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Review of Horizontal Drilling Technology for Methane Drainage From U. S. Coalbeds

By Gerald L. Finfinger and Joseph Cervik

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

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CONTENTS

ILLUSTRATIONS

REVIEW OF HORIZONTAL DRILLING TECHNOLOGY FOR METHANE DRAINAGE FROM U.S. COALBEDS

by

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

ABSTRACT

This Bureau of Mines publication reviews underground methane drainage programs being conducted in various coalbeds. Equipment used in drainage programs such as drills, underground pipelines, and methane monitoring systems is described.

INTRODUCTION

The Bureau of Mines has been conducting research in mine safety since its inception in 1910. Because uncontrolled release of methane from a coalbed is a serious safety hazard in underground coal mining, the Bureau has conducted an extensive program to study methods of controlling methane emissions. An important part of this program is the work done to determine the feasibility and effect of methane drainage from coalbeds before mining. Previous work includes studies aimed at understanding the formation and migration of methane in coalbeds (2, 8)[3] and field test methods to remove methane ahead of mining (5-6, 9). One of the most effective methods of degasification has been the drilling of small-diameter (3- to 3-1/2-inch) drainage holes horizontally into the coalbed. Horizontal holes have recently been drilled to lengths more than 2,000 feet by Bureau personnel and others (4, 10, 13). A large part of the Bureau's research effort has been directed toward developing safe and efficient techniques for drilling boreholes and conveying the flow of methane to the surface.

Experience has shown that underground horizontal boreholes have a great potential for producing large-volume flows of methane. Every foot drilled in the coalbed from underground locations is productive and gasflows increase as hole length increases. In using horizontal boreholes, dewatering pumps are not necessary because gas pressure forces water out of the hole so that methane can be recovered through the use of simple and inexpensive gas-water separators.

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[1]Geologist.
[2]Supervisory Geophysicist.
All authors are with the Pittsburgh Research Center, Bureau of Mines, Pittsburgh, Pa.
[3]Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

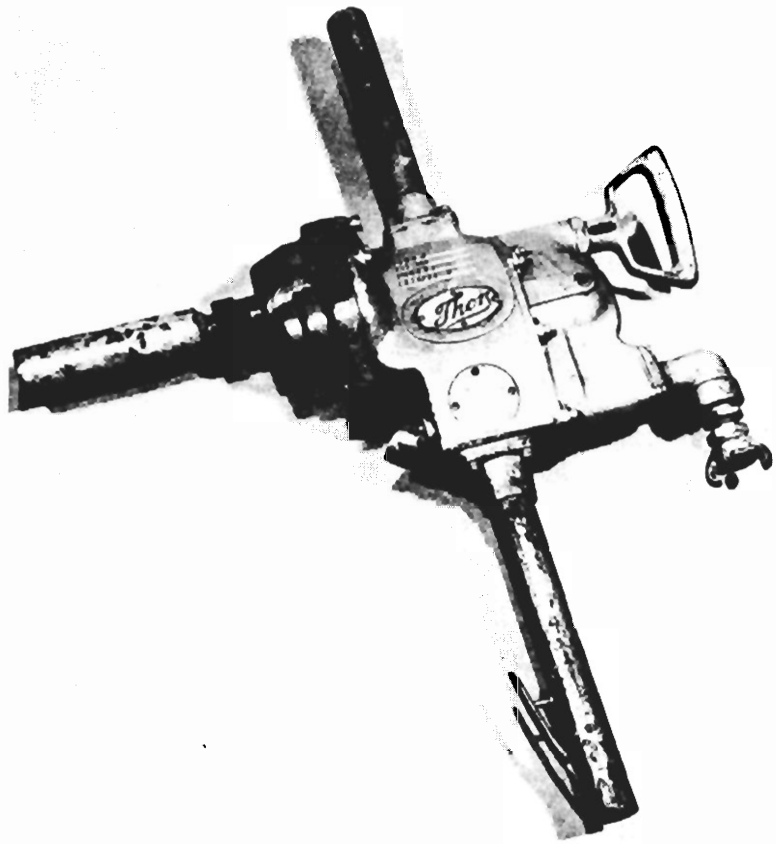

FIGURE 1. - Handheld air drill.

UNDERGROUND DRILL EQUIPMENT[4]

When the Bureau began its horizontal drilling program, very little information on drilling techniques was available. Early field studies were conducted to determine the proper procedures for drilling short horizontal boreholes (7). The first drills used were handheld (fig. 1) or post-mounted and electrohydraulic (fig. 2). These drills are easily transported but are not capable of easily drilling holes to lengths of up to 1,000 feet. Recognizing the potential of long horizontal drainage holes for degasification of coalbeds, the Bureau studied factors that influenced bit trajectory, developed methods and equipment for controlling bit trajectory, and designed, built, and tested a longhole drill unit for drilling horizontal boreholes to at least 1,000 feet.

E. J. Longyear Co.[5] designed the Bureau's first electrohydraulic longhole drill equipment (figs. 3-4). The drill unit is equipped with gages to monitor bit rotational speed, torque, and thrust. The thrust potential of the drill unit is 13,000 pounds at 2,000 psi hydraulic pressure. Feed length is about 11 feet and the overall length of the drill unit is about 18 feet. The power unit (fig. 4) consists of a 30-hp, 440 vac motor that drives hydraulic pumps to operate the thrust and spindle rotation motors on the drill unit. Using the Longyear drill, horizontal boreholes have been drilled to lengths of 2,110 feet without reaching the capacity of the drill unit (4).

One disadvantage of the Longyear drill (fig. 3) is its 18-foot length, which makes it difficult to maneuver in underground locations. The drill could be shortened to facilitate underground handling, but then the 11-foot feed would be sacrificed. An electrohydraulic longhole drill that is much

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[4]This report includes discussion of drills developed for horizontal drilling underground. Comprehensive coverage of all drills that may be used for such purpose is not intended.

