

Bureau of Mines Report of Investigations/1972

**Methane and Dust Control
by Water Infusion**

Pittsburgh Coalbed (Fairview, W. Va.)



UNITED STATES DEPARTMENT OF THE INTERIOR

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**By Abdurrahman Cetinbas, R. P. Vinson, Joseph Cervik,
and M. G. Zabetakis**

Pittsburgh Mining and Safety Research Center, Pittsburgh, Pa.



**UNITED STATES DEPARTMENT OF THE INTERIOR
Rogers C. B. Morton, Secretary**

**BUREAU OF MINES
Elbert F. Osborn, Director**

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METHANE AND DUST CONTROL BY WATER INFUSION

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by

Abdurrahman Cetinbas,¹ R. P. Vinson,² Joseph Cervik,³
and M. G. Zabetakis⁴

ABSTRACT

The effect of water infusion on the flow of methane and on the production of dust was investigated at an active face in the Pittsburgh coalbed. The average total flow of methane at the face decreased by approximately 79 percent, whereas the flow from the ribs increased about 24 percent after infusion. On the day after infusion, dust concentrations appear to have been reduced; however, the presence of large quantities of rock dust obscured the results on the following days.

INTRODUCTION

Water is now used routinely to wet the dust formed while mining coal, and thus reduce the amount becoming airborne. In conventional, continuous, and longwall mining systems, the water is generally delivered to the work area in the form of a spray. However, a column of water is utilized in wet drilling and in seam infusion.⁵ In the former, water is delivered to the bit through a hollow drill stem; in the latter, water is forced into the coal by drilling a hole and pumping the water through it into the coal seam. This tends to wet the coal and thus reduce the production of airborne dust. Unfortunately, the results have not been entirely satisfactory so that this procedure has not had widespread acceptance, except where longwall mining methods are used. Schlick⁶ notes that water infusion is used in over 50 percent of the longwall faces in Germany; German mining regulations now require water infusion wherever possible. According to Gregson,⁷ approximately 13 percent of all faces

¹Mining engineer.

²Physicist.

³Supervisory geophysicist.

⁴Research supervisor, Methane Control and Ventilation.

⁵Parisi, C. William. Respirable Coal Dust Abatement and Control. Min. Cong. J., v. 57, No. 4, April 1971, pp. 58-62.

⁶Schlick, D. P. Respirable Dust Control in the Mines of West Germany. BuMines Inf. Circ. 8490, 1970, 16 pp.

⁷Gregson, H. Deep Hole Infusion in the Kent Coalfield. Coll. Guard., v. 212, May 13, 1966, pp. 599-604.

in Great Britain are being infused through 6-foot-deep holes spaced 6 yards apart.

Experiments on water infusion first were conducted almost 30 years ago in South Wales.⁸ More recently, a number of water infusion experiments have been conducted in an effort to drive methane from a coalbed, and subsequently to block the flow of methane into the working area. Merritts and his coworkers noted that methane could be released at controlled rates by regulating the flow of water,⁹ Gregson¹⁰ reported that water reduced the high peak methane emissions encountered in the high-speed mining of gassy seams, while Walstenholme and Arscott¹¹ found that water infusion of floor boreholes was of limited use.

The present study was designed to obtain quantitative data on the effects of water infusion in reducing both dust and methane concentrations in the working areas and in the air returns of operating mines. This is the first in a series of reports on experimental investigations to determine the conditions under which water infusion can be effectively incorporated into the mining cycle of an operating mine.

ACKNOWLEDGMENTS

The cooperation of the Eastern Associated Coal Corp., Pittsburgh, Pa., during the course of this study is greatly appreciated. The authors also wish to thank William Hylton, superintendent, and James Hayhurst, mine foreman, Federal No. 2 mine, for assistance in planning and conducting the work described in this report; members of the Bureau's Pittsburgh Field Health Group in the design of the dust experiments; and Frank McCall and Helen Lang of the Bureau's Pittsburgh Mining and Safety Research Center for assistance with the dust and gas samples collected in this study.

TEST SITE

Infusion experiments were conducted in the Eastern Associated Coal Corp. Federal No. 2 mine (fig. 1). The mine operates in the Pittsburgh coalbed near

⁸Jenkins, P. T. Suppression of Dust by System of Water Infusion in Coal Seams. Proc. S. Wales Inst. Eng., v. 59, 1943, p. 306.

⁹Jackson, E. O., and W. M. Merritts. Water Infusion of Coal Pillars Before Mining, Independent Coal and Coke Co., Kenilworth, Utah. BuMines Rept. of Inv. 4836, 1951, 25 pp.

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

Merritts, W. M., C. R. Waine, L. P. Mokwa, and M. J. Ackerman. Removing Methane (Degasification) From the Pocahontas No. 4 Coalbed in Southern West Virginia. BuMines Rept. of Inv. 6326, 1963, 39 pp.

¹⁰Work cited in footnote 7.

¹¹Walstenholme, E. F., and R. L. Arscott. Methane Drainage. Coll. Guard., v. 217, No. 9, September 1969, pp. 514-520.

