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INTRODUCTION

This is the tenth annual report of research and technologic work conducted by the Bureau of Mines on the occurrence, properties, mining, preparation, and uses of coal and coal products. These annual reviews are guides to the current work and publications of the Bureau but do not replace the more complete reports published under the authorship of the individual investigators on specific problems in Bureau of Mines bulletins, technical papers, reports of investigations, and information circulars and in the technical press. The Annual Report of the Director of the Bureau of Mines to the Secretary of the Interior for the Fiscal Year ended June 30, 1945, summarizes the year's work on coal as follows:

Coal and Coal Products

The United States maintained its No. 1 industrial position in supplying fuel for war and in preparing for peace through more complete mining, improved preparation and up-grading of coal for special uses, and better utilization of coal in industrial establishments and homes.

Fuel Services. - To maintain fuel efficiency at military plants, to keep war industries operating at full capacity, to permit proper Government fuels purchases, to aid Federal coal-mine inspectors in preventing coal-dust explosions, and to assist the Bureau in coal explorations and research, 20,623 samples of various fuels were analyzed. Bureau engineers advised many Government agencies in the purchase and utilization of fuels and fuel-burning equipment; fuel efficiency and equipment acceptance tests were made. At many Army camps recommended changes in operation of equipment saved thousands of tons of coal. Choice of fuel was made for new Veterans Administration projects. Difficulties that prevented continuous boiler operation were eliminated at two naval land stations. Federal boiler plants, including all Army posts, were safeguarded from boiler-scale corrosion and caustic embrittlement through proper feed-water conditioning service. Serious corrosion in condensate return lines was studied, resulting in better protection of $300,000,000 worth of steel equipment.

National Fuel Efficiency. - A Nation-wide fuel-conservation program enlisting thousands of volunteer engineers and fuel users was conducted. A network of some 20,000 volunteers was established, and more than 13,000 industrial plants and organizations pledged cooperation aimed at saving 29 million tons of coal per year. Information on proper storing of coal was made available to industry by thousands of copies of publications. As a result of

Bureau studies, a packaged-fuel plant was established in Philadelphia for converting 150,000 tons of surplus anthracite fines into a convenient fuel, and a large percentage of total fines was blended with bituminous coal for stoker use.

Coal Mining and Exploration. - The Bureau cooperated with anthracite producers in studying the prevention of flooding of operating mines and outlined new methods of better mining of thin, steeply pitching beds which constitute a large part of the anthracite yet unmined. Economic limitations of light equipment for stripping coal from outcrops in mountainous areas were determined. Western, southern, and eastern coal areas were explored for minable reserves of coking coals; the Pacific Northwest for near-by fuel supplies. Laboratory coking tests and petrographic examinations of more than 150 coals from the United States, Chile, and China were made. Methods of increasing efficiency and production of Chilean coals were investigated and reported.

Gas-, Dust-, and Vapor-Explosion Research. - To reduce explosion hazards in coal mines and in many types of plants, tests were made on industrial powders, dusts, and vapor-air mixtures; recommendations and safety codes were furmulated for minimizing the destructive effects or preventing explosions in plants producing explosive materials and dusts; and specifications for conductive footwear and flooring materials were developed to lessen explosion hazards from static electricity. Conditions permitting safe use in coal mines of larger charges of explosives were determined by tests.

Coal Preparation and Storage. - To augment depleted supplies of high-grade coking coals and to up-grade marginal and lower-rank coals for more efficient utilization, preparatory treatments of coking coals to reduce sulfur and ash and the salvaging of refuse coal at points of mining were studied. The distribution of sulfur in coking coals of Greene County, Pa., was determined. Two Alabama companies based designs of coal-preparation plants on Bureau washability data; and studies by Bureau engineers showed that concentrating tables were effective for recovering coke breeze from dumps. Laboratory studies on the storage properties of about 35 coals were made; thousands of publications on methods of storing coal were distributed to industry by request.

