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The Direct Method of Determining Methane Content of Coalbeds for Ventilation Design

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by F. N. Kissell, C. M. McCulloch, and C. H. Elder
Pittsburgh Mining and Safety Research Center, Pittsburgh, Pa.

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THE DIRECT METHOD OF DETERMINING METHANE CONTENT OF COALBEDS FOR VENTILATION DESIGN

by

F. N. Kissell,[1] C. M. McCulloch,[2] and C. H. Elder[2]

ABSTRACT

The applicability of the "direct method" for determining the methane content of virgin coalbeds was tested. Preliminary results indicate that the direct method, when applied to exploration cores, can be successfully used to estimate coalbed gas content and also approximately predict the total gas emission from a prospective mine located in the coalbed at the exploration site.

INTRODUCTION

One of the unknowns faced by a mine operator planning a new coal mine is the amount of methane that will be released. It is not uncommon to find that a mine is much gassier than was anticipated, necessitating additional ventilation which may increase the cost substantially, especially if additional air shafts must be dug.

One way to estimate mine methane output is to use the correlation established by M. C. Irani (3).[3] Irani has shown that, for a given coalbed, the methane output of a mine correlated with a factor [depth X production]. However, these correlations are only presented for four major coalbeds (Pittsburgh, Pocahontas No. 3, Illinois 5 and 6), and they are not much help in estimating methane emission from other coals.

Possibly the best technique for measuring the gas in coal is the so-called direct method, which has been used in France for some years (1). The direct method has not been applied to virgin coalbeds but has only been used to estimate the gas in coal just ahead of a working face. Typically, a horizontal hole is drilled into the coalbed from a working face and the cuttings from the hole are collected and enclosed in a sealed container. The volume of gas emitted from the container is then measured. Later, the coal is taken from the container and crushed to a fine powder (at least 200 mesh), releasing the remainder of the gas.

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[1]Physical research scientist.
[2]Geologist.
[3]Underlined numbers in parentheses refer to items in the list of references.

Most of the gas is accounted for in this way; however, the gas which escaped the coal cuttings as they emerged from the hole must be accounted for. Five minutes may elapse between the instant the coal is cut by the drill and the time it is enclosed in the sample container, and in this interval a quarter of the gas may be lost, depending on the size of the cuttings. This "lost" gas is accounted for in the following way: It is known that the volume of gas emitted from a fine coal particle is proportional to the square roof of time, $V \propto \sqrt{\theta}$, where V is the volume emitted and θ is the time measured from the instant the emission began (6). From this, a simple equation can be derived which relates the "lost" gas to part of the gas given off from the coal while in the sample container (1).

We reasoned that if the direct method could be applied to the coal cores extracted from vertical boreholes, then the amount of methane in a virgin coalbed could be readily estimated. Routine core drilling ahead of mining is standard practice to measure coalbed thickness and assess the quality of the coal, and it would be a simple matter to add a methane test.

The usefulness of the direct method depends on accurately estimating the lost gas, which in turn depends on the accuracy of $V \propto \sqrt{\theta}$. This proportionality holds for fine coal (60 mesh and smaller) if θ is not too large. This is why the direct method works with short horizontal holes drilled into the coalbed from the mine face. However, that is no guarantee that $V \propto \sqrt{\theta}$ holds for the coal cores extracted from vertical boreholes. For one thing, the coal lumps are many inches across instead of 60 mesh. For another, the time θ is typically several hours instead of just a few minutes.

ACKNOWLEDGMENTS

The cooperation of Bureau of Mines geologists James R. White and Paul W. Jeran is greatly appreciated. James I. Joubert of the Bureau of Mines Pittsburgh Energy Research Center supplied us with all of the isotherm curves. The core at the Kepler location was loaned to us by Sam Schrader of the Pocahontas Fuel Co.

LABORATORY FEASIBILITY TEST OF THE DIRECT METHOD FOR VERTICAL BOREHOLE CORES

To find out whether $V \propto \sqrt{\theta}$ holds for coal cores at large values of θ, we initiated some laboratory desorption experiments on lump coal from the Pittsburgh and Pocahontas No. 3 coalbeds. Desorption curves for these coals are shown in figure 1. The size range was 1/4- to 1/2-inch. The coal was pressured to 200 psi and allowed at least a month to equilibrate. Then the pressure was released to atmospheric, and the emission from the coal was measured (appendix A). Figure 1 indicates that the $V \propto \sqrt{\theta}$ proportionality holds up to approximately $\sqrt{\theta}$ = 25 min$^{1/2}$ (or $\theta \cong$ 10 hours). The 1/4- to 1/2-inch size range was the largest coal that could be tested conveniently in the laboratory. However, it is probable that larger lumps would exhibit a similar emission behavior. The reason for this is that coal has a natural fracture network, and lumps that are much larger than the network spacing have about the same emission characteristics as lumps that are about the same

