FeS and Fe_3O_4, and thereby produces sufficient SO_3 to react with the alkali-metal sulfates and the oxide on the metal. The net effect is to cause corrosion by the same processes that have been ascribed to corrosion by the alkali-metal-sulfate type of deposit. The relationship between the results obtained in the laboratory and observations of furnaces before and after preventive measures have been applied is described.62/

Factors Affecting Heat Absorption in Furnaces

As part of the general program of investigations by the A.S.M.E. Special Research Committee on Furnace Performance Factors, the Bureau is making a series of determinations of furnace-heat absorption in large-utility power boiler furnaces. During the course of these studies, modifications have been made in the test technique to improve the precision of furnace testing. Automatic recording instruments have been employed, which permit more detailed sampling and examination of furnace-outlet gases than heretofore, without an appreciable increase in the time or work required. Improved designs of radiation shields have been developed for high-velocity thermocouples, with accuracy comparable to the B & W multiple-shield, high-velocity thermocouple, but which may be employed conveniently in pulverized-coal-fired furnaces. Detailed descriptions of the distribution of gas composition and temperature at the outlet of a 640,000-pound-per-hour horizontally fired boiler furnace have been published.63/ Based upon this knowledge, the sampling characteristics of the gases at the furnace outlet for furnace heat-absorption measurements have been examined, and a procedure is suggested for the rational selection of simplified sampling schedules. The methods of calculating furnace-heat absorption from the temperature and gas-composition data are examined critically, placing special emphasis on the effect of weighting with respect to mass velocity. Suggestions are presented whereby the significance of mass velocity for furnace heat-absorption calculations may be determined from the temperature and gas-composition data.

Steam-Dried Lignite

A large-scale combustion test using steam-dried lignite was carried out at the Otter Tail Power Co. plant at Crookston, Minn. The unit used was a 5,000-kw. pulverized-coal unit. Table 5 shows the pertinent results. These results confirm former tests and show improved efficiency through drying.

TABLE 5. - Combustion of pulverized lignite, Otter Tail Power Co., Crookston, Minn.

Type of lignite	Kincaid	Dakota Star
Condition of lignite	Natural	Steam-dried
Moisture ... percent	32.5	15.6
Heating value as fired ... B.t.u./lb.	7,270	9,170
Heat input/kw.-hr. generated ... B.t.u.	14,902	14,481
Lignite consumed as fired ... lb./kw.-hr.	2.05	1.58
Heat absorbed by water and steam in the boiler of total heat input ... percent	76.4	81.5

62/ Corey, R. C., Grabowski, H. A., and Cross, B. J., External Corrosion of Furnace-Wall Tubes. III. Further Data on Sulphate Deposits and the Significance of Iron Sulphide Deposits: Trans. Am. Soc. Mech. Eng., vol. 71, November 1949, pp. 951-963.

63/ Cohen, P., Corey, R. C., and Myers, J. W., Methods and Instrumentation for Furnace Heat-Absorption Studies: Temperature and Composition of Gases at Furnace Outlet: Trans. Am. Soc. Mech. Eng., vol. 71, November 1949, pp. 965-978.

CARBONIZATION OF COAL

Coke Production

Our fuel reserves were reviewed,64/ with special reference to coking coals, and the problem of utilizing progressively poorer coking coals as reserves of high-quality coals approach depletion was discussed.

Methods of meeting shortages of metallurgical coke were described to the United Nations Scientific Conference on the Conservation and Utilization of Resources held at Lake Success, N. Y., in August 1949.65/ Among the methods that relieved shortages of coke in the United States during World War II were: Reconditioning and putting into service all available slot-type and beehive ovens, since enough new ones cannot be built in time; acceleration of operations by increased temperatures and earlier pushing of coke; curtailing of nonessential uses; and improving uniformity and quality of coke by better cleaning, blending, and mixing and higher bulk density.

The threat of continuing shortages resulting from the depletion of premium grades of coking coal may be met by increased exploration and by conservation through limitations on the use of coking coal for other than coke production and by the reduction of mining losses. Conservation is aided by improved cleaning methods, which permit lower grades to replace premium grades of coal, and by blending that broadens the range of metallurgical coals.

New methods of blast-furnace operation and gas production give promise of reducing coke requirements, and there are prospects of developing coke-free methods of iron-ore reduction. Continued research is essential to develop ovens capable of coking a broader range of coals.

Survey of Carbonizing Properties of American Coals

The scope of the survey of the carbonizing properties of American coals remained the same as in the previous year, when it was narrowed by limiting experimental carbonization to tests at high temperatures. Emphasis continued to be placed upon research bearing directly on the manufacture of metallurgical coke. A high proportion of the tests were made on blends because most metallurgical coke is made from mixed coals; furthermore, the carbonizing properties of some coals coked singly are of little value in predicting the properties of cokes made from their blends.

Forty-six coals were tested during the year, and blends of most of these were carbonized. The source of coals and composition of the blends tested (carbonization, plasticity, oxidation, or expansion tests) are given in table 6. Proximate and ultimate analyses of the coals, physical properties of coke, and a summary of yield data have been published.66/

64/ Fieldner, Arno C., Coal for Coke Production: Bureau of Mines Inf. Circ. 7559, 1950, 21 pp.
65/ Fieldner, A. C., and Newman, L. L., Overcoming Shortages of Metallurgical Coke: Mech. World and Eng. Rec., vol. 126, No. 3272, Sept. 30, 1949, pp. 402-405.
66/ Davis, J. D., and Reynolds, D. A., Survey of Carbonizing Properties of American Coals - Bureau of Mines Coal Carbonization Laboratory, 1948-49: Proc. Am. Gas Assoc., 1949, pp. 413-424.

