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FACTORS AFFECTING COKE SIZE

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ABSTRACT

A pilot-plant study has been made of the relative amounts of foundry-size coke that may be produced from a blend containing Illinois coal by (1) addition of small amounts of anthracite fines, (2) similar additions of coke breeze, and (3) varying the coking time over a wide range. Results indicate that by adding 5 to 10 percent anthracite, coking time may be reduced 6 to 12 hours without decreasing the yield of large-size coke. There are certain changes in the physical properties of the coke. Where these changes are not detrimental to the ultimate use of the product, the addition of anthracite fines is an effective way to increase foundry-coke production.

Although blast-furnace coke accounts for the major coke tonnage produced and used in the Chicago and St. Louis areas, plants producing foundry coke as their chief solid fuel product are located within shipping distance of the low-sulfur coal fields of Illinois. Coking studies therefore have been made at the Illinois State Geological Survey on blends of Illinois coals with Eastern high- and low-volatile coals at coking rates and temperature conditions calculated to produce maximum yields of large foundry-size coke.

Studies have been made also on the effect of adding small percentages of anthracite fines, or coke breeze, to such foundry coke blends to determine their effect on coke size and strength. Such inerts as anthracite and breeze are known to increase the total tonnage of foundry coke that may be produced. Lengthening the coking time likewise increases the percentage of large, stable coke, but it results in the carbonization of less coal per day. These trends have been studied, and the yields, size distribution, and physical properties of the cokes have been determined and compared.

Eastern coals, both high- and low-volatile, used for this study were furnished by the Laclede Gas Co. (now the coke plant of Great Lakes Carbon Corp.), the cooperation of which we wish to acknowledge. We also acknowledge the cooperation of the Illinois coal producers who furnished the Illinois No. 6 coal used in blends, and of the Analytical Chemistry Division of the Illinois State Geological Survey for analyzing all coals used and cokes produced.

METHODS OF TESTING

Experimental blends of coals were carbonized in a slot-type pilot oven 14 inches wide and of 500 pounds coal capacity (Reed, 1947). Experimental cokes produced were dried, sized, and tested by standard ASTM methods.

The data presented here apply in detail only to the specific blend of coals carbonized. Any inert or semi-inert material added to bituminous coals af-

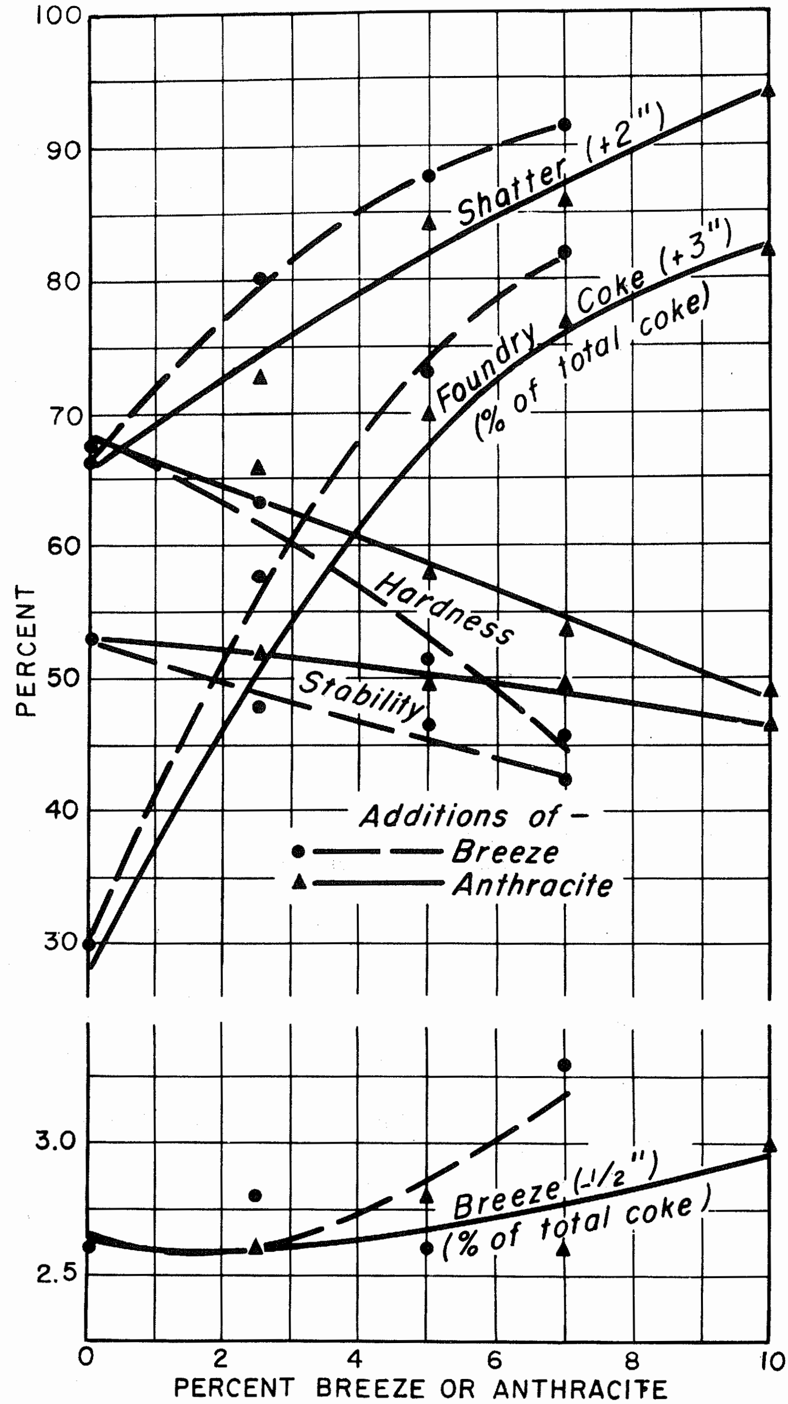

Fig. 1. - Comparison of effects of coke breeze and anthracite added to basic coke blend.

fects the plastic properties of the resulting blend, usually lowering the fluidity (Rees, 1955) and influencing the coking properties. The ability of the foreign material to improve or degrade the resulting coke, under the operating conditions used, depends on the composition of the basic coal blend.

