use of horizontal holes drilled underground either in mines or from shaft bottoms (2-4)[4] and surface vertical boreholes using modified oilfield technology (7-8, 10). Horizontal holes were found to have

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[1] General engineer.
[2] Supervisory geologist.
[3] Geologist.
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[4] Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

the advantages of relatively low drilling costs and the ability to intersect the coalbed cleat or fracture system, thus increasing permeability to gas flow. However, this drilling required underground access and facilities, which often interfered with the mining cycle. The requirement of access to the coal often limited the value of the degasification holes due to the limited time and/or distance they could be drilled ahead of mining. Hydraulically stimulated vertical holes eliminated the latter problems, but had the disadvantages of requiring large numbers of surface sites, higher costs, and production and maintenance problems.

The concept of directionally drilled degasification holes was originally considered by the Bureau of Mines as a means of combining the best elements of the surface vertical borehole and underground horizontal drilling techniques. The Bureau of Mines drilled a 3-inch-diameter directional hole in 1973 on the property of Consolidation Coal Co.'s Blacksville No. 2 mine near Jollytown, Pa., as a modification to a vertical hole drilling program. The project showed that a circular arc directional hole could be drilled to reach a coalbed and that a hole could be successfully drilled horizontally in coal up to 450 feet. Mechanical difficulties and later a lack of site access when a dam was built near the hole made further investigation of the gas drainage capacity of the hole impossible until mid-1976.

A second project was begun in 1974 with the goals of drilling long holes in the coalbed, draining large quantities of gas, and determining the economic feasibility of the technique on a production basis. Using the Jollytown project as a model, a drilling plan was drawn up, and drilling equipment purchased. This equipment included a specially designed drill rig, BQ wireline drill rod, drill pipe, and a mud pump. A pilot hole was drilled near Mather, Pa., in late 1975 (1). The project failed to achieve its goals because of an insufficient coal thickness to maintain the horizontal drilling technique, but a great deal of useful experience was gained. A review of the Bureau of Mines past directional drilling experience is summarized in the appendix.

A third directional drilling project is now in progress on the property of the Emerald Mines Corp. near Waynesburg, Pa. This project is funded by the U.S. Department of Energy with the Bureau of Mines providing research planning and technical management. The purpose of this paper is to outline the drilling program and report on the preliminary accomplishments.

ACKNOWLEDGMENT

The cooperation of the management and personnel of the Emerald Mines Corp., Waynesburg, Pa., is greatly appreciated.

PROGRAM OBJECTIVES

The major objective of this program is to demonstrate that directional drilling can be used as a technique for degasifying coalbeds ahead of mining to reduce the hazards of methane-air explosions in coal mines. Specific objectives of the project are to improve the techniques (and hence, lower the cost) of directional drilling for coalbed degasification, and to determine the actual limit of horizontal drilling using the system described here. Coalbed reservoir data will be collected from seven vertical monitoring holes within the project area for reservoir modeling. The monitoring data will provide information on the progress and extent of degasification with time, and will allow the analysis of the effectiveness of various experimental procedures to be performed on the degasification system.

SELECTION OF SITES FOR DIRECTIONAL COALBED DEGASIFICATION SYSTEMS

A number of factors must be considered in selecting sites for directional drilling for coalbed degasification in advance of mining. The coalbed should contain sufficient quantities of gas to require degasification and be deep enough to allow a well path to reach the horizontal with a reasonable angle build rate (in the range of 3° to 6° per 100 feet drilled or a minimum 800 to 900 feet of cover). In general, a particular coalbed contains more gas at greater depths; therefore, depth of the coalbed is a criterion common to both prerequisites. It is also essential to have enough lead time to permit effective degasification before starting mining operations.

Geologic factors also must be considered. The coal should be continuous over the drilling area and be free of faults, rolls, and wants so that horizontal holes may be more easily kept in the coalbed. It would also be desirable for the horizontal holes to be drilled perpendicular to the face cleat to maximize gas production (5). However, since multiple horizontal holes are to be drilled at the bottom of a single directional hole, it would be impractical or impossible to drill all holes perpendicular to the face cleat.

Dewatering of a coalbed is essential for efficient and effective degasification. A vertical dewatering hole is presently considered the best method to accomplish this task in a directionally drilled degasification system. The recommended location for a dewatering hole is just beyond the coal intercept point of the directional hole. For a circular arc directional hole, this point is about the same distance from the surface location of the directional hole as the vertical distance to the coalbed. For example, if the vertical distance to the coal is 1,000 feet, the coal intercept and the dewatering hole should be approximately 1,000 feet away. Selection of sites for the two holes must be planned as a unit since the selection of one site will greatly constrain selection of the other.

DRILLING PROGRAM

Directional Hole

The general drilling plan was to drill a 3-inch-diameter pilot hole on a circular arc starting vertical at the surface and intercepting the Pittsburgh coalbed horizontally at a vertical depth of 999 feet (EM-19, fig. 1). The hole will be reamed to a diameter of 8-3/4 inches after the coalbed has been intercepted on an acceptable drill path. Before starting the horizontal portion of the drilling, 5-1/2-inch-OD casing will be cemented in the directional hole. Three horizontal holes (fig. 2) for gas drainage will then be drilled in the coalbed, each to a planned horizontal extent of 3,000 feet.

