INTRODUCTION

The past full year of war has increased greatly the demand for virtually all kinds of fuel, and the Bureau of Mines research and service facilities have been extended to meet these unprecedented requirements.5/ Liquid fuels, such as aviation and motor gasolines, are fundamental to modern warfare. Bituminous coal and anthracite are needed, not only to serve the expanded industrial program for which coal normally is used but also to replace natural gas, wherever possible, and fuel oil in the Eastern States, New England, and the Pacific Northwest. Railroad transportation with energy derived from coal is replacing much of the motor-vehicle transportation that has been stopped or curtailed to conserve rubber. Pulverized coal has been found to be a satisfactory and cheaper substitute for fuel oil in metallurgical heating furnaces. Colloidal fuel - a mixture of coal dust and oil - may offer a partial substitution for certain coal-burning equipment. Several industrial experiments have been made with this type of fuel. The expansion of the steel industry in connection with the war program has required a corresponding increase in the production of metallurgical coke and its associated byproducts - light oil, tar, ammonium sulfate, and surplus gas. If the war is of long duration and new reserves of petroleum are not discovered, wartime trends from fuel oil to coal probably will not be reversed.

Regular inspection service was maintained for Federal agencies, with a large increase in analytical and testing work on coal samples from many sections of the country. Consulting service was rendered the Government and industry on types and changes in equipment, developing substitute fuels to meet present shortages, and recommending methods for increasing the efficiency of power-plant operation. At the request of the War Department, the Bureau has conducted a program of coal sampling and training of Army personnel in sampling at Army posts. Work on boiler feedwater was tripled over 1943 to protect the vital boiler plants in the numerous camps established.

Coal areas were explored to determine minable deposits that could be developed as additional sources of coking coal, to relieve the present critical fuel situation, and to provide a continued supply of coal in the peace era to follow. Mining practices were improved in the interest of efficiency, conservation, and safety. The inflammability and explosibility of powdered metals, military pyrotechnics, and materials used in and produced by the plastics industry received concentrated attention. The possibilities of increasing the charges of permissible explosives in coal blasting were studied.

Improvements in methods of preparation and cleaning have yielded coals of higher quality and resulted in the conversion of coals, formerly rejected as waste, into usable fuel. Methods have been developed for safely storing coal at isolated Army posts and other places far removed from the source of supply. Combustion studies have been pointed toward preventing serious loss

5/ Fieldner, A. C., Recent Developments in Fuel Supply and Demand: Jour. West. Soc. Eng., vol. 48, part 1, February 1943, pp. 127-147; Bureau of Mines Inf. Circ. 7261, 1943, 27 pp; abs. Chem. and Eng. News, vol. 21, July, 1943, p. 1067.

of steaming capacity from the external corrosion of furnace-wall tubes. An investigation has been conducted on the satisfactory utilization of small sizes of anthracite for domestic fuel. To maintain supplies of suitable coking coals needed by industry, carbonization tests were completed on several additional coals of the United States. The Coke Production Survey has made contact with the entire coke industry, and technical assistance has been rendered operators in the production of better blast-furnace fuel.

A small pilot plant for gasifying subbituminous coal and lignite was successfully operated in 1944. It was found that this method can be effectively employed to produce gas for the reduction of iron ore and for the synthesis of oil or gasoline from coal. A larger pilot plant for the production of 500,000 cubic feet of gas per day is under construction at Grand Forks, N. D.

On April 5, 1944, the Congress passed an act (Public Law 290, 78th Congress) authorizing the Bureau of Mines to construct and operate demonstration plants to produce synthetic liquid fuels from coal, oil shales, agricultural and forestry products, and other substances, in order to aid the prosecution of the war, to conserve and increase the oil resources of the Nation, and for other purposes. Further development work was completed in the laboratory-size plant at Pittsburgh, Pa., in the production of fuel oil and gasoline from coal. In the synthesis of liquid fuels from hydrogen and carbon monoxide, methods for the preparation of active iron catalysts were investigated, and engineering tests were made on new procedures for rapidly removing the heat of the reaction.

The present report is the ninth in a series of annual reports of research and technologic work on coal and covers the period from July 1, 1943, to June 30, 1944. References are given to publications of the Bureau that cover these investigations more completely. Much of the Bureau's work remains confidential, and details cannot be disclosed during the national emergency; but they will be made available to both industry and consumers when war restrictions are removed.

