RI 7658

Bureau of Mines Report of Investigations/1972

Methane Emission in Coal Mines: Effects of Oil and Gas Wells

UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 7658

Methane Emission in Coal Mines: Effects of Oil and Gas Wells

By M. G. Zabetakis, T. D. Moore, Jr., A. E. Nagel, and J. E. Carpetta
Pittsburgh Mining and Safety Research Center, Pittsburgh, Pa.

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

BUREAU OF MINES
Elburt F. Osborn, Director

CONTENTS

ILLUSTRATIONS

METHANE EMISSION IN COAL MINES: EFFECTS OF OIL AND GAS WELLS

by

M. G. Zabetakis,[1] T. D. Moore, Jr.,[2] A. E. Nagel,[3] and J. E. Carpetta[4]

ABSTRACT

The method of moving averages was found useful in assessing the nature of methane emission in coal mines. Emission rates were influenced markedly by the presence of abandoned oil and gas wells in the vicinity of the mine. Such wells appeared to increase the flow rate of methane into the mine by a factor of 2 to 30 in an active mine in the Pittsburgh coal seam.

INTRODUCTION

A recent detailed study by the Bureau of Mines of the effects of water infusion on methane flow in a coal mine revealed that while the rate of emission appeared to decrease with distance from the face, actual measured concentrations of methane fluctuated markedly about the average.[5] Because such measurements are required when assessing the effectiveness of a particular methane control procedure, a complete methane survey was made during a recent idle period in the Federal No. 2 mine. Measurements were made of the methane concentration, air flow rate, and pressure at a number of points within the mine. An attempt then was made to correlate high emission rates with the characteristics of the coalbed and the location of oil and gas wells in the vicinity of the mine.

The Bureau has been concerned, since its inception, with the hazards associated with oil and gas wells that pass through coalbeds. A study was made some years ago of the explosion hazards and the waste of coal associated with such wells.[6] Subsequently, a summary was prepared of the precautions to

---

[1] Research supervisor, Methane Control and Ventilation.
[2] Mining engineer.
[3] Mechanical engineer.
[4] Mining engineering technician.
[5] Cetinbas, Abdurrahman, R. P. Vinson, Joseph Cervik, and M. G. Zabetakis. Methane and Dust Control by Water Infusion. Pittsburgh Coalbed (Fairview, W. Va.). BuMines Rept. of Inv. 7640, 1972, 17 pp.
[6] Rice, George S., O. P. Hood, and others. Oil and Gas Wells Through Workable Coalbeds: Papers and Discussions. BuMines Bull. 65, 1913, 101 pp.

be taken when drilling oil or gas wells through workable beds.[7] More recently, a study was made of the hazards of storing natural gas underground in coal-mining areas.[8]

ACKNOWLEDGMENTS

The cooperation of the Eastern Associated Coal Corp., Pittsburgh, Pa., during this study is greatly appreciated. The authors particularly want to thank William Laird, vice president--engineering, William Hylton, superintendent, and James Hayhurst, mine foreman, Federal No. 2 mine, for assistance in planning the work described in this report. Joseph Pasini III, research supervisor, Petroleum and Natural Gas Research, Morgantown Energy Research Center, Bureau of Mines, Morgantown, W. Va., assisted in evaluating the conditions of the oil and gas wells considered in the report.

TEST SITE

The Eastern Associated Coal Corp. Federal No. 2 mine (fig. 1) operates in the Pittsburgh coalbed near Fairview, W. Va. The coalbed is 9 feet thick; 7 feet is mined at present, with the remainder left to control roof and bottom stresses. The overburden thickness ranges from about 734 to 842 feet.

In this area, the Pittsburgh coalbed has a well-developed cleat system; the face (main) cleat trends N 70° W and the butt cleat N 20° E. The permeability of the coalbed is primarily due to the cleat system.

During this study (November 3-5, 1971), the mine was idle so that methane concentrations and ventilation rates could be readily measured throughout the mine. The mine's ventilation system was found to exhaust about 675,000 cfm of mine air containing 0.70 volume-percent methane during this period. These values, as well as those obtained at various other points in the mine, are summarized in figure 2. The intake air courses are labeled with air flow rates, and the returns with air and methane flow rates and methane concentrations.

