by the BM-AGA method at 500°, 600°, 700°, 800°, 900°, and 1,000° C.; blends of this coal with 20 and 30 percent of low-volatile bituminous Pocahontas No. 3-bed coal at 900° C.; and the high-volatile A bituminous Hazard No. 7 coal at 900°C. The Hazard No. 4 bed was 33.0 to 42.25 inches thick at three points sampled in the Columbus No. 4 mine and contained no partings. The columnar sample examined microscopically contained 11 area percent of opaque attritus and 3 percent fusain; the coal, therefore, was classified as a bright coal. The carbonizing sample, taken at a representative point in the mine, contained 60.7 percent fixed carbon on the dry, mineral-matter-free basis and had a heating value of 14,440 B.t.u. per pound on the moist, mineral-matter-free basis. It contained 3.6 percent moisture, 3.8 percent ash, and 0.6 percent sulfur as carbonized. The ash softened at 2,400° F. The friability (12.9 percent by the A. S. T. M. tentative method) was low; the agglutinating index determined on a 15:1 mixture of silicon carbide and coal was 4.1. Plasticity tests indicated that Hazard No. 4 coal fuses at a relatively high temperature and has a short plastic range; the maximum fluidity in the Gieseler plastometer (10.6 dial divisions per minute) was low for a high-volatile A bituminous coal. Yields of carbonization products from Hazard No. 4 coal in the 18-inch retort at 900° C. were: coke, 66.8 percent, and, on the basis of per ton of coal carbonized - gas, 10,700 cubic feet; tar, 12.2 gallons; light oil in gas, 2.88 gallons; and ammonium sulfate, 23.4 pounds. The high-temperature cokes were highly fissured and therefore relatively weak; the 1-1/2-inch shatter and 1-inch tumbler indexes of the 900° C. cokes were satisfactory. Blending with 20 percent Pocahontas No. 3 coal greatly increased the size and strength of the 900° C. coke, but little was gained by increasing the proportion of Pocahontas No. 3 coal to 30 percent. The 900° C. gas had a heating value of 3,280 B.t.u. per pound of coal and contained 280 grains of hydrogen sulfide per 100 cubic feet. The Hazard No. 7 bed was 53.5 to 55.5 inches thick at five points in the Hardburly mine and was separated into two benches by a layer of bone 3 to 5 inches thick. Except for a higher ash content of 6.7 percent as compared to only 3.8 percent on the as-carbonized basis for the Hazard No. 4 coal, the chemical composition of the two coals checked closely. The agglutinating value, plastic properties, and yields of carbonization products of the two coals were similar; Hazard No. 7 coke was stronger than Hazard No. 4 coke. Both Hazard coals contracted during carbonization in the sole-heated, expansion-test oven. The percentage contraction at a charge density of 55.5 pounds per cubic foot was 3.2 for Hazard No. 4 coal and 9.5 for Hazard No. 7 coal. Oxidizing tests at 100° C. showed that Hazard No. 4 coal oxidizes at a high rate and that it would be almost three times as likely to heat spontaneously as Pittsburgh-bed, Warden mine, coal. The durability of coking power, defined as the time of oxidation in days in air at 100° C. required to reduce the coke-strength index 15 percent, was 3.93 days for Hazard No. 4 coal and 28.5 days for the Warden mine coal.

Effect of Temperature and Rate of Heating on Carbonization Yields

A chapter[72] discussing the dependence of yields of products on temperature and rate of heating was contributed to a recent two-volume book on the

72/ Davis, J. D., Dependence of Yields of Products on Temperature and Rate of Heating: Nat. Research Council (H. H. Lowry, ed.); Chemistry of Coal Utilization, New York, vol. 1, 1945, pp. 834-847.

chemistry of coal utilization. The dependence of carbonizing time on the width of the coke oven, methods of determining the rate of heating in coke ovens, the importance of the plastic stage of coal during carbonization, the effect of heating through the preplastic range, and Bureau of Mines work on effect of carbonizing temperature and rate of heating on yields of carbonization products were discussed. In industrial carbonization of coal it is virtually impossible to separate the effects of these two latter factors, because both factors change simultaneously. Both temperature and time of contact of the volatile products affect the extent of secondary decomposition of the so-called volatile carbonization products from coal; however, it appears that within the range of industrial carbonization conditions, at least, temperature is perhaps the more important.

