## INTRODUCTION

The research and technologic work of the Bureau of Mines on coal and coal products in the period July 1, 1948, to July 1, 1949, is summarized in this report. Based largely upon publications issued during the fiscal year, it constitutes the fourteenth in a series of such resumes. Further details of the research conducted may be found in the publications given in the footnote references, though in some cases research data not published elsewhere are presented herein.

For the first time, results of research in the experimental coal mine and on explosives and gas and dust explosions are omitted from this report. These data will be included in Bureau of Mines Report of Investigations 4667, entitled, "Annual Report of Research and Technologic Work on Explosives, Explosions, and Flames, Fiscal Year 1949."

As petroleum consumption continued to trend upward, strong interest in the synthetic liquid fuels program of the Bureau of Mines continued to be manifested. This program and the salient features of a projected synthetic liquid fuels industry, based principally upon coals as a raw material, were discussed on several occasions.3/, 4/, 5/ A complete report on Bureau of Mines research in the calendar year 1948 on developing processes for production of synthetic oil from coal was rendered to the 81st Congress.6/ A discussion7/ of our reserves of solid fuels covered our present reserve position and the potentialities of those reserves.

Construction of the Anthracite Research Laboratory,8/ authorized by the 80th Congress, was well under way by the end of the fiscal year at Schuylkill Haven, Pa., on a site of approximately 16 acres donated by the Philadelphia & Reading Coal & Iron Co. and Schuylkill County. Occupancy was expected in January 1950. Designs for a laboratory building for lignite research, to be erected on a site donated by the University of North Dakota on its campus at Grand Forks, were completed (see fig. 1).

### Summary

With coal supplies exceeding demands, the value of Bureau of Mines research on the mining, preparation, and utilization of coal became increasingly apparent. Increased efficiency and improved quality became the keynotes of the research program, along with conservation and safety.

The Bureau continued to provide service to other Federal agencies on fuels-utilization problems in its role of consultant on the purchase of fuel and fuel-burning equipment, tests of fuels and boiler-room equipment, and boiler-water chemical treatment. In providing these services, 264 boiler-water test kits, 12,005

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3/ Doherty, J. D., Coal for Synthetic Liquid Fuels: Min. Eng., vol. 1, No. 4, 1949, pp. 116-124.
4/ Cattell, R. A., and Doherty, J. D., Synthetic Liquid Fuels: (in part) Producers Monthly, vol. 12, 1948, pp. 21-29.
5/ Fieldner, A. C., Frontiers of Fuel Technology: Fuel, vol. 28, 1949, pp. 19-21; Chem. and Eng. News, vol. 26, 1948, pp. 1700-1701.
6/ Synthetic Liquid Fuels 1948 Annual Report of the Secretary of the Interior, Part I. - Oil from Coal: Bureau of Mines Rept. of Investigation 4456, 1949, 62 pp.
7/ Fieldner, A. C., Solid Fuels.....and Their Suitability for Production of Liquid and Gaseous Fuels: Oil and Gas Jour., vol. 47, 1949, pp. 138-140, 142, and 145.
8/ Buch, J. W., New Anthracite Research Laboratory at Schuylkill Haven, Pa.: Reading Railroad Mag., vol. 12, 1948, pp. 3-5, 24.