Coal Combustion. - To study slag deposits on boiler tubes from melted coal ash, to provide information for improving the design of boiler furnace, and to improve their operating efficiency, the Bureau developed apparatus to measure the thermal conductivity of coal-ash slags. Fundamental data were accumulated by a study of over 200 ash analyses; and studies of slagging and atmospheric conditions around furnace walls demonstrated one cause of tube failure and lessened boiler outage. Burning characteristics of emergency fuels and of fuels produced by new processes were determined. For the first time in the United States, the electron microscope was used to determine surface area and size distribution of powdered coal.

Coking and Gasification. - The Bureau's tests for the complete evaluation of the gas- and coke-making properties of coals were applied to coals from

newly developed fields. This work has greatly benefited the gas and coke industries and will continue to do so after the war. Greater production and improved quality of uniform coke without increased cost of capital or labor were reported at several coke plants by use of Bureau data on coal bulk-density control. Technical assistance given to beehive-oven and beehive-coke recovery operations enabled operators to produce more coke and maintain higher operating efficiencies. A method was developed for producing carbon monoxide of relatively high purity by burning pitch coke or petroleum coke with oxygen. The Nation's immense reserves of lignite were brought closer to industrial use through successful testing of a large retort for producing carbon monoxide and hydrogen from lignite by gasification. These two processes offer promise of a cheap source of materials for a multitude of purposes.

Synthetic Liquid Fuels. - The program authorized by the Congress in the Synthetic Liquid Fuels Act (Public Law 290) is underway, with construction started on the necessary buildings and equipment at three locations. Research and development work is going on meanwhile in temporary laboratories.

At Bruceton, near Pittsburgh, Pa., a plant is being built that will provide adequate facilities for research and development work on the hydrogenation and gas-synthesis processes for making gasoline and oil from coal. A staff of over 100, that will operate the Bruceton plant when ready, is now at work with facilities available at Pittsburgh. They are engaged in fundamental research, process development work, and engineering design. The work includes correlation of the activity of catalysts with physical properties as revealed by X-ray spectra and measurements of specific magnetization and surface area. Progress has been made in developing an internally cooled converter designed to reduce the steel requirements per unit of production to one-fifth or one-tenth of that required in present European equipment. The effects of variables, such as catalyst, temperature, and contact time, on primary liquefaction of coal by hydrogenation have been studied, and the experimental hydrogenation unit has been operated on a Bureau-developed process for the production of fuel oil from coal.

The demonstration plants using coal, which will produce 200 barrels of oil a day as compared to 1 to 2 barrels per day from the pilot plants, will be designed to incorporate the new developments and the best ideas obtained from a recent study of European synthetic oil plants. Detailed information on 206 proposed sites in 21 States for the hydrogenation and gas-synthesis demonstration plant has been obtained and the data tabulated and analyzed. War plants suitable for conversion to synthesis plants have been included in this study.

A laboratory for research and development work on oil shale is under construction at Laramie, Wyo. The program to obtain fundamental data on oil shale needed for the design of experimental and demonstration plants for producing marketable products from oil shale is going forward in temporary quarters. Among the processes being investigated is the so-called thermal solution process in which the oil shale is heated to moderate temperatures (400° C.) in the presence of a solvent, such as shale oil, and then extracted with a more volatile solvent.

Construction of the oil-shale demonstration plant on the Naval oil-shale reserve near Rifle, Colo., is progressing. The mine, which will provide 100 to 150 tons of shale per day for the retorts, has been opened. An important part of the mining operation will be to develop low-cost methods of mining oil shale and to demonstrate the costs of mining on a large scale. The processing section of the demonstration plant will have retorts of several types operating on a scale of 25 to 100 tons of shale per day each and equipment for refining the shale oil to produce salable products. Considerable equipment has been ordered and work on necessary roads, utilities, and housing is in progress.