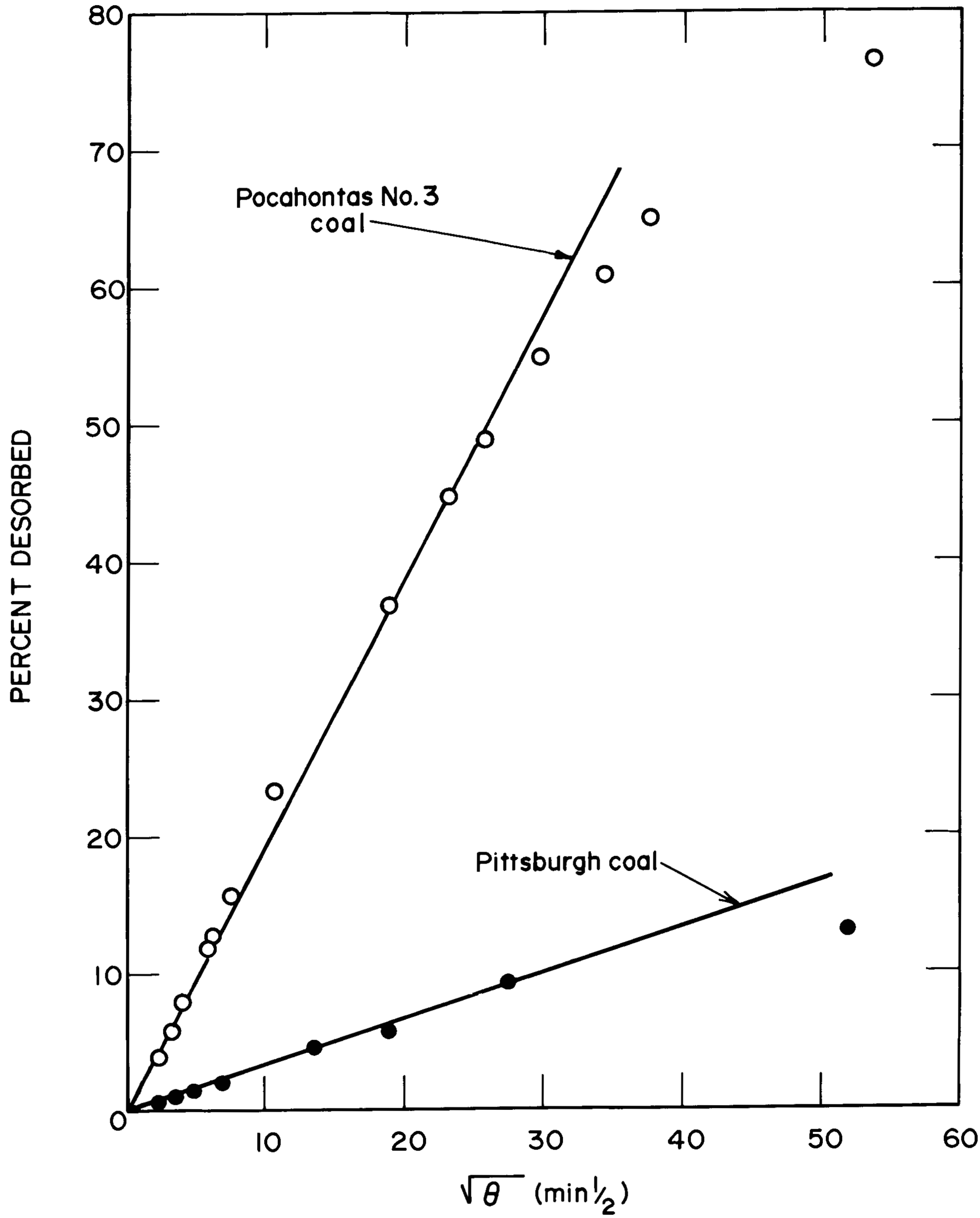

FIGURE 1. - Desorption rate curves for Pittsburgh and Pocahontas No. 3 coals, 1/4- to 1/2-inch size.

dimensions as the network spacing (1). In other words, if the network spacing is 1/2 inch, then a 6-inch lump will have the same emission characteristics as a 1/2-inch lump. Bielicki, Perkins, and Kissell (2) have found that the fracture spacing in Pocahontas No. 3 coal is about 1/16 inch and that of Pittsburgh coal is about 1/2 inch. The coal we tested was at least this large, and so we felt it correctly represented the emission behavior of larger lumps. This then indicated that the "direct method" could possibly be applied to cores from vertical boreholes.

FIELD TESTS OF THE DIRECT METHOD

The Bureau of Mines is conducting an extensive methane drainage research program, one phase of which involves drilling vertical boreholes from the surface into coalbeds in various parts of the country. Drill stem tests on these boreholes are used to measure the methane gas pressure and the coalbed permeability. Later, these are opened to drain methane from the coal. In the course of this work, coal cores were brought to the surface, which could be used to measure the coalbed methane content by the direct method.

The boreholes were drilled 9 inches in diameter to within about 2 to 3 feet of the coalbed. After logging, 7-inch casing with a guide and floatshoe

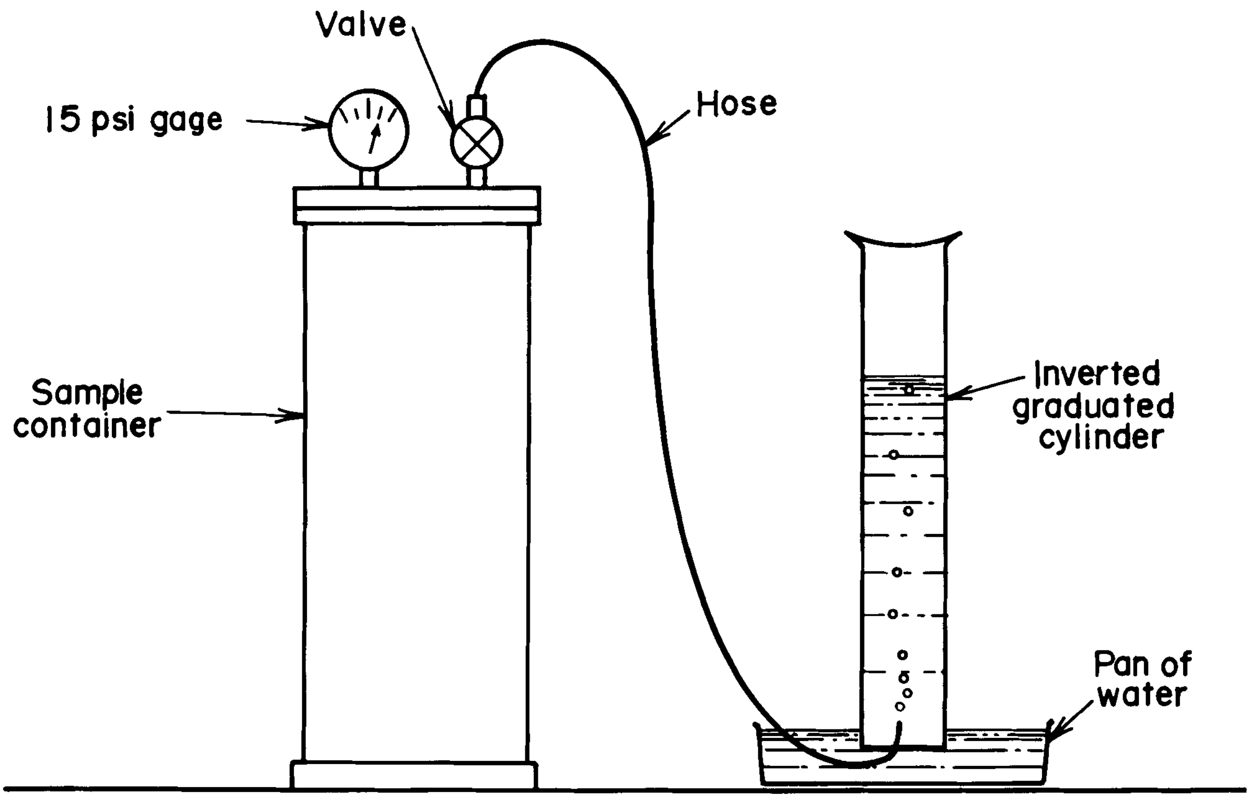

FIGURE 2. - Sample container. Gas emission is measured by displacement of water.

