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Measuring the Methane Content of Bituminous Coalbeds

UNITED STATES DEPARTMENT OF THE INTERIOR

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UNITED STATES DEPARTMENT OF THE INTERIOR
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MEASURING THE METHANE CONTENT OF BITUMINOUS COALBEDS

by

C. M. McCulloch,[1] J. R. Levine,[1] F. N. Kissell,[2] and Maurice Deul[3]

ABSTRACT

The methane content of virgin bituminous coalbed can now be measured accurately in the field with exploration core samples from vertical boreholes. The gas content of the coal per unit weight can be used either to design a mine ventilation system or to determine if degasification of the coalbed will be necessary before mining, and to determine the gas resources in the coalbed. The equipment necessary to conduct the test costs less than $50. The gas content of the coal in place in the ground is determined by summing the gas lost from coring, gas measured during desorption, and the residual gas in the coal.

Upon removal from the borehole, the core sample is placed in an airtight container and desorbed for several weeks until the desorption rate is below 0.05 cm^3/g for 5 consecutive days. The gas lost from the core while it was being cored and the residual gas are estimated by a new graphical method.

The amount of gas remaining depends upon whether the coal is friable or blocky. Friability appears to relate to the depth of the sample below the surface, fixed carbon percentage, Hardgrove grindability index, and proximity to tectonic disturbance. Friable coals emit nearly 96 pct of the total gas during desorption whereas a blocky coal emits only 60 pct of its total gas. Coalbeds that are ill defined as to their blocky or friable nature must be tested in the laboratory for unambiguous analysis.

INTRODUCTION

The large volumes of methane gas emitted in underground coal mines from the coal and surrounding rock constitute a serious fire and explosion hazard that can necessitate costly shutdown of machinery and requires constant ventilation of the working area. A major objective of the Bureau of Mines Health and Safety program has been to develop cost effective means for preventing and predicting hazardous accumulations of methane in underground mine workings.

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This approach attempts to predict in advance the amount of gas that a specific coalbed would emit during mining. If this amount is known, plans may be made for the proper ventilation needed to handle the gas or for the design of an adequate degasification plan. Kissell, McCulloch, and Elder (6)[4] have investigated two methods for making such predications: (1) An "indirect" method that measures the gas pressure at the bottom of a drill hole in the coalbed, and (2) a "direct" method that measures the gas released by a coal core extracted from the coalbed and degasified in an airtight container.

The direct method has been found to be accurate, simple, and inexpensive. It can easily be incorporated into the standard exploration procedures used to evaluate coal property. The necessary equipment costs less than $50. The revised direct method also provides a simplified procedure for estimating the quantities of residual gas.

ACKNOWLEDGMENTS

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The authors especially thank Sylvester Sudduth of the Federal Bureau of Mines, Pittsburgh Mining and Safety Research Center, Pittsburgh, Pa., for his assistance in degasifying the coal cores in the laboratory.

PREVIOUS WORK

The direct method was first used in France by Bertard, Bruyet, and Gunther (4) in 1970. Horizontal holes were drilled into the virgin coalbed from the working face, and the cuttings were collected and sealed in a container. The gas emitted in the container was measured over a period of weeks until desorption stopped. The main difficulty with the direct method was that it offered no simple way to calculate this residual gas in the coal sample after it had ceased to desorb gas. Bertard used a laboratory procedure in which the coal was crushed to a fine powder and the residual emission measured.

In 1973, Kissell, McCulloch, and Elder (6) developed a variant of the direct method in which cores were obtained from vertical boreholes and the

[4]Underlined numbers in parentheses refer to the items in the list of references preceding the appendixes.

methane in the coal was estimated. Now Kissell's method has been modified to eliminate laboratory determination of the "residual" gas and to provide a graphical solution for determining it.

COLLECTION AND DESORPTION OF COAL SAMPLES

Drilling and Coring

All core samples used in this project were taken from holes drilled vertically from the surface to intersect the coalbed. The procedure presented here are similar to those in BuMines Report of Investigations 7767 (6) with some modifications.

The diameter of the hole and the time required to drill to the top of the coalbed are not important. The hole can be cored from the surface or drilled to the top of the coalbed and then cored. The core diameters ranged from 1-1/8 to 4-1/2 inches. The cooling medium used in coring can be air, mist, water, or mud. The only difference this makes is in the calculations of the "lost" gas. The hole can be either cased or uncased. Once the coal is cored, the core barrel should be removed without delay and the core placed in the container immediately upon removal from the core barrel to minimize the lost gas. The O-ring seal on the container must be inspected before the container is sealed to make sure it is free from coal particles that would prevent an airtight seal.

This determination can be conducted successfully with only 100 grams of coal, but errors of measurement will be less for larger (1,000 grams or more) samples. More than one sample may be taken from a single core, and several desorption tests can be run simultaneously.

Measuring Desorbed Gas

Once the sample has been sealed in the container, the gas pressure builds up and should be released periodically. To prevent leakage, the pressure in the container should not exceed the strength of the seal. The strength of the seal varies with the type of container used, but the pressure should not exceed 9 lb/in^2. The initial emissions of gas from the coal are the largest; the emission rate decreases slowly as desorption time increases. The first few readings should be taken at short intervals, as often as every 10 min for a very gassy coal (see appendix B). Within a few days, the emission rate becomes low enough to require only one reading per day. Because the gages used are often not very sensitive or accurate at low pressures, gas should be released at least once a day, even if the gage does not register any pressure at all. Because the temperature at which the sample is kept can affect the emission rate, the coal should be kept at a fairly constant temperature (approximately 70° F) throughout desorption.

To measure emission, the desorbed gas is conducted through a tube attached securely to the valve head into an inverted graduated cylinder filled with water (fig. 1). When the valve is opened, gas flows into the cylinder until atmospheric pressure is attained in the container. The water

level is read before and after the gas is released. The volume of water displaced is equal to the volume of gas emitted. The valve is then closed securely until the next reading. To insure an airtight seal on the valve, the tube is removed and a cap is placed over the valve stem. This is done because a needle valve can become worn with repeated use and allow gas to escape. After each reading, the date, time, volume of gas released (cm^3), and the emission rate ($cm^3/g/day$) are recorded. It also is useful to keep a running total of the gas emissions.

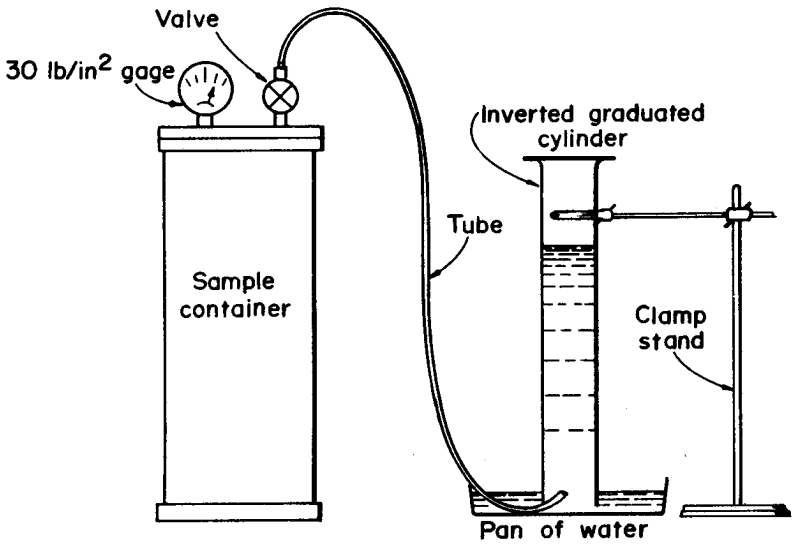

FIGURE 1. - Diagram of desorption equipment.

