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Commercial-Quality Gas From a Multipurpose Borehole Located in the Pittsburgh Coalbed

UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 8025

Commercial-Quality Gas From a Multipurpose Borehole Located in the Pittsburgh Coalbed

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COMMERCIAL-QUALITY GAS FROM A MULTIPURPOSE BOREHOLE LOCATED IN THE PITTSBURGH COALBED

by

Herbert H. Fields,[1] John H. Perry,[2] and Maurice Deul[3]

ABSTRACT

The Bureau of Mines has been promoting health and safety in mining since its establishment in 1910. One area of research covers methane control in coalbeds; this report describes a multipurpose borehole used for both degasification and the production of commercial-quality gas.

The multipurpose borehole was drilled into a barrier pillar, and seven horizontal degasification holes and one pressure point hole were drilled radially out from its perimeter. On January 28, 1974, after 505 days of degasification, a compressor was installed to the exhaust stack of the multipurpose borehole (2), and pipeline--quality gas was introduced into a commercial pipeline. As of February 4, 1975, over 171 million cubic feet of gas had been purchased by the gas company.

The in situ pressure at a depth of 200 feet into the coalbed and the average gas flow and water flow from the degasification holes as they were completed and closed off were 203 psig, 1,200,000 cfd, and 6.8 gpm, respectively. Twenty-four hours after the seven holes were connected through individual pipes to the atmosphere, the total gas and water flows and the in situ pressure dropped, respectively, to 971,000 cfd, 1.3 gpm, and 18 psig. Five hundred days later, the corresponding values were 620,000 cfd, 0.15 gpm, and 10.5 psig. Daily flows have been as high as 800,000 cfd, and as low as 360,000 cfd, during the last 500 days.

On February 4, 1975, after 882 days of degasification, 576 million cubic feet of gas had been removed from the Pittsburgh coalbed; apparently a much larger area of virgin coal is being degasified than is defined by the holes. This study indicates that horizontal boreholes drilled into a coalbed from the bottom of any shaft will effectively remove gas from the Pittsburgh coalbed.

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[1] Mining engineer.
[2] Physicist.
[3] Supervisory research geologist.

INTRODUCTION

The Bureau of Mines has promoted health and safety in mining since its establishment in 1910. Presently, in addition to other areas of research, it is engaged in methane control involving removal of methane from virgin coalbeds, from major panels being pillared, and from old gobs. Specifically, this study was designed to determine the effectiveness of long holes drilled in solid coal in degasifying a portion of the Pittsburgh coalbed.

Methane exists under pressure in micropores, joints, and fractures of gassy coalbeds, and also may be present in adjacent strata. An in situ gas pressure of 275 psi has been measured in the Pittsburgh coalbed, and the permeability of this bed has been found to be high, compared with that of other coalbeds (1).[4] Further, in a number of mines where gas wells are located in this coalbed, significant bleed off of methane through the well barrier has been found (3). Because of the high in situ gas pressure and permeability of the Pittsburgh coalbed, considerable degasification can be effected over a significant area, if accomplished ahead of mining. This report continues previous work (2) and provides additional information on degasification by drilling long holes in the coalbed from the enlarged bottom of a borehole and conducting the gas through a piping system to the surface for venting and later for utilization. The previous report (2) describes the engineering design.

ACKNOWLEDGMENTS

The cooperation of the management of Eastern Associated Coal Corp., Pittsburgh, Pa., the management of the Federal No. 2 Mine, and the management of Consolidated Gas Supply Corp., Clarksburg, W. Va., is greatly appreciated.

THE MULTIPURPOSE BOREHOLE

The borehole utilized in this study is located in the barrier pillar 130 feet east of the outside heading of a projected set of ten, 3 South mains headings. Figure 1 shows the location to be approximately 1 mile from the existing faces of 3 South mains. The borehole was called multipurpose because after completion of degasification, or when the 3 South mains headings have been developed to the borehole, it may be used as an intake airway and later as a return airway. Still later, when the pillar line has been established, the borehole can be used to degasify the gob area nearby. While serving as an intake airway, the borehole may be used as an emergency escapeway, with power cables and communication lines installed in the two degasification pipes located outside the 48-inch-OD casing.

HORIZONTAL HOLES

Seven horizontal degasification and one pressure point hole were drilled radially out from the perimeter of the multipurpose borehole. The