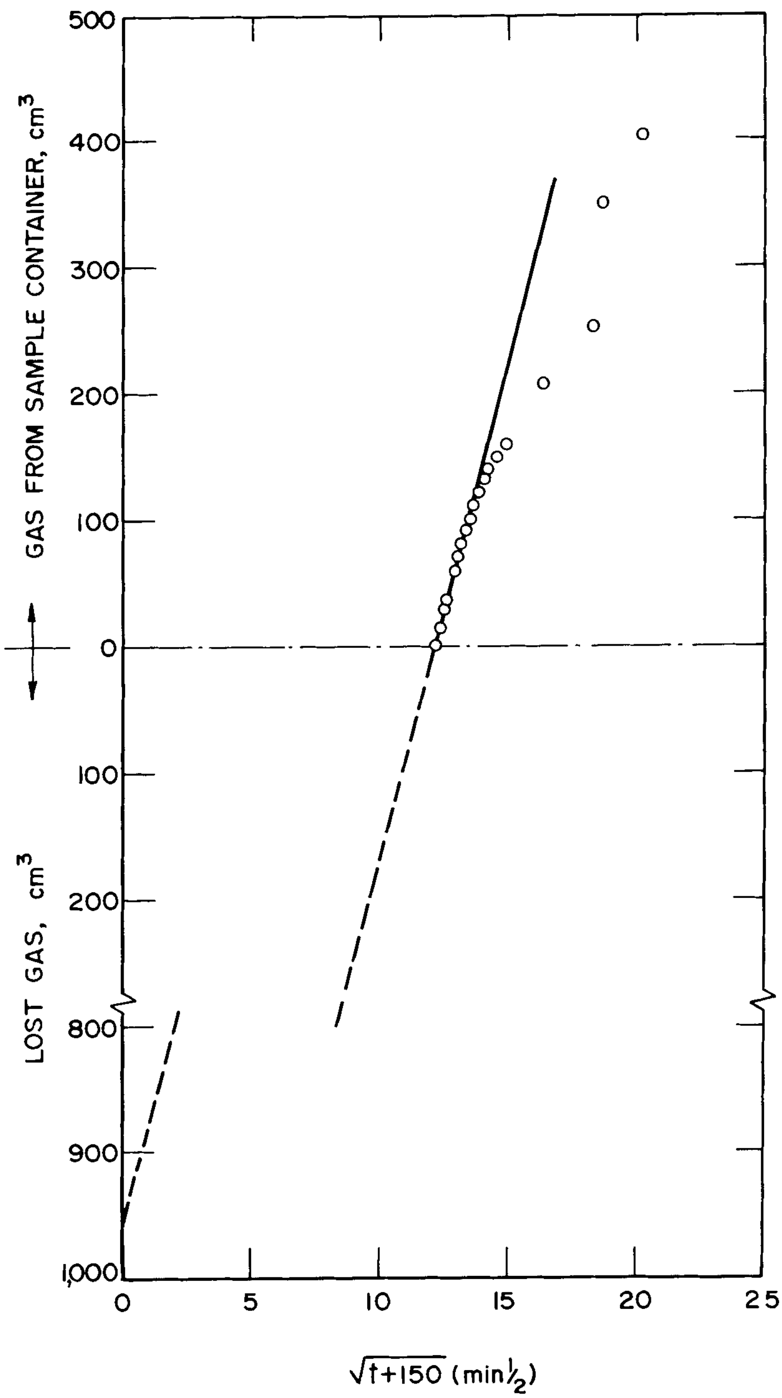

FIGURE 3. - Emission rate curve. Core from Vesta No. 5 site, Pittsburgh coalbed.

was run to the bottom and then cemented to the surface. After the cement hardened, the cement plug and float-shoe at the bottom of the casing were drilled out, and a core barrel inserted. The last few feet of overlying strata and the coal were then cored. The core. 4 inches in diameter, was brought to the surface.

Part of the core obtained in this way was broken off and inserted into a sample container (fig. 2). Generally the container was filled to the top. After the lid was sealed, the valve was opened and the volume of gas emitted was continuously recorded. The valve was then closed and the sample brought to the laboratory where the emission was monitored for several weeks, or until it diminished to a negligible rate. The coal was then crushed to at least 200 mesh, and the gas given off during the crushing was measured (appendix A).

The technique used to determine the amount of "lost" gas was slightly different from that of Bertard (1). Rather than calculating the lost gas by means of an equation (which uses only one data point), we felt a graphical technique would be more accurate. The volume of gas first given off from the sample container was plotted versus $\sqrt{\theta}$, where θ is the time since the methane pressure on the core was released. We assumed that this coincided with the coring of the coal in those cases where the coal was cored with air as a drilling medium. In cases where the coring was done with water, we assumed that the methane pressure was released and emission began when the core was halfway out of the hole.

As an example, the Vesta No. 5 coal (fig. 3) was air-cored. Here, t is the time measured from the instant the coal was inserted in the sample container. The time alapsed between this instant and the coring of the coal was 150 minutes. Then $\theta = t + 150$. By extrapolating the linear portion of the emission curve back to $\theta = 0$, the "lost" gas is obtained. For the Vesta No. 5 example (fig. 3), it is 960 cm^3. The total gas by the direct method is the "lost" gas, plus all the gas emitted from the coal while in the sample container, plus the gas released during crushing. Occasionally the extrapolation for the lost gas may be quite rough; however, the lost gas is generally only about a fourth of the total, and so the error in the total is reduced correspondingly.

It must be pointed out that it is not necessary to adhere exactly to the procedure as outlined above. In drilling the borehole, all that is necessary is to bring a coal core promptly to the surface and place it immediately in the sample container. For example, the borehole at the Kepler location was a company exploration hole which was cored all the way from the surface and never cased. Similarly, it is not necessary to wait several weeks before crushing the coal. The detailed history of each core sample is given in appendix B.