To calculate the gas emissions, the weight of the sample must be known to the nearest gram. The cylinder with valve and fittings is weighed before the coal sample is added and again before the sample is removed. The difference between the two weighings gives the weight of the coal sample. The daily emission rate (cm^3/g) should be calculated by dividing the daily emission by the sample weight.[5]

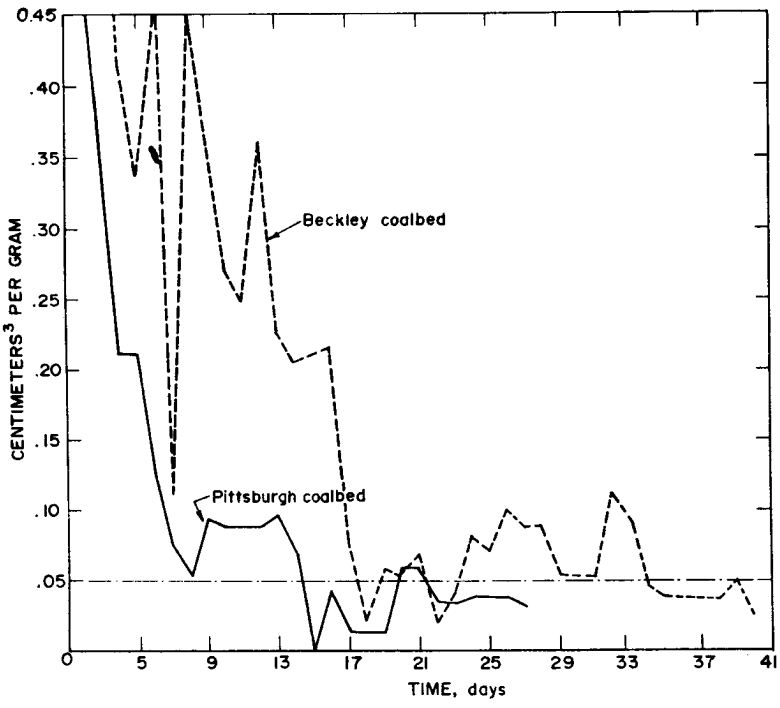

FIGURE 2. - Decline curves for Pittsburgh and Beckley coals.

[5]If the emission is unmeasured for several days, it must be averaged over that number of days. For example, if a sample is left over the weekend, measured on Monday, and 150 cm^3 of gas are released, the average daily emission for Saturday, Sunday, and Monday will be 50 cm^3. This is important because the emission rate decreases as the pressure builds up, and consequently the average over several days may be deceptively low. For example, if the container is left for 5 days and the emission rate averages 0.04 cm^3/g, measurements should not be discontinued because the next single day's emission might exceed 0.05 cm^3/g.

When the daily emission is less than 0.05 cm^3/g for 5 consecutive days, measurements should be discontinued, and the "residual" gas should be estimated by the procedure described later.

Figure 2 shows the decline curves for samples from the Pittsburgh and Beckley coalbeds. Irregularities in the curve are due mainly to changes in the temperature and the irregular intervals at which measurements were made. Level areas on the curve correspond to a reading taken after several days and averaged over that number of days.

Calculating "Lost" Gas

The core sample actually begins giving off gas before it is placed in the container. This amount of "lost" gas depends on the drilling medium and the time required to get the core into the container. If air or mist is used as the cooling medium, it is assumed that the coal begins giving off gas immediately upon penetration by the core barrel. With water or mud, desorption is assumed to begin only when the core is halfway out of the hole; that is, when the gas pressure is assumed to exceed that of the hydrostatic head.

The "lost" gas can be calculated quite accurately because for the first few hours of emission, the amount given off is proportional to the square root of the desorption time. A plot of the total emission after each reading against the square root of the time that the sample has been desorbing produces a straight line. After approximately 10 hours, the emissions are too irregular to predict.

In figure 3, two very different coals (Pittsburgh and Pocahontas No. 3) showed similar behavior although their desorption rates were different. These samples were gasified under pressure in the laboratory (6) and then degasified. Hence, there was no "lost" gas time for these samples. Both samples weighed approximately 1,000 grams.

The Pocahontas No. 3 coal, which is friable, gave off gas much more quickly than the blocky Pittsburgh coal, and the curve for the Pocahontas coal is much steeper.

If degasification were prolonged, the points would begin to deviate to the right of the line defined in the first few hours (figs. C-1 through C-5 given in appendix C). Therefore, the sample should be placed in the container as quickly as possible so as to minimize "lost" gas time.

If it is assumed that all coal samples behave like those in figure 3, such a graph can be plotted from the desorption data, starting when the sample is sealed into the container. When a sample is placed in the container, it has already been desorbing gas for several minutes. To calculate the correct slope for the sample, one must start at the point on the X axis equal to the square root of the "lost" gas time, $\sqrt{t}$.

Figure 4 shows what the "lost" gas for the Pocahontas No. 3 sample of figure 3 might have been if it had been placed in the container 25 min after

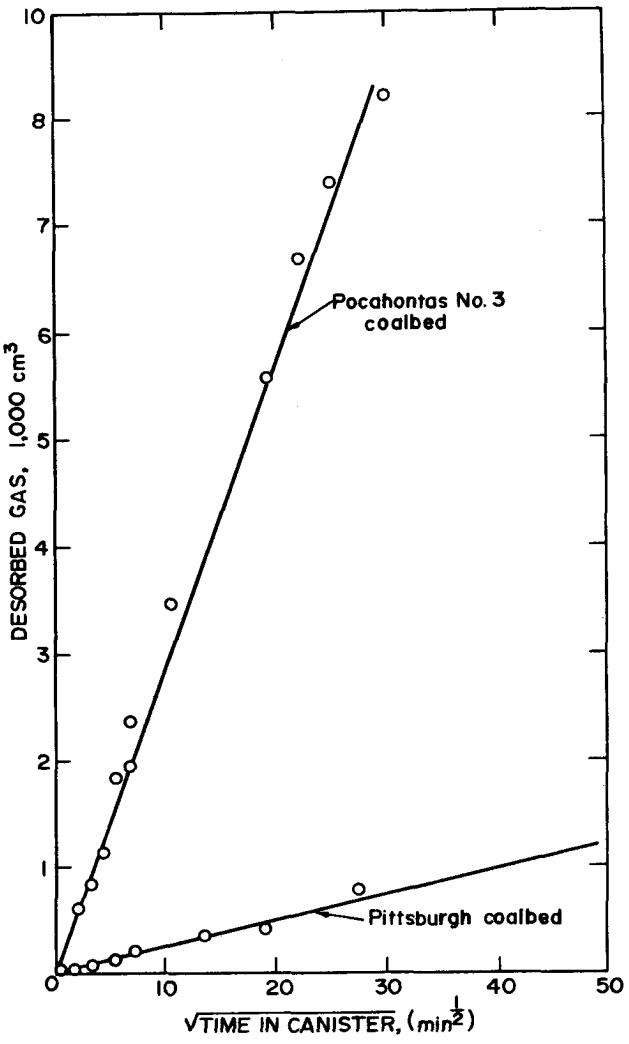

FIGURE 3. - Desorption curves for Pittsburgh and Pocahontas No. 3 coals.

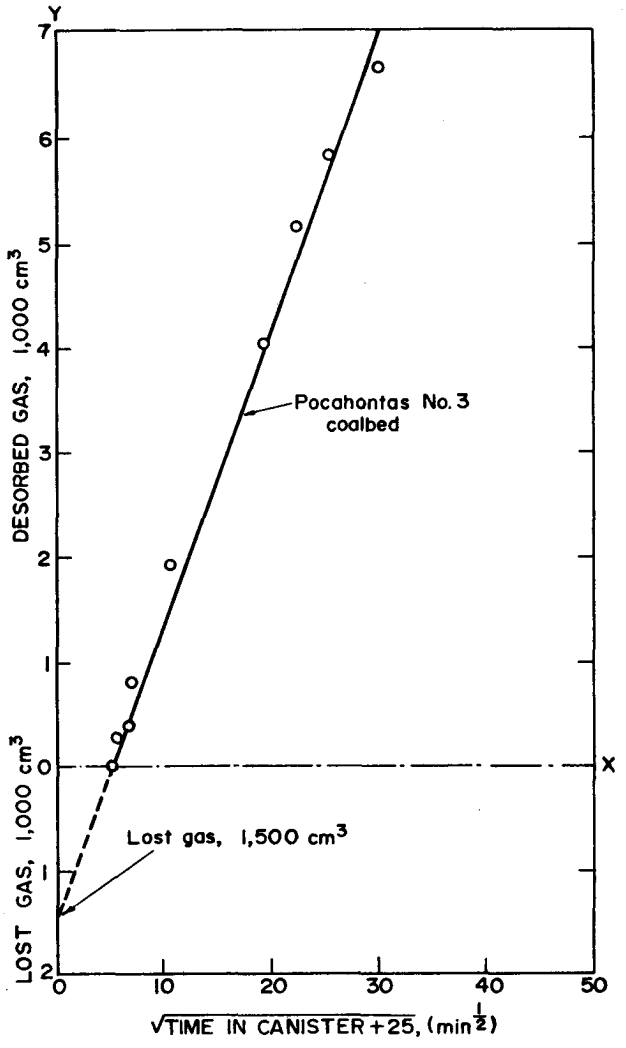

FIGURE 4. - "Lost" gas graph for Pocahontas No. 3 coalbed.

it began giving off gas. Since $\sqrt{t} = \sqrt{25} = 5$, the first point is plotted at 5 ($min^{1/2}$) on the X axis. For the next reading taken 5 min later, after 300 cm^3 of gas had been released, $\sqrt{t} = \sqrt{25+5} = 5.5$ ($min^{1/2}$) and so on, for at least 400 min (the square root of which is 20 min).[6] The line is then drawn back until it intersects the Y axis. This point is the amount of "lost" gas; in this case, it was 1,500 cm^3.