INSTRUMENTATION

A complete set of measurements (velocity, pressure, temperature, cross-sectional area, and methane concentration) was obtained at selected locations throughout the mine. Calibrated, portable instruments were used in each case; Taylor and Davis[9] anemometers were used for the velocity measurements, Wallace and Tiernan altimeters for pressure, mercury in glass wet and dry bulb thermometers for temperature and humidity, cloth tape measures for length, and

---

[7] Herbert, C. A. Notes on Precautions To Be Taken When Drilling Oil or Gas Wells Through Workable Coalbeds or Through Mine Workings. BuMines Inf. Circ. 6195, 1929, 8 pp.

[8] Wheeler, Henry P., Jr., and William E. Eckard. Underground Storage of Natural Gas in Coal-Mining Areas. BuMines Inf. Circ. 7654, 1952, 11 pp.

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

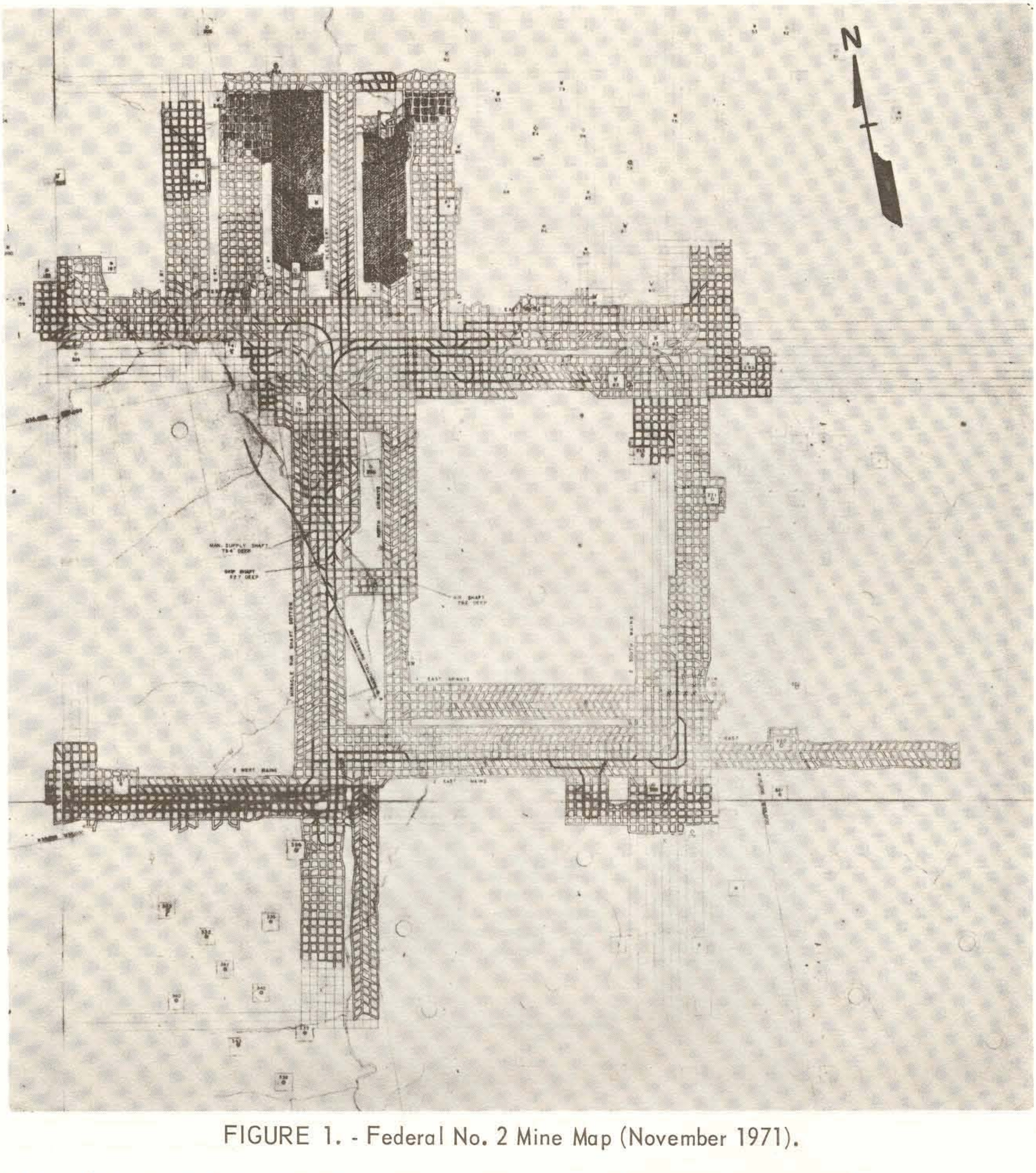

FIGURE 1. - Federal No. 2 Mine Map (November 1971).