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

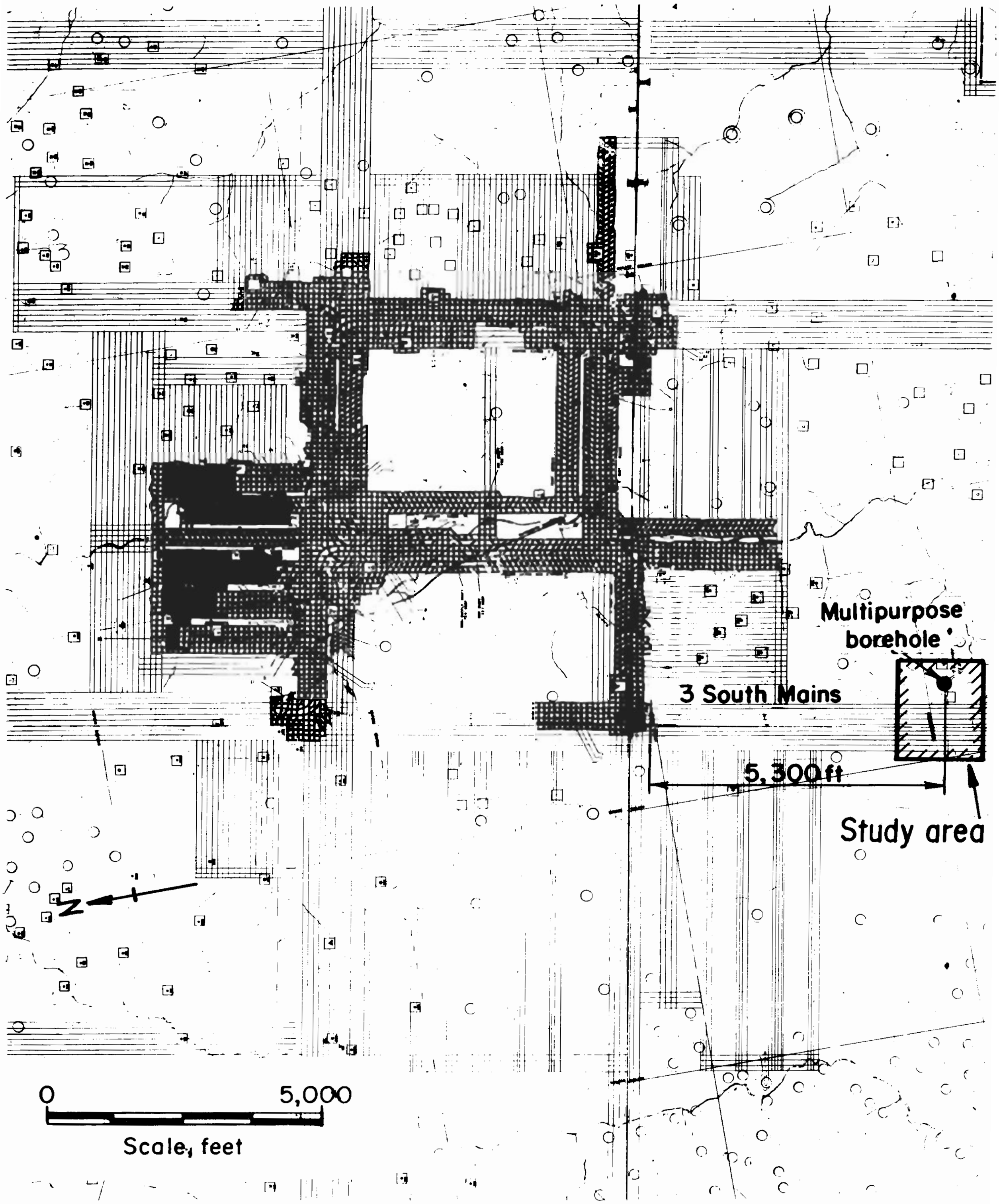

FIGURE 1. - Location of multipurpose borehole in virgin Pittsburgh coalbed.

degasification holes ranged in depth from 500 to 850 feet (fig. 2). Upon completion of each hole, a Bureau-designed mechanical packer was inserted in the hole and the hole was shut in to prevent outflow of gas until all degasification holes were completed. The in situ pressure hole was drilled to a depth of 199 feet.

DEGASIFICATION AND DEWATERING

A connection was made from the mechanical packer in each hole to a Bureau-designed water trap at each hole, and then to a 24-inch-diameter by 72-inch-high receiver tank. An orifice plate was installed in the pipe between the water trap and the receiver tank for measuring pressure in, and gas flow from, each hole. The gas is piped from the receiver tank on the bottom of the borehole through two 4-inch-diameter steel pipes to the surface, where the pipes are joined and connected to the compressor through a 6-inch-diameter pipe. A bypass is provided for venting the gas through a check valve into a 40-foot-vertical by 6-inch-diameter pipe when the compressor is not operating. Total gas flow, pressure, and time are measured by a 4-inch turboflowmeter located on the outby side of the gas compressor (fig. 3).

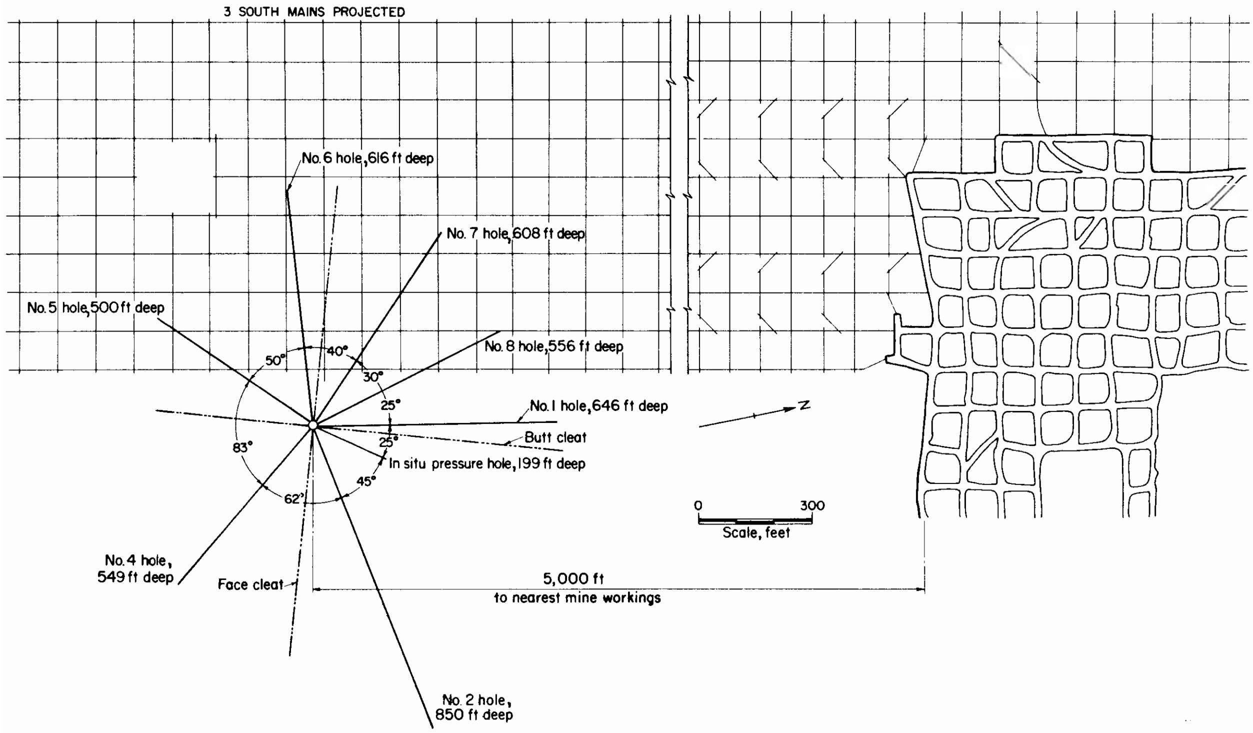

FIGURE 2. - Location of degasification holes underground with respect to closest mine workings, to projected main headings, and to face cleat.