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

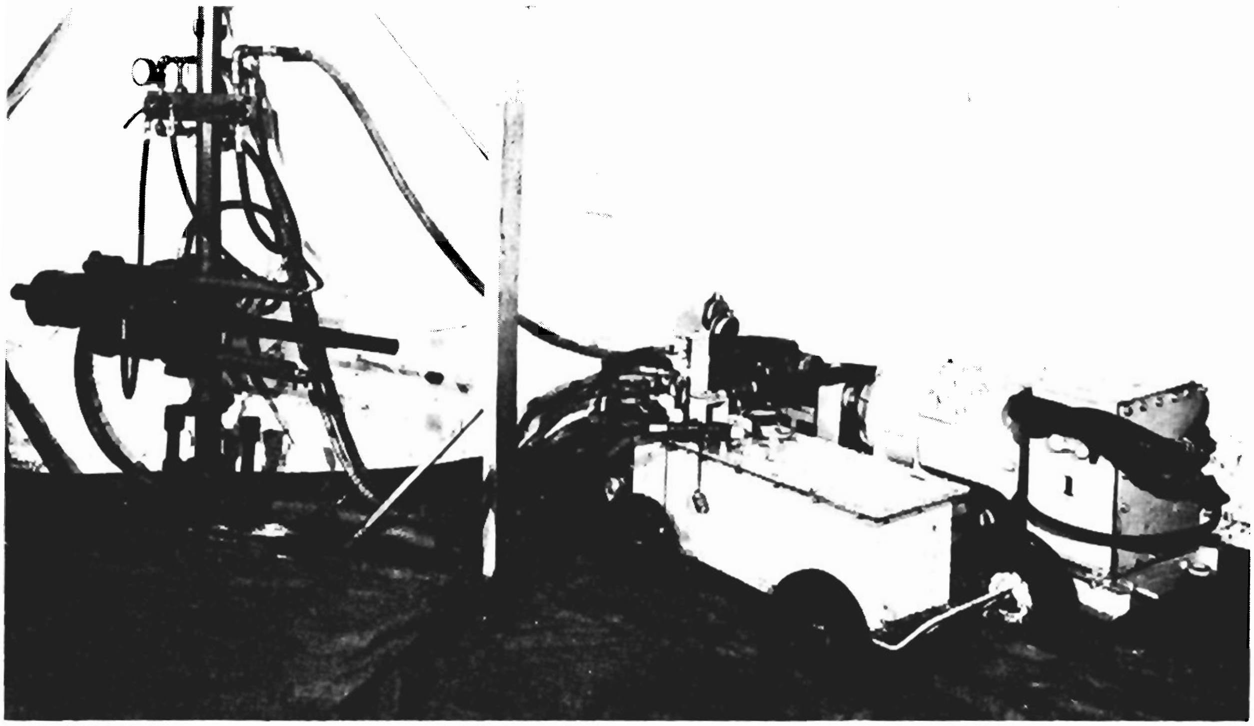

FIGURE 2. - Post-mounted electrohydraulic drill.

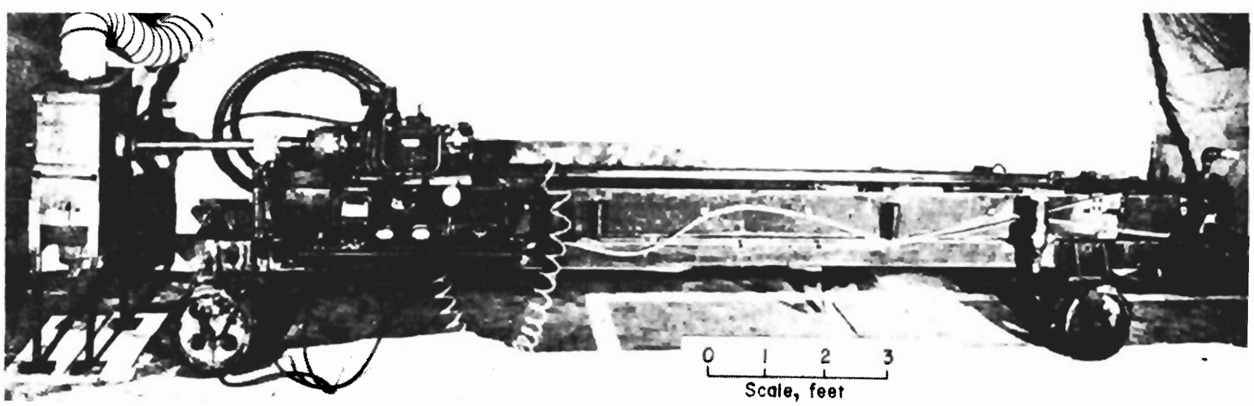

FIGURE 3. - Longyear horizontal drill.

smaller and more compact than the Longyear drill (fig. 5) was designed by the Bureau and constructed by Lambert Drilling Co. Although the feed length is limited to 2 feet, the Bureau's experience indicates that bit control during drilling is not affected by frequent interruptions in drilling because of the short feed length. A particular disadvantage of the Lambert drill is the slow retraction after the spindle has been extended its maximum length. Some horizontal boreholes have been drilled to 2,500 feet with no indications that the drill had reached its capacity (10). Bit thrust potential of the drill is 34,000 pounds at 2,000 psi hydraulic pressure. The drill is equipped with

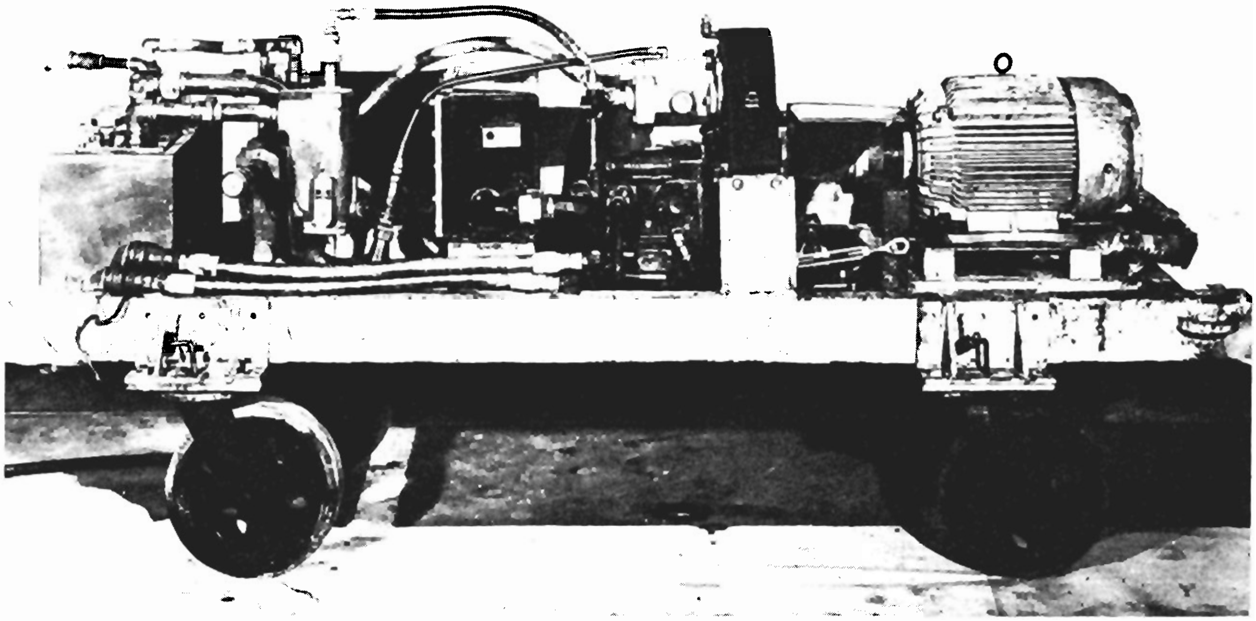

FIGURE 4. - Longyear power unit.