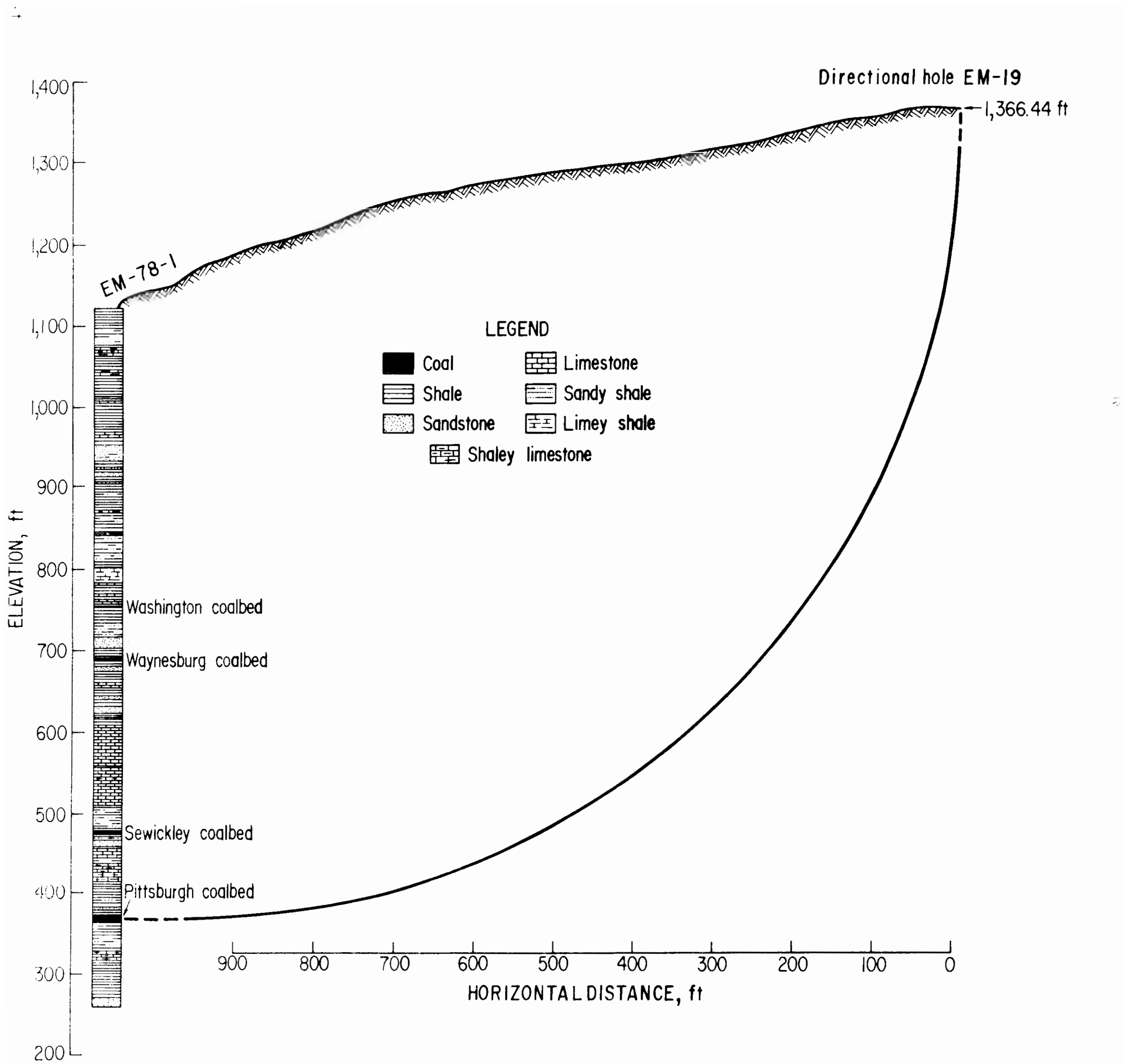


FIGURE 1. - Section view of proposed slant-hole well path with geologic column.