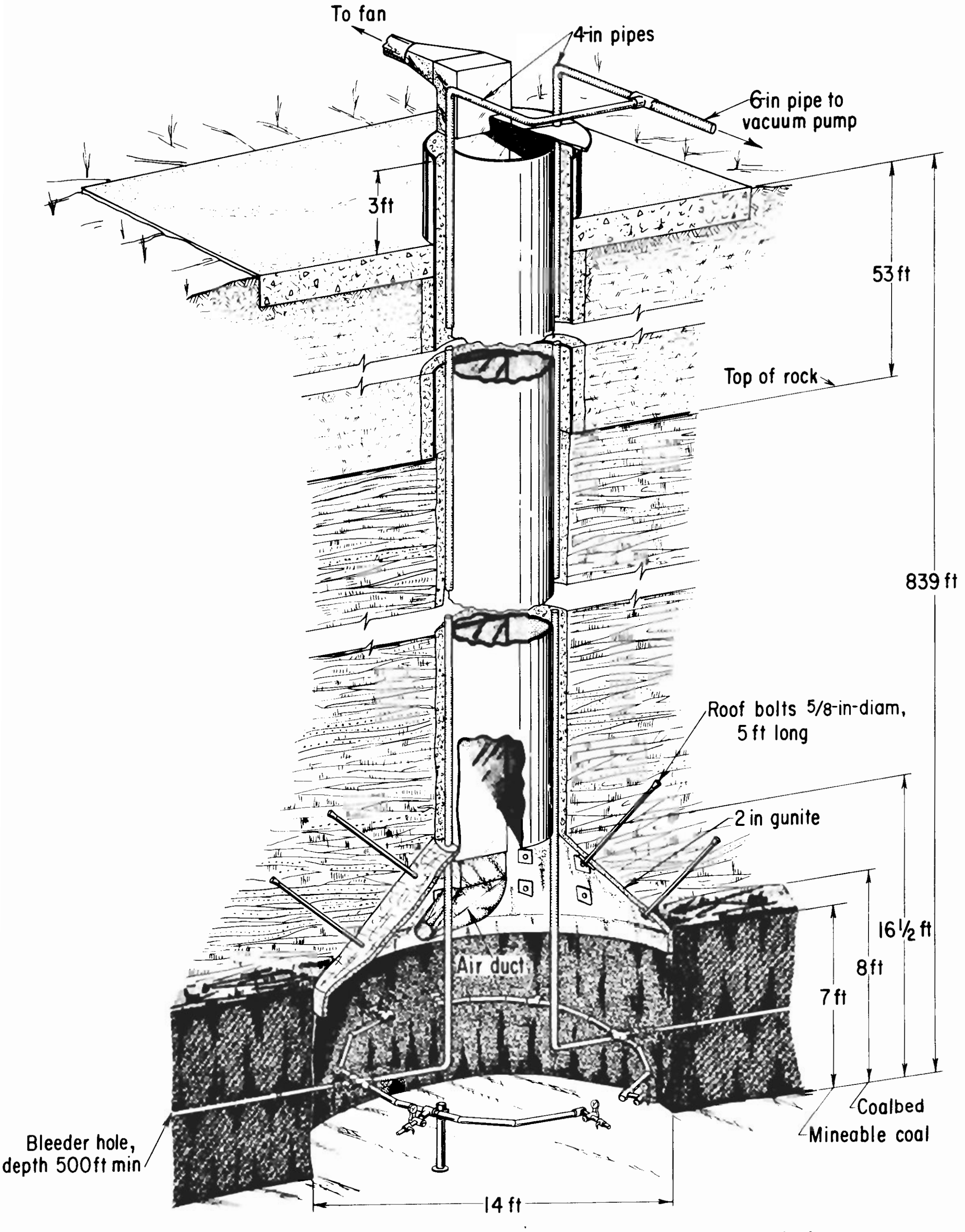

FIGURE 3. - Perspective view of completed multipurpose borehole.

In situ gas pressure and gas and water volume measurements are made at approximate 10-day intervals, and are listed in table 1 and figures 4-7.

TABLE 1. - Gas production from each horizontal hole, total gas and water flow, and in situ pressure record