Durability of Coking Power of Various Coals

The Bureau of Mines test for deterioration of coking power requires exposure to air in a rotary drum at 99.3° C. of a large (400-pound) sample of coal stage-crushed 0- to 1/4-inch in size, followed by periodic carbonization tests involving determination of the quality of the coke on charges of approximately 100 pounds of the oxidized sample. The volume of oxygen used is determined from analyses of the gases as the oxidation progresses, but the significant figure reported is the time of oxidation in days required to reduce the strength of the coke by 15 percent. This time is designated as T_{15} and and is an expression of "durability of coking power." The "durability of coking power" of BM-AGA coals tested during the year is given in table 13. The value for Pittsburgh-bed (Warden mine) coal is included for comparison. It is clear from these results that the coking power of Pittsburgh coal is extremely resistant to exposure in storage, that the No. 5 Block, Hill, and Pocahontas No. 6 coals are considerably less resistant, and that the Chilean coals can hardly be stored at all without loss of coking power.

TABLE 13. - Durability of coking power of coals

Coal No.	Coal and source	Rank	Durability of coking power, T_{15} days
28	Pittsburgh bed, Warden mine, Allegheny County, Pa.	High-volatile A	28.5
88	No. 5 Block bed, No. 5 mine, Montcoal, Raleigh County, W. Va.	do.	10.2
87	Hill bed, Hickey No. 1 mine, Cherokee County, Ala.	Medium-volatile	8.1
89	Pocahontas No. 6 bed, Birdseye mine, Sewell, Fayette County, W. Va.	do.	5.7
228	Composite Schwager area coal from near Santiago, Chile	High-volatile A	1/ .0
229	Composite Lota area coal from near Santiago, Chile	do.	1/ .0

1/ Oxidation for 1 day virtually destroyed the coking power; there remained insufficient fused coal for test.

Plasticity of Coals

Plastic properties of the 74 coal samples and blends described in table 14 were determined during the fiscal year. The 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 method. A total of 296 tests - 162 by the Gieseler method and 134 by the Davis plastometer method - were made.

TABLE 14. - Description of coals and blends tested

Coal No.	Description
87	Hill bed, Hickey mine, Fort Payne, Cherokee County, Ala. (washed)
87A	20 percent coal 87 and 80 percent Pittsburgh bed, Warden mine, coal 28 (washed)
87B	30 percent coal 87 and 70 percent coal 28
28	Pittsburgh bed, Warden mine, Allegheny County, Pa. (washed)
a87	Hill bed, Hickey mine, Fort Payne, Cherokee County, Ala. (unwashed)
89	Pocahontas No. 6 bed, Birdseye mine, Sewell, Fayette County, W. Va.
89A	20 percent coal 89 and 80 percent coal 28
89B	30 percent coal 89 and 70 percent coal 28
89	Coal 89 oxidized 7.35 days in air at 99.5° C.
75	Pocahontas No. 3 bed, Kimball, McDowell County, W. Va.
75A	20 percent coal 75 and 80 percent coal
204A	80 percent coal 28, 17 percent coal 75, and 3 percent Buckwheat No. 5-size anthracite
204B	80 percent coal 28, 15 percent coal 75, and 5 percent Buckwheat No. 5-size anthracite.
205C	80 percent coal 28, 13 percent coal 75, and 7 percent Buckwheat No. 5-size anthracite
	Coals from Chile, South America
216	Lota mine, sample from Pennsylvania State College, State College, Pa.
216A	90 percent coal 216 and 10 percent coal 75
216B	80 percent coal 216 and 20 percent coal 75
216C	80 percent coal 216 and 20 percent coal 80, Stigler bed, Garland mine, Okla.
a216	Lota mine, sample from New York City
218	Schwager mine, sample from Pennsylvania State College, State College, Pa.
218A	90 percent coal 218 and 10 percent coal 75
218B	80 percent coal 218 and 20 percent coal 75
a218	Schwager mine, sample from New York City
219	Josefina mine
220	Pupunahue mine
221	Elena mine
a228	No. 3 bed, San Jose mine, Schwager mining area, Chile
b228	No. 5 bed, San Pedro Sur mine, Schwager mining area, Chile
228	50 percent coal a228 and 50 percent coal b228
228A	90 percent of 50:50 composite (coal 228) and 10 percent coal 75
b228A	90 percent coal b228 and 10 percent coal 75
a229	Alta bed, Pique Nuevo mine, Lota mining area, corresponds to Schwager No. 5 bed
b229	Alta bed, Pique Grande mine, Lota mining area, corresponds to Schwager No. 5 bed