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This report includes work done under the technical direction of the following members of the staff of the Bureau of Mines:

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ORIGIN, COMPOSITION, AND PROPERTIES OF COAL

Inspection, Sampling, and Analysis

At the request of the War Department, the Fuel Inspection Section instituted a sampling program for coals delivered at Army posts and instructed Army personnel in proper methods of sampling. In all, 2,154 visits were made to Army posts, and 1,544 samples were collected. To assist the Solid Fuels Administration for War in improving the quality of anthracitic coal as shipped, to save manpower and transportation facilities, and to improve burning efficiency, 252 visits were made to 125 breakers and 985 samples were collected. For the general use of the Government in making coal purchases and for public information, 668 samples of bituminous coal were collected in 9 States - 6 from California, 144 from Colorado, 20 from Kentucky, 3 from Maryland, 92 from New Mexico, 138 from Ohio, 4 from Oregon, 42 from Pennsylvania, and 219 from West Virginia. Coal purchases by Federal agencies during the fiscal year 1944 amounted to approximately 11,500,000 tons. In connection with contracts for furnishing this coal, 9,005 reports of coal analyses were issued to Federal agencies. To assist research sections of the Bureau in finding coals suitable for the use of war industries in certain localities, 68 samples were collected for carbonization tests, 16 for hydrogenation assays, and 5 for oxidation and spontaneous heating studies. The carbonization samples represented 3 from California, 49 from Colorado, and 16 from New Mexico. The coals for hydrogenation included 6 column samples for microscopic studies and 10 face samples from western Kentucky for analysis. For studies of oxidizing and spontaneous heating characteristics of coal 1 sample was collected in Colorado, 2 in western Kentucky, and 2 in New Mexico.

In connection with the inspection of coal purchased by Federal agencies, the Coal Analysis Section analyzed 6,532 samples, more than 80 percent for posts and stations of the War and Navy Departments and for the Solid Fuels Administration for War. In addition, 3,381 samples were analyzed for

correlation with researches by various sections of the Bureau of Mines and other Government agencies on the utilization of coal by carbonization, combustion, and liquefaction, and in studies of special properties, such as the explosibility of coal dust.

Federal coal-mine inspectors submitted 10,704 samples of dusts taken from the ribs, roofs, and floors in 1,304 of the larger commercial mines in 23 states. The analyses of these dusts gave data for determining the susceptibility of these mines to dust explosions and for formulating recommendations to appropriate mine operators concerning possible hazards.

Fundamentals of Coal Sampling

A recent investigation6/ on the principles governing the establishment of rigorous specifications for the sampling of coal showed that mathematical probability could be applied and that the fundamental variables of ash distribution in coal could be studied by similar methods. Knowing the variability in ash content of increments of a specified weight of coal, it was found that their number can be computed to yield a sample of preassigned accuracy. Mathematical developments were made to cover both random sampling and increments taken in an orderly way over the entire lot of coal sampled.

Analyses of Kentucky Coals

A compilation7/ of analyses of Kentucky coals made by the Bureau of Mines was published as the second paper on Kentucky coal and is another in the series of papers describing coals of individual producing States. The geology of the western and eastern coal fields, methods of mining and preparation, economics of production, distribution, uses, and the relationship of mine samples to commercial shipments are discussed. Descriptions of mine, tipple, and delivered samples include chemical analyses, calorific values, classification by rank, agglomerating index, fusibility of ash, true specific gravity, sulfur forms, thickness of beds, nature of floor and roof, and partings in the bed. Kentucky ranked fourth in coal production in the United States for 1922 to 1941, except for the 2 years 1927 and 1932, when it was in third place.

6/ Landry, B. A., Fundamentals of Coal Sampling: Bureau of Mines Bull. 454, 1944, 127 pp.

7/ Fieldner, A. C., McFarlan, A. C., Toenges, A. L., Maize, E. R., Fraser, T., Crentz, W. L., Anderson, R. L., Bell, C. H., Snyder, N. H. Cooper, H. M., Abernethy, R. F., Tarpley, E. C., Swingle, R. J., and Hartner, F. E., Analyses of Kentucky Coals: Bureau of Mines Tech. Paper 652, 1944, 323 pp.

A paper[8] giving analyses and similar descriptions of Virginia coals as indicated in the preceeding paragraph for Kentucky coals was published. Original reserves of anthracitic (semianthracite) coal in Virginia have been estimated as 500 billion net tons and those of bituminous coal as 21,149 billion net tons. Production of semianthracite and bituminous coal in 1941 amounted to 18,441,000 tons from 155 mines of commercial size.

Analyses of Pennsylvania Anthracitic Coals

A publication[9] describing mine, breaker, and delivered samples and showing their analyses, with brief descriptions of the anthracite fields of Pennsylvania, methods of mining and preparation, and important economic data on the industry was issued. At the close of 1942 the estimated reserve was 14,431,250,000 long tons in the four main Pennsylvania anthracite districts. Production in 1942 for the entire State totaled 69,327,729 net tons.