Day	Date	Total gas emission, 1,000 cfd							Total gas emission, 1,000 cfd	Average waterflow discharge per hole, gpm	In situ gas pressure, psi
		Hole 1	Hole 2	Hole 4	Hole 5	Hole 6	Hole 7	Hole 8			
1	9-11-72	201	257	159	171	104	79	150	1,121	6.8	20.3
5	9-15-72	146	233	155	136	126	107	68	971	6.0	20.3
10	9-20-72	107	171	114	100	93	78	50	713	5.5	-
22	10-02-72	88	141	94	82	76	64	41	586	5.0	-
25	10-05-72	78	126	84	73	68	58	37	524	4.5	-
29	10-09-72	82	131	87	76	71	60	38	545	4.0	-
44	10-24-72	67	107	71	62	58	49	31	445	3.5	-
53	11-02-72	69	111	74	65	60	51	32	462	3.0	20.0
64	11-13-72	74	118	78	69	64	54	34	491	2.0	-
72	11-21-72	56	93	65	60	56	79	56	465	1.7	-
80	11-29-72	49	82	57	53	49	70	49	409	1.5	-
93	12-12-72	49	82	58	53	49	70	49	410	1.4	-
99	12-18-72	55	91	64	59	55	78	55	457	1.2	-
108	12-27-72	55	92	64	60	55	78	55	459	1.0	15.0
117	1-05-73	58	96	67	62	58	82	58	481	.9	-
124	1-12-73	60	100	70	65	60	85	60	500	.8	-
136	1-24-73	72	98	67	62	72	72	72	515	.75	-
144	2-01-73	71	96	66	61	71	71	71	507	.69	-
155	2-12-73	74	92	60	51	60	69	55	461	.6	-
164	2-21-73	71	97	61	66	71	76	66	508	.5	-
175	3-03-73	74	100	63	69	74	79	69	528	.49	-
185	3-13-73	75	102	65	70	75	81	70	538	.40	12.7
194	3-23-73	73	99	63	68	73	78	68	522	.36	12.5
205	4-02-73	69	94	59	64	69	74	64	493	.34	12.5
215	4-12-73	93	124	99	74	80	74	74	618	.34	12.5
225	4-22-73	89	118	95	71	77	71	71	592	.34	12.5
253	5-22-73	74	104	86	86	92	92	86	620	.34	12.1
265	6-01-73	82	116	95	95	95	102	95	680	.33	12.1
275	6-11-73	81	114	94	94	101	101	94	679	.32	11.8
285	6-21-73	78	110	90	90	97	97	90	652	.31	11.8
295	7-01-73	86	122	100	100	107	107	100	722	.31	11.8
305	7-11-73	70	99	81	81	87	87	81	586	.30	11.8
315	7-21-73	70	99	82	82	88	88	82	591	.30	11.8
325	7-31-73	88	124	102	102	110	110	102	738	.31	11.5
335	8-10-73	82	116	95	95	102	102	95	687	.30	11.5
345	8-20-73	74	120	87	94	87	107	100	689	.29	11.3
355	8-30-73	73	120	87	93	87	107	100	667	.29	11.3
365	9-09-73	80	130	94	101	94	116	109	724	.28	11.3
375	9-19-73	70	114	82	89	82	101	95	633	.27	11.3
385	9-29-73	73	125	86	92	79	106	99	660	.26	11.3
395	10-09-73	88	153	104	112	96	129	121	803	.26	11.3
405	10-19-73	78	136	93	100	86	114	107	714	.26	11.3
415	10-29-73	70	121	83	89	77	102	96	638	.25	11.3

TABLE 1. - Gas production from each horizontal hole, total gas and water flow, and in situ pressure record--Continued

Day	Date	Total gas emission, 1,000 cfd							Total gas emission, 1,000 cfd	Average waterflow discharge per hole, gpm	In situ gas pressure, psi
		Hole 1	Hole 2	Hole 4	Hole 5	Hole 6	Hole 7	Hole 8			
429	11-12-73	63	109	75	81	69	92	86	575	0.25	11.3
435	11-18-73	89	154	106	114	98	130	122	813	.25	11.3
445	11-28-73	70	122	83	90	77	103	96	641	.25	11.3
457	12-10-73	65	106	82	71	82	94	88	588	.25	11.3
465	12-18-73	72	125	85	92	79	105	99	657	.25	11.3
475	12-28-73	67	115	79	85	73	97	91	607	.24	11.3
486	1-08-74	64	111	76	82	70	93	88	584	.24	11.3
495	1-17-74	79	136	93	100	86	115	107	716	.23	11.3
505[1]	1-27-74	73	127	87	93	80	107	100	667	.21	11.3
517	2-08-74	64	111	76	82	70	94	88	585	.21	11.0
528	2-19-74	67	115	79	85	73	97	91	607	.21	9.0
535	2-26-74	68	118	81	87	74	99	93	620	.20	9.0
545	3-08-74	57	98	67	73	62	82	78	517	.20	9.0
555	3-18-74	65	112	77	83	71	94	89	591	.20	9.0
575	4-07-74	49	103	59	69	59	78	74	491	.20	9.5
585	4-17-74	51	101	66	70	66	81	70	505	.18	10.0
597	4-29-74	53	106	69	74	70	85	74	531	.18	10.0
605	5-07-74	53	106	69	75	70	85	75	533	.18	10.0
615	5-17-74	57	109	57	68	69	78	83	521	.18	10.5
628	5-30-74	76	106	75	86	61	51	50	505	.17	10.5
635	6-06-74	78	108	78	83	63	53	53	516	.17	10.5
646	6-17-74	81	139	81	81	76	64	53	575	.16	10.5
650	6-21-74	76	114	82	82	71	56	56	537	.16	10.5
660	7-01-74	77	119	82	82	72	54	54	540	.15	10.5
670	7-11-74	77	118	76	82	72	56	56	537	.15	10.5
680	7-22-74	53	111	74	84	63	79	63	527	.15	10.5
690	7-31-74	70	120	84	90	69	52	53	538	.14	11.0
700	8-10-74	52	107	69	75	71	84	75	533	.14	10.5
710	8-20-74	52	107	70	73	70	85	74	531	.13	10.5
720	8-30-74	77	115	81	82	70	57	55	537	.13	10.0
730	9-09-74	52	100	67	69	67	80	70	505	.13	10.5
740	9-19-74	77	119	82	82	70	50	60	540	1.12	10.5
750	9-29-74	57	109	57	68	75	75	80	521	.11	10.5
760	10-09-74	64	111	76	76	82	70	88	567	.10	11.0
766	10-15-74	65	112	77	83	71	94	89	591	.10	10.5
793[2]	11-11-74	75	200	100	16	12	10	14	427	.09	7.5
804	11-22-74	74	198	115	48	40	115	115	705	.09	8.0
828	12-12-74	78	186	105	55	44	122	52	642	.11	8.5
854	1-07-75	81	187	107	58	44	110	48	635	.11	9.0
868	1-21-75	77	182	150	55	39	144	48	695	.11	8.5
882	2-04-75	77	187	89	56	34	111	43	597	.11	8.6

[1]Compressor installed.
[2]Hole flooded.