TABLE 6. - Description of coals and blends

Coal No.	Description
	Kentucky
381	Elkhorn No. 1 bed, Elk Horn No. 28 mine, Floyd County, Ky.
a381	Elkhorn No. 1 bed, Elk Horn No. 28 mine, Floyd County, Ky. (washed).
381A	Blend: 80 percent Elkhorn No. 1 (381) and 20 percent Pocahontas No. 3 (f75).
381B	Blend: 70 percent Elkhorn No. 1 (381) and 30 percent Pocahontas No. 3 (f75).
382	Elkhorn No. 2 bed, Turner No. 5 mine, Floyd County, Ky.
382A	Blend: 80 percent Elkhorn No. 2 (382) and 20 percent Pocahontas No. 3 (f75).
382B	Blend: 70 percent Elkhorn No. 2 (382) and 30 percent Pocahontas No. 3 (f75).
383	Leatherwood bed, Leatherwood mine, Perry County, Ky.
383A	Blend: 80 percent Leatherwood (383) and 20 percent Pocahontas No. 3 (f75).
383B	Blend: 70 percent Leatherwood (383) and 30 percent Pocahontas No. 3 (f75).
384	Harlan bed, Path Fork mine, Harlan County, Ky.
384A	Blend: 80 percent Harlan (384) and 20 percent Pocahontas No. 3 (f75).
384B	Blend: 70 percent Harlan (384) and 30 percent Pocahontas No. 3 (f75).
	West Virginia
345	Davy-Sewell bed, Twin Branch mine, McDowell County, W. Va.
a368	Pittsburgh bed, Jamison No. 9 mine, Marion County, W. Va.
a368A	Blend: 80 percent Pittsburgh (a368) and 20 percent Pocahontas No. 3 (g75).
a368B	Blend: 70 percent Pittsburgh (a368) and 30 percent Pocahontas No. 3 (g75).
378	Firecreek bed, Laurel Creek mine, Greenbrier County, W. Va.
379	Firecreek bed, Dunedin No. 1 mine, Raleigh County, W. Va.
379A	Blend: 20 percent Firecreek (379) and 80 percent Pittsburgh (p28).
379B	Blend: 30 percent Firecreek (379) and 70 percent Pittsburgh (p28).
406	Sewell bed, Williams River mine, Webster County, W. Va.
407	Eagle bed, Cannelton No. 3 mine, Fayette County, W. Va.
413	Upper Freeport bed, Bull Run No. 1 mine, Preston County, W. Va.
413A	Blend: 20 percent Upper Freeport (413) and 80 percent Pittsburgh (q28).
413B	Blend: 30 percent Upper Freeport (413) and 70 percent Pittsburgh (q28).
413C	Blend: 50 percent Upper Freeport (413) and 50 percent Pittsburgh (q28).
425	Sewell bed, Duo mine, Greenbrier County, W. Va.
425A	Blend: 20 percent Sewell (425) and 80 percent Pittsburgh (r28).
425B	Blend: 30 percent Sewell (425) and 70 percent Pittsburgh (r28).
426	Sewell bed, Bergoo No. 6 mine, Webster County, W. Va.
426A	Blend: 80 percent Sewell (426) and 20 percent Pocahontas No. 3 (g75).
427	Sewell bed, Williams-River mine, Webster County, W. Va.
427A	Blend: 80 percent Sewell (427) and 20 percent Pocahontas No. 3 (g75).
428	Sewell bed, Sterling-Sewell mine, Nicholas County, W. Va.
428A	Blend: 70 percent Sewell (428) and 30 percent Pittsburgh (r28).

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TABLE 6. - Description of coals and blends - Continued

Coal No.	Description
	West Virginia - Continued
429	Sewell bed, Cassity No. 2 mine, Randolph County, W. Va.
429A	Blend: 80 percent Sewell (429) and 20 percent Pittsburgh (r28).
429B	Blend: 70 percent Sewell (429) and 30 percent Pittsburgh (r28).
429C	Blend: 50 percent Sewell (429) and 50 percent Pittsburgh (r28).
	British Columbia - Alaska - Western
385	No. 3 bed, Evans-Jones mine, Lower Matanuska Valley, Alaska.
385A	Blend: 70 percent No. 3 (385) and 30 percent "M" or "N" bed (386).
386	"M" or "N" bed, Chickaloon mine, Upper Matanuska Valley, Alaska.
388	No. 8 mine, Comox Lake district, Vancouver Island, British Columbia.
389	T'Sable River mine, Nelson district, Vancouver Island, British Columbia.
390	No. 9 bed, Elk River No. 9 mine, Fort Steele district, British Columbia.
391	No. 10 bed, Elk River No. 1 mine, Fort Steele district, British Columbia.
392	No. 3 bed, Elk River No. 3 mine, Fort Steele district, British Columbia.
393	No. 4 bed, Elk River No. 4 mine, Fort Steele district, British Columbia.
394	Michel mine (raw coal), Fort Steele district, British Columbia.
395	Michel mine, Fort Steele district, British Columbia.
398	No. 5 bed, Roslyn No. 3 mine, Kittitas County, Wash.
399	Peace River district, Hudson's Hope, British Columbia.
400	Robertson mine, Queen Charlotte Island, British Columbia.
401	Aldridge Creek prospect, Elk River No. 5 mine, Fort Steele district, British Columbia.
402	Aldridge Creek prospect, Elk River No. 4 mine, Fort Steele district, British Columbia.
423	Lower Sunnyside bed, Horse Canyon mine, Carbon County, Utah.
423A	Blend: 82 percent Lower Sunnyside (423), 15 percent Elk River No. 4 (393), and 3 percent pitch.
423B	Blend: 82 percent Lower Sunnyside (423), 15 percent Elk River No. 1 (391), and 3 percent pitch.
423C	Blend: 82 percent Lower Sunnyside (423), 15 percent Elk River No. 9 (390), and 3 percent pitch.
423D	Blend: 85 percent Lower Sunnyside (423) and 15 percent Pocahontas No. 3 (g75).
423E	Blend: 97 percent Lower Sunnyside (423) and 3 percent pitch.
423F	Blend: 85 percent Lower Sunnyside (423) and 15 percent Oklahoma low-volatile (424).
423G	Blend: 82 percent Lower Sunnyside (423), 15 percent Oklahoma low-volatile (424), and 3 percent pitch.
424	Oklahoma (Republic) low-volatile coal (Geneva Steel Co.).
	South America
423	No. 1 bed, Cerejon region, Colombia, South America.
433	No. 2 bed, Cerejon region, Colombia, South America.