In pilot-plant studies it is possible to obtain greater uniformity of coal composition and oven temperature than can be obtained from a commercial coke-oven battery. Coking results therefore can be duplicated closely, and trends studied more precisely than by sampling commercial coke. We have noted in previous work that the average of duplicate coking runs in the pilot oven has in a number of cases checked closely with the average of a month's daily tests on the same coal blend in full-scale ovens.

COAL BLENDS STUDIED

A basic blend composed of 16 percent Illinois No. 6 seam coal from Franklin County, 46 percent West Virginia high-volatile (Hernshaw seam) coal, and 38 percent Pocahontas No. 3 seam coal was used in all tests.

Pennsylvania anthracite (No. 5 Buckwheat) was added to this blend in percentages of 2 1/2, 5, 7, and 10. A representative size analysis of the anthracite is shown in table 1. Coke breeze of similar size consist also was added as 2 1/2, 5, and 7 percent of the blend. All blends thus formed were coked under identical heating conditions at a rate corresponding to 18 hours in an oven of 19 inches average width.

The basic blend was used also to study the effect of coking time, and was carbonized without anthracite or breeze additions at rates corresponding to 18, 22, 26, and 30 hours in the oven of 19 inches average width.

Representative analyses of the coals used in blends are shown in table 2.

RESULTS OF TESTS

Addition of anthracite. - Addition of anthracite coal to the basic blend caused a decided increase in coke size, as shown in table 3. The +3" foundry size increased from about 30 to 82 percent of the total coke production between the limits of 0 and 10 percent anthracite in the coal blend, an average increase of 5.2 percent for each percent of anthracite added. The total yield of coke also increased in amounts corresponding to the higher fixed-carbon content of the anthracite blends.

The shatter test has been used almost exclusively in the foundry coke industry as a measure of coke strength. Pilot-plant test results (table 3) indicate that the shatter index increases consistently with the percentage of anthracite.

The tumbler test, which is widely used by producers of blast furnace coke, seems to have little significance in the evaluation of foundry coke. Consequently it is not often used in this industry. Tumbler tests on the experimental cokes do indicate, however, that fairly large additions of anthracite lower the hardness factor and cause the coke to become more abraidable. For example, 10 percent anthracite in this blend reduces the hardness factor to about three-fourths of its maximum value, indicating probable production of additional coke breeze in the normal plant handling and screening equipment. End use may thus determine the amount of anthracite to be added to a blend.

