

RECENT DEVELOPMENTS IN COAL PREPARATION AND UTILIZATION

By A. C. FIELDNER

SUMMARY OUTLINE

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In the Minerals Yearbook for 1932-33¹ the writer presented the background that led up to the new developments in coal utilization. A reading of the previous discussion is necessary to provide the perspective for the following account of new developments in 1933, which also includes a brief review of the present status of the more important developments described in last year's report.

CLASSIFICATION AND PROPERTIES OF COAL

Classification.—After several years of fact finding and research, the Sectional Committee on the Classification of Coal of the American Society for Testing Materials, functioning under the rules of the American Standards Association, has recommended tentative specifications² for the classification of coals according to rank³ and grade. This agreement of the committee is timely in view of the urgent need of authoritative and uniform standards for classification under the coal codes and by regional selling agencies.

The classification by rank is based on the composition and physical properties of the coal, with emphasis on the properties that vary in the progressive alteration of coal in the natural series from lignite to anthracite. The classification by grade depends primarily on the amount and nature of the impurities and is determined by the calor-

¹ Fieldner, A. C., Recent Developments in Coal Utilization; Minerals Yearbook, 1932-33, Bureau of Mines, pp. 433-450.

² Fieldner, A. C., Report of the Sectional Committee on the Classification of Coals; Proc. Am. Soc. Test. Mat., vol. 34, 1934. (In press.) Rose, H. J., Coal Classification; Ind. and Eng. Chem., vol. 26, 1934, pp. 140-143.

³ Selvig, W. A., Ode, W. H., and Fieldner, A. C., Classification of Coals of the United States According to Fixed Carbon and B.t.u.; Am. Inst. Min. and Met. Eng. Tech. Pub. 527, 1934, 11 pp.; Trans., vol. 108, Coal Division, pp. 188-197.

ific value, amount of ash and sulphur, and ash-softening temperature of the coal as sold. Size-stability and caking properties will be included as soon as standard methods for their determination are agreed upon.

During 1933 a number of important papers were published dealing with technical aspects of coal classification. Gauger, Barrett, and Williams⁴ determined the ash-forming minerals in a number of coals, and Thiessen⁵ calculated the minerals in coal from ash analyses. Thiessen⁶ and Herzog⁷ presented data on simplified ash-correction formulas. The Illinois Geological Survey⁸ published some results from an intensive study of the calorific value of Illinois coals, with particular reference to the regional values of the different beds referred to a unit coal basis—that is, free from moisture and mineral matter.

The growing interest in the composition of coal ash has been recognized by the British Fuel Research Station. Recently it published a description of chemical methods for ash analysis.⁹ Now the application of spectrographic methods¹⁰ to the examination of ash for minor constituents and for rare elements is being studied. These may be of importance to users because of their possible catalytic effect upon the reactions of coal hydrogenation. Appreciable quantities of germanium and traces of boron, chromium, lithium, molybdenum, manganese, lead, tin, vanadium, zinc, and possibly gallium have been found in coal ashes.

The Research Council of Alberta has shown that appreciable oxidation¹¹ takes place during the air-drying of low-rank coals and that the oven-humidity influences the slacking indices of coal as determined by the accelerated test.¹² Both the Canada Department of Mines¹³ and the United States Bureau of Mines¹⁴ have continued their studies of simple methods for measuring the caking properties of coals and have published tentative procedures for these tests.

Grindability.—Heywood,¹⁵ working with British coals, finds that the relative resistances to grinding of different types of coal, in order of their increasing resistance, are: Fusain, 0.47; vitrain, 1.00; clarain

⁴ Gauger, A. W., Barrett, E. P., and Williams, F. J., Mineral Matter in Coal: Trans. Am. Inst. Minn. and Met. Eng., vol. 108, Coal Division, 1934, pp. 226-236.