TABLE 6. - Description of coals and blends - Continued

Coal No.	Description
	Miscellaneous
346	Upper and Lower Freeport beds, Kent Nos. 1 and 2 mines, Indiana County, Pa.
380	Lower Freeport bed, Kent No. 1 mine, Indiana County, Pa.
380A	Blend: 50 percent Lower Freeport (380) and 50 percent Upper Freeport (387).
380B	Blend: 33-1/3 percent Lower Freeport (380) and 66-2/3 percent Upper Freeport (387).
387	Upper Freeport bed, Kent No. 2 mine, Indiana County, Pa.
397	Upper Freeport bed, Kent No. 7 mine, Indiana County, Pa.
414	Elnora (No. 4) bed, Maid Marian (strip) mine, Daviess County, Ind.
415	Illinois No. 6 bed (raw coal).
416	Jones & Laughlin Steel Corp. C-Battery Mix (G-72 or P-45): 10 percent low-volatile Pocahontas No. 6; 40 percent high-volatile A "Dixie" (mixture of coals from Kentucky, West Virginia, and Tennessee); and 50 percent high-volatile A washed Vesta.
417	High-volatile A washed Shannopin coal (G-35 or P-27) from J. & L. mine: 1/4-inch float 1.35.
417A	90 percent coal 417 and 10 percent 535° C. coke made from coal 417: 1/4-inch float 1.55.
430	Pittsburgh bed, Champion No. 1 mine (feed coal).
431	Pittsburgh bed, Champion No. 1 mine (face discharge refuse).
	Blending coals
p28, q28, r28	Pittsburgh bed, Warden mine, Allegheny County, Pa.
f75, g75	Pocahontas No. 3 bed, Kimball, McDowell County, W. Va.
f75A	Blend: 80 percent Pittsburgh (p28) and 20 percent Pocahontas No. 3 (f75).
f75B	Blend: 70 percent Pittsburgh (p28) and 30 percent Pocahontas No. 3 (f75).

Methods of Testing

The carbonizing properties of the eastern coking coals were determined by Bureau of Mines-American Gas Association (BM-AGA) tests at 800° and 900° C. in the standard 18-inch retort. One coal and five blends were also carbonized in the 500-pound slot oven. Physical properties of the cokes from these tests were determined by standard methods of the American Society for Testing Materials.

The carbonizing properties of the British Columbian, Alaskan, Western, and Colombian coals were determined by BM-AGA tests at 900° C. in the standard 13-inch retort. These cokes were tested by BM-AGA methods; the tumbler test is less severe than the A.S.T.M. method.

Coals Tested

A relatively large proportion of the carbonization work was done on samples representing the Elkhorn No. 1, Elkhorn No. 2, Leatherwood, and Harlan beds in Kentucky and the Fire Creek, Upper Freeport, Pittsburgh, and Sewell beds in West Virginia. Five Sewell coals from four counties in West Virginia were tested because this bed has large reserves and its rank ranges from low to high volatile. The carbonizing properties of 13 British Columbian and two Alaskan coals were determined in a cooperative investigation with the United States Steel Co., which was conducted to determine the feasibility of substituting coal from the northern part of this continent for low-volatile Oklahoma coal now blended with Lower Sunnyside coal for the production of metallurgical coke in Utah. The Alaskan coals were from the upper and lower Matanuska Valley; the British Columbian coals included two from Vancouver Island, seven from Elk River beds Nos. 3, 4, 5, 9, and 10 in the Fort Steele district, two Michel-mine coals, one from the Peace River district, and one from the Queen Charlotte Isles. Lower Sunnyside coal from the Horse Canyon mine, Carbon County, Utah, was blended with the most strongly coking British Columbia coals. Two samples from Magdalena, Colombia, South America, were carbonized singly.

