High-Volatile Bituminous Coals

The high-volatile coals represented 10 beds in five States, as follows: Pennsylvania, 3; West Virginia, 4; Kentucky, 1; Illinois, 1; and Colorado, 1. All ranked as high-volatile A except Illinois No. 5, which ranked high in the high-volatile B classification.

Pittsburgh coal (348) from Republic Banning mine, Fayette County, Pa., was tested under a cooperative agreement primarily to determine the yields obtainable at 800°, 900°, and 1,000° C. from the unblended coal. The 900° C. yields were: Coke, 69.4 percent; and on the basis of per ton of coal, gas, 10,200 cubic feet; tar, 13.8 gallons; light oil, 3.26 gallons; and ammonium sulfate, 23.3 pounds.

Upper and Lower Freeport-bed coals from Kent No. 1 and Kent No. 2 mines, Indiana County, Pa., were blended in approximately equal proportions at the mines; therefore, they were tested as one coal (346). The 900° C. coke resisted breakage well in shatter test, but was rather abradable in the tumbler test. Blending with 30 and 70 percent Pittsburgh coal of similar rank weakened the coke slightly.

Eagle coal (362) from Cannelton No. 3 mine, Fayette County, W. Va., coked strongly; the cokes were significantly stronger than average cokes from high-volatile A coals. Two blends (362D and 362F) containing 80 percent Eagle and 20 percent Pocahontas No. 3 (357), or 20 percent Pocahontas No. 4 (358), respectively, yielded similar cokes, which were but slightly stronger than coke from 100 percent Eagle. Previous investigations have shown that the increase in coke strength gained by blending an exceptionally strongly coking high-volatile coal, like Eagle, with low-volatile coal is small.

No. 2 Gas coal (363) from Cannelton No. 100 mine, Kanawha County, W. Va., yielded coke that was weaker than the average from high-volatile A coals. However, when it was mixed in equal proportions with Eagle (362) for blending with low-volatile coal the resulting blends (362A, 362B, and 362C), containing 35 or 40 percent No. 2 Gas, coked about as strongly as similar binary blends (362D and 362F) composed of Eagle and Pocahontas coals. It was concluded, therefore, that No. 2 Gas may be substituted for half of the Eagle in a blend without appreciable loss in coke strength. A blend (363A) of 80 percent No. 2 Gas and 20 percent Pocahontas No. 3 (357) yielded 900° C. coke having shatter indexes equalling and tumbler indexes slightly lower than the coke from a similar blend containing 80 percent Eagle (362). No. 2 Gas contracted 13.3 percent in the sole-heated oven, and its blend (363A) with 80 percent Pocahontas No. 3 expanded 0.7 percent.

No. 5 Block-bed coal (364) from Northland mine, Wayne County, W. Va., yielded coke that withstood breakage in the shatter test but was abradable. The 1- and 1/4-inch tumbler indexes, 24 and 52, respectively, of the 900° C. coke were well below average for high-volatile A coals. The yield of tar (10.4 gallons per ton at 900° C.) was low, indicating that the sample may have been taken from a part of the bed exposed to oxidation.

Stockton-Lewiston-bed coal (366) from the H. G. Jones mine, Lincoln County, W. Va., coked more strongly than No. 5 Block (364), although the low tumbler indexes (1-inch, 34; and 1/4-inch, 53) indicate high abradability for the 900° C. coke. The yield of tar at 900° C. (11.8 gallons per ton) was 2.1 gallons less than the average for 32 coals of similar rank.

Imboden-bed coal (356) from Shadyside mine, Letcher County, Ky., was carbonized by the BM-AGA and slot-oven methods. The cokes were rather fingery and fractured readily in the shatter test. Blending with 20 percent Pocahontas No. 3 (75) strengthened the coke significantly. Tumbler- and shatter-test indexes of the blend cokes indicate that Imboden coal could be used in the production of metallurgical coke if properly blended. Although Imboden contracted 1.5 percent in the sole-heated oven, the blends (356A and 356B) containing 20 and 30 percent Pocahontas No. 3 should be carbonized at moderate bulk densities, because they expanded 6.5 and 8.3 percent, respectively.

