The gross heating value under these conditions was 532 B.t.u. per cubic foot and 1,729 B.t.u. per pound of coal as charged. The heating value of the char produced was 13,400 B.t.u. per pound as compared with 10,050 B.t.u per pound for the entering coal. The tar yield (4.4 percent) was equivalent to 10.8 gallons per ton of coal and was characterized by the small pitch (residue upon distillation to 350° C.) content and high tar-acid and olefin content. The liquor from the purifying train yielded 12.2 pounds of ammonium sulfate per ton of coal carbonized.

Effect of Acids and Alkalies on Carbonization Products

A summary of published work on the effect of acids and alkalies upon th carbonization products of coal was issued.[80] In general, the beneficial action of the reagents is not great and is largely offset by deleterious effects on certain of the carbonization products. Many of the conclusions are based on small-scale tests; and because similar or closely related studies differ in certain important respects, it is difficult to predict what success these treatments might have in industry.

Influence of Resins on Coking Properties

A study[81] was made of the influence of resins in a Utah coal on its coking properties. The coal examined was from the Blind Canyon-bed, Deer Creek mine, Huntington Canyon, Utah. The coal was first crushed to pass a 16-mesh Tyler sieve. One portion was treated twice with a sodium chloride solution of 1.1 specific gravity plus 1 part per million of tannic acid on which the resinous material floated and the coal sank. The treated coal was washed with water to remove salt and then dried in a rotating drum at 100° C. in an atmosphere of nitrogen. After cooling in nitrogen, it was carbonized at 900° C. in the 13-inch BM-AGA retort in the same manner as another portion of the raw coal. Approximately 2.8 percent of resinous material was removed by the float-and-sink treatment. The volatile combustible matter of the resinous material was 91.4 percent and the part insoluble in benzene by Soxhlet extraction 17.2 percent. Comparison of analyses of the treated and untreated coals showed that moisture and volatil matter were reduced and fixed carbon increased by the treatment. The lower moisture content of the treated coal was reflected in a lower yield of liqu in the BM-AGA carbonization tests. To make the data comparable, enough wate was added to a sample of the treated coal to equal the moisture content of the raw coal. Yields of carbonization products were obtained on the raw coal containing 5.5 percent moisture, the treated coal containing 4.0 percent moisture, and the treated coal containing 5.5 percent moisture. Removal of resins from Utah coal increased the yield of coke and decreased the yield of tar; the effect on the volume of gas was insignificant but the

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[80] Brewer, R. E., Effect of Acids and Alkalies Upon Carbonization Products of Coal: Bureau of Mines Rept. of Investigations 3726, 1943, 20 pp.

[81] Davis, J. D., and Reynolds, D. A., Influence of Resins in a Utah Coal on Its Coking Properties: Fuel in Sci. and Practice, vol. 23, March-April 1944, pp. 37-40.

yield by weight was lowered. The coke was slightly inferior to that produced from the raw coal. None of the three samples produced cokes strong enough for iron smelting, as judged by western United States standards, but the cokes should serve for smokeless domestic heating. All samples gave exceptionally high yields of gas and tar of good quality. The coal offers possibilities for gas making, provided disposal of the coke is not too difficult.