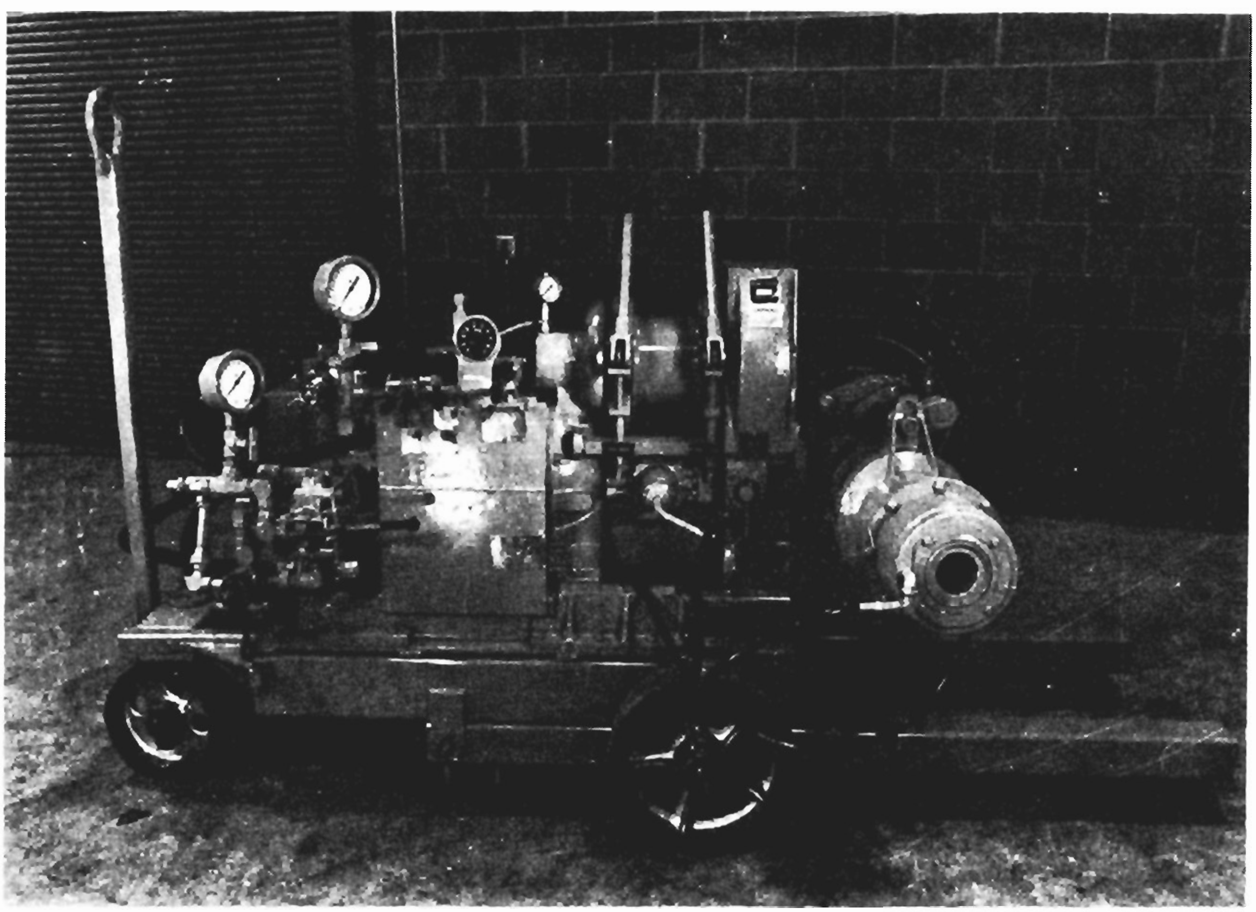

FIGURE 5. - Lambert drill.

gages to monitor bit thrust, torque, and rotational speed. Setting a drilling angle is a simple adjustment because the drill head swivels through 360°. This type of drill is presently marketed by Sprague and Henwood Co., Scranton, Pa.

Both the Longyear and Lambert drills are cribbed during drilling to the proper height and angle so that the horizontal borehole is started in about the center of the coalbed and parallel to the bedding planes. In addition, the drills are anchored to the coalbed to prevent backward movement of the drill when high thrusts are being applied to the bit. At the start of drilling, a 6-inch-diameter hole is drilled to a depth of about 22 feet and a 4-inch casing is then cemented in the hole. A gas-water separator that provides the means for controlling methane during drilling is attached to the steel casing.

Much of the labor involved in cribbing and angling drills underground becomes unnecessary with the drill equipment designed by Acker Drill Co., Inc., and J. H. Fletcher and Co. (figs. 6-7), which are similar to the drill designed by Longyear. The feed frames of the Acker and Fletcher drills can be hydraulically elevated above floor level and angled above or below the horizontal plane automatically. Gas-water separators are also an integral part of the drills. The drill carrier for the Acker and Fletcher drills are four-wheeled vehicles and are hydraulically powered so that the equipment can be trammed.

All of the preceding drills have power units that can be separated from the drill units by as much as 500 feet. The only connections between the drill and power units are hydraulic hoses except for the Acker and Fletcher drills which have Mine Safety and Health Administration (MSHA) permissible illumination. The hydraulic fluid is circulated by an electrically driven hydraulic