Explosives and Explosions

To avoid fires and explosions caused by exposure of bare electric trolley wire in mines, the Bureau of Mines has encouraged development of Diesel mine locomotives. A schedule of permissible requirements for such locomotives was published; if followed, the locomotive will be approved for use in gassy and dusty coal mines.

To permit heavier charges of explosives in coal mining and thus assist in meeting increased demands for coal, an extensive experimental study has developed conditions under which the permissible charge may be increased 1.5 to 3 pounds. A new schedule was published detailing the necessary conditions under which permissible blasting devices can be fired without stemming.

Fires and explosions in coal mines caused by explosives are reduced or prevented by the use of sheathed explosives, but under some conditions sheaths may cause toxic gas hazards to increase. Studies of such toxic gas emissions were maintained. Hazards associated with the use of liquid-oxygen explosives are being evaluated. New tests useful in this and studies of other explosives were developed.

A new test for detonators gave results more indicative of practice. An electronic chronoscope that will measure time intervals of a millionth of a second was invented.

Five explosives were added to the active list of permissible explosives, which now contains 178 names; 419 chemical analyses, 2,717 gallery tests, and 2,029 other control tests were made in connection with studies for the armed forces and in the maintenance of safe standards for mining.

ACKNOWLEDGMENTS

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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University of Alabama.
University of North Dakota.
University of Washington.

ORIGIN, COMPOSITION, AND PROPERTIES OF COALS

Inspection, Sampling, and Analysis

Owing to the coal shortage during the year, it was generally impossible to obtain bids on a guaranteed analysis basis, and in most instances Government agencies had to accept such coals as were offered or obtain coal through directives by the Solid Fuels Administration for War on a flat price basis. Consulting service, including the analyses of bids and recommendations of awards, was given on the purchase of fuel for the Department of Justice, the Office of Indian Affairs, the Federal Public Housing Authority, the Government Fuel Yards, the Veterans Administration, the Department of Agriculture, the War Department, and the Navy Department. Coal purchases by Federal agencies during the fiscal year were estimated at 11,000,000 tons; the War Department was the largest purchaser and the Navy Department the second largest. Analyses were furnished all purchasing agencies for use in evaluating coal

bids and for use when substitute coals were offered. In connection with contracts for furnishing this coal, 6,516 reports on proximate or ultimate analyses and heating value of coal and 2,366 reports on fusing temperatures of ash were issued to Federal agencies. Although no price adjustments were provided in the contracts, the War Department was supplied with analyses of reliable samples on which other action, such as cancellation of contracts, refusal of further shipments, and rejections of coal, could be taken. Coal sampling at Army posts, renewed in September 1943 upon request of the War Department, was continued, and Army personnel were instructed in proper methods of sampling. In all, 1,701 visits to Army posts were made, and 2,064 samples were collected. At the request of the War Department, a new program of collecting coals for spontaneous heating tests was started, and samples were collected at 27 mines in 11 States. Sampling at Pennsylvania anthracite breakers, initiated in November 1943 upon request of the Solid Fuels Administration for War, was continued, and 484 samples at 125 breakers were collected during the year. As a result of this work, a number of breakers were shut down, others installed new cleaning equipment, and the quality of anthracite shipped was improved generally. Coals were collected for special purposes from deposits in several States. The coals included 22 face samples at 13 mines and 10 samples at 9 mines for preliminary washing tests, with the object of increasing production in Maryland by utilizing lower-grade coals; 5 face and 5 column samples from 5 beds, and 50 special petrologic samples for the purpose of correlating coal beds and of determining carbonizing properties of coals in the vicinity of Ansted, Fayette County, W. Va.; 2 Pennsylvania anthracites to determine the effect of anthracite when blended with bituminous coal in coke making, and 77 samples at 74 mines in Colorado, 6 samples at 4 mines in New Mexico, 2 samples at 2 mines in Utah, and 2 samples in 2 mines in Wyoming for preliminary carbonization tests by a new process for carbonizing coal developed by the Bureau of Mines at Golden, Colo.