Plasticity of Coal

The plastic properties of 31 coals, 5 coal blends, and 2 layer samples of coal, whose ranks and sources are given in table 13, were determined during the fiscal year. The coals named in the table are arranged in decreasing order of rank, as expressed by dry, mineral-matter-free fixed carbon content. Most of the tests, made in duplicate by two different methods, were in connection with studies of (1) other properties of coal, such as carbonizing, expanding, oxidizing or storage, (2) explorations of new coal reserves, and (3) special points in the test procedure of the Gieseler-type plastometer for measuring the plastic characteristics of coal. The effect of storage on the plastic properties was determined on a number of coals that had been stored for known periods of time in closed containers filled with coal, except for the air remaining in the void spaces between the coal particles, of sizes as crushed for coking. The bright layer sample of Pocahontas No. 3-bed coal still showed appreciable plastic properties after 4 years' of storage, whereas the medium-volatile Stigler- and Red Ash-bed coals showed pronounced reduction in plastic properties after only 4 months of storage. Tests of the plastic characteristics of various blends of Eagle-bed coal with other coals were made in connection with studies of the carbonizing properties of this coal and its blends. The Eagle-bed coal showed a very much higher fluidity than that of Powellton bed, No. 7 mine coal. These two coals are mined in Kanawha County, West Virginia, and are of almost identical rank. They might be expected to show the same plastic properties, when judged by rank alone. Numerous earlier tests made on samples from the Eagle bed in the Bureau of Mines and other laboratories have shown that this coal is one of the most fluid coals mined in America. A Powellton-bed coal from Coal Mountain mine, Wyoming County, West Virginia showed appreciably greater fluidity than the Powellton coal from No. 7 mine, but much lower than the Eagle coal. The high-volatile A bituminous Pittsburgh-bed coal from Morgantown, W. Va., although of comparable rank to the Eagle and the two Powellton coals, showed low fluidity. It may be concluded that the plastic properties of coals cannot be predicted exactly from rank alone, nor can the plastic characteristics of coal blends be accurately foretold by calculation from the constituent coals.

TABLE 13. - Rank and source of coals tested

Low-volatile bituminous

Bright layer, Pocahontas No. 3 bed, Buckeye No. 3 mine, Wyoming County, W. Va

Splint layer, Pocahontas No. 3 bed, Buckeye No. 3 mine, Wyoming County, W. Va

Medium-volatile bituminous

Stigler bed, Garland mine, Oklahoma.

Composite of three tipple samples, Red Ash bed, Red Ash Smokeless mine, McDowell County, W. Va.

70:30 blend of Eagle bed, Carbon Fuel Company mine, Kanawha County, W. Va., and Pocahontas No. 3 bed, Buckeye No. 3 mine, Wyoming County, W. Va.

High-volatile A bituminous

Eagle bed, Carbon Fuel Company mine, Kanawha County, W. Va.

80:20 blend of Eagle bed and Pocahontas No. 3 bed.

50:50 blend of Eagle bed and Powellton bed, No. 7 mine, Kanawha County, W. Va

Powellton bed, No. 7 mine, Kanawha County, W. Va.

Powellton bed, Coal Mountain mine, Wyoming County, W. Va.

60:40 blend of Eagle bed and Stigler bed, Garland mine, Oklahoma.

Pittsburgh bed, U. S. Army Ordnance, Morgantown, W. Va.

80:20 blend of Pittsburgh bed and Pocahontas No. 3 bed.

Mary Lee bed, core-drill hole No. 13-43, Walker County, Ala.

Mary Lee bed, Top Bench, core-drill hole No. 14-43, Walker County, Ala.

Mary Lee bed, Bottom Bench, core-drill hole No. 14-43, Walker County, Ala.

Mary Lee bed, Top bench, core-drill hole No. 15-43, Walker County, Ala.

Mary Lee bed, Bottom Bench, core-drill Hole No. 15-43, Walker County, Ala.

Frederick bed (washed), Pueblo, Colo.

Selected layer, Harrisburg No. 5 bed, Thurmond mine, Gallatin County, Ill.

Elkhorn No. 3 bed, Wheelwright mine, Floyd County, Ky.

No. 6 bed (unwashed), Jonesville Coal Company mine, Washington.

Roslyn No. 5 bed (unwashed), Northwestern Improvement Company No. 3 mine, Washington.

Roslyn No. t bed (washed), Northwestern Improvement Company No. 3 mine, Washington.

Willow Creek bed, main middle bed, core-drill No. 4-31, Kemmerer, Wyo.

Willow Creek bed, lower bed, core-drill No. 4-31, Kemmerer, Wyo.

High-volatile B bituminous

Column sample, Harrisburg No. 5 bed, Thurmond mine, Gallatin County, Ill.

