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COMPARISON OF MINE SIZES OF SOUTHERN ILLINOIS COALS FOR USE IN METALLURGICAL COKE

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URBANA

CIRCULAR 205

1955

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ABSTRACT

Studies on prepared double-screened sizes of southern Illinois No. 5 and No. 6 coals indicate that these coals are uniform in composition and coking properties. Mine sizes can be mixed or substituted for each other in metallurgical coke blends without appreciable effect on the chemical or physical properties of the coke. Sizes studied included those prepared commercially in the range from 6 to 7/16 inches.

Pressures exerted on coke-oven walls by these coals blended with Pocahontas were similar throughout the range of sizes, and there was no size from either seam that produced an unsafe pressure, or that should be avoided in blends for coke production.

In this investigation the mine sizes of southern Illinois No. 5 and No. 6 seam coals have been evaluated for their use in the production of metallurgical coke. Coal from mines currently supplying the metallurgical coke industry was sampled in the sizes normally produced. Samples included the full range of washed and prepared sizes from 6 x 3 to 1 x 5/8 inches for the No. 5 coal and from the same top size to 3/4 x 7/16 inches for No. 6 coal.

The authors wish to acknowledge the cooperation of the producers of No. 5 and No. 6 coals in southern Illinois, who furnished the coals used in this study, and the Granite City Steel Company, which furnished the low-volatile coal used in the preparation of blends.

Chemical analyses of coals and cokes, and coal-plasticity determinations, were made by the Analytical Division of the Illinois State Geological Survey. We express our appreciation for their continued assistance in all our studies involving the use of Illinois coals in metallurgical coke.

PROCEDURE

Coal samples used in this investigation were taken by cutting the stream of prepared coal at the car loading boom, or at other locations where a representative sample could be obtained. Increments of approximately 25 pounds were taken and accumulated to form gross samples of 2,000 pounds which were mixed thoroughly, allowed to air-dry, sampled for analysis and plastic properties, and stored in bins from which portions were withdrawn as needed for coking tests. Only one size was sampled at a time, and all tests were made promptly to avoid extended storage and coal oxidation.

Coking properties were evaluated in blends of No. 5 and No. 6 coals with 25 percent Pocahontas coal. These blends were sampled for analysis and determination of plastic properties, and then carbonized in a movable-wall oven 17 inches wide and of 650-lb. capacity under operating conditions simulating commercial coke-oven practice (Jackman, 1955). Expansion pressure exerted on the oven walls was measured, and standard chemical and physical tests were made on all cokes produced. Yields of coke were computed, based on the weight of the air-dried coals charged to the oven.

NO. 5 SEAM

No. 5 coal of lowest available sulfur content is produced in the Saline County area. Samples of this coal were taken in 6 x 3, 3 x 1 1/2, 1 1/2 x 1, and 1 x 5/8 inch sizes. Analyses and plastic properties shown in table 1 indicate that the coal is uniform both in chemical composition and plasticity throughout this entire size range.

Similar analytical data on blends of No. 5 with 25 percent Pocahontas coal are shown in table 2. As would be expected, the blends are very uniform in composition and have a Gieseler fluidity sufficiently high to be coked successfully without addition of a more plastic coal (Reed, 1952). Analysis of the Pocahontas coal used throughout the investigation is shown in table 3.

Duplicate coking tests were made on all blends. Analyses of cokes produced are shown in table 4, and other pilot-oven data, including coke physical properties, yields, and expansion pressures are shown in table 6. All cokes had high strength and were of medium size and weight. Coke yields were uniform, the furnace size(+1 inch)comprising about 94 percent of the total product. Expansion pressures ranged from 1.2 to 1.4 lbs. per sq. in., all being sufficiently low to insure safe oven operation.

Results of all tests made on No. 5 coal indicate no significant differences in the coals as prepared over the entire size range studied. Any of these sizes might be mixed, or substituted one for the other, without significant effect on the coke produced or on the operation of coke ovens.

NO. 6 SEAM

No. 6 coal from a southern Illinois mine also was tested by the procedures previously described. Samples of the prepared coal collected for testing included 6 x 3, 3 x 1 1/2, 1 1/2 x 3/4, and 3/4 x 7/16 inch sizes. Chemical analyses and Gieseler plasticity tests made on these coals are shown in table 7. Except for the somewhat higher ash content of the 6 x 3 inch coal, all sizes are very similar in composition and plasticity. Blends for the coking tests, made with 25 percent Pocahontas (table 8) and cokes produced from these blends (table 5) reflect the uniform composition of the sizes sampled.