In connection with the inspection of coal purchased on specifications by Federal agencies, 6,491 samples from purchases, tipple, and breaker inspections were analyzed. More than 87 percent of these samples were for the War and Navy Departments and for the Solid Fuels Administration for War; the remaining 13 percent were for civilian agencies of the Government. In addition, 6,574 samples were analyzed for correlation with researches by various sections of the Bureau of Mines on the preparation and utilization of coal and coal products, by the Florida Geological Survey in its studies of peat, and by the Foreign Economic Administration in its investigations of Italian lignite and of Chinese coals. These 6,574 samples came from 22 States in this country; from Australia, China, and Italy; and from Brazil, Chile, and Columbia in South America.

Federal coal-mine inspectors submitted 7,558 samples of dust taken from the ribs, roofs, and floors in 956 commercial mines in 20 States. Analyses of these dusts gave data that were used in formulating corrective recommendations to mine operators.

In addition to services given to the several sections of the Bureau of Mines and to other Federal agencies in analyzing a total of 20,623 samples of coke, char, briquets, tar, pitch, centrifuge residues, gasoline fractions,

and coal-mine dusts, the Central Laboratory in Pittsburgh assisted other co... laboratories by sending them portions of recently analyzed samples to permit... checking laboratory procedures and equipment. Samples were furnished to 19... American laboratories during the fiscal year.

Analyses of Tennessee and Georgia Coals

A compiliation[4/] of analyses of Tennessee and Georgia coals made by the Bureau of Mines was published and is another in the series of papers describing coals of individual producing States. The topography and geology of the coal fields, methods of mining, production, preparation, distribution, uses, and the relationship of mine samples to commercial shipments were discussed. Descriptions of mine, tipple, and delivered samples included chemical analyses, calorific values, classifications by rank, agglomerating indexes, fusibility of ash temperatures, true specific gravities, and sulfur forms. Detailed descriptions were given of the location, thickness of bed, nature of floor and roof, and partings of a number of typical mines in Tennessee and Georgia. Tennessee ranked ninth in production of bituminous coal in 1942, the output being 7,425,000 tons.

Constitution, Properties and Analytical Methods

Petrologic Studies of Coal and Rock Cores from Exploration Projects

Petrologic studies were made of all coal cores and associated rock obtained from exploration projects by diamond drilling. The projects included explorations for coking coal and fuel reserves in the Paonia-Somerset region in west central Colorado and in the Deep River coal field in central North Carolina; for coking-coal reserves in the Lookout Mountain coal field in northeastern Georgia and northwestern Alabama; and for fuel reserves in the Coaldale coal district, Esmeralda County, Nev., the Coos Bay coal field in southwestern Oregon, the Narraganset coal basin in Rhode Island, the Georges Creek coal field in western Maryland, and the Toledo lignite deposit in Lewis County, Wash. Detailed descriptions of the coal cores and associated rock were recorded to coordinate with other data obtained on these exploration samples. Studies of the plant microfossils from the coal were made of the Paonia-Somerset and Coos Bay coals to correlate individual coal beds. Results obtained by microscopic and megasopic methods characterizing the Coaldale and Paonia-Somerset coals have been compiled.