Estimating "Residual" Gas

Even after the daily desorption rate is less than 0.05 cm^3/g, the coal contains residual gas. How much depends on the fracture network that defines coal friability. To estimate the "residual" gas in the Bureau of Mines experiments (6), the procedure used in the past was to crush a sample of the coal

[6]For a more complete discussion see BuMines RI 7767.

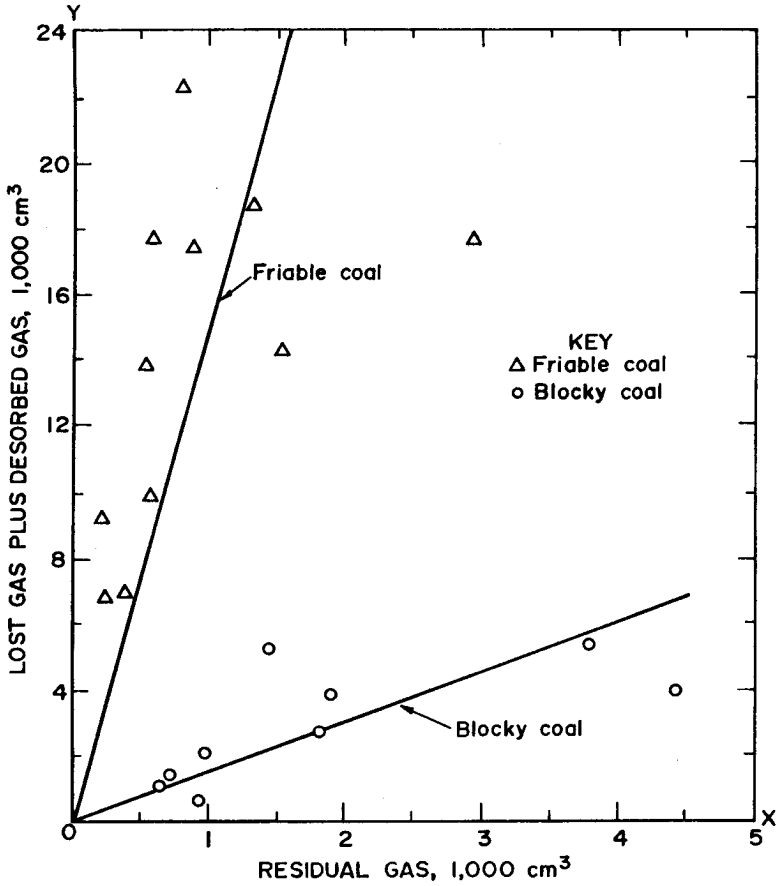

FIGURE 5. - "Lost" gas plus desorbed gas versus "residual" gas.

in a mechanical grinder to about 200 mesh inside a large sealed box filled with nitrogen. The residual methane, which desorbed quickly from the fine particles into this chamber, was determined by gas chromatography.

This method is obviously not suited for field use, and a much simpler graphical procedure was developed. Unfortunately, no quantitative relationship, such as the one used for the "lost" gas, is known. The best relationship was found by graphing the proportion of "residual" gas to desorbed gas plus "lost" gas for the 20 samples analyzed by gas chromatography (fig. 5). The two lines (one for blocky coals and one for friable coals) were determined by a least squares statistical evaluation.[7]

The blocky coals tend to release their gas more slowly and thus have much more "residual" gas than the friable coals at the end of measurement. The blocky coals (fig. 5) retained approximately 40 pct of their total gas, whereas the friable coals retain only about 6 pct.

To evaluate the "residual" gas, using the graph in figure 5, one must first determine whether the sample is friable or blocky. Friable coals are

[7]An alternative solution to calculating the "residual" gas, other than graphically, is the placement of several large ball bearings in the canister while it is being filled with the coal sample. By rotating the cylinder on any suitable tumbler after desorption of the sample, the coal would be crushed and the remaining gas given off. This method was determined by Mr. Bruce Bevins of the Chesapeake and Ohio Railway Co. It would require slight modification of the equipment (the cylinder would have to be made of steel not aluminum as was the cylinder in this study). The only drawback is that the sample would be crushed to a powder (approximately 100 mesh), but if the crushing of the sample is not detrimental then this method would be an excellent alternative.

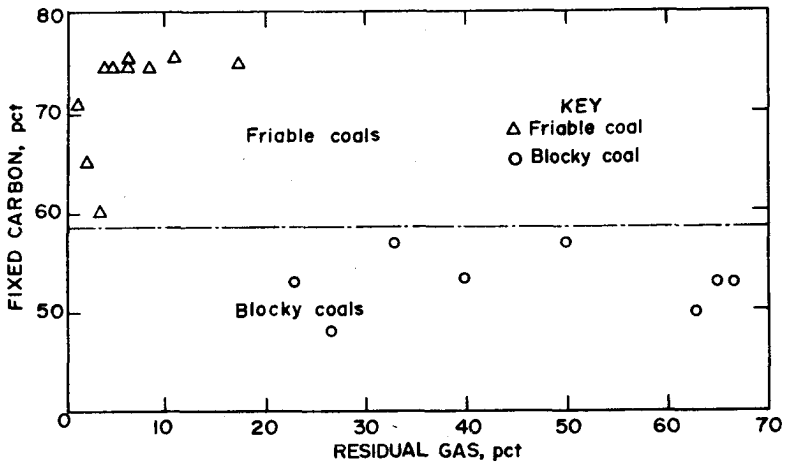

FIGURE 6. - Percent "residual" gas versus fixed carbon percent.

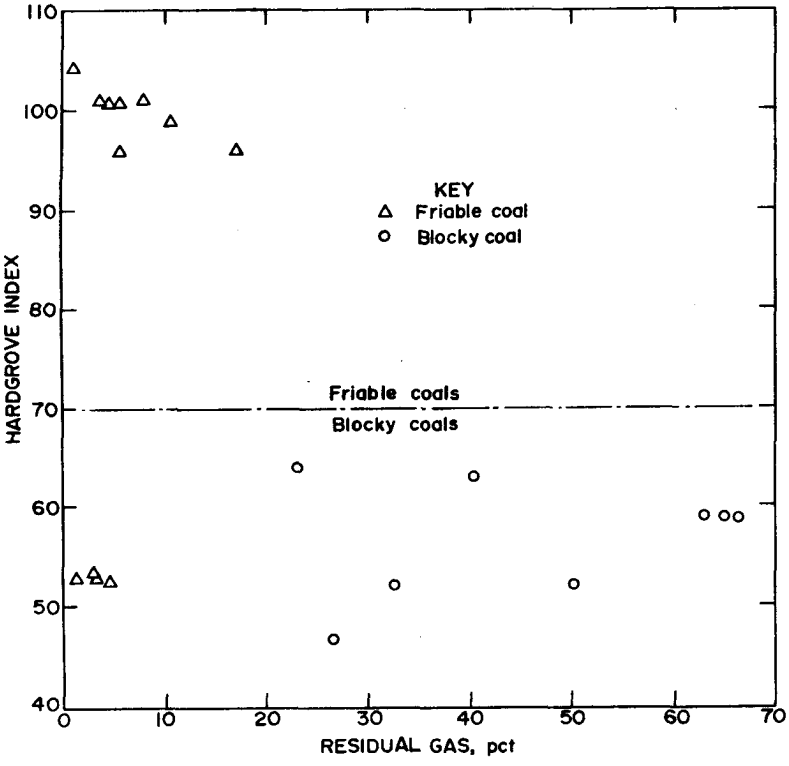

FIGURE 7. - Percent "residual" gas versus Hardgrove index.

easily degraded into small pieces, whereas blocky coals will generally break into larger pieces. Typically, Pittsburgh coal, which is blocky, has a cleat spacing of 1 inch; whereas Beckley coal, which is friable, has a cleat spacing of 1/16 inch. Why coals are friable is not completely understood. Friability appeared to be related to the fixed carbon (fig. 6), Hardgrove grindability index (fig. 7), the depth of the coalbed beneath the surface (fig. 8), and degree of tectonic activity. The fixed carbon percentage appears to be the best indicator of friability. All blocky coals tested had less than 57 pct fixed carbon; all friable coals had more than 57 pct.