Illinois No. 5-bed coal (361) from Sahara No. 16 mine, Saline County, Ill., ranked as high-volatile B, although it was high in that rank. It was carbonized in BM-AGA retorts at 800° and 900° C. and in the 500-pound slot oven. The cokes were highly fractured, and large proportions broke during the physical tests. Blending with 20 percent Pocahontas No. 3 (75) strengthened the coke appreciably. For example, in testing the slot-oven coke, the 1-1/2-inch shatter index was raised from 71 to 89, and the 1-inch tumbler index increased from 29 to 52; the hardness factor or 1/4-inch tumbler index decreased from 68 to 61. No. 5 coal contracted 3.1 percent in the sole-heated oven. Because its blends (361A and 361B) with 20 and 30 percent Pocahontas expanded 1.3 and 3.2 percent, respectively, they should be carbonized at moderate bulk densities in byproduct ovens.

The sample of coal (352) from core-drill hole No. 26-23, Gunnison County, Colo., contained 5.5 percent ash and 0.6 percent sulfur, as received, and it ranked as high-volatile A bituminous. Although the coke was rather fingery in comparison to coke from eastern coking coals, its size and other physical properties were similar to those of coke made from Lower Sunnyside coal. Results of these tests indicate that this drilled sample coked about as strongly as Lower Sunnyside.

No. 5 Block- and Pocahontas No. 6-bed Coals

An investigation of No. 5 Block-bed coal from No. 5 mine, Raleigh County, W. Va., and of Pocahontas No. 6-bed coal from Birdseye mine, Fayette County, W. Va.,[56] showed that both coals could be used in the production of metallurgical coke if blended with suitable coals of different rank. No. 5 Block, which ranked as high-volatile A coal, yielded strong coke when blended with 30 percent Pocahontas No. 3. Pocahontas No. 6, a medium-volatile coal, coked strongly when blended with 70 percent Pittsburgh-bed coal. Pocahontas No. 6 should be cleaned to lower its ash content, 13.9 percent, and lower the abradability of coke made from its blend. No. 5 Block contracted 21.5 percent in the sole-heated oven at a charge density of 55.5 pounds per cubic foot. Pocahontas No. 6 expanded only 0.2 percent under the same test conditions, although the 1.50 floats, which contained 8.6 percent ash, expanded 7.8 percent.

56/ Davis, J. D., Reynolds, D. A., Brewer, R. E., Wolfson, D. E., and Ode, W. H., Carbonizing Properties of No. 5 Block-Bed Coal from No. 5 Mine, Montcoal, Raleigh County, W. Va., and of Pocahontas No. 6-Bed Coal from Birdseye Mine, Sewell, Fayette County, W. Va.: Bureau of Mines Tech. Paper 711, 1949, 72 pp.

Paonia, Colo., Coal

The carbonizing properties of coals from 10 beds penetrated in core-drilling hole 5-33 near Paonia, Gunnison County, Colo.,57/ were determined by the BM-AGA method. Only the lowest bed yielded coherent coke and that was too weak to be suitable for use in blast furnaces.

Beckley-bed Coal, Raleigh County, W. Va.

A study of the composition and carbonizing properties of low-volatile Beckley-bed coal from Stanaford No. 1 mine, Raleigh County, W. Va.,58/ showed that coal to be suitable for blending with high-volatile A coal for the production of metallurgical coke. Beckley coal expanded strongly during carbonization but should be safe to use in moderate proportions in commercial ovens.

Blending Tests of Appalachian Coals

Physical properties of 900° C. cokes made by the Bureau of Mines-American Gas Association method from 12 high-volatile A Appalachian coals and their blends with 20 and 30 percent Pocahontas No. 3 were tabulated and compared graphically.59/ These conclusions were drawn: (1) Increases in the coking power of high-volatile A coals effected by blending with Pocahontas No. 3 generally were greatest for coals that yield the weakest coke when carbonized singly, and (2) the coke-strength indexes of the blends of an appreciable proportion of the high-volatile A coals increased only slightly on raising the proportion of low-volatile coal from 20 to 30 percent.