RESULTS FROM THE DIRECT METHOD COMPARED WITH THE INDIRECT METHOD

Another possible way to estimate the amount of methane in a virgin coalbed would be to use what is called the indirect method (4). In this method, a vertical borehole is drilled into the coal from the surface. A packer is set just above the coal for a formation test (drill stem test), and the pressure of the methane gas is measured. This pressure is then related to the gas amount by means of an empirical curve which is determined experimentally in the laboratory. However, there is some doubt as to whether the gas amount measured in this fashion is correct, for two reasons:

1. Coalbeds generally contain water along with the gas, and the pressure that is measured may be the hydrostatic head of water (4).

2. Most of the gas in coal is adsorbed under pressure on the internal surface rather than compressed in the pore space as it would be for a sandstone. The laboratory relation between the amount of gas adsorbed and the pressure is called the equilibrium adsorption isotherm. Typically, the isotherm is determined for powdered coal, and it has always been assumed that the same isotherm curves hold for coal underground. However there is no conclusive proof that this is so.

At each borehole where a direct method test was performed on the core, an "indirect method" test was also performed, as follows: After the coal was withdrawn, a well testing tool was inserted and the gas pressure in the coalbed was measured in a conventional drill stem test. A portion of the core was analyzed to obtain the coal moisture content (7). The gas pressure

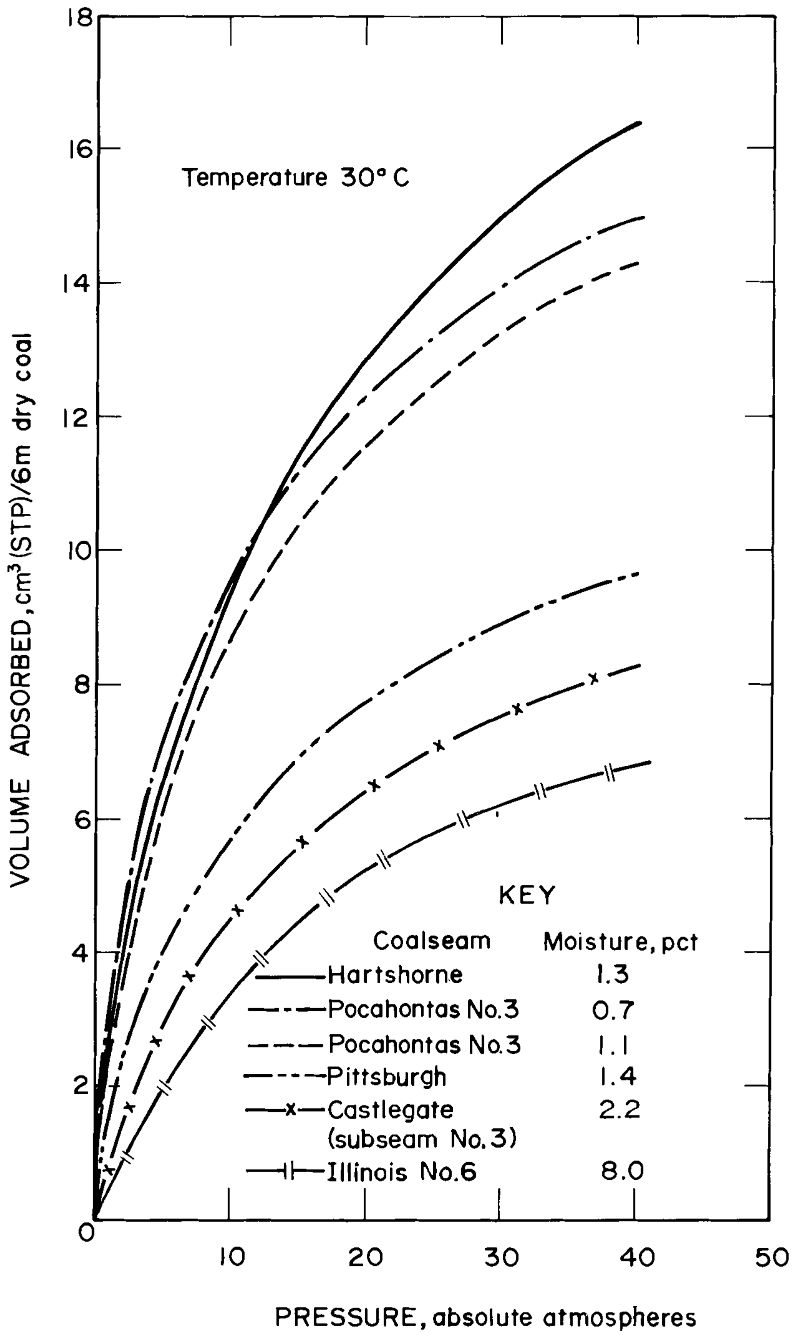

FIGURE 4. - Equilibrium adsorption isotherms. Coal type and moisture levels selected to correspond to the cores extracted from the vertical boreholes.

and the moisture content were used to determine the amount of gas adsorbed at coalbed pressure from the equilibrium adsorption isotherms in figure 4[4] (5).

The methane released is the difference between the methane adsorbed at coalbed pressure (absolute, not gage) and the methane adsorbed at 1 atm. For instance, at the Vesta No. 5 site the drill stem test gave 6.4 atm abs and the moisture content of the coal core was 1.4 percent. According to figure 4 (Pittsburgh coalbed) the amount of methane adsorbed is 4.4 cm^3 (STP)/g. At 1 atm 1.0 cm^3/g is absorbed. Thus, if the pressure is reduced from 5.8 to 1 atm abs, the indirect method indicates 3.4 cm^3 (STP)/g of methane will be released. This value may be compared with 2.6 cm^3 (STP)/g obtained by the direct method (appendix B).

Methane amounts obtained by the indirect method and by the direct method for several vertical borehole sites are compared in table 1. There is reasonably close agreement in every instance, except for the Price site.

[4]The isotherms were obtained from James I. Joubert, Pittsburgh Energy Research Center, Bureau of Mines, Pittsburgh, Pa.

TABLE 1. - Methane amounts by the direct and indirect methods

Location	Coalbed	Indirect method cm^3 (STP)/g	Direct method, cm^3 (STP)/g
Vesta No. 5..	Pittsburgh................	3.4	2.6
Loveridge....	....do....................	5.2	5.8,5.8
Howe.........	Hartshorne................	10.5	11.1
Beatrice.....	Pocahontas No. 3..........	13.5	12.1
Inland.......	Illinois No. 6............	2.7	1.7
Do........	Illinois No. 5............	.5	.9
Kepler.......	Pocahontas No. 3..........	7.8	7.9
Price........	Castlegate (subseam No. 3).	6.2,5.0	4.2

DIRECT METHOD GAS QUANTITY COMPARED WITH EMISSIONS FROM NEARBY MINES

The main purpose of determining the gas content of virgin coalbeds is in forecasting the methane emission from a prospective mine. Of the two methods, direct and indirect, the direct method is by far the most convenient and less expensive. Since routine core drilling ahead of mining is standard practice, adding a "direct method" test to assess the methane content of the core would be a simple matter.

