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A METHANE DRAINAGE PLAN USING HORIZONTAL HOLES AT THE HAWK'S NEST EAST MINE, PAONIA, COLORADO

by

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DISCLAIMER

ABSTRACT

Methane drainage from coalbeds is at present a controversial subject. The controversy stems from gas ownership questions and possible damage to the coalbed by the degasification method. However, some mines are experiencing such high methane emission rates that their ventilation systems cannot keep the methane concentration at acceptable levels.

In order to degasify a 5500' x 1700' coal panel at the Hawk's Nest East mine, horizontal holes are proposed to be drilled 1800 ft into the coalbed in a direction perpendicular to the face cleat. They will be approximately 3 1/2" in diamater and spaced 400 ft apart to rapidly degasify the panel. The estimated flow rate from the panel is 3.5 MMCFD.

The drilling could be accomplished using an Acker "Big John" Degasification Drill and a method of keeping the bit in the coalbed during drilling is discussed. A system for de-watering the effluent out of the horizontal holes and metering of the gas flow is mentioned. The piping system chosen is composed of 10" mains, 8" sub-mains, and 3" laterals suspended by hangers from the roof in the return airway. Finally, an estimate of the capital expenditures and labor costs for the project is projected to be $420,000 for the Hawk's Nest East mine.

INTRODUCTION

The presence of methane gas has plagued the coal mining industry for years. Many men have lost their lives in methane-air explosions. Consequently, mining companies spend a great deal of money keeping the methane concentration at an acceptable level within the mine by diluting it with large quantities of air. Frequently, in deep, gassy mines, even the tremendous volume of air sweeping through the mine is not enough to keep machinery at the face from shutting down due to excessive methane levels. As the mine continues to advance, so do the problems as the methane content of the coal generally increases with depth. Also, with the increased number of faces, an increasing amount of gas bleeds into the mine. One solution is to degasify the coal before it is mined. Doing so would increase safety, lower ventilation costs and, given gas ownership, can bring in additional revenue for the company. There are several methods of degasifying a coalbed prior to mining. They all consist of drilling holes into the coalbed to let the methane escape. The difference between them is the manner in which the holes are drilled and completed. Some holes are drilled from the surface into virgin coal or gob areas. Others are drilled from within the mine into virgin coal or gob areas.

HORIZONTAL DEGASIFICATION HOLES

In the case where coals are at considerable depth and under rough terrain in many western areas, horizontal boreholes from the mine workings appear to be the best method of degasification. In addition, they produce more gas per ft of hole than any other method. Horizontal holes are drilled into the coalbed, parallel to the bedding planes and away from the mine workings into virgin coal.

The direction in which the holes are drilled is important because coal has directional permeability due to its cleat system. Cleats are nearly vertical fractures in the coal along which methane can migrate. There are two types of cleats. The face cleats (the larger and more pronounced ones) and the butt cleats are approximately 90° from one another. Therefore, drilling should be done perpendicular to the face cleat in order to intersect the largest number of extensive fractures. This will result in a larger gas flow from the hole.

The gas collected from horizontal holes ranges from 80%-99% methane. Pure methane gas has a BTU content of approximately 1000 BTU/scf. This gas is piped outside and is suitable for use at the coal preparation plant. Other uses include power generation, space heating, or injection into a natural gas pipeline. Injection is feasible because good quality methane gas has the same heating value as commercial natural gas. These are only a few of its many possible uses. However, if it cannot be used due to ownership questions or other problems, the methane can be vented to the outside air. However, to do so is a waste of a valuable energy resource. Coal mines in the U.S. vent approximately 200 MMCFD of methane.

Previous Investigations

Horizontal drilling holds the most promise for degasification of a coalbed prior to mining. It is drilled entirely in coal and every foot, except the first 20-30 ft, produces methane. Holes over two thousand feet long were drilled in the Pittsburgh coalbed near Fairview, W. Va. (Cervick and others, 1975). It was found that the methane flow rate is directly proportional to the length of hole.

A flow rate of 150 CFD/ft of hole was observed at Sunnyside No. 1 mine, Sunnyside, Utah (Perry and others, 1978). Since the Hawk's Nest East mine has a similar rank and depth of coal, the observations at Sunnyside will be applied to the Hawk's Nest East mine.