Plasticity of Coals

Plastic properties of 37 coals and 28 blends were determined during the fiscal year. Of the 65 samples, table 6 describes 26 of the coals and the 28 blends. In addition, Pocahontas No. 3 bed, Lake Superior No. 3 mine, McDowell County, W. Va., raw whole coal (d357) and the 10 coals described in table 10 also were tested. All samples were tested by either the Gieseler and/or Davis plastometer methods; two or more tests on the same sample were usually made by each test method. A total of 233 tests - 117 by the Gieseler and 116 by the Davis method - were made.

57/ See footnote 9.

58/ Davis, J. D., Reynolds, D. A., Brewer, R. E., Wolfson, D. E., Ode, W. H., and Birge, G. W. Carbonizing Properties of Beckley-Bed Coal from Stanaford No. 1 Mine, Mt. Hope, Raleigh County, W. Va.: Bureau of Mines Tech. Paper 712, 1949, 38 pp.

59/ Reynolds, D. A., Effects of Blending Pocahontas No. 3 Coal with 12 High-Volatile A Coals: Am. Gas Assoc., May 1949, 5 pp.

TABLE 10. - Special samples for Lurgi process of complete gasification

Coal No.	Description and source
350	Upper Freeport bed, slope mine, Indiana County, Pa.
a350	Upper Freeport (350), fine-size coal.
351	Upper Freeport bed, Watson mine, Indiana County, Pa.
355	Pittsburgh bed, Federal No. 1 mine, Marion County, W. Va.
360	Pittsburgh bed, Laura Lee mine, Harrison County, W. Va.
367	Carbon-Emery bed, Hiawatha mine, Carbon and Emery Counties, Utah.
368	Pittsburgh bed, Jamison No. 9 mine, Marion County, W. Va.
368-h	Pittsburgh (368) preheated at about 400° C. to destroy coking.
368-Ox	Pittsburgh (368) oxidized for 1 hour at 250° to 300° C.
396	Low-ash Kentucky coal preheated at about 400° C. to destroy coking.

The plastic properties of the 26 coals and 28 blends described in table 6 and of Pocahontas No. 3 raw whole coal (d357) were determined in connection with the BM-AGA survey of their carbonizing and expanding properties. As related to these properties, the plastic characteristics may be discussed conveniently according to characteristic temperature indications of certain stages in the fusion range, the degree of maximum fluidity (dial divisions per minute) developed in the Gieseler test method, and the maximum resistance (pound-inches) observed in the Davis test method. In general, as the rank of the coal increased from high-volatile A to low-volatile bituminous, the fusion is displaced to a higher temperature, the maximum fluidity becomes less, and the maximum resistance becomes greater. These changes in plastic properties usually correlate well with corresponding increases in strengths of the cokes produced at 800° and 900° C. from coals of the respective ranks. Variations in chemical and petrographic composition among individual coals of a given rank have a greater influence on the maximum fluidity and maximum resistance values than on the temperature range of fusion. For this reason, the plastic properties of the coals and blends are given in table 11 in terms of these values in relation to the strengths of their corresponding cokes.

Table 10 gives the source of 10 coals whose fusion properties were determined by the Davis plastometer method to ascertain the suitability of these coals for complete gasification by the Lurgi process. The first seven samples listed in the table gave Davis maximum resistance values ranging from 7.8 for coal 360 to 40.5 for coal a350. The last three samples were tested with the new drum-rabble assembly in the Davis plastometer retort and gave Davis maximum resistances of 75.5, 46.8, and 29 pound-inches, respectively. The plastic properties of all 10 samples indicate that these coals would have to be preheated or oxidized for some time before they would be suitable for charging into the Lurgi generator.