Riken detectors for methane concentration. In addition, gas samples were taken for subsequent analysis on a model C-40 Instruments Inc. gas chromatograph equipped with a flame ionization detector. Methane concentrations also were measured with Riken detectors in the returns at 100-foot intervals. A total of 16 men (six crews) was utilized to obtain these readings; a mining engineer was in charge of each crew.

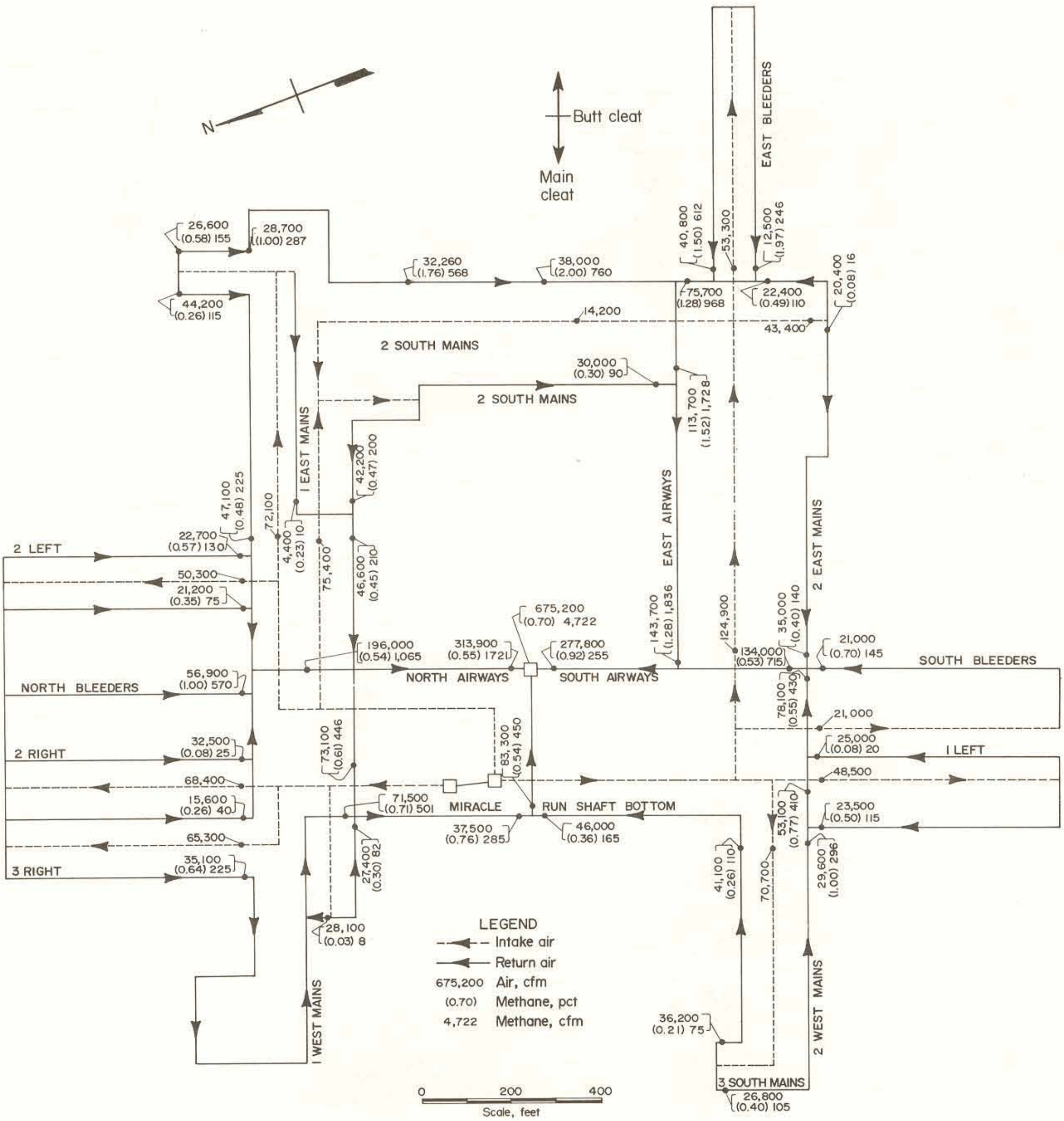

