423

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Drying and Preheating Coals Before Coking

Part 1. Individual Coals

H. W. Jackman
R. J. Helfinstine

ILLINOIS STATE GEOLOGICAL SURVEY
John C. Frye, *Chief* URBANA

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ABSTRACT

A coal preheater capable of drying and preheating sufficient coal for one complete coal charge to the pilot coke oven has been designed and built in the Illinois State Geological Survey laboratories. Coking tests on high-volatile A, B, and C bituminous coals preheated to a maximum of about 450° F have indicated that preheating consistently reduces coking time and increases the potential coke making capacity of a coke oven. The strength of coke made from the individual high-volatile coals tested is consistently improved by preheating. Similar tests being made on coal blends such as those used commercially to produce metallurgical coke will be described in a subsequent publication.

INTRODUCTION

The demand for metallurgical coke, coupled with high operating and replacement costs of coke ovens, has been responsible for a continuing interest in development of methods to increase the daily throughput of coal in ovens producing coke for blast furnace and foundry uses.

Several ways to accomplish this objective have been proposed, including the construction of tall coke ovens, holding 27 to over 30 tons of coal, as compared with 15 to 18 tons in the average present-day oven. Tall ovens have been developed and used in Europe, and several batteries are under construction or planned in this country and Canada.

Also planned is an increase in the oven coking rate by use of high density silica brick and thinner oven wall shapes, allowing more rapid transfer of heat from oven flues to coal. This combination of dense silica and thinner walls has been shown in experimental ovens to be effective in decreasing coking time with a corresponding increase in coke making capacity per oven (Price and Palumbo, 1965).

Still another way to reduce coking time and increase coke production would be by drying and preheating coal before charging to coke ovens. Although such preheating facilities are not yet available commercially, coke-oven builders are considering how this might be accomplished safely and economically. At least one coke oven battery in the United States has been equipped to preheat coal experimentally, and it is reported that a procedure for partially drying and preheating coal before coking is being developed in Japan (Yoshida, 1967).

When coke producers became aware that coal preheating with significant reduction in coking time might become a commercial possibility, the Illinois State Geological Survey received inquiries regarding the effects of preheating Illinois coals and blends in which they are used. Although the U. S. Bureau of Mines had published valuable information on their experiences with preheating certain coals, including one from Illinois (Smith et al., 1956), it was decided to design and build an experimental preheater with a capacity to dry and preheat sufficient coal for one complete charge for the Geological Survey's 17-inch pilot coke oven (Jackman et al., 1955). Investigations then could be made on the effects of preheating any Illinois coal or coal blend that might be of interest to the Chicago or St. Louis steel industry.

COAL PREHEATER

The coal preheater consists of an enclosed steel cylinder with a conical discharge end, which rotates in an electrically heated oven (fig. 1). The cylinder is 36 inches in diameter, 57 inches in length, including the cone, and has a capacity of about 24 cubic feet. A 700-pound charge of coal at normal moisture occupies slightly more than half the total capacity.

The cylinder, or drum, rests on power-driven rollers within the oven and is rotated at one-half revolution per minute. Eight lifting fins, which are welded to the inside surface of the drum, cause the coal to mix continuously as the hottest coal from near the heated surface is moved toward the center.

Temperature within the heating oven is normally controlled at 500° F. A thermocouple extending into the center of the drum is used as the sensing element to a temperature recorder-controller. The controller cuts off the heat to the oven at any predetermined temperature. The total time required for preheating has varied from $3\frac{1}{2}$ to 7 hours, depending upon the moisture content of the coal and its final temperature.

Coal moisture, which is driven off during the heating period, is released through a pipe extending from the drum and oven. A water seal at the end of the pipe prevents passage of air into the preheating drum if the temperature within the drum should fall and thereby create a partial vacuum. The properties and yields of coke and tar produced have demonstrated that there is little, if any, oxidation of the coals during preheating.

After preheating to the desired temperature, the drum is lifted out of the oven and weighed to determine the percentage weight loss of the coal during preheating. This loss is assumed to be largely water and is subtracted from the original coal moisture to determine the moisture content of the coal as charged to the coke oven. At preheating temperatures above 350° F, this weight loss may exceed the ASTM moisture content of the original coal by 0.5 to 1.5 percent, indicating

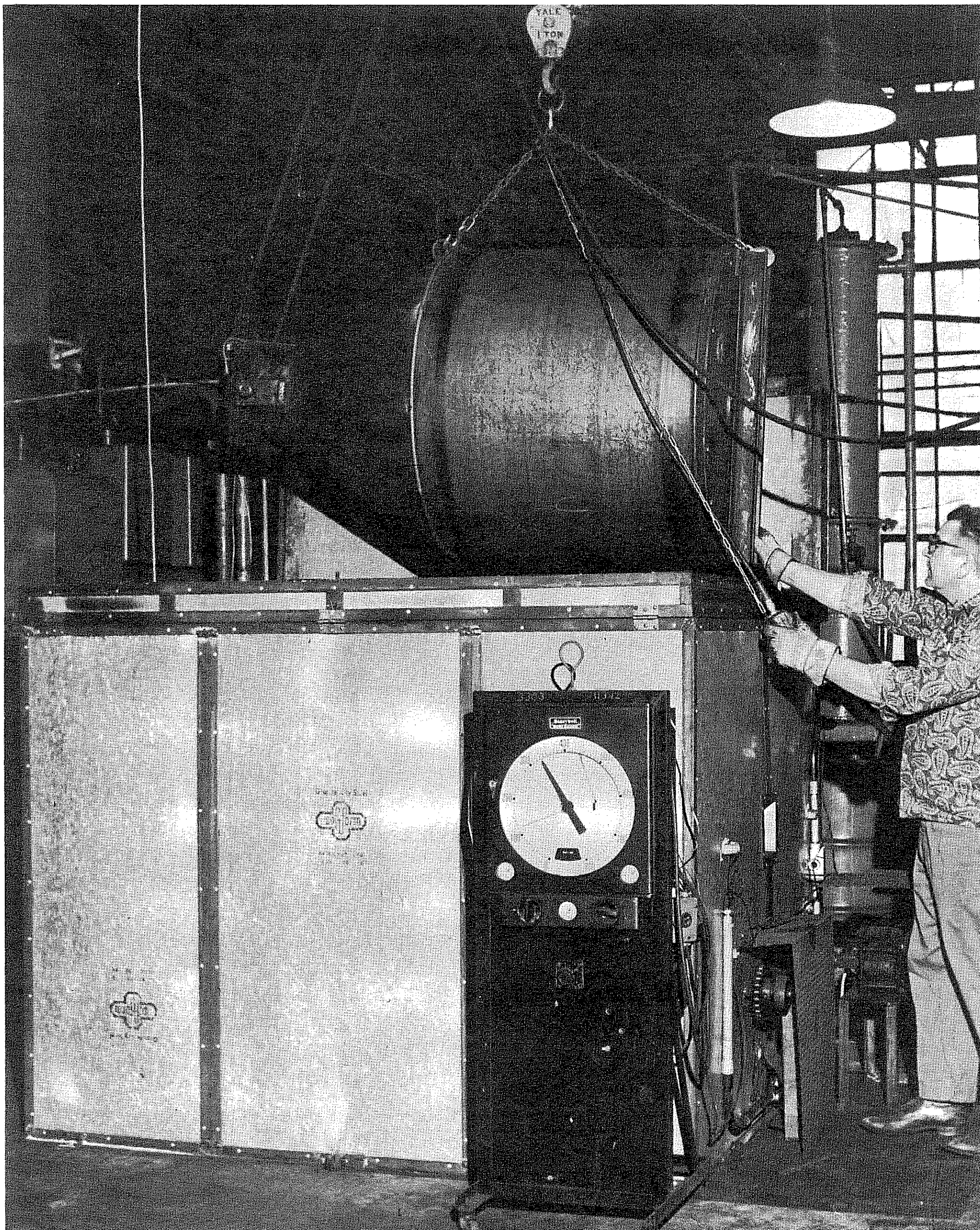

Figure 1 - Coal preheating drum and preheating oven.

some small loss in volatile matter or water of hydration not usually driven off in the ASTM moisture test.

After weighing, the drum of preheated coal is suspended over the coal charging hole in the top of the coke oven. A sliding valve is drawn and the coal drops quickly into the oven with little contact with air. The drum is then lifted from the charging hole, and the lid to the charging hole is replaced. The coal in the pilot oven is leveled by hand through the leveling bar hole in the oven door. More coal is charged into the oven than is required to fill to the proper level, and the excess is raked out while leveling and is deducted from the total weight of coal charged.

Acknowledgments

We wish to acknowledge the assistance and cooperation of the coal and coke producers during the construction of the preheater and auxiliary equipment and for their further interest in the investigation by supplying the coals that have been tested. Those companies cooperating include the Bell and Zoller Coal Co., Freeman Coal Mining Corp., Granite City Steel Co., Indiana Gas and Chemical Corp., Inland Steel Co., Interlake Steel Corp., Old Ben Coal Corp., Sahara Coal Co., and Wisconsin Steel Co.

TEST PROGRAM AND COKING PROCEDURES

Five coals have been tested to determine the effects of preheating shown in this report. Included are three high-volatile B bituminous coals and one high-volatile C bituminous coal from Illinois and one high-volatile A bituminous coal from West Virginia. Tests are in progress on blends of high- and low-volatile coals such as are used commercially for metallurgical coke. Test results on blends are not included in this report, but will be discussed in a second publication. All coals tested were washed and prepared at the mines with top size not over 3 inches and bottom sizes ranging from one-quarter inch to zero. Coal analyses are shown in table 1.

