be calculated for any burner tube from a knowledge of only two constants which are specific for the gas mixture and which represent critical gradients of gas velocity at the stream boundary. Flames of natural gas and air, of hydrogen with air and oxygen, and of acetylene with oxygen were investigated. The latter are among the hottest and fastest-burning known, while natural-gas-air flames are comparatively cool and have very-low-burning velocities. The data extend over an extreme range of conditions, and the existence of two critical boundary velocity gradients has been verified for all cases. In addition, the relationships that govern the formation of tilted flames, such as the flame shown in figure 6, have been investigated. Flames of this type are characterized by dynamic asymmetry of the effluent gas stream and consequent distortion of the flow pattern, permitting partial entrance of the combustion zone into the burner tube. Since such flames are generally unstable, their formation places a further limitation on the range of usable flames. A generally applicable equation has been found which permits calculation of the range of gas flow over which burner flames tend to become tilted.

The mechanism of flame propagation has been clarified, and a difficulty of long standing concerning the stability of a combustion zone in a gas stream has been resolved. The dynamics of the thermal expansion of the gas in burner flames has been developed. The quantitative relation between the pressure of the gas stream in the burner tube, the burning velocity, and gas density has been verified experimentally. Finally, it has been demonstrated that quantitative relations exist between the critical boundary velocity gradient for flash-back, the limiting tube diameter for flame propagation and the limiting electrode distance for electric spark ignition. These relations have been derived from consideration of the depth of penetration of the quenching of explosive reactions by solid surfaces.

Carbonization and Gasification

The main objectives of the work for the fiscal year were: Proving of new or imperfectly known reserves of coking coals; finding new methods of using available coals, estimating the storage properties of coals, and determining the yields or tar oils with a view to possible increased utilization of the neutral oils as fuel and the tar acids in the manufacture of plastics.

Coals received for complete series of tests were: (1) Eagle-bed bituminous coal from Kanawha County, W. Va., (2) Powellton-bed bituminous coal from the same location, (3) Elkhorn No. 3-bed bituminous coal from Floyd County, Ky., (4) Monarch-bed subbituminous coal from Sheridan County, Wyo., and (5) Velva mine lignite from Ward County, N. D. The Eagle-, Powellton-, and Elkhorn-bed coals rank as high-volatile coking coals; Elkhorn coal has a dry, volatile-matter content of 39.6 percent and would also be classified as a gas coal. All three coals contain low sulfur and low ash and are satisfactory in this respect for making coke and gas. The Eagle and Powellton coals are hoisted from the same shaft and loaded at the same tipple. Tests of these two coals showed that they could be mixed at the mine and the mixture used for coking purposes. The main objective in the tests of Elkhorn-bed coal was to determine whether a more readily available

Beckley-bed, low-volatile bituminous coal could be substituted for the Pocahontas No. 3-bed, low-volatile bituminous coal regularly used in blends with the Elkhorn coal. Because the Beckley-bed coal varies in expanding properties, depending upon its location in the various mines, the expanding properties of 17 different samples of Beckley-bed coal were determined. The Monarch-bed subbituminous coal produced char on carbonization, instead of coke. However, the ash and sulfur contents were low, and the char should be satisfactory in metallurgical processes where a true coke is not required. This char has been proposed for use in the manufacture of sponge iron. The ash content of the Velva lignite on the dry basis was 11.9 percent and that of its char 15.0 percent. The sulfur content was only 0.3 percent. It was proposed to process this lignite for production of solid fuel and tar oils.