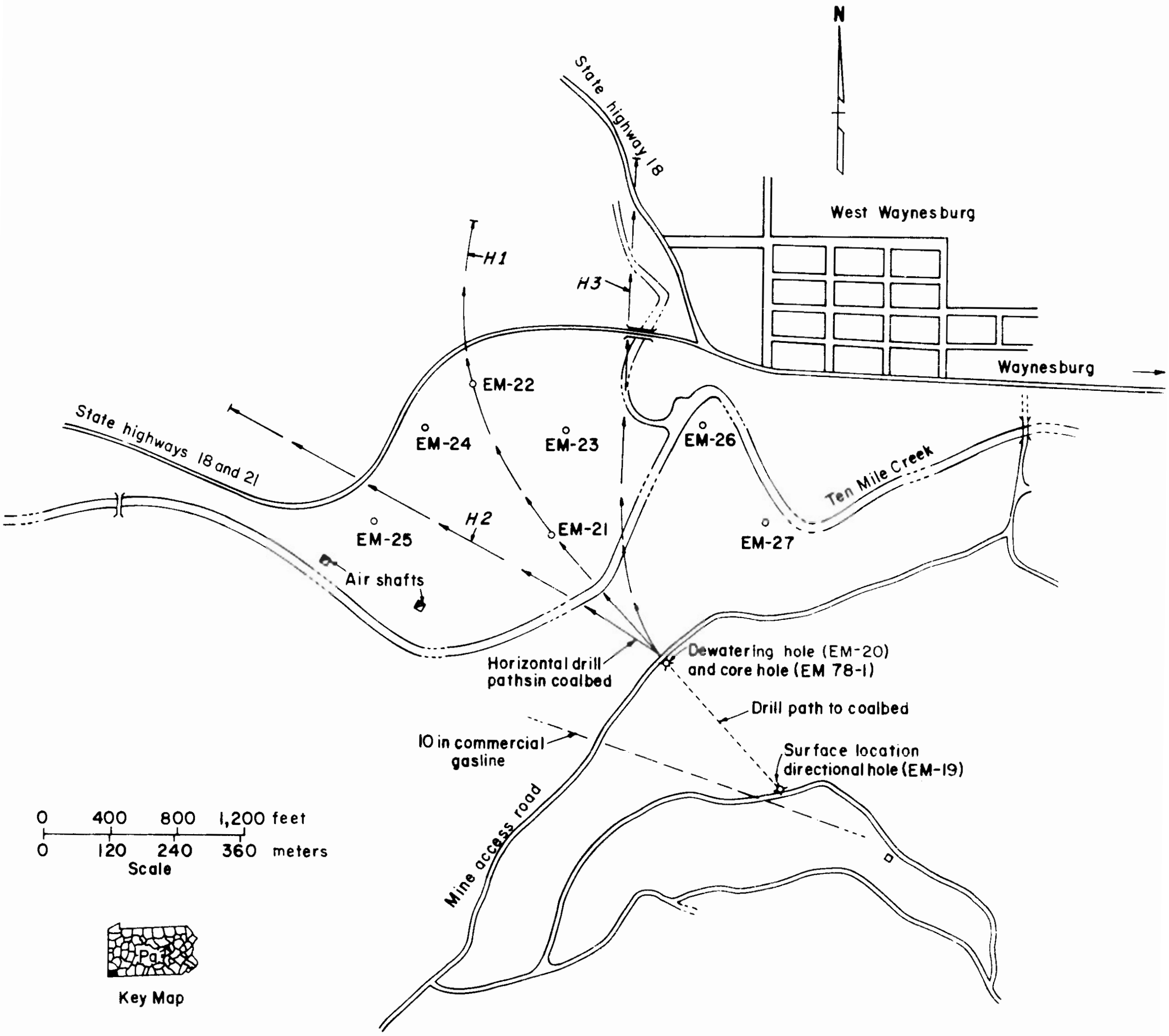


FIGURE 2. - Plan view of drill sites and proposed slant- and horizontal-hole well paths.

The pilot hole was drilled using a 2-3/8-inch-diameter Dyna-Drill[5] (fig. 3) and a 3-inch-diameter Christensen drill bit constructed of whole stone drill bortz (diamonds) and General Electric Strata Paxs. The drill pipe was BQ wireline drill rod. The hole was started vertically for approximately 50 feet before beginning an angle build up of approximately 6.0° per 100 feet of drilled depth.

Control of the pilot hole was accomplished by the use of 45- and 30-minute bent housings (with or without standoff rings) on the Dyna-Drill (fig. 3). Azimuth was controlled by rotation of the tool face. Drilling

[5]Reference to specific equipment, trade names, or manufacturers does not imply endorsement by the Bureau of Mines.

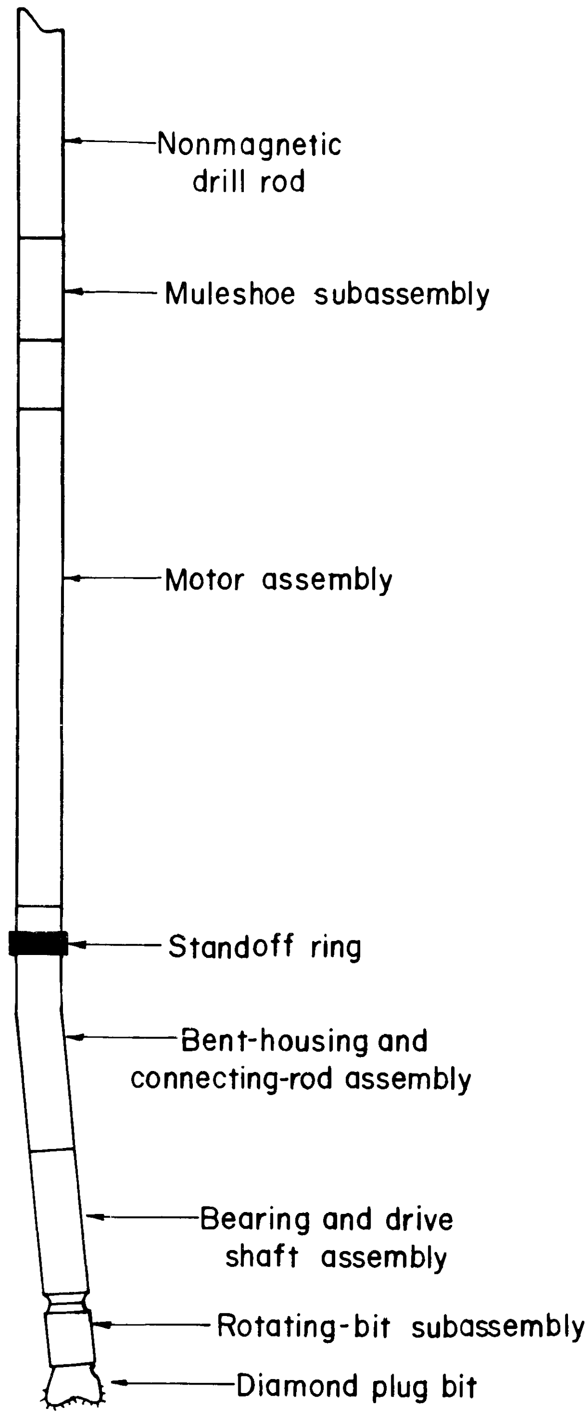


FIGURE 3. - Dyna-Drill tool assembly.

parameters, including pump pressure, mud volume pumped, penetration rates, and pulldown pressure, are recorded using a geolograph. These data will be used to determine the optimum drilling parameters for maximum penetration rate with acceptable directional control.