Each coal is first coked in the moist condition, as received from the mine. Next, it is air dried at room temperature and coked and tested to determine the effects of this surface drying. A third coking test is made after partially heat drying the coal in the preheater. For this test, the coal is heated to 210° F and is held at this temperature while the drum rotates for 2 hours. These coking tests are followed by others in which the coals are first preheated to approximately 250°, 350°, and 450° F.

All coals are coked at the same oven flue temperature and under identical operating conditions. Changes in the times required to coke and in the physical properties of the cokes are assumed to be due to the increased rate of coking as coal moisture is eliminated and as the temperature of the coal is increased by preheating. Data from coking tests have been plotted and curves drawn to illustrate graphically the effects of drying and preheating.

The pilot coke oven, which is 17 inches in width, holds 675 pounds of coal at normal moisture, having a dry coal bulk density of about 46 pounds per cubic feet. The oven walls, which until recently were built of silicon carbide brick $4\frac{1}{2}$ inches thick, have been replaced with the same thickness of fire clay brick. With

TABLE 1 — ANALYSES OF COALS TESTED[1]

Type	Coal	Moisture (%)	Moisture-free basis				Free-swelling index	Maximum Gieseler fluidity (dial div per min)
			Volatile matter (%)	Fixed carbon (%)	Ash (%)	Sulfur (%)		
High-volatile C bituminous	Ill. No. 6	13.9	44.6	48.0	7.4	2.30	3½	920
High-volatile B bituminous	Ill. No. 5	8.5	36.8	55.6	7.6	1.50	5	103
	Ill. No. 6-A	9.3	39.7	53.0	7.3	1.28	3½	53
	Ill. No. 6-B	10.0	37.9	55.2	6.9	1.02	5	15
High-volatile A bituminous	Eagle	3.2	35.1	61.1	3.8	0.73	9	26,600

[1]Analytical data by the Coal Analysis Laboratory.

this change, the oven is now operated at a constant flue temperature of 2300° F so that coals at normal moisture are coked at a rate of about 1.0 inch per hour. The coking period is considered to be that time from the moment the coal is dropped into the oven until the temperature at the center of the coke bed reaches 1775° F. Coke is then pushed, quenched, dried, sized, and tested. In addition, a continuous record is made of the pressure exerted on the oven walls by the coal during carbonization.

The pilot coke oven is not a precision testing device. The data given should not be considered as an exact measure of performance, because the tests for coke strength, size, and gravity are empirical and adequate sampling is difficult. Therefore, the curves drawn do not always intersect the plotted points, but are meant to show the most probable trends of the properties being determined.

RESULTS

High-volatile C Bituminous Coal from Illinois

It can be assumed that preheated coal cokes rapidly because of less moisture to evaporate and higher coal temperature as charged to the coke oven. It follows that drying and preheating very high moisture coal would cause the greatest reduction in coking time, provided this coal was preheated to the same temperature as other lower moisture coals.

High-volatile C bituminous coal, mined over much of Illinois, is high in moisture. This coal is agglomerating, and much of it is higher in Gieseler fluidity than the high-volatile B bituminous coals from Illinois that are used for metallurgical coke by the steel industry. A C-rank coal, with 13.9 percent moisture, was obtained from an underground mine in the No. 6 Coal in central Illinois. This coal was tested over the range of drying and preheating to determine the maximum reduction in coking time that might be expected from an Illinois coal of this rank and moisture content.

This C-rank coal was prepared for coking tests in the manner described previously. The bulk density of the "as received" coal in the coke oven was 36.8 pounds per cubic foot calculated to the dry basis. Coking by our standard operating procedure required 18 hours and 45 minutes. Subsequent air drying of a portion of this coal by spreading on the laboratory floor overnight reduced the moisture to 11.8 percent. The bulk density of the air-dried coal, when subsequently charged to the coke oven, was increased to 40.4 pounds per cubic foot (dry basis), and the coking time was reduced to 18 hours.

A third portion of this coal, heat dried in the preheater for two hours at 210° F to 11.3 percent moisture, was coked in 17 hours and 10 minutes. Longer drying at this temperature would undoubtedly have driven off more moisture and reduced the coking time still more. Examination of the "Coking Time" curve in figure 2 indicates how further drying would probably have affected coking time.

Following these initial drying studies, the C-rank coal was preheated to constant temperatures of 255°, 360°, and 428° F. In each case, the preheated coal was coked under the same oven temperature conditions. Coking time was reduced consistently to a minimum of 12 hours. This represents a reduction in coking time of 6 hours and 45 minutes, or 36.0 percent. Considering this decrease in coking time and the increase in bulk density due to removal of surface moisture, it was computed that an oven battery operated on this coal preheated to this temperature could produce 79 percent more furnace size coke than when operated on "as received" coal.

Complete coking results of this series of tests are shown in figures 2 and 3, and in table A of the Appendix. Dry coal bulk density remained between 40 and 42 pounds over the entire preheating range, expansion pressure was affected only slightly, and coke strength was increased consistently at the high preheating temperatures as shown by the tumbler test indices.

In addition, the apparent gravity of the coke was reduced considerably by drying the coal, and it continued to drop at the higher preheat temperatures. Coke size increased as the coking time was reduced, which is contrary to normal coking practice. Furnace coke yield (plus 1-inch size) increased slightly, and the minus 1-inch screenings were reduced. The yield of tar remained practically constant. The fact that coke screenings were reduced and tar yield was not lowered indicates that very little, if any, coal weathering occurred during preheating.

High-volatile B Bituminous Coals from Illinois

A series of coking tests was made on each of three dried and preheated high-volatile B bituminous coals from Illinois. One was a No. 5 Coal and the other two No. 6. All of these coals are used commercially in blends for metallurgical coke. All are mined in the southern Illinois low-sulfur area, and all showed similar coking trends when preheated and coked in the Geological Survey pilot oven. In this report, these No. 6 coals are identified as No. 6-A and No. 6-B.

Coking results with the Illinois No. 5 Coal are shown in figures 4 and 5 and in table B of the Appendix. Bulk density in the coke oven is seen to increase with air drying, and then remain practially constant. Coking time of the air-dried coal increased from 16 hours and 15 minutes to 17 hours and 15 minutes at this greater bulk density and then dropped to about 12 hours as preheat temperature was increased to 440° F. Expansion pressure increased, but not dangerously, at a low preheat temperature and then remained essentially constant. The coke became stronger at the

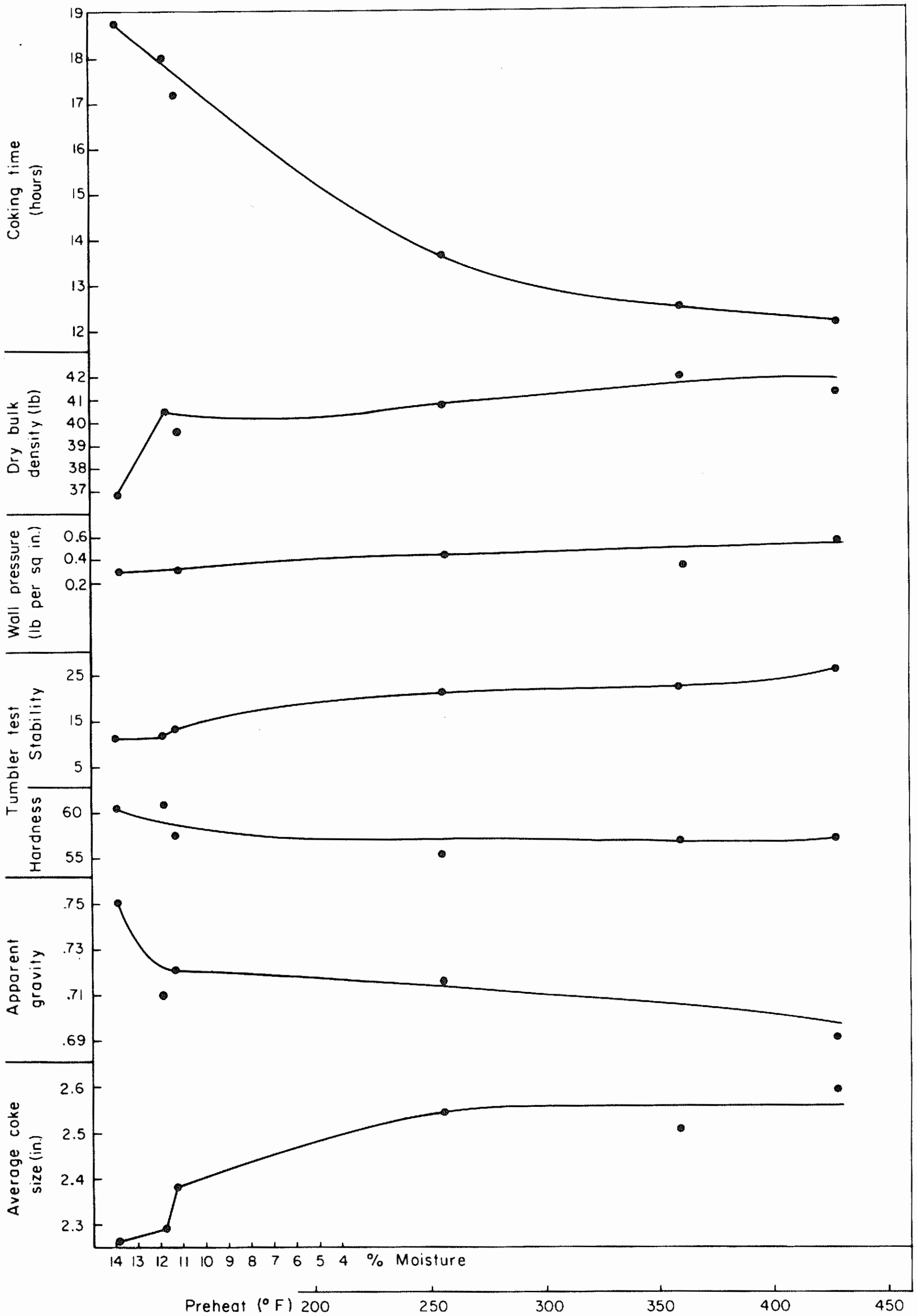

Figure 2 - Results of coking tests on high-volatile C bituminous coal (Ill. No. 6).