Table 4 gives the yields of carbonization products at 900° C., obtained on the as-carbonized basis by Bureau of Mines - American Gas Association (BM-AGA) 18-inch retort tests, for high-volatile A bituminous Eagle-bed and Elkhorn No. 3-bed coals, and for blends of these coals with low-volatile bituminous Pocahontas No. 3-bed coal, for a 50:50 blend of high-volatile Eagle-and Powellton-bed coal, for subbituminous Monarch-bed coal, and for Velva lignite. The volatile matter, on the as-carbonized basis, was 32.7 percent for the Eagle coal and 38.5 percent for the Elkhorn coal. The corresponding ash contents were 7.4 and 3.0 percent, respectively. Therefore, Eagle should yield more coke and less volatile products than Elkhorn coal, as is shown in table 4. When the Eagle coal was blended with an equal quantity of Powellton coal, which contained 33.1 percent volatile matter and 2.0 percent ash on the as-carbonized basis, the yield of gas was raised from 10,500 to 11,000 cubic feet per ton, the yield of tar was increased from 12.6 to 13.6 gallons per ton, and the yield of coke was decreased from 72.1 to 71.1 percent. The Monarch subbituminous coal yielded somewhat less coke and considerable more tar than were obtained in a similar earlier test of Puritan mine subbituminous coal from Weld County, Colo. The Velva as-received lignite contained 37.0 percent moisture. Before it could be carbonized at 900° C. in the 18-inch retort, it was necessary to dry the lignite to a moisture content of 10 percent. The yields of carbonization products shown in table 4 are on that basis. The yields of tar and light oil from the dried product are very low, and the volume yield of gas is quite high. The high yield of gas results from reaction of the moisture remaining in the coal with the char being produced, and perhaps also with the tar products, to form water gas. Table 5 shows the yields of carbonization products obtained at 500° C. in 13-retort tests from the original lignite and from two dried products. At 500° C. the water-gas reaction is not appreciable. The advantage of drying the lignite before carbonization is shown by the increased yields of valuable products, such as coke, gas, tar, and light oil. It is believed that these yields represent approximately those to be expected by batch carbonization of dried lignite at low temperatures.

Table 6 gives the analyses of the cokes and chars. The granular char from the lignite is high in ash and probably would require briquetting for satisfactory use as domestic fuel. Both the lignite and subbituminous coal chars are high in volatile matter. The fact that the cokes and chars all have about the same hydrogen and total carbon contents, if expressed on a dry, ash-free basis, indicates that the excess volatile matter in the chars contains but little combustible carbon.

TABLE 4. - Yields of carbonization products, as-carbonized basis

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TABLE 4. - Yields of carbonization products, as-carbonized basis

Coal 82 - 100 percent Eagle bed
Coal 82A - 80 percent Eagle bed and 20 percent Pocahontas No. 3 bed (coal 75)
Coal 82B - 70 percent Eagle bed and 30 percent Pocahontas No. 3 bed (coal 75)
Coal 82C - 50 percent Eagle bed and 50 percent Powellton bed (coal 83)
Coal 84 - 100 percent Velva lignite
Coal 85 - 100 percent Monarch bed
Coal 86 - 100 percent Elkhorn No. 3 bed
Coal 86A - 80 percent Elkhorn No. 3 bed and 20 percent Pocahontas No. 3 bed (coal 75)
Coal 86B - 70 percent Elkhorn No. 3 bed and 30 percent Pocahontas No. 3 bed (coal 75)

(Carbonization tests at 900° C.)

Coal No.	Retort diameter, inches	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. To 170° C.	$(NH_4)_2SO_4$, pounds
82	18	72.1	14.1	6.2	1.08	0.213	4.7	98.4	10,500	12.6	2.97	.45	20.9
82A	18	74.3	13.4	5.4	1.03	.207	4.5	98.8	10,500	11.0	2.84	.53	20.8
82B	18	75.6	13.2	4.7	.94	.202	4.5	99.1	10,400	9.7	2.62	.54	19.6
82C	18	71.1	14.7	6.8	1.13	.219	4.7	98.7	11,000	13.6	3.11	.57	20.8
84 2/	18	53.4	37.9	.4	.28	.062	7.3	99.3	18,200	.8	.76	.06	12.9
85	13	44.8	23.1	2.6	.88	.021	25.9	97.3	11,850	5.8	2.44	.88	24.3
86	18	66.4	16.1	7.4	1.28	.158	7.7	99.0	10,850	15.4	3.57	2.11	26.8
86A	18	69.5	14.7	6.4	1.01	.158	7.1	98.9	10,350	13.7	2.87	2.15	24.5
86B	18	71.3	13.8	6.1	.96	.162	6.9	99.2	10,250	13.0	2.73	2.07	23.7