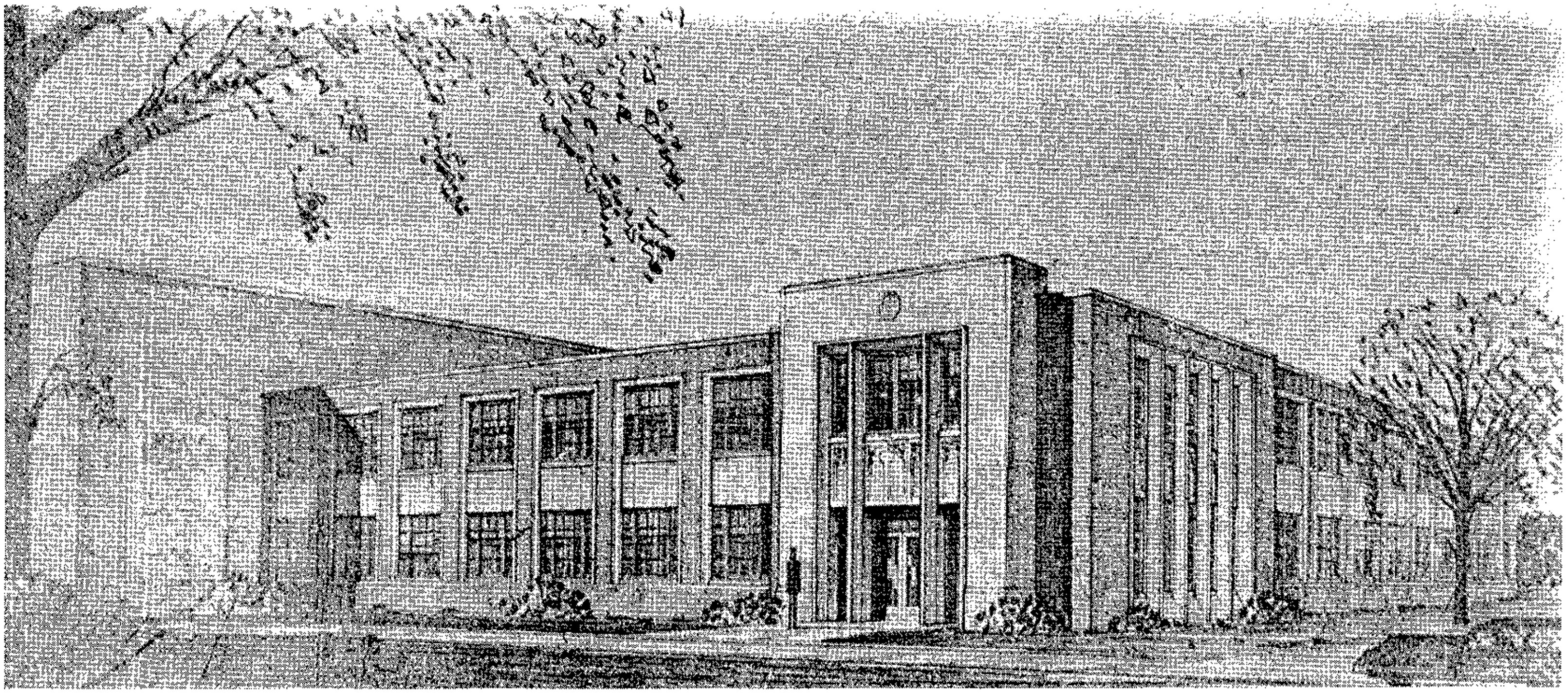

Figure I. - Lignite research laboratory, Grand Forks, N. Dak.

bottles of chemical reagents, and 10,040 test kit replacement items were distributed to Federal boiler installations; 742 samples of boiler water and 7,057 samples of coal from Government purchases, tipple inspections, and export shipments were analyzed. As in previous years, fuel-engineering services were most productive, yielding savings in operation costs at numerous Government fuel-burning and boiler installations. Boiler-water research demonstrated the value of certain chemicals in controlling corrosion in steam lines. Control of causticity was proved effective in preventing boiler-seam cracking.

Many data were added to our knowledge of the fundamental properties and constitution of coal by petrographic studies of coals from Maryland, Colorado, North Carolina, Alabama, California, and Wyoming.

To meet the needs of fuel-short and strategic areas, core-drilling investigations of Alaskan coal deposits were continued. The Eska Creek area was found to be unsuitable for the development of a mechanized mine, and diamond drilling in the Wishbone Hill area southwest of Jonesville, Alaska, was begun. Reconnaissance of other coal fields yielded data on which future investigations will be based.

Diamond-drilling investigation of the Coosa coal field, Alabama, revealed a reserve of coal in the Fairview bed estimated at 14,580,000 tons, of which 11,660,000 tons should be recoverable. In the Minnesota Creek area, Gunnison County, Colo., minable coal reserves totaling 781,000,000 tons were found, of which 624,800,000 tons may be assumed to be recoverable. Other drilling projects were completed in the Castleman Basin, Maryland, in the Deep River coal field, North Carolina, and in the Coal Creek district of Colorado.

Confronted by depletion of our coking-coal reserves and the necessity for accurate information about remaining reserves to serve as a basis for national security planning, the Bureau of Mines undertook a field investigation of known minable coking-coal reserves. During the year, field parties collected information in Pennsylvania, West Virginia, and Kentucky. Under the State Department program of cooperation with other American republics, the Bureau of Mines studied and reported on the coal fields and industry of Brazil and Chile. To increase efficiency in coal mining, the Bureau studied the extraction of pillars with mechanized equipment as well as overall mining practice in Arkansas and the Missouri River Basin.

