in the slagging-type gas producer shown in figure 21. Preliminary tests have indicated that a satisfactory slag can be produced from these materials if a high enough rate of gasification can be maintained in the equipment. Because of the low reactivity of the anthracite, high temperatures must be maintained in the fuel bed, and it may be necessary to water-cool the reaction zone of the producer.

Wartime Utilization of Coal in Germany

Early in 1945, a Solid Fuels Mission was organized under the auspices of the Technical Industrial Intelligence Committee to study wartime developments in Germany coal technology. Some of these developments in the preparation and utilization of solid fuels in Germany during World War II have been summarized in published reports.57/

The mission gave particular attention to the chief coal-mining districts of Germany - the Ruhr and the Saar. As the Ruhr coal basin was the arsenal of German heavy industrial and war-making economy, more attention was given to it. The Bergbauverein, with headquarters at Essen-Heisigen, carried out the principal research on all phases of coal technology from mining to utilization. Of particular interest in the field of preparation were plants at Essen and Aachen for preparing a coal containing only 0.5 to 0.7 percent ash used in manufacturing electrodes. The plant at Essen, located at the Queen Elizabeth mine, accomplished this by a two-stage cleaning process consisting of a heavy-medium separation in a suspension of magnetite followed by pulverization of the clean product and its recleaning by froth flotation. At Aachen the extremely low-ash coal for electrode manufacture was produced by a combination of froth flotation and digestion of the recleaned coal in a hot, dilute mixture of hydrochloric and hydrofluoric acids. Another process used in the Ruhr to give virtually ashless coal involved solution of the coal in organic solvents produced by hydrogenation of coal in another plant and the separation of the undissolved material by filtration.

In the Saar, satisfactory blast-furnace coke was made from high-oxygen coking coals by substituting low-temperature coke made by the Krupp-Lurgi process for low-volatile coal previously shipped to the Saar from the Ruhr.

In both the Saar and the Ruhr, two significant features of coal preparation differed from common practice in the United States. The first was the wide use of piston jigs for treating closely sized coal, even down to one-half inch, as distinguished from the wide range of sizes treated in the Baum-type jig in the United States; the other was the almost universal practice at coking-coal mines of cleaning coal finer than about 1 mm. by froth flotation.

57/ Yancey, H. F., Mining in Europe; Wartime Coal Production and Utilization: Coal Age, 1945, vol. 50, pp. 115-118.

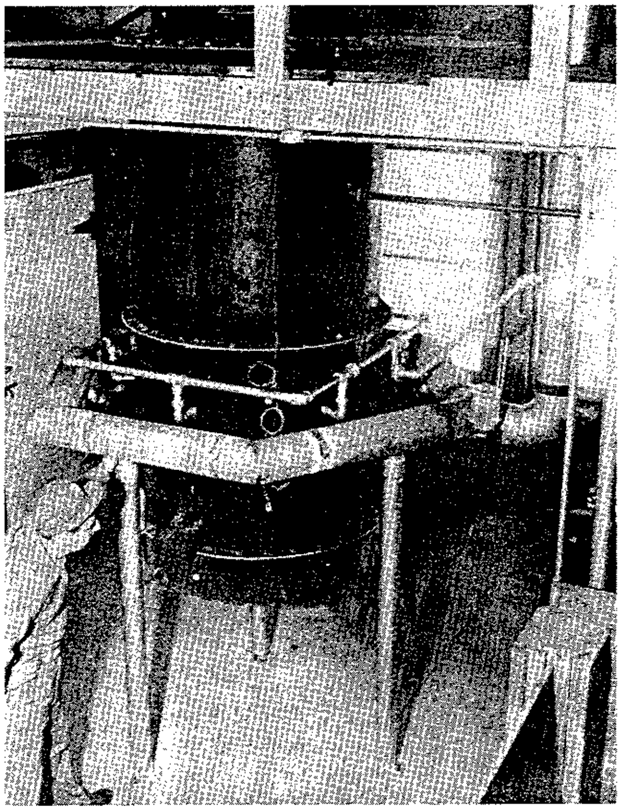

Figure 21. - Slagging-type gas producer for use on Rhode Island anthracite.