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 a pressure of 30 inches of mercury.
2/ Dried to 10-percent moisture content before carbonization.

TABLE 5. - Yields of carbonization products from Velva lignite, as-carbonized basis

(Carbonization tests at 500° C. in 13-inch retort)

Test No.	Moisture, percent	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
84-1	37.0	46.6	5.9	1.1	0.15	0.007	40.5	94.3	2,050	2.5	0.45	0.06	6.8
84-9	8.0	69.2	11.9	2.1	.21	.007	12.7	96.1	3,250	5.1	.63	.19	9.4
84-13	6.5	70.8	11.8	2.1	.22	.012	10.9	95.8	3,300	5.0	.65	.20	9.3

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 a pressure of 30 inches of mercury.

TABLE 6. - Analysis of coke and char, dry basis

Coal 82 - 100 percent Eagle bed
Coal 82A - 80 percent Eagle bed and 20 percent Pocahontas No. 3 bed (coal 75)
Coal 82B - 70 percent Eagle bed and 30 percent Pocahontas No. 3 bed (coal 75)
Coal 82C - 50 percent Eagle bed and 50 percent Powellton bed (coal 83)
Coal 84 - 100 percent Velva lignite
Coal 85 - 100 percent Monarch bed
Coal 86 - 100 percent Elkhorn No. 3 bed
Coal 86A - 80 percent Elkhorn No. 3 bed and 20 percent Pocahontas No. 3 bed (coal 75)
Coal 86B - 70 percent Elkhorn No. 3 bed and 30 percent Pocahontas No. 3 bed (coal 75)

(Carbonization tests at 900° C.)

Coal No.	Retort diameter, inches	Proximate, percent		Ultimate, percent						Heating value, B.t.u. per lb.
		Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	
82	18	1.0	88.8	10.2	0.6	87.0	1.3	0.2	0.7	12,950
82A	18	.9	89.8	9.3	.6	87.9	1.2	.3	.7	13,040
82B	18	1.0	90.0	9.0	.6	88.2	1.2	.2	.7	13,170
82C	18	.8	92.5	6.7	.6	90.7	1.3	.1	.6	13,460
84 1/	18	3.8	76.7	19.5	.7	77.6	.4	1.5	.3	11,610
85	13	3.0	87.8	9.2	.8	87.8	.9	.8	.5	13,130
86	18	1.9	93.6	4.5	.6	91.9	1.5	.8	.7	13,730
86A	18	2.4	92.4	5.2	.5	91.2	1.3	1.0	.8	13,660
86B	18	2.0	92.3	5.7	.5	91.0	1.3	.8	.7	13,650

1/ Dried to 10-percent moisture content before carbonization.

Table 7 shows the physical properties of the cokes. The chars from the lignite and subbituminous coal were not fused, so that the usual standard tests for physical characteristics could not be made. The fresh lignite char was very sensitive to spontaneous heating. Compared with the more significant indexes of the measurable physical properties that have been averaged for cokes produced from 25 high-volatile coals previously tested, the Eagle coal shows an average 1 1/2-inch shatter index, lower 1-inch and 1/4-inch tumbler indexes, and higher apparent specific gravity. The 50:50 blend of Eagle and Powellton coals produced a weaker coke of higher apparent specific gravity, and coke from the Elkhorn coal is inferior by all indexes, as compared with the average indexes of the 25 cokes.