Past experience has indicated that the plastic properties of certain coals of poor fusion properties were not evaluated properly by Davis plastometer test method. Such coals tend to fuse around the shaft, and little or no fused material remains between the faces of the rabble arms and the retort wall; the indicated resistance, therefore, is too low. To remedy this defect, a closed drum was built around the shaft, and the four rabble arms were fastened on the outside surface of the drum at the same relative positions as in the old Davis plastometer. Because of the reduced volume in the new assembled retort, a smaller coal sample was required. Numerous tests with 12- and 8-gram samples showed that the 8-gram sample of through 20-mesh coal, as compared with the 18-gram sample used in the old assembly, was suitable.

Characteristic temperatures, appropriately corrected for the different heat gradients in the two retort assemblies, agreed well. As expected, the Davis maximum resistance obtained on a given coal by the new-type assembly is higher than that by the old assembly because of reduced free volume within the retort.

TABLE 11. - Plastic properties of coals and blends

Coal No.	Gieseler 1/	Davis 2/	Remarks
			Low-volatile coals
345	405	23.2	The plastic properties of these coals followed closely the same order as their relative rank.
370	2,160	40.5	
347	61	60	
358	140	28	The plastic properties of the eight coals and the four blends indicate that if the coals are properly blended, strong cokes may be expected.
369	115	3/	
372	4	4/77	
357	1.6	3/	
d357	4.7	3/	d357 is raw whole coal from the same source as 357.
345A	5/	6/	
370A	5/	6/	
347A	5/	6/	
369A	5/	28	
			Medium-volatile coals
375	900	4/14.5	Plastic properties of 374 and 378 indicate that their cokes should be slightly less abradable than the coke from 375. The appreciable maximum fluidities of the six blends indicate that their cokes would be weaker than the cokes from the corresponding medium-volatile coals.
374	1,580	4/38.5	
378	2,000	4/25	
375B	7/	8/	
378B	7/	8/	
374A	7/	8/	
375A	7/	9/	
378A	7/	9/	
374B	7/	9/	
			High-volatile coals
364	49	3/	The coals tested covered the whole range of rank of high-volatile A bituminous coals (dry, mineral-matter-free fixed carbon less than 69 percent, and moist B.t.u. 14,000 or more). The maximum fluidity, therefore, ranges from very low to peak and then to lower values with in-increasing rank of the coals. The plastic properties of the high-volatile coals, except for the lower ranking high-volatile A coals and the high-volatile B coal, indicate that they should produce good cokes. Except for blend 346A, which contained two high-volatile A coals and developed a very high maximum fluidity, all other blends should produce strong cokes.
366	97	9.5	
352	106	8.2	
363	30,000	4/12	
363A	1,265	4/19	
346	20,000	28.6	
346A	20,000	31.6	
348	7,845	37	
376	7,500	4/50	
362	5,850	7.5	
362A	5,725	19.3	
362B	1,190	8.8	
362C	2,610	4/79	
362E	320	42.5	
362D	1,000	44.5	
362F	705	4/21	

TABLE 11. - Plastic properties of coals and blends (Cont'd.)

Coal No.	Gieseler 1/	Davis 2/	Remarks
			High-volatile coals
o28	5,725	4/25	o28 is Pittsburgh coal containing 62.8 percent dry, mineral-matter-free, fixed carbon and is one of the representative samples of the standard blending coal (28).
356	1,850	8.5	
356A	500	19	
356B	180	27	
373	3,080	4/64	
b371	10/		
c371	10/		
d371	10/		
e371	10/		
f371	10/		
b371A	11/		
c371A	11/		
d371A	11/		
e371A	11/		
f371A	11/		

1/ Gieseler maximum fluidity in dial divisions per minute.
2/ Davis maximum resistance in pound-inches.
3/ Did not fuse at normal rate of 3° C. per minute.
4/ New type plastometer described later in this report.
5/ Higher Gieseler maximum fluidity than for corresponding constituent low-volatile coal.
6/ Lower Davis maximum resistance values than for corresponding constituent low-volatile coal.
7/ Gieseler maximum fluidity value appreciably increased over that of corresponding constituent medium-volatile coal.
8/ Higher Davis maximum resistance values than for corresponding constituent medium-volatile coal.
9/ Lower Davis maximum resistance values (new type plastometer) than for corresponding constituent medium-volatile coal.
10/ Gieseler maximum fluidity values ranged from 2865 for coal f371 to 5500 for coal b371.
11/ With the exception of blend c371A, the Gieseler maximum fluidity values of the blends were higher than those of the corresponding channel samples. Different degrees of fluidity may be expected because the composition of the coal varies from point to point in the mine.