The Hardgrove grindability index measures the degree to which a 16- by 30-mesh sample of coal can be pulverized to a fine powder under specific tests conditions (7). It is a reasonably good indicator of friability (fig. 7). Except for Alabama coals, all the Hardgrove grindability indexes were less than 70 for all blocky coals tested and more than 70 for all friable coals tested.

Although depth alone is not a good indicator, it supports the correlation of friability with Hardgrove index and fixed carbon percentage. Most of the blocky coals were from shallow depths, less than 800 feet below the surface, and all of the friable coals were from depths below 600 feet. Some coals, like the Mary Lee coals, behave like friable coals in spite of low Hardgrove indexes and low fixed carbon percent because of the degree of deformation. The Mary Lee coals, obtained from the heavily faulted Warrior Basin, were so badly broken that it was often difficult to recover core samples.

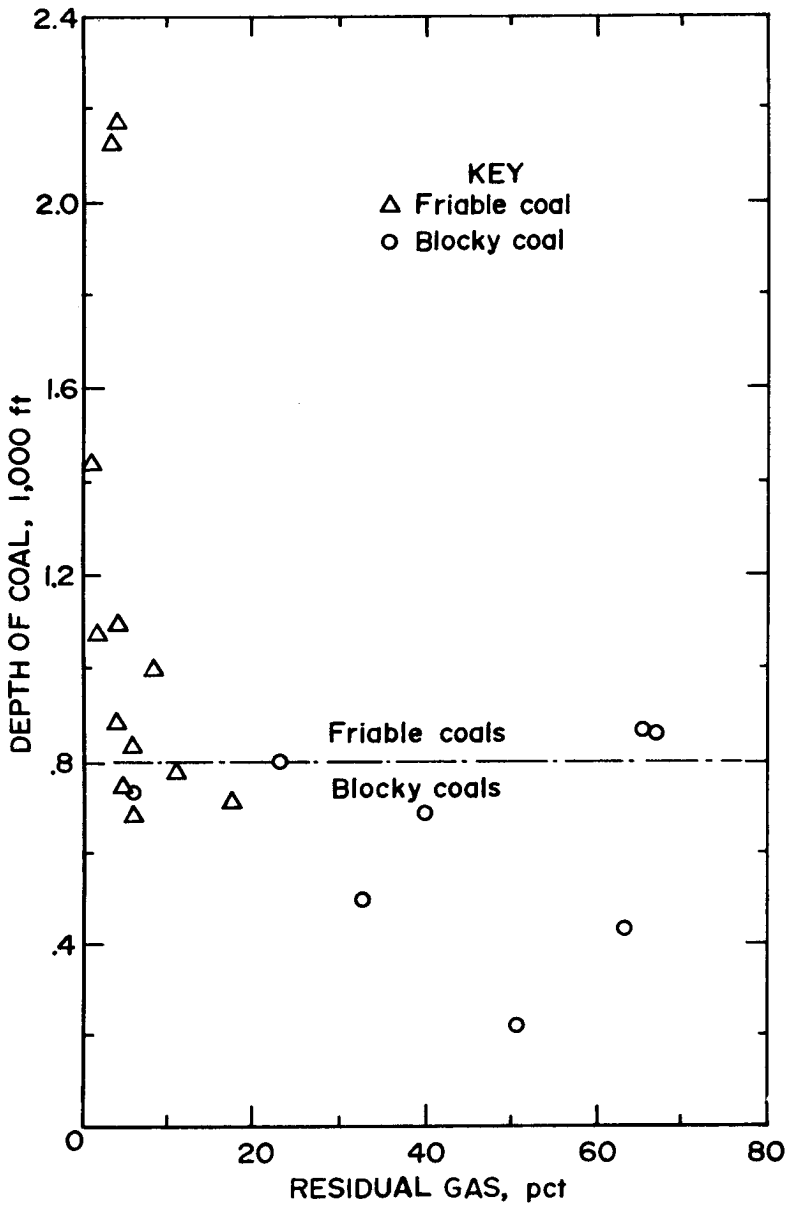

FIGURE 8. - Percent "residual" gas versus depth of coal.

Coalbeds, like the Pittsburgh, known to be blocky may well have different characteristics at greater depth, and one must be prepared to deal with transitional zones in coalbeds occurring in widely different terrains. A friable Pocahontas coal may be friable even under very little cover. The relationships discussed here are best applied where the friable or blocky nature of the coal is well defined; where there is no clear definition, the "residual" gas will be best determined in the laboratory.

Having determined whether the coal is blocky (lower line, fig. 5) or friable (upper line, fig. 5), add the quantities of "lost" and desorbed gas and find the point on the Y axis that corresponds to this sum. Follow this line over until it intersects the corresponding friable or blocky line on the graph. The quantity of "residual" gas can then be read directly on the X axis. For example, if a sample of a friable coal desorbed 8,000 cm^3 gas, and 500 cm^3 was lost, the total of 8,500 cm^3 is found on the Y axis. This is projected horizontally to the friable line and from there vertically to the X axis to read 500 cm^3 "residual" gas. All the samples previously measured by the direct method (6) were checked against the graphically determined values. With the graph, the total gas was estimated with an accuracy of about ±11 pct for the blocky and about ±4 pct for the friable coals.

APPLICATION OF DIRECT METHOD

The sum of "lost" gas, desorbed gas, and "residual" gas yields the total gas content of a coal sample. The gas content in cubic centimeters per gram

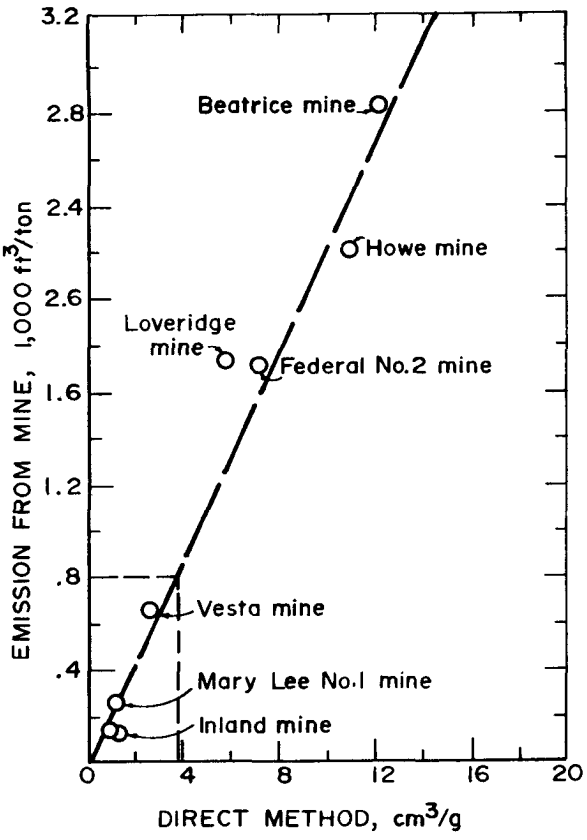

FIGURE 9. - Gas content of coal versus actual mine emission, adapted from reference 6.

may be converted to cubic feet per ton using the conversion factor of 32. For example, 5 cm^3/g is equal to 160 ft^3/ton.