TABLE 14. - Description of coals and blends tested (cont'd.)

Coal No.	Description
c229	Chica bed, Pique Grande mine, Lota mining area, corresponds to Schwager No. 4 bed.
d229	Arriba bed, Pique Grande mine, Lota mining area, corresponds to Schwager No. 3 bed
229	Composite of Lota coals: 5 percent coal a229, 45 percent coal b229, 25 percent coal c229, and 25 percent coal d229
229A	90 percent coal 229 (4.5 percent coal a229, 40.5 percent coal b229, 22.5 percent coal c 229, and 22.5 percent coal d229) and 10 percent coal 75
229B	90 percent coal 229 (4.5 percent coal a229, 40.5 percent coal b229, 22.5 percent coal c229, and 22.5 percent coal d229) and 10 percent char made from coal b228
c229A	90 percent coal c229 and 10 percent coal 75
c229B	90 percent coal c229 and 10 percent char made from coal b228
[illegible]229	Coal 229 oxidized 1.10 days in air at 99.3° C.
	Special samples
[illegible]88	No. 5 Block (Lower Kittanning) bed, No. 5 mine, Raleigh Co., W. Va.
[illegible]	Layer 5 - 167 mm. thick; 15.06" to 21.63" from base of bed
[illegible]	Layer 6 - 126 mm. thick; 21.63" to 26.59" from base of bed
[illegible]	Layer 12 - 46 mm. thick; 43.29" to 45.10" from base of bed
[illegible]	Layer 16 - 110 mm. thick; 51.80" to 56.13" from base of bed
[illegible]	Layer 17 - 61 mm. thick; 56.13" to 58.53" from base of bed
[illegible]	Michigan spore coal, Williamston, Mich.
[illegible]P-59	Pittsburgh bed, No. 20 mine, Pa.
[illegible]35	Coke-oven mix from charging car, Cia Carbonifera de Sabinas, S. A., Rosita, Coahuila, Mexico
[illegible]38	Powellton bed, Nos. 7 and 9 mines
[illegible]39	Powellton bed, Powellton No. 3 mine
[illegible]40	Pocahontas bed, General Coal Crozer mine
	Core-drill hole 5-33, Paonia, Gunnison County, Colo. sec. 33, T. 13 S., R. 90 W.
[illegible]01	Depth 267 feet; coal 6 feet, 3 inches
[illegible]02	Depth 296 feet; coal 1 foot, 8 inches
[illegible]	Depth 357 feet; coal 1 foot, 2 inches
[illegible]	Depth 395 feet; coal 16 feet, 2 inches
[illegible]	Depth 447 feet; coal 6 feet, 10 inches
[illegible]	Depth 459 feet; coal 4 feet, 11 inches
[illegible]	Depth 570 feet; coal 8 feet, 11 inches
[illegible]	Depth 583 feet; coal 11 inches
[illegible]	Depth 599 feet; coal 11 feet, 3 inches
[illegible]	Depth 653 feet; coal 3 feet, 8 inches
[illegible]	Depth 670 feet; coal 3 feet, 1 inch

TABLE 14. - Description of coking power of coals tested (cont'd.)