CARBONIZATION AND GASIFICATION

Laboratory Tests of Coking Coals

In the survey of gas- and coke-making properties of American coals, small-scale laboratory carbonization tests are made of coals from various sources to determine their suitability for the production of metallurgical coke. The tests include the Fischer low-temperature carbonization assay, the United States Steel Corporation high-temperature distillation test, and the Bureau of Mines agglutinating-value test. In a study of the carbonization properties of western coals, agglutinating-value tests of 88 coals and small-scale carbonization assays of 29 coals were reported. The agglutinating value results showed that certain areas in Colorado, New Mexico, Utah, Washington, and Wyoming contain coals that have coking properties sufficiently high for the production of metallurgical coke. Low-temperature tar yields by the Fischer assay ranged from 11.5 gallons per ton of coal for a Washington lignite to 59.0 gallons per ton for a cannel coal from Utah. No trend in yields could be noted for coals from the various States because of the wide variation in rank of the coals. Cannel coal from a bench in the King-Cannel mine, Kane County, Utah, yielded 59.0 gallons of tar and 3.82 gallons of light oil per ton of coal, compared to 26.4 gallons of tar and 2.02 gallons of light oil from the bench of common banded (bright) coal in the same mine. Spores that are commonly abundant in cannel coals are prominent contributors to tar and light-oil yields.

Tar and light-oil yields of a sample of lignitic coal from Ouachita County, Ark., were determined by the Fischer low-temperature carbonization assay. On an as-received coal basis, the tar and light oil yields were 25.4 and 1.83 gallons per ton, respectively. These yields are considerably higher than those usually obtained from coals of this rank. The high tar yield of a similar coal from the same district tested several years ago was accounted for by the large amount of yellow waxy material it contained; it is probable that this also accounts for the unusually high tar yield of the more recent sample of coal.

During the year, agglutinating-value tests were made of more than 150 diamond drill-core and mine samples of coal submitted in connection with exploration projects for new sources of coking coals. The coals were from the following areas: Coosa field in St. Clair County, Ala., Coal Creek area in Paonia district, Gunnison County, Colo., Lookout Mountain field in Dade County, Ga., Georges Creek field in Allegany and Garrett Counties, Md., and Deep River field in Chatham County, N. C. The agglutinating values of the Coosa-field coals in Alabama ranged from 4.6 to 9.9 kilograms. These values, obtained at a 15:1 ratio of silicon carbide to coal, indicate that many of the coals are strongly coking. The Coal Creek coals from Colorado had agglutinating values ranging from 3.4 to 5.9 kilograms. These values are higher than those determined for Minnesota Creek coals from the same district previously examined. Agglutinating values and BM-AGA carbonization-test results showed that some of the Coal Creek coals have coking properties superior to those of the lower Sunnyside coals of Utah, a standard western coal for making metallurgical coke. The agglutinating values of the Georgia and North Carolina coals and most of the Maryland coals would classify them as strongly coking.

Agglutinating values that have proved to be useful as an approximate measure of coal oxidation are used to determine the changes that take place in the coking quality of coals during storage. In connection with a survey of storing properties of coals, agglutinating values of 48 samples were determined during the year. The coals examined were from the following sources: Black Creek and Hill beds, Alabama; Elkhorn No. 3 bed, Kentucky; Raton bed, New Mexico; Pittsburgh No. 8 bed, Ohio; McAlester bed, Oklahoma; Pittsburgh bed, Pennsylvania; McKay and Roslyn No. 5 beds, Washington; and Beckley, Eagle, Pocahontas No. 3, Pocahontas No. 4, and Powellton beds, West Virginia.

In connection with a study of complete gasification of Alabama coals, agglutinating values of 11 samples of coal were determined by the Bureau of Mines method. The values ranged from 3.2 to 8.3 kilograms, which indicates that the samples ranged from fair- to good-coking.