The total methane content of any coalbed area can be calculated by multiplying the total tonnage estimated for that area by the methane content per unit weight determined by the direct method. This is useful for resource evaluation where the methane may be recovered or for estimating ventilation requirements for mines (fig. 9).[8] These data indicate that the methane emitted from a mine can be estimated using the results of the direct method. The methane emission from a mine in cubic feet per ton of coal mined is greater than the calculated cubic feet of methane per ton of coal in place. This is because the rib and face coal, roof, floor, pillars, gob areas, and old workings all give off gas in addition to small amounts of gas emitted from the extracted coal (7).

In figure 9, cubic feet of methane emitted per ton of coal mined is plotted versus the methane content of the sample. The correlation is good for mines that are large and deep, have a sustained coal production of at least several thousand tons a day, and have been in operation for a number of years. New mines emit less methane per ton of coal mined than older mines with extensive old workings and gob areas that still bleed gas. Hence an estimate using figure 9 may be too high for a new mine, but after the mine has been worked for some time, the emission will approach the relationship in figure 9.

CONCLUSIONS

It has been shown that the methane content of a virgin coalbed can be estimated in the field using simple, low-cost equipment. The "residual" gas can be evaluated graphically instead of by the complicated laboratory procedure used previously. The graphic method gives an acceptable level of accuracy provided that a distinction is made between friable and blocky coals. Friable coals tend to have a higher gas content and to emit gas more quickly than blocky coals. Whether coal is blocky or friable correlates with depth of burial, rank, cleat spacing, and proximity of tectonic disturbances.

[8]Taken from BuMines RI 7767, for more complete discussion see RI 7767.

Based on the calculated methane content/unit weight, the total gas content of the coalbed for a mine property can be estimated. Additionally, an estimate may be made as to the amount of gas that a mature mine may be expected to emit. These figures may be used to design a suitable ventilation system for a given mine or to establish the need for degasification in advance of mining.

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APPENDIX A.--DESCRIPTION OF EQUIPMENT

One of the main advantages of the modified "direct" method is the simplicity of the equipment. All that is needed is an airtight container that can withstand up to 30 lb/in^{2}g, a valve fitting for the container, flexible tube, graduated cylinder, ring stand, clamp, and pan. This can all be built or bought for about $50 and can be used repeatedly.

In the Bureau experiments, containers were fabricated from 4-inch aluminum pipe. The bottom of the pipe was sealed shut. A flange was welded to the top, and a lid was sealed on with an O-ring in the flange. The lid was also equipped with a gage and a valve. The container was checked at a pressure of 30 lb/in^{2}g for several days to make sure there were no leaks. A standard needlepoint valve was used with a sealing cap above the valve on the stem.

Any flexible tubing can be used to run from the valve stem to the graduated cylinder that is filled with water and inverted in a pan approximately 2 inches deep. The cylinder (250, 500, or 1,000 ml) is held 3/4 to 1 inch above the base of the pan by a ring stand and clamp (fig. 1). The tube is run into the pan and up into the cylinder. The valve should be opened slowly so that the flow of gas from the container to the cylinder is gradual. The use of plastic cylinders is recommended in the field.

APPENDIX B.--EXAMPLE OF CALCULATIONS FOR A COAL CORE SAMPLE FROM THE PITTSBURGH COALBED, GREENE COUNTY, PA.

1. Coring and Collection of Samples

Coring began at 11:15 a.m.; an NX core barrel (2-1/8-inch ID) was used with water as a drilling medium. At 12:12 p.m., the coal was intersected at a depth of 675 feet. Coring was continued through the coal and finally stopped at 12:28 p.m. At 12:35 p.m., the core started out and at 12:40 p.m., it was on the surface. Two 6-inch pieces were cut from the top and bottom of the core and placed in separate cylinders, which were sealed at 12:52 p.m. From this time onward the emission was monitored.

Since the hole was drilled with water, it is assumed that the coal began giving off gas halfway out of the hole (approximately, 12:37 p.m.). Therefore, the "lost" gas time was (12:52-12:37) 15 min.

(Note: If the core had been drilled with air or mist the "lost" gas time would have been (12:52-12:12) 40 min.)

Sample weight = (cannister + sample) weight - canister weight = 1,382 grams of coal.

2. Desorption of the Coal in the Container

Gas was released from the container about every 15 min for the first few hours, and then once a day for 34 days until the emission rate per day had fallen below 0.05 cm^3/g for 5 consecutive days. At this time, 3,603 cm^3 of gas had been desorbed (table B-1).

3. Calculation of "Lost" Gas (fig. B-1)

Since the "lost" gas time was 15 min, the first measurement of zero is at $\sqrt{15} = 3.87$ $(min^{1/2})$. Fifteen minutes later the valve was opened and 92 cm^3 of gas released. Therefore, the second point is at $\sqrt{15+15} = 5.48$ $(min^{1/2})$ and 92 cm^3. Fifteen minutes later, 84 cm^3 of gas were released. The third point is, therefore, at $\sqrt{15+15+15} = 6.71$ $(min^{1/2})$ and at 92+84 = 176 cm^3. A table of all points used in the "lost" gas graph (fig. B-1) appear in table B-2. The graph shows a quantity of 240 cm^3 "lost" gas.

4. Calculation of "Residual" Gas

Desorbed gas + "lost" gas = 3,603+240 = 3,843 cm^3. This point is found on the Y axis of figure 5, taken over to the blocky coal line and read down to the X axis as 2,450 cm^3 of "residual" gas. The sample was actually crushed and released 1,617 cm^3 "residual" gas. This difference of 833 cm^3, 15 pct of the total, is relatively large but acceptable.

5. Final Results

Total gas = "lost" gas + desorbed gas, + "residual" gas = 240 + 3,603 + 1,617 = 5,460 cm^3, and total gas/sample weight = $\frac{5,460}{1,382} = 3.95$ cm^3/g. Using the conversion factor of 32, this represents 126 ft^3/ton for a virgin coalbed. Based on figure 9, this would correspond to 800 ft^3 of gas per ton of coal mined, and a mine producing 2,000 tons of coal per day would require ventilation for 1.8 $MMft^3$ of gas.

TABLE B-1. - Pittsburgh coalbed, Greene County, Pa.

Started coring coal..... 12:12 p.m.
Started out of hole..... 12:35 p.m.
Began giving off gas..... 12:37 p.m.
Core at surface..... 12:40 p.m.
Core in canisters..... 12:50 p.m.
Weight of sample.....grams.. 1,382

Date	Time	Gas released, cm^3		Emission rate, $cm^3/g/day$	Total gas, cm^3
04-17	1:05 p.m.	92		-	92
	1:20 p.m.	84		-	176
	1:35 p.m.	34		-	210
	1:50 p.m.	36		-	246
	2:05 p.m.	40		-	286
	2:20 p.m.	33		-	319
	4:00 p.m.	232		1,202	551
04-18	10:15 a.m.	670		485	1,221
04-19	8:10 a.m.	300	375	271	1,521
	3:45 p.m.	75			1,596
04-20	No reading	-		-	1,596
04-21	No reading	-		-	1,596
04-22	8:30 a.m.	508		[1]123	2,104
04-23	8:00 a.m.	158		[1]114	2,262
04-24	11:10 a.m.	83		60	2,345
04-25	8:00 a.m.	64		46	2,409
04-26	8:40 a.m.	124		90	2,533
04-27	No reading	-		-	2,533
04-28	No reading	-		-	2,533
04-29	8:15 a.m.	330		[1]80	2,866
04-30	8:40 a.m.	123		89	2,989
05-01	3:25 p.m.	90		65	3,079
05-02	9:45 p.m.	0		0	3,079
05-03	3:20 p.m.	55		40	3,134
05-04	No reading	-		-	3,134
05-05	No reading	-		-	3,134
05-06	3:09 p.m.	56		[1]14	3,190
05-07	No reading	-		-	3,190
05-08	2:45 p.m.	140		[1]51	3,330
05-09	No reading	-		-	3,330
05-10	2:10 p.m.	90		[1]33	3,420
05-11	No reading	-		-	3,420
05-12	No reading	-		-	3,420
05-13	10:30 a.m.	133		[1]32	3,553
05-14	8:30 a.m.	50		36	3,603
Desorbed gas.....cm^3..					3,603
"Lost" gas.....cm^3..					240
"Residual" gas.....cm^3..					1,617
Total.....cm^3..					5,460
Gas content of coal.....cm^3/g..					3.95

[1]Average reading. See footnote 5 in text.