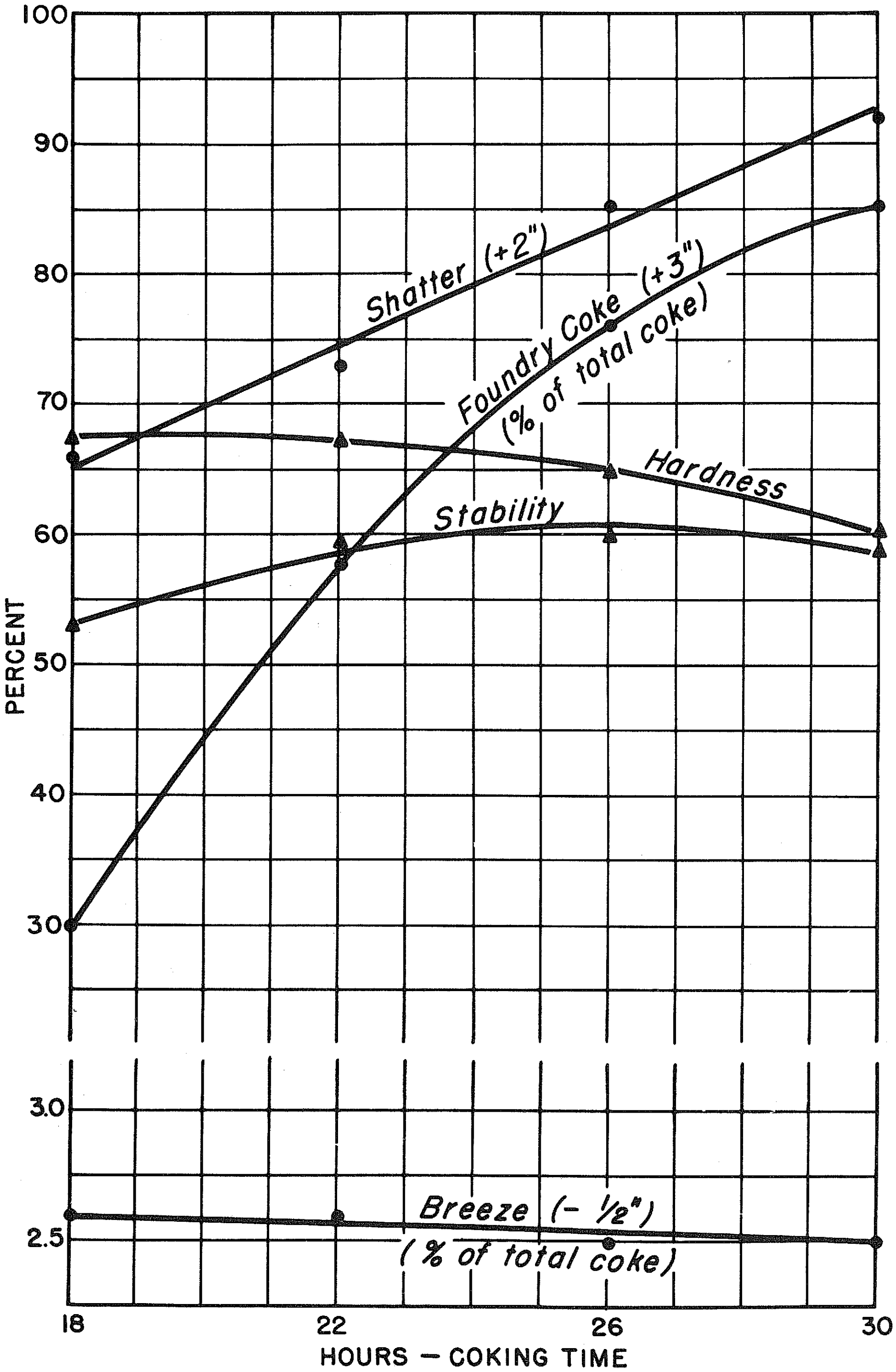

Fig. 2. - Effect of lengthening coking time.

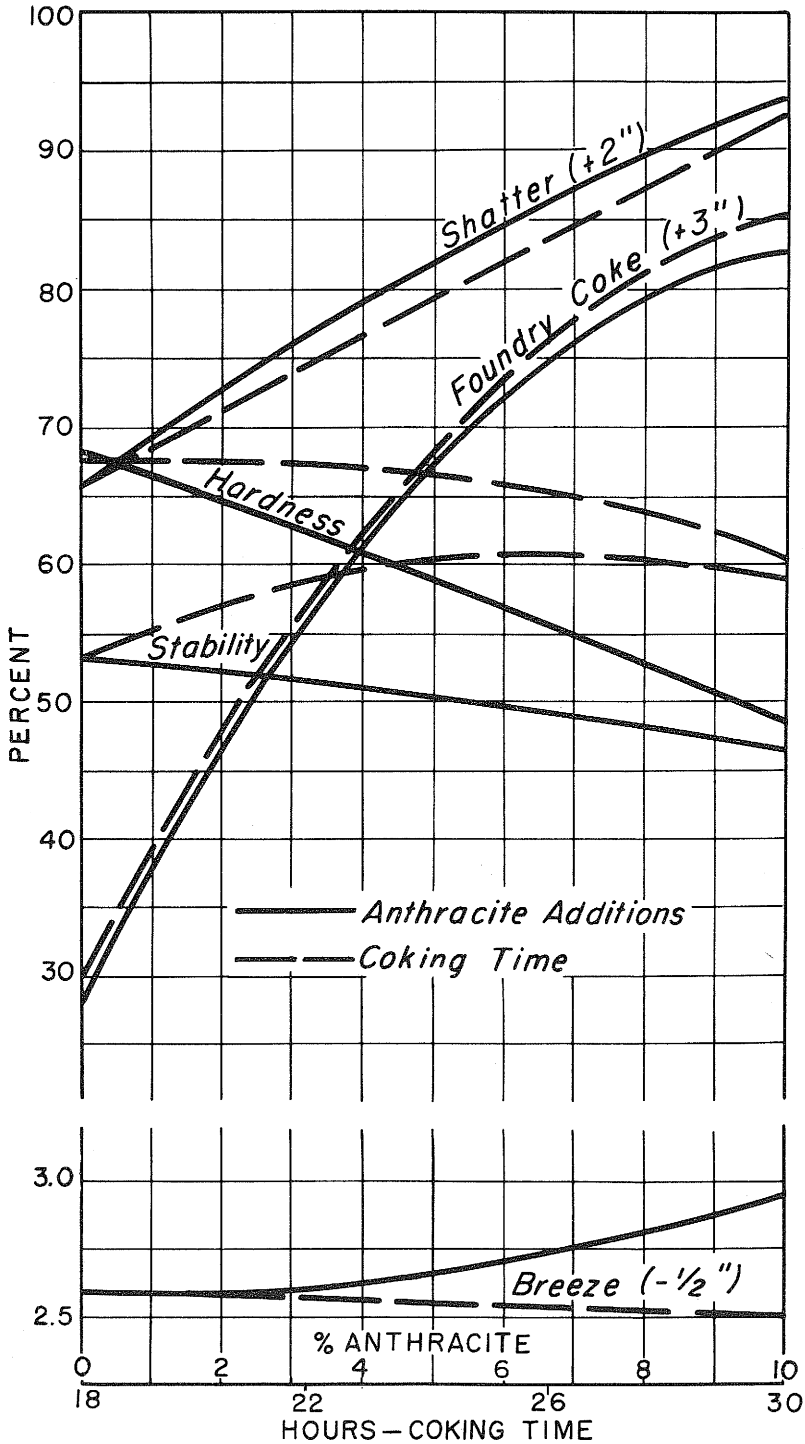

Fig. 3. - Effects of anthracite additions and coking time compared.

Coke breeze compared with anthracite. - Results of the coking tests in which coke breeze was added to the basic coal blend are shown in table 4. Breeze used in these tests was produced from a similar coal blend and pulverized to approximately the same size consist as the anthracite coal.

Addition of breeze caused a greater increase in the percentage of large-size coke than resulted from addition of anthracite. The +2" shatter index was higher, and, as usual, followed coke size closely. Tumbler stability and hardness indices were lower, however, than when anthracite was used, indicating a softer coke structure with greater tendency toward abrasion.

