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METHANE CONTROL PROGRAM

SORPTION INVESTIGATIONS OF METHANE ON COAL

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ILLUSTRATIONS

SORPTION INVESTIGATIONS OF METHANE ON COAL

by

J. H. Perkins[1] and Joseph Cervik[2]

ABSTRACT

The Bureau of Mines has conducted desorption work on fine coal particles at near atmospheric pressure. An apparatus has been developed that uses a capacitance manometer to measure desorption of methane from coal particles up to 2 inches in diameter and pressures up to 1,000 psi. This will make it possible to duplicate the desorption process as it occurs in its natural underground environment.

INTRODUCTION

A comprehensive methane control research program is being conducted by the Bureau of Mines to establish the geological structural controls that govern the migration and retention of methane in coalbeds; determine the physical properties of methane and of the coal and other strata with which methane is associated; devise methods by which methane may be removed from, or controlled in, coalbeds prior to and during coal extraction; develop mechanical equipment and instrumentation needed to control methane; and conduct field trials of the methane control techniques developed. This is one of a series of reports on specific aspects of the program.

High methane concentrations that result during mining are, in part, due to the desorption of methane from coal. Methane emission due to desorption can create serious safety hazards both inside and outside coal mines. It has been observed that a lump of coal, after being mined, will continue to liberate methane for months. This "slow bleeding" or desorption is the result of methane gas that is stored in the micropore structure of the coal. This method of transport has been shown to be governed by Fick's law of diffusion:[3]

$$q' = -DA\frac{dc}{dl},$$

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

where

q' = volume flow rate;

D = diffusion coefficient;

A = cross-sectional area;

c = concentration of gas in solid coal;

l = length.

Consequently, the rate of desorption of gas from coal depends upon equilibrated pressure, coal particle size, and diffusivity coefficient.

Several attempts to measure the rate of desorption have been made. Hofer and others[4] did work with fine coal samples near atmospheric pressure. They concluded that in terms of the fractional approach to equilibrium, the law governing the rate of sorption is nearly independent of pressure, and that the adsorption and desorption curves were identical. This work also showed that the rate of adsorption increases eightfold as the particle size decreases from 6 to 8 to 270 to 325 mesh per inch. However, there have been measurements of gas bed pressures higher than 550 psi, and it is well known that mining machines degrade coal in sizes from very fine dust to particles several inches in diameter. Therefore, there exists a need to work on coals at higher pressures and larger particle sizes.[5]

The Bureau of Mines attempted to work with large sizes of coal, using a flame ionization detector. This device burns a sample of methane gas in an oxygen-hydrogen flame resulting in an ionized methane molecule, and an electrometer measures the change in charge that results from the ionization of the gas. The apparatus is capable of measuring methane in parts per million, but its sensitivity to atmospheric pressure changes makes it impossible to calibrate for flows of methane less than 1 cu cm/min.

An apparatus has been developed that allows samples of coal up to 2 inches in size to be equilibrated at pressures up to 1,000 psi. Desorption curves can be obtained for these samples that simulate any conditions underground. This apparatus makes it possible to correlate the rate and amount of methane desorbed from coal, with the equilibrated bed pressure of the coal and the type of mining machinery used.

DESORPTION PHENOMENON IN COAL

As mining progresses, more coal becomes exposed and, thus, more gas can be emitted into the mine by the desorption process.

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[4]Hofer, L.J.E., James Bayer, and Robert A. Anderson. Rates of Adsorption of Methane on Pocahontas and Pittsburgh Seam Coals. BuMines Rept. of Inv. 6750, 1966, 13 pp.

[5]Work cited in footnote 3.