Most sites shown in table 1 were located within a mile of an operating coal mine. In figure 5 the methane emission from the mine (ft^3/ton of coal mined) is plotted against the amount of methane in the coalbed measured by the direct method (cm^3(STP)/g.[5] If methane came only from the coal that is removed from the mine, then these amounts should be equal. For instance at the Loveridge site (table 1) the direct method gives 5.8 cm^3/g of methane in the coalbed. Since 1 cm^3/g is equivalent to 32 ft^3/ton, then the emission from the mine would be $5.8 \times 32 = 186$ ft^3/ton. However, figure 5 shows the actual emission from the mine is about 1,700 ft^3/ton, which is a factor of 9 higher than the gas in the removed coal. This is not surprising, for methane is emitted not only by the coal being removed, but by all the coal that is left behind as ribs and pillars, as well as by the adjacent strata.

The interesting feature of figure 5 is that, for all except the least gassy Inland mine, the ratio $\frac{\text{mine emission}}{\text{direct amount}}$ is relatively fixed; it varies between about 6 and 9. This is despite the fact that these mines are in widely different coalbeds with different kinds of adjacent strata. The mines themselves do have similarities: All are fairly large, deep mines with a sustained and constant coal production of at least several thousand tons a day; virtually all have been in operation for many years and have extensive old workings and gob areas.

Data are available for only six mines, so the correlation shown in figure 5 must be regarded as tentative. However, in coalbeds for which data

[5]One mine is included (Federal No. 2) for which only the indirect test was performed.

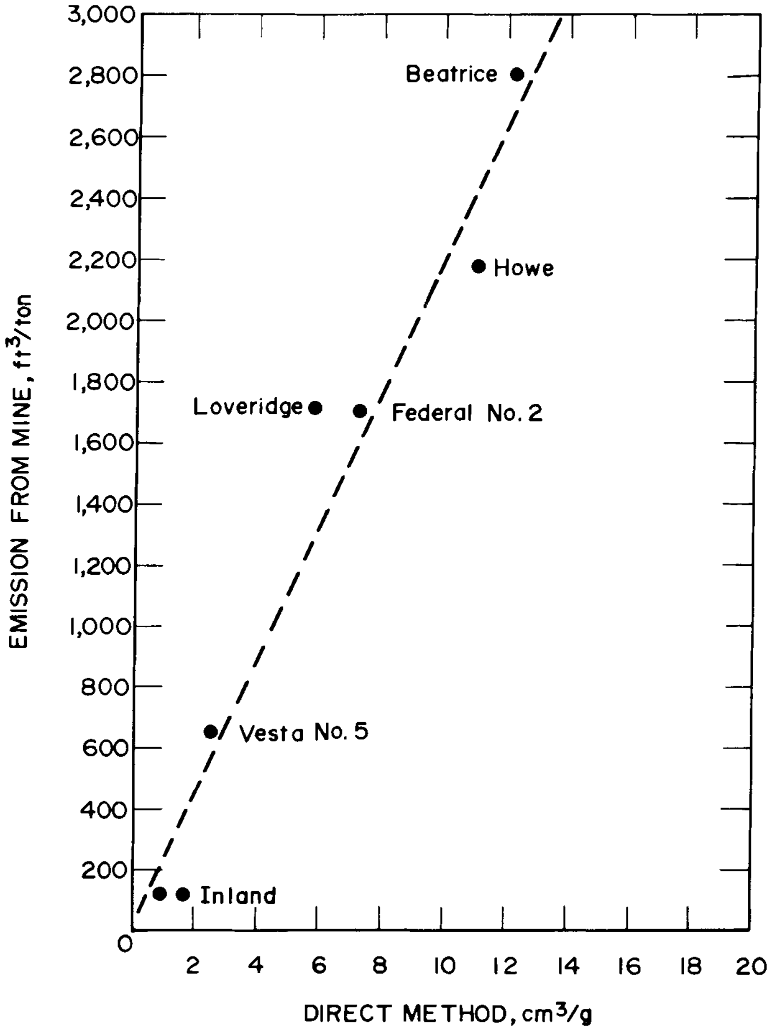

FIGURE 5. - Coalbed gas amount via the direct method versus actual mine emission.

similar to that used by Irani are not available, the direct method combined with figure 5 should provide an approximate long-range forecast for any coal mine on the drawing board.

CONCLUSIONS

These preliminary studies have indicated that the methane output of an entire mine can be estimated by a direct gas measurement on an exploration core in conjunction with the correlation in figure 5. The method seems to work even if the drill bit has cut into the coalbed by mistake (as in Loveridge borehole 1), or even if the coalbed is missed and just a few lumps of rider coal are obtained (as in the Beatrice site borehole).

The technique appears to fit where the mines are large and deep, have a sustained coal production of at least several thousand tons a day, and have been in operation for many years. This means that it is a long-range forecast.

In new mines--those which have been in operation only a few years--the emission in cubic feet per ton is much lower than emission from older mines which have extensive old workings and gob areas that are still bleeding gas. Hence the factor of 6 to 9 from figure 5 will be on the conservative side. Nevertheless, after the mine has been worked for some time, the emission may approach the relationship given in figure 5.

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APPENDIX A.--MEASURING TECHNIQUE

The most convenient way to measure methane emission from the sample container is to displace water in an inverted graduated cylinder (fig. 2). Readings of the volume emitted should start as soon as the coal is in the sample container and be taken at least every 15 minutes for the next several hours. This initial monitoring is used to obtain the emission curves shown in figures 3, A-1, and A-2. During this initial period the container valve should be left open, to prevent back pressure from building up.[1]

After the initial monitoring the valve was closed and the sample container was taken to the laboratory where the emission was monitored until it became negligible. Generally this was done by opening the sample container valve every day or so.

When emission had virtually stopped, the coal was crushed to at least 200 mesh in two stages--first to 8 mesh in a chipmunk crusher, and then to 200 mesh in a rotary grinder. The crushing devices were both enclosed in a plexiglass box which was purged with nitrogen. The coal was then crushed and the methane content in the box was analyzed with a gas chromatograph. This procedure was adopted because all the equipment was on hand, but the crushing technique used by Bertard (1) is much simpler.