Spring Valley bed, Lees mine, Lincoln County, Wyo.

No. 3 bed, Sweetwater No. 2 mine, Sweetwater County, Wyo.

No. 9 bed, Pacific mine, Muhlenberg County, Ky.

No. 9 bed, oxidized 7 days in air at 100° C., Pacific mine, Muhlenberg County, Ky.

No. 6 bed, Dawson Collieries mine, Hopkins County, Ky.

Lower Sunnyside bed, Columbia Steel Corporation mine, Utah.

Lower Sunnyside No. 1 bed, Sunnyside mine, Carbon County, Utah.

Lower Sunnyside bed, commercial shipment, Carbon County, Utah.

TABLE 13. - Rank and source of coals tested (Cont'd.)

Subbituminous A

Plus 1-1/4" float on 1.35 sp. gr., Coalmont bed, Moore mine, Jackson County, Colo.

Subbituminous B

Monarch bed, Monarch mine, Sheridan County, Wyo.

Lignite

Velva mine, Ward County, N. Dak.

The plastic properties of the last 25 coals listed in table 13 were determined in connection with studies of their coking properties, as determined by the BM-AGA survey method. All of these coals, at present, are not used or are used only to a limited extent commercially for coking purposes. Studies of the plastic properties of the core-drill samples from different benches of the Mary Lee bed in Alabama and of the Willow Creek bed in Wyoming made possible correlations of the plastic properties of the different coals in the mineable benches. The Frederick-bed coal from Colorado, the selected layer from Harrisonburg No. 5 bed from Illinois, and the Elkhorn No. 3 bed from Kentucky showed plastic properties that indicate fair coking properties. The Frederick coal formed a spongy coke, which can be counteracted by proper blending. The selected layer of the Illinois coal contained only 4.3 percent ash, as compared with 20.8 percent ash in the column sample of this coal. The high ash can be reduced considerably by treatment, making available a new coking coal. The Elkhorn coal, while not as good as some other Elkhorn coals, with proper preparation should be a good source of coking coal. The three high-volatile A Washington coals and the high-volatile B coals showed rather rapid oxidation. For example, the two Roslyn-bed Washington coals, after several weeks of storage, showed a marked reduction in their plastic properties and No. 9-bed coal from Kentucky after 9 days has almost completely lost its fusion properties. The lower-ranking, high-volatile B bituminous showed poor fusion properties as measured by the plastometer tests. The subbituminous coals and the lignite did not fuse at the normal rate of heating of 3° C. per minute.

The Gieseler-type plastometer test method has undergone some minor changes in construction and operating technique since its initial development by the Bureau of Mines in 1939. The proposed method, as published[82] in 1943 for information only, represented the consensus of experience of members of Subcommittee XV on Plasticity and Swelling of Coal, Committee D-5 on Coal

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[82] American Society for Testing Materials, Proposed Method of Test for Plastic Properties of Coal by the Gieseler-Type Plastometer: Proc. Am. Soc. Test. Materials, vol. 43, 1943, pp. 301-305.

and Coke, of the American Society for Testing Materials, who were then regularly using the Gieseler apparatus in different laboratories. Two main differences were noted at that time in the operating technique as practiced in two laboratories. These differences were (1) the manner of using the brake between observations of the dial movement, and (2) the use or non-use of a washer inserted in the retort above the compressed charge of coal. A series of tests on a number of bituminous coking coals of various ranks were made to study these points of difference. It was found that all readings for a coal having a fluidity of less than 150 dial divisions could be made without the use of the brake. This method of observation proved to be fully as reliable and much less tedious than the proposed technique in which the brake is alternately set and released before each reading. The use of the brake is unnecessary in testing coals of low fluidity and is not recommended. Tests on a large number of coals of various swelling powers were made with and without the washer inserted in the retort above the coal charge. It was found that the washer does not accomplish its claimed purpose in preventing swelling of the coal out of the retort and into the barrel of the plastometer. One coal even showed greater swelling when the washer was used. This condition may result from the fact that once a large amount of liquid and plastic material is pushed from the heated coal charge into the barrel above the level of the washer, it is then retarded from falling back into the retort because of its continual decomposition into semicoke which does not get back through the hole in the washer. It is recommended that the use of the washer be discontinued. The effect of the use of the washer and other points in operating technique have been discussed.[83]