The suitability of German shearing machines in increasing recovery of anthracite was demonstrated in underground operations, and tests of a German pneumatic packing machine were successful.

Bureau of Mines research on the use of Diesel engines underground was summarized and indicated that adequate ventilation and the provision of flame protective devices are essential to safe operation. Schedules for Bureau of Mines testing of Diesel mine locomotives for permissibility were issued. The Bureau of Mines continued to test mine atmospheres for toxic constituents, a program that involved the analysis of 15,000 samples of mine air and the examination of 750 samples of air-borne dusts. After testing respiratory protective devices, 6 new approvals and 37 extensions of approval were granted.

In its investigation of the prevention of flooding of anthracite mines, the Bureau completed a survey of underground water pools and assembled information from thousands of boreholes in the anthracite fields. Possible sites for drainage tunnels were considered. Testing of electrical equipment for permissibility for use in coal mines was continued, and 53 approvals were granted. A notable contribution to safety in coal mines was made during the year when the Bureau demonstrated the practical application of roof support in coal mines by means of suspension roof supports.

The need for improvement in coal-preparation practices continued to be felt as coal mining became more and more mechanized. To meet this need, a Bureau-developed process for cleaning and recovering fine coal was installed commercially at two mines in Alabama, and a cyclone-thickener unit was installed at a preparation plant in West Virginia. The usefulness of both installations was demonstrated during the year. The status of coal-washing practices in Washington, Oregon, and Alaska, where coal-preparation problems are particularly acute, was summarized, and a study of sampling coal for float-and-sink tests promised to facilitate future research. Paralleling the study of known minable reserves of coking coal, research was conducted on the preparation characteristics of high-sulfur coking coals in southwestern Pennsylvania and northern West Virginia. Methods of producing extremely clean coal suitable for electrode carbon in Germany were reviewed, and a bibliography of publications on the briquetting of coal was prepared.

With increasing industrialization in the west, emphasis has been placed on the development of satisfactory methods of efficiently utilizing the huge reserves of low-rank coals in that area. Pilot-plant tests of drying processes for low-rank coals were particularly promising. Millions of tons of lignite now being excavated from a dam site in North Dakota were stored satisfactorily by Bureau-developed methods.

To promote conservation in the domestic use of coal, a research program to assist householders in selecting coal-burning equipment and to assist coal producers in preparing coal for domestic stoker use was completed. Conservation in the utilization of fuel was furthered also by research on the reactivity of solid fuels and a study of furnace performance.

The reserves study and preparation phases of the Bureau's program to increase our available sources of coking coals were supplemented by continuation of the survey of the carbonizing properties of American coals, in which particular emphasis was placed upon coals and blends of coals suitable for the manufacture of metallurgical coke. Various properties of 37 coals and 28 blends were determined during the year, including the coke-, gas-, and byproduct-making properties of 20 coals. The blending of Appalachian coals was studied, and the carbonizing properties of Chilean coals were determined.

Research was continued on the complete gasification of coal by the Lurgi process, and further progress was made in developing a satisfactory externally heated, continuous, annular retort for the gasification of lignite. Continuing its investigation of the feasibility of utilizing coal without mining by means of underground gasification, the Bureau of Mines undertook its second field-scale project at Gorgas, Ala., in cooperation with the Alabama Power Co. The installation was planned in five straight-line sections, the first of which, 300 feet long, was ignited by means of a thermite hand grenade in March 1949. The project has been operated continuously since that time.

Development of methods for the production of liquid fuels from coal continued to be a major part of the Bureau of Mines research program. Laboratory-scale experimentation on the production of synthesis gas demonstrated that all grades of coal can be continuously gasified successfully to furnish synthesis gas from which liquid fuels can be synthesized. In the course of this work, a pneumatic feeder was developed which provides a method of feeding solids to a reaction zone at a uniform rate. The other most promising process for the production of liquid fuel from coal, hydrogenation of coal, was the subject of laboratory and pilot-plant study, and the results were most encouraging. Research on the liquid-phase and vapor-phase hydrogenation of coal, the testing of catalysts, and the separation and identification of coal-hydrogenation products were important aspects of the work. Other types of Fischer-Tropsch processes have been developed for the liquefaction of coal by the hydrogenation of carbon monoxide. Much attention has been paid to the role of various catalysts in these processes.