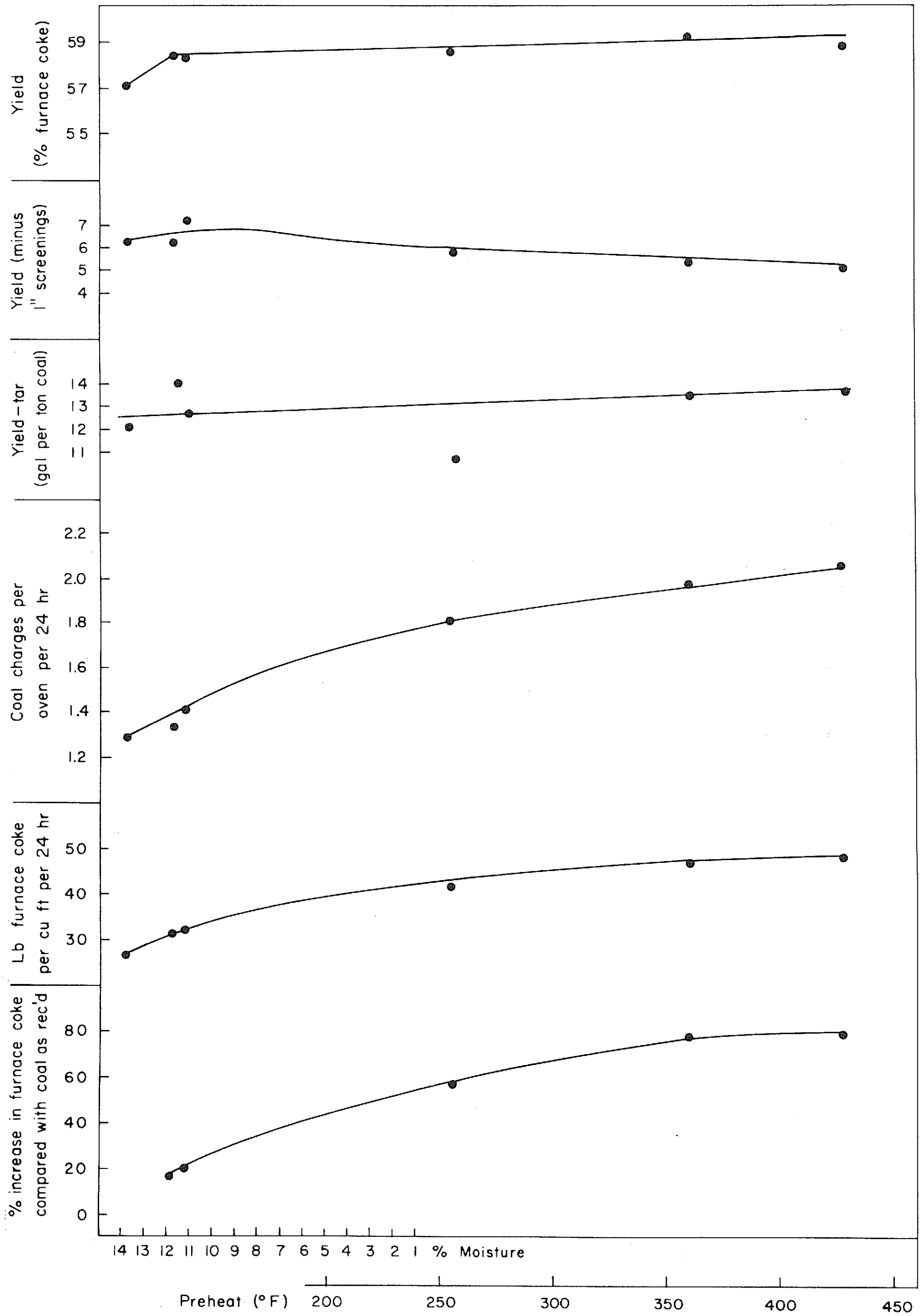

Figure 3 - Results of coking tests on high-volatile C bituminous coal (Ill. No. 6).

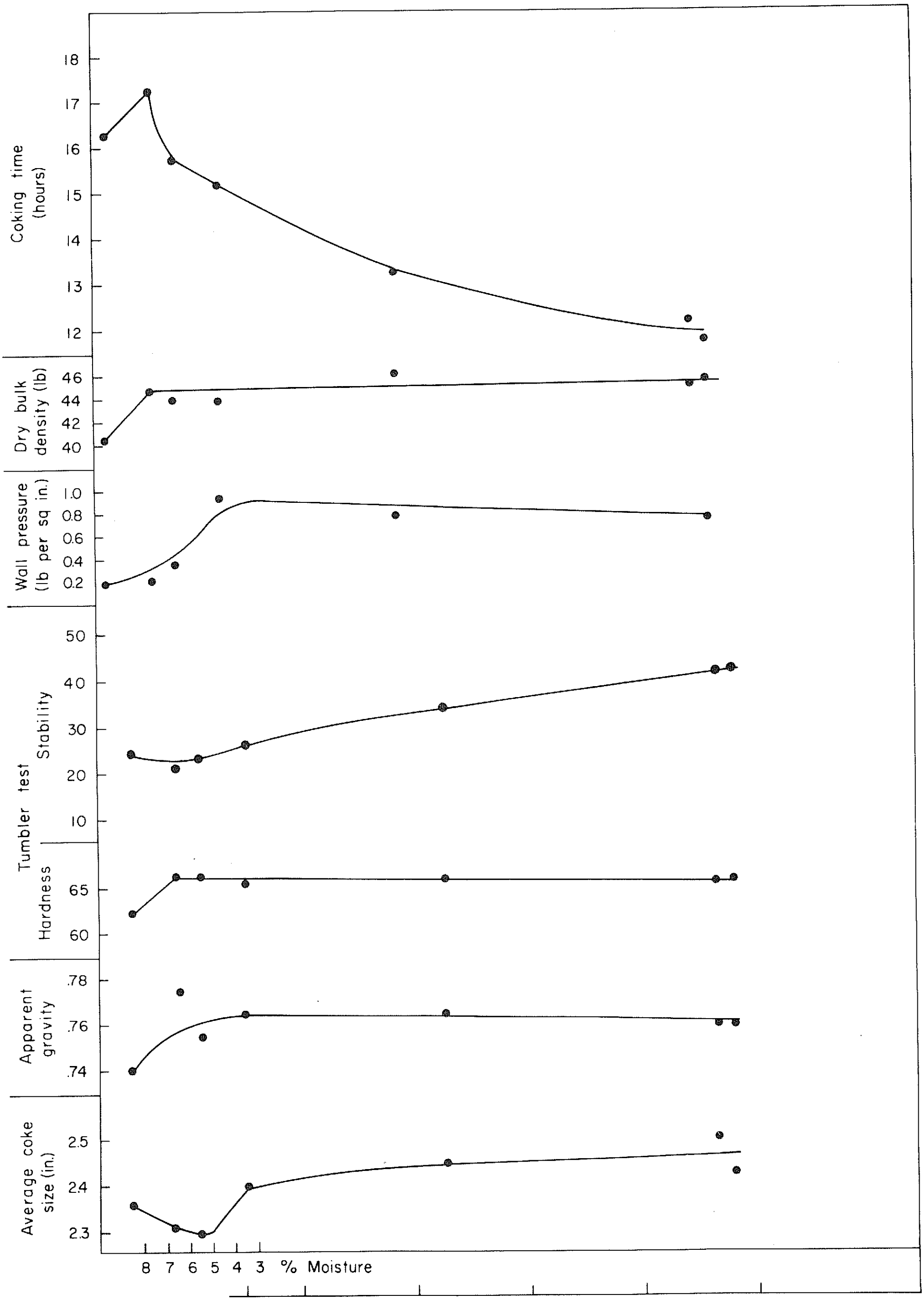

Figure 4 - Results of coking tests on high-volatile B bituminous coal (Ill. No. 5).