The total gas by the direct method is the "lost" gas obtained by extrapolation from the initial measurement, plus all the gas emitted from the coal while in the sample container, plus the gas released during crushing.

Any vessel capable of withstanding moderate pressures will do for the sample container. The ones used by the Bureau are fabricated from 4-inch aluminum pipe. The top lid is sealed with an O-ring and is equipped with a 15-psi gage and a valve.

[1] Occasionally, when it was not practical to monitor the volume emitted at the well site, the valve was closed while the cylinder was transported to a nearby motel. In such cases, we tried to avoid letting the pressure build up beyond a few psi, as then this would begin to affect the emission rate.

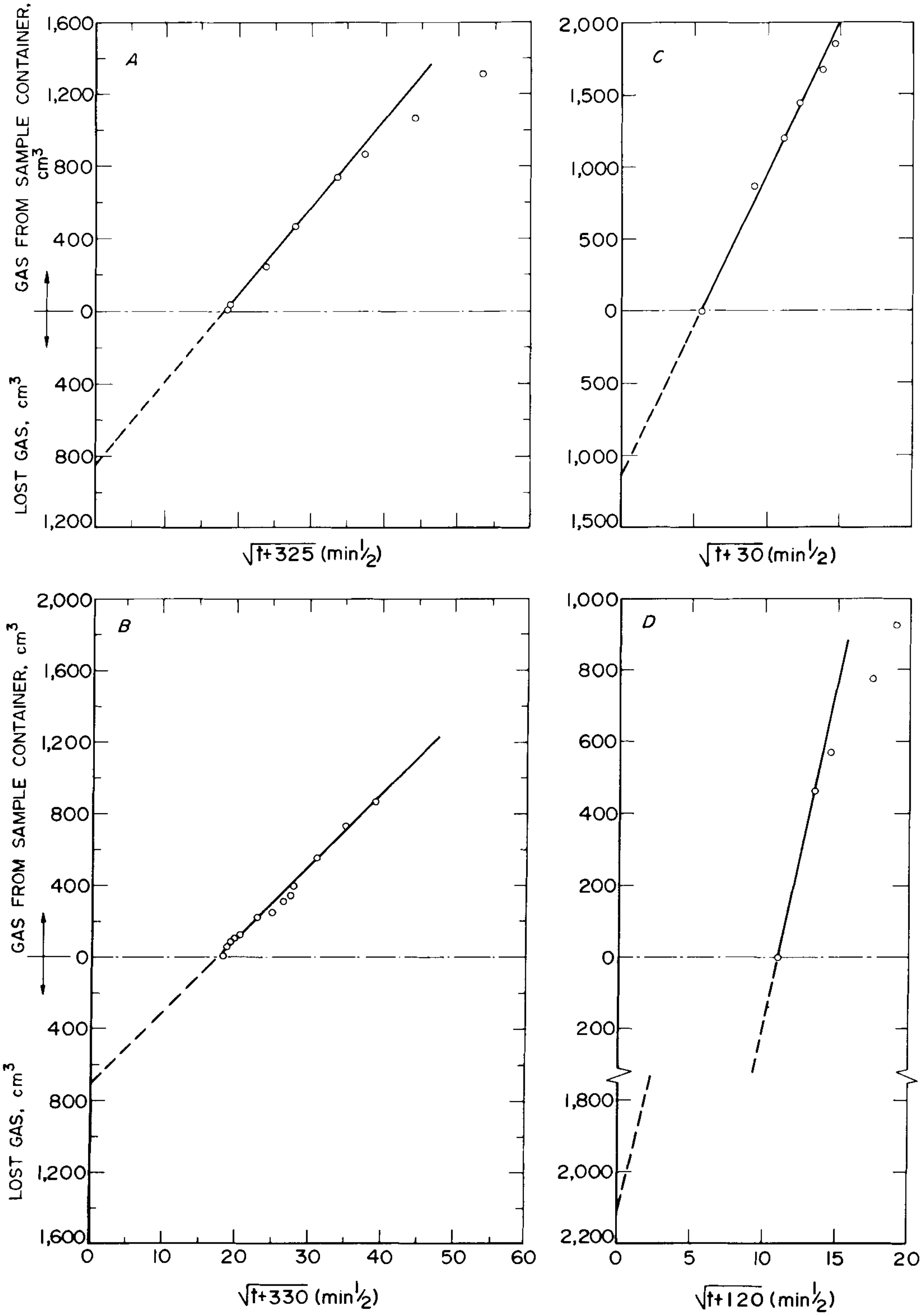

FIGURE A-1. - Emission rate curves: *A,* Core from Loveridge site–borehole 1, Pittsburgh coalbed; *B,* core from Loveridge site–borehole 2, Pittsburgh coalbed; *C,* core from Howe site–Lower Hartshorne coalbed; and *D,* core from Beatrice site–Pocahontas No. 3 coalbed.