Sewell-Bed Coal

The Sewell coal bed extends from the southern boundary of West Virginia northeast to Preston County, which borders Pennsylvania, and its original tonnage was estimated to be about 6-1/4 billion tons. The coal rank ranges from low-volatile in the south to high-volatile A in the north. Because only a few high-ranking low-volatile coals from the southern part of this bed had been tested previously, the survey was extended to those counties containing medium- and high-volatile coal. The variation of carbonizing and expanding properties of Sewell bed with rank and geographical location is shown in table 7. The following five coals were tested: (1) Duo mine in Greenbrier County (425), Bergoo No. 6 mine in Webster County (426), Williams River mine in Webster County (427), Sterling-Sewell mine in Nicholas County (428), and Cassity No. 2 mine in Randolph County (429). These coals ranked either low in the medium-volatile group or high in the high-volatile A group; they contained 67.0 to 72.5 percent fixed carbon on the dry, mineral-matter-free basis. Their contents of ash and sulfur as carbonized (3.1 to 8.0 and 0.6 to 1.1 percent, respectively) showed that they qualified chemically for the manufacture of metallurgical coke. The ranges in strength indexes of the 900° C. cokes were: 1-1/2-inch shatter, 83-90; 1-inch tumbler, 43-50; and 1/4-inch tumbler, 59-66. The experimental data indicate that these coals are suitable for commercial carbonization and that they could be blended with coals of different rank. Duo-mine coal should be blended with high-volatile A coal to lower its expansion and thereby avoid damage to oven walls. Bergoo No. 6, Sterling-Sewell, and Cassity No. 2 coals coked strongly when carbonized singly; possibly, they could be carbonized without blending if high-charge densities were avoided. Williams River coke had lower tumbler indexes than the others, and because these indexes were raised appreciably by blending with 20 percent Pocahontas No. 3, blending with low-volatile coal is recommended for commercial carbonization.

TABLE 7. - Survey of carbonizing properties of Sewell-bed coal from West Virginia

Coal No.	Mine	County	Dry, mineral-matter-free, fixed carbon, percent	As received, percent: Volatile matter	As received, percent: Ash	As received, percent: Sulfur	Coke index, percent: Shatter, 1-1/2-inch screen	Coke index, percent: Tumbler, 1-inch screen	Expansion, percent
26..	Cranberry	Raleigh...	78.6	20.5	2.1	0.8	86.9	1/69.6(58.6)	-
55..	Wyoming	Wyoming...	77.5	22.0	2.9	.7	85.7	1/68.9(58.9)	+26.0
27..	Summerlee	Fayette...	78.5	26.5	2.4	.5	79.4	1/68.0(58.0)	-
425.	Duo	Greenbrier	72.5	26.2	3.1	1.1	90.0	54.0	+23.1
426.	Bergoo	Webster ..	69.5	26.6	5.4	.6	85.0	50.0	-11.7
429.	Cassity	Randolph..	69.2	28.3	7.4	.6	96.0	58.0	- 4.7
427.	Williams-River.	Webster ..	67.4	30.5	5.5	.6	90.0	43.0	- 7.0
428.	Sterling-Sewell	Nicholas..	67.0	30.9	4.3	.6	86.9	54.2	- 1.5
	Average		71.8	26.7	4.1	.7	87.5	58.2	-
	High		78.6	30.9	7.4	1.1	96.0	69.6	-
	Low		67.0	20.5	2.1	.5	79.4	43.0	-

1/ Figures in parentheses are estimated for A.S.T.M. tumbler; the BM-AGA 1-inch index (used in early work) is about 10 points higher than the A.S.T.M.

British Columbia, Alaska, and Western Coals

The coals from Upper and Lower Matanuska Valley in Alaska differed markedly in coking power. No. 3-bed coal (385) yielded 63.2 percent char, which was poorly fused and too weak to test. M-bed coal (386) expanded strongly and yielded 78.2 percent coke, which was very strong. The latter should be valuable for blending with lower-rank (high-volatile) coals; it contained 12.7 percent ash and 0.5 percent sulfur.

Both samples from Vancouver Island ranked as high-volatile A and coked strongly. No. 8-mine coal (388) yielded 69.5 percent coke, and P'Sable River-mine coal (389) yielded 71.3 percent. The indexes of the respective cokes were: 1-1/2-inch shatter, 82 and 77; 1-inch tumbler, 56 and 59; and 1/4-inch tumbler, 65 and 65. These indexes are higher than the average for coals of similar rank.

Lower Banner Coal, Russell County, Va.

The carbonizing properties of Lower Banner-bed coal from No. 56 mine, Dante, Russell County, Va., were determined by BM-AGA tests at low, medium, and high temperatures and by expansion tests in the sole-heated oven.67/ This coal ranked as high-volatile A bituminous, and its yields of carbonization products approximated the average yields for coals of similar rank. The cokes made at all temperatures were well-fused; the high-temperature cokes were medium-grained and moderately fissured. The 900° C. coke resisted breakage by impact well but was more abradable than the average BM-AGA coke made from high-volatile A coals. Blending with Pocahontas No. 3 coal strengthened the 900° C. coke materially, and the blend containing 30 percent of this low-volatile coal coked more strongly than the blend containing 20 percent. Three samples from mine No. 56 contracted 22.2 to 25.8 percent in the sole-heated oven at the standard bulk density of 55.5 pounds per cubic foot. The blends

67/ Davis, J. D., Reynolds, D. A., Brewer, R. E., Ode, W. H., Naugle, B. W., and Wolfson, D. E., Carbonizing Properties of Lower Banner Coal from No. 56 Mine, Dante, Russell County, Va.: Bureau of Mines Tech. Paper 720, 1949, 45 pp.

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containing 20 and 30 percent Pocahontas No. 3 contracted 11.5 and 6.0 percent, respectively. Oxidation tests in air at 100° C. for periods of 3.9, 11.2, and 19.2 days showed that Lower Banner oxidized more rapidly than Pittsburgh coal.