Swelling Properties of Coal During the Coking Process

Expansion tests in the sole-heated oven were made on three high-volatil bituminous coals included in the BM-AGA Survey of American Coals and of blends of these coals with low-volatile Pocahontas No. 3 coal. Table 14 shows the results of these tests and 17 tests made on different samples of Beckley-bed coal. Special interest is attached to the tests on Eagle-bed coal and blends of this coal with Powellton-bed coal because these two coals may be mined together through a single shaft. The sample of Eagle coal was obtained from a prospect hole extending from the Powellton bed, since this part of the Eagle bed is undeveloped. The results of the expansion tests indicate that all of these coals and blends would be safe to use in byproduct ovens. An additional check in the vertical slot oven on the ternary blend containing equal parts of Eagle and Powellton coals with 30 percent Pocahontas No. 3 coal charged at an approximate dry bulk density of 48.4 pounds per cubic foot showed a maximum wall pressure of 1.5 pounds per square inch. This result substantiates the sole-oven data in indicating that this blend is safe for byproduct oven use.

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[83] Brewer, R. E., Discussion of "The Gieseler Method for Measurement of th Plastic Characteristics of Coal," by Glenn C. Soth and Charles C. Russell: Proc. Am. Soc. Test. Materials, vol. 43, 1943, pp. 1190-1191.

TABLE 14. - Expansion in the sole-heated oven, calculated to a charge density of 55.5 pounds per cubic foot

Coal No.	Composition	Expansion, percent
82	100 percent Eagle bed, West Virginia	-21.2
83	100 percent Powellton bed, West Virginia	- 9.0
82C	50 percent Eagle (82) + 50 percent Powellton (83)	-17.2
82A	80 percent Eagle + 20 percent Pocahontas No. 3 (75)	-11.8
82B	70 percent Eagle + 30 percent Pocahontas No. 3	- 5.9
82D	35 percent Eagle + 35 percent Powellton + 30 percent Pocahontas No. 3	- 3.6
86	100 percent Elkhorn No. 3 bed, Kentucky	- 1.0
86A	80 percent Elkhorn No. 3 (86) + 20 percent Pocahontas No. 3 (75)	+ 5.1
86B	70 percent Elkhorn No. 3 + 30 percent Pocahontas No. 3	+ 6.7
XP39	Beckley bed, West Virginia	+14.4
XP40	do.	+19.9
XP41	do.	+26.4
XP42	do.	+ 8.9
XP43	do.	+13.4
XP44	do.	+12.1
XP45	do.	+15.8
XP46[1]	do.	+37.4
XP47	do.	+22.8
XP48	do.	+ 7.0
XP49	do.	+ 7.6
XP50[1]	do.	+ 7.4
XP51	do.	+17.1
XP52	do.	+15.6
XP53	do.	+ 7.0
XP54	do.	+17.6
XP55	do.	+21.3

[1] Single tests.

A thorough study of the expanding properties of Beckley-bed coal from Wyoming County, W. Va., was made to determine its suitability as a substitute for Pocahontas No. 3-bed coal for blending with high-volatile Kentucky coal. There are no mines in the Beckley property intended for development, but samples were taken in the adjacent Glen Rogers, Glen White, Eccles, and Slab Fork mines. It is believed that results of tests of these samples give a good idea of what may be expected in the undeveloped property. Seventeen samples of Beckley coal and several samples of Pocahontas coal were tested under the same condition to compare the two coals. Expansion tests were made in the sole-heated and vertical-slot ovens. The more significant of the results from the sole-heated oven are given in table 14.

