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CARBONIZING PROPERTIES OF McALESTER BED COAL FROM DOW NO. 10 MINE, DOW, PITTSBURG COUNTY, OKLA.

(Preliminary Report)

By

Joseph D. Davis and D. A. Reynolds

This report represents the results of work done under a cooperative agreement between the Bureau of Mines, U. S. Department of the Interior, and the Oklahoma Geological Survey

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CARBONIZING PROPERTIES OF McALESTER BED COAL FROM DOW NO. 10 MINE, DOW, PITTSBURG COUNTY, OKLA.[a]

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INTRODUCTION

This report gives the analysis and results of carbonization tests made at 500° and 900° C. by the Bureau of Mines-American Gas Association method[1]* on a sample of McAlester bed coal from the Dow No. 10 mine at Dow, Pittsburg County, Okla. It also gives results of tests of this coal in blends with Hartshorne coal from Mine 17 at Bokoshe, Le Flore County, Okla. This work was done in cooperation with the Oklahoma Geological Survey, and a description of the geology of the bed by Robert H. Dott, director of the Survey, is included.

Acknowledgments

The writers wish to acknowledge indebtedness to J. G. Puterbaugh, president of the McAlester Fuel Co., and W. B. Hillery, president of the Premium Smokeless Fuel Co., for furnishing the samples of coal for test, and also to G. J. Flynn, Jr., Bureau of Mines engineer, who supervised the sampling.

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a/ Published by permission of the Director, Bureau of Mines, U. S. Department of the Interior.

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* See references at front of this report.

GEOLOGY OF THE McALESTER BED COAL[2/]

By Robert H. Dott[d/]

The McAlester bed coal occurs in the upper third of the McAlester shale, Des Moines series of Pennsylvanian rocks. The McAlester bed and its probable equivalent, the Lehigh bed, have widespread distribution in the eastern coal field of Oklahoma, occurring within mineable depths in parts of Coal, Atoka, Pittsburg, Latimer, Le Flore, and Haskell Counties.

The McAlester-Lehigh bed is one of the most important of the Oklahoma coal beds, and has accounted for a large percentage of the state's production. This bed has been, or is being mined extensively in the Lehigh-Coalgate district (Coal County); Savanna, McAlester-Dow, Hartshorne-Haileyville, and Adamson districts (Pittsburg County); and to a small extent in the Howe-Wilburton district (Latimer-Le Flore Counties).

The geology of the McAlester coal has not been worked out completely, but available information indicates that the Lehigh coal of Coal County is probably of the same age as the McAlester, and the Stigler bed of Haskell and Muskogee Counties is equivalent to either the McAlester-Lehigh bed, or more likely, to another that lies 50 to 60 feet above it, in the Howe-Wilburton district. They occur near the same stratigraphic position in the upper part of the McAlester shale, although the exact position varies considerably in different districts, owing to the variations in thickness of the formation.

Character of the coal in the different districts is as follows:

Lehigh-Coalgate. Thickness 3.3 to 5.0 feet, generally increasing from southwest to northeast; the coal is generally clean, and free from persistent shale bands, but contains one or more thin bands of pyrite; distri-