Fick's law illustrates that when a piece of coal is placed in an atmosphere of methane, adsorption of the methane by the coal will take place. The total amount of the methane adsorbed is a function of the environmental pressure, temperature, and time. The time for this adsorption to reach equilibrium is a function of the size and shape of the coal particle. The reverse of this process, desorption, takes place when the environmental pressure is reduced. The amount of gas desorbed and rate of desorption are governed by the same factors that control adsorption. It has been shown that although a small pile of finely powdered coal (275 to 325 mesh) and a pile of 1/4-inch by 0 coal will adsorb the same quantity of gas at 1 atmosphere pressure when the pressure is reduced, the fine coal releases its gas in 1 hour; the 1/4-inch coal releases its gas in 30 days. For coal particles of the order of 1/2-inch, with no cracks or other defects, the desorption process may take from 6 months to 1 year.[6]

Experiments have shown that when a mining machine is operating there is an increase in methane emission. Ignoring Darcy flow, two factors contribute to this increase:

1. The miner is degrading coal into particles ranging from very fine dust to large pieces. This degradation accelerates the release of gas from coal by the desorption process.

2. Coal about 150 feet in advance of the face is desorbing gas because of the existence of a draining radius.[7] This clearly demonstrates the need for correlating desorption rates of methane with gas bed pressures and particle size.

DISCUSSION OF SORPTION APPARATUS

The apparatus developed by the Bureau of Mines (fig. 1) is capable of measuring desorption rates for pressures from 1,000 psi to vacuum, and for coal particles up to 2 inches in diameter; coal blocks up to 18 inches in diameter also can be studied at pressures up to 600 psi. These measurements are made by placing the coal sample in a pressure vessel and pressurizing the vessel with methane. When the desorption process has ended and equilibrium has been reached, the pressure surrounding the coal particle is reduced to simulate the condition the coal would experience in a mine. The pressure in the vessel will begin to increase owing to the desorption of methane from the coal. This buildup in pressure is monitored by a capacitance manometer capable of sensing pressure changes of 0.01 psi. The capacitance manometer controls a valve that allows the excess gas to be bled into a second vessel, where the quantity of gas desorbed can be calculated by using pressure-volume relationships.

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[6]Work cited in footnote 3.
[7]Work cited in footnote 3.