Table 8 shows the physical and chemical properties of the gas. Judged by the yield of gas expressed in terms of British thermal units per pound of coal carbonized, the yields of gas from Eagle coal and from the five blends containing low-volatile Pocahontas No. 3 coal are about normal. The yield of gas from Elkhorn is higher and is characteristic of other Elkhorn coals tested. The high CO content in the gas from the lignite and the subbituminous coal resulting from the water-gas reaction at the 900° C. carbonization temperature accounts for the seemingly high B.t.u. per pound of coal values for the gases from these low-rank coals.

Table 9 gives analyses of the tar distillates and light oils. The composition of the tars and light oils from the two high-volatile coals and their blends is normal for coals of their ranks. The lignite and subbituminous coal are characterized by high-tar acid content. The high-toluene and low-benzene contents of the light oil from the lignite is noteworthy; apparently the toluene was protected from decomposition by the presence of excess moisture and water gas.

Carbonizing Properties of American Coals

Studies of the carbonizing properties, plasticity, expansion, effect of oxidation, and deterioration in storage of bituminous coking coals were continued. The work of the survey of carbonizing properties of American coals from its inception in 1928 through 1944 has been briefly outlined in a recent report.[72] This report brings the index of coals tested by the Bureau of Mines-American Gas Association (BM-AGA) method up to date, discusses the development of auxiliary tests, and outlines the uses to which the methods have been put in promoting the war program. Up until 1942 the test methods developed with the advice of the Advisory Committee of the American Gas Association had been applied to 66 coals. The present paper gives the sources and analyses of 20 additional coals.

72/ Davis, J. D., and Reynolds, D. A., Work of the Survey of Carbonizing Properties of American Coals: Bureau of Mines Rept. of Investigations 3760, 1944, 17 pp.

TABLE 7. - Physical properties of cokes

Coal 82 - 100 percent Eagle bed
Coal 82A - 80 percent Eagle bed and 20 percent Pocahontas No. 3 bed (coal 75)
Coal 82B - 70 percent Eagle bed and 30 percent Pocahontas No. 3 bed (coal 75)
Coal 82C - 50 percent Eagle bed and 50 percent Powellton bed (coal 83)
Coal 86 - 100 percent Elkhorn No. 3 bed
Coal 86A - 80 percent Elkhorn No. 3 bed and 20 percent Pocahontas No. 3 bed (coal 75)
Coal 86B - 70 percent Elkhorn No. 3 bed and 30 percent Pocahontas No. 3 bed (coal 75)

(Carbonization tests at 900° C. in 18-inch retort)

Coal No.	True specific gravity	Apparent specific gravity	Cells, percent	Shatter test, cumulative percent upon-				Tumbler test, cumulative percent upon-			
				2-inch screen	1-1/2-in. screen	1-inch screen	1/4-inch screen	2-inch screen	1-1/2-in. screen	1-inch screen	1/4-inch screen
82	1.87	0.93	50.3	50.1	71.9	88.4	97.2	0.6	11.9	40.1	65.5
82A	1.89	.93	51.0	49.8	76.8	91.5	97.9	2.4	17.5	47.3	71.2
82B	1.88	.91	51.8	57.6	81.7	93.2	97.9	3.1	21.5	51.3	70.5
82C	1.85	.92	50.2	40.1	66.5	89.5	98.0	.0	11.2	47.0	70.1
86	1.86	.76	59.0	28.1	53.5	79.5	98.0	.0	4.4	34.6	74.4
86A	1.88	.80	57.2	47.4	75.3	92.1	98.3	4.0	25.1	57.2	74.6
86B	1.80	.83	53.9	25.3	74.5	92.3	98.8	5.4	25.1	59.2	71.5