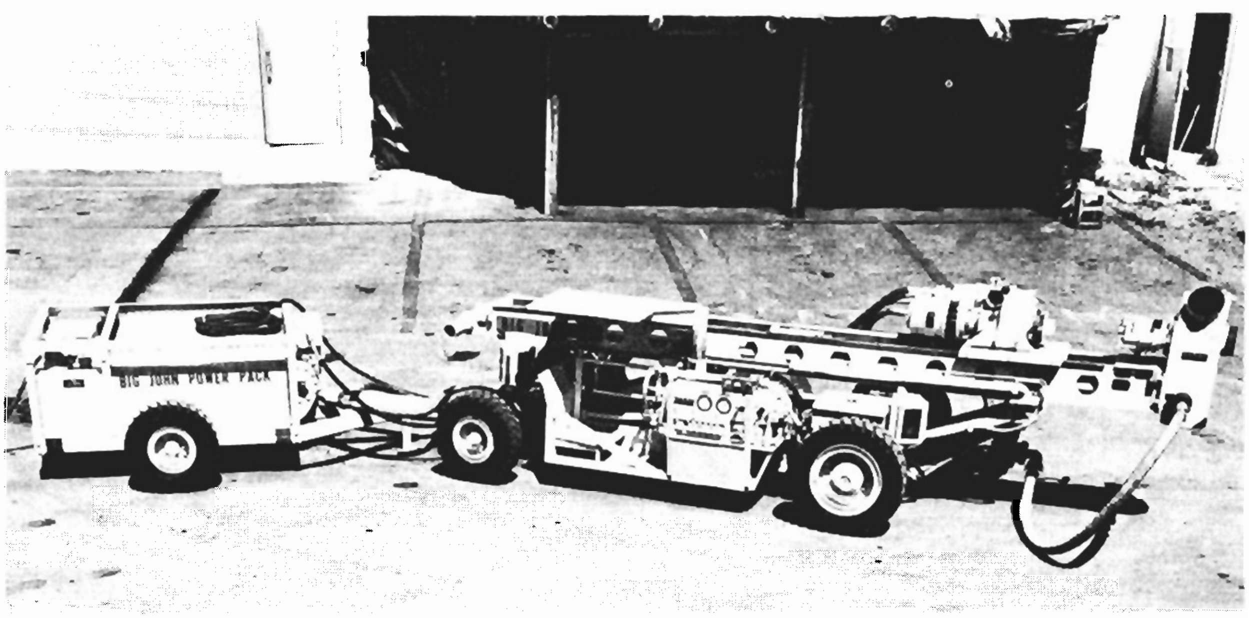

FIGURE 6. - Acker Drill Co. drill.

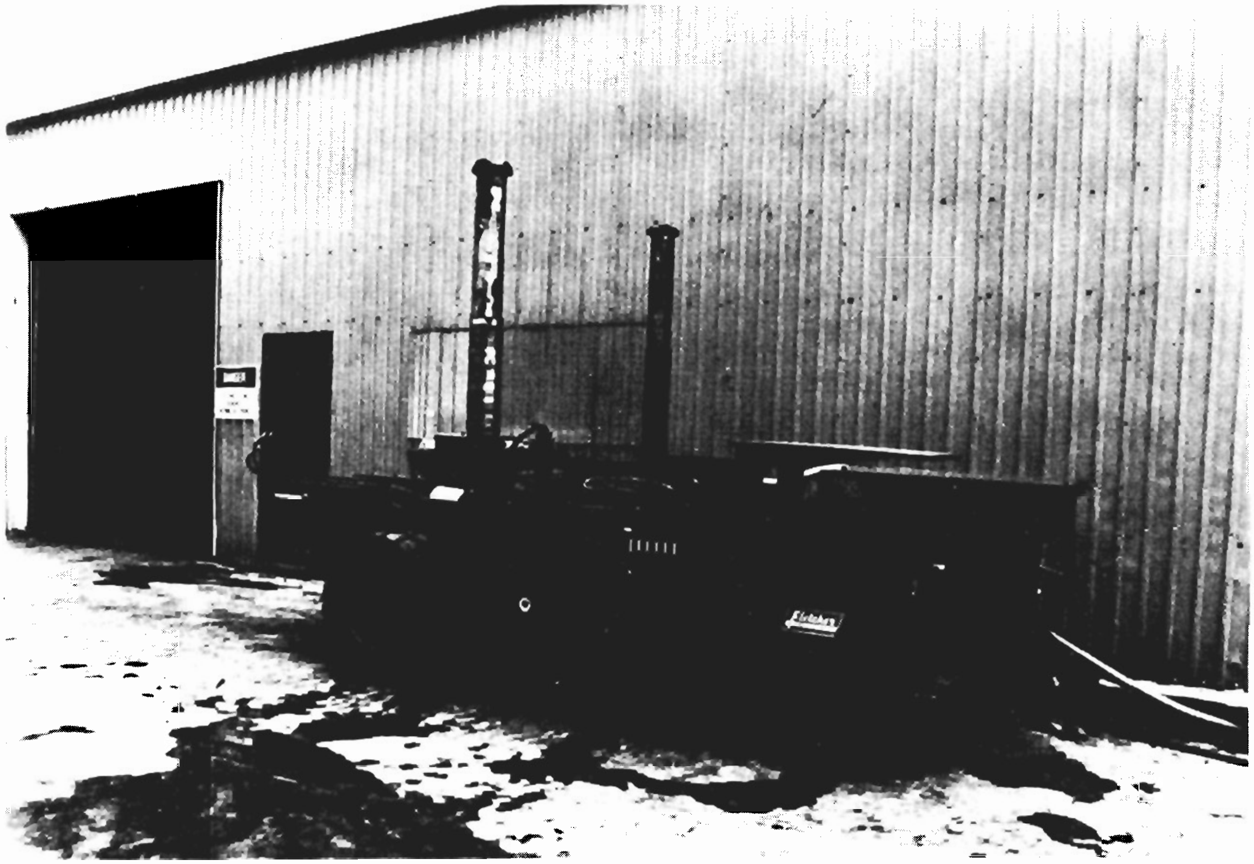

FIGURE 7. - J. H. Fletcher and Co. drill.

pump from the reservoir on the power unit to the drill unit. Therefore, the drills can be used in return airways while the power unit remains in fresh air. The Acker, Fletcher, and Lambert drills are equipped with hydraulic chucks that greatly reduce the time of chucking and pipe pulling operations.

Longyear, Inc., designed a second electrohydraulic drill with the drill and permissible power unit mounted on the same frame (fig. 8). Because the drill unit cannot be separated from the power unit, its use is limited to intake air and face areas except in States where permissible equipment can be operated in return airways. The drill is a smaller version of the first drill Longyear designed (fig. 3); feed length is only 6 feet compared with the 11-foot length of the first drill. The drill is equipped with a hydraulic chuck and gages to monitor bit thrust, torque, and rotational speed.