Directional surveying of the pilot hole and Dyna-Drill orienting was performed using magnetic singleshot equipment and a muleshoe orienting sub. A nonmagnetic stainless steel Dyna-Drill and 80 feet of stainless steel drill rod were used to minimize the effects of the drill string on azimuth readings. Surveying was done at either 10- or 20-foot intervals (each joint or every other joint), and calculations were made using angle averaging and radius-of-curvature methods. Frequent well projections were made to determine whether the hole was too far off course. Once the hole was near the coalbed, an effort was made to guide its path toward the vertical dewatering hole.

The mud system used was a low solids, polymer mud. Two types of polymer were used, one to prevent fluid loss and the other to provide gel strength and aid in removal of drill cuttings. This system, used throughout all drilling on the Mather hole, kept the hole open without problems for 4 months.

The directional hole will be reamed to 8-3/4 inches by running the BQ drill rod in the completed pilot hole and drilling over it with a reaming bit. This procedure will insure that the reaming bit does not leave the pilot hole drill path.

Immediately after the reaming is completed, a string of 5-1/2-inch-OD K-55 casing, 4.95- to 4.8-inch ID, will be run and cemented in the hole from bottom to surface. It is planned that the bottom of the casing will extend approximately 50 feet horizontally into the coalbed.

The entire mud system, including all mud in the hole, will be changed after cementing, and clear water will be used on the horizontal holes. This will be done to prevent loss of coalbed permeability, which might take place if additives were used that could plug or block fracture openings.

The 2-3/8-inch Dyna-Drill and BQ drill rod will be used to drill the 3-inch-diameter horizontal holes in the coalbed. After the first hole (H-1) is drilled to the maximum length considered either economically or physically feasible, holes H-2 and H-3 will be sidetracked in the directions shown on figure 2.

The surface facility of the completed hole will include a wellhead for servicing the well, gas flow measuring equipment, water separator, flare stack, flame arrestor, and gasline shutoff valves. All of the equipment will be installed in a protective wellhouse.

Results of Drilling Core and Dewatering Holes at Anticipated Coalbed Intercept

Before drilling began on the directional hole, a corehole (EM-78-1, fig. 2) was drilled near the anticipated coalbed intercept. The corehole was used to confirm the presence, thickness, and elevation of the coalbed, and to provide stratigraphic information for correlation to the directional hole. Samples of the Washington, Waynesburg, Sewickley, and Pittsburgh coalbeds were obtained for gas content evaluation by the direct method (6, 9). A stratigraphic column of this corehole is shown on figure 1.

Experience at the Jollytown site indicated that conventional sucker-rod water-pumping equipment will not function properly in a horizontal position. The efficient production of gas from coalbeds is dependent upon the dewatering of the coal. A vertical dewater hole (EM-20, fig. 2) was drilled near the anticipated intercept of the coalbed and adjacent to the corehole (EM-78-1). A schematic of this hole is shown in figure 4. The dewatering hole was drilled as a "straight" hole, but a multishot directional survey of the hole showed that the well path deviated considerably (fig. 5). The deviation probably occurred because the drill pipe was not adequately stabilized, but the deviation is not expected to cause any problems.

The dewatering hole was drilled 17-1/2 inches in diameter to a depth of 16 feet and 16-inch-diameter conductor pipe was set. A 14-3/4-inch-diameter hole was then rotary drilled using foam, to a depth of 215 feet where 203 feet of 10-3/4-inch-OD casing was cemented in place. This intermediate casing was set to seal off lost circulation zones encountered in the corehole at the same site. The casing was cemented using thixiotropic cement to prevent losing a large volume of cement to the lost circulation zones. A 25-percent overrun was specified on the cement volume to insure sealing off the lost circulation zones and to provide an adequate bond on the casing. There was only minimal circulation of cement to the surface, indicating that the lost circulation zones had taken cement. The cement job proved to be successful in that the lost circulation problems were eliminated. Full returns of cement were obtained when the 7-inch primary casing was later set, further indicating a successful cementing procedure on the intermediate casing.