Elkhorn coal contracted but slightly on carbonization in the sole-heated oven at high bulk densities, and its blends with Pocahontas No. 3 coal expanded moderately. A blend containing 70 percent Elkhorn and 30 percent Beckley (Glen Rogers mine) developed 0.9 pound per square inch pressure in the vertical-slot oven and a similar blend of Pocahontas and

Elkhorn coals developed 0.7 pound pressure. These blends could be used safely in byproduct ovens. Tests made in the sole-heated ovens on 100 percent charges of Beckley coal showed a wide range in expanding properties for the various samples from four mines. The Beckley bed is irregular in this district and some of the samples represent the full thickness, whereas others were from the top or bottom benches. These differences in the samples may account for differences in the expanding properties.

The small-scale, vertical-slot oven which was designed and built last year was tested under different operating conditions. This oven is similar in principle to the large vertical oven in that two walls, one of which is movable, are heated electrically and that carbonization expansion pressures may be measured at constant volume. The carbonizing chamber is 12 inches wide by 13 inches high, and the charge weighing about 17 pounds is 5 inches thick. The oven is shown open in figure 7 and closed for testing in figure 8. Its construction and operating characteristics are satisfactory; the heating elements are unaffected by the carbonization products, and transmission of expansion pressure to the movable wall is virtually frictionless. Analysis of the results of tests completed during the past year indicates that freedom of movement of the top boundary of the charge greatly affects the expansion pressure on the walls. The tests were made with the top of the charge under pressures to simulate the lower sections of byproduct ovens and also with top voids as obtained in the large-scale vertical slot oven. The latter method promises to be the better but results obtained to date are erratic and duplicate determinations frequently show poor checks. There seems to be an inherent tendency in small-scale tests toward exaggeration of expansion pressures, so that empirical modifications are necessary to obtain results comparable to large-scale results. It is hoped that further experimentation with this oven will yield more satisfactory results and that it can be used for many of the tests now made in larger test ovens which require more time and personnel. Temperature measurements in a charge carbonized in the small oven at rates about the same as those obtained in byproduct ovens indicated that the two individual plastic layers average about 0.2 inch in thickness near the walls, they then widen as they approach the center until at the time of coalescence the double layer is about 1.4 inches thick. Lowering the carbonizing temperature by 100° C. increased slightly the thickness of the plastic layer.

Problems of Metallurgical Coke for Western Furnaces

Metallurgical coke and the byproducts of the carbonization of coal continue in strong demand. In cooperation with the Government-Industry Advisory Committee on Improving Coke Production, the Bureau of Mines has conducted studies on control of impurities in mine-run, metallurgical coal, selective mining of metallurgical-grade coal, effect of control of bulk density of the coke-oven charge on the optimum physical properties of the coke, and other problems, the solution of which, should aid in maintaining maximum rate of production of good-quality coke. A general statement of the problems involved has been published.[84]

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[84] Fieldner, A. C., Problems of Metallurgical Coke for Western Furnaces Being Solved-Byproducts in Demand; Min. and Met., vol. 25, 1944, pp. 101-102.