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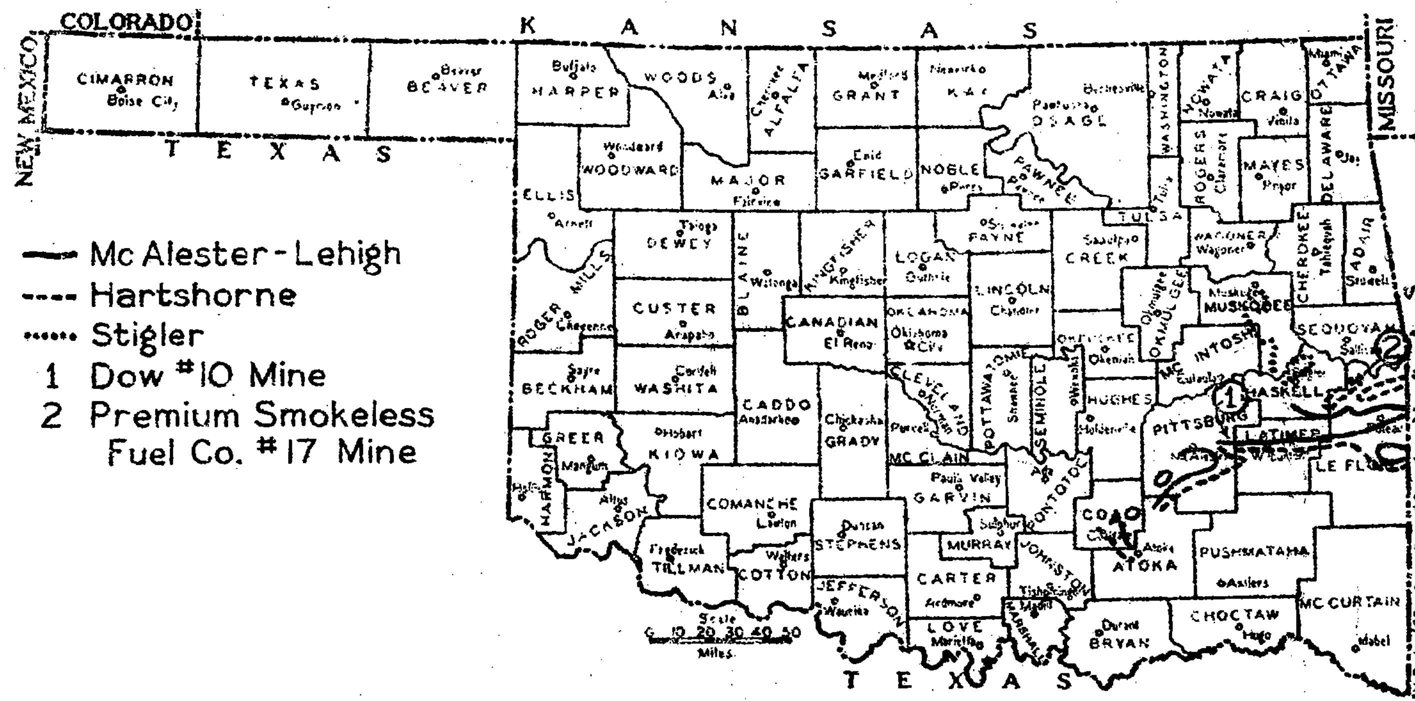
d/ Director, Oklahoma Geological Survey.



INDEX MAP SHOWING OUTCROP OF SOME OF THE COALS OF EASTERN OKLAHOMA bution and attitude of the coal is related to the west flank of the Lehigh syncline, and to the Coalgate anticline. Dips into the Lehigh syncline and on the southeast flank of the Coalgate anticline are sufficiently gentle to permit mining for distances of 1 to 1½ miles down-dip from the outcrop, whereas, the north flank of the Coalgate anticline is much steeper, and mining is correspondingly restricted.

McAlester district and environs. Thickness 1.7 to 4.1 feet, average where mined 3.5 feet; contains several thin partings, most of which are very thin bands of pyrite that can be removed from the coal easily; rocks of the district have been extensively folded, and the dip of the coal has been the most important controlling factor in its development, being mined only where the dip is less than 45°. Where the dip is less than 20° and the thickness 3 feet or more, the bed has been mined extensively.

Howe-Wilburton district. Thickness 1.5 to 2.8 feet of clean coal, too thin for profitable mining under existing conditions, in comparison with the Upper and Lower Hartshorne coals of the district. Several strip pits and slope mines have been operated in the McAlester bed in the vicinity of Red Oak, Fanshawe, and Hughes. Dips vary from 2° to 30° in the area between Wilburton and the Oklahoma-Arkansas State Line, being most gentle in the Howe portion of the district. West from Wilburton to the Pittsburg-Latimer County line, on the north flank of the Adamson anticline, dips on the McAlester coal range from 30° to vertical.