Pilot-plant coking test results on the No. 6 coal blends, shown in table 9, indicate that the cokes are uniformly strong, with tumbler and shatter indices similar to those of the No. 5 coal blends. Cokes are of medium size and gravity, with a fairly low percentage of fines. Coke yields are consiste

about 93.5 percent of the total coke being of furnace size (+1 inch). Expansion pressure exerted by the No. 6 blends is low, varying from 0.6 to 0.9 lb. per sq. in.

This series of tests on No. 6 coal indicates that all prepared coals from this mine in the size range tested are consistent in chemical and coking properties and may be mixed or interchanged without appreciable effect on coke properties or oven operation. One possible exception is the 6 x 3 inch size in which the ash in the sample taken is about 1 percent higher than that in the other sizes.

NO. 5 AND 6 SEAMS COMPARED

No. 5 and No. 6 coals are both of bituminous B rank. No. 5 is the strongest coking coal mined commercially in Illinois. That from Saline County averages about 14,730 Btu on a moisture- and ash-free basis, compared with 14,470 Btu for the No. 6 coal used in this study.

No. 5 coal prepared for the coke industry has a higher sulfur content than No. 6, normally ranging from 1.4 to 2 percent, depending on the location of the mine and the method of preparation. No. 6 coal currently available contains 1.1 to 1.3 percent sulfur. The Gieseler fluidity of No. 5 coal usually falls in the range of 50 to 150 dial divisions per minute; fluidity of No. 6 coal normally ranges from 5 to 35 dial divisions per minute, although some may go higher.

Because of its relatively low fluidity, No. 6 coal usually is not coked in a two-way blend with Pocahontas. No. 5 coal, owing to its higher sulfur content, normally is not used as a large percentage of a coal blend for metallurgical coke. However, mixtures of No. 5 and No. 6 coals blended with Pocahontas are coked commercially to produce a product of very good quality. Either coal may be blended with both high- and low-volatile Eastern coals to reduce expansion pressure or to improve coke properties.

Coking results for both series of tests are summarized and compared in table 10. Values are the average of those obtained from the four mine sizes of each coal. In blends with 25 percent Pocahontas, both coals are shown to produce cokes of approximately the same strength, as indicated by the tumbler and shatter indices. Coke from No. 6 coal is slightly larger, and the No. 6 blends exert less pressure on oven walls during the carbonizing period.

No. 5 coal produces a higher yield of coke owing to its lower moisture content and to other inherent properties. This advantage is offset by its higher sulfur content, but is worth consideration where sulfur requirements allow it to be used.

SUMMARY AND CONCLUSIONS

This investigation of the mine sizes of Illinois coals used in the coke ndustry may be summarized as follows:

1. The prepared sizes of No. 5 seam coal from Saline County show only inor variations in chemical composition over the range studied. Blends of

each mine size with Pocahontas coal when coked in the pilot oven indicate that there is no appreciable difference in the physical properties or yields of the cokes produced.

2. No. 6 coal, as prepared at a southern Illinois mine, is also uniform in composition throughout the range of sizes studied. Coking tests on blends indicated that all sizes would produce coke having essentially the same physical and chemical characteristics.

3. Expansion pressure exerted on oven walls during the coking period shows little variation throughout the size ranges of No. 5 or No. 6 coal. Pressure exerted by No. 5 coal is greater than that exerted by No. 6, but in no case did the pressure exceed that commonly accepted as safe practice in oven operation. In the size range studied, there are no coals from either seam that cause excessive pressure or that should be avoided in blends for coke production.

4. Both No. 5 and No. 6 coals blended with Pocahontas produce strong cokes with shatter and tumbler indices similar to those of the better grade blast furnace cokes in general use. Cokes are of satisfactory size and gravity. The coke yield from the No. 5 seam is greater, but the higher sulfur content limits its use in blends for metallurgical coke.

REFERENCES

Jackman, H. W., et al., 1955, Coke oven to measure expansion pressure - modified Illinois oven: Preprint, Am. Inst. Min. Met. Eng., 1955; available as Illinois Geol. Survey Reprint Series 1955-E.

Reed, F. H., et al., 1952, Some observations on the blending of coals for metallurgical coke: Blast Furnace and Steel Plant, v. 40, no. 3, p. 305-311, 344; reprinted as Illinois Geol. Survey Circ. 178.