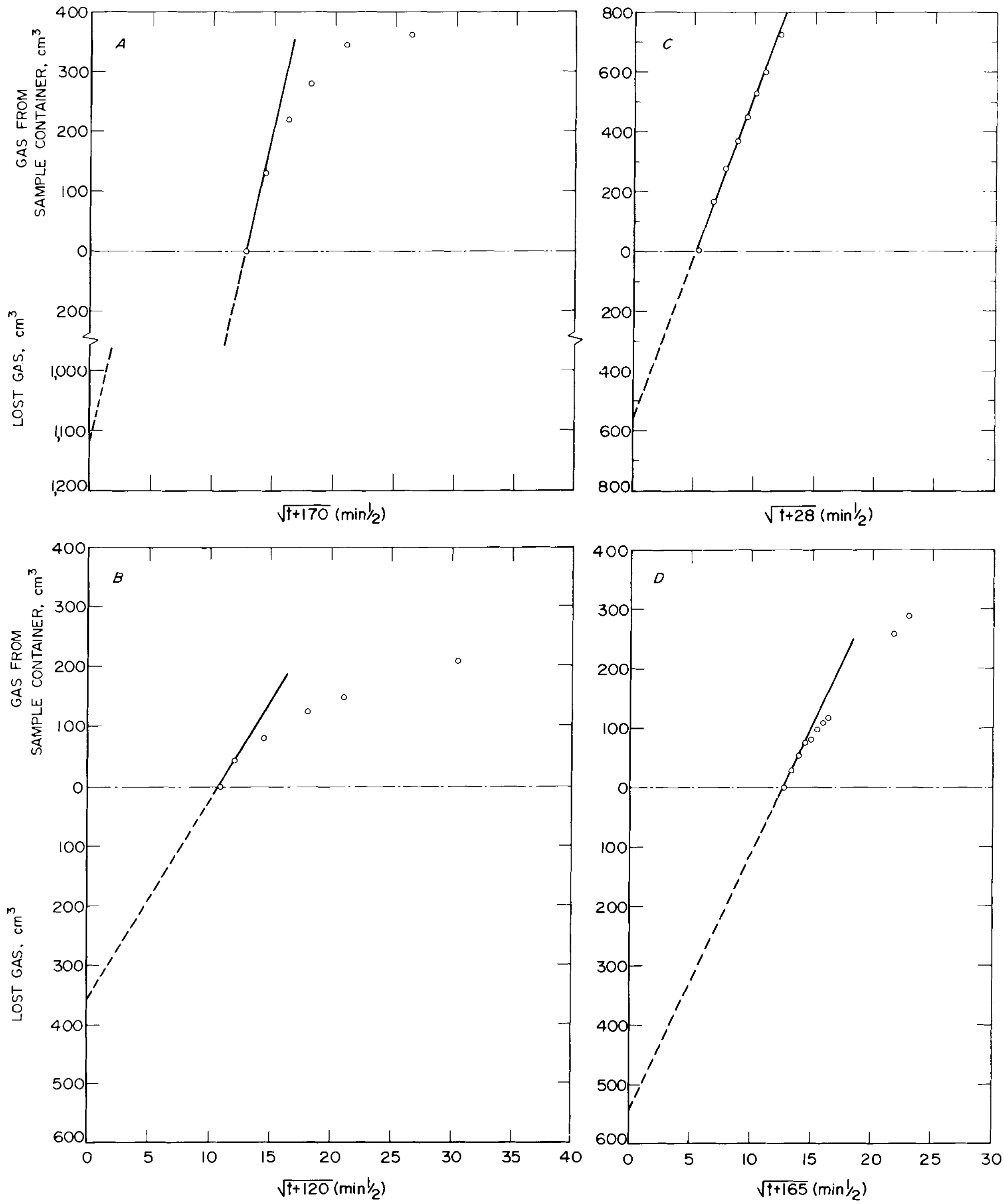

FIGURE A-2. - Emission rate curves: *A*, Core from Inland site 1–Illinois No. 6 coalbed; *B*, core from Inland site 2–Illinois No. 5 coalbed; *C*, core from Kepler site–Pocahontas No. 3 coalbed; and *D*, core from Price site–Castlegate coalbed (subseam 3).

APPENDIX B.--VERTICAL BOREHOLES

The results from the vertical boreholes are discussed individually, to show how the values in table 1 were obtained and also to show how the circumstances of drilling may differ.

Vesta No. 5 Site, Pittsburgh Coalbed

By the evening of the first day the bit had penetrated to within a few feet of the coalbed. Seven-inch casing was set to the bottom of the hole and then cemented to the surface. On the second day the cement was drilled out, the bit was replaced with a core barrel, and coring (with air) began. At 1:10 p.m. the drilling froth turned black, indicating that the coal had been reached. By 3:40 the coal was out and a portion of the core was in the sample container. Emission was carefully measured for the next 7 hours (fig. 3). Then, for the next month, the gas was vented off and measured every few days. The emission for the first 7 hours was used to plot figure 3. The total emission from the container after a month was 1,850 cm^3. Another 960 cm^3 is obtained from the extrapolation in figure 3. On the assumption that the core began to release gas at 1:10 p.m., the extrapolation was for 150 minutes. The amount released in crushing was 1,790 cm^3. When these volumes are added, converted to STP, and divided by the sample weight of 1,570 grams, the total by the direct method was 2.60 cm^3(STP)/g.

The extrapolation in figure 3 is a long one (as are many of the others), and it is quite likely that considerable errors may creep in. However, the lost gas (960 cm^3) is less than a fourth of the total, and so any errors will be reduced by at least a factor of four.

A portion of the original core was analyzed for moisture, which was found to be 1.4 percent. A drill stem test performed immediately after the core was taken from the borehole showed that the methane pressure in the coalbed was 6.37 atm abs. The isotherm in figure 4 shows that, for Pittsburgh coal at 6.37 atm and 1.4 percent moisture, 4.4 cm^3(STP)/g of methane is adsorbed. At 1 atm and 1.4 percent moisture about 1.0 cm^3/g is adsorbed. According to the indirect method 3.4 cm^3(STP)/g would be released. The amount by the direct measurement was 2.6 cm^3(STP)/g.

Loveridge Site--Borehole 1, Pittsburgh Coalbed

This borehole was completed on the first day, when the drill bit accidentally cut into the first foot of coal. The borehole was then cased and cemented and left standing that night. Air coring began on the morning of the second day. By 9 a.m. the core barrel had cut through the cement plug and was cutting the coal. The coal was out and in the sample container by 2:25 p.m. Emission was measured for the next few days (fig. A-1A). A total of 6,420 cm^3 was given off from the container over the next 2 months. Extrapolation for 325 minutes (9 a.m. to 2:25 p.m.) gave 855 cm^3, and crushing released 4,850 cm^3. The sample weight was 1,864 grams, and the total released (corrected to STP) was 5.8 cm^3(STP)/g.

A drill stem test gave a coalbed methane pressure of 12.0 atm abs. Moisture analysis on part of the remaining core gave 1.5 percent water. The isotherm indicated that 6.2 cm^3/g is adsorbed under these conditions. If 1.0 cm^3(STP)/g is adsorbed at atmospheric pressure, the amount released should be 5.2 cm^3/g. The direct method gave 5.8 cm^3(STP)/g.

Loveridge Site--Borehole 2, Pittsburgh Coalbed

This borehole was completed soon after the first one. Coring of the coal began at 11 a.m., and the core was in the sample container by 4:30 p.m. Emission from the container was measured carefully for the next 24 hours (fig. A-1B). The total given off for the next 6 weeks was 4,730 cm^3. Extrapolation of figure A-1B for 330 min (11 a.m. to 4:30 p.m.) gave 700 cm^3 and crushing gave 3,550 cm^3. Dividing by the sample weight of 1,366 grams and correcting to STP, the total released was 5.8 cm^3(STP)/g. This was exactly the amount released from the core at borehole 1, a short distance away.