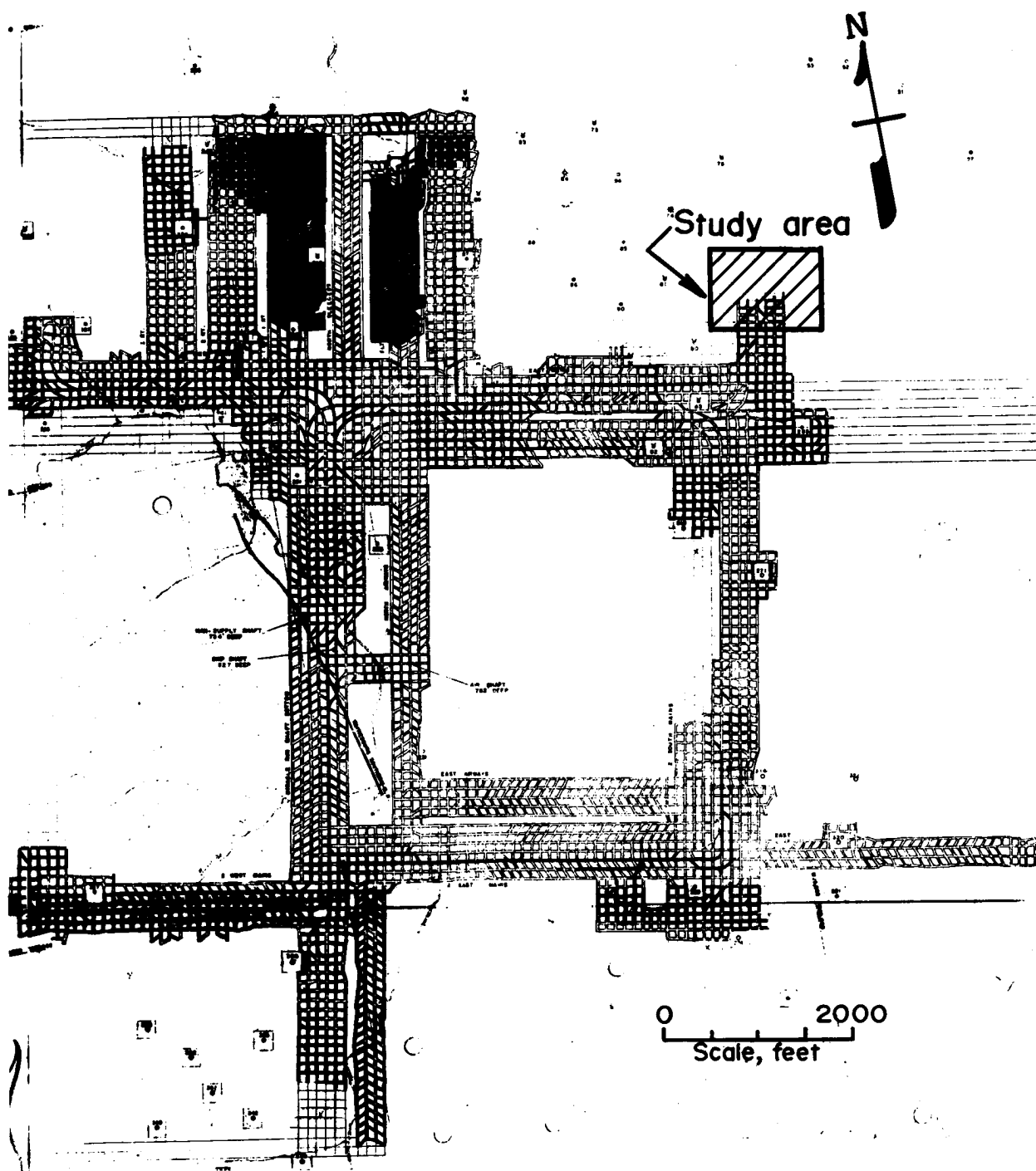


FIGURE 1. - Federal No. 2 Mine Map.

Fairview, W. Va. The coalbed is 9 feet thick; 7 feet is being mined at present and the remainder is left to control roof and bottom stresses. Overburden thickness ranges from 734 to 842 feet.

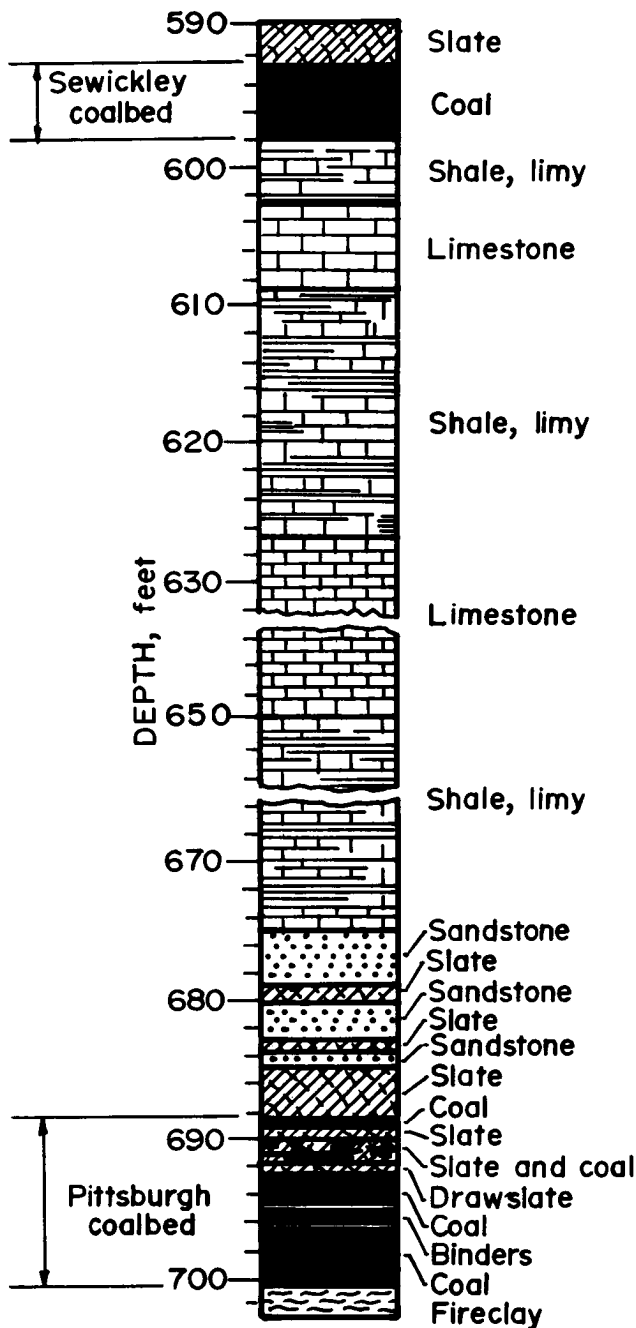


FIGURE 2. - General Lithology of Sewickley and Pittsburgh Coalbeds and the Adjacent Strata.

approximately 38,000 cfm passes to the left (entry 1), and 20,000 cfm to the right (entry 6). At the face, an exhaust fan with 20-inch-diameter extensible tubing is used to exhaust methane-air mixtures at a rate of 9,500 cfm. The volume flow of methane from the face area of the section is 59 cfm for the left split and 73 cfm for the right split. The total flow of methane from the mine is approximately 8 million cu ft per day (about 5,550 cfm).

Federal No. 2 mine property lies on the Belle Vernon anticline and the Waynesburg syncline. These geologic structures trend generally NNE-SSW. Figure 2 shows the general lithology between the two major coalbeds in this area; the Sewickley coalbed lies approximately 100 feet above the Pittsburgh coalbed.

There are two well-developed cleat systems in the Pittsburgh coalbed; the face cleat trends N 70° W and the butt cleat N 20° E. The permeability of the coalbed is due to these systems. The fracture spacing is about 6 inches. The associated gas pressure of the coalbed as measured by a drill stem test conducted on a surface borehole drilled into the coalbed in a remote area is about 275 psig.

The present study was conducted in a section being mined with a twin-borer continuous miner. Room-and-pillar mining is used with six headings 14 feet wide on 100-foot centers; crosscuts are on 80-foot centers.

The mine's ventilation system exhausts about 870,000 cfm of mine air through a single shaft. A split system of ventilation is used in the study section to control methane at the face areas. Figure 3 shows a schematic of the ventilation plan. Entries are numbered 1 through 6 from left to right. Entries 1 and 6 are return air courses; entries 2, 3, and 5 are the intake air courses; and entry 4 is neutral (belt-line heading). The intake air headings in this section course approximately 58,000 cfm of air to the face areas;

LEGEND

- | | |
|---------------------|--|
| ← Intake air | ⊙ Man door |
| ↔ Return air | △ Dust sampler |
| - - - Line brattice | ○ Recording methanometer station |
| Permanent stopping | ⊗ Recording methanometer and recording anemometer station. |
| ⊕ Curtain stopping | |