Constitution, Analytical Methods, and Standardization

The Coal Constitution Laboratory has investigated the constitution of a number of coals whose mining, carbonization, and liquefaction properties are being studied by other sections of the Bureau of Mines. Core-drill samples from exploration projects in Wyoming, Colorado, Nevada, Oregon, and Alabama were examined, and measurements and locations of different kinds of material in the drill column were recorded. After separation of the coal cores and associated rock, samples of the cores were prepared for proximate and ultimate analyses, agglutinating-value tests, and microscopic examination. The procedures of petrographic analysis were studied with particular reference to coordination of megascopic and microscopic methods of petrologic integration. A number of coals were investigated to determine the relation of their petrographic composition to special chemical and physical characteristics.

An electron microscope was installed late in the fiscal year at the Central Experiment Station, Pittsburgh, Pa. It is hoped that with this new tool of research many of the baffling problems encountered in coal research may be explained, particularly from observations of the detailed structure of material made at high magnification.

Miscellaneous analytical work for various sections of the Bureau of Mines included analyses of 486 samples of coal and miscellaneous materials.

8/ Fieldner, A. C., Eby, J. B., Campbell, M. R., Toenges, A. L., Fraser, T., Crentz, W. L., Anderson, R. L., Bell, C. H., Snyder, N. H., Cooper, H. M., Abernethy, R. F., Tarpley, E. C., and Swingle, R. J., Analyses of Virginia Coals: Bureau of Mines Tech. Paper 656, 1944, 159 pp.

9/ Fieldner, A. C., Ashley, G. H., Toenges, A. L., McElroy, G. E., van Siclen, M., Buch, J. W., Snyder, N. H., Cooper, H. M., Abernethy, R. F., Tarpley, E. C., and Swingle, R. J., Analyses of Pennsylvania Anthracitic Coals: Bureau of Mines Tech. Paper 659, 1944, 271 pp.

These analyses included determinations of the agglutinating value and gas- and coke-making properties of coals; the composition of boiler-water compounds, boiler scales, sludges, deposits, and rock dusts; the percentages of phosphine in acetylene generated from calcium carbide; and chemical analyses of coal-ash slags and slag deposits, clays, coal savers, shales, and other miscellaneous materials.

In connection with the survey of the coking properties of American coals, small-scale laboratory carbonization tests were made of coals of the United States and Alaska to determine their suitability for the production of coke or char. These tests included the Fischer low-temperature carbonization assay, the U. S. Steel Corporation high-temperature distillation test, and the Bureau of Mines agglutinating-value test. Results of these tests on several coals were incorporated in publications cited later. (See Carbonization and Gasification, p. 41.)

The agglutinating-value test has proved valuable for measuring the extent of oxidation of stored coal compared with fresh coal, in studies of the storing qualities of coals now in use, and of coals from new sources now being explored.

Construction of new blast furnaces in the West for the production of steel has created a demand for western coals of satisfactory coking quality. Small-scale coking and agglutinating-value tests have been useful to coke-oven operators and other users of western coals.

Rare and Uncommon Chemical Elements in Coal

A review summarizing available published information concerning the occurrence of rare and uncommon chemical elements in coals of the United States and other countries was prepared.[10/] Although more than half of the known elements have been reported as occurring in coal, the percentages are apparently too low to warrant their industrial recovery. Flue dusts from certain gas works in England are potential sources of germanium and gallium.

Yields of Primary Tar and Light Oil from Coals of Various Ranks and Types

A method was developed for predicting low-temperature yields of primary tar and light oil from chemical analyses of coals of various ranks and types.[11/] The combined percentage of tar and light oil was found to equal $0.697X + 0.0031X^2 - 6.4$, where X equals the volatile matter minus 1.3 times the oxygen. Equations relating tar and light-oil yields with the hydrogen contents of common banded (bright), splint, and cannel coals were derived. These linear equations have two constants whose values differ slightly for coals of different types.

10/ Gibson, F. H., and Selvig, W. A., Rare and Uncommon Chemical Elements in Coal: Bureau of Mines Tech. Paper 669, 1944, 23 pp.

11/ Ode, W. H., and Selvig, W. A., Low-Temperature Distillation Yields of Primary Tar and Light Oil from Coals of Various Ranks and Types: Bureau of Mines Rept. of Investigations 3748, 1944, 10 pp.