TABLE 1. Analyses of coal from McAlester bed, Dow No. 10 mine, Dow, Pittsburg County, Okla., and blends of this coal with Hartshorne-bed coal 1/

Coal No.	Description	Condition 2/	Proximate, percent				Ultimate, percent					Air drying loss, percent	Heating value, B.t.u. per lb.	Softening temperature of ash, °F.
			Moisture	Volatile Matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur			
73	100 percent McAlester bed	1	3.8	36.3	55.5	4.4	5.4	77.0	1.8	10.9	0.5	1.1	13,570	2,290
		2	-	37.7	57.8	4.5	5.1	80.0	1.9	8.0	.5	-	14,110	—
		3	-	39.5	60.5	-	5.4	83.8	2.0	8.3	.5	-	14,780	—
73A	80 percent McAlester bed and	1	3.5	31.6	59.8	5.1	5.2	77.5	1.9	9.4	.9	1.8	13,620	2,300
	20 percent Hartshorne bed	2	-	32.8	61.9	5.3	4.9	80.3	1.9	6.7	.9	-	14,110	—
		3	-	34.6	65.4	-	5.2	84.8	2.0	7.1	.9	-	14,900	—
73B	70 percent McAlester bed and	1	3.3	30.0	61.2	5.5	5.0	78.0	1.8	8.7	1.0	1.8	13,600	2,300
	30 percent Hartshorne bed	2	-	31.0	63.3	5.7	4.8	80.6	1.9	6.0	1.0	-	14,070	—
		3	-	32.9	67.1	-	5.1	85.5	2.0	6.3	1.1	-	14,920	—
74	100 percent Hartshorne bed,	1	1.6	16.6	74.2	7.6	4.2	81.2	1.7	3.6	1.7	.9	13,940	2,340
	No. 17 Mine, Bokoshe,	2	-	16.9	75.4	7.7	4.1	82.5	1.7	2.3	1.7	-	14,160	—
	Le Flore County, Oklahoma	3	-	18.3	81.7	-	4.4	89.4	1.9	2.5	1.8	-	15,340	—

1/ Analyses by H. M. Cooper, chemist, Bureau of Mines.

2/ 1, Sample as received; 2, moisture-free; 3, moisture- and ash-free.

TABLE 2. Yields of carbonization products, as carbonized basis

Coal 73 - 100 percent McAlester bed
Coal 73A - 80 percent McAlester bed and 20 percent Hartshorne bed
Coal 73B - 70 percent McAlester bed and 30 percent Hartshorne bed

Coal No.	Retort diameter, inches	Carbonizing temperature, °C.	Yields, percent by weight of coal 1/							Yields per ton of coal 1/				
			Coke	Gas	Tar	Light oil	Free ammonia	Liquor	Total	Gas, cubic feet	Tar, gallons	Light oil, gal. In gas	Light oil, gal. Tar to 170°C.	$(NH_4)_2SO_4$ pounds
73	13	500	75.7	6.6	8.5	0.31	0.037	8.5	99.7	2,800	19.9	0.97	1.21	7.1
73	18	900	66.0	17.0	6.1	1.19	.193	8.2	98.7	11,150	12.7	3.29	.58	25.6
73A	18	900	69.5	16.9	5.0	.99	.159	6.7	99.3	11,300	10.5	2.73	.49	22.2
73B	18	900	71.5	16.3	4.1	.86	.208	6.1	99.1	11,500	8.6	2.35	.39	25.9

1/ Coke, tar, ammonia, and light oil are reported moisture-free; gas is reported as stripped of light oil and saturated with water vapor at 60° F. and under 30 inches of mercury.

TABLE 4. Analysis of coke, dry basis

Coal No. 1/	Retort diameter, inches	Carbonizing temperature, °C.	Proximate, percent			Ultimate, percent						Heating value, B.t.u. per pound
			Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur		
73	13	500	12.0	81.8	6.2	3.0	84.3	2.3	3.7	0.5		13,940
73	18	900	2.2	90.8	7.0	.6	90.4	1.4	.2	.4		13,480
73A	18	900	2.0	90.8	7.2	.6	90.0	1.4	.1	.7		13,440
73B	18	900	1.8	91.1	7.1	.6	89.8	1.4	.3	.8		13,440