The occurrence and petrologic characteristics of the Willow Creek coal bed in southwestern Wyoming and of a coal deposit near Coaldale, Nev., were studied in connection with exploration projects (see Exploration of Coal Deposits, pp. 25 and 29). The Main Middle Willow Creek bed contained about 30 area percent of anthraxylon, 50 of translucent attritus, 18 of opaque attritus, and 2 of fusain. Microscopic studies indicated that the relatively

4/ Fieldner, A. C., Nelson, W. A., Toenges, A. L., Fraser, T., Crentz, W. L., Anderson, R. L., Bell, C. H., Snyder, N. H., Cooper, H. M., Abernathy, R. F., Tarpley, E. C., and Swingle, R. J., Analyses of Tennessee Coals (Including Georgia): Bureau of Mines Tech. Paper 671, 1945, 243 pp.

inert behavior of opaque attritus gave rise to pebbly structure in the coke. Compositional deficiencies of this coal for metallurgical coke production might be improved by blending with a coking coal containing a high percentage of anthraxylon. Studies of the Coaldale deposit showed that the coal was exceptionally high in detrital minerals, particularly in feldspar, and would have little practicability for important production.

Methods of Petrologic Study

A review was made of petrologic concepts and the methodology of quantitative petrology. A new method was devised with the objective of resolving coal into six primary components, without regard to lithology. The method should better characterize coals already prepared for market; its application will be tested further, using prepared fractions of commercial coal.

Definition of "Typical" Coal

To determine how typical an individual coal may be from evaluation of its petrographic analyses, the average petrographic compositions of American coals of different age groups were calculated from data obtained in Bureau of Mines studies of the past 15 years. Table 1 summarizes these data, which tend to show a systematic variation in average composition. Since the data are based on micro preparations, which necessarily involve some loss of most friable materials, it is probable that the average values for fusain, in particular, may be somewhat lower than the true value for the coal beds. However, since all the coals were analyzed under the same conditions, the data should indicate rather accurately the relative amounts of components. The fact that Carboniferous coals have about twice as much opaque attritus and fusain as the generally lower-rank coals of Tertiery age may be of general significance in their utilization. For example, these two constituents are notably less amenable to liquefaction by pressure hydrogenation than is the remainder of the coal; furthermore, fusain may not be forming in present day peats in the same way as it did in the past.

TABLE 1. - Average petrographic composition of coals of different geological age

Component	Geological age, area percent		
	Carboniferous	Cretaceous	Tertiary
Anthraxylon.....	53.0	46.8	51.7
Translucent attritus.	31.3	40.4	40.2
Opaque attritus.....	12.2	10.9	6.6
Fusain.....	3.5	1.9	1.5

Petrology of Coal-Column Samples from Operating Mines

Studies of column samples from various coal beds have been evaluated with reference to the average data for coals of different age groups as given in Table 2. Because of the great differences in type and rank, which probably indirectly account for additional differences in the petrologic entities reported, comparison of the lignite with the Carboniferous age bituminous coals must be made with reservation. Petrologic analyses of nine other column samples were completed, but reports have not yet been issued.

TABLE 2. - Summary of petrologic values from coal-column studies

Component area, percent 1/	Noonan lignite, Divide County, N. Dak.	Pocahontas No. 6 (?) coal, Fayette County, W. Va.	No. 5 Block coal, Raleigh County, W. Va.	Coal at Nebo Hopkins County, Ky.	Western Kentucky coals				Mannington (No. 6) coal, Hopkins County, Ky.
					No. 14 coal, Hopkins County	No. 12 coal, Hopkins County	No. 11 coal, Hopkins County	No. 9 coal, Muhlenberg County	
Anthraxylon..	56.2	58.4	36.5	47.8	63.6	64.1	64.1	64.8	51.1
Translucent attritus....	33.4	31.4	45.8	40.2	28.6	31.2	29.3	26.7	34.7
Opaque attritus....	3.8	5.1	15.6	7.3	5.0	2.4	3.3	5.4	4.7
Fusain.....	6.6	5.1	2.1	4.7	2.8	2.3	3.3	3.1	9.5
Ash, percent, as-received basis.....	7.8	14.0	10.1	7.9	9.6	18.4	6.9	9.3	3.2

1/ Petrologic values reported on visible-mineral free basis; that is, coal omitting visible impurities.