Based upon the laboratory and pilot-plant research on the gas synthesis and coal-hydrogenation processes, two coal-to-oil demonstration plants were dedicated at Louisiana, Mo., in May 1949. Although these plants were not completed to the full operation stage, successful unit operations have been carried out in both.


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## ORIGIN, COMPOSITION, AND PROPERTIES OF COAL

### Inspection, Sampling, and Analysis

At the time contracts for coal were let for the fiscal year 1949, demand was in excess of the supply, and Government agencies were not always able to obtain coal of the desired quality. Coal was purchased on a guaranteed-analysis basis, including penalties for delivery of substandard coal, by the Bureau of Prisons, Department of Justice, Bureau of Indian Affairs, Department of the Interior, and for export. Other departments purchased coal at a fixed price subject to adjustment by negotiation for delivery of substandard coal, or at a fixed price not subject to adjustment for quality. Contracting for coal for the fiscal year 1950 began in March, and by that time the market had changed from a "seller's" to a "buyer's" market, resulting in a flood of bids on Government requirements. All departments issued specifications calling for bids on a guaranteed-analysis basis, including penalties for delivery of substandard coal. In general, each department purchases its own coal supply, except that the Navy Department purchases coal for the Army and the Bureau of Federal Supply purchases a supply for other agencies whose requirements are small.

Coal requirements of Federal agencies for the fiscal year were estimated at approximately 5,500,000 tons. Owing to the large number of bids for 1950 requirements, there was a large increase in requests from Government agencies for analyses for use in evaluating coal bids. In addition, recommendations were made for awards of contracts for a number of agencies.

For the use of various Government agencies in making coal purchases and for public information, 756 tipple samples were collected at 191 mines in four States.

At the close of the year, requests for sampling more than 600 mines were on file. For research on carbonization, free swelling, grindability, gasification, and other properties of coal, 183 samples were collected in 158 mines. Approximately 500,000 tons of coal purchased by the War Department on a guaranteed-analysis basis for shipment to Japan were inspected and sampled at Philadelphia, Pa.; Baltimore, Md.; and Norfolk, Va.

Upon request of the Air Forces, schools for coal samplers, attended by samplers from airfields in surrounding territories, were conducted at Griffiss Field, Rome, N. Y.; Wright-Patterson Field, Dayton, Ohio; Warner Robins Field, Warner Robins, Ga.; and Hill Field, Ogden, Utah.

Proximate or ultimate analyses were made of 7,057 samples of coal and coke from Government purchases, tipple and breaker inspections, and coal exported to Europe and Japan. The greater portion of these samples came from branches of the Department of National Defense; the rest were from civilian agencies such as post offices, Federal buildings, Indian Affairs, Federal Bureau of Supply, Veterans Administration, and others.

Research and test work of the Bureau required analysis of 8,428 samples of coal or products derived from coal in connection with investigations on the mining, preparation, and utilization of coal. In cooperation with the Economic Cooperation Administration, coals from Greece and Korea were analyzed.

The inspectors of the Coal Mine Inspection Branch of the Health and Safety Division submitted 8,631 samples of road, roof, rib, and gob dusts from the larger shipping coal mines. These samples represent 1,693 inspections and approximate the number of mines in which dusts were taken for analysis. The samples are usually received, analyzed, and the report sent out the same day to the inspectors for their use in determining the safety of operations in the mines and in formulating recommendations where changes are indicated.

The total of 24,116 samples of coal, coke, char, tar, coal-mine dusts, and related materials that were analyzed represents the largest number of samples ever handled by the laboratory, exceeding the previous high year of 1943 by 6.4 percent and last year by 19.3 percent. In addition, investigation of the deterioration of the free-swelling index of coal in storage was continued.

## Analyses of Miscellaneous Materials

Chemical analyses of 110 samples of miscellaneous materials were made in connection with various investigations of coal utilization and safety in mines.