⁵ Thiessen, Gilbert, The Ash-to-Mineral-Matter Correction in Coal Analysis—A Study Based Upon Coal Ash Analyses; Am. Inst. Min. and Met. Eng. Contrib. 68, 1934, 12 pp.

⁶ Thiessen, Gilbert, A Proposed Simplification of the Parr Unit Coal Formula: Fuel, vol. 12, 1933, pp. 403-411.

⁷ Herzog, E. S., Application of Ash-Correction Formulas to Alabama Coals: Fuel, vol. 12, 1933, pp. 112-117.

⁸ McCabe, L. C., Mitchell, D. R., and Cady, G. H., A Preliminary Report on Unit Coal-Specific-Gravity Curves of Illinois Coals: Trans. Am. Inst. Min. and Met. Eng., vol. 108, Coal Division, 1934, pp. 222-223. Cady, G. M., and Rees, O. W., Unit Coal as a Basis of Coal Standardization as Applied to Illinois Coals: Trans. Am. Inst. Min. and Met. Eng., vol. 108, Coal Division, 1934, pp. 224-225.

⁹ King, J. G., and Crossley, H. E., Methods for the Quantitative Analysis of Coal Ash: Dept. Sci. and Ind. Research, Fuel Research, Physical and Chemical Survey of the National Coal Resources, no. 28, H.M.S. Office, London, 1933, 20 pp.

¹⁰ Report of the Fuel Research Board, Dept. Sci. and Ind. Research, H.M.S. Office, London, 1933, p. 34.

¹¹ Stansfield, E., Lang, W. A., and Gilbart, K. C., Oxidation of Coal and its Relation to the Analysis of Coal: Am. Inst. Minn. and Met. Eng. Contrib. 69, 1934, 10 pp; Trans., vol. 108, 1934, pp. 243-254.

¹² Stansfield, E., and Gilbart, K. C., Effect of Oven-Humidity on Accelerated Weathering Tests of Coal: Am. Inst. Min. and Met. Eng. Tech. Pub. 543, 1934, 8 pp; Trans., vol. 108, 1934, pp. 237-242.

¹³ Swartzman, E., Burrough, E. J., and Strong, R. A., A Laboratory Test on Coals for Predicting the Physical Properties of the Resultant Byproduct Coke: Canada Dept. Mines, Mines Branch, Rept. 737-2, 1933, 24 pp. (Advance Section of Investigation of Fuels and Fuel Testing, 1932.) Gilmore, R. E., Connell, G. P., and Nichols, J. H. H., Agglomerating and Agglutinating Tests for Classifying Weakly Caking Coals: Trans. Am. Inst. Min. and Met. Eng., vol. 108, Coal Division, 1934, pp. 255-266. Burrough, E. J., Swartzman, E., and Strong, R. A., Classification of Coals Using Specific Volatile Index: Canada Dept. Mines, Mines Branch, Rept. 725-2, 1933. (Advance Section of Investigations of Fuels and Fuel Testing, 1930-31, pp. 36-50.)

¹⁴ Selvig, W. A., Beattie, B. B., and Clelland, J. B., Agglutinating-Value Test for Coal: Proc. Am. Soc. Test. Mat., vol. 33, pt. II, 1933, pp. 741-760. Barkley, J. F., and Burdick, L. R., Caking Action of Coal on Stokers: Power Plant Eng., vol. 38, 1934, pp. 132-134.

¹⁵ Heywood, H., Characteristics of Pulverized Fuel: Jour. Inst. Fuel, vol. 6, 1933, pp. 241-248.

and durain, 2.18. However, he finds that the hardness and toughness of the coal pulverized has but little effect on "characteristic curves" in which the relative diameters of the particles are plotted against the amounts of residue remaining on the sieve.