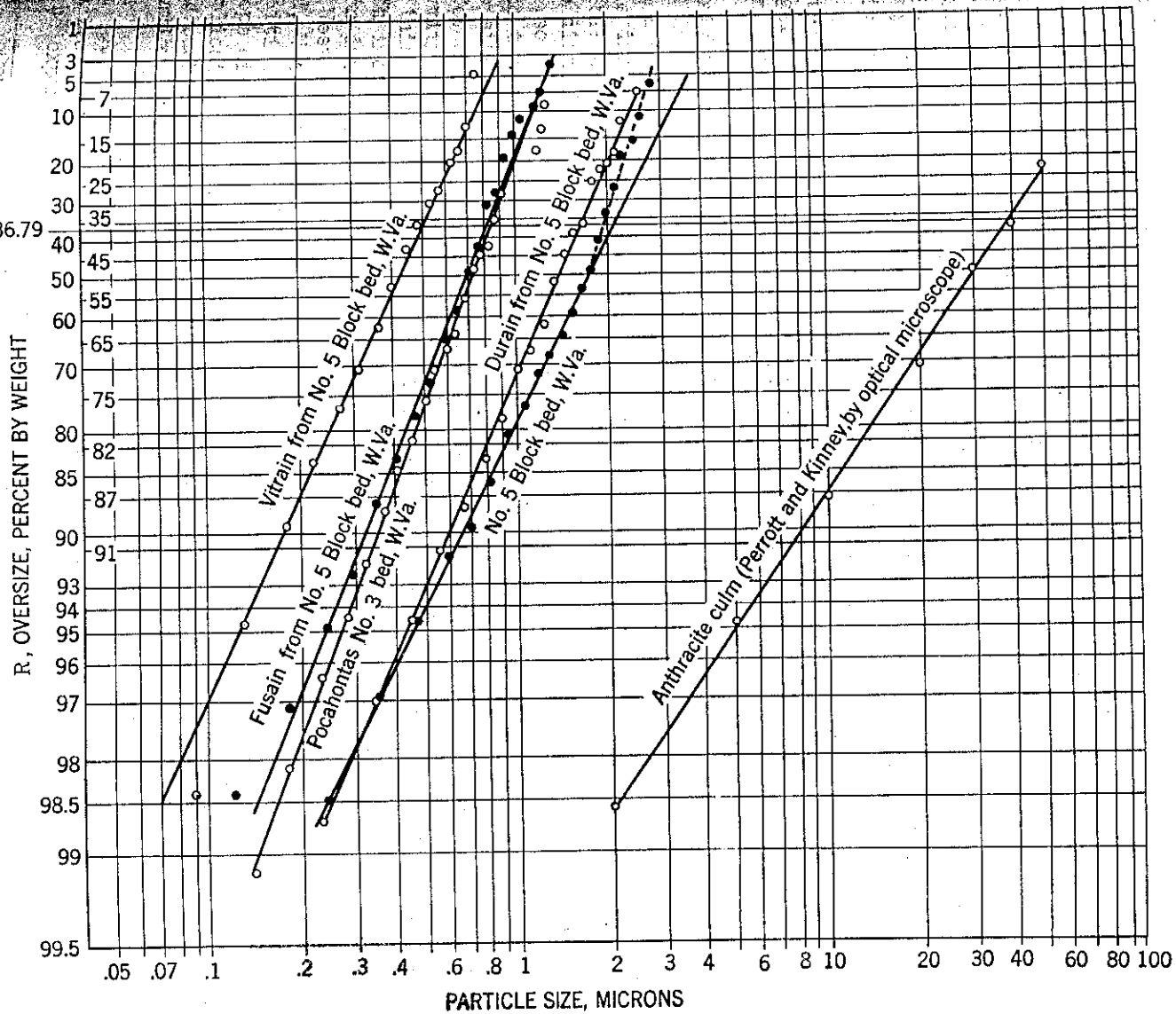

Figure 1. - Size distribution of subsieve coal particles.