This work included complete analyses of 38 samples of coal ash from coals being investigated for use in the synthetic liquid fuels program and four samples of ash from Kentucky coal burned in a boiler furnace during heat absorption tests. Analyses of ash from seven samples of roof and floor rock adjoining the coal bed in Underground Gasification Project No. 2, Gorgas, Ala., showed that the ignited rock had a high silica content. Complete analyses of 24 boiler scales or water-formed deposits and of 10 boiler compounds collected from steam plants of various Government agencies were made to assist in the preparation of recommendations for improved feed-water treatment at these plants.

Examination of eight samples of rock dusting materials showed that one sample, a limestone from Kentucky, would be suitable for rock-dusting coal mines. The other materials tested did not meet all the requirements for a satisfactory rock dust. In connection with health and safety investigations, an analysis was made of blast-furnace slag proposed as a substitute for sand as traction material for mine locomotives. Other analyses showed a high silica content in two samples of rock collected during an inspection of dust hazards in a quarry producing aggregate for concrete.

Sixteen other materials were analyzed or tested in connection with investigations of carbonization, complete gasification, and combustion of coal.

## Constitution, Properties, and Analytical Methods

### Petrographic Studies of Coal

Petrographic examinations were made of 168 cores, totaling 589 feet, recovered from coal investigations in Garrett County, Md.; Eska, Alaska; Gunnison and Routt Counties, Colo.; Chatham County, N. C.; Walker County, Ala.; Contra Costa County, Calif.; and Johnson County, Wyo. Laboratory study of the cores involved complete megascopic examination and preparation of descriptive log strips used in correlating the drilling data and the various coal beds encountered in the test drilling. On the basis of petrographic interpretation of the cores, 390 feet of coal was selectively sampled for special chemical and physical tests.

Complete thin-section analyses were made of the following Colorado coals: 70-inch column sample from the Lennox bed, Edna mine, Routt County; 124-inch column sample from the No. 4 bed, King mine, near Paonia, Delta County; and a drill-core sample representing a 12-foot, 11-inch coal bed from the Coal Creek area, Gunnison County. Their petrographic composition is given in table 1. The results show that these coals consist principally of anthraxylon and translucent attritus. Their low content of opaque attritus and fusain, which are components classed as relatively inert to chemical reactions, indicate that the coals would be suitable for preparation of synthetic liquid fuels by the hydrogenation process.

TABLE 1. - Petrographic composition of Colorado coals

| Petrographic components | Edna mine | King mine | Drill core |
|---|---|---|---|
| Anthraxylon .................. | 49.9 | 48.3 | 45.6 |
| Translucent attritus ......... | 45.4 | 46.0 | 47.4 |
| Opaque attritus .............. | 2.1 | 2.1 | 4.0 |
| Fusain ....................... | 1.4 | 1.9 | 3.0 |
| Translucent mineral matter ... | 1/.1 | 1/1.7 | - |
| Pyritic mineral matter ....... | 1.1 | 2/0.1 | - |

1/ Principally calcite and clay minerals.
2/ Less than.

Cores from the drilling investigations in the Minnesota Creek area, Gunnison County, Colo.,9/ were studied megascopically, and cores from two test holes were selected as being representative of the coal beds cored in the various test holes and were analyzed microscopically by the thin-section method. The results showed the coal in all eight beds to be more than 3 feet thick in one hole and the seven

9/ Toenges, Albert L., Dowd, James D., Turnbull, Louis A., Davis, J. D., Smith, H. L., and Johnson, Vard H., Reserves, Petrographic and Chemical Characteristics, and Carbonizing Properties of Coal Occurring South of Dry Fork of Minnesota Creek, Gunnison County, near Paonia, Colo., and the Geology of the Area: Bureau of Mines Tech. Paper 721, 1949, 48 pp.

beds in the other hole to be remarkably uniform in petrographic composition. On the basis of thin-section analyses, these coals were classified as bright, with relatively low amounts of opaque attritus and fusain and only a very small amount of mineral matter, usually in the form of dispersed clay minerals, fine quartz grains, and pyrite. Carbonization tests showed that the coals examined produce a rather inferior grade of coke, which is not equal to that made from the Lower Sunnyside coal in Utah.