Two modifications¹⁶ of the ball-mill method for determining the grindability of coal have been proposed, and enough progress has been made in correlating¹⁷ laboratory "grindability" tests with actual pulverizer performance to permit practical use of these tests. The equally important test for friability or size-stability has been studied. Yancey and Zane¹⁸ conclude that the drop or shatter test is best adapted for showing the breakage occurring in handling the larger sizes of coal in loading and unloading cars but that the tumbler test is the method most generally suitable for estimating the relative friability of different coals because it combines the shattering due to impact and the attrition due to rubbing together of pieces of coal.

Sampling.—Issuance of British Standard Specification for the Sampling of Large and Run-of-Mine Coal¹⁹ in August 1933 calls attention to the valuable work of Grumell and Dunningham²⁰ in making a new study of the principles of coal sampling and in reviewing the classical work of Bailey²¹ upon which the present American methods for coal sampling are based. They confirm the necessity for strict observance of the quantities of coal required according to Bailey's "size-weight" theory for each step in the size reduction of gross samples but present a new theory based upon the variability or "average error" of coal consignments. Their data tend to show that the "average error" is a characteristic of commercial coals and increases with increasing ash content. In general, the British methods²² permit the taking of smaller gross samples, especially in the larger sizes of coal, than does the method of the American Society for Testing Materials, which is a general method applicable to all grades and sizes of coal.

Mott and Wheeler²³ investigated the commercial sampling of coke. They found that more care was required to obtain a correct sample with respect to moisture than with respect to ash. They give a formula for calculating the number of increments necessary from different parts of the consignment to insure a water content within 1 percent of its true value.

Plastic properties.—A large number of papers has been published during the year on methods for determining the upper and lower

¹⁶ Baltzer, C. E., and Hudson, H. P., A Method for Rating the Grindability or Pulverizability of Coal, Developed by the Fuel Research Laboratories (F.R.L.), Department of Mines, Canada: Canada Dept. Mines, Mines Branch, Rept. 737-1, 1933, 17 pp. (Advance Section of Investigations of Fuels and Fuel Testing, 1932.) Yancey, H. F., Furse, O. L., and Blackburn, R. A., Estimation of the Grindability of Coal: Trans. Am. Inst. Min. and Met. Eng., vol. 108, Coal Division, 1934, pp. 287-294.

¹⁷ Hardgrove, E. M., The Relation Between Pulverizing Capacity, Power, and Grindability: Paper Presented at the Semiannual Meeting of Am. Soc. Mech. Eng., Chicago, June 27, 1933; abstract in Power, vol. 77, 1933, p. 342. Frisch, Martin, and Holder, G. C., Correlation of Grindability with Actual Pulverizer Performance: Combustion, vol. 4, no. 12; vol. 5, no. 1, 1933, pp. 29-34.

¹⁸ Yancey, H. F., and Zane, R. E., Comparison of Methods for Determining the Friability of Coal: Rept. of Investigations 3215, Bureau of Mines, 1933, 24 pp.

¹⁹ British Standards Institution, British Standard Specification for the Sampling of Large and Run-of-Mine Coal: No. 502, London, 1933, 39 pp.

²⁰ Grumell, E. S., and Dunningham, A. C., Report on the Sampling of Small Fuel up to 3 Inches; Embodying Some General Principles of Sampling: British Eng. Standards Assoc., no. 403, 53 pp. London, 1930. Grumell, E. S., and King, J. G., The Sampling of Coal and Coke: Proc. Internat. Assoc. Test. Mat., 1931, pp. 317-348; Jour. Inst. Fuel, vol. 6, 1933, pp. 143-159.

²¹ Bailey, E. G., Accuracy in Sampling Coal: Ind. and Eng. Chem., vol. 1, 1909, pp. 161-178.

²² British Standard Specification for the Sampling and Analysis of Coal for Export, British Eng. Standards Assoc., no. 404, 1930, 34 pp. London, 2s. net. British Standard Specification for the Sampling and Analysis of Coal for Inland Purposes: British Eng. Standards Assoc., no. 420, London, 1931, 44 pp.