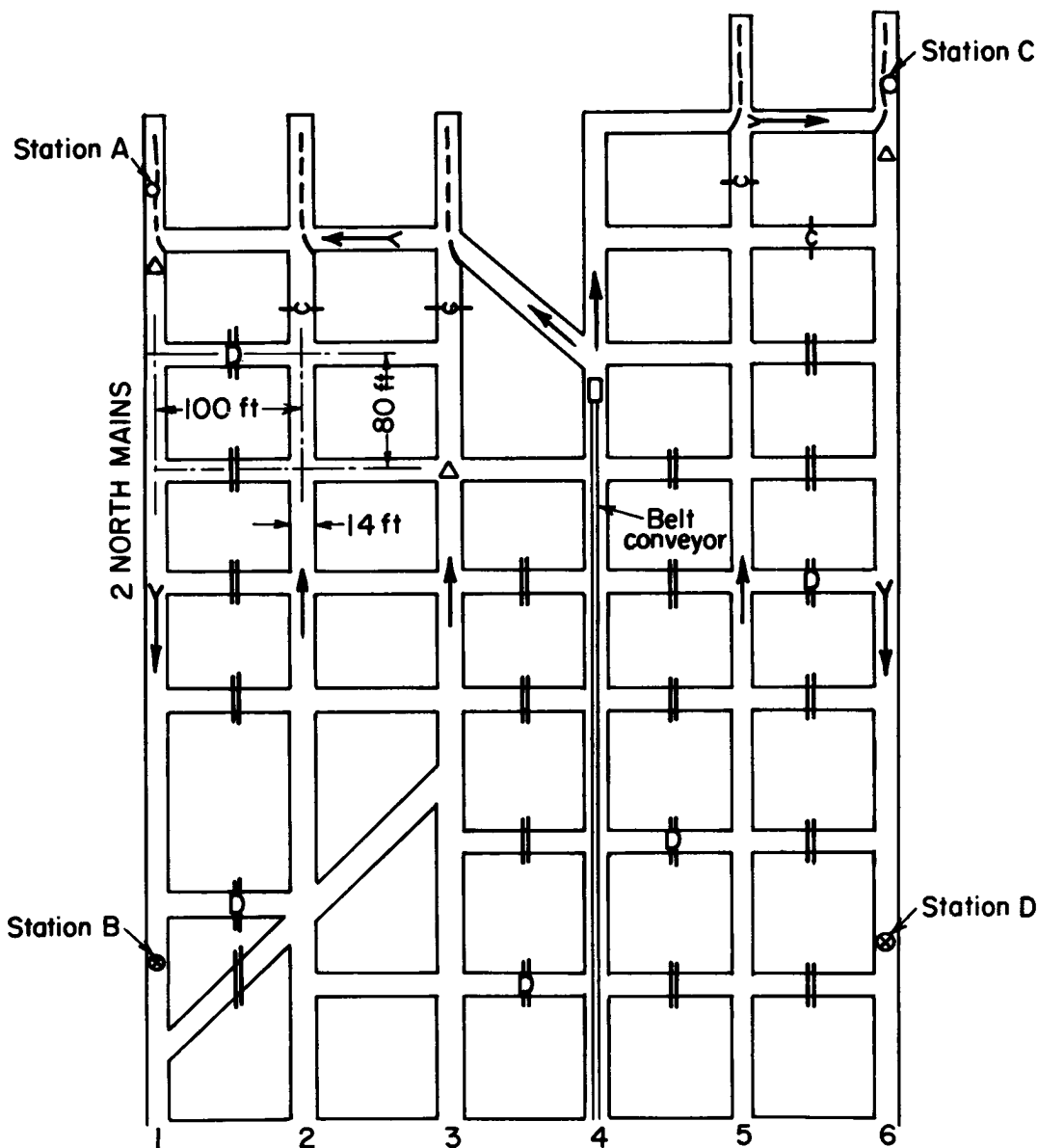


FIGURE 3. - Enlarged View of Study Area.

Table 1 shows the daily coal production from the study section during the period considered here; average daily raw coal production was about 617 tons. Total coal production from the mine was about 5,100 tons per day.

TABLE 1. - Daily coal production--study area, Federal No. 2 mine

<u>Date, 1971</u>	<u>Tons</u>
September 15.....	815
September 16.....	331
September 17.....	435
September 18.....	¹ 0
September 19.....	¹ 0
September 20.....	903
<u>September 21.....</u>	601
¹ Idle.	

INSTRUMENTATION

Methane measurements were made with Bureau of Mines pellester type recording methanometers¹² and Riken¹³ gas indicators (0 to 10 volume-percent scale). In addition, gas samples were taken for analysis on an Instruments Inc. model C-40 gas chromatograph equipped with a flame ionization detector.

Dust concentrations were obtained using MSA Monitare model G personal dust samplers. Instrument packages at each sampling location consisted of two units to permit the collection of respirable as well as total airborne dust.

Air velocity measurements were made with BM-24¹⁴ (recording) and Taylor (handheld) anemometers. Rockwell industrial watermeters were utilized to determine the rate and quantity of water used for infusion as well as that used by the spray system on the continuous miner.

Infusion holes were drilled with single post-mounted and handheld hydraulic drills. These holes were sealed with 2-5/8-inch-diameter Lynes inflatable packers (fig. 4); the overall length of each packer is 53 inches; the sealing segment is 36-3/4 inches long. Packers are connected in series with 5-foot lengths of 1-inch-OD schedule 80 pipe. The inflation chambers are interconnected with 1/4-inch-diameter plastic tubing. In practice, packer assemblies are made up and inserted into each infusion hole until the correct seal depth is reached.

¹²LaScola, J. C., and Joseph Cervik. Development of Recording Methanometers and Recording Anemometers for Use in Underground Coal Mines. BuMines Tech. Prog. Rept. 15, 1969, pp. 9-13.

¹³Reference to specific makes or models of equipment is made to facilitate understanding and does not imply endorsement by the Bureau of Mines.

¹⁴Work cited in footnote 12.

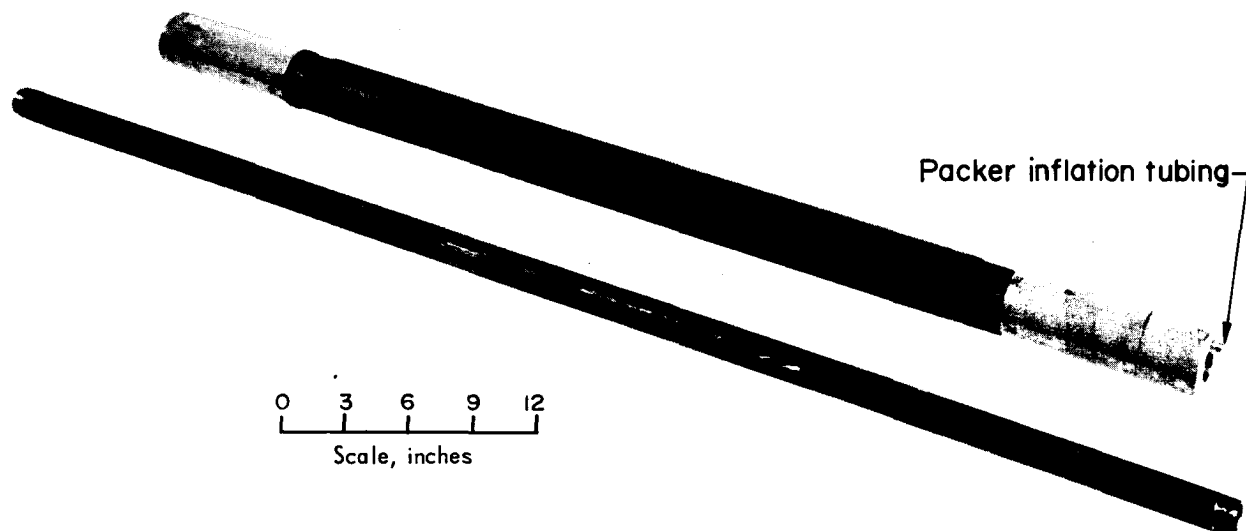


FIGURE 4. - Lynes Inflatable Packer and Schedule 80 Spacing Pipe.

EXPERIMENTAL PROCEDURE

Methane monitoring started 3 days prior to infusion and was continued 24 hours a day for 8 consecutive days. Two recording methanometers and one BM-24 recording anemometer were installed in each return airway (fig. 3) with the sensing heads located at points found to have the average air velocity of the airway. Inby stations were kept approximately 50 feet, and outby stations 600 to 650 feet, from the face in the vicinity of the areas designated as stations A, B, C, and D. In addition to the continuous recordings, spot measurements were made at every block between the inby and outby stations, at the face area, and at the intake airways. Methane readings were taken at the rib and at the center of the airway in each case.

Dust sampling started 3 days before infusion and was completed 9 days later. This yielded 3 days of preinfusion sampling and 4 days of postinfusion sampling; samples were taken only on the day shift (8 a.m.-4 p.m.) on normal production days. At the beginning of the day shift, dust-monitoring personnel mounted one instrument package at each of the following locations: On the continuous miner approximately 3 feet inby the operator; on the loader approximately 3 feet inby the operator; in both left and right returns approximately 150 feet outby the face. In addition, an MSA personal dust sampler was located in an intake airway approximately 250 feet outby the face (fig. 3). After mounting, each sampler was checked periodically for correct flow and proper positioning of the sampling head.