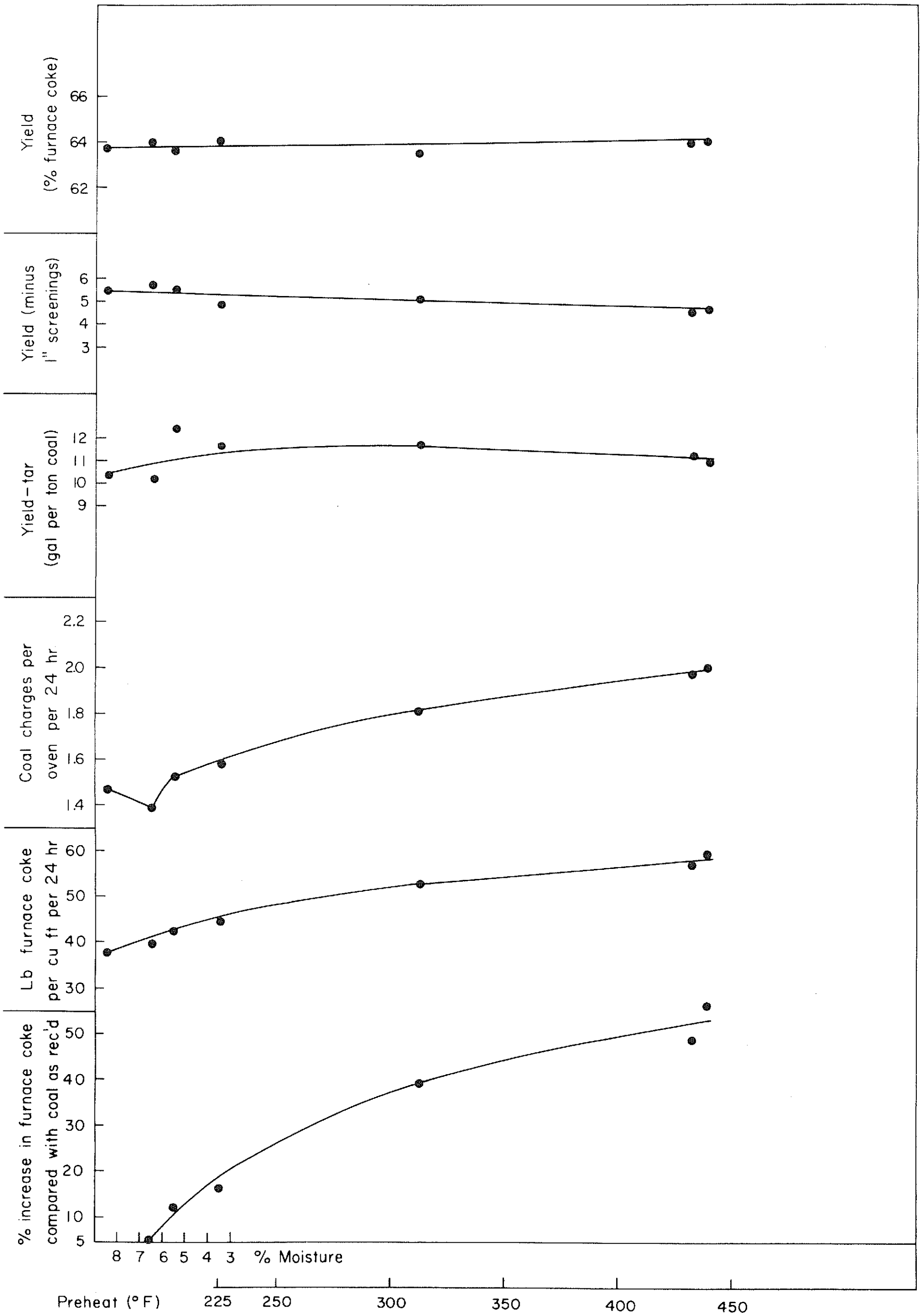

Figure 5 - Results of coking tests on high-volatile B bituminous coal (Ill. No. 5).

faster coking rates, and the average size increased. The apparent gravity of the cokes remained constant after the coal moisture had been largely eliminated.

Here, again, the yield of coke screenings was reduced slightly by preheating and the tar yield remained practically constant, indicating that little or no weathering occurred during preheating. Reduction in coking time and the initial increase in bulk density resulted in a potential increase of 50 percent, or slightly more, in coke production at the highest preheat temperature used.

Drying and preheating studies made with the two Illinois No. 6 Coals gave similar, although not identical, coking results, and these results were also similar to those obtained with the No. 5 Coal. Results of the coking tests are shown in figures 6, 7, 8, and 9 and in tables C and D of the Appendix.

Time required to coke each of the No. 6 Coals was reduced about 7 hours by preheating to 450° F. Dry bulk density of the coals in the coke oven remained essentially constant after air drying and removal of surface moisture. Expansion pressures exerted on coke oven walls were increased slightly with No. 6-A Coal and considerably with the No. 6-B Coal. However, at no time did this wall pressure exceed 1.55 pounds per square inch. Coke strength and size were increased as the coals were coked more rapidly, and the specific gravity of the cokes tended to increase at the highest preheat temperature. Coke screenings were decreased, and coke oven capacity was increased approximately 75 percent.

High-volatile A Bituminous Coal

For comparison with the Illinois coals, a strongly coking high-volatile A bituminous coal from the Eagle seam in West Virginia was tested in the same manner as the higher moisture Illinois coals. This Eagle coal contained only 3.2 percent moisture as received, which was reduced by air drying to 2.0 percent. As with the Illinois coals, it was heat dried at 210° F, and subsequently preheated over the range 300° to 440° F before coking.

Due in part, at least, to its low moisture content, this A-rank coal in the "as received" condition was coked in less than 15 hours. Air drying to remove surface moisture caused the dry bulk density to increase from 44 to 48 pounds per cubic feet and caused the coking time to increase to 16 hours and 15 minutes. Heat drying and subsequent preheating reduced the coking time to a minimum of 12 hours, as with the B- and C-rank Illinois coals. Compared with the "as received" coal, this reduction in coking time was only 2 hours and 50 minutes. Expansion pressure increased very little.

The tumbler stability index of the Eagle seam coke was fairly high at 44 when coking the "as received" coal. This increased consistently to a maximum of 52 when the coal was preheated to 435° F. Coke screenings decreased slightly, and the tar yield remained essentially constant. The potential coking capacity of the coke oven increased consistently as the preheat temperature was raised but showed only a 27 percent increase at 435° F preheat. Coking results are shown in figures 10 and 11, and in table E of the Appendix. It is interesting to note that this Eagle seam coal, when preheated to 435° F and coked by itself, produced coke having a tumbler stability index in the range of that required for metallurgical coke.

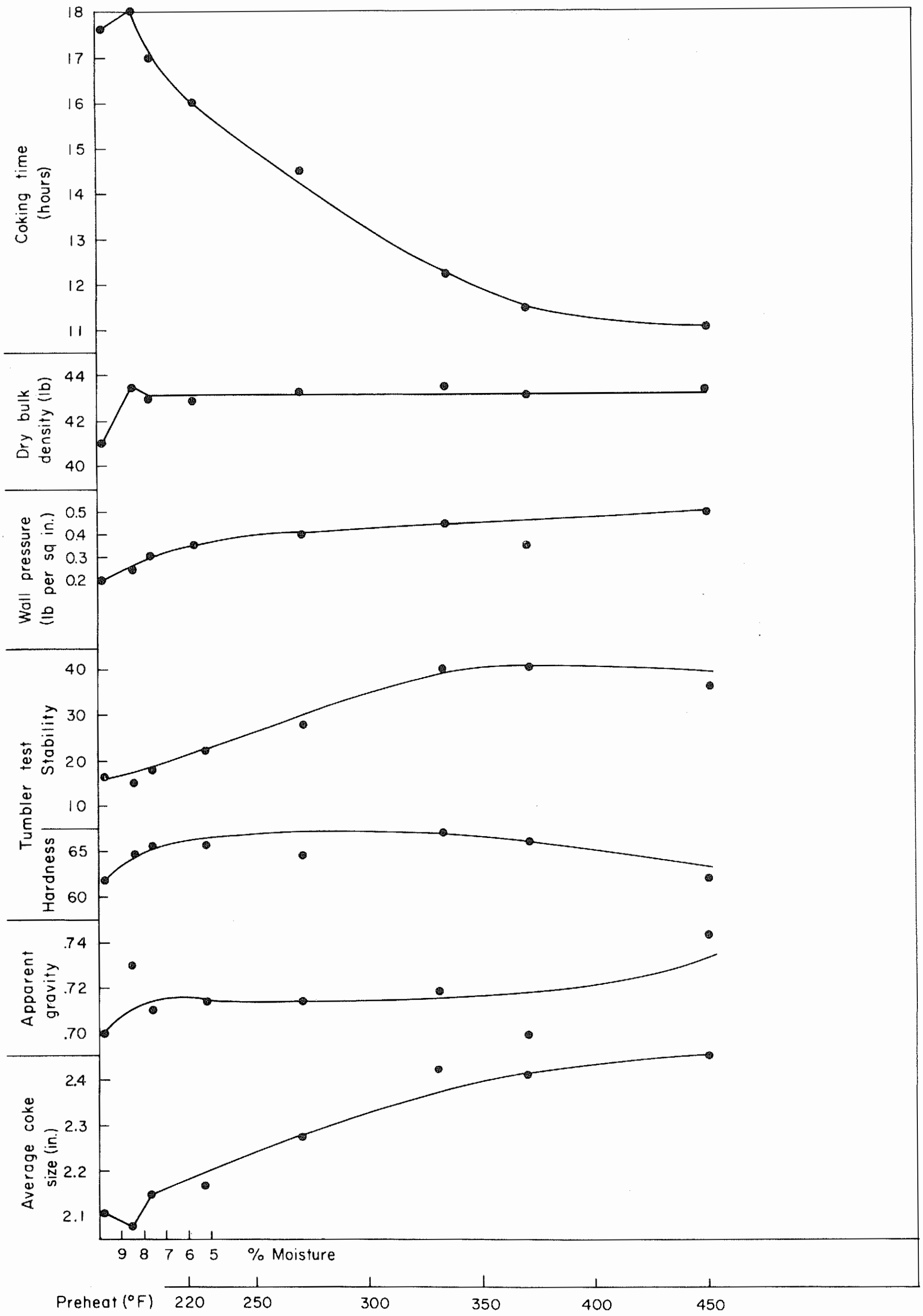

Figure 6 - Results of coking tests on high-volatile B bituminous coal (Ill. No. 6-A).