FIGURE 2. - Simplified Ventilation Scheme, Federal No. 2 Mine. Methane concentrations in volume-percent appear in parentheses followed by the methane flow rates in cubic feet per minute.

RESULTS AND DISCUSSION

The measurements obtained by the underground crews were adjusted, where necessary, against laboratory calibration curves and subsequently displayed on a large mine map. These measurements were used to obtain air and methane

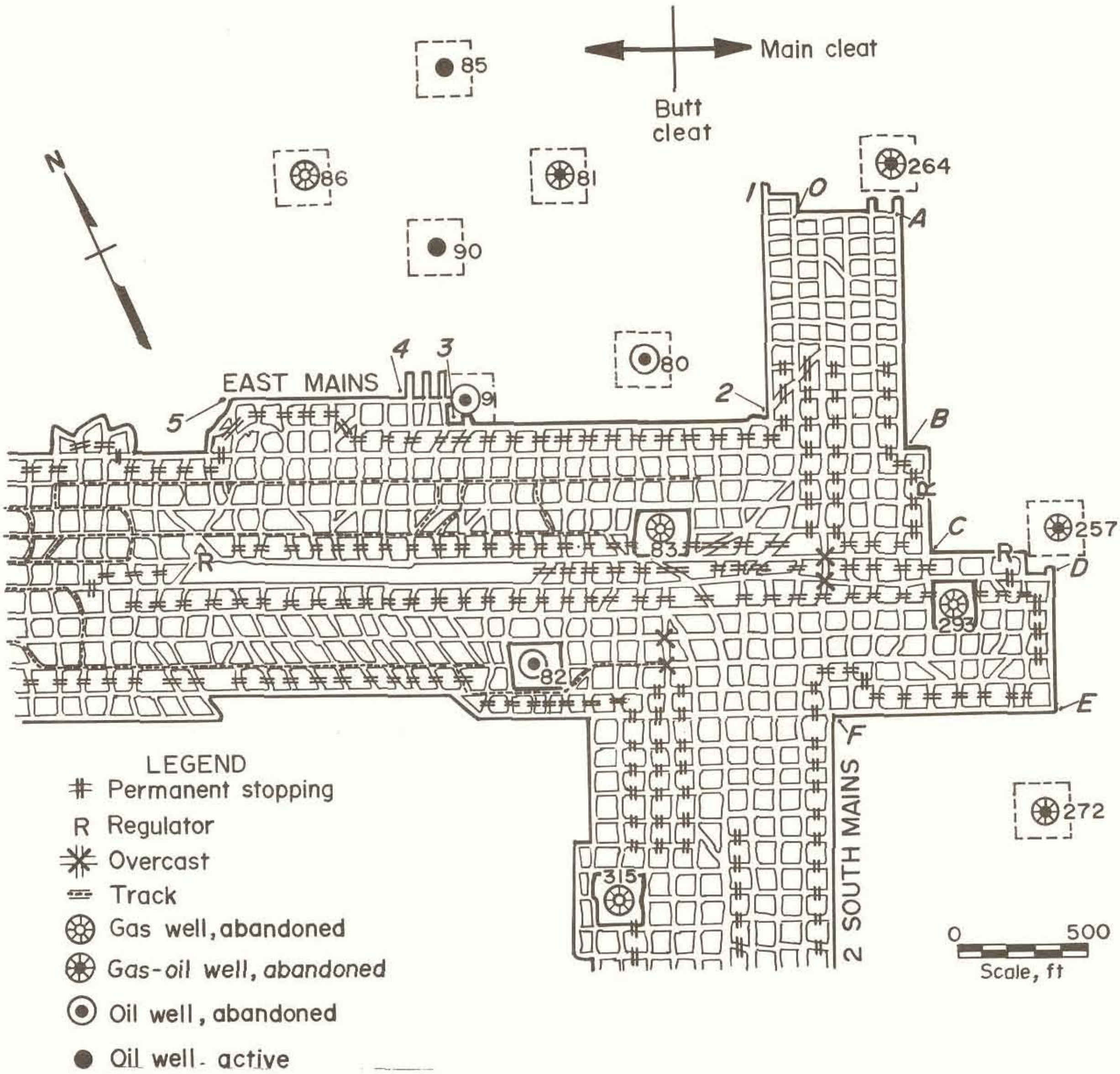

FIGURE 3. - Enlarged View of Northeast Quadrant.