TABLE 5. Physical properties of coke

Coal No. 1/	Retort diameter, inches	Carbonizing temperature, °C.	True Specific gravity	Apparent specific gravity	Cells, percent	Screen sizes, cumulative percent upon			Shatter test, cumulative percent upon			Tumbler test, cumulative percent upon		
						4-in. screen	3-in. screen	2-in. screen	2-in. screen	1½-in. screen	1-in. screen	1½-in. screen	1-in. screen	1/4-in. screen
73	13	500	1.46	0.71	51.4	76.5	88.4	92.9	77.0	87.5	90.9	33.5	47.3	51.8
73	18	900	1.90	.76	60.0	33.2	52.3	73.2	7.4	28.8	66.5	.5	14.3	71.7
73A	18	900	1.92	.80	58.3	41.1	67.1	90.7	33.2	65.1	89.1	17.5	52.1	73.8
73B	18	900	1.93	.82	57.5	33.9	58.2	82.9	42.7	72.0	92.8	22.3	57.6	74.3

1/ Coal 73 - 100 percent McAlester bed
Coal 73A - 80 percent McAlester bed and 20 percent Hartshorne bed
Coal 73B - 70 percent McAlester bed and 30 percent Hartshorne bed

TABLE 6. Physical and chemical properties of gas

Coal No. 2/	Retort diameter, inches	Carbonizing temperature, °C.	Specific gravity	Gross heating value 1/: B.t.u. per cubic foot, Determined	Gross heating value 1/: B.t.u. per cubic foot, Calculated	Gross heating value 1/: B.t.u. per pound of coal	H_2S, grains per 100 cubic feet	Composition, dry, percent by volume: CO_2	Illuminants	O_2	H_2	CO	CH_4	C_2H_6	N_2
73	13	500	0.627	837	802	1,170	120	8.8	2.4	0.3	22.4	4.1	50.7	10.1	1.2
73	18	900	.404	569	551	3,170	100	3.2	3.5	.3	51.4	10.9	28.6	.8	1.3
73A	18	900	.396	549	543	3,100	140	3.1	3.5	.3	54.0	9.7	27.6	.6	1.2
73B	18	900	.377	528	522	3,040	110	2.6	2.8	.3	56.7	9.5	26.4	.3	1.4

TABLE 7. Analysis of tar distillate and light oil

Coal No. 2/	Retort diameter, inches	Carbonizing temperature, °C.	Distillate, percent by volume of dry tar: Acids	Bases	Neutral oils	Neutral tar oil, percent by volume: Olefins	Aromatics	Paraffins and naphthenes	Refined light oil from gas, percent by volume: Benzene	Toluene	Paraffins	Solvent naphtha	Crude light oil from gas: Olefins, percent by volume	Naphthalene percent by weight
73	13	500	30.9	1.9	33.6	12.3	54.2	33.5	15.3	12.5	51.6	20.6	33.5	0.00
73	18	900	13.5	2.7	28.5	11.5	85.8	2.7	65.3	21.8	5.2	7.7	12.5	.03
73A	18	900	15.1	2.7	30.2	12.0	86.6	1.4	63.2	23.7	3.8	9.3	12.9	.07
73B	18	900	13.7	2.5	29.3	9.0	89.2	1.8	62.5	23.2	4.4	9.9	13.6	.11

1/ Stripped of light oil and saturated with water vapor at 60° F. and under 30 inches of mercury.
2/ Coal 73 - 100 percent McAlester bed.
Coal 73A - 80 percent McAlester bed and 20 percent Hartshorne bed.
Coal 73B - 70 percent McAlester bed and 30 percent Hartshorne bed.

BUREAU OF MINES TESTS

Chemical Composition of Coals and Blends

Table 1 gives the chemical composition and heating values of the coals and blends and the softening temperatures of their ashes. The rank of the McAlester coal is high-volatile A and that of the Hartshorne is low-volatile. The ash and sulfur contents of McAlester coal are well within the limits set by the American Society for Testing Materials[3] for coke- and gas-making coals; the ash content of Hartshorne coal is moderate, but the content of sulfur is somewhat high. It should be such that the sulfur content of the coke will not be more than 1.3 percent;the calculated percentage of sulfur in coke from 100 percent Hartshorne coal is 1.6. However,this coal could not be coked alone in byproduct ovens because it would expand enough to ruin the walls. Table 4 shows that when Hartshorne coal is blended with the low-sulfur McAlester coal,the sulfur content of the coke is well within the limits set by the American Society for Testing Materials. The ashes from both coals soften at low temperatures; it is believed that the cokes would give some trouble from clinkering of the ash if used in a water-gas set or for domestic heating. The softening temperature of the ash in coke used by blast furnaces is of no importance.