²³ Mott, R. A., and Wheeler, R. V., The Commercial Sampling and Analysis of Coke: Coll. Guard., vol. 147, 1933, pp. 869-871, 912-916.

temperatures of the plastic stage of coals and the degree of plasticity attained. Bunte²⁴ and associates of the Gas Institute of Karlsruhe, Germany, have developed an electric furnace and apparatus for determining simultaneously the plastic range and plasticity by the Foxwell nitrogen-flow method, swelling index, and rate of gas evolution.

Pieters, Koopmans, and Hovers²⁵ have devised a novel type of plastometer, which measures the resistance offered by the compressed charge of pulverized and heated coal to the horizontal movement of a vertical needle.

Gieseler,²⁶ after study of previous methods, offers a different type of apparatus, with which he measures the plasticity by determining the velocity of rotation of a stirrer shaft immersed in the closely confined charge of pulverized coal. The shaft is driven by a constant force, and the apparatus is standardized with oils of known viscosity.

Arnu,²⁷ using a modification of the dilatometer method of Audibert and Delmas, showed that even mild oxidation or weathering greatly reduced the swelling properties of certain coals and suggested the use of this test for selecting coal or mixtures of coal for the production of metallurgical coke.

Ping,²⁸ using the Layng-Hathorne nitrogen-flow method, determined the plastic range of 17 Chinese coals and found that pressure difference plastic range arranged the coals in order of their coking ability.

Mott and coworkers of the Department of Fuel Technology of Sheffield University have continued their studies of the mechanism of coke formation. They developed a form of dilatometer known as the Sheffield laboratory coking apparatus,²⁹ in which a column of 60-mesh coal is heated gradually and allowed to expand against a loaded plunger. They found that swelling of single particles of bright and dull coals began at approximately the same temperatures as contraction of the column of particles of the same coal subjected to a load of 100 grams and, in case of bright coals, ended at approximately the temperature of final expansion.³⁰ At the temperature where the column began to contract under load, designated as the softening point, the individual particles began to soften and fill the voids. As long as the gas could escape between voids the column did not expand, but when the softening proceeded to the point where the single particles coalesced to fill the voids the coal column began to expand owing to the force of the evolved gases.³¹ The upper temperature limit of plasticity was marked by a sudden release of gases owing to the formation of a rigid coke structure; this limit varied with the degree of freedom for the coal to expand, being raised from about 400° to 500° C. when the coal was heated under conditions not permitting any expansion or free escape of gas.³²

²⁴ Bunte, K., Brückner, H., and Ludwig, W., Experimental Arrangement for Determining the Behavior of Coal During Softening and Coke Formation: Glückauf, vol. 69, 1933, pp. 765-770.

²⁵ Pieters, H. A. J., Koopmans, H., and Hovers, J. W. T., Some Characteristics of a Coalification Series: Fuel, vol. 13, 1934, pp. 82-86.

²⁶ Gieseler, K., Measurement of the Plastic Properties of Heated Coal: Glückauf, vol. 70, 1934, pp. 178-183.

²⁷ Arnu, M. C., La Fusion de la houille: Rev. ind. min., no. 296, Apr. 15, 1933, pp. 155-173.

²⁸ Ping, K., The Plastic Range of Coking Coals in China: Geol. Surv. China Bull. 21, 1933, pp. 45-56.

²⁹ Davies, R. G., and Mott, R. A., The Sheffield Laboratory Coking Test: Fuel, vol. 12, 1933, pp. 294-303.

³⁰ Burdakin, L., and Mott, R. A., The Temperature Range of Swelling of Single Coal Particles: Fuel, vol. 12, 1933, pp. 232-235.

³¹ Davies, R. G., and Mott, R. A., The Softening and Swelling of Coal in Relation to Plasticity: Fuel, vol. 12, 1933, pp. 330-340.

³² Davies, R. G., and Mott, R. A., The Plasticity of Coal: Fuel, vol. 12, 1933, pp. 371-382.