Float-and-sink samples of Pittsburgh bed (Shannopin mine) coal, Greene County, Pa.		
Fractions	Ash, percent	Sulfur, percent
Float 1.25 sp. gr.	1.87	1.47
1.26 - 1.27 sp. gr.	2.61	1.55
1.28 - 1.29 sp. gr.	4.52	1.87
1.30 - 1.31 sp. gr.	6.88	2.29
1.32 - 1.33 sp. gr.	8.04	2.56
1.34 - 1.35 sp. gr.	8.92	2.76
1.35 - 1.37 sp. gr.	10.96	3.30
1.37 - 1.40 sp. gr.	13.08	3.90
1.40 - 1.50 sp. gr.	17.60	4.82
1.50 - 1.60 sp. gr.	23.34	5.26

A problem of considerable importance to Alabama coke-oven operators is obtaining economically a nearby source of low- or medium-volatile bituminous coal suitable for blending with the high-volatile A bituminous coals that are now mined and coked in Alabama. Tests of the plastic properties of both washed and unwashed samples of Hill bed, Hickey mine, medium-volatile bituminous coal from Fort Payne, Cherokee County, Ala., indicated that this coal should be suitable for blending purposes. The main difference in plastic properties between the washed and unwashed samples was that the latter showed an intermittent resistance in the later stages of the plastic temperature range as determined in the Davis plastometer test. This resistance is probably due to the presence of hard ash particles. Plastic properties also were determined in 20:80 and 30:70 blends of the washed Hill-bed coal and Pittsburgh-bed, Warden mine, washed coal. The typical, high-volatile A bituminous Warden coal is used commercially in coke-oven charges and has been used generally as a standard blending coal in BM-AGA survey tests of American coals. The plastic properties of the two blends of Hill-bed and Pittsburgh-bed coals indicate that good coke can be expected from blends of Hill-bed coal and typical high-volatile A bituminous coals such as are mined in Alabama.

Plastic properties were determined on (1) a sample of medium-volatile bituminous, Pocahontas No. 6-bed (Birdseye mine) coal from Fayette County, W. Va.; (2) two blends of this coal with 80 and 70 parts, respectively, of Pittsburgh-bed (Warden mine) coal; and (3) the Pocahontas No. 6-bed coal after 7.35 days of oxidation in air at 99.3° C. The plastic properties of the Pocahontas coal were typical of higher-ranking, medium-volatile coals. The blends showed plastic properties that are characteristic of blends of medium-volatile and high-volatile A bituminous coals in the proportions named. Pocahontas No. 6-bed coal, after 7.35 days of oxidation, showed only slight fusion. Although not as desirable as low-volatile bituminous fusion. Although not as desirable as low-volatile bituminous Pocahontas No. 3-bed coal, the medium-volatile bituminous Pocahontas No. 6-bed coal appears to be suitable for blending with high-volatile A bituminous coal.

Tests of the plastic properties of Pocahontas No. 3-bed coal from McDowell County, W. Va., indicated that this low-volatile coal should produce a good coke. Such strong resistance was developed in the Davis plastometer test that the limit of the springs was reached, indicating a maximum resistance of more than 29 pound-inches. The coke residue formed in both the Davis and Gieseler plastometer tests was very strongly swollen. Plastic properties of a blend containing 20 percent of this coal and 80 percent of Pittsburgh-bed (Warden bed) washed coal were typical of a blend containing these proportions of low- and high-volatile A bituminous coals. To determine the effect of substituting Buckwheat No. 5-size anthracite for a part of the low-volatile bituminous coal in coke-oven charges, three blends containing 80 percent high-volatile A bituminous coal, and low-volatile bituminous coal plus anthracite were prepared. The blends consisted of 80:17:3, 80:15:5, and 80:13:7 parts, respectively, of Pittsburgh-bed (Warden mine) coal, Pocahontas No. 3-bed coal, and Buckwheat No. 5-size anthracite. With increasing percentages of anthracite, the Gieseler maximum fluidity and the Davis maximum resistance values decreased somewhat, indicating that the resulting cokes would become progressively weaker and, if too much anthracite were substituted for the low-volatile bituminous coal, would be too weak for metallurgical use.