Table 1. No. 5 Coal
Analyses and Plastic Properties

Mine size	M.	Dry basis V.M.	F.C.	Ash	Sulfur	F.S.I.
6" x 3"	5.6	37.7	55.4	6.9	1.60	6
3" x 1 1/2"	5.8	36.7	55.9	7.4	1.47	6
1 1/2" x 1"	5.4	37.1	55.9	7.0	1.43	5 1/2
1" x 5/8"	4.5	36.7	55.5	7.8	1.49	6 1/2

	Gieseler fluidity Dial div. per min. at °C.		Plastic range (°C.) Softening	Solidification
6" x 3"	122	428	384	459
3" x 1 1/2"	110	429	384	458
1 1/2" x 1"	96	433	387	463
1" x 5/8"	81	428	387	462

Table 2. Blends of No. 5 Coal with Pocahontas
Analyses and Plastic Properties

Run	Blend	M.	Dry basis V.M.	F.C.	Ash	Sulfur	F.S.I.
97-102-103	75% No. 5 (6" x 3") 25% Pocahontas	4.5	32.0	61.0	7.0	1.29	6 1/2
93-94	75% No. 5 (3" x 1 1/2") 25% Pocahontas	4.5	31.7	61.5	6.8	1.21	6
119-120	75% No. 5 (1 1/2" x 1") 25% Pocahontas	4.1	31.9	61.1	7.0	1.31	6
104-105	75% No. 5 (1" x 5/8") 25% Pocahontas	3.9	32.0	60.5	7.5	1.32	6 1/2

	Gieseler fluidity Dial div. per min. at °C.		Plastic range (°C.) Softening	Solidification
97-102-103	21	431	393	464
93-94	30	429	388	462
119-120	15	435	395	468
104-105	18	436	396	464

Table 3. Pocahontas Coal Used in All Blends
Analysis and Plastic Properties

	Dry basis				
M.	V.M.	F.C.	Ash	Sulfur	F.S.I.
4.3	16.3	77.7	6.0	0.77	7 1/2

Gieseler fluidity		Plastic range	
Dial div. per min. at	°C.	Softening	Plasticity
6	474	444	506

Table 4. Cokes Produced from Blends Containing No. 5 Coal

		Dry basis			
Run	Blend	V.M.	F.C.	Ash	Sulfur
97-102-103	75% No. 5 (6" x 3") 25% Pocahontas	1.0	89.2	9.8	1.00
93-94	75% No. 5 (3" x 1 1/2") 25% Pocahontas	0.9	89.6	9.5	0.94
119-120	75% No. 5 (1 1/2" x 1") 25% Pocahontas	1.3	88.9	9.8	0.82
104-105	75% No. 5 (1" x 5/8") 25% Pocahontas	1.0	88.5	10.5	1.03

Table 5. Cokes Produced from Blends Containing No. 6 Coal

		Dry basis			
Run	Blend	V.M.	F.C.	Ash	Sulfur
89-90	75% No. 6 (6" x 3") 25% Pocahontas	1.3	87.9	10.8	0.86
84-85	75% No. 6 (3" x 1 1/2") 25% Pocahontas	0.9	88.4	10.7	0.83
86-87-88	75% No. 6 (1 1/2" x 3/4") 25% Pocahontas	1.1	88.4	10.5	0.84
91-92	75% No. 6 (3/4" x 7/16") 25% Pocahontas	1.1	88.8	10.1	0.83

Table 6. Coking Results from Pilot Oven

Coal Blend - 75% No. 5
25% Pocahontas

	No. 5 (6" x 3") Runs 97-102-103	No. 5 (3" x 1 1/2") Runs 93-94	No. 5 (1 1/2" x 1") Runs 119-120	No. 5 (1" x 5/8") Runs 104-105
Coke physical properties				
Tumbler test				
Stability	54.8	55.4	56.2	55.0
Hardness	65.7	66.5	66.7	65.6
Shatter test				
+2"	76.2	80.9	75.8	76.9
+1 1/2"	91.9	92.7	92.4	92.4
+1"	97.1	97.7	97.5	97.1
Coke sizing				
+4"	4.5	5.4	3.7	5.2
4" x 3"	21.1	18.5	28.2	25.4
3" x 2"	47.3	48.4	41.0	45.3
2" x 1"	21.1	21.7	21.7	18.0
1" x 1/2"	2.3	2.3	1.7	2.3
-1/2"	3.7	3.7	3.7	3.8
Av. size (in.)	2.47	2.45	2.53	2.55
Apparent gravity	0.82	0.82	0.81	0.82
Coke yields (% of coal charged)				
Total	70.3	70.5	70.2	70.4
Furnace (+1")	66.1	66.2	66.4	66.1
Nut and pea (1" x 1/2")	1.6	1.6	1.2	1.7
Breeze (-1/2")	2.6	2.7	2.6	2.6
Expansion pressure				
Lbs. per sq. in.	1.30	1.40	1.26	1.25
Bulk density (lbs. per cu. ft.)	50.0	49.9	49.9	49.9
perating data				
Pulverization (-1/8")	80.4	80.6	82.6	81.1
Flue temp. (°F.)	1950	1950	1950	1950
Coking time (hr.)	17	17	17	17