Cores recovered in diamond-drilling investigation of the Fairview and Coal City basins in St. Clair County, Ala., were studied in the laboratory.10/ A column sample and drill-core sample from the Fairview bed were thin-sectioned and analyzed microscopically. On the basis of the microscopic analyses, the Fairview bed is classified as bright coal. The anthraxylon content ranges from 57 to 64 percent and is associated with 19 to 20 percent translucent attritus. Opaque attritus is not particularly high, ranging from 8 to 9 percent, but an unusual feature of the petrographic composition is the relatively large amount of fusain present - 8 to 15 percent. Coal beds normally rarely exceed 3 percent fusain content. The microscopic study showed that most of the mineral matter, which reached rather high concentrations in some layers, consists of pyrite, calcite, and clay minerals. The pyrite and calcite, principally of secondary origin, occurred in lenses and veinlets, many of which are visible to the naked eye. The clay minerals were present as dispersed detrital particles in the attrital layers of coal. Evidence that the Fairview bed had been subjected to the stresses of crustal movement was seen in the arching of certain anthraxylon layers and minute faulting and fracturing.

Petrographic analyses were made of float-and-sink fractions of three samples of broken coal from the Pittsburgh bed to determine whether coal-preparation methods, particularly gravity separation, could be used for concentrating in the low specific-gravity fractions certain coal components such as anthraxylon and bright attritus considered superior for hydrogenation. Also, it was desired to know whether a maximum rejection could be achieved in the heavy specific-gravity fractions of coal less favorable for hydrogenation, such as dull attritus with high content of opaque matter, fusain, and associated free mineral matter. The three sized fractions (1-1/2-inch by 3/8-inch, 3/8-inch by 14-mesh, and 14-mesh by 100-mesh), prepared by crushing and screening the mine samples, were classified in gravity separation liquids of 1.3 and 1.6 specific gravities. The three float-and-sink fractions were crushed to pass 8-mesh and, with the untreated minus 100-mesh fraction, were screened on 10 sieves, from 10-mesh through 200-mesh. The composition of each screen fraction was determined by petrographic method of particle identification and count using an ore-dressing microscope.

The data show that anthraxylon and bright attritus are concentrated in coal that floats on separation liquids of 1.3 to 1.6 specific gravities. Fusain is concentrated in minus 100-mesh fines and mineral matter in the 1.60 sp. gr. sink. The results indicate that coal can be improved for hydrogenation by preparation methods.

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10/ Toenges, Albert L., Turnbull, Louis A., Jolley, Theodore R., Shields, Joseph J., Smith, H. L., O'Donnell, H. J., Cooper, H. M., Abernethy, R. F., Gandrud, B. W., Riley, H. L., and Rothrock, Howard E., Investigation of Coal Deposits in the Fairview and Coal City Basins of Coosa Field, St. Clair County, Ala.: Reserves, Petrography, and Chemical Properties of Coals; Washability Characteristics of Coal from Fairview Bed; and Geology of the Area: Bureau of Mines Tech. Paper 719, 1949, 104 pp.

A complete thin-section analysis was made of an 81-inch column of lignite obtained from the American Lignite Products Co.'s mine in Amador County, Calif. The column sample represents the upper part of a lignite bed which ranges in thickness from 1 to 12 feet. The sample is of particular interest because the deposit is being exploited as a source of raw material for a wax-extraction plant, which is the only one of its kind operating in the United States. Petrographic analysis of this lignite permitted comparison with similar lignites from deposits occurring in southern Arkansas and at one time used to a limited extent for wax extraction in a lignite-processing plant now abandoned. The Amador County lignite proved to be an attrital type containing an extremely high proportion of translucent attritus. Approximately one-quarter of the translucent attritus consisted of yellow translucent matter of relatively small particle size, predominantly minus 0.050 mm. The general petrographic composition differed from the Arkansas attrital lignites in much lower content of resin bodies and considerably finer particle size of the attritus ground mass.

Examination of coal that has been reduced by various stages of preparation into granular form is the subject of continuing investigation in the coal petrography laboratory. Despite considerable work done, a standard method of analysis has not been developed, as the problems involved are not simple. Various types of plastics and waxes, such as bakelite and carnauba wax, are used with heat and pressure in a small hydraulic laboratory press to bind granular coal into so-called briquettes about 1 inch in diameter and up to 3 inches in length, which are used for preparing thin sections. The crushing effect of the press on particles of coal was studied, and it was found that with the use of certain high-melting waxes, such as carnauba, extremely high pressures not only are not necessary but are detrimental in that a high percentage of particles are crushed to very fine sizes, making microscopic work very difficult. Tests of the crushing effect of the hydraulic press were made on samples of anthraxylon and splint coal closely sized into 14- by 20-mesh and 65- by 100-mesh fractions, with pressures of 500, 1,000, 2,000, and 3,000 p.s.i. The least measurable effect of crushing was noted in briquettes made with the 65- by 100-mesh fractions using pressure of 500 p.s.i. Anthraxylon was more responsive to the crushing action than splint coal. It was concluded that for microscopic examination using magnifications from 60 to 150 power, satisfactory thin sections can be prepared from briquettes made with granular coal sized 65- by 100-mesh and formed at pressure of 500 p.s.i.