The properties of 24 high-volatile A bituminous coals and coal blends and 3 subbituminous B coals from 5 mining areas in Chile were determined. Gieseler and Davis plastometer tests made on two samples of high-volatile A bituminous coal from the Lota area and on blends of 80 and 90 percent of the Lota coal with 20 and 10 percent, respectively, of low-volatile bituminous coal from the Pocahontas No. 3 bed, McDowell County, W. Va. showed low fluidity and low resistance, and only slight fusion at the normal rate of heating of 3° C. per minute. The high-ranking, low-volatile bituminous West Virginia coal (dry, mineral-matter-free, fixed-carbon content, 81.7 percent) and the high-volatile A Chilean coal (dry, mineral-matter-free, fixed-carbon content, 53.8 percent) are too far apart in rank to permit good fusion. A third blending with 10 percent medium-volatile bituminous coal from the Stigler bed, Garland mine, Okla., proved somewhat better.

Plastic properties were determined on two samples of high-volatile A bituminous coal from the Schwager area. These samples were characterized by low maximum fluidities in the Gieseler tests and low intermittent resistance and slight fusion in the Davis tests. Blending this coal with 10 percent low-volatile bituminous coal from the Pocahontas No. 3 bed, caused no appreciable differences, but increasing the amount of low-volatile coal to 20 percent resulted in a considerable increase in maximum resistance as measured in the Davis plastometer.

Subbituminous B coals from the Josefina mine, the Pupunahue mine, and the Elena mine showed no fusion in the Gieseler tests at the normal rate of heating of 3° C. per minute.

Tests of plastic properties were completed on two high-volatile A bituminous coals from the Schwager mining area. The No. 3-bed (San Jose mine) coal showed a maximum fluidity in the Gieseler plastometer test of 295 dial divisions per minute, and a maximum resistance of 6.5 pound-inches and a fairly long plastic temperature range in the Davis plastometer test. The No. 5-bed (San Pedro Sur mine) coal showed only 9.2 dial divisions per minute in the Gieseler test and 9.5 pound-inches in the Davis test. These results indicate better coking properties for the No. 3-bed coal than for the No. 5-bed coal. Blending 90 percent of the No. 5-bed coal with 10 percent Pocahontas No. 3-bed coal lowered the maximum fluidity and maximum resistance somewhat and lengthened considerably the plastic temperature range in the Davis test. A composite sample consisting of 50 percent of the No. 3-bed coal and 50 percent of the No. 5-bed coal raised the maximum fluidity to 41 dial divisions per minute and lowered the maximum resistance to 2.1 pounds-inches. Blending 90 percent of this composite of high-volatile A bituminous coals with 10 percent low-volatile bituminous Pocahontas No. 3-bed coal increased the maximum resistance and lengthened considerably the plastic temperature range in the Davis test.

Plastic properties were determined in the Gieseler and Davis plastometers for four high-volatile A bituminous coals from the following beds and mines in the Lota mining area: Alta bed, Pique Nuevo mine; Alta bed, Pique Grande mine; Chica bed, Pique Grande mine; and Arriba bed, Pique Grande mine. In general, the plastic characteristics observed were high fusion temperatures, low maximum fluidities below 5.0 dial divisions per minute, and short plastic temperature ranges. The Chica-bed coal showed no fusion at the normal rate of heating of 3° C. per minute in the Davis test, and the Arriba-bed coal showed a slightly higher maximum fluidity and resistance than did the three other coals. Tests on a composite of the four coals consisting of 5 percent Alta bed (Pique Nuevo mine) coal, 45 percent Alta bed (Pique Grande mine) coal, 25 percent Chica bed (Pique Grande mine) coal, and 25 percent Arriba-bed (Pique Grande mine) coal, and on a blend of 90 percent of this composite with 10-percent low-volatile bituminous, Pocahontas No. 3-bed coal also showed plastic characteristics of poor fusion and low maximum fluidity and resistance. A second blend of 90 percent Lota composite and 10 percent char from the No. 5-bed (San Pedro Sur mine) coal in the Schwager mining area showed only slight fusion at the normal rate of heating of 3° C. per minute in the Davis tests. Oxidizing the composite of Lota coals reduced the maximum fluidity in the Gieseler tests and destroyed the fusion properties in the Davis tests. Blending 90 percent Chica-bed coal with 10 percent of low-volatile, Pocahontas No. 3-bed coal or with 10 percent of char made from the No. 5-bed (San Pedro Sur mine) coal from the Schwager mining area also resulted in slight fusion in the Davis tests.