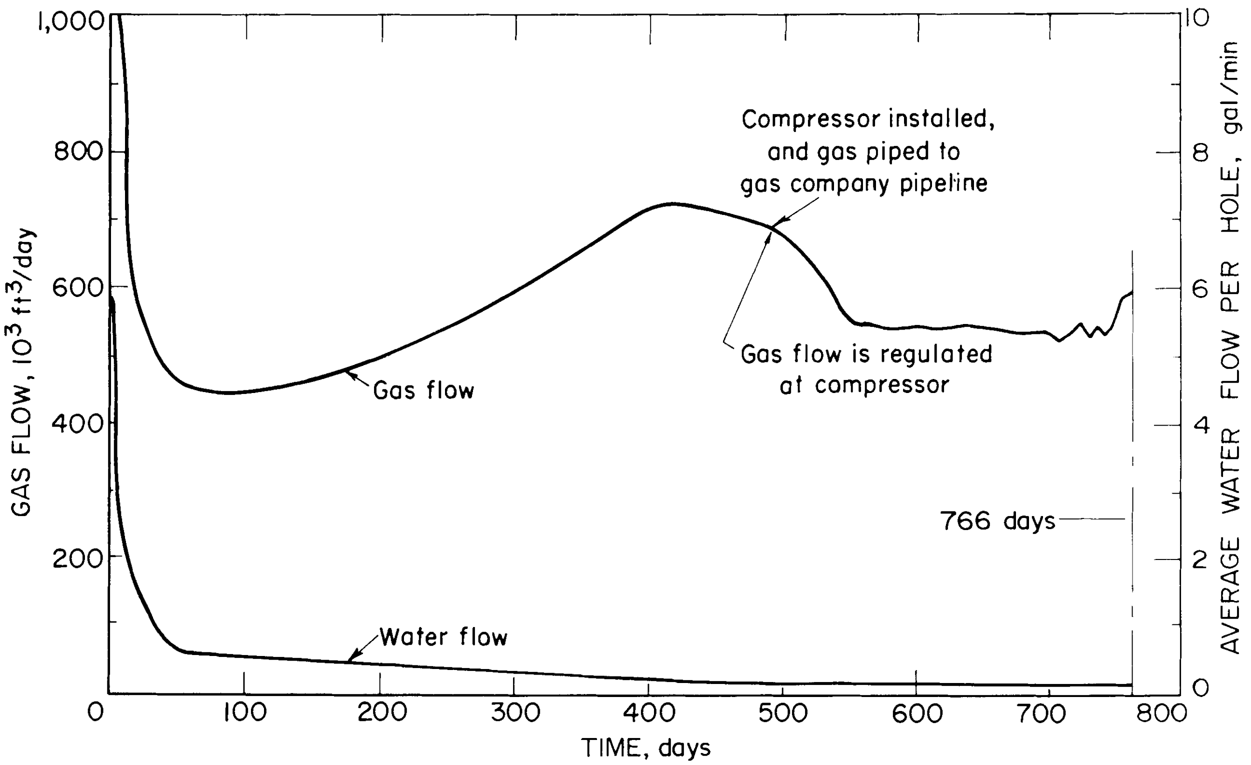

FIGURE 4. - Gas and water flow rates.

COMPRESSOR INSTALLATION

On January 28, 1974, the gas being exhausted into the atmosphere was connected to a commercial pipeline (fig. 8). The methane gas is of pipeline quality and has not, as yet, required remedial treatment for acceptance into the gas company's supply line. However, should daily flow exceed 600,000 cfd, it is possible the CO_2 will need to be removed.

A rotary compressor was installed; the discharge pressure varies from 25 to 35 psig, and the negative pressure on the intake side fluctuates between 20 and 30 inches water gage. Daily gas flow into the commercial gas line has averaged 522,000 cfd. Because of mechanical problems with the compressor, it was operated intermittently for the first 2 months. Numerous adjustments were needed to regulate temperature, flow, water condensation, and intake and discharge pressure. These problems were routinely corrected.

After installing the compressor, and after inducing a negative pressure of 25 inches water gage, the in situ pressure dropped from 11.3 to 9.0 psig due to a defective inflatable packer; the packer was replaced and the in situ pressure has increased to 11.0 psig. Vacuum is regulated at the discharge end of the compressor by returning part of the gas to the intake side. The amount of gas discharged is governed by the limits of the compressor and the allowable pressure in the commercial pipeline. When the flow from the borehole system exceeds the capacity of the compressor, the gas returned to the