Alaskan Coals

Fischer low-temperature carbonization assays were made of five samples of Upper Cretaceous coals from northern Alaska to determine the value of these coals as a potential source of liquid fuel. The samples were collected in the summer of 1945 by U. S. Geological Survey parties working in the Chandler and Anaktuvuk Rivers area as a part of the Navy Department's petroleum investigations in Naval Petroleum Reserve No. 4. Rank classification of the coals could not be made because of loss of bed moisture during the period between collection and analysis of the samples; however, four of the coals were probably no higher than subbituminous in rank, as indicated by their high oxygen content on a dry, ash-free coal basis. The range of yields of carbonization products was as follows: Char, 66 to 79 percent; tar, 8.7 to 21.5 gallons per ton; light oil, 0.95 to 1.74 gallons per ton, and gas, 1,890 to 2,950 cubic feet per ton. The coals were noncoking in the Fischer assay; the carbonized residues were loose powders.

Chilean Coals

In connection with a survey of carbonizing properties of coals of Chile, made at the request of the Chilean Government, Fischer low-temperature carbonization assays were made of a sample of attrital coal from the Elena mine, Magallanes Province, and of samples of attrital coal and anthraxylon from the Volcano mine, Magallanes Province. These samples were separated from selected samples of lump coal to determine the effect of types of coal upon the yields of carbonization products. The low-temperature carbonization yields on a dry, mineral-matter-free basis are as follows:

	Elena mine,	Volcano mine	
	attrital coal	Attrital coal	Anthraxylon
Coke, percent	63.1	63.8	71.3
Tar, percent	14.3	11.7	2.4
Light oil, percent	0.91	0.98	0.24
Gas, cubic feet per ton coal .	3,610	4,090	3,680
Gas, B.t.u. per pound coal ...	620	1,010	730

The attrital coals are shown to yield much more tar and light oil and less coke than the anthraxylon. These differences in tar and light-oil yields may be due to variations in the concentration of waxy material in the two types of coal. The tars from the attrital coals contained a large amount of pale-yellow waxy material similar in appearance to that from certain resinous or waxy western coals. The anthraxylon yielded virtually none of this material.

Chinese Coals

At the request of the Foreign Economic Administration in assisting the Chinese Government in the development of coal resources of China, small-scale laboratory coking tests were made of two samples of washed coal from the Nantung mine, Tolientzu bed, Szechwan Province, and three samples of coal from the Tung Ling and Wei Yuan mines, Szechwan Province.

According to their fixed-carbon content, the samples from the Nantung mine are classified as near the border line between low-volatile and medium-volatile bituminous coals. Their agglutinating values at the 15:1 ratio were 7.9 and 8.5 kilograms, respectively. These high values, together with visual examination of the carbonized residues from the laboratory carbonization assay, showed that the coals were strongly coking. Yields of carbonization products by the United States Steel Corp. high-temperature carbonization assay were as follows:

	Dry-coal basis	
	Sample 1	Sample 2
Coke, percent	84.3	82.4
Tar, gallons per ton coal	4.2	5.1
Light oil, gallons per ton coal	1.88	2.37
Ammonium sulfate, pounds per ton coal	19.4	18.4
Gas, cubic feet per ton coal	9,960	9,980
Gas, B.t.u. per pound coal	2,580	2,660

The agglutinating values of the coals from the Tung Ling and Wei Yuan mines ranged from 3.5 to 7.0 kilograms, which shows that these coals are medium to strongly coking.

Sardinian Coals

As a part of an investigation of a commercial low-temperature carbonization plant at San Antioco, Sardinia, Fischer assays were made of samples of lump coal from three mines in Sardinia to determine the yields of low-temperature carbonization products of these coals. The coals are high-volatile and contain 8.4 to 9.2 percent sulfur on an as-received coal basis. The following summary shows the yields of carbonization products obtained:

	Tanas mine	Serbariu mine	Bacu Abis mine
Carbonized residue, percent	68.2	67.2	66.7
Tar, gallons per ton coal	42.9	32.1	33.6
Light oil, gallons per ton coal	3.82	3.41	3.98
Liquor, percent	4.8	9.2	9.1
Gas, cubic feet per ton coal	1,980	2,100	2,030
Gas, B.t.u. per pound coal	960	820	770
H_2S in gas, percent by volume	25.6	23.1	26.3

Because of their high content of sulfur, these coals yield a large amount of hydrogen sulfide on carbonization; the percent by volume of hydrogen sulfide in the gas ranged from 23.1 to 26.3 percent. The carbonized residue from the Tanas mine sample showed that this coal is quite strongly coking. The other two coals were noncoking, or nearly so.