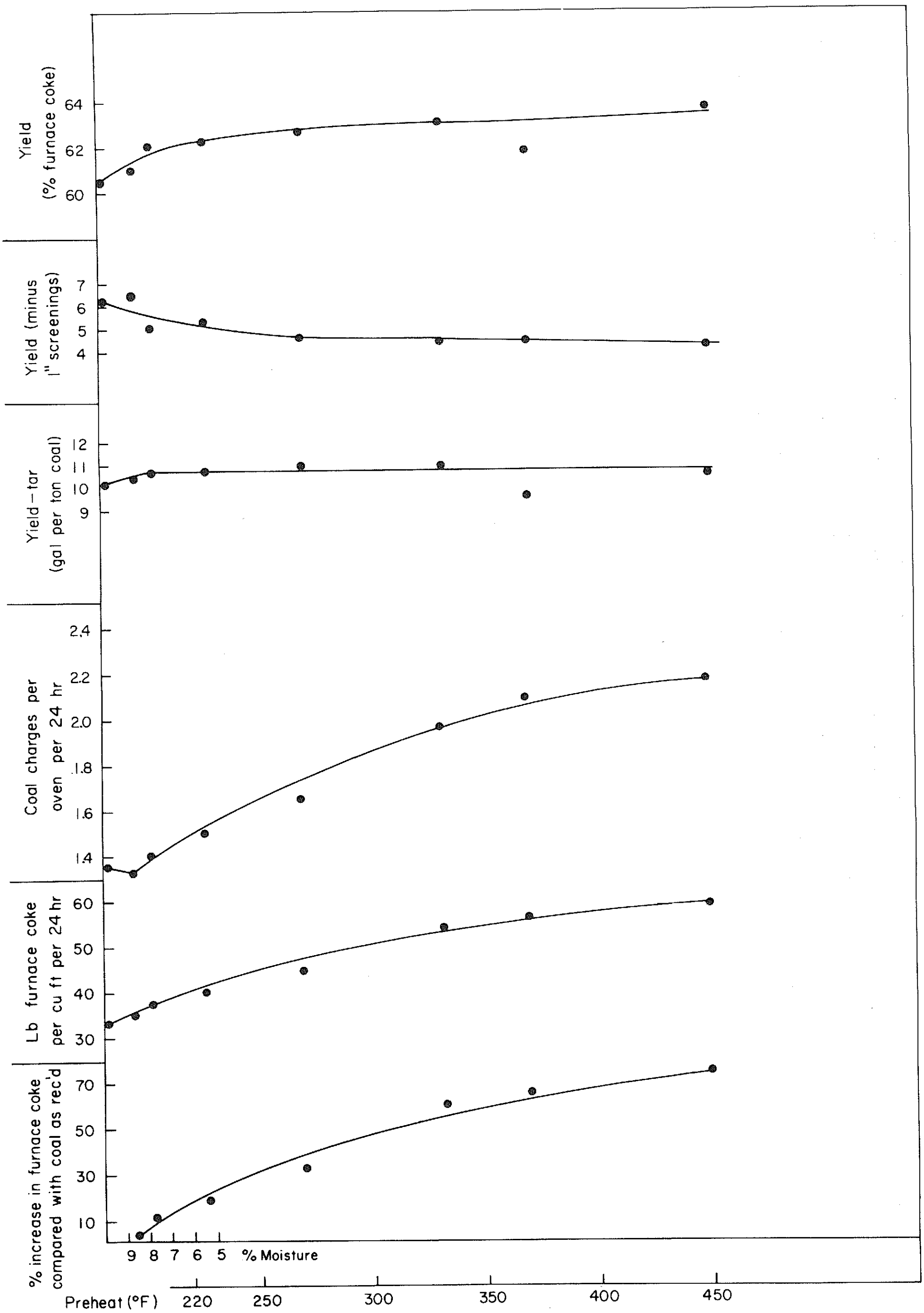

Figure 7 - Results of coking tests on high-volatile B bituminous coal (Ill. No. 6-A).

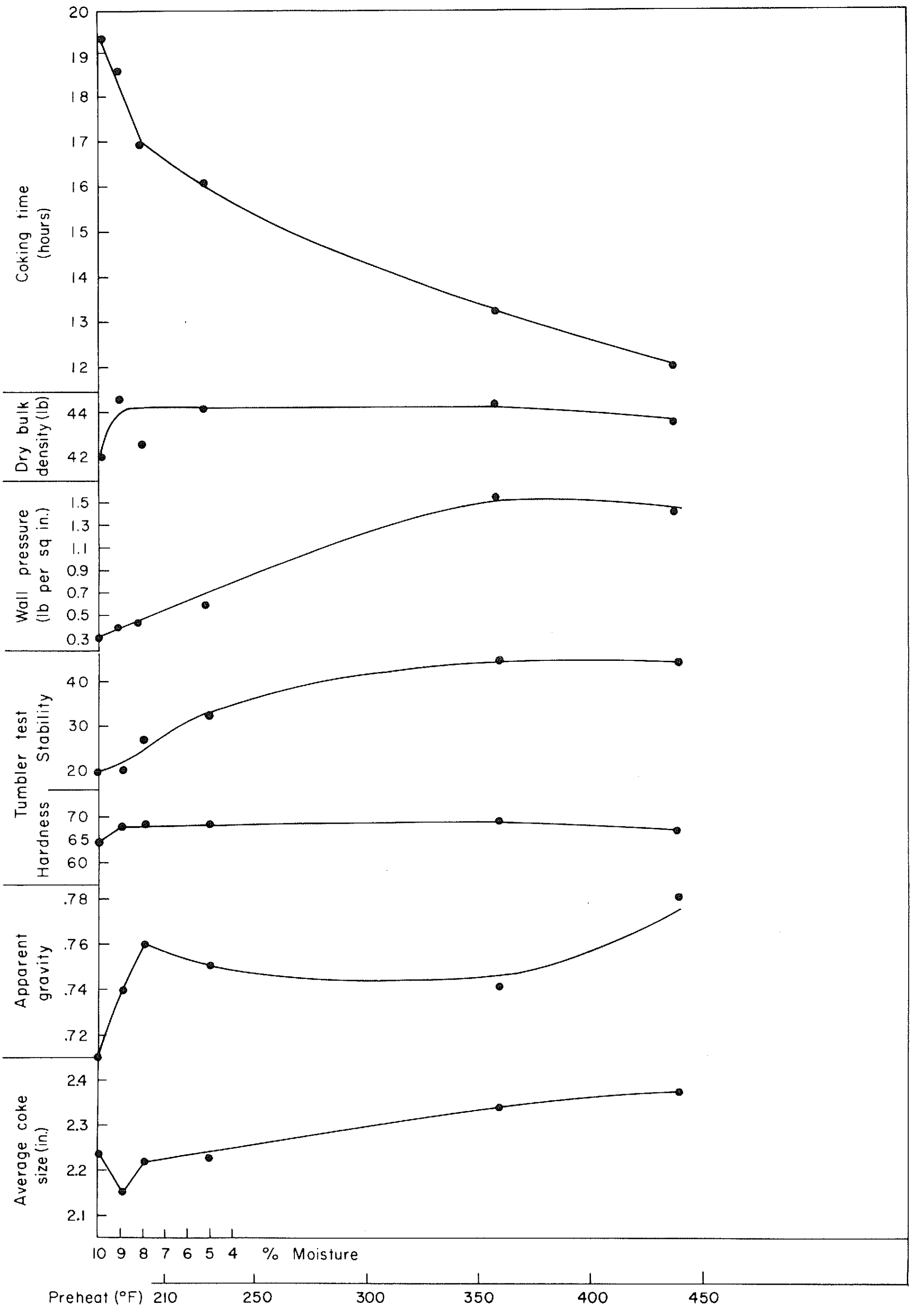

Figure 8 - Results of coking tests on high-volatile B bituminous coal (Ill. No. 6-B).