To infuse the coal, four 3-inch-diameter holes were drilled into the coal at the face area (fig. 5). Holes 1, 2, and 3 were approximately 127 feet deep; they were sealed with packers to a depth of 75 feet, leaving the back 52 feet of hole open for water infusion (fig. 6). Hole 4 was approximately 55 feet

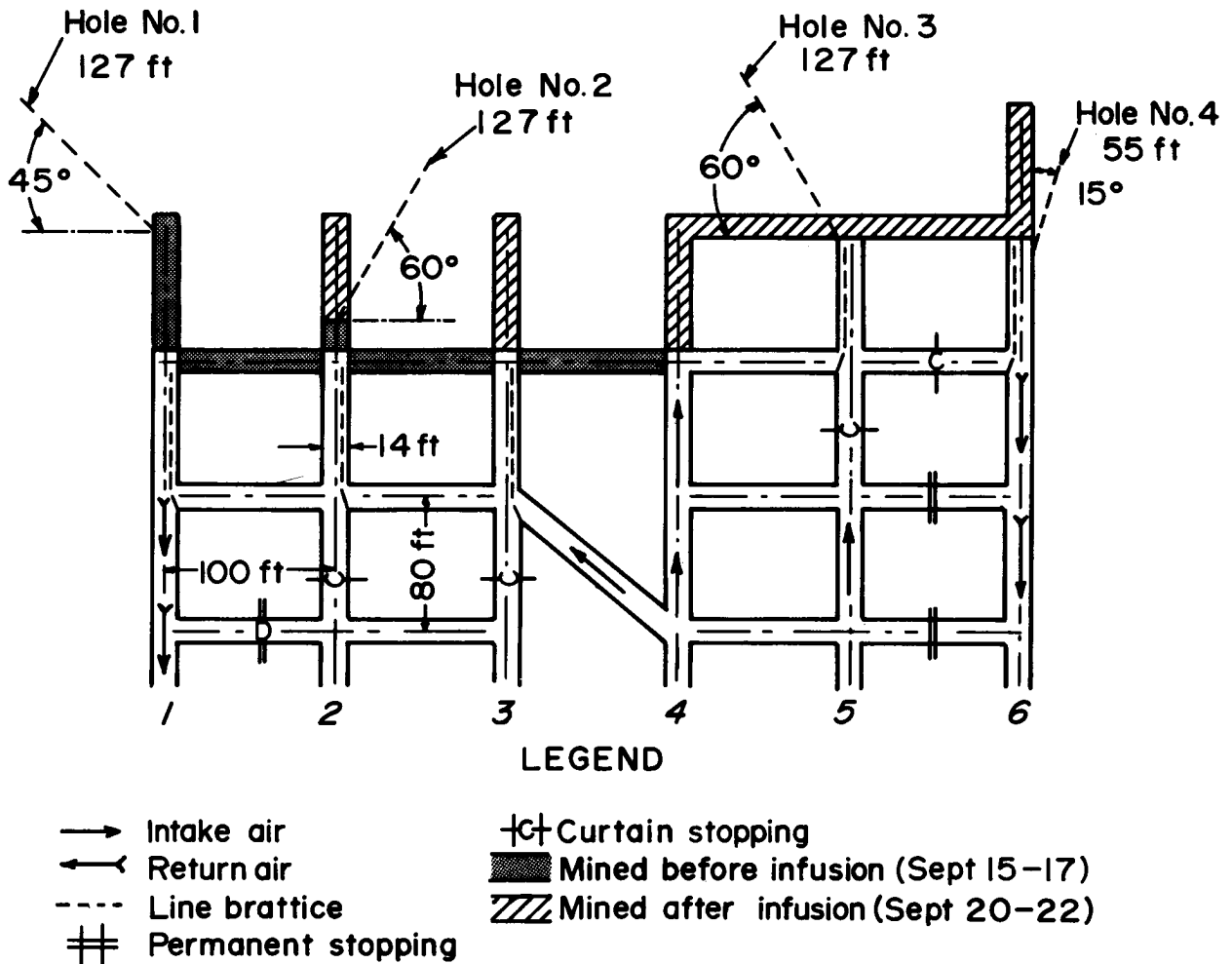


FIGURE 5. - Location of the Infusion Boreholes.

deep, and was sealed to a depth of 40 feet; 15 feet of hole was open for water infusion. Once in place, the packers were inflated to 800 psi with a pressurized mixture of ethylene glycol and water. After the packers were inflated, the mine water supply was connected directly to the 1-inch pipe and the coal infused (fig. 6). Infusion pressure at holes 1 and 2 was 410 psi with an average infusion flow rate of about 10 gpm; flow rates ranged from a high of 19 to a low of 8 gpm. Infusion pressure at holes 3 and 4 was 320 psi with an average infusion flow rate of about 8.5 gpm; flow rates ranged from a high of 10 to a low of 5 gpm. Water appeared at the face and rib areas in 7-1/2 hours (hole 4) to 42 hours (hole 3). Infusion was continued in holes 1, 2, and 4 for varying periods after water appeared at the face.

An observer was stationed at the face area during all normal production shifts to record the complete mining cycle. He recorded the intervals when mining occurred, the amount of coal mined, the direction and rate of face advance, and the periods during which rock dust was dispersed in by the dust samplers.

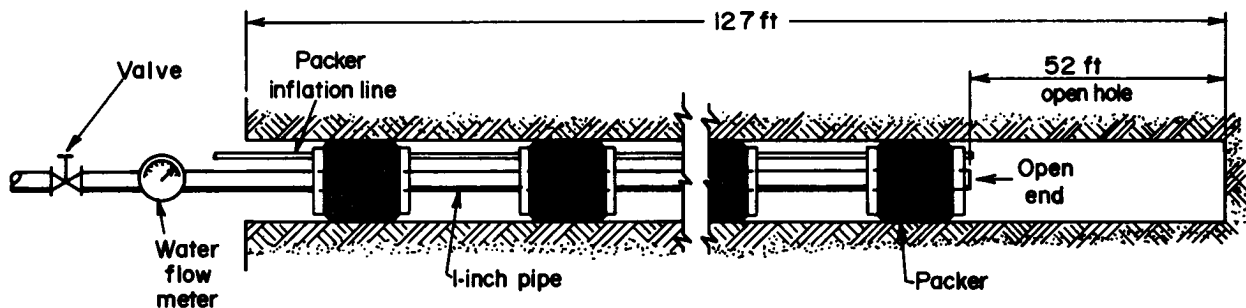


FIGURE 6. - Schematic of Sealed Infusion Borehole.

RESULTS AND DISCUSSION

Methane Emission

Figures 7 and 8 show the methane flow rates at each of two locations in the return entries of the study area during the entire period.

Curves a and c show the flow rates at the inby stations, and curves b and d show the rates at the outby stations. The average methane flow rates before (September 15-17) and after (September 20-22) infusion are listed in table 2. The average total methane flow rate at the face dropped from 132 cfm (\bar{X}_1) before infusion to 28 cfm (\bar{X}_2) after infusion (fig. 9); the average flow rate was thus reduced approximately 79 percent.¹⁵ This decrease ($\bar{X}_1 - \bar{X}_2$) was found to be statistically significant at the 0.05 level of significance in each case; the 95-percent confidence interval is shown for each of the inby curves in figures 7 to 9. The scatter ranged from a low of 4 cfm (one standard deviation) in the left return to a high of 8 cfm in the right return after infusion; the scatter was 6 cfm in both left and right returns before infusion.