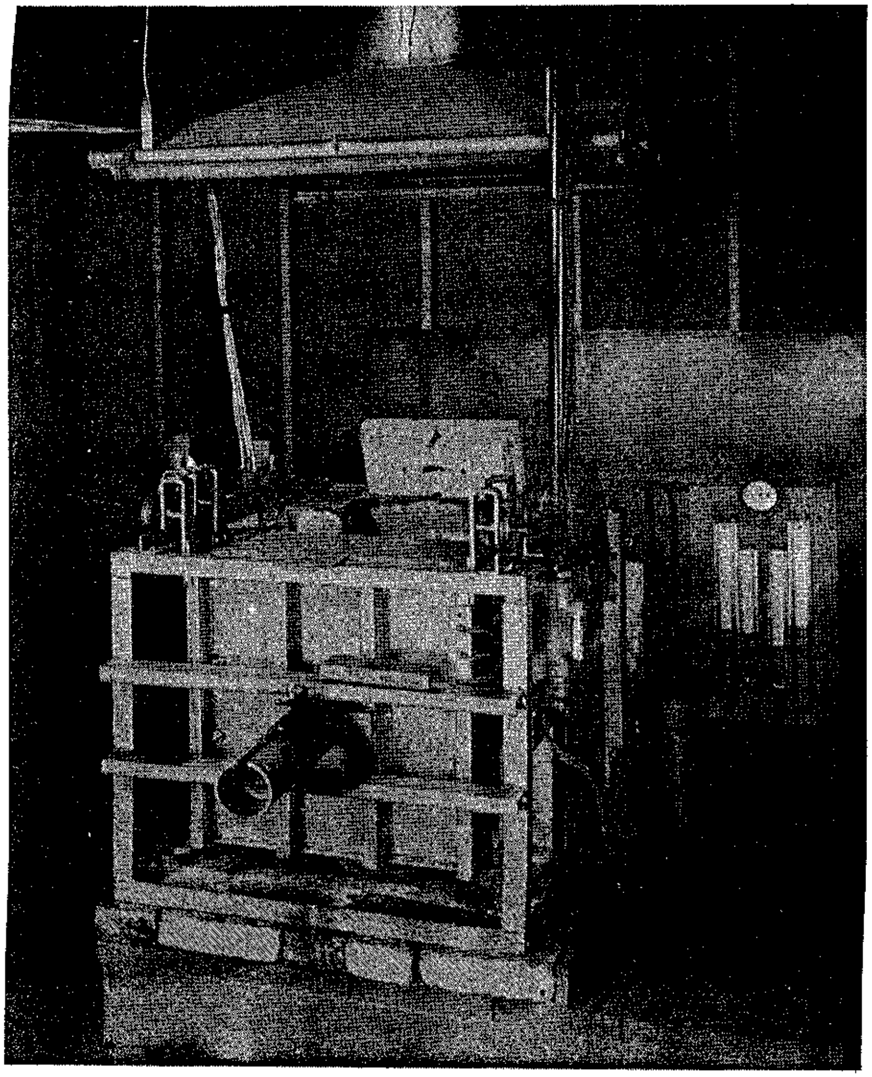

FIGURE 7.- Expansion oven, open.