Drilling of Horizontal Holes

The main problem encountered in drilling horizontal holes is keeping them in the coalbed. The bit tends to drop down into the floor or go up into the roof because of the force of gravity or deflection off of a hard inclusion. Because deviations from the "horizontal" will occur, precise surveying and a method of correcting the deviation are needed.

The Bureau of Mines found a drill string configuration that works well (Cervick and others, 1975). It consists of replacing the first rod in the string of BQ rods with a heavy NW drill rod. The 20 ft NW rod weighs 205 lb and the BQ rod weighs 80 lb. The NW rod adds weight to the bottom side of the bit and stiffens the drilling assembly. A centralizer is placed behind the bit and another on the end of the NW rod (Figure 1). This assembly can be made to drill upward, downward, or horizontally.

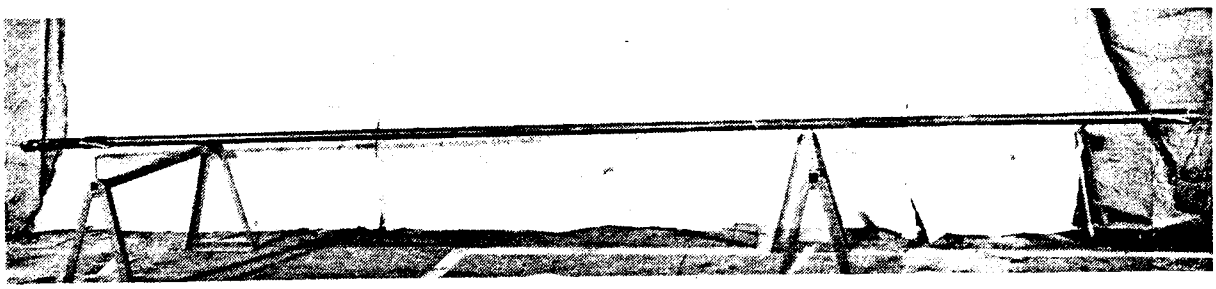

Figure 1. Drill string configuration (Photo courtesy U.S. Bureau of Mines).

Two factors affect the trajectory of the hole: the bit thrust and rotational speed. Bureau of Mines (Cervick and others, 1975) found that a thrust of 1200 lbs. and a rotational speed of 400-600 rpm using a 3 1/2" bit will hold the hole trajectory. These numbers are subject to many factors and could be quite different in another coalbed. If the bit starts to turn up, a reduction in thrust and an increase in rotational speed will wear away the bottom of the hole and turn the bit downward. It can be brought down quickly by removing the front stabilizer. When the bit drops towards the floor, it can be angled upward by increasing thrust and reducing rotational speed. The back stabilizer is removed to bring it up quickly.

The correct bit choice is a very important part of the entire drilling assembly. When drilling coal, a three-blade drag bit is preferred as it has three to four times the penetration rate of a tri-cone roller bit in coal and costs less. The only disadvantage is that it will not penetrate a hard inclusion.

Finally, there is no substitute for a driller that has experience in drilling long horizontal holes. He must be familiar with the equipment and its responses to drilling conditions. He must also be able to react quickly to hard spots which deflect the bit in an unpredictable manner, and soft spots where the bit arcs rapidly downward.

During the drilling, hole surveys must be made every 30 ft initially until the drilling parameters are determined. Once determined, surveys every 50 ft are usually sufficient unless severe (greater than 1 degree) deviations occur. A single-shot survey instrument is used to determine the inclination of the hole. It contains electrical components and therefore must be permissible and approved for use in coal mines. Two such instruments are the Sperry-Sun or Eastman Well Surveying Co single-shot surveying instrument. When the inclination of the bit is to be determined, the surveying instrument is placed in its protective casing. It is then inserted into the drill rod and pumped with water to the end of the hole. At a preset time, the film disk is exposed and the instrument is retrieved by wire-line, which is attached to the protective casing. The film disk is removed, developed, and read. Determination of the inclination at the end of a thousand ft hole takes about an hour.

During the drilling operation, a plot should be maintained of the trajectory of the hole so that the location of the bit with respect to the floor or roof is known at all times. If the coalbed changes in thickness or slope, another variable is introduced.