Expanding Properties

Results of the expansion tests are given in table 12. Averages are given for tests in the sole-heated oven except for three coals that were not tested in duplicate. All results are expressed as expansion, or contraction at a bulk density of 55.5 pounds per cubic foot.

TABLE 12. - Expanding properties of coals

Coal No.	Test moisture percent	Average test bulk density, pounds per cubic foot	Sole-heated oven expansion, percent: At 55.5 pounds per cubic foot[1]	Sole-heated oven expansion, percent: Dry solid coal	Vertical oven, maximum pressure on movable wall, pounds per square inch[2]
Low-volatile coals					
345[3]	1.7	52.70	+11.2	69.0	-
345A	1.6	53.70	-3.7	46.3	-
347[3]	1.4	54.68	+6.4	63.7	-
347A	2.1	53.33	-4.8	45.3	-
357	1.1	55.43	+10.9	68.3	-
a357	1.5	53.07	+13.1	72.6	-
b357	1.4	53.13	+13.1	73.7	-
c357	1.8	53.75	+10.2	68.8	-
358	1.0	53.47	+16.2	74.6	-
a358	1.4	52.99	+25.3	89.1	-
b358	1.5	53.15	+20.4	82.2	-
c358	1.3	53.22	+21.3	85.0	-
370	4.4	53.05	+5.7	59.4	-
370A	2.8	53.22	-4.0	46.5	-
372	2.3	53.56	+25.1	95.3	-
374	1.7				
Medium-volatile coals					
374	1.7	53.63	+6.7	57.9	-
374A	1.9	53.46	-4.3	44.6	-
374B	2.0	53.45	-.7	50.2	-
375	1.1	52.98	+18.4	72.0	-
375A	1.7	53.29	-5.6	41.2	-
375B	1.6	53.28	-2.0	46.6	-
High-volatile coals					
b326	3.4	55.27	-10.1	29.1	-
b326	3.4	51.87	-	-	3.6
b326	3.4	21.71	-	-	4.1
a331	3.6	53.07	-5.6	46.3	-
a331	3.6	50.56	-	-	1.1
a331	3.6	50.41	-	-	2.0
346[3]	1.7	54.83	+1.8	44.2	-
346A	1.8	53.05	-16.2	27.5	-
356	3.0	52.70	-1.5	49.4	-
356A	2.7	52.29	+6.5	58.7	-
356B	2.4	53.37	+8.3	62.6	-
361	6.4	53.22	-3.1	57.0	-
361A	5.5	53.06	+1.3	63.7	-
361B	5.2	53.11	+3.2	65.0	-
362	1.9	53.41	-2.6	46.0	-

TABLE 12. - Expanding properties of coals (Cont'd.)

Coal No.	Test moisture percent	Average test bulk density, pounds per cubic foot	Sole-heated oven expansion, percent: At 55.5 pounds per cubic foot 1/	Sole-heated oven expansion, percent: Dry solid coal	Vertical oven, maximum pressure on movable wall, pounds per square inch 2/
		High-volatile coals (Cont'd.)			
362A	1.5	53.31	+1.4	51.4	-
362B	1.6	53.53	+4.8	55.0	-
362C	1.7	53.28	+4.1	53.3	-
362D	1.6	53.41	+5.1	55.0	-
362E	1.6	53.67	+5.1	56.5	-
362F	2.5	53.63	+3.8	54.3	-
363	1.7	53.60	-13.3	29.8	-
363A	1.4	53.25	+.7	51.3	-
364	4.9	53.84	-15.9	31.1	-
366	4.4	53.30	-17.8	35.1	-
371	2.4	53.44	-23.1	22.9	-
b371	2.6	52.79	-11.0	36.5	-
c371	2.5	53.11	-4.4	45.5	-
d371	3.4	53.34	-9.9	43.5	-
e371	4.1	53.02	-15.1	34.3	-
f371	5.3	53.03	-11.2	39.0	-
b371A	3.6	52.43	+1.0	56.5	-
c371A	3.2	52.76	+6.5	59.6	-
d371A	3.7	53.05	-.2	54.8	-
d371A	3.3	49.72	-	-	1.5
d371A	3.4	50.88	-	-	1.9
e371A	3.7	53.00	-3.6	51.8	-
f371A	4.9	53.07	-3.3	52.0	-
373	2.4	56.37	-6.7	46.0	-
376	.8	55.31	-11.9	37.6	-
376	.8	55.46	-	-	3.4
376	.8	54.75	-	-	4.3