Thick Freeport and Pittsburgh Coals, Pennsylvania; Elkhorn Coal, Kentucky; and America and Mary Lee Coals, Alabama

The carbonizing properties of nine coals mined and carbonized commercially by the Republic Steel Corp. were determined in a cooperative investigation with that firm.[68] BM-AGA carbonization tests were made at 800°, 900°, and 1,000° C. on the single coals because the corporation was particularly interested in the yields of carbonization products. Two Thick Freeport-bed coals represented the Indianola and Russellton mines in Allegheny County, Pa.; two Pittsburgh coals represented the Clyde and Crescent mines in Washington County, Pa.; Elkhorn-bed coal was from the Republic mine, Pike County, Ky.; America-bed coal was obtained from the Virginia mine, Jefferson County, Ala.; and two Mary Lee-bed coals were from Sayreton mines Nos. 1 and 2 and Sayre mine, Jefferson County, Ala. The Alabama coals ranked higher and yielded more coke and less other products than the other coals. Cokes from the Thick Freeport, Pittsburgh, and Elkhorn coals were well-fused, medium-grained, and moderately fissured; America and Mary Lee cokes were finer-grained and less-fissured. The heating values of the gases in B.t.u. per pound of coal were: Thick Freeport, Indianola and Russellton mines, 3,180 and 3,120, respectively; Pittsburgh, Crescent and Clyde mines, 3,020 and 3,060, respectively; America, 2,700; Mary Lee, Sayreton mines Nos. 1 and 2, 2,760, Sayre mine, 2,750, and Sayreton No. 2 mine, 2,870. The expansions (or contractions) in the sole-heated oven at 55.5 pounds per cubic foot were: Thick Freeport, Indianola mine, -12.7, and Russellton mine, -14.6; Pittsburgh, Crescent mine, -16.6, and Clyde mine, -15.3; Elkhorn, -11.1; America, -4.3; and Mary Lee, Sayreton No. 2 mine, -2.9, Sayreton Nos. 1 and 2 mines, -7.3, and Sayre mine, -11.3.

Testing Alabama Coals in the 17-Inch Test Oven

Test work was continued on the carbonizing properties of Alabama coals using the 17-inch, 1/2-ton charge, experimental, movable wall coke oven at the Bureau of Mines Southern Experiment Station, Tuscaloosa, Ala. The coals tested were from the northwest and northeast portions of the Warrior field and the northern section of the Cahaba coal field. These coals covered the range of volatile matter (25 to 37 percent) into which substantially all of the Alabama coals fall. The coals were carbonized at 2,000° and 2,400° F., and the flue temperature resultant coke was evaluated in terms of the Standard A.S.T.M. tests for coke quality. The wall force exerted during carbonization was also determined. The oven has been found satisfactory for testing purposes.

Foundry Cokes from Sunnyside Coal, Utah

A study of the possibilities of making foundry coke from the lower Sunnyside seam coal of Carbon County, Utah, with blends of low-volatile coal, pitch, and medium-volatile char, was initiated at Denver in cooperation with the Utah Fuel Co.

68/ Davis, J. D., Reynolds, D. A., Naugle, B. W., Wolfson, D. E., Birge, G. W., Flickinger, C. E., and Graham, J. P., Carbonizing Properties of Thick Freeport and Pittsburgh Coals from Pennsylvania, Elkhorn Coal from Kentucky, and America and Mary Lee Coals from Alabama. Application of BM-AGA Carbonization Test Results to Byproduct Practice: Tech. Paper 726, 1949, 58 pp.