The Bureau of Mines (Cervick and others, 1975) did research in order to improve drilling speed. They found that increasing the bit diameter improves the performance of the drill. By increasing the bit diameter from 3 1/2" to 3 5/8", the penetration rate increased approximately 60%. The heavier bit required more thrust to keep it horizontal than the smaller one and, therefore, had a higher penetration rate. Bureau of Mines believes that increasing bit size to 3 3/4" would significantly increase the penetration rate even more. The disadvantage is that the bit tends to wear faster at higher thrust levels.

Methane Control During Drilling

Another contingency to consider is what to do with the methane gas that escapes from the hole during drilling. For a two thousand ft hole in the Sunnyside mine (Perry and others, 1978) 200 cfm of methane were emitted from the hole. To keep the methane concentration at the site below 1%, 20,000 cfm of methane-free air would be required. This amount of air is not available everywhere within the mine, so another method of handling the methane is needed.

The Bureau of Mines (Cervick and others, 1975) designed a stuffing box that removes the methane before it escapes into the air. The drilling is conducted through this box which is attached to a twenty ft length of 6" pipe (Fig. 2). This pipe, called the anchor pipe, is grouted into the coalbed. Water and drill cuttings coming out of the pipe drop to the bottom of the box and the methane is drawn off the top by a slight vacuum. The vacuum is maintained in the box by means of flexible tubing connected to an exhauster or similar apparatus in a return airway.

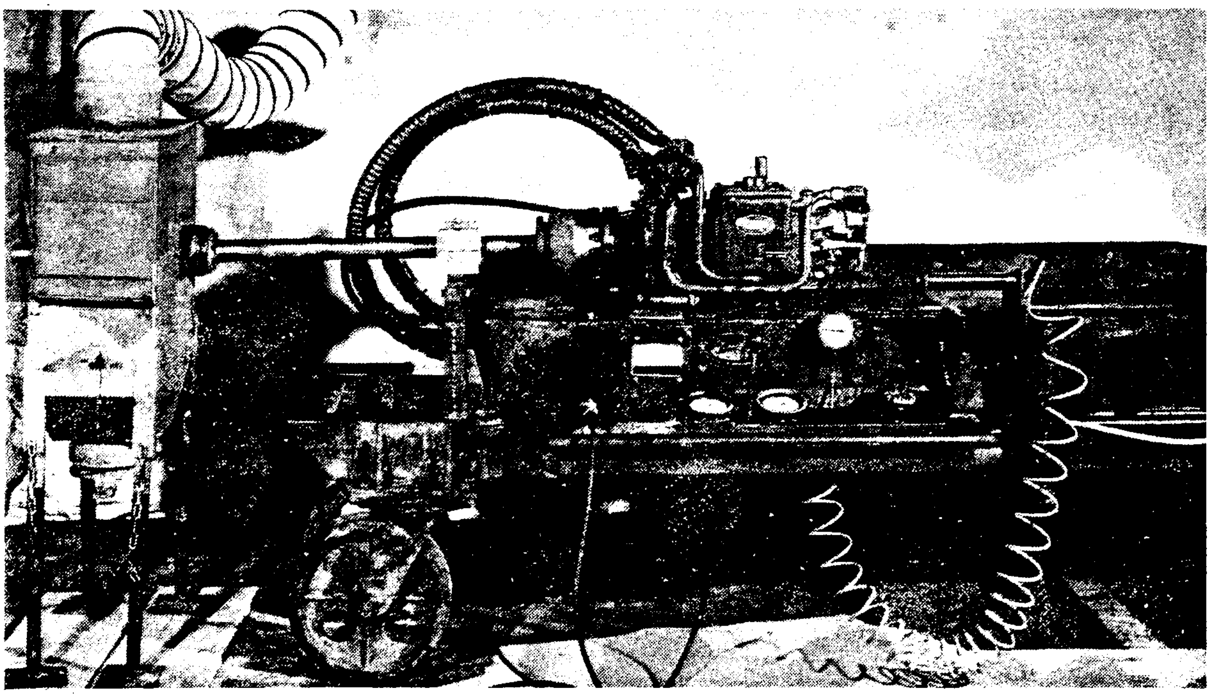

Figure 2. Stuffing box (Photo courtesy U.S. Bureau of Mines).

Difficulties also arise as drill pipe is pulled or during hole surveys when methane begins to flow into the mine. A one-way check valve placed in the drill string eliminates this problem.