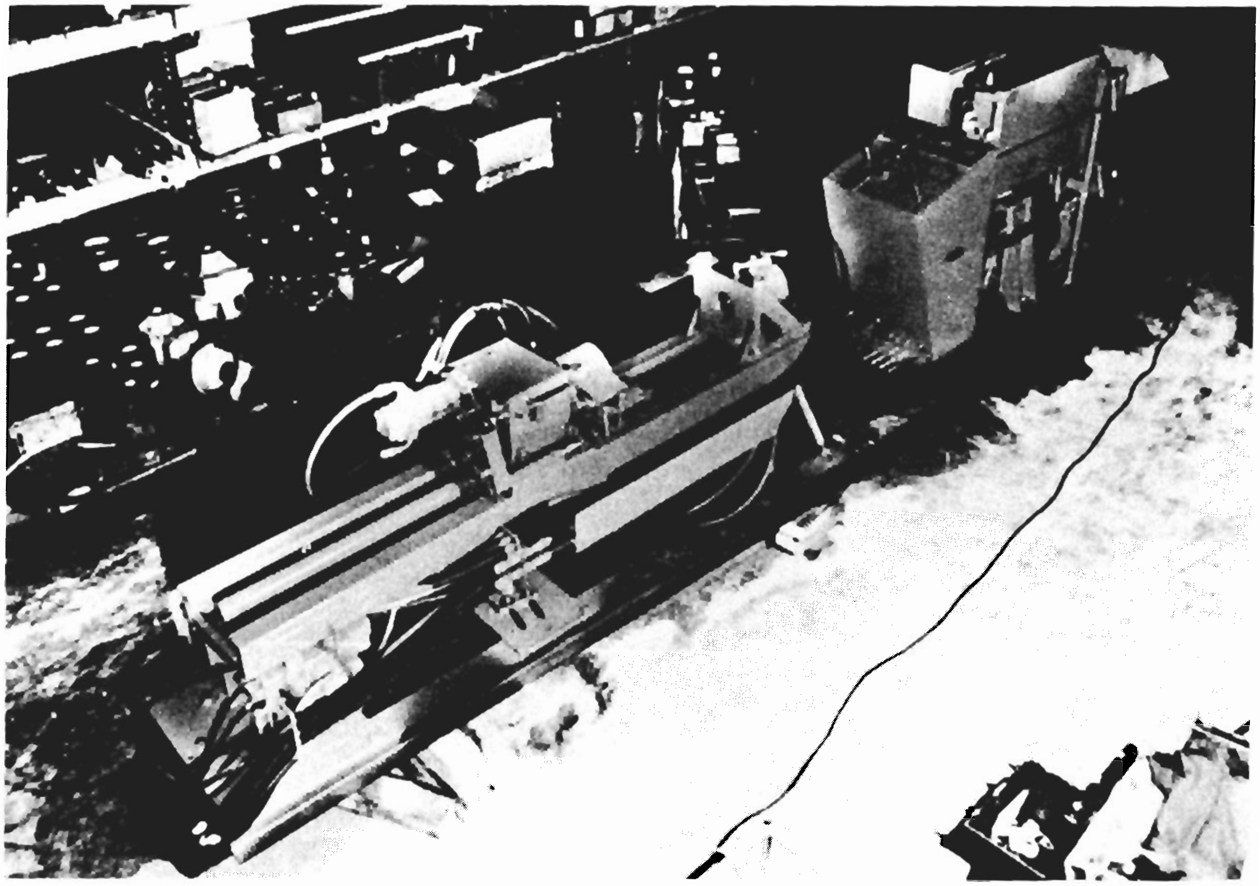

FIGURE 8. - Longyear Drill Co. drill.

Other drills that can be used to drill horizontal boreholes are manufactured in Europe and marketed in the United States. These drills are electrohydraulic, smaller and lighter than the preceding five drills, and generally are mounted on posts. In Europe, these drills are used to drill methane drainage holes into strata above the mined coalbed. The Victor Minotaur drill (fig. 9) marketed by Dowty Corp., Pittsburgh, Pa., the Boyles Bros. Model HNH drill (fig. 10) marketed by Dresser Industries, Inc., Dallas, Tex., and the Atlas Copco Diamec 250 drill (fig. 11) marketed by Christensen Diamond Products, Salt Lake City, Utah, are similar in construction. Each has a drill head that is mounted on a feed frame. The feed length ranges from 2.5 feet for the Victor drill to 5 feet for the Atlas Copco and to 7 feet for the Boyles' drill. The Atlas Copco drill will probably require modification before it can be used routinely for drilling in coalbeds because the thrust and rotation cannot be controlled independently; such control is essential for change in bit inclination. For ease in underground maneuvering, each of these drills can be fitted with axles and wheels.

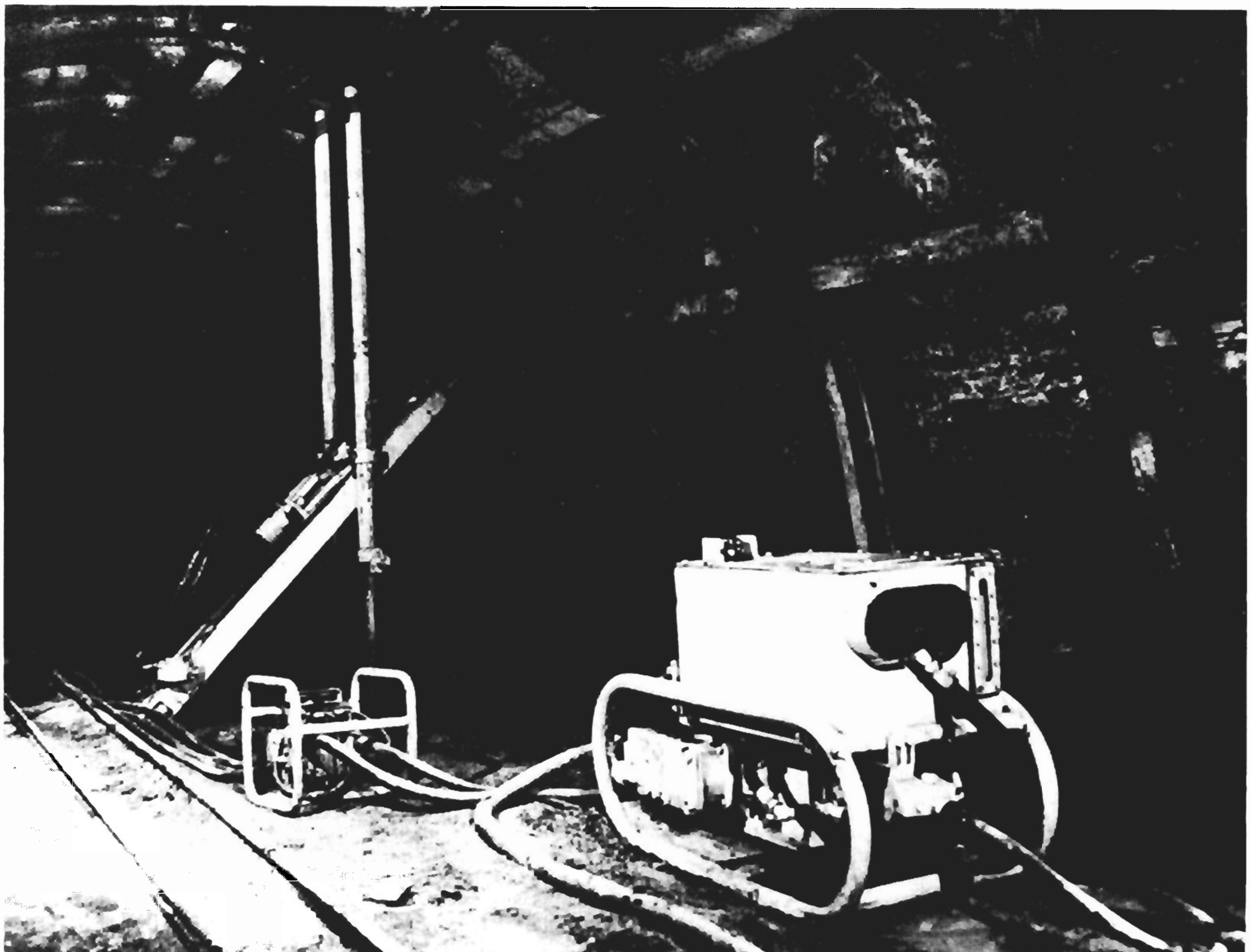

FIGURE 9. - Victor drill.