Plastic properties were determined on No. 5 Block-(Lower Kittanning)-bed, No. 5 mine, coal from Raleigh County, West Virginia, and on five layer samples selected from the columnar section of this coal. The petrographic composition of the coal and the five layer samples had been determined in detail in the Bureau's petrographic laboratory. An attempt was made to correlate the plastic properties with the petrographic composition. In general, if the total anthraxylon and translucent attritus were present in large proportions, either separately or as the sum of the two, the fluidity of the samples was high. The presence of high opaque attritus content reduced the fluidity of the samples. There seems to be a general relationship also between the types of vitrain present, rather than its total amount, and the fluidity developed during plastometer tests. The fluidity was high in some of the samples containing but little vitrain and in all the samples containing appreciable vitrain.

Fusion properties were determined on a sample of cleaned spores which had been separated from a spore coal mined in the Williamston Basin, Mich. Duplicate tests in the Gieseler plastometer at a heating rate of 3° C. per minute showed sharp melting of the entire sample at 398° C. and 393° C., and a maximum fluidity of 60,000 dial divisions per minute at 401° C. The sharp fusion and the high fluidity of the sample immediately above the fusion temperature indicate that the spores are quite homogeneous in composition.

Plastic properties of five coals were determined in connection with studies of their expanding properties. These coals included: (1) Pittsburgh-bed, No. 20 mine, high-volatile A bituminous coal; (2) a medium-volatile bituminous coke-oven mix taken from the charging at Cía Carbonifera de Sabinas, S.A., Rosita, Coahuila, Mexico; (3) high-volatile A bituminous, Powellton-bed (Nos. 7 and 9 mines) coal; (4) high-volatile A bituminous, Powellton-bed (No. 3 mine) coal; and (5) low-volatile bituminous, Pocahontas-bed (General Crozer mine) coal. The Pittsburgh-bed coal showed good initial fusion properties but gave two pronounced high maximum resistance values of 26.0 and 40.5 pound-inches at 494° C. and 518° C., respectively, and an intermittent resistance above 578° C. These properties indicate that this coal is not as uniform in composition as many other Pittsburgh-bed coals that have been tested by the Bureau of Mines. The Mexican coal blend showed plastic properties typical of medium-volatile coal and therefore should produce a good coke. The Powellton-bed (Nos. 7 and 9 mines) coal contained 66.0 percent dry, mineral-matter-free, fixed carbon and was much less fluid than the Powellton-bed (No. 3 mine) coal which contained 62.7 percent dry, mineral-matter-free, fixed carbon. The former coal showed such strong swelling that the Gieseler plastometer test had to be discontinued at 441° C.; it produced an intermittent resistance in the Davis plastometer up to 580° C., at which temperature the test was discontinued. The Pocahontas-bed coal showed plastic properties typical of a coal of low-volatile bituminous rank.

The plastic properties were determined by either or both the Gieseler and the Davis plastometer test methods on 10 core-drill samples representing coal taken at various depths in sec. 33, T. 13 S., R. 90 W., Gunnison County, Colo. None of the 10 samples showed fusion at the normal rate of heating of [illegible] C. per minute used.