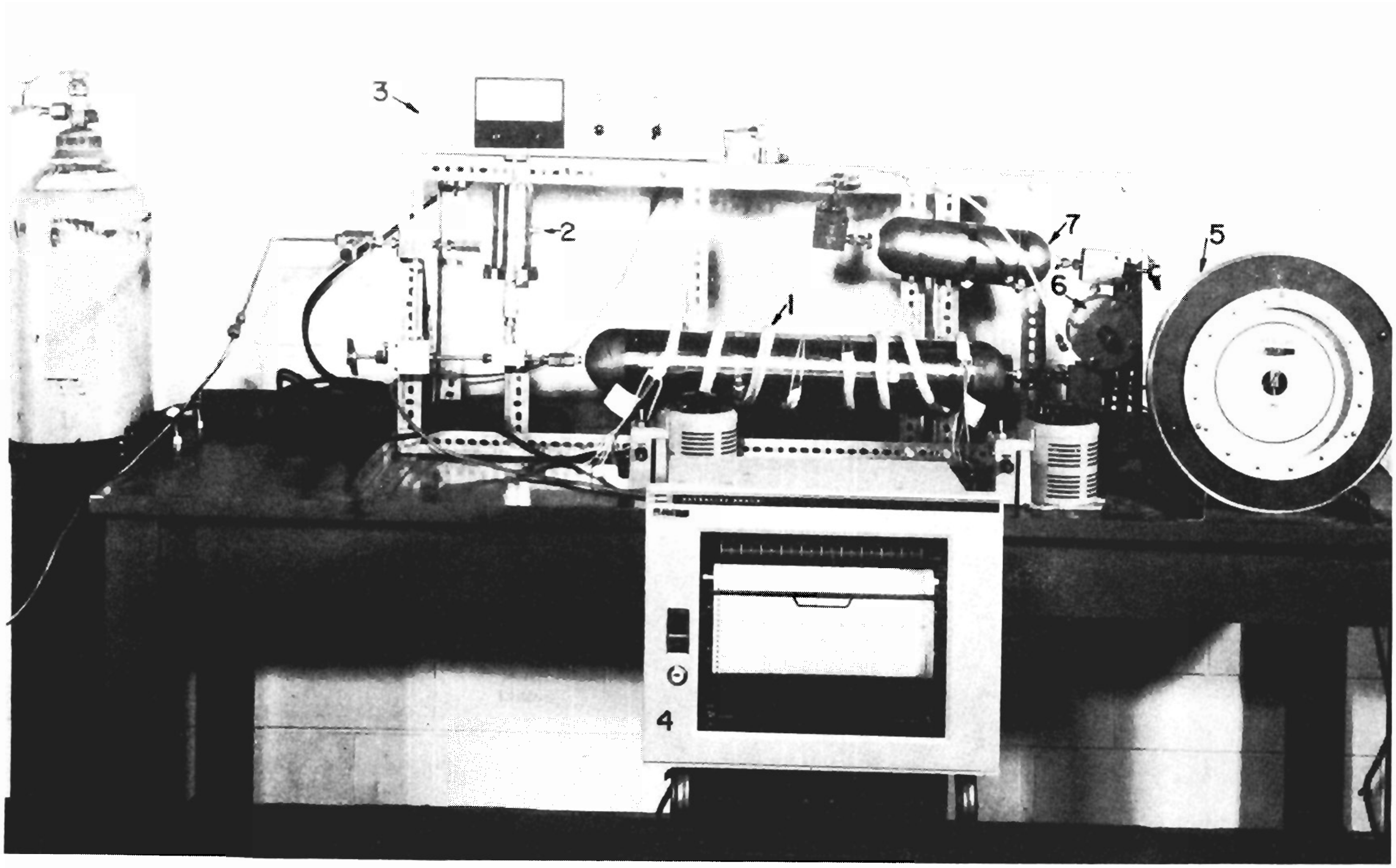

FIGURE 1. - Sorption Apparatus. 1. Pressure vessel containing the coal sample; 2. capacitance manometer head which senses pressure changes in pressure vessel No. 1; 3. capacitance bridge network; 4. recorder for recording pressure buildup in pressure vessel No. 1 due to desorption; 5. pressure meter for reading pressures in pressure vessel No. 1 (has been replaced by a pressure transducer); 6. air valve actuated by the capacitance manometer which allows excess pressure to bleed from pressure vessel No. 1; 7. reservoir for collecting the desorbed gas.