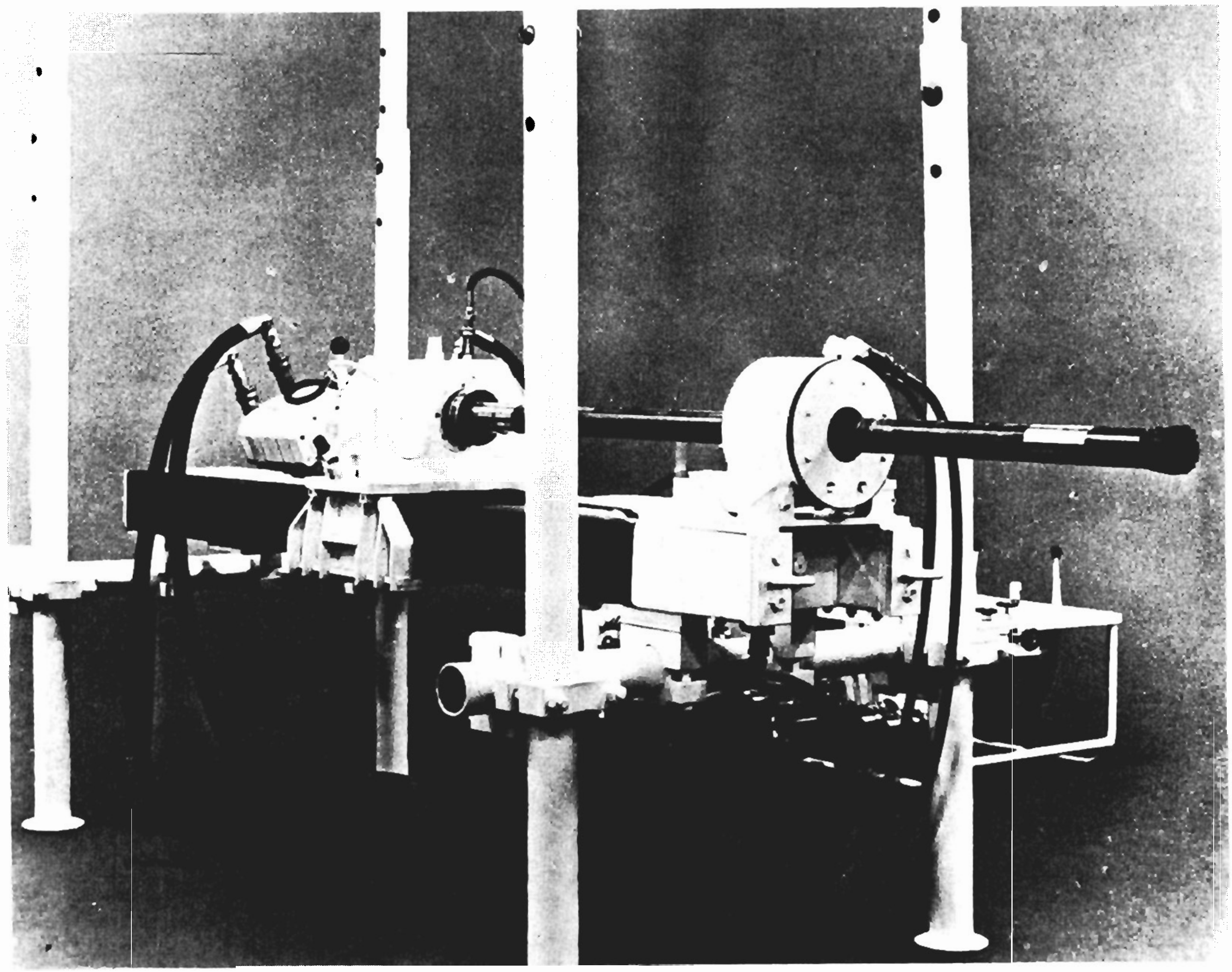

FIGURE 10. - Dresser drill.

FIGURE 11. - Atlas Copco drill.

Horizontal drilling technology has been developed by the Bureau to the point where lengths of 1,000 feet are easily attained (12). In some cases, holes have been drilled to 2,100 feet, but with difficulty (4). Surveying to determine bit angle is an important part of horizontal drilling. Boreholes should be surveyed at least every 20 feet to determine bit inclination. If the bit begins to deviate from its programmed trajectory, bit thrust and rotational speed must be changed to keep the bit within the coalbed. Bit inclination can be determined using commercially available pumpdown equipment such as the single-shot instruments by Sperry Sun and Eastman Well Surveying Co. An in-hole cableless surveying unit is being developed by Ensco under contract with the Bureau.

DRAINAGE AND CONTROL TECHNOLOGIES

Drainage of the large volumes of methane produced from horizontal holes requires underground pipelines to transport methane to the surface. Underground methane pipelines for gob gas have been used by the coal mining industry in Germany since 1943 (1). After World War II, increased production due to mechanization, and mining of deeper and gassier coalbeds, necessitated methane drainage throughout European coalfields, where it now is a fully integrated part of longwall mining (3).

Most underground methane pipelines in the United States are experimental and use both steel and plastic lines. Because of the risk of damage from roof falls and bottom heaving, it is important to include a means of shutting off the flow of methane from the drainage hole to prevent methane from escaping from a damaged or faulty pipeline. Automatic shut-in of each horizontal hole is accomplished by means of a spring-loaded ball valve (normally closed) that is held open with 55 psig of compressed air (fig. 12) supplied by a small compressor (1 cfm, 50 psig). Compressed air is piped to the pneumatic valve for each hole through brittle polyvinyl chloride (PVC) pipe strapped to the top of the pipeline along its entire length (fig. 13). Methane sensing and control systems, which are commercially available, vent the compressed air line and consequently close the pneumatic valves should abnormal methane concentrations be detected. The pneumatic valves close automatically when a sensor malfunctions, when an electrical line to a sensor is cut or broken, or when the PVC pipe is broken by a roof fall. Requirements for underground methane pipelines will vary depending upon the type of pipe, the location of the pipeline, and the amount of methane gas transported. Guidelines for installation, maintenance, and safe operation of underground pipelines have been developed by the Bureau (16) and MSHA (15).