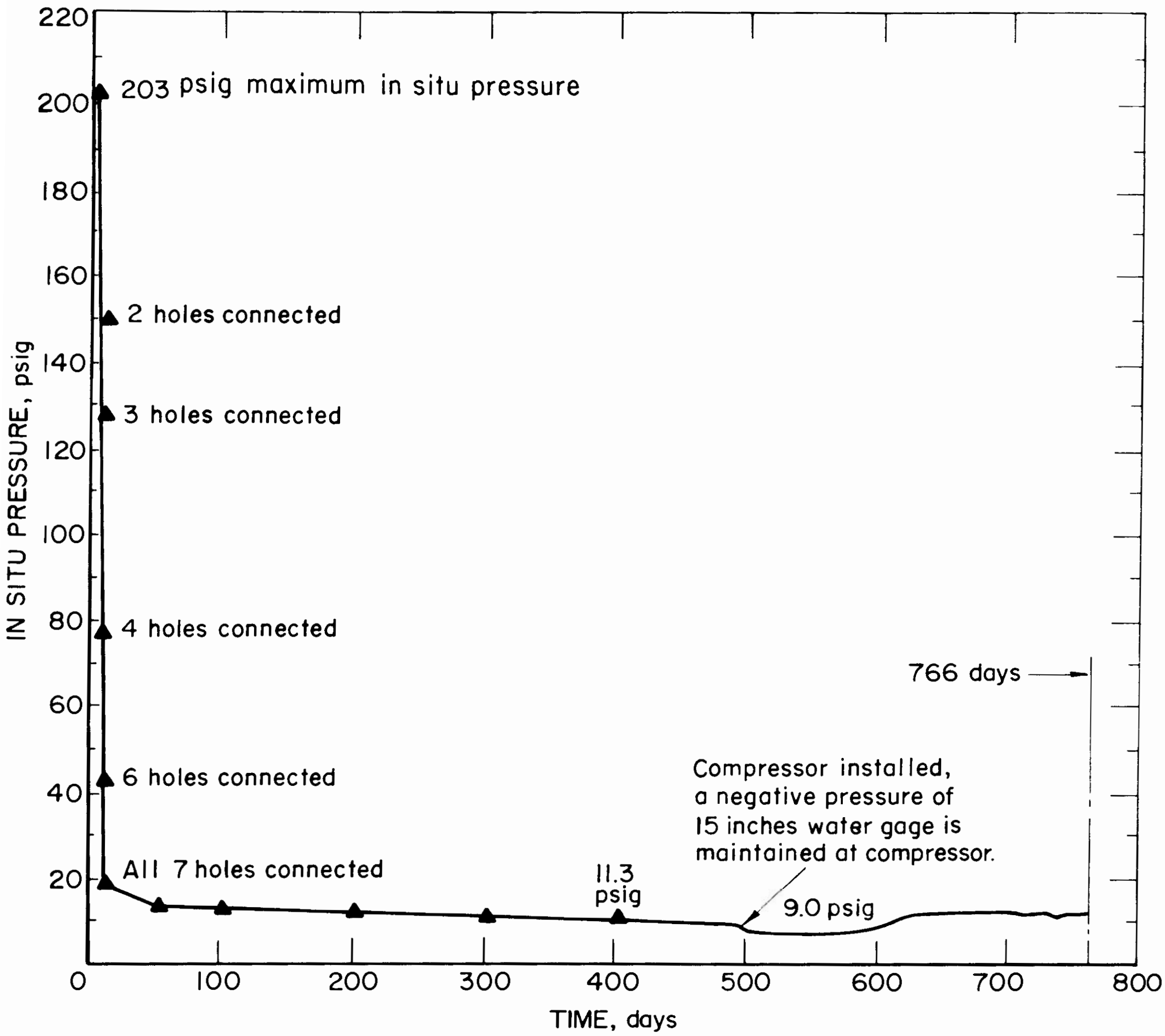

FIGURE 5. - In situ pressure.

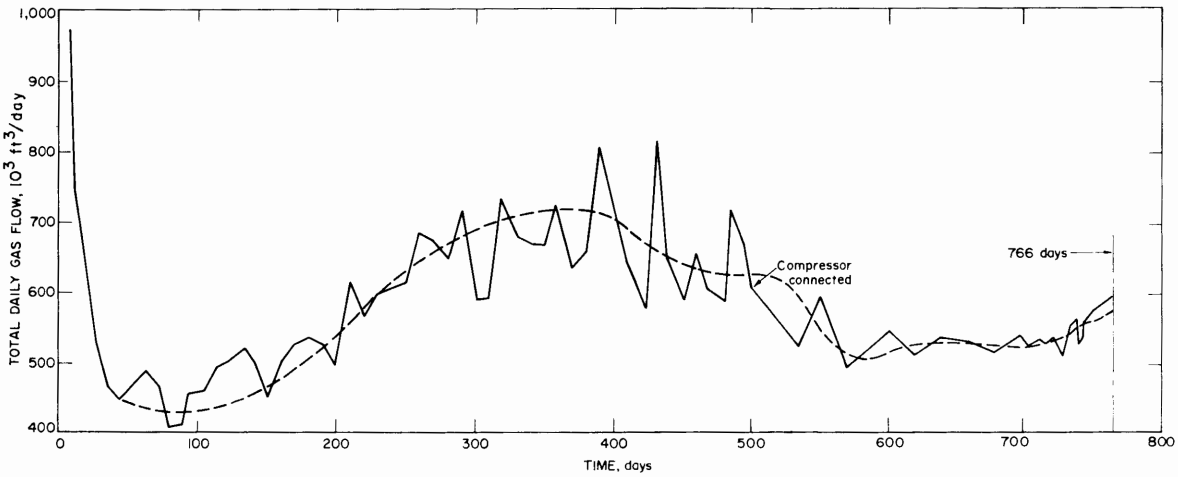

FIGURE 6. - Daily total gas flow.