Data from tables 3 and 4 are plotted in figure 1 to show more clearly a comparison of the physical properties of cokes made with addition of anthracite and breeze.

Lengthening coking time. - A third series of tests was made with the basic coal blend at coking rates corresponding to 18, 22, 26, and 30 hours in a commercial oven of 19 inches average width. Results are shown in table 5. Foundry-size coke (+3") increased from about 30 to 85 percent of the total coke production over this range of coking time, or at an average of 4.6 percent per additional hour of coking.

The shatter-test indices increased directly with increase in coking time. In this series, however, tumbler stability increased with longer time, and although the hardness factor dropped off, the change was much more gradual than in the other series. Data from table 5 are plotted in figure 2.

COMPARISON OF COKES

Sizing and physical tests. - Comparing the cokes produced in the two series of tests in which foundry coke yield was increased by (1) addition of anthracite, and (2) lengthening the coking time, it was apparent that the percentage of +3" coke produced in 30 hours without anthracite very nearly equaled that produced in 18 hours with 10 percent anthracite in the blend. Data presented in tables 3 and 5 were combined in figure 3, and the horizontal scales so adjusted that 30 hours coking time coincided with 10 percent anthracite.

The curves representing foundry coke yields nearly coincide for their entire length. Shatter-test curves also are similar. We may observe, for example, that addition of 5 percent anthracite to the coal blend coked in 18 hours produces approximately the same increase in coke size as does lengthening the coking time from 18 to 24 hours. Addition of 7 percent anthracite is equivalent to lengthening the coking time to 26 hours.

Differences in the cokes made by the two methods used to increase sizes are shown by the tumbler stability and hardness curves. Anthracite causes both stability and hardness to decrease, whereas longer coking time makes coke more stable with only a minor decrease in the hardness index. As stated previously, this seems to have little significance to the foundry coke user. The production of coke fines (-1/2" breeze) tends to increase slightly with additional anthracite, but remains practically constant when coking time is changed.

Cell structure. - The cokes were compared further by preparing cross sections of representative pieces showing cell structure. Figures 4 and 5 show the full length pieces. In figures 6 and 7, enlargements show cell structure of the midlength section of each piece.

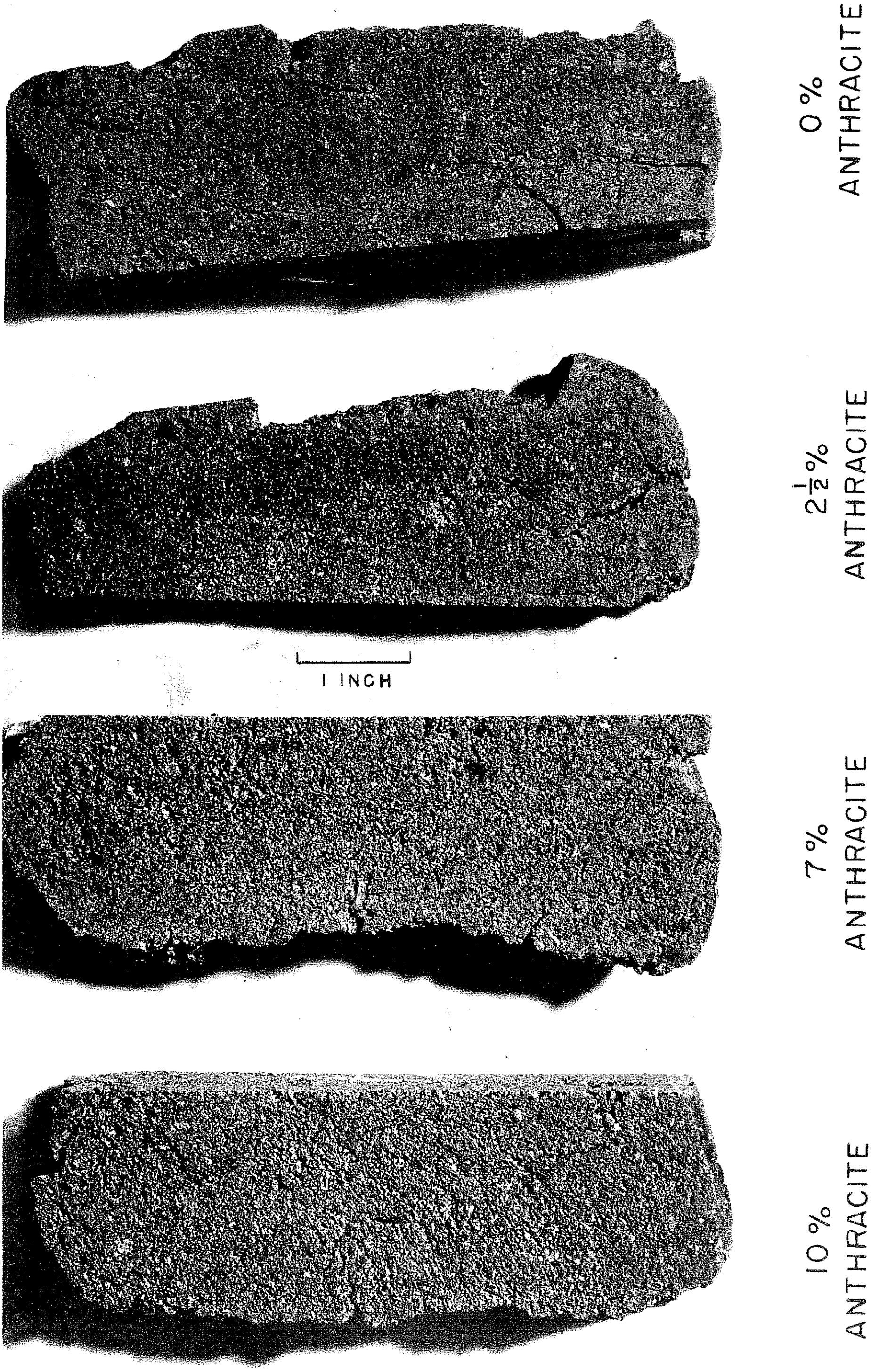

Fig. 4—Cross sections showing cell structure of representative pieces of anthracite coke.