The Free-Swelling Index of Coal

A report[58] was prepared in response to numerous requests for information concerning the A.S.T.M. Tentative Method for Free-Swelling Index of Coal, particularly as to interpretation of results and operating techniques. It includes a discussion of some of the results that have been obtained by the Bureau of Mines, following installation of the test in 1938 and procedures used to overcome difficulties with coals giving carbonized buttons whose shapes do not correspond with the standard profiles as given in the published method.

Briefly, this swelling test consists of heating one gram of pulverized coal in a silica crucible over a gas flame under prescribed conditions to form a coke button, which is compared in size and shape with a series of standard profiles numbered 1 to 9. These profiles are intended to cover the size and shape of buttons obtained from coals covering a wide range in plastic properties. The number of the standard profile with which the maximum cross-sectional area of the button most nearly corresponds is recorded as the swelling index.

The free-swelling test has proved to be useful for obtaining information regarding the coking properties of coal on fuel beds. Coals that swell excessively may cause trouble by clogging the grates and requiring a high forces draft to obtain the proper rate of combustion. The free-swelling index test gives better differentiation between coals in measuring this characteristic than can be obtained by examination of the coke buttons from the standard volatile-matter test or from agglutinating-value results.

58/ Selvig, W. A., and Ode, W. H., An Investigation of a Laboratory Test for Determination of the Free-Swelling Index of Coal: Bureau of Mines Rept. of Investigations 3989, 1946, 8 pp.