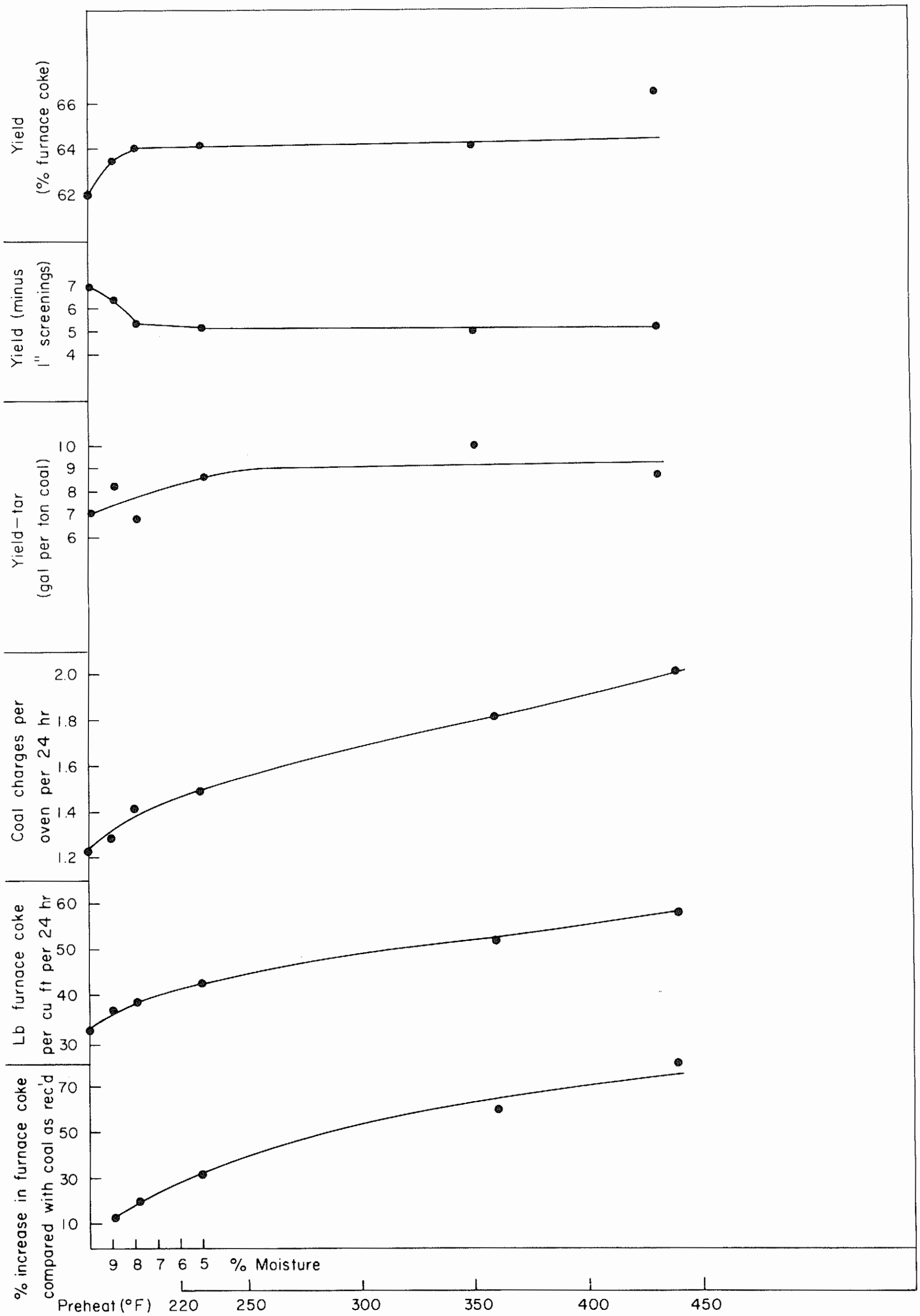

Figure 9 - Results of coking tests on high-volatile B bituminous coal (Ill. No. 6-B).

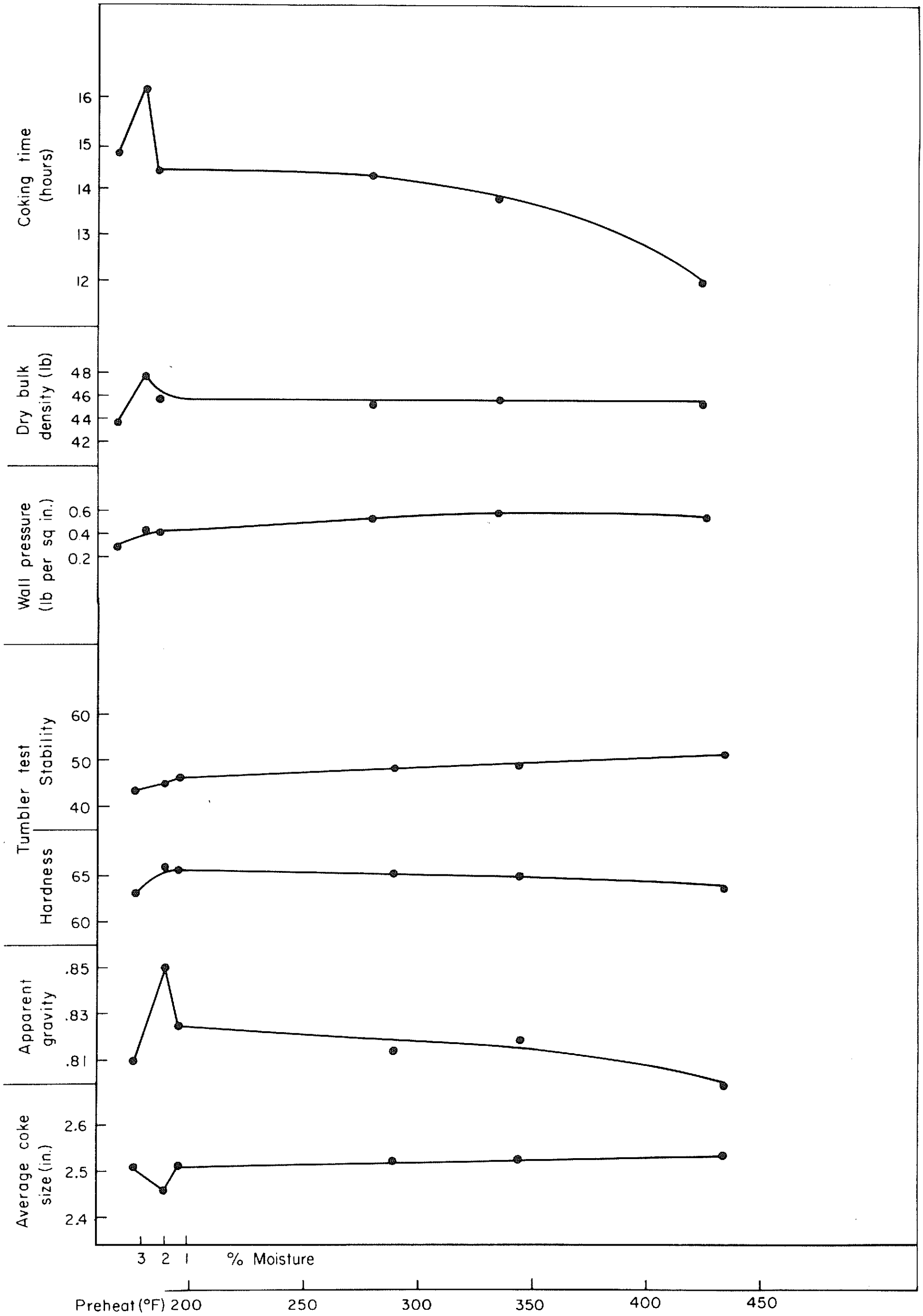

Figure 10 - Results of coking tests on high-volatile A bituminous coal (West Virginia Eagle).

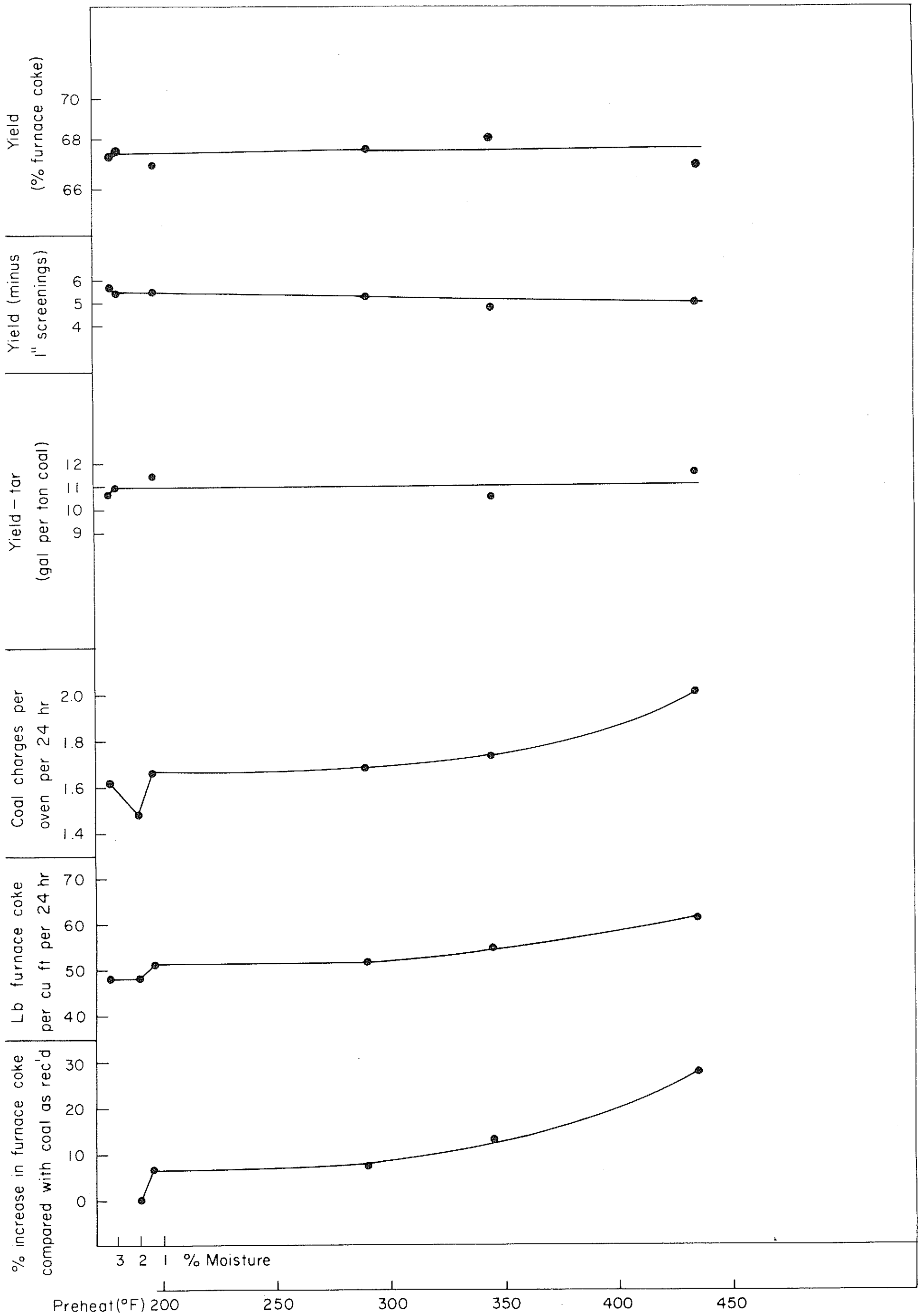

Figure 11 - Results of coking tests on high-volatile A bituminous coal (West Virginia Eagle).