The range between the softening or initial contraction temperature and the initial expansion temperature is termed the stage of primary plasticity, and the range over which the coal swells is called the stage of secondary plasticity. It was found that the temperature of initial oil evolution coincided with that of initial gas evolution and that these phenomena occurred at about the initial contraction or softening temperature as determined in the Sheffield Laboratory dilatometer test.³³

Mott³⁴ believes that the development of plasticity in a coal and consequently its coking properties are conditioned by the wettability of the solid residue by the oils formed on heating the coal. Oxidizing the surfaces of coal particles decreases the wettability and consequently destroys the plasticity and coking power. Foxwell³⁵ agrees that wettability is an important factor but believes that the action of expanding gases in forcing fluid matter to the surfaces of particles and in swelling the pieces of coal so as to put the charge under pressure also is necessary to the formation of a strong, coherent coke.

Chemical constitution and utilization.—Lowry, of the Coal Research Laboratory, Carnegie Institute of Technology, on the basis of a critical review of published data, concludes that the coal molecule has resulted from condensation and polymerization of polynuclear six-membered carbon ring compounds³⁶ and suggests that this structure becomes more and more condensed as coal passes through the various ranks—peat, lignite, bituminous coal, and anthracite. The aromatics found in coal tar result primarily from dehydrogenation and decarboxylation of depolymerized nuclei present in the original coal.³⁷ He points out the need for additional work on the fundamental chemistry of coal and its reactions in order that it may be utilized to better advantage.³⁸

An excellent review of the nature and occurrence of lignite and the progress made in its utilization has been published by Lavine.³⁹

PREPARATION OF COAL

General features.—In 1933 continued progress was made in the preparation of coal for the market, though at a somewhat reduced pace. Development was confined principally to the improvement of existing facilities or the installation of new equipment for sizing and/or cleaning small coal, to meet the demand partly occasioned by the increased use of automatic stokers for heating homes and other small buildings.

The capacity of screening and hand-picking methods installed or contracted for during the year was reported to be about 6,770 tons per hour and that for mechanical cleaning equipment about 5,575 tons per hour.⁴⁰ This survey showed that new major preparation facilities were installed at 63 plants during the year and that 31 of these included units for the mechanical cleaning of all or some portion

³³ Allison, J. P., and Mott, R. A., *The Influence of Oil on Coke Formation: Fuel*, vol. 12, 1933, pp. 258-268.

³⁴ Mott, R. A., *The Formation of Coke: Fuel*, vol. 12, 1933, pp. 412-418.

³⁵ Foxwell, G. E., *The Mechanism of Coke Formation: Gas Jour. (London)*, vol. 201, 1933, p. 813; vol. 202, 1933, pp. 41, 100.

³⁶ Lowry, H. H., *The Chemical: Coal: Ind. and Eng. Chem.*, vol. 26, 1934, pp. 133-139.

³⁷ Lowry, H. H., *Thermal Decomposition of the "Coal Hydrocarbon": Ind and Eng. Chem.*, vol. 26, 1934, pp. 320-324.

³⁸ Lowry, H. H., *Some Aspects of Coal Utilization: Trans. Am. Inst. Chem. Eng.*, vol. 30, 1933. (In press.)

³⁹ Lavine, Irvin, *Progress in Low-Rank Coals: Ind. and Eng. Chem.*, vol. 26, 1934, pp. 154-164.

⁴⁰ Coal Age, *Preparation at Bituminous-Coal Operations Reflects Changing Market Demands: Vol. 39, 1934, pp. 60-62.*

of the product. All modern types of coal washing and cleaning equipment were represented. The new jig installations are mostly of the Baum type, in which air pressure instead of a piston is used to produce mobility in the jig bed. So far as is known, the first use of the photoelectric cell for controlling the discharge of refuse from a jig bed has been made at one of the mines of the Union Collieries Co., at Renton, Pa.