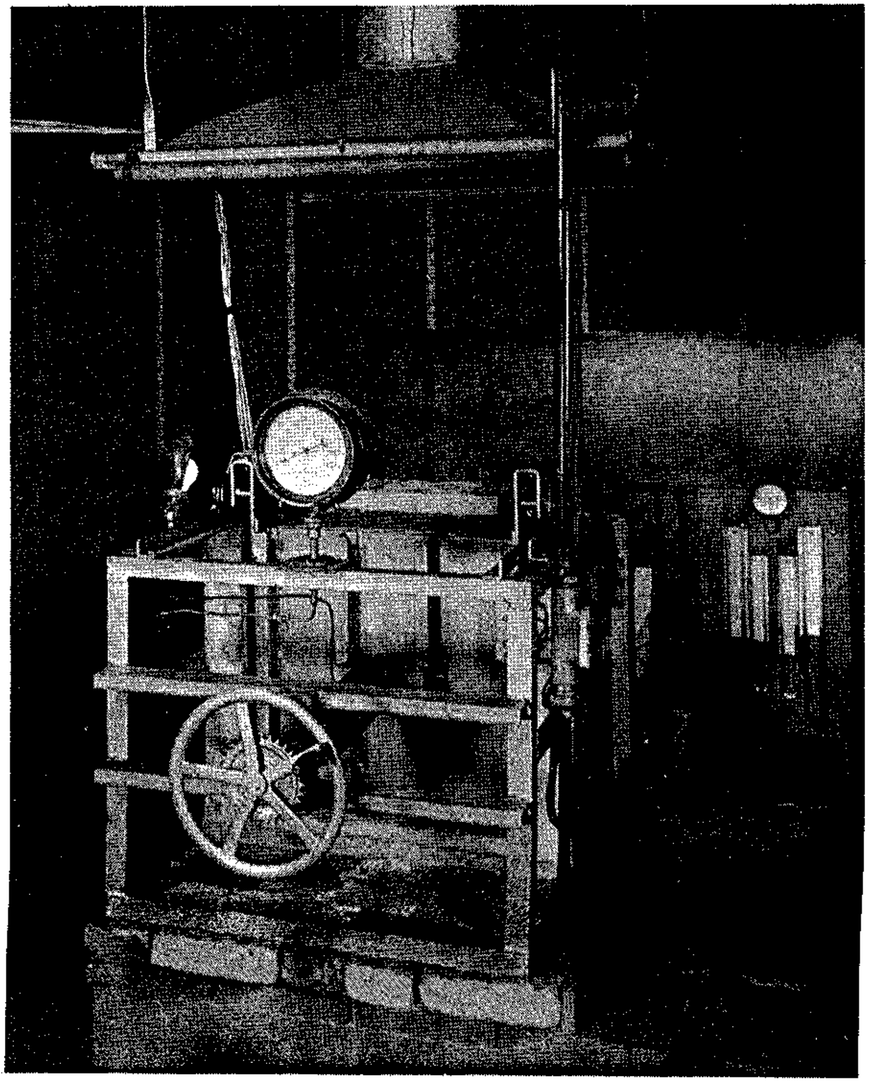

FIGURE 8.- Expansion oven, closed.

It has been indicated that the production of pig iron could be increased appreciably if present blast furnaces were supplied with a more uniform coke. One cause of nonuniformity of the coke produced by ordinary American plant practice is the prevailing lack of precise control of the bulk density of the coal charge in the byproduct oven. This problem is an individual one for each plant and local conditions must be considered in determining its solution. Information on this problem has been collected and published by the Bureau[85] to aid the coke-plant operator in his endeavors to obtain more uniform coke. Since air-dried coal has the highest bulk density, care must be taken in using dry coal to avoid dangerous expansion, pushing difficulties, and nonuniform oven operation. This condition can be alleviated by adding water to the dry coal. The effect of moisture is very pronounced, especially in the lower ranges. Where lower bulk density is desired and the initial moisture is not too high, addition of water may result in more uniform bulk density.

The use of oil for the control of bulk density seems to be desirable, since it decreases the bulk density of dry coal and increases that of wet coal. Bulk-density control by the use of oil may increase production under certain conditions, but it is necessary to observe caution in a plant that employs expanding coals to an extent that the expansion pressure of the coal is near the permissible maximum. In addition, the use of oil aids in diminishing dust, causes the coal to flow more freely from the larry car, and lessens difficulties due to freezing in cold weather. In general, finer crushing gives lower bulk density. More uniform coke can be obtained if exactly the same weight of coal is charged to each oven each time.

Beehive-Coke Production

Contributing 11 percent of the total requirements of this country, beehive coke has proved a most important source of blast-furnace fuel for our wartime steel program. The beehive oven, long ago abandoned as obsolete, has in some ways proved to be a savior of the necessary expanding steel industry.[86] To assist beehive-oven operators in their efforts to produce fuel of good quality, the Bureau recruited a crew of field engineers and equipped a special mobile laboratory with instruments for measuring oven temperatures and oven-draft conditions, sampling and analyzing exit gases, and making float-and-sink tests for refuse in coal. Aid was also rendered operators in procuring equipment and coal.

The technical services made available to the industry through the trained technicians and the mobile laboratory included the development of rapid field tests which showed that satisfactory coal from the Pittsburgh

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[85] Seymour, W., and Schmidt, L. D., Control of Bulk Density of the Coal Charge in Byproduct Coke Ovens: Bureau of Mines Rept. of Investigations 3743, 1943, 13 pp.

[86] Kelley, J. A., Beehive Coke Industry Revived: Min. Cong. Jour., vol. 29, 1943, pp. 22-25.