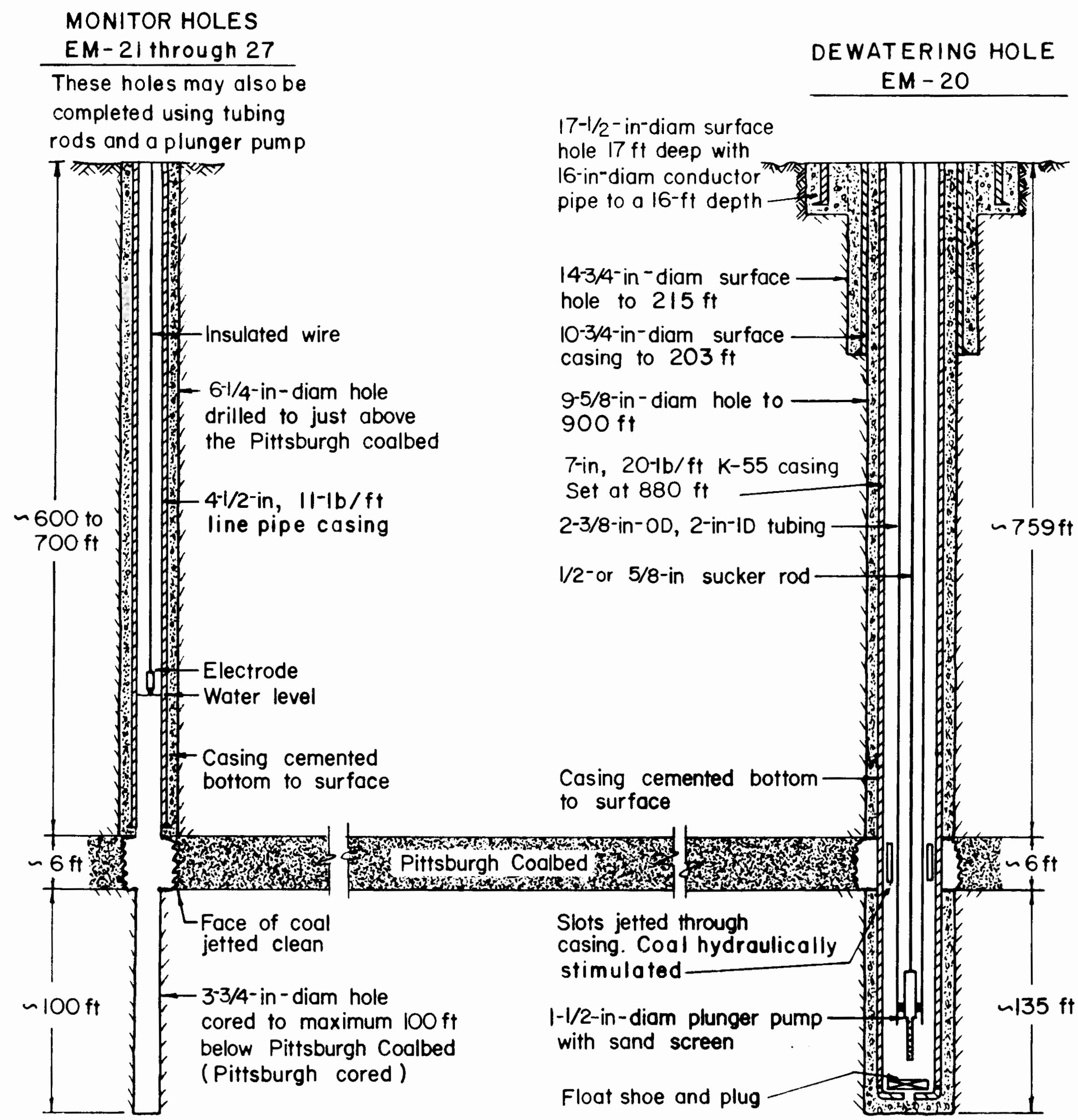


FIGURE 4. - Schematic diagram of completed dewatering hole and proposed monitoring holes.

The hole was then rotary drilled to approximately 135 feet below the Pittsburgh coalbed using one 9-5/8-inch-diameter bit and one 9-1/2-inch-diameter bit. Before setting the final string of casing, a suite of geophysical logs (including density, neutron, and gamma ray) were run to determine the exact measured depth of the coalbed. This was necessary for the proper positioning of the casing collars and centralizers above and below the coalbed.

A caliper log was run to calculate the volume of cement needed to set the casing and to determine the well bore diameter adjacent to the coalbed. If the hole had been excessively washed out in the coalbed, the cementing