TABLE 2. - Average methane flow rates, cfm

Station	Left return	Right return	Total
PREINFUSION			
Inby.....	59	73	132
Outby.....	91	152	243
Difference.....	32	79	111
POSTINFUSION			
Inby.....	14	14	28
Outby.....	62	104	166
Difference.....	48	90	138

The average methane flow rates at the outby stations (face plus ribs) decreased from 243 before infusion to 166 cfm after infusion, a decrease of

¹⁵The average flow rate was reduced approximately 50 percent in a subsequent study in an adjoining property when methane was emitted along the face cleat.

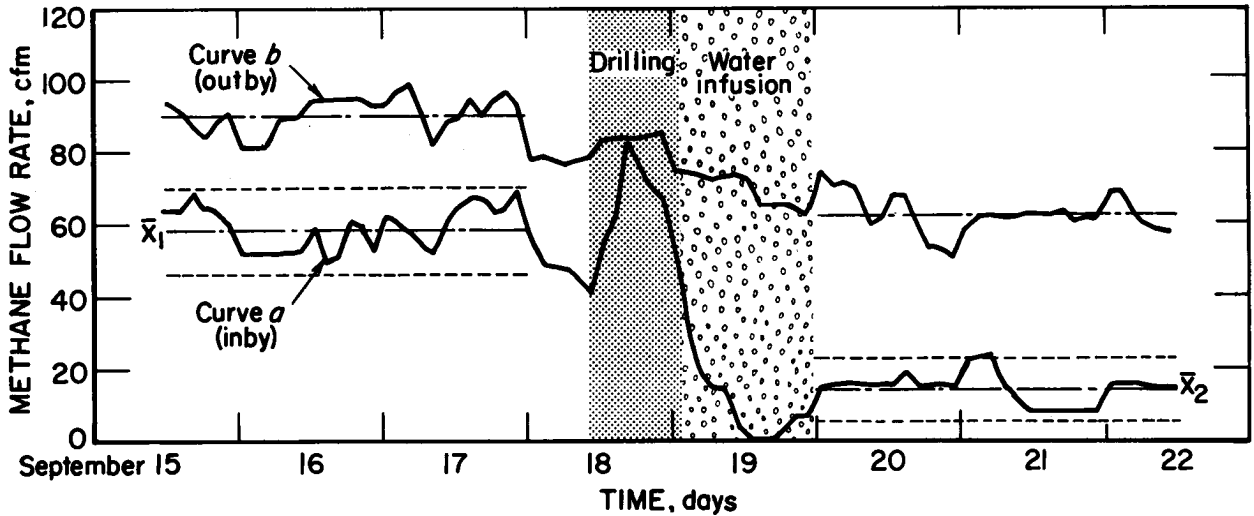


FIGURE 7. - Methane Flow Rates in Entry 1.

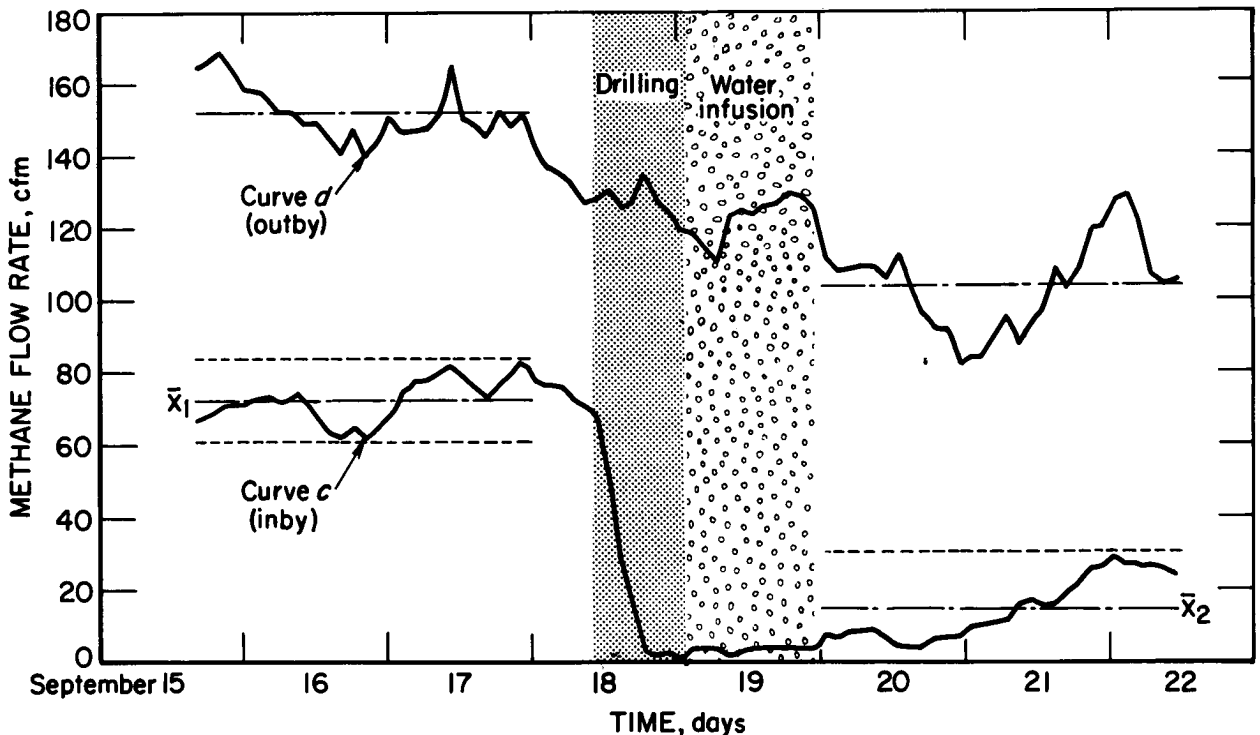


FIGURE 8. - Methane Flow Rates in Entry 6.

about 32 percent. But the methane flow rate from the ribs increased about 24 percent following infusion (111 versus 138 cfm). While some increase is to be expected as additional rib area is exposed, much of the additional flow occurred because methane was diverted from the face by the infused water. The water not only diverted methane out through the ribs, but also generated steeper concentration gradients in the return near the face. This is clearly