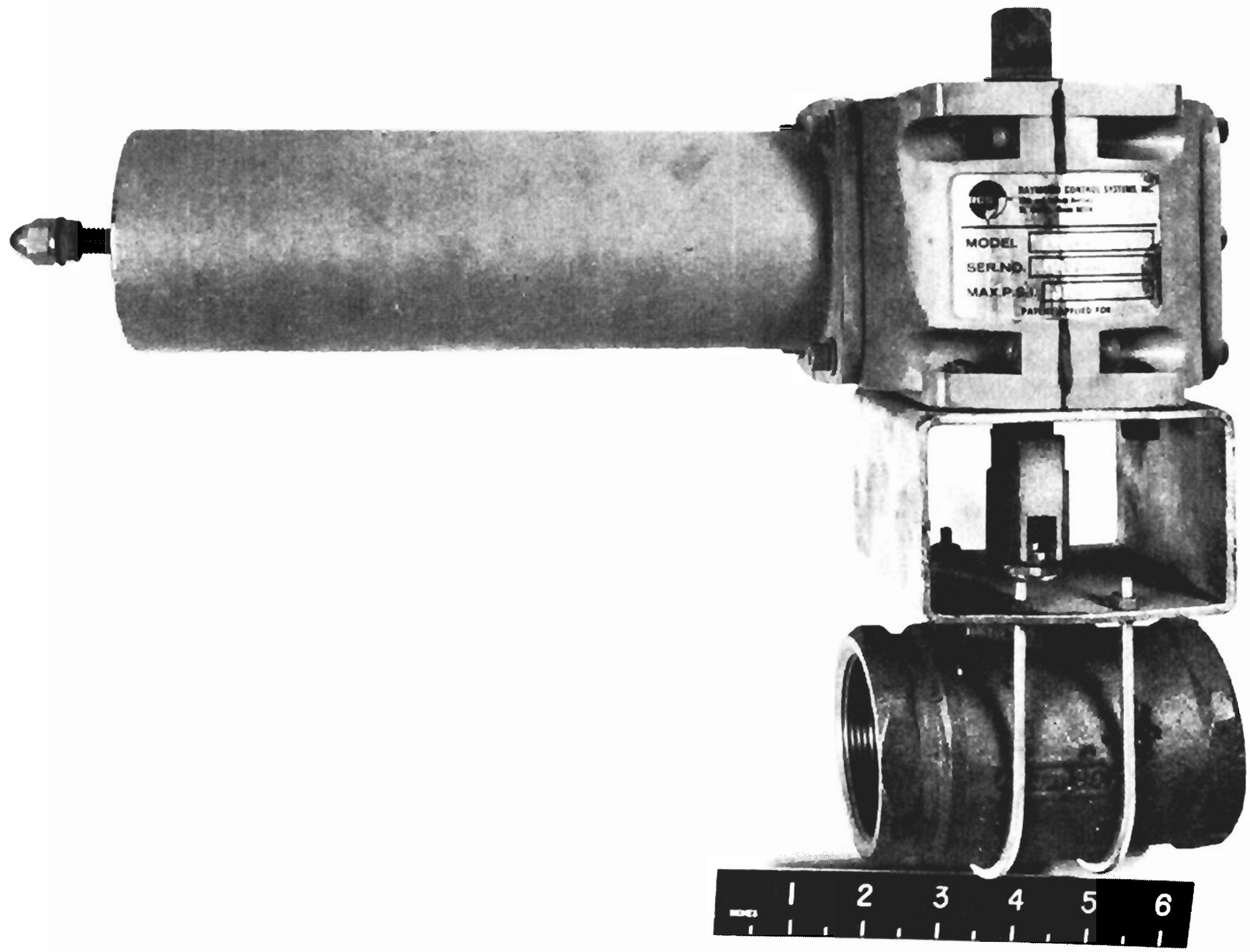

FIGURE 12. - Spring-loaded ball valve that closes automatically to prevent the flow of methane under unsafe conditions.

FIGURE 13. - Steel pipeline, 3/4-inch PVC pipe, sensor head.

EXPERIENCE WITH HORIZONTAL DRILLING

Since the characteristics of different coalbeds vary, the parameters used for horizontal drilling may also vary. Therefore, using horizontal boreholes, the Bureau is conducting field demonstrations in cooperation with operators of mines located in areas not previously degasified.

Over the past 5 years, industry interest in methane drainage has grown and is expected to accelerate in the next 5 years with the development of horizontal drilling technology, longhole drill equipment, methane sensing and control systems, and guidelines for installing, maintaining, and operating underground pipelines. In addition, the demonstration projects have shown that large volumes of methane can be removed from coalbeds with up to 70 pct reduction of methane flows as the degasified zone is mined (5, 10, 13).

Pittsburgh Coalbed, Pa. and W. Va.

Much of the initial degasification work by the Bureau of Mines on degasification of coalbeds was done in the Pittsburgh coalbed. The most recent project was the drilling of four long, horizontal boreholes into virgin coal in Bethlehem Mines Corp.'s Marianna No. 58 mine. The total length of the holes drilled was about 5,700 feet; one hole was 2,500 feet long. After 500 days, more than 100 MMcf of methane had been removed from the coalbed. Preliminary results indicate that methane emissions from the face area were reduced by 80 pct. Bethlehem Mines Corp. is currently investigating the possibility of applying methane drainage to other mines using similar techniques.

Eastern Associated Coal Corp. is experimenting in the Federal No. 2 mine with a tunnel-boring machine that is driving an entry 6,000 feet into virgin coal. Although the advance rate of the tunnel has been slow and consequently methane problems have been minimal, horizontal drainage holes are being drilled in advance of the machine to control methane flows at the face of the tunnel. Boreholes are drilled to about 1,000 feet with a Longyear electro-hydraulic drill (fig. 8). Longyear designed the drill for drilling in limited space and, consequently, the drill and power units are mounted in line on a single frame. The feed length is about 6 feet and the total length of the drill unit is about 12 feet. Drilling is conducted on intake air only.

Consolidation Coal Co. (Consol) has experimented with both rotary and nonrotary horizontal drilling techniques. While the Bureau uses only a rotating drill string (4), Consol developed a nonrotating drill string with a downhole drill motor and a patented deflection device. Consol claims this technique provides more positive control of borehole deviation, both vertically and laterally and that it appears to be faster although somewhat more difficult to operate. The company has designed and developed a mobile horizontal drill rig and a borehole survey instrument (14). The survey instrument not only measures the pitch and roll of the bit, but also the azimuth of the borehole and the thickness of the coalbed ahead of mining (14). The drilling system has drilled more than 20,000 feet of horizontal boreholes to reduce methane face emissions in advancing sections. Horizontal boreholes 1,000 feet long are routinely completed in eight working shifts including setup time. The greatest effect of

boreholes drilled in advance of mining is in face areas, where up to 68 pct decline in methane concentrations is reported. Methane flows in the returns were reduced by 50 pct (14).