1/ End-of-test contraction for contracting coals; maximum expansion for expanding coals.
2/ Each vertical-oven test reported individually.
3/ Single tests.

In a study of Thick Freeport-bed coal (371), six channel samples of "low coal" were blended with 17-1/2 percent Lower Kittanning (372) for expansion tests. "Low coal" is taken from those parts of the mine where the upper and lower benches have merged. Because the lower bench coal normally expands slightly, this "low coal" may be unsafe to blend with the strongly expanding Lower Kittanning coal. Sample c371 contracted the least of the "low coals," and its blends (c371A) expanded the most (6.5 percent). The other blends contracted, except b371A, which expanded 1.0 percent.

Upper and Lower Freeport coal (346 and b326), Upper Freeport (a331), and Upper Freeport (376) are borderline coals that frequently have yielded cokes that have been difficult to push when carbonized commercially. Upper and Lower Freeport (346) was the only one of these coals to expand in the sole-heated oven, and the fact that another sample (b326) did not expand is not surprising, because Freeport coals usually are inconsistent in expanding. Sample b326 exerted pressures of 3.6 and 4.1 percent during carbonization in the large vertical oven. Two samples of Upper Freeport, representing different mines, differed in expanding properties - Sigley mine coal (376) contracted 11.9 percent in the sole-heated oven and produced wall pressures of 3.4 and 4.3 pounds per square inch in the large vertical expansion oven, whereas Watson mine coal (a331) contracted only 5.6 percent in the sole-heated oven and produced wall pressures of 1.1 and 2.0 pounds per square inch in the large vertical expansion oven.

New Experimental Coke Oven

During the past year the 1/2-ton laboratory coke oven installation at the Bureau of Mines Southern Experiment Station, Tuscaloosa, Ala., was completed. From preliminary tests it was concluded that:

1. The quality of the coke produced in the oven, under identical operating conditions, is reproducible within the known limits of accuracy of the conventional ASTM tests.

2. The quality of coke from the test oven is substantially the same as that from a full-scale commercial oven when the same coal mix and operating conditions are used.

3. The wall pressure-time history for a given coal under the same carbonizing conditions is reproducible.

4. The apparent specific gravity of the coke from the test oven is approximately 10 percent lower than commercial coke. This difference is due to the oven geometry.

5. The test oven is substantially free from end effects when the coke 6 inches from the unheated faces is considered.

6. The addition of 1 quart of oil per ton of coal charged increases the bulk density by 5 percent and the apparent specific gravity of the coke by 2 percent. Additions of greater quantities of oil would cause a further increase in these two quantities.

Oxidizing Properties of Bituminous Coals

The effects of oxidation at room temperature and at 99.3° C. on 11 coking coals were determined.60/ The effects on carbonizing properties were decreased strength and fusion of coke and yield of tar, increased apparent specific gravity of coke and yield of ammonium sulfate, and irregular proportions of acids and residual pitch in

60/ Brewer, R. E., Reynolds, D. A., Steiner, W. A., and Van Gilder, R. D. Carbonizing Properties of Coking Coals, Effect of Oxidation in Storage: Ind. Eng. Chem., vol. 40, 1948, p. 1243-1254.