Yields of Carbonization Products

Table 2 shows the yields of carbonization products obtained from the McAlester coal at 500° and 900° C., and from the blends at 900° C., and table 3 compares the yields at 900° for the McAlester coal with those obtained at the same temperature from Pittsburgh (Pennsylvania) high-volatile A coal from the Warden mine, Sutersville, Allegheny County, Pa.[4] The Warden coal has been used as a high-volatile blending standard by the Bureau.

McAlester coal yields less coke and tar and more gas,light oil, and ammonium sulfate than the Pittsburgh coal. It also yields more liquor, which usually is an indication of lower coking rank. On the whole, the yields of products from the McAlester coal must be considered satisfactory. Blending with the low-volatile Hartshorne coal increases the yield of coke and decreases the yields of tar, liquor, and light oil. The yield of gas on the volume basis is somewhat higher for the blends than for the unblended McAlester coal; however, it will be shown that the heating value of the gas is greater for McAlester coal when calculated on the basis of per pound of coal. The yields of carbonization products at 500° C. are characteristic of a coal of this rank.

TABLE 3. Comparison of Yields from McAlester Coal with those from the Pittsburgh, Pa., Bed

Product	Coal	
	McAlester	Pittsburgh
Coke, percent	66.0	68.8
Liquor, percent	8.2	7.3
Gas, cu. ft.1/	11,150	10,650
Tar, gallons1/	12.7	14.9
Light oil, gallons1/	3.3	2.8
$(NH_4)_2SO_4$, pounds1/	25.6	19.0

1/ Basis, ton (2,000 lb.) coal carbonized.

Analysis of Coke

Table 4 contains the analyses of the cokes. The low-temperature coke (500°) made from McAlester coal contains more volatile matter and hydrogen than the 900° C. coke; also, the heating value is higher, and the ash content is lower. These characteristics distinguish low- from high-temperature cokes, because devolatilization of the charge is more complete at high temperatures. The analyses of the blend cokes are very similar to that of the McAlester coke, except that blending increased the sulfur content. The reason for this is the higher sulfur content of the Hartshorne coal; however, in the blend cokes the sulfur content is well within the limit set for blast-furnace coke.

Physical Properties of the Coke

The physical properties of the 500° and 900° cokes are given in table 5.

The coke from McAlester coal was medium-grained, and that made at high temperatures had the metallic luster characteristic of most metallurgical cokes. It was of small size, however, and was highly fissured. These fissures caused considerable degradation in size when the coke was tested by the shatter and tumbler methods. The 1-1/2-inch shatter index was 28.8, and the 1-inch tumbler index was 14.3;the corresponding indexes for 25 high-volatile A coals averaged 72.2 and 50.8, respectively5/. This comparison indicates that McAlester coal yields very weak coke in comparison with eastern high-volatile coking coals. Fortunately, however, low-volatile coal is available in nearby districts for blending with McAlester coal, and the results of this investigation indicate that a very satisfactory coke can be made from the blends. For example, blending with 20 and 30 percent Hartshorne coal increased the apparent specific gravity, size, and stability of the 900° coke significantly. The apparent specific gravity,0.76, was increased to 0.80 and 0.82; the cumulative percentages on the 3-inch screen increased from 52.3 to 67.1; and the 1-1/2-inch shatter and 1-inch tumbler indexes increased to 65.1 and 52.1, respectively, for the 20-percent blend, and 72.0 and 57.6, respectively, for the 30-percent blend. The coke from the blend containing 30 percent Hartshorne coal was more stable than that from the blend with only 20 percent; possibly stability could be increased further by blending with greater proportions of this low-volatile coal, but the expanding properties of such blends should be determined before carbonizing in byproduct ovens.