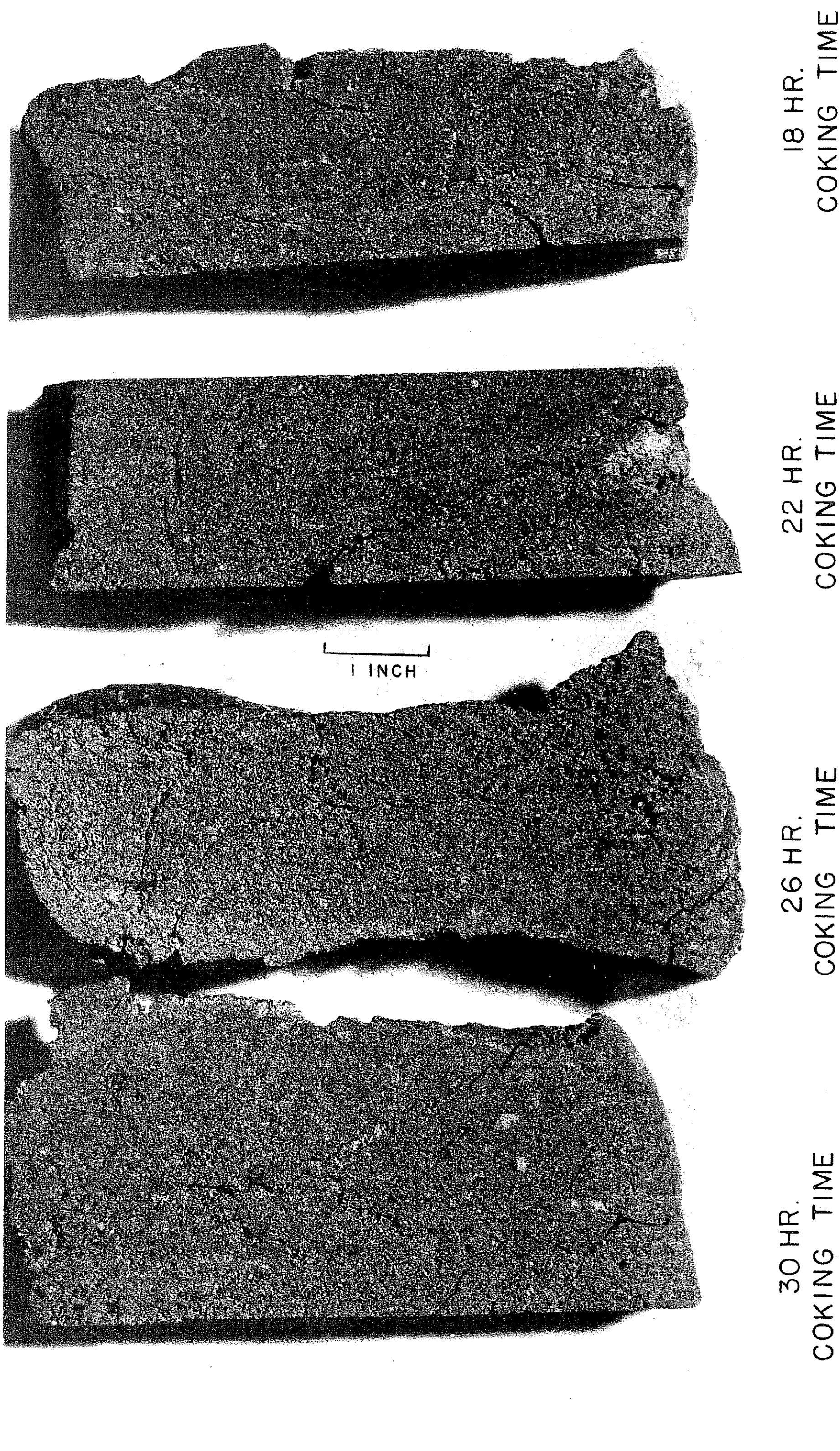

Fig. 5—Cross sections showing cell structure of cokes made at various coking times.