SUMMARY AND CONCLUSIONS

In response to requests for information regarding the effects of preheating on the coking properties of Illinois coals and coal blends, the Illinois State Geological Survey has designed and built a coal preheater capable of drying and preheating sufficient coal for one complete coal charge to the pilot coke oven. Coking tests on high-volatile A, B, and C bituminous coals dried and preheated over the range 210° to 450° F have indicated that preheating consistently reduces coking time and increases the potential coke making capacity of a coke oven. All individual coals tested to date have developed greater strength (tumbler stability indices) when preheated. Coke screenings (minus 1 inch) are reduced, and coke size is increased. Preheating tends to increase the expansion pressure exerted on coke oven walls, but no pressures considered dangerous have been encountered when coking individual high-volatile coals.

This publication presents data obtained when coking individual coals. Similar data obtained when preheating and coking coal blends will be presented in a subsequent publication.

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APPENDIX

Tables A through E of this section present in tabular form the complete pilot plant coking results for each of the coals studied and described in this publication. Data include preheat temperatures, coking time, dry coal bulk densities, coke physical properties, yields of coke and tar, coal pulverization, moisture in dried and preheated coals, and the effect of preheating on the capacity of coke ovens to produce coke.

Table F shows the laboratory analyses of the cokes produced in each series of drying and preheating tests.

TABLE A — RESULTS OF COKING TESTS ON HIGH-VOLATILE C BITUMINOUS COAL (ILL. NO. 6)

	Condition of coal					
	As rec'd.	Air dried	Heat dried at 210° F	Preheat at 255° F	Preheat at 360° F	Preheat at 428° F
	Run number					
	1143 E	1144 E	1151 E	1150 E	1146 E	1145 E
Coking time (hr:min)	18:45	18:00	17:10	13:35	12:25	12:00
Bulk density (dry coal; lb per cu ft)	36.8	40.4	39.6	40.6	41.8	41.0
Coke physical properties						
Tumbler test						
Stability	11.1	11.4	13.0	20.5	21.9	25.3
Hardness	60.4	60.7	57.3	55.0	56.6	56.6
Shatter test (%)						
+2"	44.0	42.0	51.0	59.2	52.0	62.0
+1½"	67.0	63.4	75.0	76.0	71.0	88.4
+1"	82.0	81.0	84.0	88.0	86.0	90.0
Sizing (%)						
+4"	0.0	0.0	3.0	5.5	4.1	7.0
4" x 3"	24.4	25.1	28.2	31.6	29.6	29.6
3" x 2"	36.8	37.7	33.2	32.9	36.1	37.0
2" x 1"	28.7	27.3	24.7	20.9	22.3	18.5
1" x ½"	5.2	6.0	6.2	5.4	4.1	3.8
-½"	4.9	3.9	4.7	3.7	3.8	4.1
Average size (in.)	2.26	2.29	2.38	2.54	2.50	2.59
Apparent gravity	0.75	0.71	0.72	0.715	—	0.69
Coke yields (% of dry coal)						
Total coke (dry)	63.4	64.7	65.5	64.3	64.3	63.5
Furnace (+1") (dry)	57.1	58.4	58.3	58.5	59.1	58.6
Nut (1" x ½") (dry)	3.2	3.8	4.1	3.5	2.7	2.4
Breeze (-½") (dry)	3.1	2.5	3.1	2.3	2.5	2.5
Tar yield (gal dry tar; per ton dry coal)	12.1	14.0	12.7	10.7	13.3	13.5
Expansion pressure (lb per sq in.)	0.3	0.1	0.3	0.4	0.25	0.45
Pulverization (-1/8")	84.5	88.8	85.2	85.1	84.8	83.8
Coke temperature (° F)	1775	1775	1775	1775	1775	1775
% moisture in coal as charged*	13.9	11.8	11.3	0.2	-1.5	-0.9
Coke oven capacity						
Coal charges/oven/24 hr	1.28	1.33	1.40	1.77	1.93	2.0
Lb furnace coke/cu ft/ 24 hr	26.9	31.4	32.3	42.0	47.6	48.1
% increase in furnace coke (compared with coal "as received")	—	16.7	20.0	56.1	77.0	79.0

*Minus values indicate weight loss on preheating greater than ASTM moisture values.

TABLE B — RESULTS OF COKING TESTS ON HIGH-VOLATILE B BITUMINOUS COAL (ILL. NO. 5)

	Condition of coal						
	As rec'd.	Air dried	Heat dried at 210° F	Preheat at 225° F	Preheat at 313° F	Preheat at 433° F	Preheat at 440° F
	Run number						
	1117 E	1118 E	1119 E	1120 E	1121 E	1122 E	1129 E
Coking time (hr:min)	16:15	17:15	15:45	15:10	13:15	12:10	11:45
Bulk density (dry coal; lb per cu ft)	40.6	44.8	44.0	43.9	46.1	45.2	45.6
Coke physical properties							
Tumbler test							
Stability	24.3	21.2	23.7	26.6	33.9	41.2	41.2
Hardness	62.3	66.4	66.4	65.5	65.9	65.7	65.9
Shatter test (%)							
+2"	48.0	48.0	46.0	50.0	56.0	60.0	52.0
+1½"	75.0	70.0	71.0	77.0	80.2	83.0	81.0
+1"	95.0	86.0	88.0	89.4	91.2	93.0	93.0
Sizing (%)							
+4"	4.3	3.9	2.9	3.9	5.9	5.1	3.8
4" x 3"	19.4	18.2	18.2	20.7	19.9	25.1	22.2
3" x 2"	41.7	40.6	42.6	43.1	44.6	42.1	44.4
2" x 1"	26.7	29.0	28.2	25.2	22.3	21.3	23.1
1" x ½"	4.2	4.6	4.7	3.8	3.8	2.9	2.8
-½"	3.7	3.7	3.4	3.3	3.5	3.5	3.7
Average size (in.)	2.36	2.31	2.30	2.39	2.45	2.51	2.43
Apparent gravity	0.74	0.775	0.755	0.765	0.765	0.76	0.76
Coke yields (% of dry coal)							
Total coke (dry)	69.0	69.7	69.1	68.8	68.4	68.0	68.2
Furnace (+1") (dry)	63.5	64.0	63.6	64.0	63.4	63.7	63.8
Nut (1" x ½") (dry)	3.0	3.2	3.2	2.6	2.6	1.9	1.9
Breeze (-½") (dry)	2.5	2.5	2.3	2.2	2.4	2.4	2.5
Tar yield (gal dry tar; per ton dry coal)	10.4	10.2	12.4	11.6	11.6	11.0	10.7
Expansion pressure (lb per sq in.)	0.2	0.2	0.35	0.95	0.79	—	0.75
Pulverization (-1/8")	86.7	83.4	—	81.0	81.8	82.5	86.3
Coke temperature (° F)	1775	1775	1775	1775	1775	1775	1775
% moisture in coal as charged*	8.5	6.5	5.5	3.5	-0.2	-1.1	-1.2
Coke oven capacity							
Coal charges/oven/24 hr	1.475	1.39	1.525	1.58	1.81	1.975	2.04
Lb furnace coke/cu ft/24 hr	38.0	33.9	42.7	44.4	53.0	56.8	59.3
% increase in furnace coke (compared with coal "as received")	—	5.0	12.4	16.8	39.5	49.5	56.1

*Minus values indicate weight loss on preheating greater than ASTM moisture values.

TABLE C — RESULTS OF COKING TESTS ON HIGH-VOLATILE B BITUMINOUS COAL (ILL. NO. 6-A)

	Condition of coal							
	As rec'd.	Air dried	Heat dried at 218° F	Preheat at 227° F	Preheat at 270° F	Preheat at 332° F	Preheat at 370° F	Preheat at 450° F
	Run number							
	1111 E	1112 E	1113 E	1114 E	1115 E	1134 E	1149 E	1161 E
Coking time (hr:min)	17:40	18:05	17:00	16:00	14:30	12:15	11:30	11:05
Bulk density (dry coal; lb per cu ft)	41.0	43.5	43.0	42.9	43.3	43.6	43.2	43.4
Coke physical properties								
Tumbler test								
Stability	16.4	15.0	18.0	22.1	28.0	40.5	40.7	36.6
Hardness	61.8	64.8	65.7	65.7	64.6	67.3	66.2	62.3
Shatter test (%)								
+2"	46.0	45.0	47.2	41.0	47.0	56.0	55.0	57.0
+1½"	73.2	68.8	76.2	76.4	80.8	82.0	84.0	81.0
+1"	86.4	86.0	89.8	87.8	92.4	93.0	93.2	93.0
Sizing (%)								
+4"	0.0	0.0	0.0	0.0	0.0	3.4	2.3	3.1
4" x 3"	15.1	15.3	15.1	15.3	19.8	23.4	23.7	24.4
3" x 2"	39.4	36.9	42.7	43.7	45.3	42.4	44.2	43.9
2" x 1"	35.7	38.1	34.8	33.1	27.7	24.2	23.4	22.5
1" x ½"	5.5	6.2	3.6	4.3	3.5	3.2	3.2	2.9
−½"	3.9	3.5	3.8	3.6	3.7	3.4	3.2	3.2
Average size (in.)	2.11	2.08	2.15	2.17	2.28	2.43	2.42	2.46
Apparent gravity	0.70	0.73	0.71	0.715	0.715	0.72	0.70	0.745
Coke yields (% of dry coal)								
Total coke (dry)	66.8	67.5	67.1	67.6	67.2	67.5	66.2	68.0
Furnace (+1") (dry)	60.5	61.0	62.1	62.3	62.7	63.1	61.8	63.7
Nut (1" x ½") (dry)	3.7	4.1	2.4	2.8	2.2	2.1	2.2	2.0
Breeze (−½") (dry)	2.6	2.4	2.6	2.5	2.3	2.3	2.2	2.2
Tar yield (gal dry tar; per ton dry coal)	10.2	10.4	10.7	10.75	11.0	11.0	9.6	10.6
Expansion pressure (lb per sq in.)	0.2	0.25	0.3	0.35	0.4	0.45	0.35	0.5
Pulverization (−1/8")	75.5	81.2	(Average of 81.0)			79.2	85.2	88.3
Coke temperature (° F)	1775	1775	1775	1775	1775	1775	1775	1775
% moisture in coal as charged*	9.8	8.5	7.7	5.8	1.4	−0.3	−0.5	−0.7
Coke oven capacity								
Coal charges/oven/24 hr	1.36	1.33	1.41	1.50	1.65	1.96	2.09	2.16
Lb furnace coke/cu ft/24 hr	33.7	35.3	37.7	40.1	44.8	53.9	55.8	58.7
% increase in furnace coke (compared with coal "as received")	—	4.7	11.9	19.0	32.9	60.0	65.5	74.2