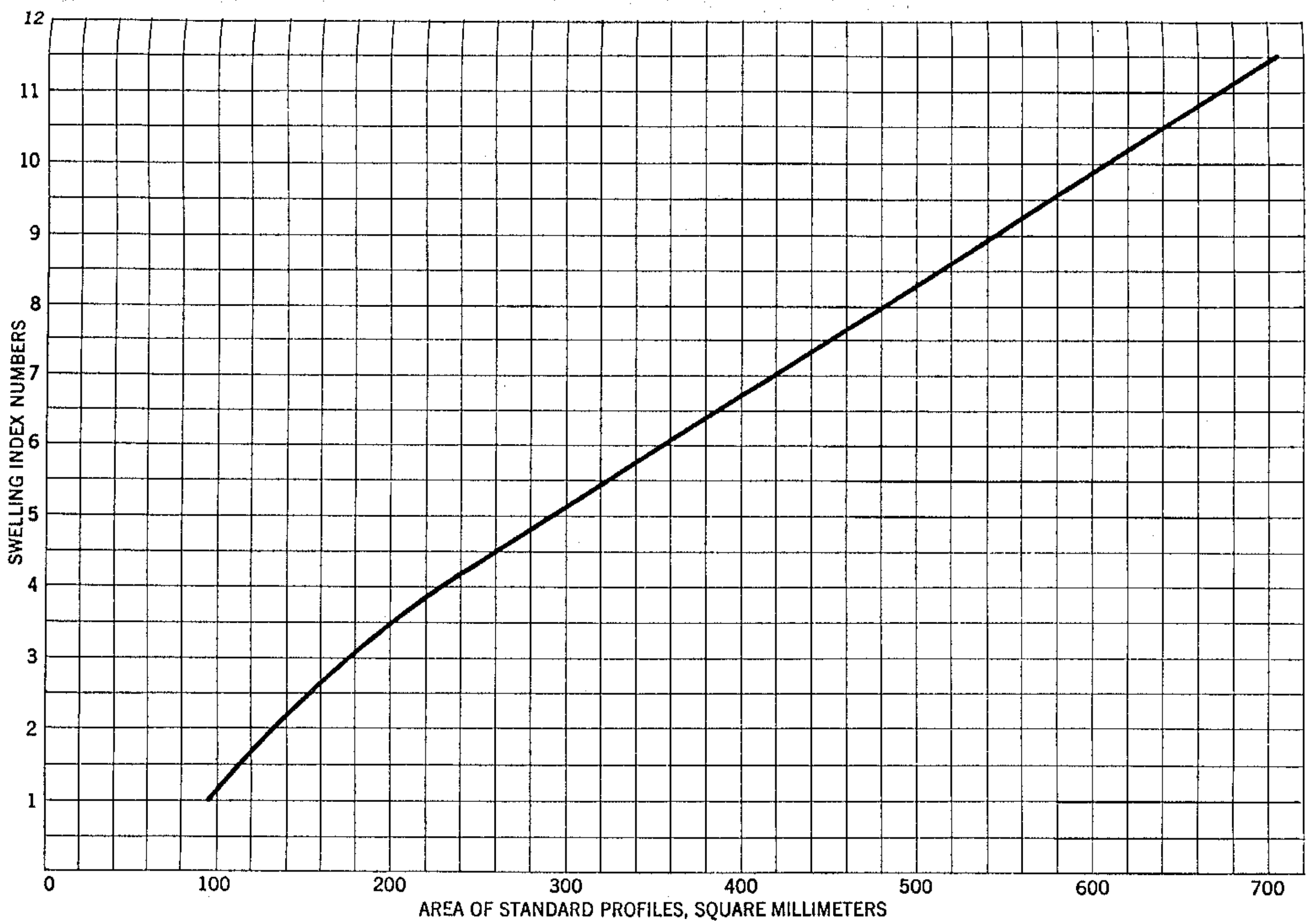

Figure 22. - Relationship of areas of standard profiles to swelling index number.

Experiments made to determine whether there was any correlation between the results of the free-swelling test and expansion or contraction that takes place during carbonization of coal in coke ovens showed that no relationship existed. The "free-swelling" property of coal heated under no restraining influence must not be confused with the "expansion" property of coal when carbonized in a confining space.

Difficulty has been experienced in assigning swelling numbers to coals that give buttons that show no relationship in shape to the standard profiles. In addition, some buttons are larger than that of standard profile 9, the largest profile in the series. The use of some other method of measurement of the coke buttons makes the test somewhat more laborious, but it appears to be necessary for troublesome coals. The modifications that have been tried for evaluating the coke buttons of nonstandard shape were volume and cross-sectional area measurements. The latter method has proved to be more satisfactory. The scheme adopted was to determine the relationship of the areas of the standard profiles to the swelling index numbers. A curve based upon these data is shown in figure 22. When a coke button of unusual shape is obtained, its outline is drawn on paper and the area is measured. The area obtained can then be referred to the curve for determination of the corresponding swelling number.

Wartime Progress in Coke Production

There was a marked advance in the preparation of by-product coal due to changes in mining practice and developments in mechanical cleaning.59/. However, the search for and development of new coals suitable for byproduct coking did not keep pace with preparation methods.

Competition in oven design has resulted in high efficiency in operation of the oven proper. The mechanical and electrical equipment used in the handling of coal and coke at the ovens has been improved considerably.

Few changes have been made in the basic design of the coke-handling plant, but there has been much progress in turning out a more uniform product through blending and control of the bulk density of the coal charge. Methods of testing coke are under investigation.

The financial returns from coke-oven byproducts may be increased by the recovery of new products such as pyridine and by efforts to produce more highly refined and pure aromatic hydrocarbons.

Survey of Carbonizing Properties of American Coals

Work on the Survey of Carbonizing Properties of American Coals was continued. This work included application of the test procedure developed by the Bureau of Mines in cooperation with the American Gas Association (known

59/ Seymour, William, Wartime Progress in Coke Production: Bureau of Mines Rept. of Investigations 3907, 1946, 13 pp.