TABLE 8. - Physical and chemical properties of gas

Coal 82 - 100 percent Eagle bed
Coal 82A - 80 percent Eagle bed and 20 percent Pocahontas No. 3 bed (coal 75)
Coal 82B - 70 percent Eagle bed and 30 percent Pocahontas No. 3 bed (coal 75)
Coal 82C - 50 percent Eagle bed and 50 percent Powellton bed (coal 83)
Coal 84 - 100 percent Velva lignite
Coal 85 - 100 percent Monarch bed
Coal 86 - 100 percent Elkhorn No. 3 bed
Coal 86A - 80 percent Elkhorn No. 3 bed and 20 percent Pocahontas No. 3 bed (coal 75)
Coal 86B - 70 percent Elkhorn No. 3 bed and 30 percent Pocahontas No. 3 bed (coal 75)

(Carbonization tests at 900° C.)

Coal No.	Retort diameter, inches	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 value: CO_2	Illuminants	O_2	H_2	CO	CH_4	C_2H_6	N_2
82	18	0.357	602	590	3,160	300	1.4	4.5	0.3	55.1	5.2	31.3	0.9	1.3
82A	18	.339	581	569	3,050	250	1.7	3.7	.3	57.3	4.9	29.8	1.0	1.3
82B	18	.336	566	556	2,940	230	1.7	3.3	.3	59.0	4.5	29.0	.8	1.4
82C	18	.356	597	587	3,280	240	1.2	4.3	.3	55.4	5.1	32.3	.4	1.0
84[2/]	18	.554	331	329	3,010	30	12.9	.5	.2	47.6	28.2	6.8	.7	3.1
85	13	.517	450	440	2,680	150	12.8	2.3	.4	47.8	16.1	19.0	.7	.9
86	18	.393	610	603	3,310	330	2.4	5.2	.3	50.6	7.4	31.4	1.5	1.2
86A	18	.377	600	582	3,110	320	2.2	4.1	.4	54.6	6.2	28.6	2.3	1.6
86B	18	.359	586	576	3,000	300	1.9	4.1	.3	55.9	5.7	29.0	1.6	1.5

1/ Stripped of light oil and saturated with water vapor at 60° F. and under a pressure of 30 inches of mercury.
2/ Dried to 10-percent moisture content before carbonization.

TABLE 9. - Analysis of tar distillate and light oil

Coal 82 - 100 percent Eagle bed
Coal 82A - 80 percent Eagle bed and 20 percent Pocahontas No. 3 bed (coal 75)
Coal 82B - 70 percent Eagle bed and 30 percent Pocahontas No. 3 bed (coal 75)
Coal 82C - 50 percent Eagle bed and 50 percent Powellton bed (coal 83)
Coal 84 - 100 percent Velva lignite
Coal 85 - 100 percent Monarch bed
Coal 86 - 100 percent Elkhorn No. 3 bed
Coal 86A - 80 percent Elkhorn No. 3 bed and 20 percent Pocahontas No. 3 bed (coal 75)
Coal 86B - 70 percent Elkhorn No. 3 bed and 30 percent Pocahontas No. 3 bed (coal 75)

(Carbonization tests at 900° C.)

Coal No.	Retort diameter, inches	Distillate, percent by volume of dry tar			Neutral tar oil, percent by volume			Refined light oil from gas, percent by volume				Olefins in crude light oil from gas, percent by volume
		Acids	Bases	Neutral oils	Olefins	Aromatics	Paraffins and naphthenes	Benzene	Toluene	Paraffins	Solvent naphtha	
82	18	3.9	2.1	28.0	8.2	90.9	0.9	67.1	20.0	4.5	8.4	11.7
82A	18	3.9	1.6	26.3	8.6	88.8	2.6	68.7	20.5	4.4	6.4	11.4
82B	18	5.8	1.8	29.6	8.5	86.2	5.3	62.8	20.7	6.3	10.2	13.2
82C	18	3.8	1.4	23.0	6.8	90.6	2.6	70.1	18.7	3.3	7.9	10.6
84 1/	18	9.2	2.5	38.3	13.0	62.2	24.8	46.3	30.4	3.2	20.1	20.5
85	13	17.9	3.7	40.0	14.0	75.9	10.1	64.3	19.0	4.4	12.3	16.8
86	18	7.8	2.1	32.8	11.0	84.3	4.7	67.6	17.1	7.6	7.7	13.6
86A	18	12.9	2.3	37.2	10.0	83.7	6.3	55.7	20.3	11.6	12.4	17.8
86B	18	14.0	2.1	37.1	10.0	81.4	8.6	53.4	19.1	13.8	13.7	20.4