*Minus values indicate weight loss on preheating greater than ASTM moisture values.

TABLE D — RESULTS OF COKING TESTS ON HIGH-VOLATILE B BITUMINOUS COAL (ILL. NO. 6-B)

	Condition of coal					
	As rec'd.	Air dried	Heat dried at 213° F	Preheat at 230° F	Preheat at 360° F	Preheat at 440° F
	Run number					
	1166 E	1167 E	1165 E	1164 E	1163 E	1162 E
Coking time (hr:min)	19:30	18:35	16:55	16:05	13:15	12:00
Bulk density (dry coal; lb per cu ft)	42.1	44.6	42.5	44.2	44.4	43.5
Coke physical properties						
Tumbler test						
Stability	20.0	20.3	27.1	32.5	44.6	43.9
Hardness	64.4	68.0	68.4	68.2	68.9	66.4
Shatter test (%)						
+2"	44.8	37.8	43.0	45.0	60.4	55.2
+1½"	73.0	74.0	69.0	80.8	85.0	80.8
+1"	87.6	86.0	87.0	90.0	93.0	91.2
Sizing (%)						
+4"	3.4	2.3	1.9	2.3	2.3	1.3
4" x 3"	17.1	13.4	16.3	14.6	18.5	20.3
3" x 2"	39.6	41.0	41.2	44.2	47.3	49.0
2" x 1"	29.9	34.2	33.0	31.4	24.8	22.6
1" x ½"	4.3	4.1	3.6	3.7	3.4	3.1
-½"	5.7	5.0	4.0	3.8	3.7	3.7
Average size (in.)	2.24	2.15	2.22	2.23	2.34	2.37
Apparent gravity	0.71	0.74	0.76	0.75	0.74	0.78
Coke yields (% of dry coal)						
Total coke (dry)	69.0	69.9	69.3	69.2	68.9	71.2
Furnace (+1") (dry)	62.0	63.5	64.0	64.1	64.0	66.3
Nut (1" x ½") (dry)	3.0	2.9	2.5	2.5	2.3	2.2
Breeze (-½") (dry)	4.0	3.5	2.8	2.6	2.6	2.7
Tar yield (gal dry tar; per ton dry coal)	7.1	8.2	6.8	8.6	9.9	8.5
Expansion pressure (lb per sq in.)	0.3	0.4	0.45	0.55	1.55	1.4
Pulverization (-1/8")	84.4	87.8	85.2	87.4	82.2	84.0
Coke temperature (° F)	1775	1775	1775	1775	1775	1775
% moisture in coal as charged*	10.0	8.9	7.9	5.0	-0.2	-1.4
Coke oven capacity						
Coal charges/oven/24 hr	1.23	1.29	1.42	1.49	1.81	2.00
Lb furnace coke/cu ft/ 24 hr	32.1	36.5	38.6	42.25	51.4	57.6
% increase in furnace coke (compared with coal "as received")	—	13.7	20.2	31.5	59.6	79.5

*Minus values indicate weight loss on preheating greater than ASTM moisture values.

TABLE E — RESULTS OF COKING TESTS ON HIGH-VOLATILE A BITUMINOUS COAL (WEST VIRGINIA EAGLE)

	Condition of coal					
	As rec'd.	Air dried	Heat dried at 210° F	Preheat at 290° F	Preheat at 345° F	Preheat at 435° F
	Run number					
	1152 E	1153 E	1154 E	1157 E	1156 E	1155 E
Coking time (hr:min)	14:50	16:15	14:25	14:20	13:50	12:00
Bulk density (dry coal; lb per cu ft)	43.9	47.9	45.75	45.4	45.9	45.6
Coke physical properties						
Tumbler test						
Stability	43.7	45.2	46.8	48.7	49.6	52.1
Hardness	63.2	66.2	65.9	65.5	65.2	63.9
Shatter test (%)						
+2"	63	55	57	64	59	60
+1½"	87	85	85	86	86	86
+1"	95	95	94	95	95	95
Sizing (%)						
+4"	4.4	3.5	5.6	6.6	4.7	5.3
4" x 3"	25.6	24.5	23.1	23.2	26.1	24.4
3" x 2"	43.3	45.0	44.8	43.7	43.0	45.1
2" x 1"	21.0	21.5	21.0	21.2	21.4	20.3
1" x ½"	2.6	2.5	2.6	2.2	2.1	2.1
–½"	3.1	3.0	2.9	3.1	2.7	2.8
Average size (in.)	2.52	2.47	2.52	2.54	2.54	2.55
Apparent gravity	0.81	0.85	0.825	0.815	0.82	0.80
Coke yields (% of dry coal)						
Total coke (dry)	71.5	71.6	71.0	71.4	71.6	70.3
Furnace (+1") (dry)	67.5	67.7	67.1	67.7	68.2	66.9
Nut (1" x ½") (dry)	1.8	1.7	1.8	1.5	1.5	1.4
Breeze (–½") (dry)	2.2	2.2	2.1	2.2	1.9	2.0
Tar yield (gal dry tar; per ton dry coal)	10.7	11.0	11.5	9.3	10.5	11.6
Expansion pressure (lb per sq in.)	0.3	0.45	0.4	0.55	0.6	0.55
Pulverization (–1/8")	90.9	90.5	90.7	89.3	90.8	91.7
Coke temperature (° F)	1775	1775	1775	1775	1775	1775
% moisture in coal as charged*	3.2	2.0	1.4	0.0	–0.4	–0.5
Coke oven capacity						
Coal charges/oven/24 hr	1.62	1.48	1.66	1.67	1.73	2.00
Lb furnace coke/cu ft/ 24 hr	48.0	48.0	51.0	51.4	54.1	61.0
% increase in furnace coke (compared with coal "as received")	—	0.0	6.2	7.1	12.7	27.1

*Minus values indicate weight loss on preheating greater than ASTM moisture values.

TABLE F - ANALYSES OF COKES PRODUCED (IN PERCENT)

Coal coked	Volatile matter	Fixed carbon	Ash	Sulfur
High-volatile C Bituminous (Ill. No. 6)				
As received	0.8	88.5	10.7	1.76
Air dried	0.8	88.8	10.4	1.79
Heat dried at 210° F	1.4	86.8	11.8	1.86
Preheated to 255° F	1.1	87.3	11.6	1.77
Preheated to 360° F	1.0	88.5	10.5	1.74
Preheated to 428° F	1.1	88.2	10.7	1.75
High-volatile B Bituminous (Ill. No. 5)				
As received	1.3	87.9	10.8	1.24
Air dried	1.5	87.8	10.7	1.26
Heat dried at 210° F	1.1	88.6	10.3	1.21
Preheated to 225° F	1.3	88.3	10.4	1.29
Preheated to 313° F	1.9	87.8	10.3	1.24
Preheated to 433° F	1.6	87.7	10.7	1.39
Preheated to 440° F	1.3	88.4	10.3	1.19
High-volatile B Bituminous (Ill. No. 6-A)				
As received	1.1	87.9	11.0	0.94
Air dried	1.2	87.5	11.3	0.95
Heat dried at 218° F	1.7	87.0	11.3	0.93
Preheated to 227° F	1.4	87.3	11.3	0.98
Preheated to 270° F	1.8	86.7	11.5	0.96
Preheated to 332° F	1.6	87.0	11.4	0.97
Preheated to 370° F	1.4	88.0	10.6	1.03
Preheated to 450° F	1.5	87.8	10.7	0.94
High-volatile B Bituminous (Ill. No. 6-B)				
As received	1.2	88.2	10.6	0.75
Air dried	1.4	88.3	10.3	0.72
Heat dried at 213° F	1.5	88.3	10.2	0.79
Preheated to 230° F	1.3	88.2	10.5	0.78
Preheated to 360° F	1.2	88.5	10.3	0.76
Preheated to 440° F	1.5	88.1	10.4	0.78
High-volatile A Bituminous (West Virginia Eagle)				
As received	0.6	93.8	5.6	0.61
Air dried	1.2	93.2	5.6	0.56
Heat dried at 210° F	0.9	93.3	5.8	0.60
Preheated to 290° F	1.1	93.2	5.7	0.55
Preheated to 345° F	1.1	92.9	6.0	0.57
Preheated to 435° F	0.9	93.2	5.9	0.54

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