The power unit (Fig. 3) for the drill is a 30 hp, 440 V permissible motor and starter box, with two hydraulic pumps and a forty gallon hydraulic fluid reservoir. One pump pressures the five foot hydraulic cylinder on the drill unit. The second, a reversible, variable displacement pump, powers the motor which turns the spindle on the drill unit.

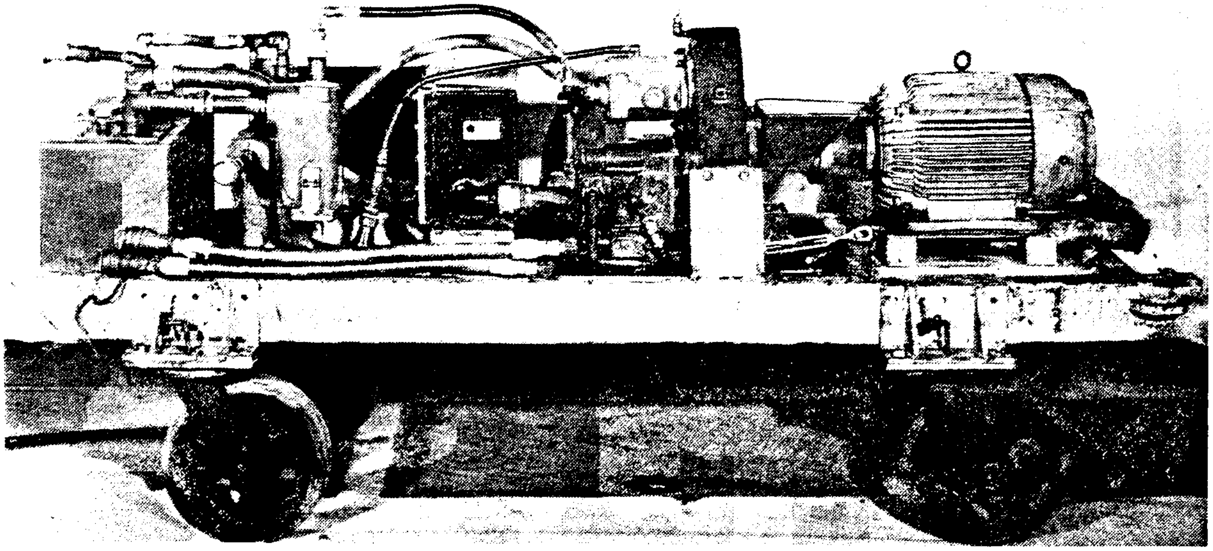

Figure 3. Longyear (Minneapolis, MN) power unit (Photo courtesy U.S. Bureau of Mines).

The drill unit (Fig. 4) consists of a five ft hydraulic cylinder mounted within its frame, and a spindle mounted on a movable carriage. Valves, gages, and levers controlling rotational speed, thrust, and movement of the carriage are located on the drilling unit. When drilling, the drill pipe water pressure should be monitored constantly to insure water circulation. Otherwise, the bit can get stuck.

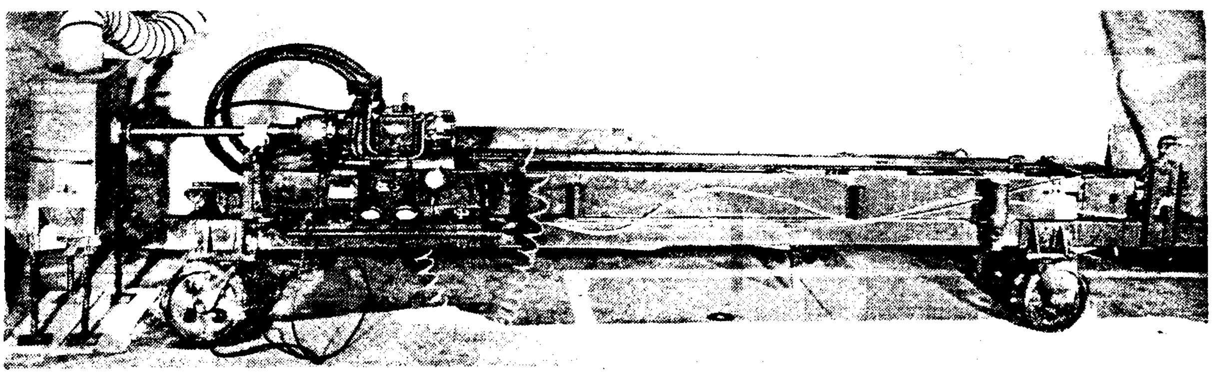

Figure 4. Longyear (Minneapolis, MN) drill unit (Photo courtesy U.S. Bureau of Mines).