The apparent trend toward the increased use of the smaller sizes of coal has caused further attention to be given to dedusting methods, better cleaning methods, and improved methods for crushing coal with a minimum production of dust. Curiously enough, this trend toward small coal appears at a time when the introduction of new methods of mining—such as the coal saw, compressed air and carbon dioxide, and new methods of blasting—tend toward increasing the percentage of lump coal produced.

Two new dry-cleaning shaking tables were developed during the year; one employs both reciprocation and flow of air to produce mobility in the separation bed,⁴¹ and the other utilizes reciprocation without air to separate 2 to 1½-inch nut coal in a bed of ⅝- to 0-inch coal.^{41 42} The former device was developed at the Battelle Memorial Institute, Columbus, Ohio, and the latter has been installed at the No. 18 mine of the Peabody Coal Co., West Frankfort, Ill., to handle a size formerly hand-picked.

The Southern Experiment Station of the Bureau of Mines, in cooperation with the University of Alabama, has continued washability studies of southern coals.⁴³ The University of Illinois has published a study of the washing characteristics of Illinois coals.⁴⁴

Flotation.—Little progress was made in the United States in the increased use of froth flotation for cleaning fine coal sludges, although the Pittsburgh Coal Co. continued the flotation plants at its mines. In Europe about 60 coal flotation plants have been installed; Germany and Spain have over 20 and England 6, with a combined capacity of about 3,000,000 tons per year.⁴⁵ A summary of the present status of coal flotation was published during the year by the Bureau of Mines.⁴⁶ In England the Fuel Research Station⁴⁷ continued its study of the Elmore vacuum system of flotation for cleaning fine coal, largely because of the ease of draining the clean coal produced. Coal up to ½-inch size is handled by this process with no frothing reagent.

The Fuel Research Station also continued its investigation of the baffling of conical sludge tanks to improve settling of sludge and clarification of washery water. Tanks with two types of baffles gave 27- and 43-percent increase in settling capacity over the same tank without baffles.

⁴¹ See footnote 40, p. 631.

⁴² Morrow, J. B., *Progress in the Coal Industry; Coal Preparation: Min. and Met.*, vol. 15, 1934, p. 57.

⁴³ Gandrud, B. W., Richardson, A. C., and Payne, W. G., *Washability Studies of the Blue Creek Bed at the Connellsville Mine, Connellsville, Ala.: Rept. of Investigations 3200, Bureau of Mines, 1933, 10 pp.* Richardson, A. C., and Carrington, W. H., *Washability Studies of the Mary Lee Bed, at the Powhatan Mine, Powhatan, Ala.: Rept. of Investigations 3204, Bureau of Mines, 1933, 15 pp.* Richardson, A. C., and Gandrud, B. W., *Washability Studies of Coal from the Mary Lee Bed at the Bankhead Mine, Bankhead, Ala.: Rept. of Investigations 3206, Bureau of Mines, 1933, 9 pp.* Richardson, A. C., and Gandrud, B. W., *The Cleaning of Fine Coal from the Mary Lee Bed at the Porter Mine: Rept. of Investigations 3209, Bureau of Mines, 1933, 8 pp.*

⁴⁴ Mitchell, D. R., *The Possible Production of Low Ash and Sulphur Coal in Illinois as Shown by Float-and-Sink Tests: Univ. of Illinois-Eng. Exp. Sta. Bull. 253, 1933, 44 pp.*

⁴⁵ Mayer, Erwin W., *Why and When to Use Flotation Process: Coal Age*, vol. 38, 1933, pp. 333-334.

⁴⁶ Yancey, H. F., and Taylor, J. A., *Flotation Processes for Cleaning Fine Coal: Information Circ. 6714, Bureau of Mines, 1933, 31 pp.*

⁴⁷ Report of the Fuel Research Board, Dept. Sci. and Ind. Research, H.M.S. Office, London, 1932, pp. 23-25.

German investigators⁴⁸ found that fusain could be floated effectively from dust and slimes of certain Ruhr and British coals; with certain others no selective flotation was obtained.