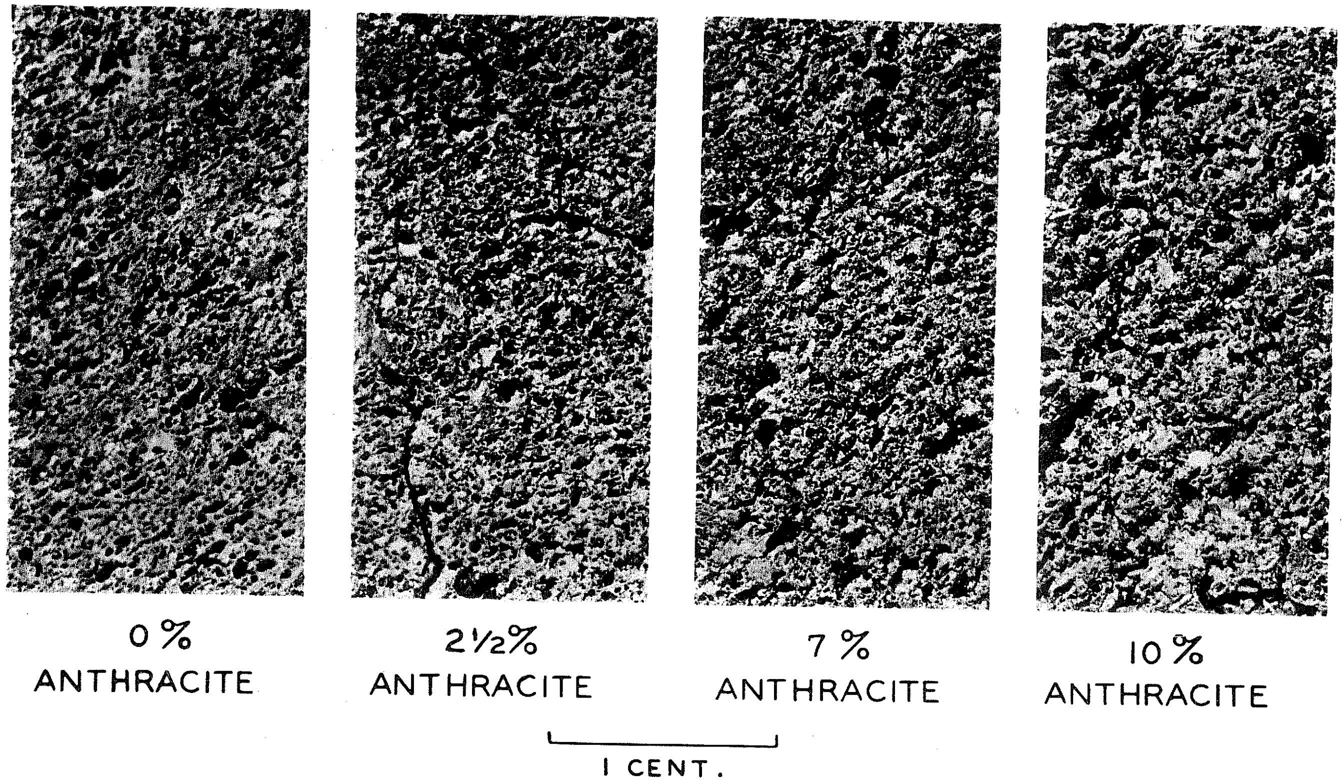

Fig. 6—Cell structure of anthracite cokes; enlargement at midlength.

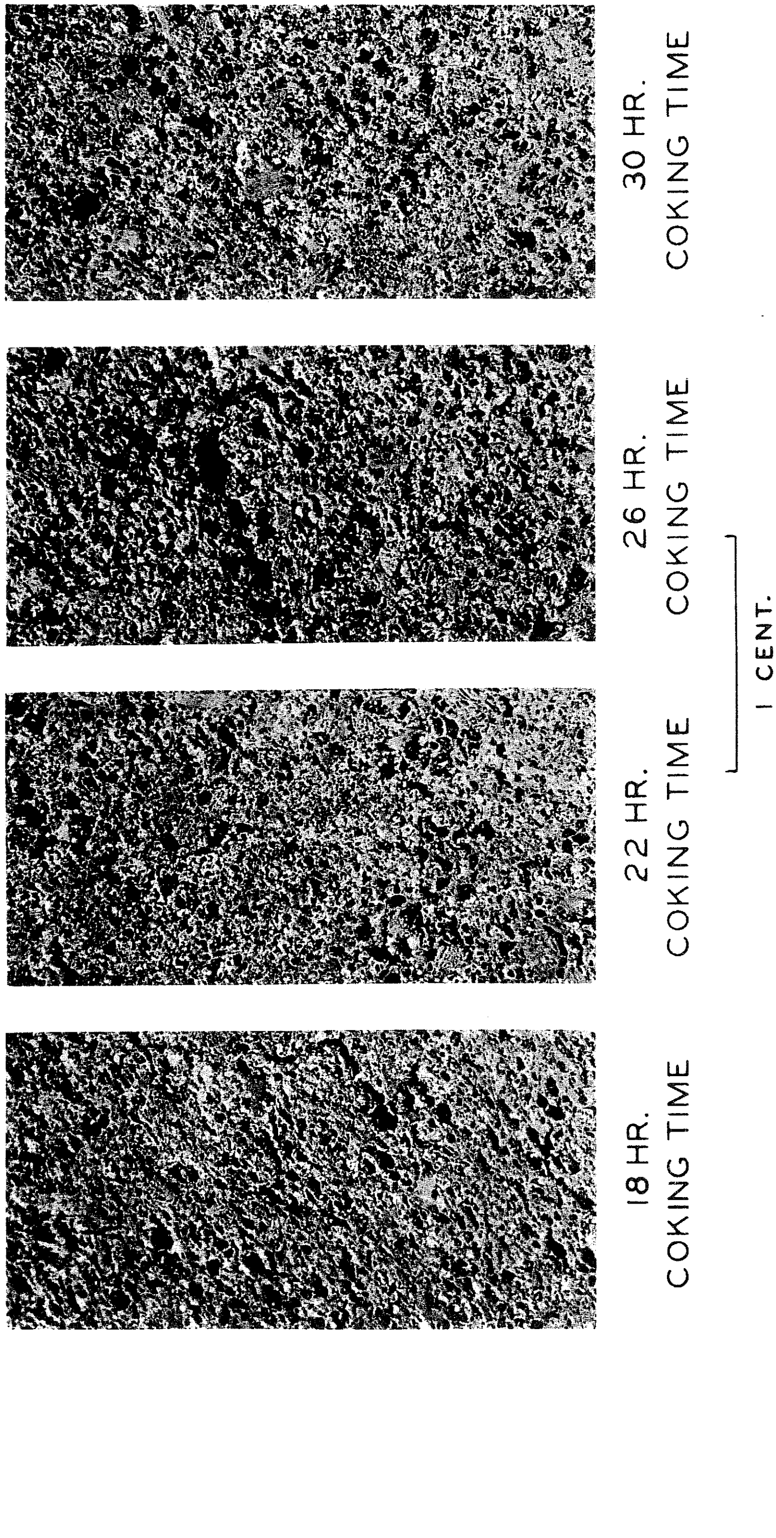

Fig. 7—Cell structure of cokes made at various coking times; enlargement at midlength.