During drilling, the power unit is kept in the intake air and hydraulic lines are run between the drill and the power unit (up to 500 ft). At the drill site, the drill is cribbed and anchored to the floor and roof to prevent movement of the drill unit while drilling.

Drilling rates average about 100 ft/shift for a 2,000 ft hole (Joseph Cervick, oral commun.). This number can vary if unusual conditions are encountered. The drilling crew consists of a driller and driller's assistant.

Safety Regulations

There are no MSHA regulations pertaining to horizontal drilling per se. However, if a mine is seriously considering horizontal drilling, it should draft a set of guidelines explaining how it plans to do the methane drainage. Once approved, these guidelines become law for the mine and the mine can be cited for failure to comply with them.

PIPING SYSTEM

Pipe Size

Finding the correct pipe sizes for the methane drainage system is an extremely complex problem due to the configuration of the piping system. Energy Applications, Inc. (Tongue and others, 1976) solved it by specifying a flow of 2 MMCFD. They used the IGT Distribution formula with the assumptions of medium pressure, smooth pipe, and partially turbulent flow (see Appendix A). Solving the equation, they found that the main line should be 8" I.D. and the laterals feeding into it should be 2" I.D.

To apply this formula to the Hawk's Nest East mine, an estimate of the flow from the horizontal holes is needed. As mentioned earlier, the flow rates from the horizontal holes at Sunnyside will be applied to the Hawk's Nest mine because of a similar rank and depth of coal. For the 5500 ft long panel being degasified, spacing the holes 400 ft apart and drilling 1800 ft into the coalbed perpendicular to the face cleat yields 13 holes--a total of 23,400 ft of hole. If the flow rate is 150 CFD/ft of hole, the total flow rate is 3.5 MMCDF.

Since this result is considerably greater than the 2 MMCFD for which Energy Applications (Tongue and others, 1976) designed, larger pipe sizes are required to keep the head loss in the pipe at an acceptable level. Therefore, the main line should be increase to 10" I.D. and the lines issuing out from the holes should be increased to 3" I.D. For cost effectiveness, 10" pipe is used only to carry the gas out of the mine.

The 3" pipe coming out each hole feeds to an 8" pipe. At the center of the 8" pipe is a "Tee" connection which connects the 8" pipes with the 10" main (Figure 5).

Pipe Material

The next step is to determine the best pipe material. Each material has several advantages and disadvantages related to their physical characteristics (Figure 6). Du Pont Aldyl "A" polyethylene pipe was chosen as the best material for the main pipe. However, the largest size available is 8" I.D. Therefore, carbon steel is the next best alternative for all three pipe sizes. Victaulic rolled groove ends used with victaulic lightweight couplings would provide a strong, leakproof seal where the pipe sections are joined together.

Installation

The easiest and safest way to install the pipe is by hangers from the roof. They are spaced according to the weight of the pipe and other factors, such as the weight of material flowing.

The installation of a 3" globe valve in each 3" lateral line will allow the mine operator to control the flow from the boreholes if necessary. The installation of Rockwell 3" Mode DPS-H security valves in the lateral pipes increases safety by automatically shutting off the gas flow if a roof fall or fire should damage the pipe anywhere in the system. These valves are connected together with 1/2" x .062" wall polyethylene tubing containing nitrogen at 30 psi. This control line runs the entire length of the piping network. A break anywhere in the line will allow the nitrogen to escape and the spring-loaded valves will close. These valves are reset manually. An extra nitrogen cylinder would insure a supply of nitrogen to re-pressurize the system in case of an accidental rupture of the control line.

In addition to the shut-off valves in the laterals, Energy Applications also recommends 8" Maxitrol-Century Automatic Shut-off Valves in the 8" pipe. If the valves sense an increased flow through the pipe, which would occur if the pipe downstream breaks, they automatically close.