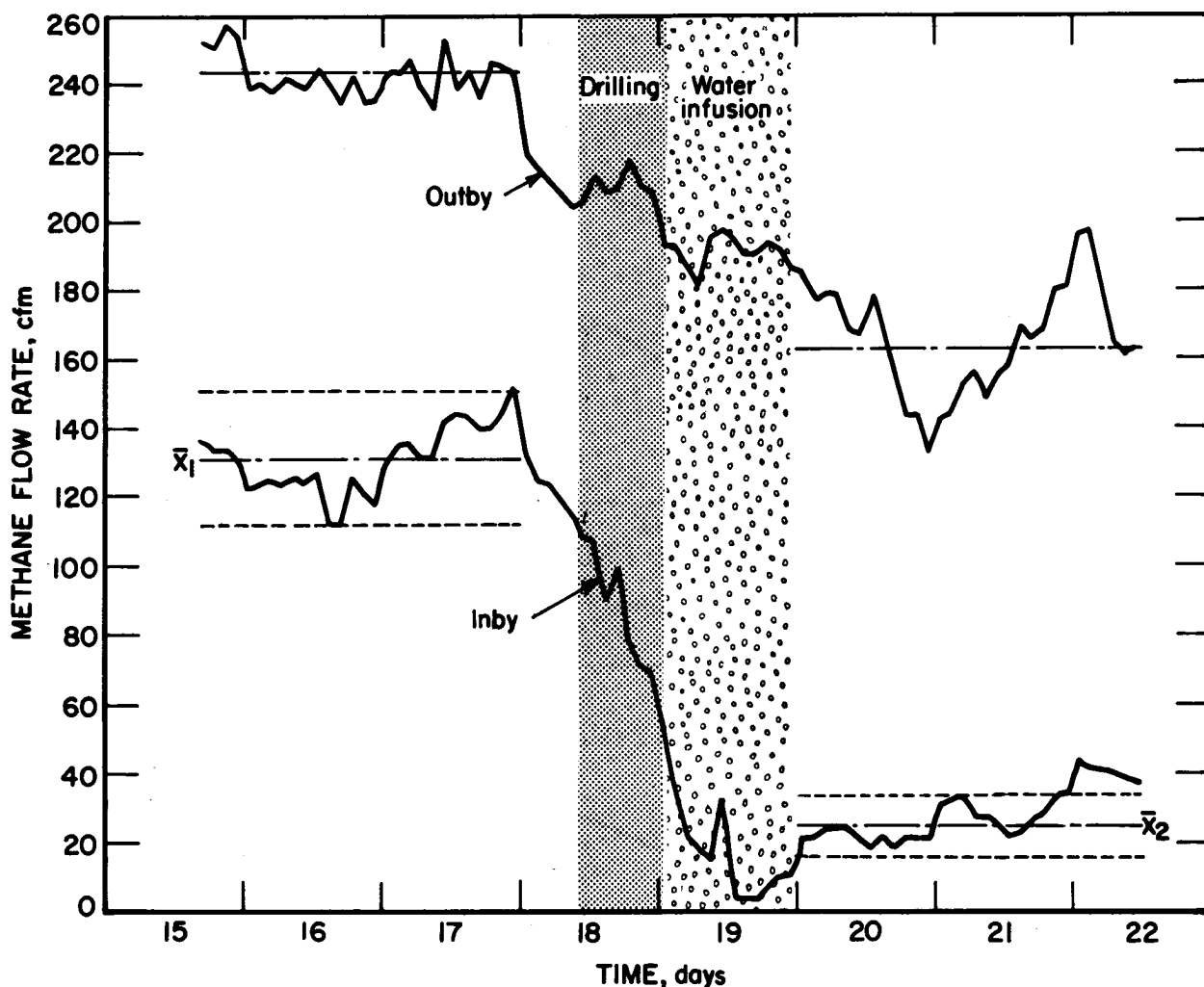


FIGURE 9. - Total Methane Flow Rates From the Study Area.

evident in the results of the surveys made early in the morning of September 17 and 21 in entries 1 and 6 with a Riken detector. Methane concentrations increased with increasing distance from the face. However, the initial rates of increase were greater after infusion than before. These data, converted to methane flow rates, are presented in figures 10 and 11. No attempt was made to obtain concentrations at points corresponding to the average air-speed, so that the data in figures 10 and 11 do not check with those at the corresponding points in figures 7 and 8. However, they are internally consistent and show the diverting effect of infused water on methane emission from the ribs. In addition, each set of figures, as well as the data in table 2, illustrates the important effect of relative rib location on methane flow. Thus, the rib flow in the right return (entry 6) was 2.8 times the flow in the left return (entry 1) before infusion and 1.8 after infusion. The mine map (fig. 1) shows that the right side of this section is in virgin coal; the left side is adjacent to other mine workings, so that partial degasification has occurred.

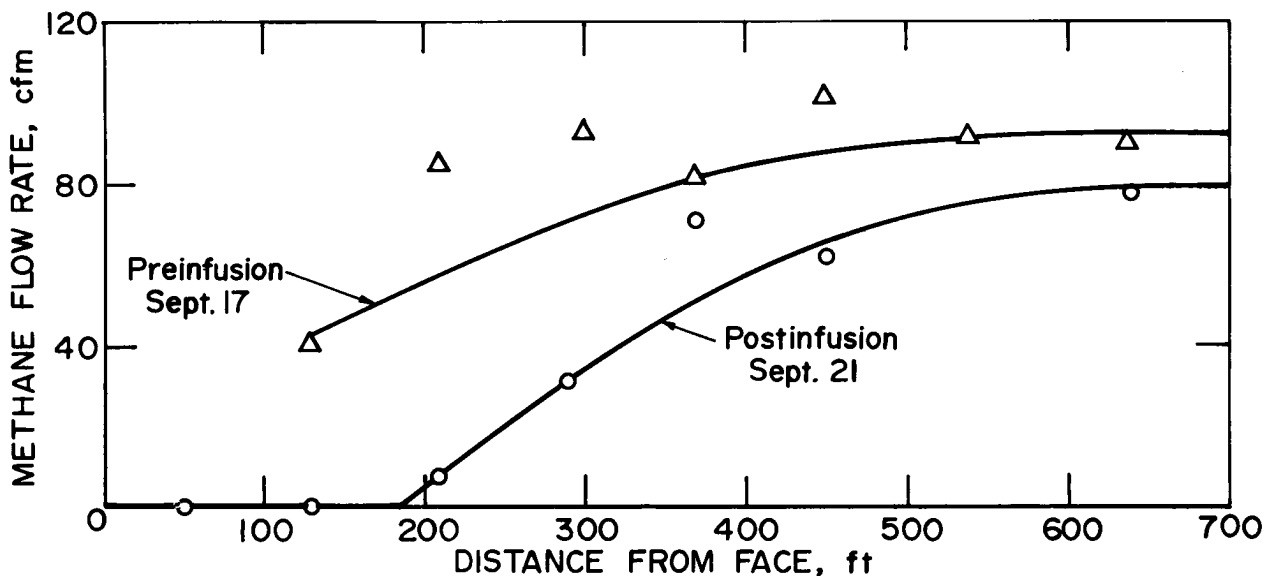


FIGURE 10. - Methane Flow Rates From Face and Rib of Entry 1.

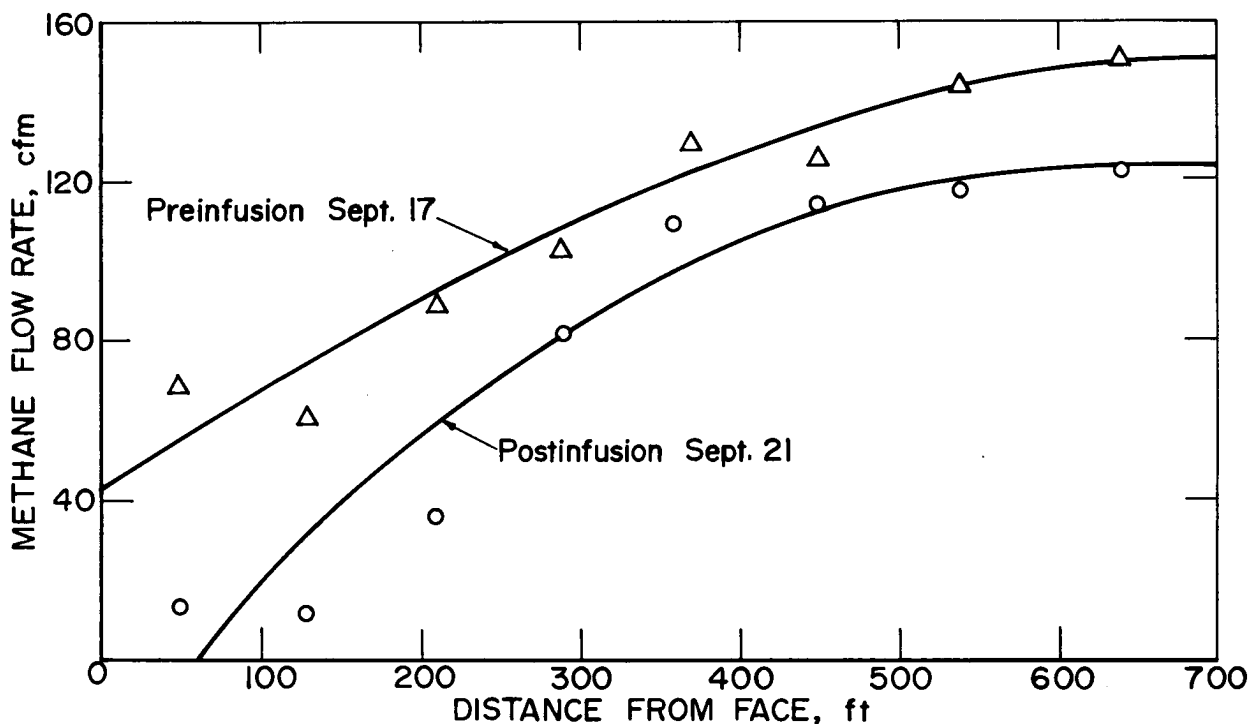


FIGURE 11. - Methane Flow Rates From Face and Rib of Entry 6.