Physical and Chemical Properties of Gas

Table 6 gives the physical and chemical properties of the gas.

The specific gravity of the 900° gas from McAlester coal is 0.404, which is higher than the average of

0.374 for five representative high-volatile A coals[6/]; and this higher gravity is due to the relatively high percentages of oxides of carbon. The heating value of the gas (3,170 B.t.u. per pound of coal carbonized) is satisfactory, although it is somewhat lower than the average of 3,284 B.t.u. obtained for the five coals of similar rank. Gas makers evaluate and compare different gas coals on this basis. Blending with low-volatile Hartshorne coal lowered the heating value of the gas per cubic foot and also on the basis per pound of coal; leaner gas is obtained when the volatile matter in the charge is reduced by blending with coal of higher rank. The hydrogen sulfide content of the gas, 100 grains per 100 cubic feet, is low enough to make the gas highly satisfactory in that respect.

Analysis of Tar Distillate and Light Oil

Table 7 gives the analyses of the tar distillate and light oil.

The high-temperature tar from the McAlester coal contains a high percentage of tar acids (13.5 percent); eastern high-volatile coals generally contain less than half that amount. Probably the McAlester tar would sell at a premium for this reason, because there is increasing demand for cresylic acids contained in the tar-acid fractions.

For the present, at least, coke-oven light oils should be evaluated on the basis of the yields of pure benzene and toluene because of the importance of the former for making synthetic rubber and of the latter for making explosives. The probable yields in gallons per ton of coal carbonized, as calculated from the yield of total light oil after removal of the olefins, are, for the 900° test on McAlester coal, 1.88 gallons of benzene and 0.63 gallon of toluene. A content of 5.2 percent of paraffins (which is high) might make refining of the benzene and toluene difficult, but the proportion of paraffins could be reduced by carbonizing at higher temperatures.

Expanding Properties During Coking

McAlester coal and blends of this coal with low-volatile Hartshorne coal were made in the Bureau of Mines vertical slot oven. Table 8 gives the results obtained.

TABLE 8. Results of Expansion Pressure Tests, Vertical Slot Oven

Coal	Charge density, pounds per cu. ft.	Maximum expansion pressure, pounds per sq. in.
McAlester	50.7	0.8
90 percent McAlester 10 percent Hartshorne	49.0	.9
80 percent McAlester 20 percent Hartshorne	50.8	1.4
70 percent McAlester 30 percent Hartshorne	50.3	1.1

None of these pressures are considered dangerous to coke-oven walls at the test-charge densities. However, the blends should be made carefully to prevent local segregation of the low-volatile coal in the oven; Hartshorne coal expands strongly and might develop high local pressures if segregated. Charge densities in coke ovens average around 50 pounds per cubic foot, although locally the densities may be higher because of irregular charging or having the leveling bar out of line; it is important to find and correct such defects; otherwise, charges may stick in the ovens and injure the walls.

Storing Properties

The coking power of some strongly coking high-volatile coals is improved slightly by moderate weathering in storage, but excessive weathering will destroy the coke-making property entirely. Coals differ in the extent to which exposure affects the coke-making property. In general, the stronger the coke from fresh coal the longer it can be stored without appreciable loss of coking power; but other properties, notably the friability of the coal, affect storing properties. If coal breaks readily in mining and handling, a large proportion of fines will be produced, exposing a relatively large surface to oxidation; whereas, if the coal is resistant to breakage, the surface exposed is much smaller per unit weight of coal, and loss by oxidation is much slower. The Bureau of Mines compares the storing properties of coals by exposing large samples to uniform oxidizing conditions and then making periodic coking tests as oxidation progresses on samples taken from the main lot of coal being oxidized. The length of time that a coal can be oxidized without reduction in strength of the coke can then be determined. One basis of comparison is the length of time of oxidation required to reduce the strength of coke by 15 percent. On this basis Pittsburgh (Pennsylvania) bed coal resisted oxidation almost 6 times as long as the McAlester bed coal from Dow No. 10 mine. It is evident that this particular sample of McAlester coal loses coking power rapidly owing to oxidation and must be stored with extreme care. This is particularly true when it is considered that the fresh coal yields weak coke unless blended with low-volatile coal.