The piping network is kept in the return airways as an additional safety precaution. If an accident occurs to the pipe the methane that escapes will be purged from the mine very quickly. This prevents the methane gas from going farther into the mine.

Additionally, methane sensors located along the pipeline provide protection from small leaks in the pipe. If the sensor detects a methane level above normal, the sensor opens a three-way valve allowing the nitrogen in the control line to escape. This closes the 3" security valves and stops the flow of methane within the pipe.

PRODUCTION

Separation of Gas and Liquid

Before the effluent out of the horizontal holes can flow into the 3" laterals, it must go through a liquid separation system. This system must be capable of removing entrained as well as slugs of liquid. Since no system is 100% effective, it would be wise to place manual valves at several low spots in the piping system to drain off the water that will accumulate there.

It is possible to purchase a large enough separator to handle both the entrained liquids and heavy slugs of water. Unfortunately, such a separator is large and expensive. Energy Applications (Tongue and others, 1976) has designed a combination system which is small and inexpensive that has the required capacity. This system uses a water tap, a small gas/liquid separator, and a small drip tank. Most of the liquid will fall out in the drip tank and drain to the trap. Entrained water will be removed by the separator, downstream from the drip tank, and drain to the water trap. The trap, which is equipped with a float valve, will dump the water without allowing any gas to escape. The trap should be inspected periodically to make sure the float valve is working properly.

Metering of the Gas

Metering of the flow rates from the horizontal holes is done to provide data to the operator of the methane removal system. This allows him to evaluate the effectiveness of each borehole and provides a means of detecting malfunctions or line blockages. A 3" Venturi meter would work well for measurement at each borehole. They are inexpensive and require no maintenance. Flow rates can be calculated from the differential pressure reading across the Venturi meter with a portable master meter carried from one borehole measurement station to another. Accuracy will probably be in the range of $\pm 2\%$.