Comparison of Standard Test Sieves

In analyzing and testing powdered materials there is frequent need of a ready means of comparing the data of sieve analyses as determined by one series of test sieves with those of a series more familiar to the user. To meet this need a tabular comparison and discussion of its significance were made of the fine-series, square-mesh-wire test sieves currently used in four different countries.12/ The sizes of openings, in millimeters, for the standard series of sieves used in Great Britain, the United States, Germany, and France were compared. The openings for all sieves, expressed on the same horizontal line of the table, are within the permissible variations of the average opening of the corresponding U. S. Standard sieve. The "mesh-number" designations commonly used are included in parentheses in the table. In a technical sense the work "mesh" is meaningless, unless the diameter of the wire size used in the sieve is also specified, so that the size of the opening can be determined. The use of the term "mesh" should be discouraged, unless the particular corresponding name of the sieve is stated; thus, U. S. Standard No. 35, or 500-micron, sieve.

Application of the Rosin-Rammler Law for Screening Coal

It is sometimes desirable to know what changes in sizing characteristics would appear in screened coals if screens of different-size openings than those employed had been used. A study was made of the application of the Rosin-Rammler law as a solution to this problem.13/

The equation for the Rosin-Rammler law is

$$R = 100e^{-\left(\frac{X}{\bar{X}}\right)^{n}},$$

where R is the "residue", or percentage of oversize after particles of diameter X and smaller are screened out. $\bar{X}$ and n are constants (for a given coal), and e is the base of the Napierian logarithms. The law appears to describe satisfactorily the size distribution in coals. The validity of the law is discussed and calculations to compute the "missing sizes" in coal are shown. This general subject is also discussed by Bertrand A. Landry.14/

12/ Brower, R. E., Comparison of Fine-Series, Square-Mesh-Wire Test Sieves of Different Countries: Bureau of Mines Rept. of Investigations 3766, 1944, 5 pp.

13/ Scott, G. S., Application of the Rosin-Rammler Law to the "Missing Sizes" in Screened Coal: Bureau of Mines Rept. of Investigations 3732, 1943, 9 pp.

14/ Landry, B. A., See footnote 6, p. 5.

Precision of the Volatile Matter Determination

A statistical study[15] dealing with errors of analysis in the volatile-matter determination for anthracite, low-temperature coke, and subbituminous coal was made at the request of Committee D-5 on Coal and Coke of the American Society for Testing Materials. The investigation was based on duplicate determinations of 100 samples of each of these three materials and showed that the present A.S.T.M. permissible differences of 0.2, 0.2, and 0.5 percent, respectively, were too stringent. It was recommended that the A.S.T.M. permissible differences between duplicate determinations of volatile matter by the same laboratory be revised to permit 0.3 percent for anthracite, 0.5 percent for low-temperature coke, and 0.7 percent for subbituminous coal.

Standardization of Proximate Analysis

Points of difference in the standard procedures of the British Standards Institution and of the American Society for Testing Materials for determining volatile matter in coal were discussed.[16] The latter method, which is used by the Bureau of Mines, specifies a temperature of 950° C., compared with 925° C., as specified by the British standard. In the United States little use is made of the "air-dried" analysis in comparing coals, because the lower-rank coals, which contain relatively large quantities of bed moisture, would be unduly favored.

Cooperative Investigation on Fusibility of Coal Ash

A cooperative investigation by 16 participating laboratories in the United States and Canada showed that furnace atmosphere is the most important factor in the ash fusion determination.[17] These laboratories, using 5 types of gas- and 2 types of electric-furnaces with 5 kinds of atmospheres, provided 23 furnace-type and furnace-atmosphere combinations. Results obtained were within the permissible tolerances of A.S.T.M. method D271-40 for the coal-ash samples tested. In general, softening temperatures observed with natural gas were higher than those with the manufactured gas or the gas of constant composition which was used in the electric furnace.

COAL MINING

Experimental Mine and Dust Explosions

Studies of Coal-Mine Roof

The mechanical properties and behavior of roof rocks in the Midland mine of the Pittsburgh Coal Co. were studied to determine the causes of the partial

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15/ Selvig, W. A., Precision of the Volatile-Matter Determination for Anthracite, Low-Temperature Coke, and Subbituminous Coal: Bureau of Mines Rept. of Investigations 3739, 1943, 6 pp.

16/ Fieldner, A. C., and Selvig, W. A., Discussion of "The Proximate Analysis of Coal" by Joseph Brown and Alan S. Bean: Jour. Inst. Fuel, vol. 16, August 1943, p. 182.

17/ Cooper, H. M., and Abernethy, R. F., Cooperative Investigation of the Effect of Furnace Type and Atmosphere on Fusibility of Coal Ash: Bureau of Mines Rept. of Investigations 3724, 1943, 43 pp.