TABLE B-2. - Data for "lost" gas graph

"Lost" gas time:

Placed in canister	12:52
Began emission	12:37
Minutes	15

Reading	Time	Time since placed in can, min	$\sqrt{\text{Time in can+15}}$ ($\text{min}^{1/2}$)	Gas released, cm^3	Total gas, cm^3
1	12:50	0	3.87	0	0
2	1:05	15	5.48	92	92
3	1:20	30	6.71	84	176
4	1:35	45	7.75	34	210
5	1:50	60	8.66	36	246
6	2:05	75	9.49	40	286
7	2:20	90	10.25	33	319
8	4:00	190	14.32	232	551

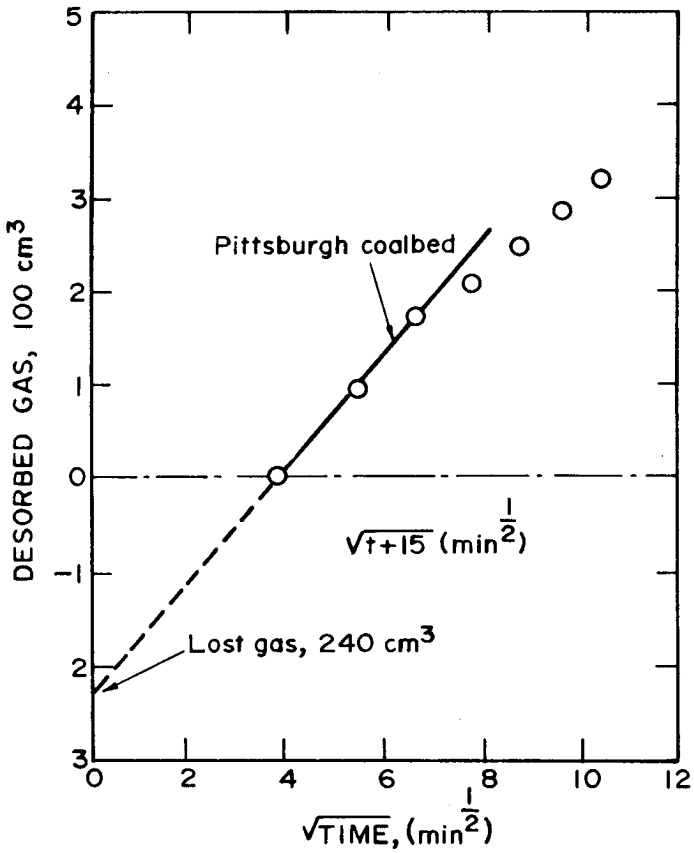

FIGURE B-1. - "Lost" gas curve for Pittsburgh coalbed sample.

APPENDIX C.--"LOST" GAS CHARTS FOR COAL CORE SAMPLES

Figure C-1 presents the "lost" gas emission curves for samples from the Mary Lee, Beckley, Blue Creek, and Pittsburgh coalbeds. Figure C-2 presents the "lost" gas emission curves for samples from the New Castle, Blue Creek, Pittsburgh, and Beckley coalbeds. Figure C-3 presents the "lost" gas emission curves for samples from the Pittsburgh and Hartshorne coalbeds. Figure C-4 presents the "lost" gas emission curves for the samples from the Illinois No. 6, Pocahontas No. 3, Illinois No. 5, and Castlegate coalbeds. Figure C-5 presents the "lost" gas emission curves for samples from the Pond Creek, Beckley, and Sewell coalbeds.

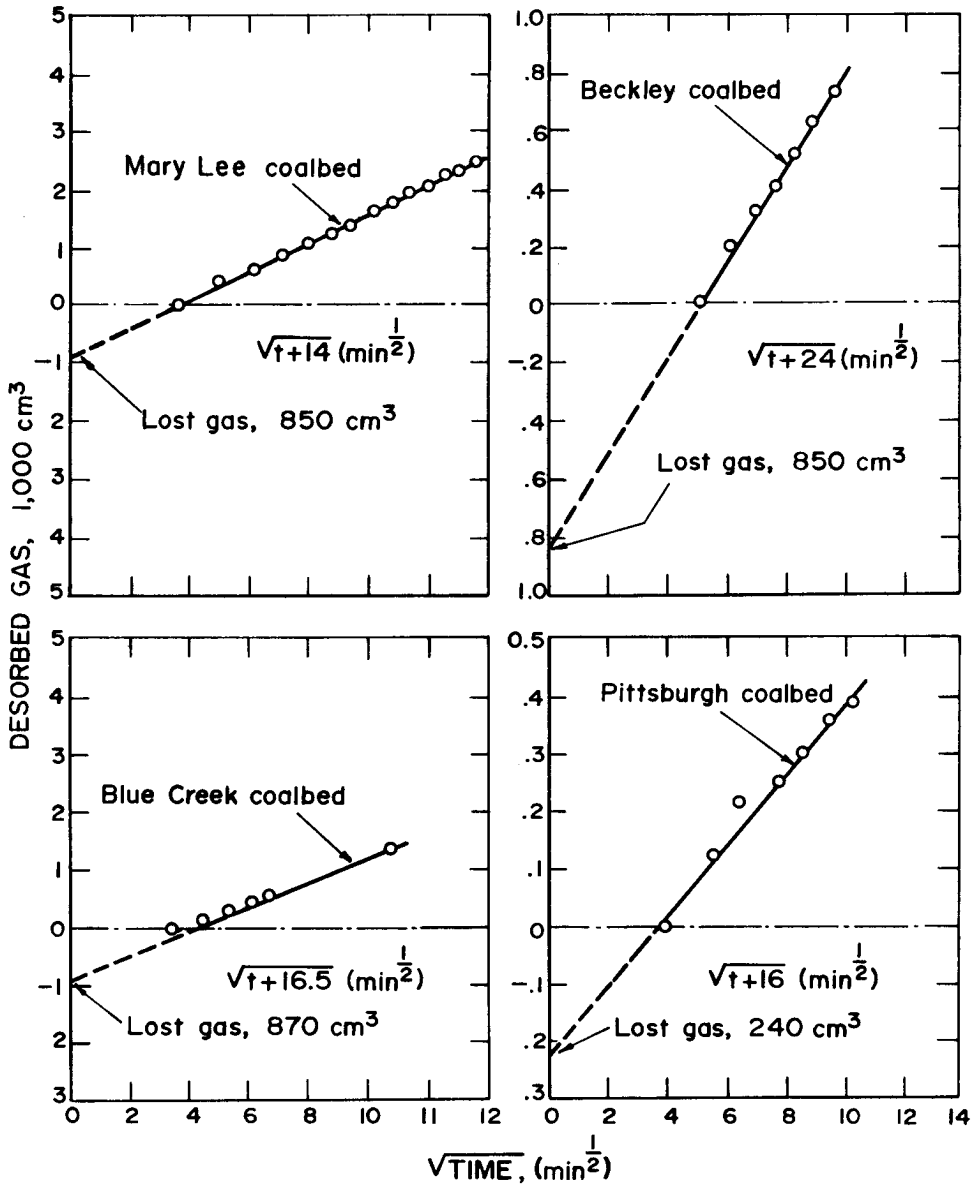

FIGURE C-1. - "Lost" gas emission curves: Samples from the Mary Lee, Beckley, Blue Creek, and Pittsburgh coalbeds.