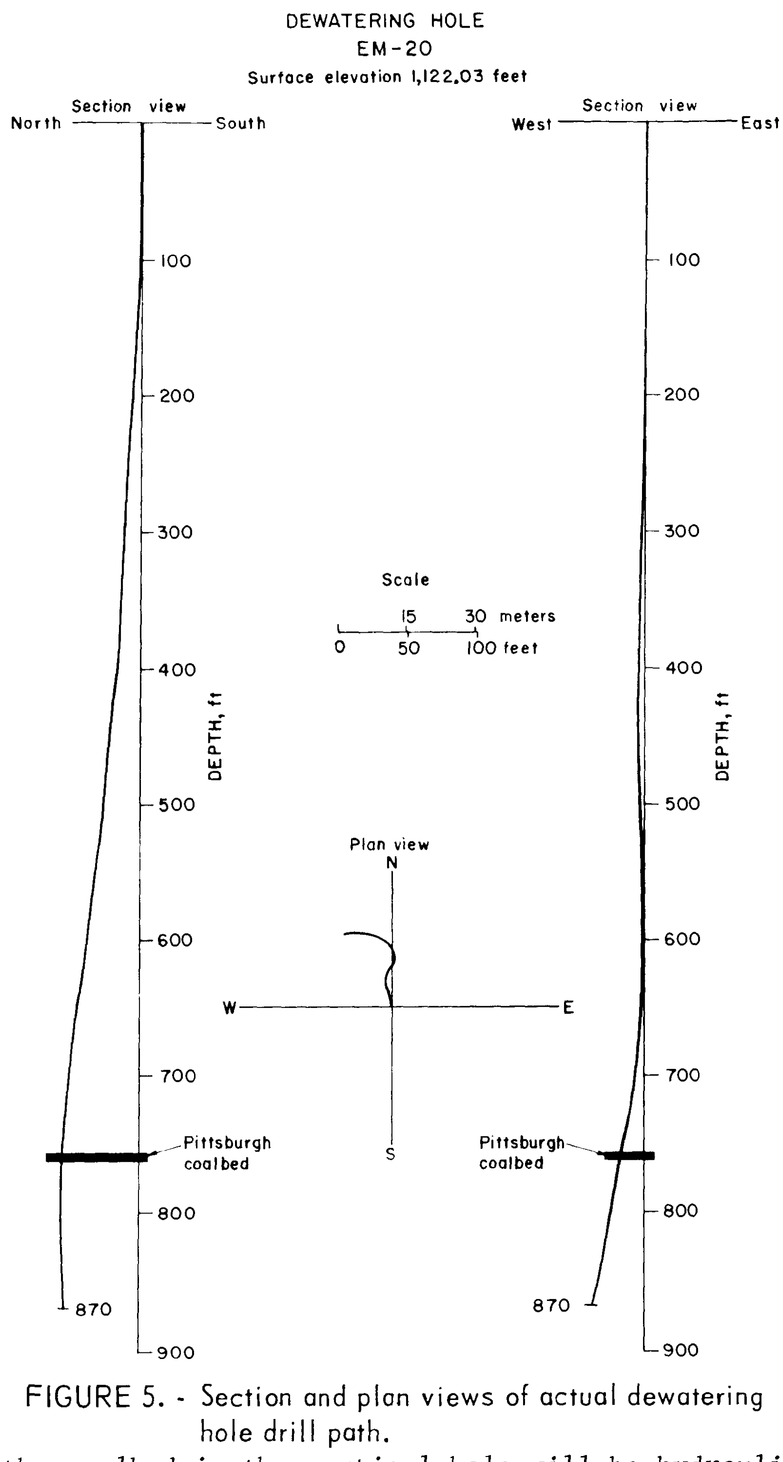


FIGURE 5. - Section and plan views of actual dewatering hole drill path.

technique for the casing would have required special equipment to keep the cement out of the coalbed interval. Knowing the thickness of cement between the casing and the coalbed is important because the "slotting" tool to be used to provide communications between the casing and the formation can only penetrate approximately 12 inches of casing and cement. The caliper log indicated that the coalbed was not "washed out," and a conventional cementing technique was used. Thixiotropic cement was used to keep infiltration of cement into the coalbed and the accompanying loss of permeability to a minimum. Eight hundred and eighty feet of 7-inch-OD, K-55, short thread and coupling, 20-lb/ft casing was used with a "cement shoe" on the bottom. Cased hole geophysical logs, including an uncalibrated gamma ray and collar log, were run to confirm the position of the casing collars and to recheck the measured depth of the Pittsburgh coalbed.

Water level and pressure-monitoring equipment will be installed on the hole and data collected until the directional hole has entered the coalbed and casing has been installed. Before starting the horizontal drilling, the coalbed in the vertical hole will be hydraulically stimulated through previously cut slots. The stimulation procedure is designed to insure the efficiency of the dewatering process and enhance the degasification of the coalbed by increasing the formation permeability (7-8, 10).

A down-hole plunger pump capable of producing up to 120 bbl/day will initially be installed on the dewatering hole. The pump will be run by a 7.5-hp motor using three-phase, 440-volt power. The motor and pumping unit are capable of pumping over 250 bbl/day with larger down-hole pumps if greater water volumes are encountered than anticipated.

Dewatering is not scheduled to begin until the horizontal drilling portion of the project is completed. If the coalbed is dewatered before horizontal drilling, the drilling fluid and cuttings could reduce the permeability of the coalbed.

Since the dewatering hole should behave as a conventional vertical degasification well and produce gas as dewatering proceeds, it has been engineered to produce and monitor both gas and water. The surface facility (fig. 6) will also include a flare stack with a flame arrestor to safely vent gas and a protective enclosure for the wellhead equipment. A 40- by 15- by 4-foot-deep holding pond will be located near the hole for disposal and treatment of the produced water.

Vertical Monitoring Holes

Seven vertical boreholes have been drilled to the Pittsburgh coalbed in the area to be degasified by the directional hole. These holes (EM-21 through EM-27, fig. 2) will be used primarily to monitor the coalbed formation pressures by observing changes in water level in each hole. A lowering of the