Cervik¹⁶ has noted that methane exists in coalbeds as a compressed gas in the fracture system and an adsorbed gas in the micropore structure of solid

¹⁶Cervik, Joseph. An Investigation of the Behavior and Control of Methane Gas. Min. Cong. J., v. 53, No. 7, July 1967, pp. 52-57.

coal. In an undisturbed coalbed the amount of adsorbed gas is in equilibrium with the gas pressure in the fracture system. For a blocky coal such as that in the Pittsburgh coalbed, the contribution to the total flow of gas due to desorption is expected to be small in comparison to the flow of compressed gas through the fracture system. For highly fractured coal such as that in the Pocahontas No. 3 coalbed in southern Virginia, the contribution to the total flow of methane due to desorption may be appreciable.

For purposes of discussing methane migration, a coalbed consists of the solid coal or matrix and the fractures. The coalbed is waterflooded through the fracture system and can be characterized as a filling of the fracture void volume with water. Water cannot enter the matrix because of the extreme fineness of the pores in the solid coal; these are estimated to be but a few angstrom units in diameter.

Emplacement of a waterbank across the face area of a mine section has been shown to block the flow of gas through fractures. Therefore, methane in the fracture system which would flow normally toward the section (primarily along the butt cleat in this case) is diverted and enters the section outby the face area. Curves a and c (figs. 7 and 8) show that the flow of methane from the face area is not reduced to zero immediately after infusion (September 20). Methane in the adsorbed state is not affected by the water infusion process because its flow is controlled by a methane concentration gradient between the matrix and fracture system. In addition, degradation of coal increases the rate of flow by desorption.¹⁷ Thus, the volume flow of methane immediately after infusion, about 14 and 6 cfm from the left and right sides, respectively, is attributed to desorption. Under normal circumstances the quantity of methane given off by desorption is small in comparison to the contribution of flow through the fracture system.

The effect of drilling holes in the coalbed on the left side of the section and the flow of methane from these holes is apparent from curves a and b (fig. 7). The horizontal holes were drilled on September 18, followed by water infusion of the coalbed on September 19.

Curve a shows a pronounced increase in methane flow during the drilling operation. The methanometer sensing head was approximately 20 feet from the discharging hole, and the peak is probably indicative of incomplete mixing of methane from the hole with the ventilating current. Curve b also shows a rise in volume of methane passing the outby station which is not as pronounced as that at the inby station but does reflect a more thorough mixing of methane and air. (The barometric pressure was relatively steady during this period, rising from about 1,021 to 1,022 mb between noon on September 17 and noon on September 18.)

The effect of drilling holes on the right side of the section has been obscured by experimental difficulties. Curve d (fig. 8) shows a small peak on

¹⁷Airey, E. M. Gas Emission From Broken Coal. An Experimental and Theoretical Investigation. Internat. J. Rock Mech. Min. Sci., v. 5, 1968, pp. 475-494.

September 18, but the inby station (curve c) shows only a sharp decrease; the sensing head of the methanometer was again approximately 20 feet from the hole. There are several possible reasons for this effect. The brattice in entry 6 had excessive air leakage which may have forced the methane flow from the hole to follow a path close to the rib, thus bypassing the methanometer sensing head. In addition, considerable difficulty was experienced in drilling the outside hole in entry 6. Two attempts were made to drill this hole and both terminated in the roof at about the 55-foot depth. During this drilling, water may have partially infused the coalbed surrounding the hole and forced the methane into the entry downstream from the sensing head. Methane peaks did occur at the outby station on September 18.

Analysis of coal samples taken near the boreholes before and after infusion indicates that the total moisture content increased by about 0.7 weight-percent. If we assume the infused water (approximately 6,000 cubic feet) was dispersed uniformly in the coalbed, it would have penetrated a volume of about 850,000 cubic feet of coal. Assuming that the water spreads along the face at twice the rate at which it spreads along the butt cleat, the water infused across the face and into the coal at least 200 feet. This should be adequate to reduce the methane flow for at least a week at present mining rates, although as new surfaces are exposed, the water is driven out of the coal. Further, there is reason to believe that the presence of water facilitates the removal of the coal. Thus, despite an excess of water at the face, more coal was mined on the day after the infusion than on any other day during the investigation.

Dust Production

The beneficial effect of water infusion on dust is not as apparent as it is on methane. Both total and respirable dust were monitored. All dust concentrations were converted to MRE equivalents and the concentrations expressed in mg/m^3 (table 3).

TABLE 3. - Dust survey data

Date	MRE equivalents, mg/m^3								Ventilation in returns, cfm^3		Auxiliary ventila- tion directed down return	Produc- tion day shift, tons	Opera- tion time borer, min
	Boring machine		Loading machine		Left return		Right return						
	R ¹	T ²	R ¹	T ²	R ¹	T ²	R ¹	T ²	Left	Right			
9-15-71	4.9	Lost	1.2	16.6	0.6	13.4	(⁴)	(⁴)	36,000	21,000	Right	485	135
9-16-71	.3	97.1	.8	5.7	.3	12.1	0.1	4.4	38,000	20,000	Left	208	63
9-17-71	1.2	22.7	1.1	21.4	2.0	16.4	1.6	20.1	39,000	20,000	do.	200	46.5
9-20-71	1.6	53.2	.8	15.6	(⁴)	(⁴)	.3	3.6	37,000	17,000	do.	480	108.5
9-21-71	1.6	64.1	1.2	15.5	.3	3.3	.9	16.4	38,000	18,000	Right	289	78
9-22-71	1.9	25.4	.9	9.2	.9	3.2	2.2	22.2	37,000	20,000	do.	116	40.5
9-23-71	2.2	48.4	.6	4.9	1.2	8.6	(⁴)	(⁴)	38,000	20,000	do.	239	57

¹Respirable dust.

²Total dust.

³Airflow taken 600 feet outby the face.

⁴High concentration of rock dust voided the sample.

In an attempt to eliminate the effect of variable coal production during dust monitoring, dust concentrations were divided by tonnage of coal produced. Figures 12 and 13 are histograms of the total and respirable dust concentrations per ton of coal mined during the dust sampling cycle; they are based on data from the left and right return airways.