To determine the relation between plastic properties and the specific gravity of the sample, a study was made of the plastic properties of float-[illegible]-sink fractions from Pittsburgh-bed (Shannopin mine) coal, Greene County, [illegible] As is known, in a series of float-and-sink samples the specific gravity [illegible]reases with increased amounts of ash and sulfur. In general, the fluidity [illegible] the samples decreased as the ash and sulfur contents increased. There were [illegible] exceptions to this general trend, but quite likely the chemical composi-[illegible] is related to the petrographic composition in such a manner that both [illegible] reflected in the plastic characteristics.

A detailed study was made of the chemical and petrographic composition and the physical properties of 19 representative American bituminous coking coals in relation to the maximum fluidity of these coals as measured by the Gieseler plastometer test method.73/ The coals studied included 5 low-, 4 medium-, and 10 high-volatile A bituminous coals whose carbonizing properties had already been determined in the BM-AGA survey of American coals. Factors of chemical and petrographic compositions that were found to contribute toward increasing the fluidity of a coal above that expected from consideration of its rank alone are high contents of anthraxylon and translucent attritus and the presence of cannel coal. For coals of similar rank, those of the higher physical strength, as measured by friability tests and the data of screen analyses, generally show higher maximum fluidity. Factors that reduce the fluidity of a coal below that expected from its rank are high oxygen, high ash, and other materials, such as opaque attritus and fusain, that are stable toward heat. The type and amount of petrographic constituents present is much more important than the rank of the coal in determining the fusion properties of bituminous coking coals.

A chapter 74/ describing the plastic, agglutinating, agglomerating, and swelling properties of coals was contributed to a recent two-volume book on the chemistry of coal utilization. The chapter includes a classification of the different methods of test, a summary of published investigations, an evaluation of test data in relation to commercial coke-oven practices, suggested desirable problems for further research, and a comprehensive bibliography of selected world literature dealing with these subjects.

Swelling Properties of Coal During the Coking Process

Bureau of Mines testing equipment now available includes two vertical-slot ovens - one holding a charge of 350 pounds and one a cahrge of 17 pounds; also the sole-heated expansion oven described in previous reports. The vertical-slot ovens are heated from both walls and operate at constant volume; the pressure exerted by the expanding coal is measured during the tests. The sole-heated oven is heated only at the floor and is operated under a constant pressure of 2.2 pounds per square inch; the percent expansion (or contraction) obtained under these conditions is taken as the characteristic expansion index of the coal. The sole-heated oven is charged with 40 pounds of coal; test results are of value in indicating contraction and for rough comparison of expanding properties of different coals. The two vertical-slot ovens give the maximum pressure to be expected on coke-oven walls; this figure is of much more practical importance than percentage of expansion under constant load. The small vertical-slot oven is more convenient to use than the large one because of the smaller charge and shorter operating time. However, it gives

73/ Brewer, R. E., Plastic Characteristics of Coal. Correlation with Chemical and Physical Properties and Petrographic Composition: Ind. Eng. Chem., vol. 36, 1944, pp. 1165-1168.

74/ Brewer, R. E., Plastic, Agglutinating, Agglomerating, and Swelling Properties of Coals: Nat. Research Council (H. H. Lowry, ed.), Chemistry of Coal Utilization, New York, vol. 1, 1945, pp. 160-309.

high maximum pressures because of the thinner layer of coke, the normal contraction of which counteracts the expansion of the charge while plastic. The pressure values divided by 2 closely approximate those obtained in the large slot oven.

Table 15 gives the expanding properties of BM-AGA coals and of special coals submitted by coke-oven operators tested during the year; the test oven used is indicated in each case. Medium-valatile bituminous Hill-bed coal in 100-percent charges expanded moderately. The blend with 80 percent Pittsburgh standard high-volatile A bituminous coal contracted slightly in the sole-heated oven and did not exert dangerous pressures in the large vertical slot oven. The blend of 20 percent Pocahontas No. 3 low-volatile coal and 80 percent high-volatile Pittsburgh coal exerted about the same maximum pressure in the large vertical-slot oven and about 1.7 times that maximum in the small vertical-slot oven. This blend is widely used in ovens making metallurgical coke; therefore, it may be concluded that the Hill coal should be perfectly safe when substituted in this proportion for Pocahontas No. 3 coal. No. 5 Block-bed coal contracted to about the same extent as Pittsburgh coal and, therefore, should be a good high-volatile blending coal, so far as expansion is concerned. Pocahontas No. 6 coal, although of medium-volatile rank, hardly expanded at all, but the raw coal had an ash content of 13.9 percent. The float coal on a 1.50-gravity solution contained 8.6 percent ash and expanded 7.4 percent, which is not excessive for coals of this rank. The effect of ash reduction on expansion is clearly indicated.