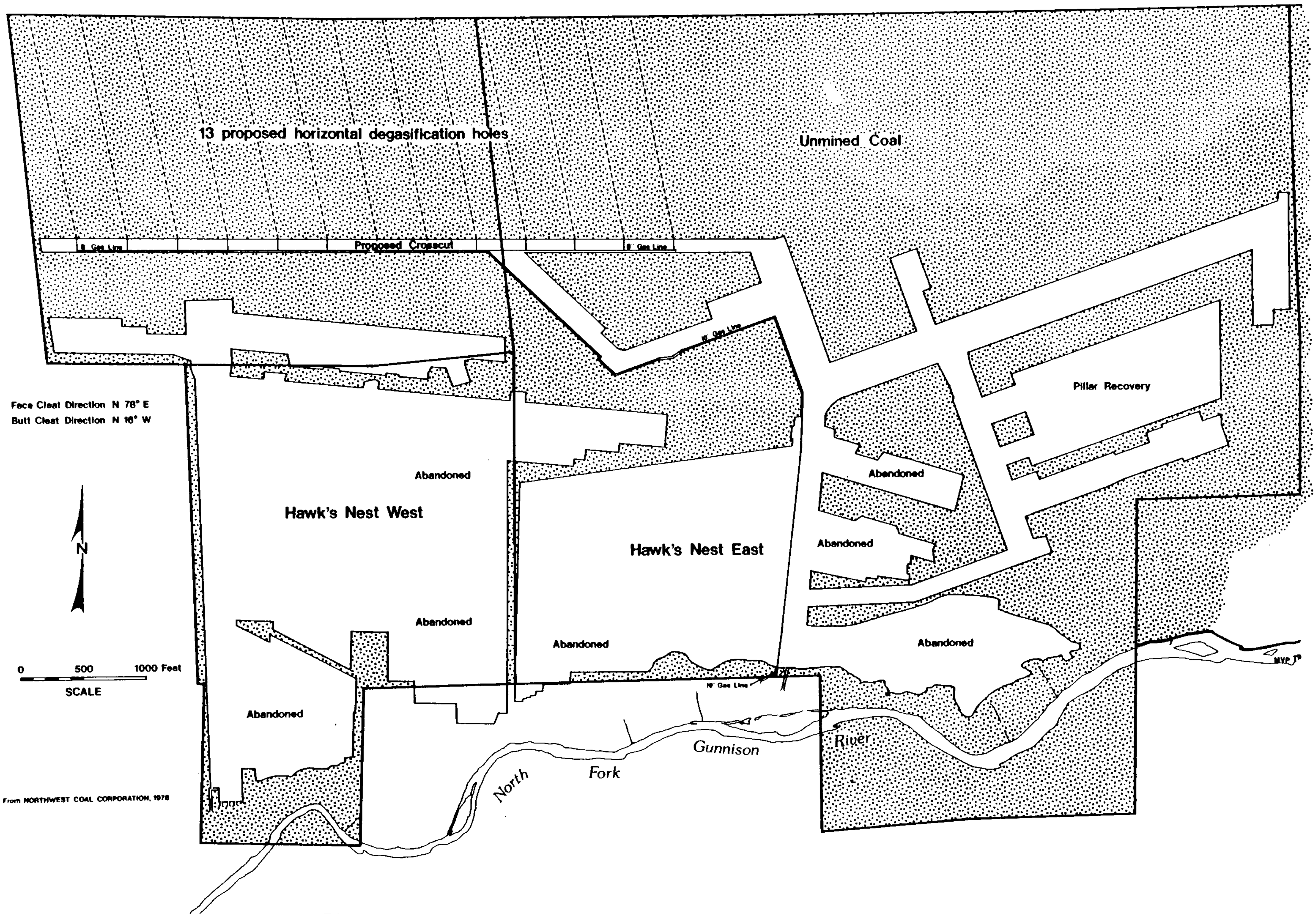

Figure 5. Proposed orientation of the horizontal degasification holes at the Hawks's Nest Mines, Paonia, Colorado.

For the surface measurement station, an orifice meter would work well. Natural gas utilities rely on orifice measurement for most of their large volume flow metering applications. If the surface meter is to be used as a sales meter for sale of the gas to a pipeline or gas utility, the buyer may wish to provide the metering facility or have specific recommendations for their measurement needs.

Gas Compression

If the gas is to be injected into a pipeline, it must be compressed to pipeline pressure levels. The compressor could have a natural gas-fired engine running on methane. Generally, a compressor like this will consume approximately 5% of its inlet gas as fuel for the engine. Once started, these units run unattended but require daily maintenance.

Economic Study

A study has been made of the cost associated with the proposed degasification project at Hawk's Nest. The costs quoted are the latest available at the time of this report. Total cost for the project is estimated as $420,000, using a contingency factor of 1.2 to take into account any overlooked costs. The following page lists the individual costs.

	Aluminum	Copper	Carbon Steel	Stainless Steel	Fiber-glass	Polyethy-lene	Polybuty-lene	Poly-vinyl Chloride
1.a)Resistance to Internal Corrosion caused by Coalbed Gas & Liquids	Good	Good	Good	Good	Good	Good	Good	Good
b)Resistance to External Corrosion caused by Mine Environment	Good	Fair	Poor	Good	Good	Good	Good	Good
c)Resistance to External Corrosion caused by Electrolysis	Poor	Fair	Fair	Good	Good	Good	Good	Good
2.a)Resistance to Impact Forces	Good	Fair	Good	Good	Poor	Good	Poor	Fair
b)Resistance to Failure as a Result of Bending or Tensile Stresses**	Poor	Poor	Fair	Fair	Poor	Fair	Poor	Poor
3.Fire Resistance:a)Safety with respect to Causing a Fire	Poor	Good	Fair	Fair	Good	Good	Good	Good
b)Ability to Resist Heat or Fire	Fair	Fair	Good	Good	Poor	Fair	Fair	Fair
4.Ability to Withstand Design Pressures	Good	Good	Good	Good	Good	Good	Good	Good
5.a)Weight (Per 21' Joint of 8.625" O.D. Pipe)*	205 lbs	665 lbs	470 lbs	470 lbs	75 lbs	168 lbs	166 lbs	247 lbs
b)Ability to be Easily and Safely Connected	Poor	Poor	Fair	Fair	Poor	Good	Good	Fair
6.a)Approximate Cost per Ft.of Pipe (8.625" O.D. Pipe)*	$9.00	$60.00	$6.00	$40.00	$5.00	$5.25	$7.00	$5.00
b)Availability of Pipe in Various Diameters and Wall Thicknesses	Good	Poor	Good	Fair	Fair	Good	Fair	Good

*The comparisons shown are based upon the wall thicknesses of 8" pipe that would most likely be used if that particular material were selected. Copper-.3125; Fiberglass-.162; Aluminum-.322; Carbon Steel-.250; Stainless Steel-.250; Polyethylene-.750; Polybutylene-.750; Polyvinyl Chloride-.750

**Includes consideration of the joining method

Figure 6. Pipe materials comparison chart (from Energy Applications, Inc., 1976).