1/ Dried to 10-percent moisture content before carbonization.

The carbonizing properties and petrographic composition of Thick Freeport-bed coal from Harmar mine[73] were determined. The columnar sample for microscopic studies and the 3,000-pound sample for carbonization tests were taken from the same part of the mine, where the bed was 85.5 inches thick. From both of these samples, 13.5 inches of roof coal, which was not being mined because of its high-sulfur content, and 12.5 inches of bony coal dividing the two benches were excluded. The columnar sample contained 96 percent bright coal and 3.0 percent fusain; anthraxylous components predominated. The carbonization sample contained 35.3 percent volatile matter, 2.8 percent moisture, 6.3 percent ash, and 1.2 percent sulfur upon the as-carbonized basis and 61.7 percent fixed carbon upon the dry, mineral-matter-free basis. The heating value was 14,860 B.t.u. per pound on the moist, mineral-matter-free basis. The coal therefore ranks as high volatile A bituminous. The ash softened at 2,300° F. The friability of the coal, as represented by the carbonizing sample, was 32.3 percent and the agglutinating value index was 7.1 for the 15:1 ratio of silicon carbide to coal. The maximum fluidity, 300 dial divisions per minute by the Gieseler plastometer test, was low for a high-volatile A bituminous coal. The yields of carbonization products were normal for a coal of this rank. Blending with 20 and 30 percent of low-volatile No. 4-bed coal increased the yield of coke and decreased the yields of gas, tar, and light oil but did not affect the yield of ammonium sulfate appreciably. The strength of the cokes was also increased by blending. Similar trends were obtained by blending with 25 percent of low-volatile Pocahontas No. 3-bed coal and with 20 percent of low-volatile Eureka coal from the Lower Kittanning bed. Thick Freeport-bed coal contracted 6.1 percent in the sole-heated oven during carbonization at an average calculated bulk density of 55.5 pounds per cubic foot. Coal from the top bench in the mine contracted 11.8 percent, and that from the bottom bench expanded 0.6 percent. Oxidation of Thick Freeport coal in air at 99.3° C. for 4.0, 9.1, 13.0, and 22.1 days progressively loweredthe yield of tar at 800° C. but did not affect the strength of coke until the period of oxidation exceeded 9.1 days. The proportion of aromatic constituents in the neutral tar oil was increased and those of paraffins and naphthenes were decreased; simultaneously, the proportion of light oil was increased.

The composition and carbonizing properties of nine coals from the Western Region Interior Province and certain blends of these coals were investigated.[74] These coals included: Henryetta bed, Atlas No. 2 mine, Okmulgee County, Okla.; Bevier bed, No. 18 mine, Cherokee County, Kans.; McAlester Bed, Dow No. 10 and Bernardi mines, Pittsburg County, Okla.; Stigler bed, Garland mine, Haskell County, Okla.; Hartshorne Bed, Great Western and Quality mines, Sebastian County, Ark.; No. 17 mine, LeFlore County, Okla.; and Hartshorne bed, San Bois No. 14 mine, Haskell County, Okla. The Hartshorne beds were not identified as Upper or Lower Hartshorne

73/ Davis, J. D., Reynolds, D. A., Sprunk, G. C., Holmes, C. R., and McCartney, J. T., Carbonizing Properties and Petrographic Composition of Thick Freeport-Bed Coal from Harmar Mine, Harmarville, Allegheny County, Pa., and the Effect of Blending This Coal With Pocahontas No. 3- and No. 4-Bed Coals: Bureau of Mines Tech. Paper 655, 1943, 46 pp.