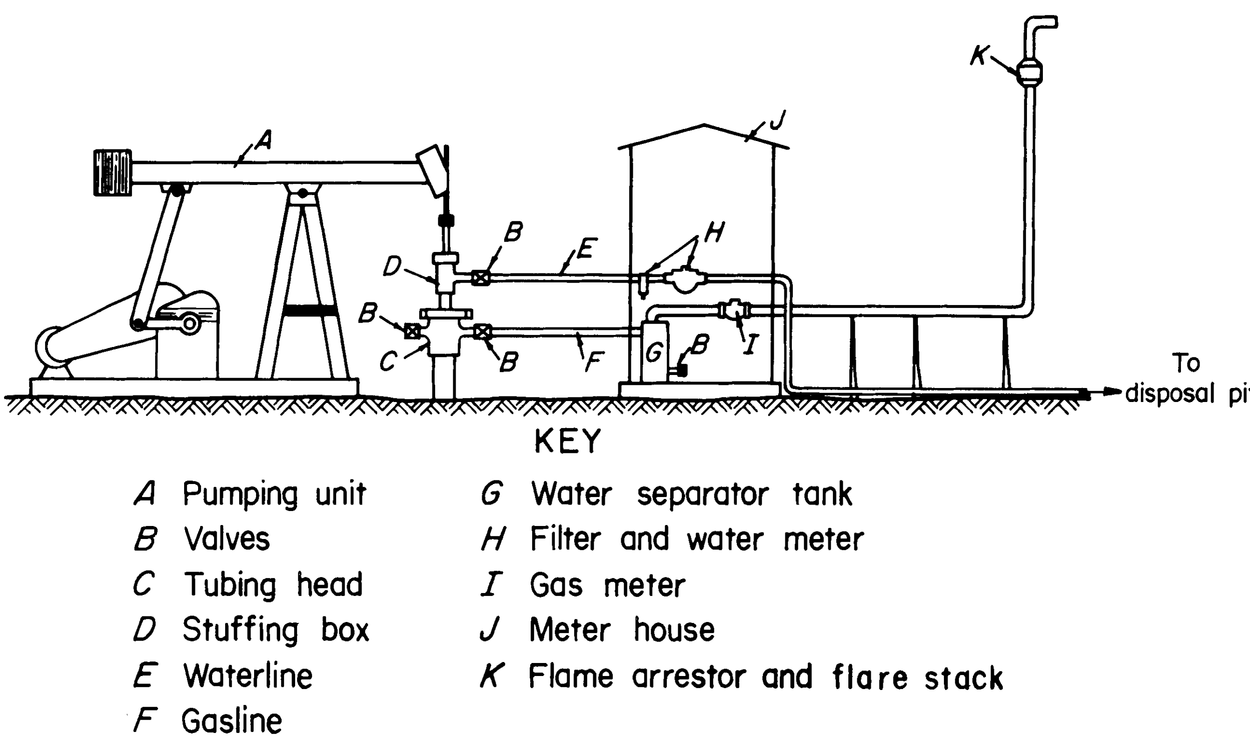
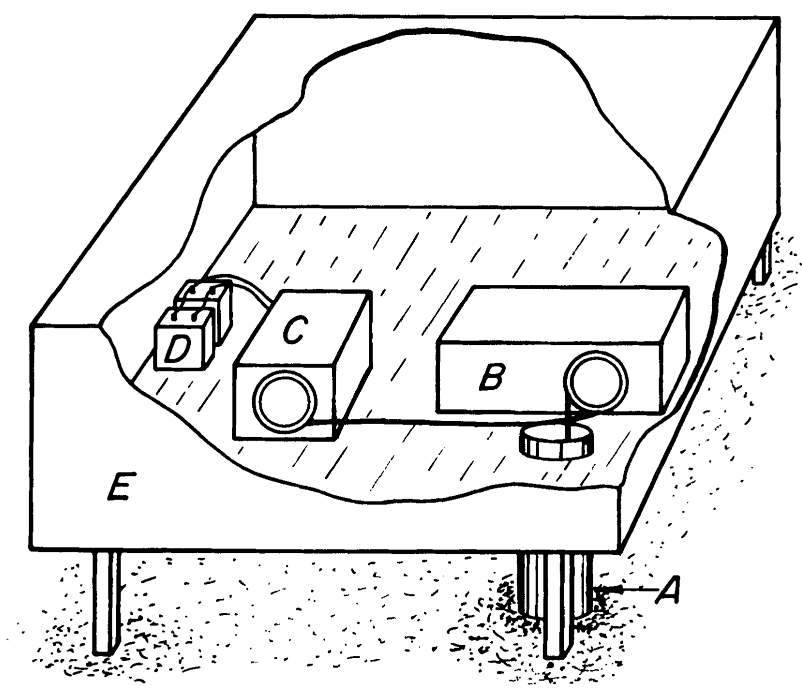


FIGURE 6. - Schematic diagram of proposed surface facility at dewatering hole.

water column height in a hole will indicate the loss of formation pressure caused by removal of water and gas from the dewatering and directional holes. If the directional hole is surrounded by holes equipped with continuous recording water level devices, both the degree and areal extent of degasification can be monitored. The holes will also be completed for the production and measurement of gas and water. This will allow short periods of production so that formation evaluation tests can be conducted. The holes can also be used for general coalbed dewatering should the prime dewatering hole prove inadequate. However, these holes should not be used for production since any long-term production from these holes would make it difficult to determine the effectiveness of the directional hole, and fluid levels cannot be used to determine formation pressures in producing holes.

The monitoring holes were drilled using cable tool and rotary drill rigs. A 6-1/4-inch hole was drilled to just above the Pittsburgh coalbed, and a string of 4-1/2-inch casing cemented in place (fig. 4). A coring rig will drill out the cement plug, and cores of the Pittsburgh coalbed will be taken in each hole so that the gas content of the coal may be determined. Approximately 100 feet of hole will be drilled below the coalbed to be used as a sump as in the main dewatering hole.



KEY

A Casing

B Recorder

C Keck water-level-sensing device

D Batteries to power Keck device

E Platform and insulated housing

FIGURE 7. - Schematic diagram of water-level-sensing device to be installed on monitoring holes.

Each hole will be "jetted" using the same equipment that is to be used to "slot" the casing in the dewatering hole. This technique performed in the open hole will remove the coal exposed to drilling fluids helping to minimize loss of permeability and pressure drops (skin damage) caused by plugging of the fracture system (cleat) near the well bore. Each monitor hole will be completed with surface equipment similar to that in the dewatering hole (fig. 6); in addition, a water-level-sensing device with a continuous data recorder (fig. 7) will be installed on each hole. The holes will probably not be stimulated hydraulically unless they are eventually used for sustained gas and/or water production.