CAPITAL EXPENDITURES AND LABOR COSTS

Drill	
Acker "Big John" Degasification Drill	$135,000
Piping System	
7000' of 10 3/4" x .109" wall thickness steel with victaulic rolled groove ends @ $4.12/ft	29,000
4900' of 8 3/8" steel pipe with victaulic rolled groove ends @ $3.44/ft	17,000
300' of 3 1/2" steel pipe with victaulic rolled groove ends @ $1.45/ft	500
350 10" victaulic #75 light weight couplings @$30.60	11,000
245 8" victaulic light weight couplings @ $16.63 ea.	4,500
15 3" victaulic light weight couplings @ $4.23 ea.	100
610 pipe hangers on 20' centers @ $5 ea.	3,100
13 3" vic flange adaptors @ $30.40 ea.	400
Total Pipe Cost	$65,600
Valves, Elbows, etc. @ 10% of total pipe cost	$ 6,000
Total pipe cost including valves etc.	$72,200
Miscellaneous	
13 separators and float traps @ combined cost of $900 for both	12,000
13 Rockwell 3" Mode DPS - H Security Valves @ $12.30	16,000
Lease on Sperry-Sun single shot surveying instrument for 6 months	5,000
Total Miscellaneous Cost	$33,000
Labor	
Drilling labor cost is 2 men (8 hrs day/man)(234 days)($14/hr)	$52,500
Installing 10" pipe .36 hr/ft (7000')($14/hr)	35,300
Installing 8" pipe .30hr/ft (4900')($14/hr)	20,600
Installing 3" pipe .18hr/ft (300')($14/hr)	800
*Labor rate includes benefits	
TOTAL LABOR COST	$109,200
TOTAL COST	$349,400
TOTAL COST X 1.2 ENGINEERING CONTINGENCY FACTOR	$420,000

REFERENCES CITED

Cervick, Joseph, and Fields, H. H., and Aul, G. N., 1975, Rotary Drilling Holes in Coalbeds for Degasification: U.S. Bureau of Mines Report of Investigations 8097, 21 p.

Perry, J. H., and Aul, G. N., and Cervick, Joseph, 1978, Methane Drainage Study in the Sunnyside Coalbed, Utah: U.S. Bureau of Mines Report of Investigations 8323, 11 p.

Tongue, David W. et al, 1976, Design and Recommended Specifications for a Safe Methane Gas Piping System: Grand Rapids, Michigan, Energy Applications, Inc. Final Report on U.S. Bureau of Mines Contract no. JO 155145, 80 p.

Appendix A

The IGT distribution formulation is:

$$Q_b = C\,(T_b/P_b)\left(\frac{P_1{}^2-P_2{}^2}{T_fL}\right)^{.5555}\left(\frac{D^{2.667}}{G^{.4444}u^{.1111}}\right)$$

where

Q_b - flow	T_f - flowing temperature
C - constant	L - length
T_b - base temperature	D - pipe inside diameter
P_b - base pressure	G - specific gravity
P_1 - upstream pressure	u - viscosity
P_2 - downstream pressure	

The following values were assumed in the model study of Energy Applications, Inc.

Q - 2 MMCFD, 200 MCFD	T_f - 515°R
C - .6643	L - 10,000 ft; 95 ft
T_b - 520°R	D - unknown
P_b - 14.4 psia	G - .66
P_1 - 18.9 psia	u - $7\cdot10^{-6}$
P_2 - 14.054 psic	

Two MMCFD is used to solve for the main pipe diamter which gives an 8" I.D. main pipe. 200 MCFD is the flow rate out of each horizontal hole and this results in a 2" I.D. lateral.

Using the estimated total flow rate of 3.5 MMCFD at the Hawk's Nest East mine, a pipe with an inside diameter of 10" is required. With the estimated 270 MCFD as the flow rate from each horizontal hole gives a pipe with a 3" inside diameter.