In testing the coals proposed by the Rochester Gas & Electric Co., it was desired to distinguish between the expanding properties of the two Freeport coals and to determine which of the three Pittsburgh coals was the most contracting. The tests indicated that the Indiana County Freeport coal expanded the least and the Banning Pittsburgh coal contracted the most. It was concluded, therefore, that blends of these two coals are likely to be safer to use than blends of the other Freeport coal with either of the other two Pittsburgh coals. From experience of the Bureau of Mines, such a conclusion is usually justified.

The blends of Powellton coals with Crozer Pocahontas were submitted in connection with development of new sources of supply for the synthetic ammonia works at Belle, W. Va. It was desired to know if any of them would prove dangerously expanding; results of the tests indicated that they are not.

The Rosita coal from Mexico showed contraction and should give no trouble in coke-oven operation.

The coals from the Chilean Schwager mining area are contracting; the No. bed contracted more than the No. 5 bed. It is desired to use these coals blended in coke ovens; test results show such practice to be perfectly safe.

TABLE 15. - Expanding properties of coals

Coal	Sole-heated oven: Expansion, percent at 55.5 pounds per cu. ft.	Vertical-slot ovens, Maximum pressure, pounds per square inch: 350-pound vertical slot oven	17-pound vertical slot oven
BM-AGA coals			
Hill bed (coal 87), Hickey No. 1 mine, Cherokee County, Ala.			
Washed	+20.3		
Unwashed	+14.8		
20 percent Hill bed and 80 percent Pittsburgh bed (coal 28), Warden mine	- 1.5	1.69	
20 percent Pocahontas No. 3 bed (coal 75) and 80 percent Pittsburgh bed	-	1.49	2.54
No. 5 Block bed (coal 88), No. 5 Block mine, Raleigh County, W. Va.	-17.3		
Pocahontas No. 6 bed (coal 89), Birdseye mine, Preston County, W. Va.	+ .2		+4.9
Float on 1.50 gravity	+ 7.4		
Coals proposed by Rochester Gas and Electric Co.			
Upper Freeport bed, Burke No. 1 mine, Preston County, W. Va.	+ 9.2		
Lower & Upper Freeport beds, Kent Nos. 1 and 2 mines, Indiana County, Pa.	+ 3.0		
Pittsburgh bed, Banning No. 1 mine, Westmoreland County, Pa.	-25.1		
Pittsburgh bed, Jamison No. 20 mine, Westmoreland County, Pa.	-17.7		
Pittsburgh bed, Warden mine, Allegheny County, Pa.	-15.6		
Coals proposed for DuPont Ammonia Works, Belle, W. Va.			
50 percent Carbon Fuel Powellton and 50 percent Koppers Powellton (100 percent through 1/4-inch)	-26.3	None	
50 percent Carbon Fuel Powellton and 50 percent Koppers Powellton (100 percent through 1/8-inch)	-	None	
20 percent Crozer Pocahontas, 40 percent Carbon Fuel Powellton, and 40 percent Koppers Powellton	-14.2	+ 1.3	
35 percent each of Koppers and Carbon Fuel Powellton and 30 percent Crozer Pocahontas	- 9.7	+ 1.9	
Miscellaneous coals			
Rosita mine, Coahuila, Mexico	-12.7	+ 1.2	
No. 3 bed, San Jose mine, Schwager district, Santiago, Chile	-15.1		
No. 5 bed, San Pedro mine, Schwager district, Santiago, Chile	- 9.6		