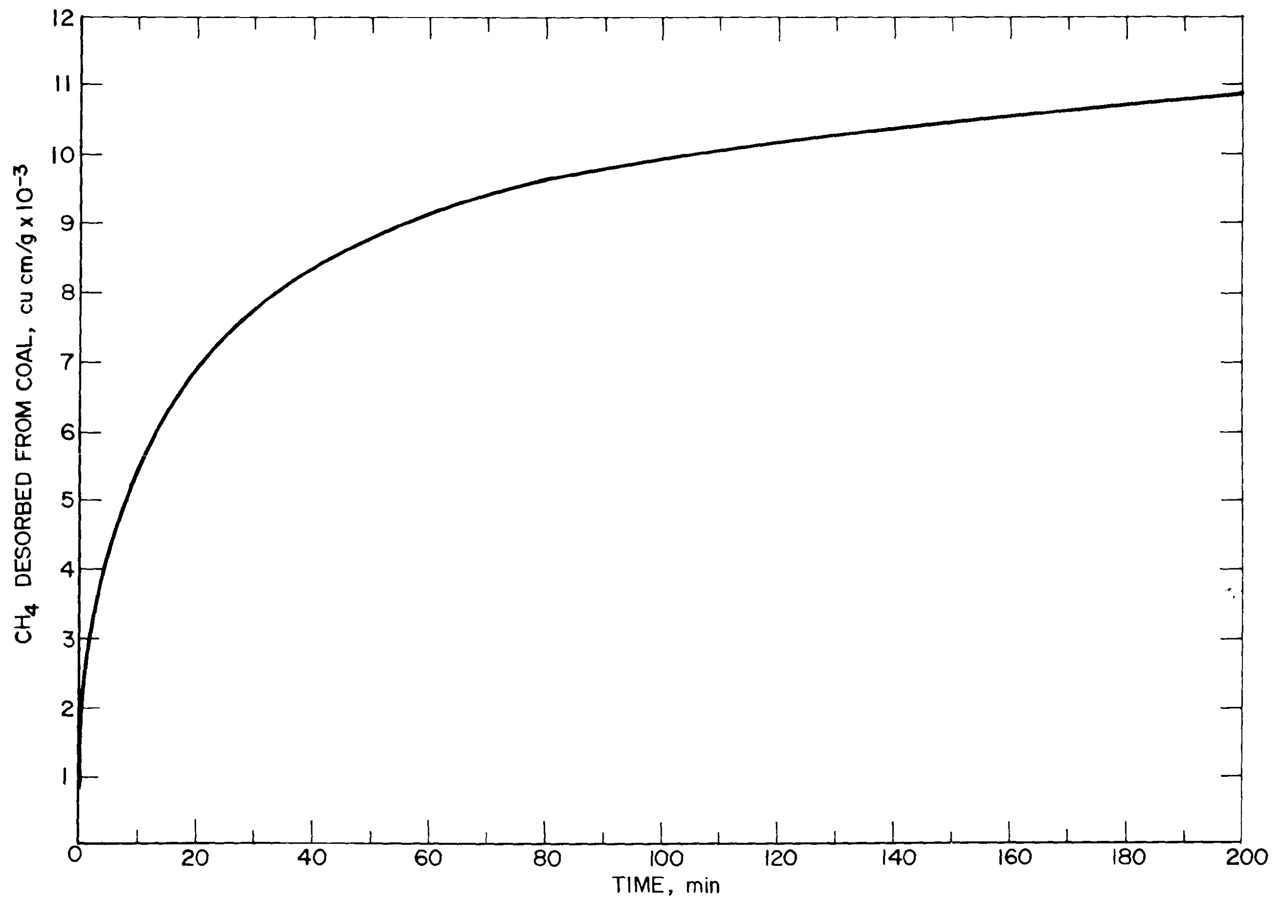

FIGURE 2. - Desorption Curve for Pittsburgh Coal, 180 to 200 Mesh.

With this apparatus, it is possible to correlate particle size to the rate of desorption. It should be helpful in predicting the practicability of various methods of degasification such as sinking methane drainage boreholes into the coalbed. This apparatus will be able to correlate the amount of gas desorbed with a drop in bed pressure. Since a borehole will produce a draining radius, a drop in bed pressure in the area of the borehole can be expected. Provided there are no clay veins or other obstructions in the coalbed, estimates of the volume of desorbed gas, based on the expected pressure drop around the boreholes, can then be made. Assuming similar conditions at the active face of a coal mine, this apparatus will yield information that will aid in predicting the amount of gas moving into the mine through the face.

Figure 2 shows a desorption curve obtained from a 852-gram, 180- to 200-mesh, sample of Pittsburgh-bed coal. This figure shows the desorption curve obtained from equilibrating the sample at 270.9 psi, and then reducing the pressure to 173 psi. It should be noted that 90 percent of the methane was emitted within the first 100 minutes, but that some desorption is still taking place at 200 minutes. The gas desorbed at time zero is the gas that was given off when the pressure was initially reduced.

CONCLUSIONS

The apparatus described is the latest of the Bureau's efforts to develop a system to measure desorption rates of methane from large coal samples at pressures up to 1,000 psi. This apparatus will now be used to measure the rates of desorption from many different samples of coal and attempt to correlate the previously mentioned parameters.

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