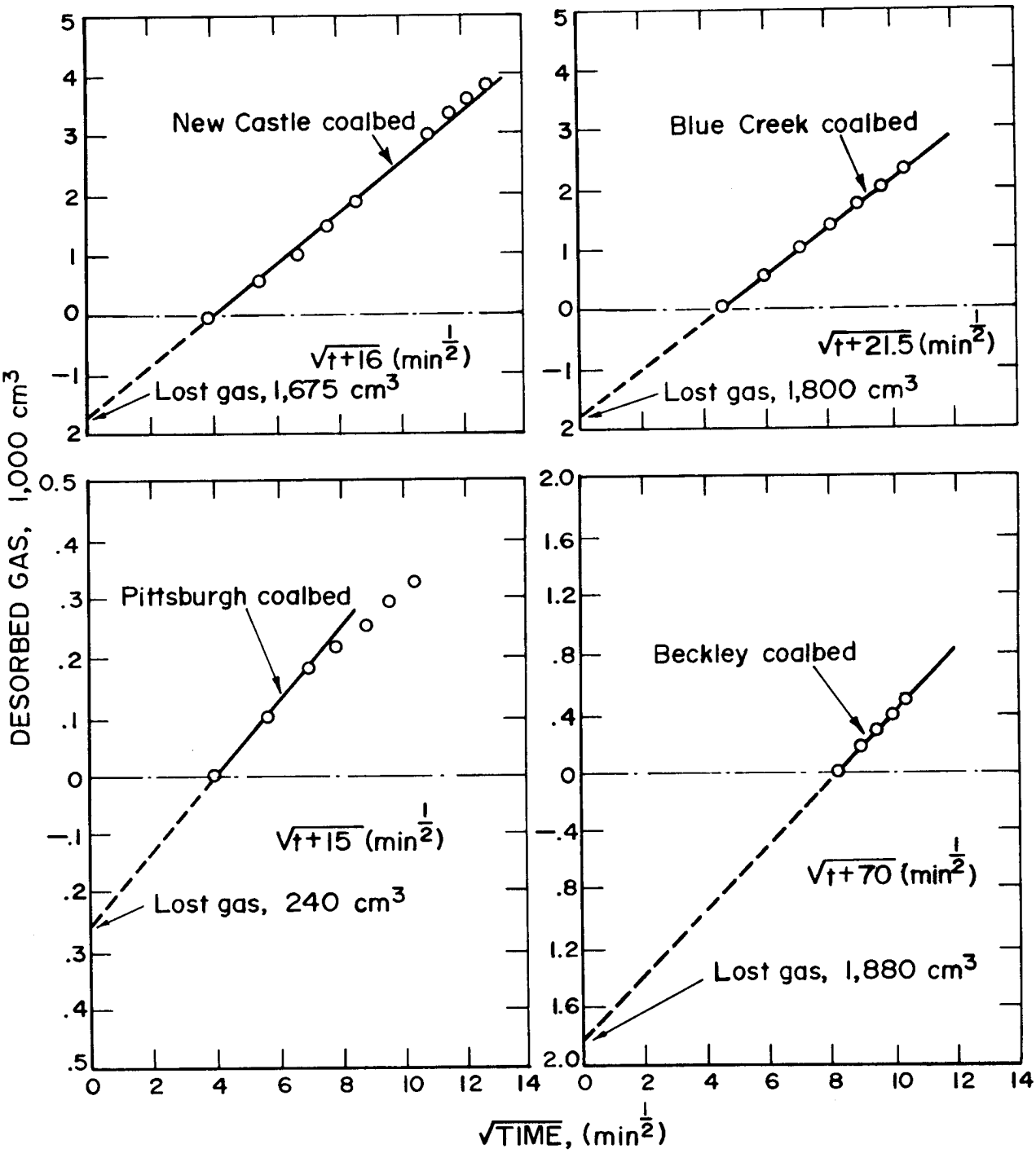

FIGURE C-2. - "Lost" gas emission curves: Samples from the New Castle, Blue Creek, Pittsburgh, and Beckley coalbeds.

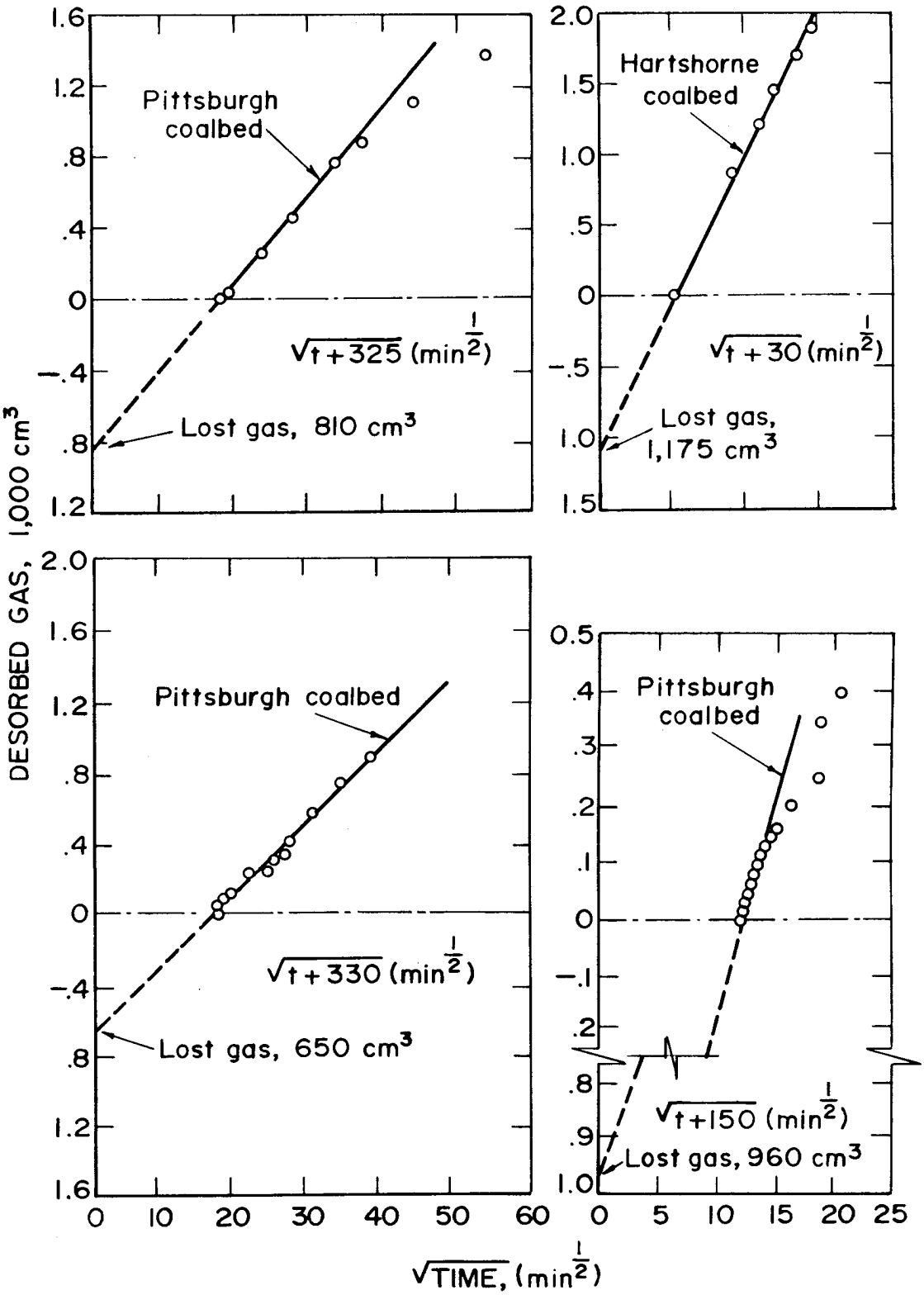

FIGURE C-3. - "Lost" gas emission curves: Samples from the Pittsburgh and Hartshorne coalbeds.