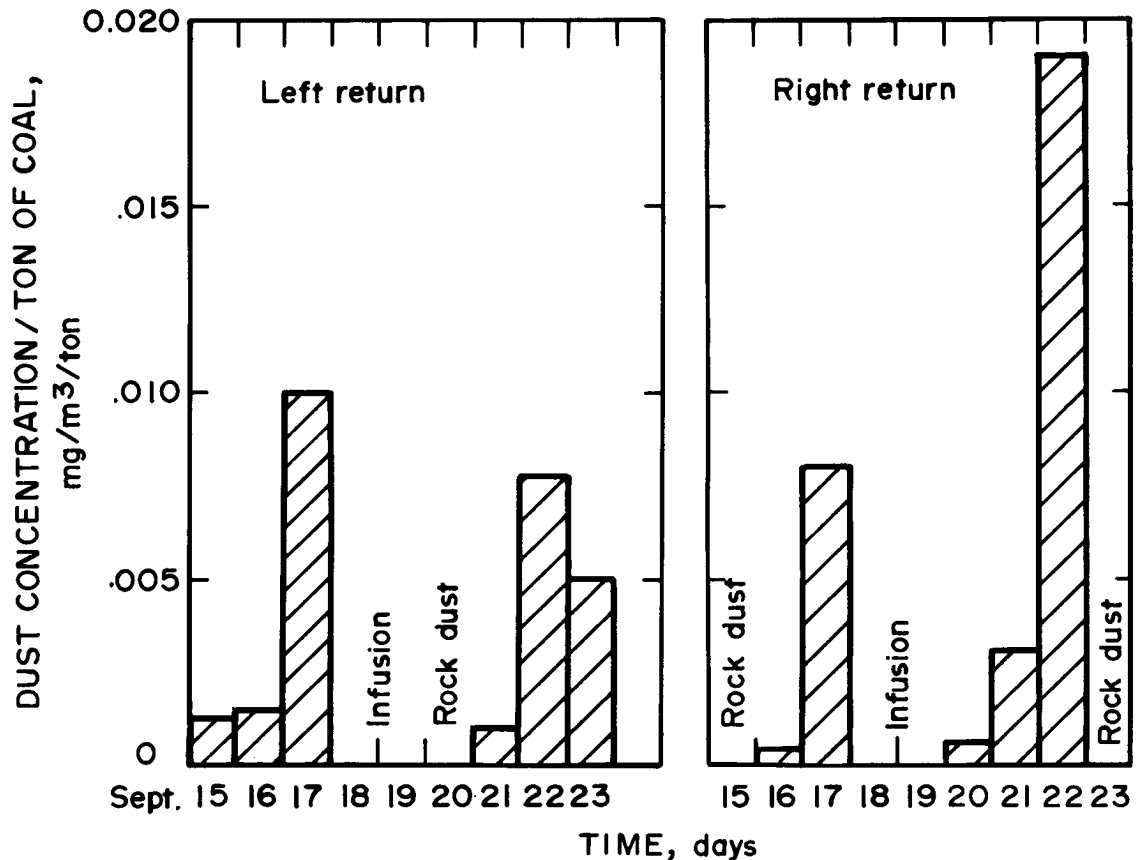


FIGURE 12. - Respirable Dust Histograms.

The dust concentrations in both returns were unusually high on September 17 and 22. On September 17, entry 1 was being advanced and the auxiliary ventilation fan was exhausting within approximately 50 feet of the dust samplers in the return. On the right side of the section, entries 5 and 6 were rock dusted and the air through these entries was exhausted down the right return (entry 6). The dust samples in the right return were therefore influenced by rock dusting.

On September 22, entry 6 was being advanced and the auxiliary ventilating fan was exhausting within 50 feet of the dust samplers. This condition caused unusually high dust concentrations at the samplers, resulting in an abnormal sample; this entry also was rock dusted.

No histograms are given of the dust samples from the miner and loader locations. The daily concentrations of these samples varied too much to permit a proper analysis. They were influenced by many factors, such as placement of the auxiliary exhaust tubing. When the tubing was run along the left side of the miner, most of the dust produced by the borer was drawn away from the samplers on the right side of the miner. At times, the auxiliary tubing was run along the right side of the miner. In this situation much of the dust produced by the miner was sampled.

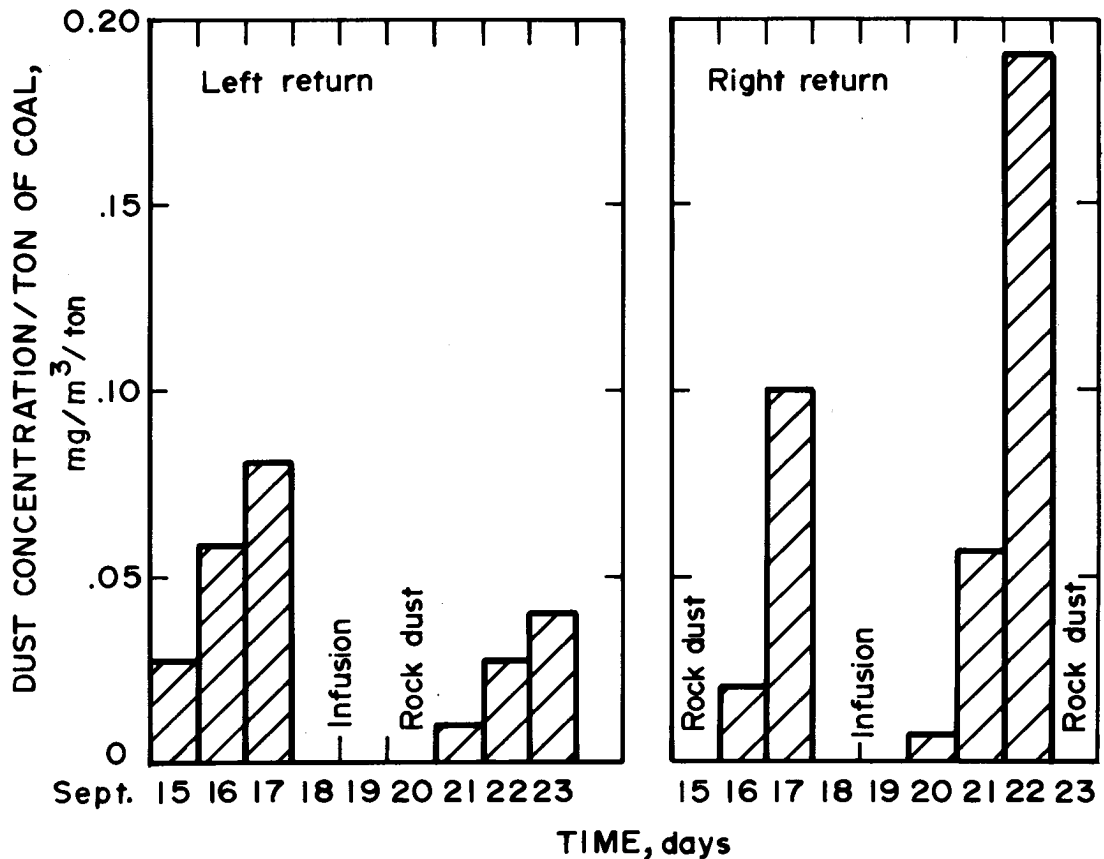


FIGURE 13. - Total Dust Histograms.

Another factor influencing these samples was the practice of rock dusting by hand. When mining operations were temporarily halted, the machine operators would often rock dust in the area being mined. Thus, some of the filters collected airborne rock dust.

Rock dust contamination of some samples, the wide variation of measured concentrations before and after infusion, and the small number of measurements make interpretation of the data difficult. However, there is an indication that water infusion does suppress total dust more than it suppresses respirable dust. Figures 12 and 13 show that the dust concentrations were relatively low on the two day shifts following infusion. On these two day shifts, water infusion of the bed was continued while mining was in progress, but discontinued the following day. The low dust levels may be attributed to infusion of the bed during mining. Moreover, the production on these two shifts after infusion was higher than the average for that section.

CONCLUSIONS

Methane was diverted from an active face in the Pittsburgh coalbed by infusing the coal with water. Infusion holes 55 to 127 feet and 100 to 300 feet apart were effective in this respect for at least 5 days. The infused water also seems to have reduced the total and respirable dust for at least

1 day. The procedures described here can be incorporated into the mining cycle if the drill crews operate during idle shifts or over a weekend, making it possible to increase the level of safety materially with no loss in face productivity. Additional work is required to determine the effect of water infusion on the rate at which coal is mined and dust is produced, and to establish optimum hole depths and water infusion levels.