quantity balances. Methane flow rates were computed from the measured methane concentrations and interpolated air flow rates. A summary of these data is given in a simplified schematic presented in figure 2. For example, in the northeast quadrant, 72,100 cfm of (intake) air is split at a face area with 44,200 cfm passing to the left, 26,600 passing to the right, and the balance returning along the 1 East Mains. The left split picks up 0.26 percent and the right split 0.58 percent methane at the face to yield methane flow rates of 115 and 155 cfm, respectively. Additional methane is picked up as the air passes along each return. As noted in earlier studies in the Pittsburgh coalbed, the methane emission rate is generally higher in entries adjacent to virgin coal than in those near old workings; similarly, rates usually are higher when a return intersects the main or face cleat rather than the butt cleat at right angles.

In addition, as mixing is not instantaneous (entry widths are approximately 15 feet), and emission rates are not uniform along any passageway, methane concentrations fluctuate markedly along any active entry.[10] An attempt was made to analyze these fluctuations by using the method of moving averages. This statistical technique, ordinarily used in time series analysis to determine trends in business cycles, appears to work well here. In brief, all methane flow rates were recorded in sequence at 100-foot intervals along each entry. Averages then were computed for rates 1 through 5, 2 through 6, 3 through 7, and so forth. These then were assigned to the third, fourth, fifth, and succeeding points. For example, if we again consider the area in the northeast quadrant (fig. 3), we find the methane flow rate (Q) rises slowly in passing from point 0 toward point 1 and then more quickly as point 1 is passed; the flow rate levels off as point 2 is passed, and then rises again as we approach point 3. The smoothed (measured) data are presented in the lower half of figure 4. The first recorded value is the "raw" point obtained at 0, the next is the average value obtained from the first five points, and so forth. (Similar data are presented by Cetinbas and coworkers.[11]) The slope of this (measured) curve is given in the upper half of this same figure. This represents the methane flow rate per foot of entry or face area (dQ/dX). Interestingly, it exhibits two very pronounced peaks. Comparison of these peaks with the data presented in figure 3 indicates the first is probably due to gas bleeding along the main cleat from the abandoned gas-oil well 81 and perhaps oil well 80; the second peak corresponds very closely to the position of abandoned oil well 91. A similar trend was found in proceeding from 0 to A, B, . . . (fig. 5). The first peak corresponds to abandoned gas-oil well 264, the next to well 257, and the third to well 272. Again, the