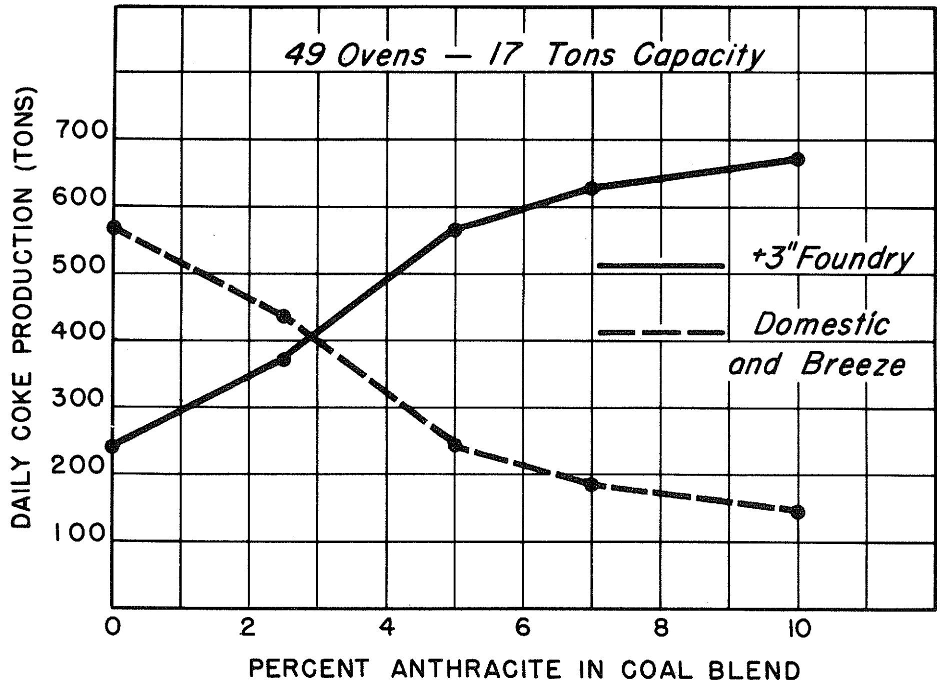

Fig. 8. - Daily coke production with anthracite coal blends; 18-hour net coking time.

A small addition of anthracite to the coal blend apparently produces a more uniform cell structure. Large additions produce a coarser structure with thicker cell walls. Cell structure is quite uniform for the full length of each piece. Changes in coking time appear to have little effect on the cell structure of the coke.

APPLICATION TO COKING PRACTICE

As the yield of foundry coke may be increased either by adding anthracite fines to the coal blend or by lengthening the coking time, we have made a comparison of the expected daily production of foundry-size coke from a specific battery of coke ovens operated under both these conditions. A battery of 49 ovens with an average width of 19 inches and a coal capacity of 17 tons per oven is assumed. Coke yields are based on pilot-plant results.

Table 6 shows the total tons of foundry coke and the tons of domestic coke and breeze that could be produced per day from this battery on an 18-hour net coking schedule with additions of anthracite in the percentages studied. Gross coking time is assumed to be 10 minutes longer than the net time. Table 7 shows the corresponding coke tonnages from this battery operated without anthracite, but at various coking rates. Data are plotted in figures 8 and 9.

The results show that the maximum daily tonnage of +3" foundry coke can be made at about a 26-hour coking time without the help of anthracite (fig. 9). This same daily tonnage (428 tons) could be produced in 18-hours coking time by adding about 3 1/4 percent anthracite to the coal blend. An increase of about 240 tons per day in domestic coke and breeze would result (fig. 8). Increasing

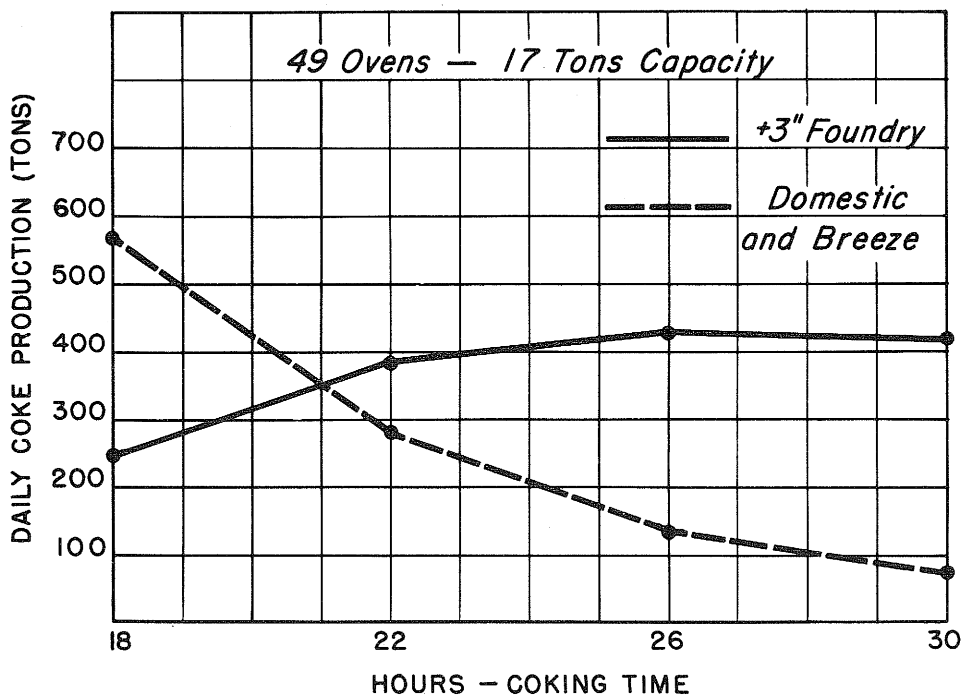

Fig. 9. - Daily coke production at various coking times; no anthracite.