Determination of Chlorine in Coal

A method of determining chlorine in coal, as published in British Standards Institution No. 1016, was investigated.

The British method is a modified Eschka procedure whereby a 5-gram sample of coal is ignited with sodium carbonate at 475° C. for 20 to 24 hours. The sample is then acidified with nitric acid and chlorine determined by the Volhard method. Chlorine was determined in three coals by this method and, for comparison, by a water-extraction method and an oxygen-bomb method in which chlorine is determined in the bomb washings. Results are given in table 2.

The percentages of chlorine are recorded to three decimal places to show variations more clearly. Previous work has shown that for some coals, water extraction does not recover all of the chlorine, but for these coals virtually all was recovered. Results by the British method agree with those obtained by the bomb method for two of the samples and are slightly higher for the third. It was concluded that the British procedure is a practical method of determining chlorine in coal.

TABLE 2. - Chlorine content of coal

| Source of coal | | | Percent chlorine in coal | | |
|---|---|---|---|---|---|
| State | County | Bed | British method | Oxygen-bomb method | Water-extraction method |
| Ill. | Perry | No. 6 | 0.019 | | |
| | | | .014 | 0.021 | 0.010 |
| | | | .016 | .013 | .013 |
| | | Ave. | .016 | .017 | .012 |
| Ky. | Muhlenburg | No. 9 | 0.024 | | |
| | | | .027 | 0.026 | 0.019 |
| | | | .024 | .024 | .020 |
| | | Ave. | .025 | .025 | .020 |
| W. Va. | Marshall | Pittsburgh | 0.224 | 0.182 | |
| | | | .227 | .187 | 0.192 |
| | | | .223 | .207 | .195 |
| | | Ave. | .225 | .192 | .194 |

## Free-Swelling Index of Coal

In the Standard Method of Test for Free-Swelling Index of Coal (A.S.T.M. Designation: D 720 - 46), the specifications provide that the temperature of the inner surface of the bottom of the crucible used in carbonizing the coal shall reach 800 $\pm$ 10° C. in 1-1/2 minutes and 820 $\pm$ 5° C. in 2-1/2 minutes after placing the crucible over the gas flame. The crucible used shall also meet certain dimensional requirements, the weight of the crucible being within the limits of 11.0 to 12.75 grams. At the normal gas pressure in some laboratories, the required crucible temperatures are difficult to attain. Also, it is often not easy to purchase silica crucibles that will meet the weight specifications. Because of these difficulties, tests were made as to the effect of varying the carbonizing temperature and crucible weights to determine whether tolerances in the specifications could be increased.

Free-swelling tests of three samples of coal were made at 750° C., 775° C., and 800° C. Table 3 shows the results of the tests made at these temperatures. In general, the carbonizing temperature has a significant effect upon free-swelling results, the swelling indexes increasing at higher temperatures. Therefore, the specified temperatures of the standard method must be maintained.

Tests of the effect of crucible weight showed that within the range of weight limits studied (10.7 to 15.3 grams), free-swelling results were not significantly affected. It was concluded that if the crucibles used permitted the proper temperatures to be reached with no change in burner adjustment during tests with crucibles of various weights, the weight limits specified in the standard method probably could be increased.

TABLE 3. - Effect of temperature upon free-swelling indexes of coal

| Source of coal examined | | | Free-swelling index at crucible temperature, °C. | | |
|---|---|---|---|---|---|
| State | County | Bed | 750 | 775 | 800 |
| Illinois | Madison | No. 6 | 3 | 3 | 3 |
| Pennsylvania | Somerset | E | 6-1/2 | 7 | 8 |
| West Virginia | Logan | Chilton | 7 | 8 | 8-1/2 |