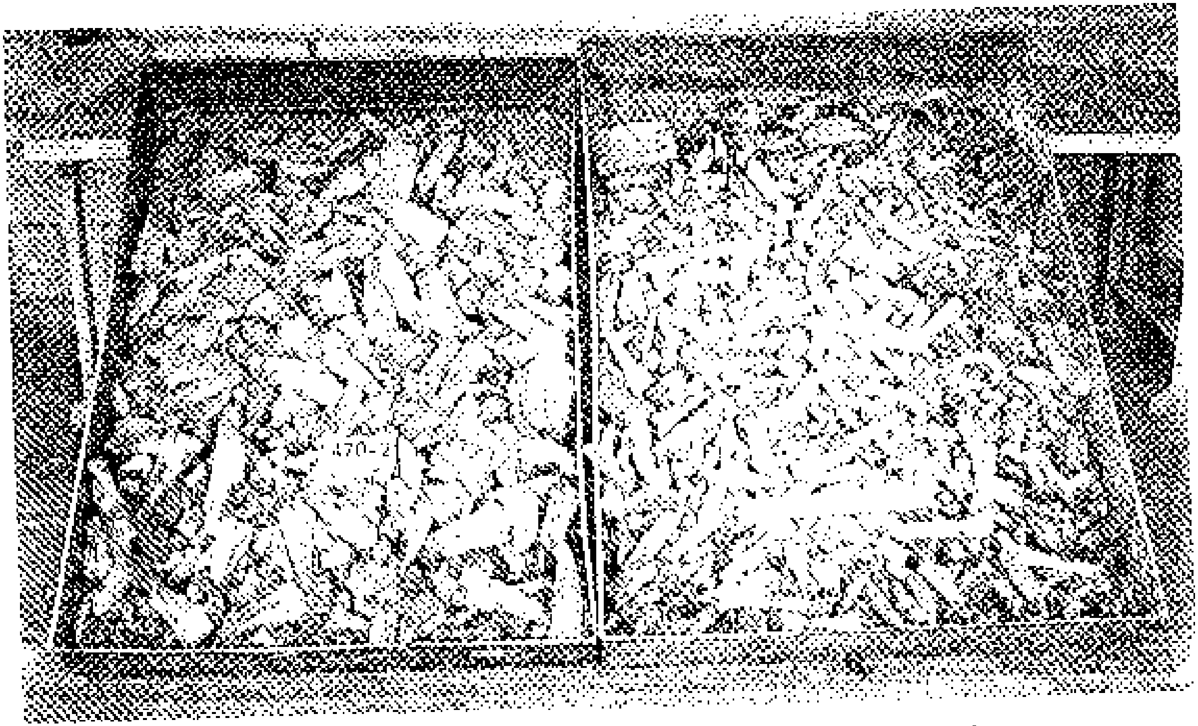

Figure 10. - Coke from 100 percent Lower Sunnyside coal, showing typical fingery structure.

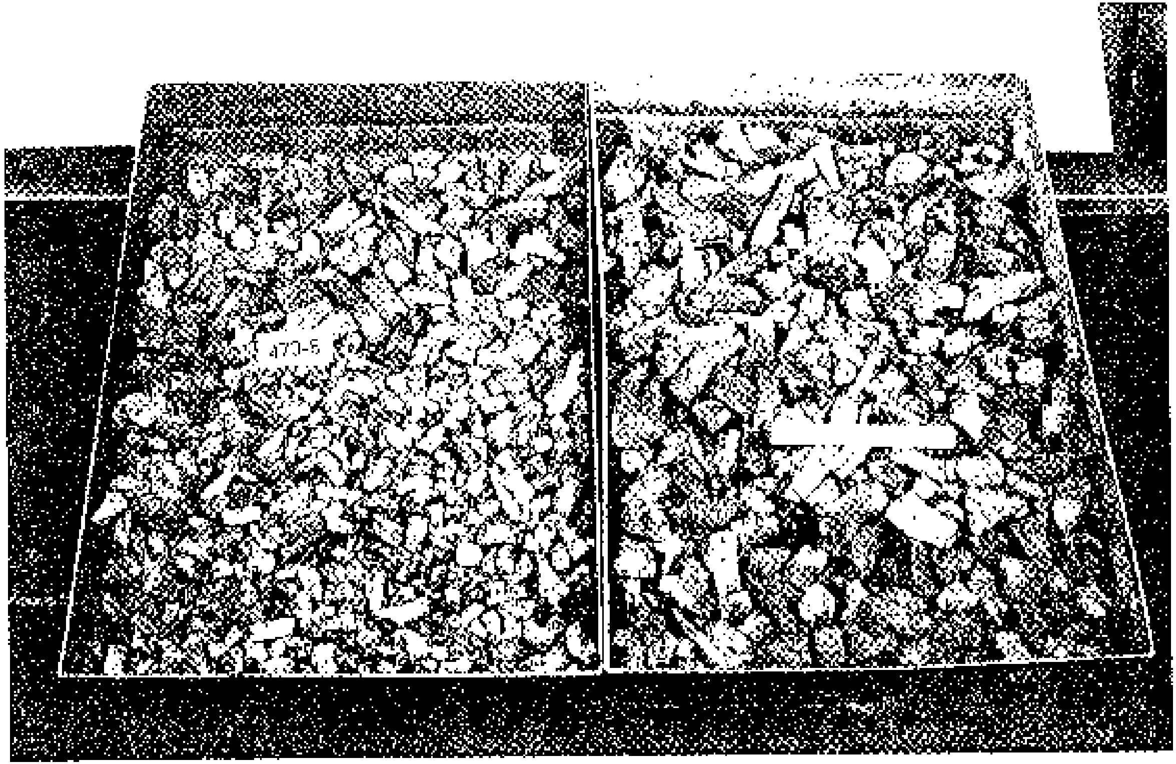

Figure 11. - Coke from 70 percent Lower Sunnyside coal plus 30 percent medium-volatile coal from Oklahoma, showing blocky structure obtained.

Blast-furnace coke is being produced from this coal in three byproduct coke plants, and foundry coke is being produced at one beehive plant. The byproduct coke made from Sunnyside coal is of poor quality when judged by eastern practice, but western blast-furnace operators dependent upon this coke have developed techniques that permit them to use this material efficiently. This coke is not suitable for foundry use. The beehive plant does not supply sufficient foundry coke to meet the demand in the western States, and the economics of the industry do not favor the erection of new beehive-coke plants. Foundry coke is currently being imported from all of the major coke-producing areas of the country.

A program specifically aimed at determining the optimum blend of Sunnyside coal with other materials that will yield a suitable foundry coke in byproduct ovens was undertaken by the Bureau in cooperation with the Utah Fuel Co., one of the major producers of metallurgical-grade Sunnyside coal. Carbonization tests were made in a 500-pound experimental slot oven under time and temperature conditions similar to those found in commercial byproduct ovens using the Sunnyside coal. The cokes produced from this oven were tested by A.S.T.M. standards and by methods and techniques developed in the Utah byproduct coke plants.