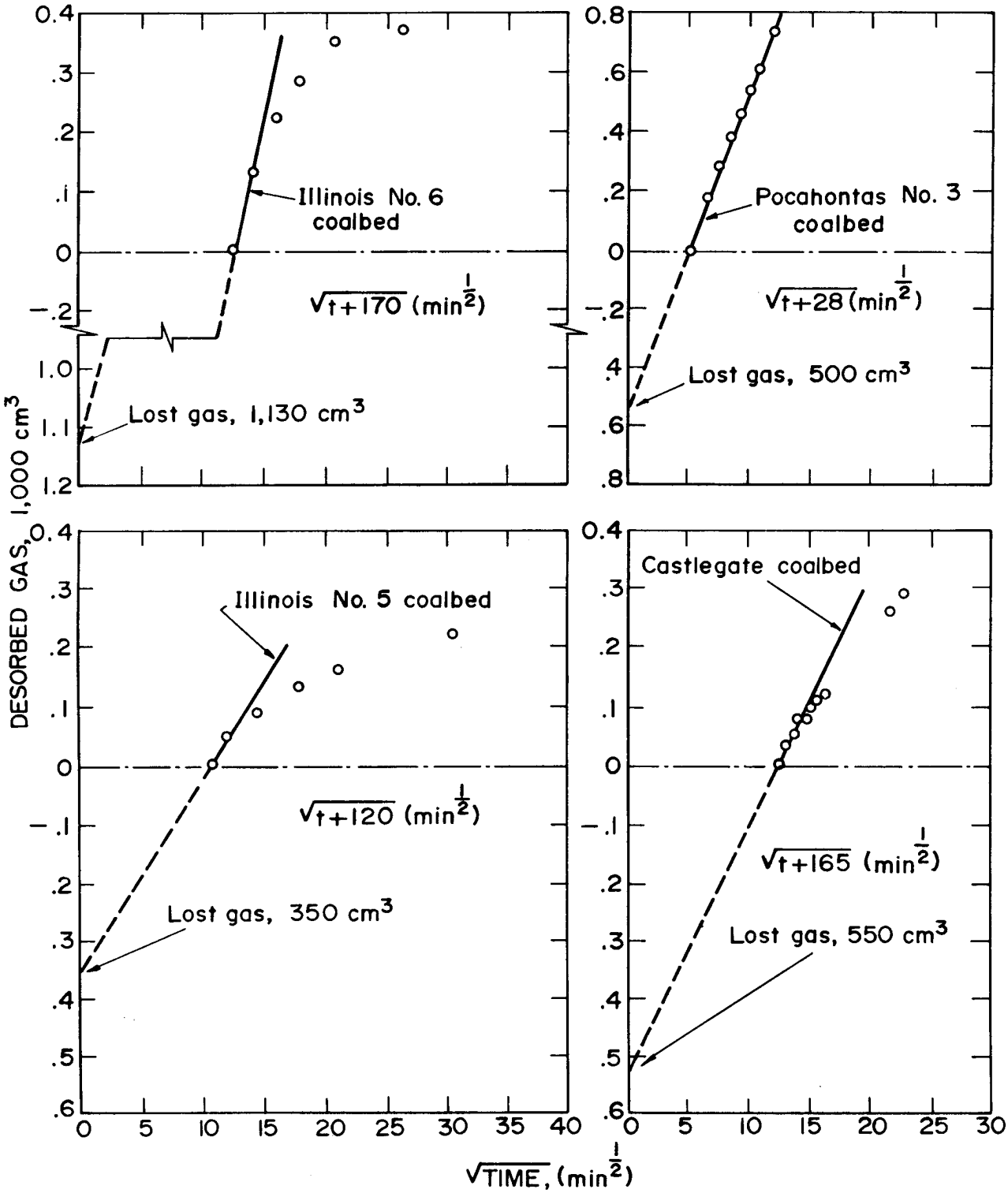

FIGURE C-4. - "Lost" gas emission curves: Samples from the Illinois No. 6, Pocahontas No. 3, Illinois No. 5, and Castlegate coalbeds.

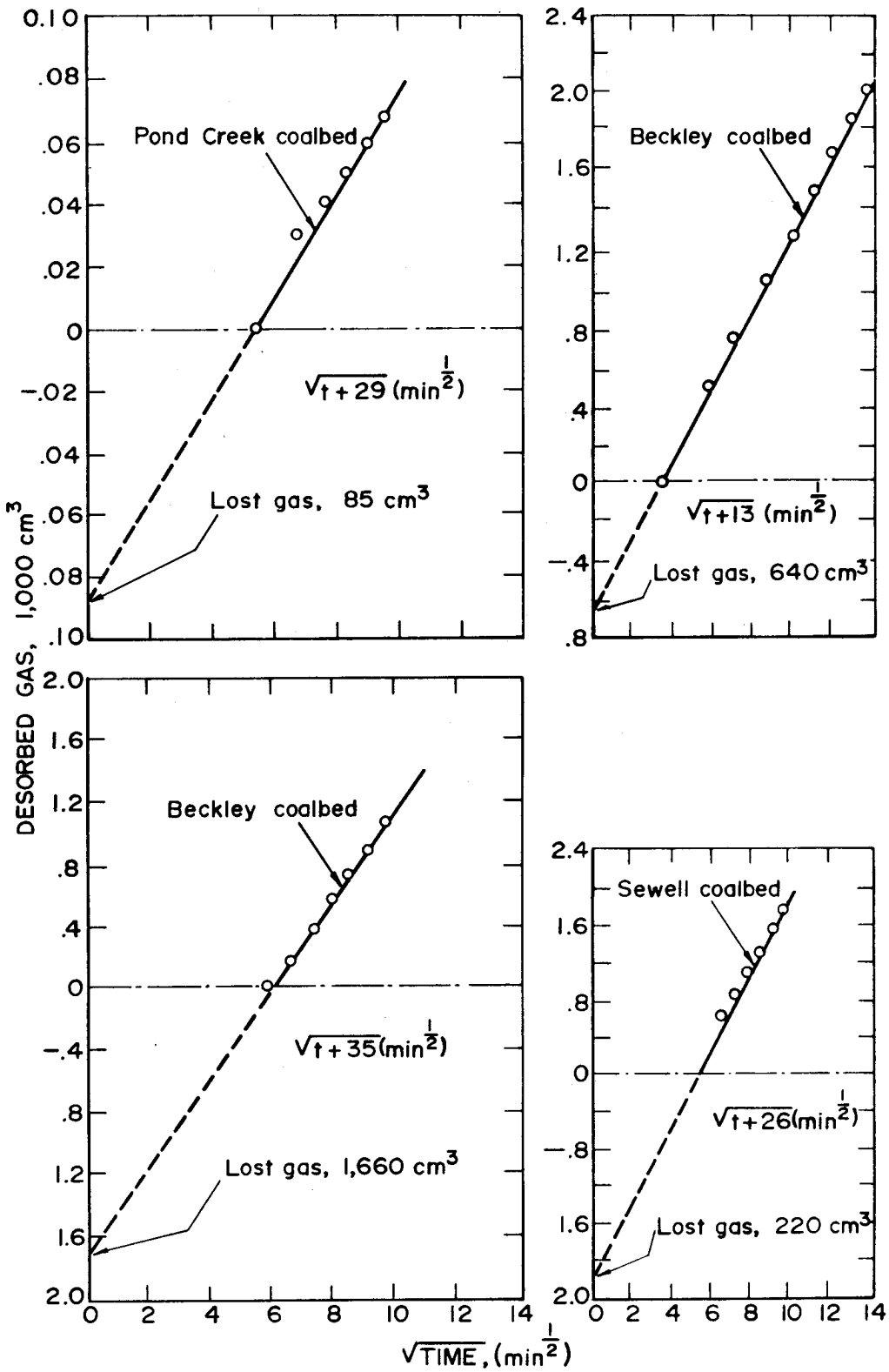

FIGURE C-5. - "Lost" gas emission curves: Samples from the Pond Creek, Beckley, and Sewell coalbeds.

APPENDIX D.--DATA ON DEGASIFICATION SAMPLES

Coalbed	Location	Depth of sample, feet	Gas content, cm^3/g
Blocky coals:			
Pittsburgh.....	Washington County, Pa.....	427	2.93
Do.....	Marion County, W. Va.....	850	6.50
Do.....	.....do.....	850	6.57
Do.....	Greene County, Pa.....	675	3.95
Do.....	.....do.....	675	6.50
Castlegate No. 3....	Carbon Fuel Co., Utah.....	1,016	4.69
Illinois No. 5.....	Jefferson County, Ill.....	793	.98
Illinois No. 6.....	.....do.....	733	1.92
Pond Creek.....	Pike County, Ky.....	500	1.28
Do.....	.....do.....	150	.70
Friable coals:			
Sewell.....	Raleigh County, W. Va.....	680	9.34
Beckley.....	.....do.....	990	12.55
Do.....	.....do.....	875	14.13
Do.....	.....do.....	830	15.36
Do.....	.....do.....	740	13.71
Mary Lee.....	Tuscaloosa County, Ala....	1,076	6.55
Blue Creek.....	.....do.....	2,185	16.24
Do.....	.....do.....	1,099	13.56
New Castle.....	.....do.....	2,137	16.42
Pocahontas No. 3....	Wyoming County, W. Va.....	762	8.90
Do.....	Buchanan County, W. Va....	1,430	13.62

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