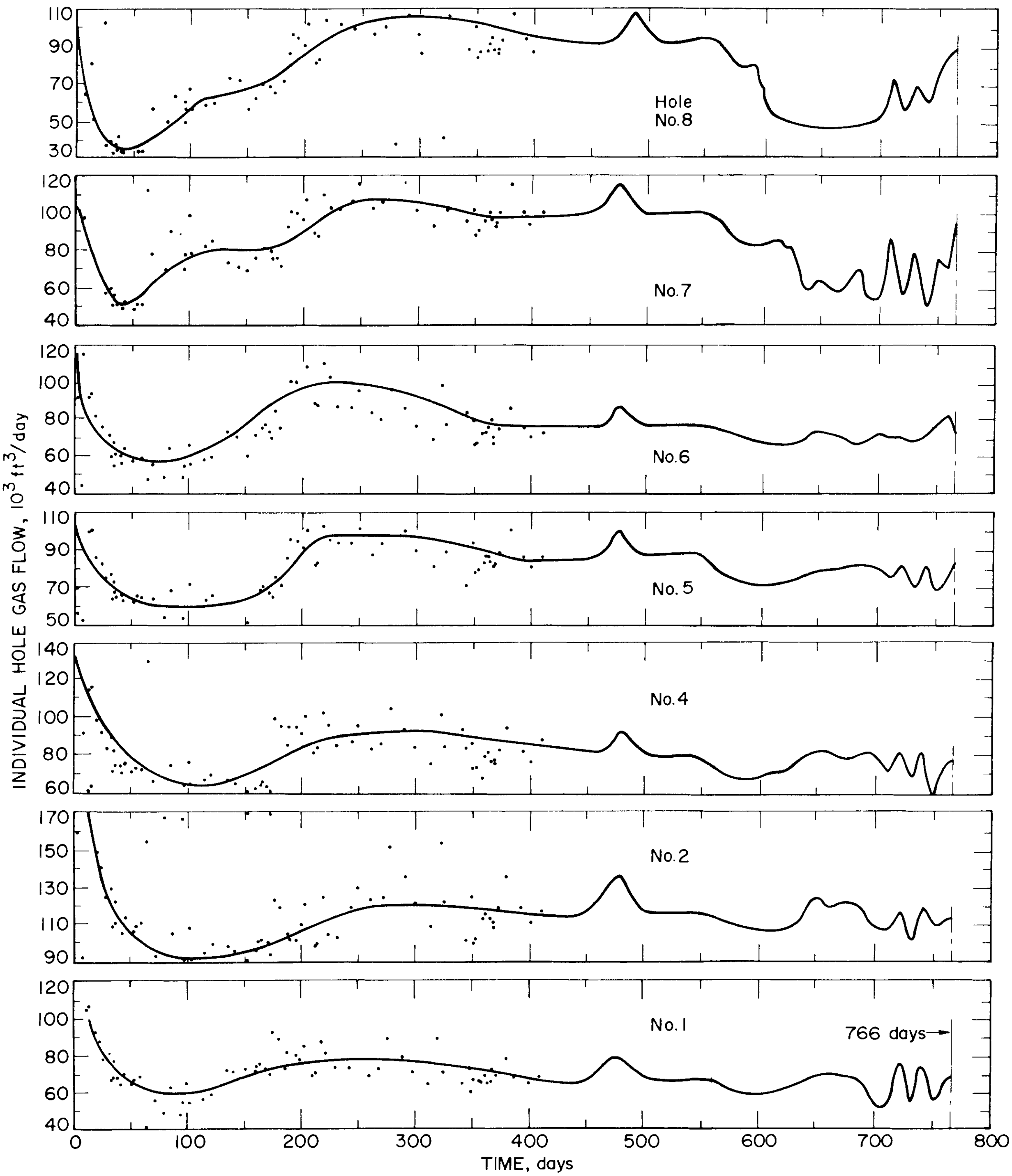

FIGURE 7. - Individual hole gas flows.

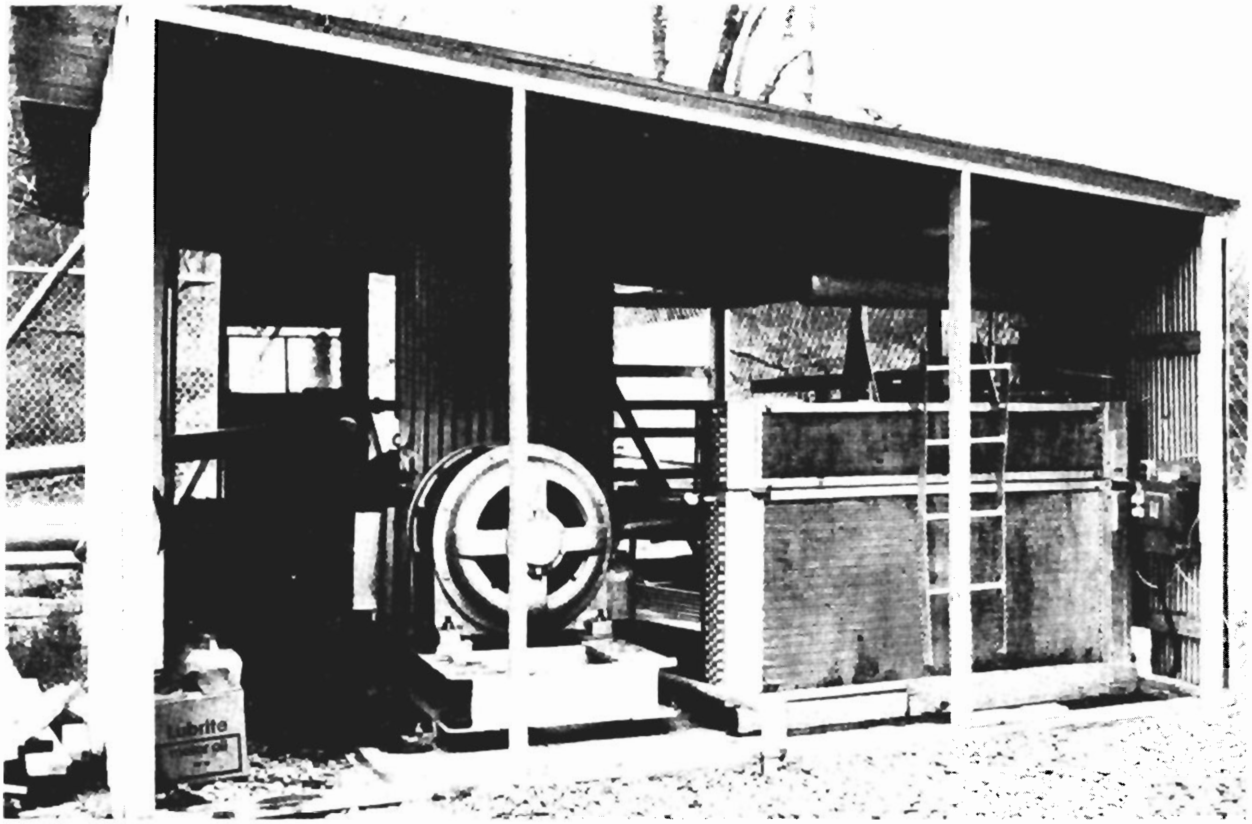

FIGURE 8. - View of compressor installation.

intake side causes a backup of gas in the entire system; this explains the drop in the rate of emission from the borehole that started when the compressor was first connected, as shown in figure 6. The discharge pressure varies between 14 and 27 psig. Maximum allowable discharge temperature is 180° F.