After determining the properties of coke made from straight Sunnyside coal, the effect of the addition of 5 and 10 percent of coal-tar pitch were studied, followed by the testing of 10, 20, and 30 percent blends of a low-volatile bituminous coal from western Arkansas and a 30 percent blend with a medium-volatile coal from Oklahoma. Marked improvements in the physical properties were produced by the addition of the blending materials, the most satisfactory blend tested to date being the 70 percent of Sunnyside coal with 30 percent of the medium-volatile Oklahoma coal. The results of the physical tests made on the cokes are shown in table 8. One of the most notable improvements was in the production of a blocky coke. Straight Sunnyside coal produces a fingery coke, as shown in figure 10, that is not satisfactory for use in the foundry cupolas because of its low packing density and inherently weak structure. A more blocky coke, produced from a blend of 70 percent Lower Sunnyside coal and 30 percent medium-volatile coal from Oklahoma, is shown in figure 11. In addition to its improved shape, this coke is also more resistant to degradation than is the coke made from the straight Sunnyside coal. The addition of coal-tar pitch increased the average size of the coke but did not produce a coke strong enough for the purpose.

Low-temperature Carbonization of Noncoking Coals

An investigation of the low-temperature carbonization of the lower-rank coals was initiated to determine the technical and economic possibilities of carbonizing these coals for production of char for electric-power generation and tars for industrial chemicals. Pilot plants for drying and carbonizing lignite in the entrained and fluidized state were operated successfully on a scale of 2 to 10 tons per day.

When raw lignite containing 37 percent moisture is carbonized at 900° F., more than 75 percent of the available heat in the raw fuel is confined in the char, which represents about 45 percent of the weight of the original lignite; furthermore, about 15 percent of the heat in the raw lignite is recovered as tar. These high-grade products from lignite are valuable industrial raw materials, and their cost of transportation should be considerably less than the cost of shipping the same quantity of heat in the form of raw lignite. The processed materials are also more uniform and stable in physical and chemical properties than the raw fuel.

TABLE 8. - Physical properties of cokes produced from Utah Sunnyside coal and blends

Charge composition	100 percent Sunnyside	95 percent Sunnyside, 5 percent coal-tar pitch	90 percent Sunnyside, 10 percent coal-tar pitch	90 percent Sunnyside, 10 percent Arkansas low-volatile coal	80 percent Sunnyside, 20 percent Arkansas low-volatile coal	70 percent Sunnyside, 30 percent Arkansas low-volatile coal	70 percent Sunnyside, 30 percent Oklahoma medium-volatile coal
Charging density..............lb./cu.ft.	52	52	52	52	52	52	52
Flue temperature ....°F.	2,300	2,300	2,300	2,300	2,300	2,300	2,300
Carbonization time ....hours	16.5	16.5	16.5	16.5	16.5	16.5	16.5
Average inside oven wall temperature,°F.	1,859	1,879	1,882	1,849	1,869	1,904	1,873
Average coke size1/ ....inches	1.66	1.79	2.15	1.86	2.02	2.09	2.17
Drop shatter test, Columbia Steel Co. method:2/							
Cumulative percentage retained on 1-1/2-inch screen	30.0	43.3	64.0	40.0	65.3	73.3	72.7
Tumbler test, Columbia Steel Co. method:2/							
Cumulative percentage retained on 1.05-inch screen	43.3	68.7	76.7	73.3	84.7	86.7	84.0
Cumulative percentage retained on 0.263-inch screen	86.7	90.0	91.3	90.0	91.3	90.7	90.0
Shape factor3/	1.16	1.04	0.88	1.00	0.68	0.76	0.67

1/ Square-hole screens.
2/ Reynolds, D. A., Davis, J. D., Brewer, R. E., Ode, W. H., Wolfson, D. E., and Birge, G. W., Carbonizing properties of Western Coals: Bureau of Mines Tech. Paper 692, 1946, 79 pp.
3/ Shape factor is a measure of the ratio of length of piece to average diameter. Fingery cokes have shape factors over 1, and satisfactory foundry cokes have shape factors of 0.60 to 0.70.