74/ Davis, J. D., Reynolds, D. A., Elder, J. L., Ode, W. H., Holmes, C. R., and McCartney, J. T., Carbonizing Properties of Western Region Interior Province Coals and Certain Blends of These Coals: Bureau of Mines Tech. Paper 667, 1944, 138 pp.

beds, because the information available did not warrant positive identification at the mines. The first three of these coals were carbonized at 500°, 600°, 700°, 800°, 900°, and 1,000° C. McAlester (Bernardi mine), Stigler, and Hartshorne (San Bois No. 14 mine) coals were carbonized at 900° and 1,000° C. Carbonization tests also were made at 900° C. of 80:20 and 70:30 blends of coal from (1) Atlas No. 2 and Great Western mines, (2) Atlas No. 2 and Quality mines, (3) Bevier-bed and low-volatile Pocahontas No. 3-bed (Buckeye No. 3 mine, Raleigh County, W. Va.), (4) Bevier-bed and Quality mine coals, and (5) McAlester-bed, Dow No. 10 mine, and Hartshorne-bed, No. 17 mine coals. In addition, carbonization tests were made both at 900° and 1,000° C. on 40:60, 50:50, and 60:40 blends of McAlester-bed, Bernardi mine, and Hartshorne-bed, San Bois No. 14 mine coals; on a 60:40 blend of this McAlester coal and Stigler bed, Garland mine coal; and on a 50:25:25 blend of Bernardi, San Bois No. 14, and Garland mine coals.

The Henryetta coal is high-volatile B; the Bevier and the two McAlester coals are high-volatile A; the Stigler bed and Hartshorne bed, San Bois No. 14 mine coals are medium-volatile; and the other three Hartshorne bed coals are low-volatile bituminous in rank. The chemical composition of the nine coals is normal for coals of their respective ranks. Henryetta, Bevier, and the two McAlester coals from Dow No. 10 and Bernardi mines contained 12.7, 9.1, 10.9, and 9.6 percent oxygen, on the as-carbonized basis. The Henryetta coal also contained relatively high moisture and sulfur, namely, 6.8 and 2.1 percent, and Bevier coal has a sulfur content of 2.4 percent on the as-carbonized basis. Petrographic analyses showed that Henryetta, Bevier, and McAlester (Dow No. 10 mine) were 100 percent bright coal and contained 3 to 5 percent fusain; Hartshorne (No. 17 mine) contained 98 percent bright coal, 2 percent semisplint, and 5 percent fusain. Mineral matter was well-distributed uniformly in all coals except Bevier, which contained a 2-inch layer of high-ash coal at the top of the bed. Agglutinating values for the 15:1 ratio of silicon carbide to coal were: Henryetta, 4.5; McAlester, (1) Dow No. 10 mine, 5.4, and (2) Bernardi mine, 7.0; Hartshorne, (1) Great Western mine, 5.7, (2) No. 17 mine, 7.0, (3) Quality mine, 10.1, and (4) San Bois No. 14 mine, 9.8; Stigler, 9.4; and Bevier, 8.7. Bevier coal was highly plastic; it attained a maximum fluidity of 1,140 dial divisions per minute at 404° C. in the Gieseler test, whereas the fluidity of the other three high-volatile coals was less than four dial divisions per minute. Yields of carbonization products from the high-volatile coals varied according to their composition and plastic properties. The two McAlester coals contained higher fixed carbon and yielded more coke at 900° C. and more gas at all carbonizing temperatures than were obtained from the highly fluid Bevier coal, which yielded more tar and light oil than the McAlester coals.