the anthracite to 5 percent would raise the daily production of foundry-size coke to 569 tons, an increase of nearly 33 percent over the maximum production with all-bituminous coal. Similarly, 7 percent anthracite would increase foundry-coke production to 630 tons, an increase of 202 tons per day, or 47 percent.

SUMMARY AND CONCLUSIONS

We have shown by pilot-plant studies that adding anthracite coal fines to a blend of Illinois and West Virginia high-volatile and Pocahontas coals increases materially the percentage of foundry-size coke that may be produced. The addition of ten percent anthracite causes an increase in coke size equivalent to that produced by lengthening the coking time from 18 to 30 hours.

Shatter indices increase directly with coke size regardless of the method used to increase the size. The coke was found to be more abraidable when large percentages of anthracite coal were used.

Addition of finely pulverized coke breeze to the coal blend also produces large-size coke. This coke is less resistant to abrasion than that made from the anthracite blends.

No attempt has been made to evaluate the cokes for cupola practice. Foundry coke of acceptable quality is known to be made commercially, however, from blends containing 5 to 10 percent of anthracite fines. We have concluded, therefore, that the addition of anthracite is an effective way to increase foundry-coke production.

Table 1. - Size Analysis of Anthracite

+10 mesh	-	0.5%
10 x 20 mesh	-	25.5%
20 x 40 mesh	-	61.0%
40 x 100 mesh	-	12.5%
-100 mesh	-	0.5%

Table 2. - Analyses of Coals Used

		Dry basis			
	M.	V.M.	F.C.	Ash	Sulfur
Illinois No. 6 (3" x 2")	8.6	37.2	54.6	8.2	0.77
West Virginia Hernshaw	2.3	36.2	57.7	6.1	0.84
Pocahontas No. 3	3.3	16.4	76.6	7.0	0.67
Anthracite (No. 5 Buckwheat)	10.2	5.0	79.7	15.3	0.55

Table 3. - Addition of Anthracite to Basic Coal Blend

	Percent anthracite added				
	0	2.5	5	7	10
Total coke (% of coal) (corrected to 1% V.M.)	73.5	73.8	74.0	74.4	74.6
Foundry coke (+3") (% of total coke)	29.9	46.1	69.9	77.0	81.9
Breeze (-1/2") (% of total coke)	2.6	2.6	2.8	2.6	3.0
Shatter index (+2")	66.1	72.7	84.4	85.9	94.0
Tumbler test					
Stability (+1")	53.1	52.0	49.7	49.6	46.3
Hardness (+1/4")	67.5	65.9	58.0	53.6	49.2
Apparent gravity	.900	.913	.907	.918	.913

Table 4. - Addition of Coke Breeze to Basic Coal Blend

	Percent breeze added			
	0	2.5	5	7
Total coke (% of coal) (corrected to 1% V.M.)	73.5	74.4	75.2	74.9
Foundry coke (+3") (% of total coke)	29.9	57.7	73.1	82.1
Breeze (-1/2") (% of total coke)	2.6	2.8	2.6	3.3
Shatter index (+2")	66.1	80.1	87.6	91.4
Tumbler test				
Stability (+1")	53.1	47.8	46.5	42.4
Hardness (+1/4")	76.5	63.2	51.4	45.7
Apparent gravity	.900	.892	.887	.907

Table 5. - Lengthening Coking Time

	Coking time (hours)			
	18	22	26	30
Total coke (% of coal) (corrected to 1% V.M.)	73.5	-	73.2	73.8
Foundry coke (+3") (% of total coke)	29.9	57.9	76.2	85.3
Breeze (-1/2") (% of total coke)	2.6	2.6	2.5	2.5
Shatter index (+2")	66.1	73.2	85.3	92.0
Tumbler test				
Stability (+1")	53.1	59.6	60.2	59.1
Hardness (+1/4")	67.5	67.5	65.1	60.5
Apparent gravity	.900	.897	.907	.914

Table 6. - Daily Coke Production - Anthracite Blends
(18-hour net coking time)

Battery of 49 ovens, 19 inches average width
and 17 tons coal capacity.

	Percent anthracite				
	0	2.5	5	7	10
Ovens pushed (24 hours)	64.7	64.7	64.7	64.7	64.7
Coal charged (tons)	1100	1100	1100	1100	1100
Total coke produced (tons)	809	812	814	818	821
+3" foundry coke (tons)	242	374	569	630	672
Domestic coke and breeze (tons)	567	438	245	188	149

Table 7. - Daily Coke Production Over Range of Coking Time
(no anthracite)

Battery of 49 ovens, 19 inches average width
and 17 tons coal capacity.

	Net coking time (hours)			
	18	22	26	30
Ovens pushed (24 hours)	64.7	53.1	45.0	39.0
Coal charged (tons)	1100	902.7	765	663
Total coke produced (tons)	809	664	562	487
+3" foundry coke (tons)	242	384	428	415
Domestic coke and breeze (tons)	567	280	134	72

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