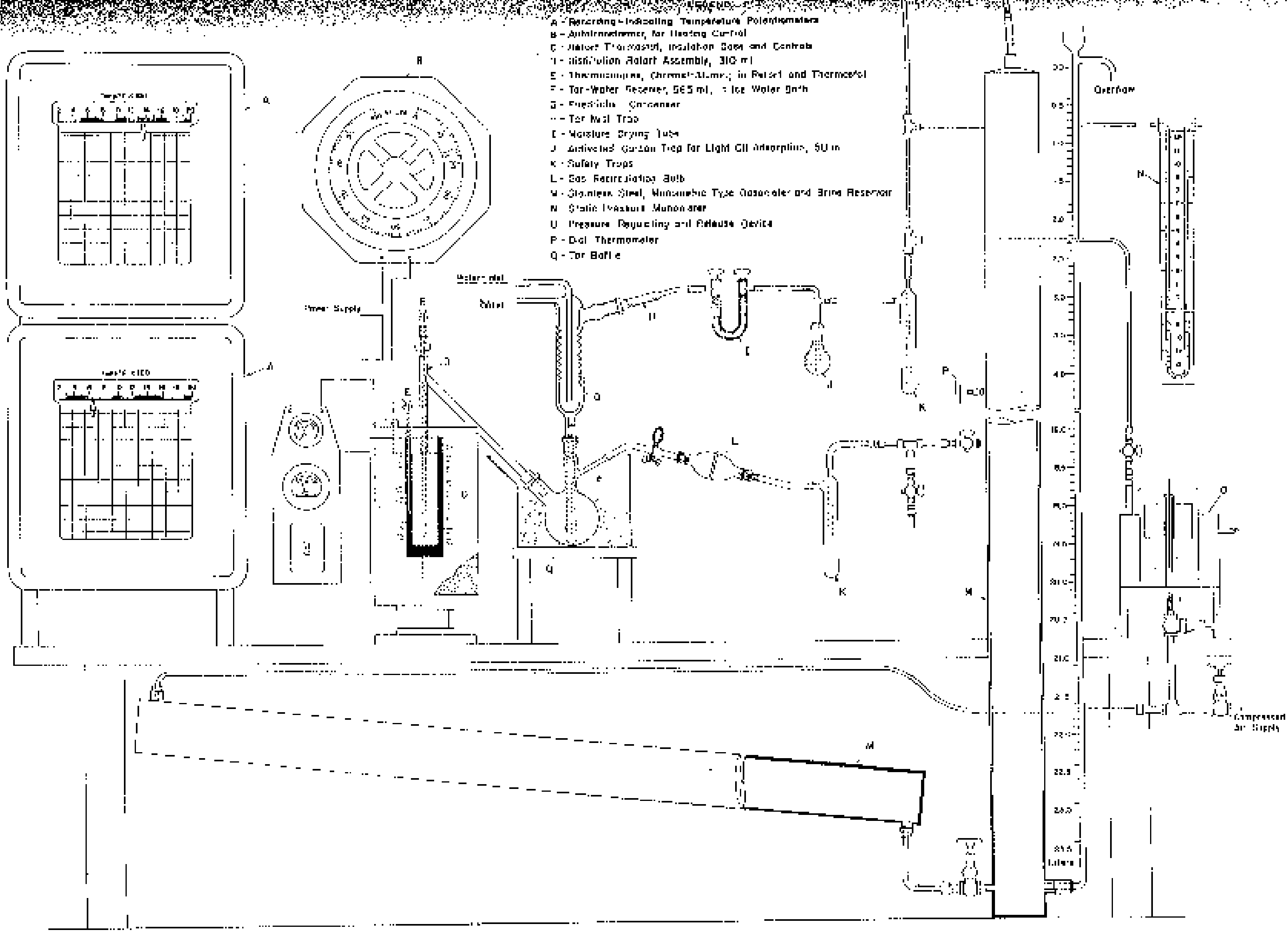

Figure 12. - Modified distillation assay apparatus.

A survey of the yields and properties of products of low-temperature carbonization from representative western coals was made.69/ This study indicates that certain favorable high-volatile coals will yield as much as 40 gallons of low-temperature tar per ton of coal processed.

An improved assay test for determining the yield of products from coal by carbonizing at various temperatures was devised. This test is made in the equipment illustrated in figure 12. The small retort has a capacity of about 6 ounces of coal. It furnishes valuable data on the effect of temperature on products of distillation, for results indicate that the yields shown by the assay can be obtained on a commercial scale by carbonizing the coal in a fluidized state.

Desulfurization During Carbonization with Added Gases

Diverse requirements of coal and its products to meet new and wider applications in industry have focused increased attention towards the development of methods for removing or reducing the undesirable sulfur content of the high-sulfur coals that must be used in the future. Experimental results of an investigation70/ showed that the desulfurizing action, namely, a lowering of the sulfur content in the coke, is increased (1) by addition of ammonia, hydrogen, or nitrogen during carbonization, (2) by introduction of these gases at temperatures lower than the final carbonization or reaction temperature, (3) by continued time of treatment of the coal or coke sample at the reaction temperature with these added gases, and (4) by use of fine-size coke. Carbonization of the coal with added ammonia gas caused a large percentage of the coal sulfur to be converted to volatile sulfur compounds; ammonia was markedly superior to hydrogen, and hydrogen was considerably more effective than nitrogen.

The laboratory investigation suggests that a cheap source of ammonia, such as from ammoniacal liquor, and a simple scrubbing train containing an alkaline solution of suitable composition and concentration might be utilized commercially to effect desulfurization of the solid, liquid, and gaseous products obtained by carbonization, gasification, and combustion of coal.

Ammonium Sulfate Yields

In order to account for differences in commercial yields of ammonium sulfate obtained in different parts of this country, the yields obtained in BM-AGA tests at 800°, 900°, and 1,000° C. from 45 high-volatile A, 14 medium-volatile, and 8 low-volatile coals were averaged by States and compared.71/ Average yields as pounds per ton of coal ranged as follows: High-volatile A coals, 22.5 to 35.9 at 800° C., 19.6 to 30.1 at 900° C., and 15.5 to 27.4 at 1,000° C.; medium-volatile coals, 21.9 to 27.0 at 800° C., 18.0 to 24.4 at 900° C., and 12.0 to 19.2 at 1,000° C., and low-volatile coals, 17.5 to 19.2 at 800° C., 14.0 to 14.9 at 900° C., and 9.0 to 9.2 at 1,000° C. Average yields were: (1) High for Washington, Alabama, and Utah, (2) about the same as the overall average for Kentucky and Oklahoma, and (3) low for Pennsylvania and West Virginia coals.

69/ Parry, V. F., Goodman, J. B., and Gomez, Manuel, Low-Temperature Distillation Assays of Representative Western United States and Alaska Coals: Colorado School of Mines Quarterly, vol. 45, No. 2A, April 1950, pp. 133-162.

70/ Brewer, R. E., and Ghosh, J. K., Desulfurization of Coal during Carbonization with Added Gases - Quantitative Determination of Sulfur Compounds: Ind. Eng. Chem., vol. 41, September 1949, pp. 2044-2053.

71/ Reynolds, D. A., and Wolfson, D. E., Coal Carbonization: Ammonium Sulfate Yields from Coals of Various Regions of the United States: Bureau of Mines Rept. of Investigations 4526, 1949, 15 pp.