Table 7. No. 6 Coal
Analyses and Plastic Properties

Mine size	M.	Dry basis V.M.	F.C.	Ash	Sulfur	F.S.I.
6" x 3"	8.3	37.7	53.7	8.6	1.20	5
3" x 1 1/2"	8.3	38.0	54.2	7.8	1.16	4
1 1/2" x 3/4"	7.4	38.1	54.4	7.5	1.18	4 1/2
3/4" x 7/16"	7.8	38.7	53.8	7.5	1.21	5 1/2

	Gieseler fluidity Dial div. per min. at °C.		Plastic range (°C.) Softening	Solidification
6" x 3"	23	426	382	454
3" x 1 1/2"	38	425	377	454
1 1/2" x 3/4"	65	425	381	457
3/4" x 7/16"	27	425	382	453

Table 8. Blends of No. 6 Coal with Pocahontas
Analyses and Plastic Properties

Run	Blend	M.	Dry basis V.M.	F.C.	Ash	Sulfur	F.S.I.
89-90	75% No. 6 (6" x 3") 25% Pocahontas	6.5	32.4	59.9	7.7	1.15	4 1/2
84-85	75% No. 6 (3" x 1 1/2") 25% Pocahontas	6.5	32.7	60.0	7.3	1.12	5
86-87-88	75% No. 6 (1 1/2" x 3/4") 25% Pocahontas	6.0	33.0	59.7	7.3	1.12	5 1/2
91-92	75% No. 6 (3/4" x 7/16") 25% Pocahontas	6.0	32.8	60.1	7.1	1.14	5

	Gieseler fluidity Dial div. per min. at °C.		Plastic range (°C.) Softening	Solidification
89-90	9	425	385	459
84-85	12	426	386	460
86-87-88	8	419	386	456
91-92	7	421	386	457

Table 9. Coking Results from Pilot Oven

Coal Blend - 75% No. 6
25% Pocahontas

	No. 6 (6" x 3") Runs 89-90	No. 6 (3" x 1 1/2") Runs 84-85	No. 6 (1 1/2" x 3/4") Runs 86-87-88	No. 6 (3/4" x 7/16") Runs 91-92
Coke physical properties				
Tumbler test				
Stability	54.4	54.5	54.5	53.8
Hardness	64.8	64.4	65.5	65.1
Shatter test				
+2"	82.8	81.8	81.5	77.1
+1 1/2"	93.9	93.0	92.9	91.8
+1"	97.1	97.3	97.1	96.6
Coke sizing				
+4"	7.7	8.4	7.3	5.2
4" x 3"	26.1	26.8	21.5	24.5
3" x 2"	44.8	42.3	45.4	44.6
2" x 1"	14.9	15.9	18.7	18.9
1" x 1/2"	2.2	1.7	2.4	2.6
-1/2"	4.3	4.9	4.7	4.2
Av. size (in.)	2.63	2.63	2.53	2.52
Apparent gravity	0.81	0.79	0.80	0.81
Coke yields (% of coal charged)				
Total	67.5	67.3	67.5	68.0
Furnace (+1")	63.1	62.9	62.8	63.4
Nut and pea (1" x 1/2")	1.5	1.2	1.6	1.8
Breeze (-1/2")	2.9	3.2	3.1	2.8
Expansion pressure				
Lbs. per sq. in.	0.77	0.64	0.72	0.90
Bulk density (lbs. per cu. ft.)	49.9	50.2	50.1	49.9
Operating data				
Pulverization (-1/8")	80.8	79.5	78.5	77.6
Flue temp. (°F.)	1950	1950	1950	1950
Coking time (hr.)	17	17	17	17

Table 10. Comparative Coking Results
No. 5 and No. 6 Coals

	75% No. 5 25% Pocahontas (Av. 4 mine sizes)	75% No. 6 25% Pocahontas (Av. 4 mine sizes)
Coke physical properties		
Tumbler test		
Stability	55.4	54.3
Hardness	66.1	65.0
Shatter test		
+2"	77.5	80.8
+1 1/2"	92.4	92.9
+1"	97.4	97.0
Coke sizing		
+4"	4.7	7.2
4" x 3"	23.3	24.7
3" x 2"	45.5	44.3
2" x 1"	20.6	17.1
1" x 1/2"	2.2	2.2
-1/2"	3.7	4.5
Av. size (in.)	2.50	2.58
Apparent gravity	0.82	0.80
Coke yields (% of coal charged)		
Total	70.3	67.6
Furnace (+1")	66.2	63.1
Nut and pea (1" x 1/2")	1.5	1.5
Breeze (-1/2")	2.6	3.0
Expansion pressure		
Lbs. per sq. in.	1.30	0.76
Bulk density (lbs. per cu. ft.)	49.9	50.0
Operating data		
Pulverization (-1/8")	81.2	79.1
Flue temp. (°F.)	1950	1950
Coking time (hr.)	17	17

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