RESULTS AND DISCUSSIONS

The total gas flow from the borehole after 180 days was 91 million cubic feet, a daily average of nearly 500,000 cfd. The water discharge per hole and the in situ pressure were 0.34 gpm and 12.7 psig. Based on the average depth of hole (618 feet), about 9,600,000 cubic feet, or 384,000 tons of coal is within the roughly circular area defined by the radial holes. The gas content per ton of coal is estimated to be 120 cubic feet. This calculates to be 46 million cubic feet of gas in the defined area, indicating that a much larger volume of coal has been degasified than is subtended by the drainage holes.

After another 200 days (400 total days), the total amount of gas removed from the coalbed was 231 million cubic feet; the overall average increased to 577,000 cfd. The gas volume emitted is 12 times the gas estimated to be in the area subtended by the seven horizontal holes, indicating that an ever-increasing volume of coal is being degasified. The in situ pressure and water flow were 11.3 psig and 0.25 gpm. The methane content of the gas is more than 87 percent (table 2).

TABLE 2. - Analyses of four samples from total gas emission

	Sample 1, 7-10-72	Sample 2, 9-15-72	Sample 3, 6-21-74	Sample 4, 7-21-74
Ethane (C_2H_6)........................	300 ppm	321 ppm	0.05 pct	0.27 pct
Carbon dioxide (CO_2)............pct..	9.5	9.0	9.24	8.51
Oxygen (O_2).....................pct..	.6	1.2	.07	.01
Nitrogen (N_2)...................pct..	2.0	2.4	.35	.20
Methane (CH_4)...................pct..	87.9	87.4	90.28	90.88

The daily flow rate fell for the first 150 days, from 971,000 cfd to 504,000 cfd. An equation for the daily flow rate (DFR) for the first 150 days would be--

$$DFR = \exp(-0.032004^{d} + 13.09461) \text{ cfd} + 500{,}000 \text{ cfd}$$

$1 \leq d \leq 150$ where d is the number of days.

From the 160th day, the daily flow rate increased by 900 cubic feet of gas per day. The daily flow rate equation for this period is approximated by--

$$DFR = 505{,}000 + 733\,(d - 160) \quad 160 \leq d \leq 400$$

or

$$\exp(0.014838^{d} + 6.143162) + 500{,}000 \text{ cfd}$$

where d is again the number of days. These equations give values within 8 percent of the actual recorded values.

Fluctuations in barometric pressure affect the free flow of gas from the multipurpose borehole, as would be expected, but the data are subject to such large irregularities due to waterflow and temperature variations that we have not subjected them to statistical analysis.

As of February 4, 1975, 171 million cubic feet of gas had been piped to the gas company's line. Figures 4-6 reflect the changes in gas and water flow and in situ pressure before and after the compressor was placed in operation.

At least 2 years will be required before the 3 South mains are developed to the multipurpose borehole location. Methane emission will be monitored periodically during development of the mains to determine the actual area of effectiveness of this degasification technique. It is expected that upon maximum practical degasification of the area involved, coal can be mined with few hazards from ignitions and explosions, provided the minimum required ventilation is utilized. It is further expected that this situation will prevail some distances from the borehole.

Regarding the cost effectiveness of the degasification technique used in conjunction with the experimental multipurpose borehole, at a contract cost of $848,000, the following logic is used: Assume a minimum of 40 minutes lost production time per shift in development within virgin coal (this loss has been measured in Federal No. 2 mine because of methane emission rates at the face); at an average production rate of 4 tons per minute, 160 tons of coal would be lost per shift. Assume further that 480 tons of raw coal are produced per shift in the degasified area, as compared with 320 tons where not degasified. On a clean coal basis, the tonnages would become 410 and 275, respectively. The face labor costs per shift in both cases would be $450 (all fringe benefits included) for a continuous miner operator, a loading machine operator, a ventilation man, two shuttle car operators, a mechanic, a general serviceman, a boom operator, and a foreman. The face labor costs per ton of clean coal would be $1.10 for the degasified area and $1.62 for the nondegasified area, a difference of $0.52 per ton. For each 1 million tons of clean coal, the savings due to degasification would be $520,000.

The value of the methane removed from the coalbed in this project as of February 4, 1975, is $259,000, assuming a sale price of 45 cents per thousand cubic feet of 576 million cubic feet.

CONCLUSIONS

Based on the results obtained in 882 days, it can be concluded that the multipurpose borehole is a useful degasification technique. The final degasification will greatly exceed the estimated amount of gas calculated to be in the virgin area subtended by the drainage holes. A special multipurpose borehole is quite expensive; there was a need for such a hole 4 years ago when there was no access to virgin coal, but if a coalbed needs to be degasified in a great hurry, so that mining can proceed, other methods of degasification should be tried.

Instead of drilling a special hole, mine shafts that will ultimately be required for ventilation, skip, or man and material shafts, should be sunk to the coalbed long before normally required so that degasification through horizontal boreholes can be conducted from the shaft bottom. Work is now underway at Eastern Associated Coal Corp.'s Federal No. 2 mine using the Honey Run return air shaft sunk approximately 2 years ahead of mining. Horizontal drainage holes have been drilled routinely at relatively low cost. As of February 4, 1975, five holes have been drilled to depths of 670, 1,067, 1,167, 2,126, and 960 feet. Gas flows from these holes have been averaging more than 900,000 cfd, and as of February 4, 1975, 549 days after work started, more than 481 million cubic feet of methane had been exhausted. Plans have been completed to conduct this gas into a commercial pipeline.

Pipeline-quality gas can be safely removed from virgin areas of the Pittsburgh coalbed, and in commercial quantities. This will no doubt be an incentive for coal and gas companies to develop similar degasification programs. Tools and technology are now available, to accomplish degasification of the very gassy Pittsburgh coalbed without special equipment. Work is underway to degasify other gassy coalbeds using this technique.

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