The high moisture content of Henryetta coal accounted for its high yield of liquor. Blending with low- or medium-volatile coals increased the yield of coke and decreased the yields of tar and light oil. Cokes from the 100 percent charges of high-volatile coals were weaker than cokes obtained from representative eastern gas coals. McAlester-bed, Dow No. 10 mine coal yielded the weakest coke of all, but the Bernardi mine coal from the same bed gave much stronger coke. This difference in coking power of these two McAlester-bed coals reflects differences in their contents of oxygen, agglutinating values, and plastic properties. Blending Henryetta and Bevier coals with low-volatile Hartshorne coal greatly increased the strength of the coke, and the content of sulfur was reduced when Quality mine

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coal was used in the blend. Blends of Bevier with 20 and 30 percent Quality mine coal yielded stronger coke than blends containing the same proportions of Pocahontas No. 3 coal. McAlester coal from the Bernardi mine yielded strong coke when blended with 40 and 50 percent medium-volatile Hartshorne coal and with 40 percent Stigler coal. These medium-volatile coals yielded strong coke when carbonized alone, but they expanded too strongly to be used safely along in byproduct ovens.

Tests in movable-wall ovens by the Koppers Co. and by the Bureau of Mines indicated that a 50:50 blend of McAlester (Bernardi mine) and Hartshorne (San Bois No. 14 mine) can be carbonized without damage to oven walls through expansion. The 50:50 blend of McAlester (Bernardi mine) and Stigler coals was judged unsafe by similar tests, and a 50:25:25 blend of these McAlester and Hartshorne coals and Stigler coal was judged safe. The gases from all nine coals were relatively lean on the basis of the yield of 900° C. gases, expressed in British thermal units per pound of coal. The gases contained relatively large volumes of hydrogen sulfide. No relationship could be established between the forms of sulfur in the coal and the distribution of sulfur in the gas and coke. Bevier coal differed greatly from Henryetta and McAlester coals in respect to oxidizing properties. It withstood the effects of oxidation exceptionally well, whereas Henryetta and McAlester coals lost their coke-making power rapidly. Stigler coal oxidized slowly; its characteristic rate of oxidation in air at 100° C. was 0.255, which is almost as low as the rate of 0.236 for Pittsburgh-bed coal. Corresponding rates for Hartshorne (San Bois No. 14 mine), McAlester (Bernardi mine), and McAlester (Dow No. 19 mine) coals were 0.335, 0.405, and 0.523, respectively.

The results of an investigation of the composition and carbonizing properties of Pocahontas No. 3 coal from Kimball, McDowell County, W. Va., have been published.[75] Chemical analyses, agglutinating values, plastic characteristics, assays at high and low temperatures, expansion tests, and Bureau of Mines-American Gas Association carbonization tests at 500°, 600°, 700°, 800°, 900°, and 1,000° C. were made. Oxidized samples were carbonized at 800° C., and blends with high-volatile Pittsburgh-bed coals at 900° C. Pocahontas No. 3-bed coal ranks as a low-volatile bituminous coal. It contains 2.4 percent moisture, 16.6 percent volatile matter, 75.8 percent fixed carbon, 5.2 percent ash, and 0.7 percent sulfur on the as-carbonized basis. The ash softened at 2,400° F. The proportions of ash and sulfur are well below the limits specified for coals suitable for the production of metallurgical coke. The agglutinating value, at a silicon carbide-coal mixture of 15:1, was 10.9 and the maximum plasticity by the Gieseler plastometer was 2.7 dial divisions per minute at 481° C.

75/ Davis, J. D., Reynolds, D. A., Ode, W. H., and Holmes, C. R., Carbonizing Properties of Pocahontas No. 3-bed Coal from Kimball, McDowell County, W. Va., and the Effect of Blending this Coal with Pittsburgh-bed Coal: Bureau of Mines Tech. Paper 670, 1944, 35 pp.