Lykes Resources, Inc., is planning an extensive methane drainage program at the newly opened Emerald mine located in Waynesburg, Pa. Underground degasification will be conducted with Acker Drilling Co.'s "Big John" drill (fig. 6). Methane from the horizontal holes will be transported to the surface using a polyethylene pipeline. Drilling techniques will be similar to those developed by the Bureau in earlier studies.

Sunnyside Coalbed, Utah

Kaiser Steel Corp. is currently working with the Bureau of Mines on degasifying an area of coal at its Sunnyside No. 1 mine that will not be mined for 2 or 3 years. Two horizontal boreholes (9) 500 feet long have removed 60 MMcf of methane over a 16-month period. Bureau personnel will begin the drilling of three long horizontal boreholes at the end of 1979. The methane will be carried through a pipeline to the surface where it will be burned in the mine's coal cleaning plant. Kaiser Steel Corp. is planning to continue the drilling program if results are successful.

Beckley Coalbed, W. Va.

A recent drilling program was conducted by the Bureau of Mines and the Maple Mining Co. at the Maple Meadow mine in the Beckley coalbed in southern West Virginia. Eight holes, with a total length of 4,850 feet, were recently drilled from the bottom of a 24-foot-diameter ventilation shaft that was sunk 3 years in advance of mining. Results from the project are not yet available since the drilling was only recently completed, although methane drainage rates are low because the shaft bottom is located in a synclinal area that is draining water from a large area of the coalbed.

Mary Lee and "Blue Creek" Coalbeds, Ala.

Jim Walter Resources, Inc., is presently working with the Bureau of Mines on investigating longhole drilling to intercept methane flows in the Mary Lee and "Blue Creek" coalbeds. Several short holes were drilled in mines No. 3 and 4, located near Birmingham, Ala. The coalbed is highly fractured, and may be under local stress resulting in holes caving immediately after drilling. Attempts are now being made to guide long horizontal boreholes into specific heights of the upper or lower portion of the coalbed. A successful hole, 1,000 feet deep, has recently been drilled in the lower portion of the coalbed with a resulting initial methane flow of 200,000 cfd. If further tests are successful, the mine plans to initiate its own drilling program. The mine operators are requesting approval to use a polyethylene pipeline to transport the methane to the vertical drill hole for subsequent sale or utilization. An Acker "Big John" drill unit will be used for the drilling program.

United States Steel Corp. has been drilling horizontal boreholes to intercept methane flows at the Oak Grove mine near Birmingham, Ala., since 1976.

Fifteen holes have been drilled in the Blue Creek coalbed; the longest hole is 1,040 feet. Drilling rates have ranged from 15 to 115 feet per 5-hour shift. The drill unit used is a Joy face-type that was modified by Acker Drill Co. Control of the bit path is similar to the method developed by the Bureau of Mines.

The gas drained by the holes is transported to the surface through a steel pipeline. Gas flows have been reported as high as 100,000 cfd from a 1,000-foot hole.

Pocahontas No. 3 Coalbed, Va.

Preliminary tests have been conducted in the Pocahontas No. 3 coalbed by Island Creek Coal Co. at the Virginia Pocahontas No. 5 mine to determine the effectiveness of methane drainage techniques in advance of mining. Horizontal boreholes were drilled to depths of 500 feet into virgin coal. As mining advanced into the degasified zone, tests indicated substantially less quantities of methane than in other areas of the mine. The company has purchased an Acker drill unit and has successfully drilled several horizontal boreholes to depths of over 1,000 feet in approximately seven shifts, not counting setup time. The methane produced from the horizontal boreholes is transported to the surface through an underground plastic pipeline (17).

Hartshorne Coalbed, Okla.

Since 1975 Ker-McGee Corp. has been drilling long horizontal boreholes at the Choctaw mine in Stigler, Okla., to drain methane from the Hartshorne coalbed. Boreholes have been drilled successfully to 3,000 feet using in-hole motors. Approximately 20 horizontal boreholes have already been completed and an additional 20 holes are being planned. Cumulative gas flow rates as high as 2 MMcf per day have been reported.

"B" Seam, Colo.

Mid-Continent Coal and Coke Corp. is removing methane from gob areas of an advancing longwall in the Dutch Creek mine located at Carbondale, Colo., by drilling holes into overlying strata (11). The 2-inch-diameter boreholes are drilled to 150 feet on 50-foot centers. An EDECO minihydrac drill is used to drill the holes at an inclination of 60°. The gas is transported to the surface through a 6,000-foot pipeline. Vacuum is applied to the boreholes by Nash vacuum pumps that are located on the surface. This method of methane drainage is patterned after methods used in Great Britain and Europe where advancing longwall mining is common.

SUMMARY

The Bureau of Mines has shown through field demonstrations that horizontal boreholes drilled into the coalbed are an effective method of intercepting methane flows. As a result of research and development efforts by the Bureau and industry, equipment for drilling from underground locations is now available from commercial sources. Drilling long horizontal boreholes can now be

accomplished in most coalbeds. The equipment needed to safely transport the methane to the surface is also commercially available. Publications by the Bureau are cited that discuss how to drill horizontally in coalbeds and how to safely handle the methane.

As deeper coalbeds are mined, the need for advance methane drainage will become a necessity instead of an option. Proper planning in the early stages, long before the mine is opened, will result not only in a safer work environment, but in a potentially more profitable operation by reducing ventilation costs and increasing production.

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APPENDIX.--DRILL UNITS

1. Acker Drill

   Acker Drill Co., Inc.
   Box 830
   Scranton, Pa. 18501

2. Atlas Copco Drill

   Christensen Diamond Products
   P.O. Box 41136
   2215 Distributor's Dr.
   Park Fletcher
   Indianapolis, Ind. 46241

3. Dresser Drill

   Dresser Industries, Inc.
   P.O. Box 1879
   Columbus, Ohio 43216

4. Longyear Drill

   Longyear Co.
   925 Delaware St., S.E.
   Minneapolis, Minn. 55414

5. Fletcher Drill

   J. H. Fletcher and Co.
   P.O. Box 2143
   Huntington, W. Va. 25722

6. Lambert Drill

   Sprague and Henwood, Inc.
   221 West Olive St.
   Scranton, Pa. 18501

7. Victor Drill

   Dowty Corp.
   Progress St.
   Cranberry Industrial Park
   Zelienople, Pa. 16063

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