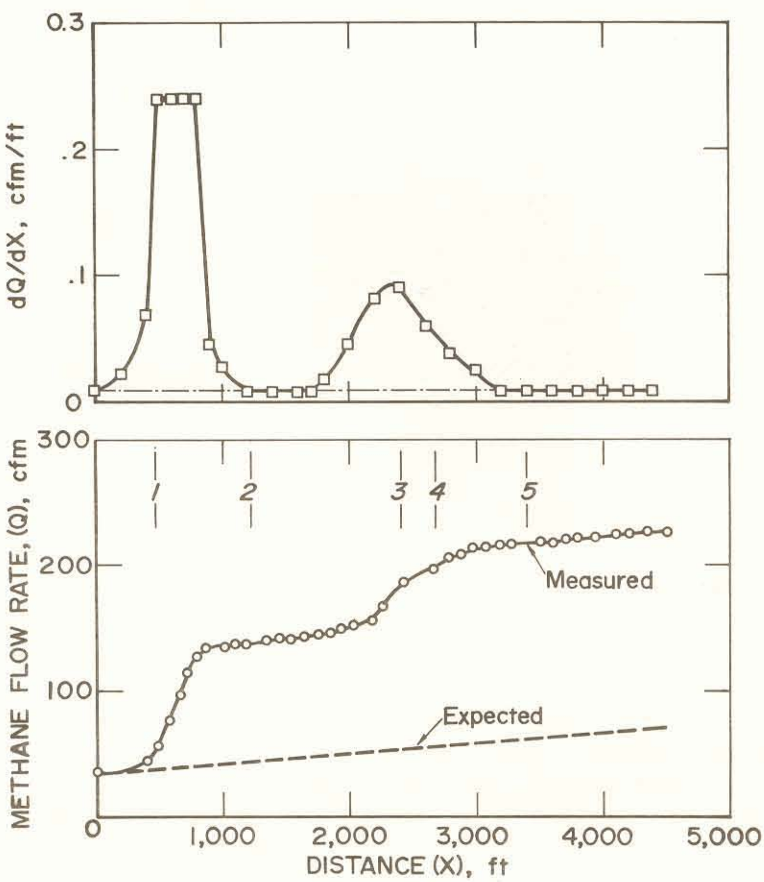

FIGURE 4. - Methane Flow Rate, Left Air Course, Northeast Quadrant.

[10]Work cited in footnote 5.
[11]Work cited in footnote 5.

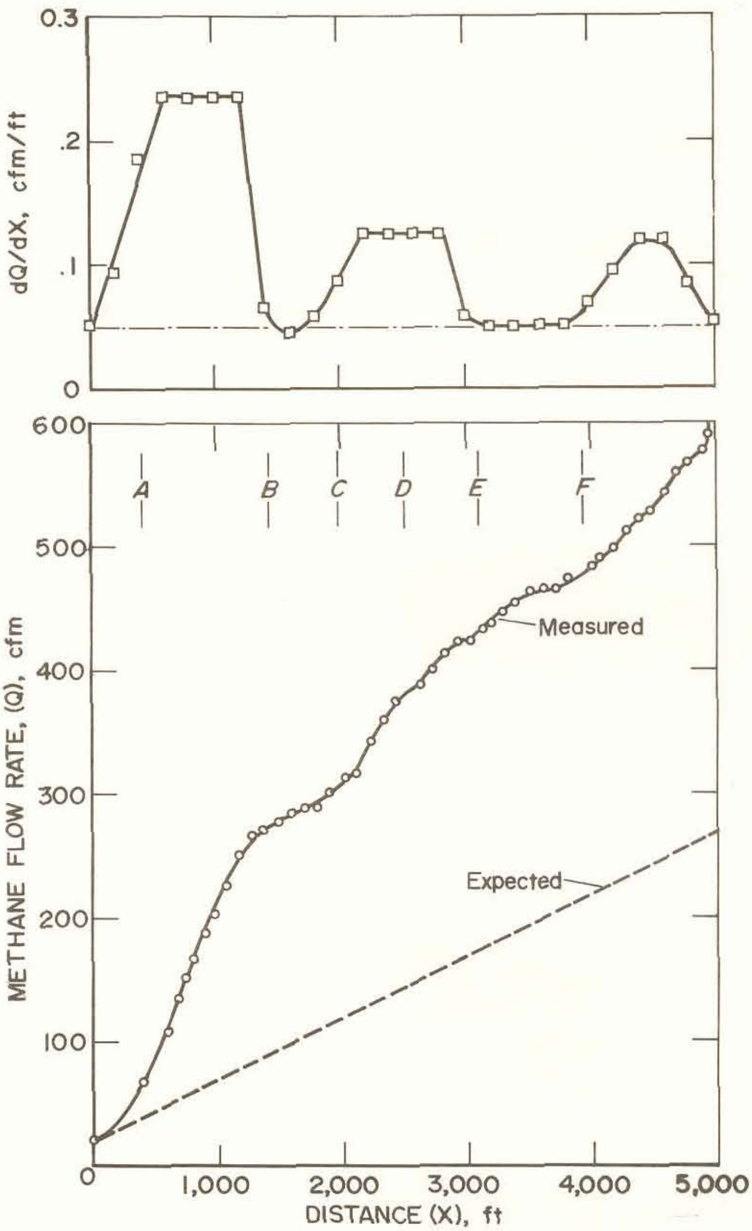

FIGURE 5. - Methane Flow Rate, Right Air Course, Northeast Quadrant.

methane appears to pass more readily along the main cleat even though a shorter path would be available if it were to pass through the butt cleat.