Howe Site--Oklahoma (Lower) Hartshorne Coalbed

This borehole was drilled in the usual fashion, but it was cored with water whereas the previous ones were cored with air. We assumed that the methane release from the core began when the core was halfway out of the hole, and so the time to the sample container was only 30 minutes. The extrapolation from figure A-1C gives 1,150 cm^3, and 8,010 cm^3 was given from the sample container in the next 3 weeks. Crushing yielded a negligible amount of gas because this particular coal is very friable, so that gas escapes more quickly from it (2). By the end of 3 weeks, emission was essentially complete. The sample weight was 725 grams, and so the total emission after correcting to STP was 11.1 cm^3/g.

The drill stem test was not successful, so the pressure was deduced by measuring the water level height in the cased borehole. It was 17.2 atm abs. The core contained 1.3 percent moisture. The isotherm in figure 4 gives 12 cm^3(STP)/g for 17.2 atm and 1.3 percent moisture. At 1 atm, 1.5 cm^3/g is adsorbed, and so the indirect method indicates 10.5 cm^3(STP)/g should be released.

Beatrice Site--Pocahontas No. 3 Coalbed

This borehole was drilled with a cable tool and cored with water as a drilling medium. Coring began at 3 p.m. of the first day, and by 7:17 p.m. the core was out. It contained no coal. On the next day, another core was taken. This was started at 8:30 a.m. and was out of the hole by 1:30 p.m. The core was 3 feet long and had 2 inches of coal at the very top and 3 inches at the very bottom. The rest was rock. Despite the poor quality of the sample, the coal was placed in the sample container at 3 p.m. It was assumed that emission began at 1 p.m. The extrapolation from figure A-1D gives 2,100 cm^3 of lost gas, and a total of 5,230 cm^3 was given off from the sample container over a period of 8 weeks. Only 54 cm^3 was given off in the crushing, as the coal is very friable. The sample weight was 542 grams, so the total by the direct method was 12.1 cm^3(STP)/g. The pressure was not measured at this hole; however, a drill stem test in a nearby hole gave a pressure of 40.4 atm abs. The coal moisture content was 0.7 percent. Figure 4 gives 15 cm^3/g at 40.4 atm and 1.5 cm^3/g at 1 atm, so the indirect method indicates 13.5 cm^3(STP)/g should be released.

Inland Site--Illinois 5 and 6 Coalbeds

These coalbeds are only 60 feet apart. At this site the No. 5 coalbed was the deeper at 793 feet, while the No. 6 coalbed was at 733 feet. It might be expected that the methane amounts would be similar; however, a drill stem test in the No. 6 coalbed gave 9.3 atm abs (or 122 psig), while a test in a separate borehole drilled into the No. 5 coalbed gave 2.4 atm abs (or 21 psig). The corresponding amounts, using figure 4 and subtracting 0.5 cm^3/g as the 1 atm value, are 2.7 cm^3(STP)/g for the Illinois No. 6 and 0.5 cm^3(STP)/g for the Illinois No. 5 coalbed. The core moisture values were high--about 8 percent.

The direct method results were as follows: For the No. 6 coalbed the extrapolated amount from figure A-2A was 1,120 cm^3, 1,730 cm^3 were given off while in the sample container, and crushing yielded 180 cm^3. The sample weight was 1,568 grams, and so the direct method gave 1.7 cm^3(STP)/g. For the No. 5 coalbed the extrapolated amount from figure A-2B was 360 cm^3, 943 cm^3 were given off while in the sample container, and crushing yielded 310 cm^3. The sample weight was 1,644 grams, and so the direct method gave 0.9 cm^3(STP)/g. In both cases the extrapolation had to be made using two points.

The direct amounts from both coalbeds are plotted in figure 5, although the mine is in the No. 6 coalbed. These are proportionally quite high when compared with the mine emission. For the No. 6 coalbed the ratio $\frac{\text{mine emission}}{\text{direct amount}} = 2.2$, whereas for gassier coalbeds it varied between 6 and 9. There are two possible reasons for this: First, the total amount of gas released is quite small and so errors in the absolute amount can lead to very large proportional errors. Second, both cores were not recovered quickly enough, and not enough data points were taken in the first hour. It follows that the lost gas may be incorrectly estimated, and this may be especially true in the case of the No. 6 coalbed, where the lost gas was unusually high compared with that from the No. 5 coalbed (figs. A-2A and A-2B).

Kepler Site--Pocahontas No. 3 Coalbed

This was a company exploration hole, which was cored all the way from the surface and never cased. The hole was water-cored, and only 28 minutes elapsed before the coal was enclosed in the sample container. The emission curve and extrapolation are shown in figure A-2C. Comparison with figure A-1D shows the advantages of water coring and enclosing the coal in the sample container as quickly as possible. The data are much more likely to be in a linear portion of the emission curve, and the "lost" gas is a much smaller percentage of the total, especially when the coal is friable. Here, the lost gas was 560 cm^3, the amount given off while in the sample container for 4 weeks was 12,300 cm^3, and the amount from crushing was 3,010 cm^3. The sample weight was 1,783 grams, and so the total corrected to STP, is 7.9 cm^3(STP)/g. The core contained 1.1 percent moisture, and the methane pressure, measured at a nearby borehole, was 11.8 atm abs. Figure 4 indicates 9.3 cm^3/g is adsorbed under these conditions. If 1.5 cm^3/g is substracted as the 1-atm value, then 7.8 cm^3(STP)/g should have been released.

Price, Utah Site--Castlegate Coalbed (Subseam 3)

This borehole was air cored and so the elapsed time since emission began was 165 minutes. The extrapolation of the emission curve is shown in figure A-2D. The lost gas amounted to 545 cm^3, the amount released while in the sample container was 4,720 cm^3, and the amount released upon crushing was 1,430 cm^3. The sample weight was 1,427 grams, and the total amount of gas by the direct method was 4.2 cm^3(STP)/g.

A drill stem test in the borehole from which the core was taken gave a pressure of 24.4 atm abs. Figure 4 shows 7 cm^3(STP)/g is adsorbed at this pressure and 0.8 cm^3(STP)/g is adsorbed at 1 atm abs. This indicates 6.2 cm^3(STP)/g should be released, which is somewhat higher than the 4.2 from the direct method. The moisture content of the core was 2.2 percent.

However, the borehole pressures were not consistent. A drill stem test in a nearby (1,500 feet away) borehole gave 16.6 atm abs, and this indicates about 5 cm^3(STP)/g should be released.