SUMMARY

Work was begun in September 1978 on a project to drill a directional coalbed degasification hole at Emerald Mine near Waynesburg, Pa. A 3-inch-diameter circular arc pilot hole was drilled to intercept the Pittsburgh coalbed horizontally at a vertical depth of 999 feet. The hole will be reamed to 8-3/4 inches in diameter so that 5-1/2-inch-OD casing can be cemented in place. A vertical dewatering hole and a corehole have been completed at the coalbed intercept point of the directional hole. Seven vertical monitor holes have been drilled and cased in the horizontal drilling area, and the holes will be equipped to measure coalbed pressures.

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APPENDIX.--JOLLYTOWN AND MATHER SLANT HOLE HISTORIES

The Bureau of Mines drilled the first directional hole into a coalbed in 1973 on the property of Consolidation Coal Co.'s Blackville No. 2 mine near Jollytown, Pa. The 3-inch hole was started at a 20° angle at the surface and intercepted the Pittsburgh coalbed at a vertical depth of 776 feet. The actual drilled distance along the circular arc to the coalbed intercept was approximately 1,310 feet.

The original hole was drilled using a Joy 22 drill rig, BQ wireline rod, and a 1-3/4-inch Dyna-Drill tool for directional control. Horizontal drilling in the coalbed at Jollytown reached 414 feet. At this depth it became impossible to pull the drill string, and a decision was made to establish production by "perforating" the 414 feet of pipe in the coalbed. The efficient production of gas from coalbeds is dependent upon several factors including dewatering of the coal. Gas flow rates as high as 25 to 30 Mcfd were reported immediately after the hole was swabbed to remove water. A rapid influx of formation water killed the gas flow within 15 to 20 minutes. A down-hole sucker-rod pump was installed at a depth of 1,310 feet for continuous production of water. The water flow rate began at 14 bbl/day and declined to 7 bbl/day after several weeks. Gas production during this testing phase ranged from 1,200 to 3,800 cfd.

The BQ rod in the Jollytown hole was overreamed to a depth of approximately 1,000 feet, and the old pipe was removed. A string of 4-1/2-inch casing was then installed to allow the use of larger down-hole pumps and provide a less restricted gas flow. Two additional holes were drilled into the coalbed from the bottom of the casing. The maximum horizontal penetration of the coalbed by these holes was approximately 400 feet due to the low pulling capacity of the rig. Shortly after this phase of drilling, the coal company began construction of a holding pond adjacent to the drill site, necessitating a shutdown of research activities for approximately 2 years.

The Jollytown hole was cleaned out in early 1976, and a down-hole sucker rod pump was installed at a depth of 1,410 feet. Water production was 3-1/2 bbl/day initially, declining to less than one-half bbl/day in approximately 2 months. The "water" produced was in many instances a black muddy sludge. Gas production ranged from less than 1,000 cfd up to 3,100 cfd. Various remedies, including moving the pump progressively up the hole to position it in less horizontal attitudes, failed to improve the production of water and gas. The hole was abandoned in late 1976.

The Jollytown hole proved that a directional well path could be started near vertical at the surface and controlled to intercept a specific small target in a comparatively short vertical distance. The experience in attempting to establish production through the slant hole indicated that conventional sucker-rod water-pumping equipment would not function properly in a horizontal attitude and that other methods of dewatering would be needed. The problem of keeping the hole and pump free from particulate matter was thought to result from the casing being set too high, leaving approximately 300 feet of open hole exposed between the bottom of the casing and the top of the coalbed.

In the fall of 1975, the Bureau of Mines began a second directional drilling project (1). This hole, at Mather, Pa., was to degasify the Upper Freeport coalbed in advance of mining. Due to the problem of pulling pipe at the Jollytown site, a larger drill rig with greater pulling capacity was used. The rig was completely hydraulic to aid in providing a smooth feed of drill pipe while using the Dyna-Drill. A newly developed 2-3/8-inch Dyna-Drill was used in place of the 1-3/4-inch tool used at Jollytown.

The general drilling plan included a 3-inch-diameter pilot hole drilled on a 1,500-foot well path to intersect the coalbed at a vertical depth of 930 feet. After the intercept of the coalbed, the hole was to be reamed to 8-3/4 inches, and 5-1/2-inch casing was to be installed. Three horizontal gas collection holes up to 3,500 feet long were then to be drilled into the coalbed.

The pilot hole was completed to the coalbed intercept point, but not without many difficulties. Most of the problems encountered were mechanical or involved directional control. Mechanical problems included rig, Dyna-Drill, and mud pump breakdowns. Problems in maintaining the proper well path required three plug backs and redrilling prior to the first intercept of the coalbed.

The first penetration of the Upper Freeport horizon at Mather encountered only 0.5 foot of coal. Approximately 1,500 feet of exploratory horizontal drilling after the initial coalbed intercept and five additional penetrations of the coalbed horizon could not locate sufficient continuous thickness of coal to continue the project. Seven coreholes in the vicinity of the drill site indicated 5.9 to 8.5 feet of Upper Freeport coal. The first penetration of the coalbed was only 750 feet from a corehole that indicated 6.75 feet of coal.

The Mather project confirmed the feasibility of drilling a directional hole to a predetermined target. The 2-3/8-inch Dyna-Drill was developed into a usable tool, and considerable experience was gained in directional control of the hole, especially in the horizontal phase of the drilling. The project also suggested the need for more complete geologic evaluation of drill sites, to include the drilling of a corehole at the proposed initial coalbed intercept. The corehole would confirm the thickness and exact elevation of the coal for accurate drill path projections.

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