The effects of these wells can be determined by subtracting the peak contributions from the total emission rate of methane. This has been done in each case by use of the broken curve in figures 4 and 5 to compute the "expected" flow rates (the average emission rate per foot of entry is about 0.008 cfm/ft for paths 0, 1, 2, 3, 4, and 5, and 0.05 cfm/ft for paths 0, A, B, C, D, E, and F). Thus, while the measured methane flow rate along the left return is 225 cfm at 4,500 feet from point 0, the expected flow rate is 70 cfm. On this basis, the contribution from the wells is 155 cfm. The corresponding figures at approximately 5,000 feet from 0 along the right return are 600 to 275 cfm; the contribution from the wells in this case is 325 cfm, or 58 percent of the total. These methane flow rates (155 and 325 cfm) require approximately 68,500 cfm of air to attain the exhaust level found here (0.7 volume-percent methane). Accordingly, the power required to supply this amount of air across the 4.8-inch water gage pressure drop encountered in this mine is[12]

$$\text{Air hp} = \frac{Hq}{6,350} = \frac{4.8 \times 68,500}{6,350} = 51.8$$

[12]Kingery, D. S. Introduction to Mine Ventilation Principles and Practices. BuMines Bull. 589, 1960, p. 27.

where H = pressure loss in inches of water

and q = air flow rate in cfm

This represents an expenditure of approximately $380 per month ($4,560 per year) at a modest $0.01 per kilowatt-hour rate. Further, the loss in coal (approximately 10,000 tons per well), as well as the disruption of a uniform mining plan and the increase in resistance of the air course that results when a barrier is left in place around a well, raises a question regarding the advisability of continuing present practices. Work at the Bureau's Morgantown Energy Research Center has shown that a well can be safely sealed below the coal and mined through in certain instances. Several wells (for example, 91, 257, and 264) are presently being investigated to determine what effect cleaning out and sealing to the base of the coal will have on the methane concentration in the section of the mine.

The "expected" curves (figs. 4 and 5) were constructed by adding to the methane flow rate at the origin (point 0), the steady-state flow rate along the entry. This is quite evident in figure 4, where the "expected" curve is parallel to the "measured" curve near the origin, between 1,100 and 1,700 feet, and at distances beyond about 3,000 feet. Surprisingly, except for the effects of the wells, the steady-state flow rate along each rib appears to be fairly constant. If we assume that the ribs were formed at a uniform rate, then the data presented in the upper graphs of figures 4 and 5 can be converted to plots of methane flow rate per foot of entry against time. Stewart[13] has shown that the expected solution in this case takes the form

$$\dot{q} = C_0 \sqrt{\frac{D}{\pi t}}$$

where C_0 is the initial gas concentration in the coal, D is the diffusivity, t is the time, and $\dot{q}$ is the methane flow per unit area of rib. Thus $\dot{q}$ would be expected to decrease with time for constant C_0 and D. By analogy, dQ/dX would also decrease with distance under these conditions. Actually, dQ/dX appears to be constant if we subtract the effects of the oil and gas wells so that D (and therefore the permeability) must increase with time. Stewart[14] ascribes this increase to a change in stress and the concomitant "relaxation of cleat and bedding joints." However, if we consider the moisture removed by the ventilation air (on occasion, in excess of 50,000 gallons per day in this mine), we can only conclude that such an increase also must be related to a decrease in the water content of the coal.

[13] Stewart, Ian McC. Diffusional Analysis of Seam Gas Emission in Coal Mines. Canadian Min. and Met. Bull., April 1971, pp. 62-70.
[14] Work cited in footnote 13.

CONCLUSIONS

The method of moving averages appears to be a useful technique in assessing the nature and origin of methane emission into a coal mine. Using this technique, an analysis of the flow of methane into the Federal No. 2 mine indicates that considerable quantities of this combustible can be ascribed to the presence of abandoned gas and oil wells in the vicinity of the mine. The cost of removing this gas as well as that associated with the loss of coal in mining around a well suggests the use of a recently developed Bureau of Mines technique to seal and mine through such wells.

☆ U.S. GPO: 1973—710-618/21

INT.-BU.OF MINES,PGH.,PA. 17674