A British patent⁴⁹ has been issued for the separation of resins from finely powdered coal in two stages of flotation. Ammonium hydroxide, turpentine, pine oil, or cresol is the frothing agent in the first stage; and potassium alum, with additional ammonium hydroxide, is used in the second stage.

Dedusting.—The practice of removing some portion of the finer sizes from the feed to a washing or cleaning plant, or from a product for some special market, increased during the year. In Illinois two mines installed or modified equipment for dedusting buckwheat coal marketed as stoker fuel. Ten-mesh vibrating screens operating in combination with air aspiration for removal of material through 48-mesh are used at one of the plants and vibrating screens alone at the other.

Although screening fine coal from the feed to washing or cleaning plants has been a common practice,⁵⁰ the removal of the finest sizes pneumatically has not progressed in the United States as rapidly as in Europe.⁵¹ The disposal of the dust so produced is a major problem. An excellent review⁵² of the various systems employed in England and the methods of utilizing the dust has been issued by the Utilization of Coal Committee of the Institution of Mining Engineers.

Prevention of breakage.—An improved device for minimizing the breakage of coal during the loading of ships was announced in England.⁵³ It consists of a telescopic tube that maintains a continuous unbroken column of coal to the point of discharge. Breakage of the column due to the collapse of the heap of coal or other sudden movements is said to be impossible. Such a device may prove useful for purposes other than ship loading.

Dust-prevention treatment and dyeing.—Continued interest has been shown in the preparation of dustless coal and coke. Calcium chloride, oils, and various other materials are sprayed on domestic fuels, either at the mine or coal yard, to prevent dusting.⁵⁴

The necessity of providing a quantitative method for measuring dustiness of coal and coke has been recognized by the Koppers

⁴⁸ Kühlwein, F. L., Separation of Fusain by Selective Coal Flotation: Glückauf, vol. 70, 1934, pp. 245-252

⁴⁹ Skerrett, H. N., Process for the Extraction of Resin from Coal: British Patent 357733, Oct. 1, 1931.

⁵⁰ Yancey, H. F., and Fraser, T., Coal-Washing Investigations; Methods and Tests: Bull. 300, Bureau of Mines, 1929, pp. 203-206.

⁵¹ Futers, T. Campbell, A New Dedusting Plant: Coll. Guard., vol. 147, 1933, pp. 335-336. Holmes, C. W. H., The Dedusting of Coal: Coll. Guard., vol. 147, 1933, pp. 197-200. Hebley, Henry F., The Dedusting of Coal: Am. Inst. Min. and Met. Eng. Contrib. 43, 1933, 39 pp.; Trans., vol. 108, 1934, pp. 88-127; abstracted in Coal Age, as What Has Dedusting to Offer Coal Operators in Preparation and Sales Advantages: vol. 38, 1933, pp. 263-265. Appleyard, K. C., Dedusting Coal: Coal Age, vol. 38, 1933, pp. 54-55, 89-91. Report of the Fuel Research Board: Dept. Sci. and Ind. Research, H. M. S. Office, London, 1933, pp. 49-51. Chapman, W. R., Recent Progress in Coal-Cleaning Practice in Great Britain: Proc. 3d Internat. Conf. on Bituminous Coal, Carnegie Inst. Technol., vol. 2, 1931, pp. 742-758. Rosin, P., and Rammler, E., Aspirators and Their Investigation: Glückauf, vol. 68, 1932, pp. 529-537.

⁵² Institution of Mining Engineers, Utilization of Coal Committee, The Dedusting of Coal: Mem. 13, 1934, 4 pp.

⁵³ Futers, T. Campbell, The Morison-Leonard Anti Coal Breaker for Loading Ships: Coll. Guard., vol. 147, Dec. 15, 1933, pp. 1112-1114. Morison, Alan Mushet, and Leonard, Wilfred John, Apparatus for Discharging Coal and Other Materials: United States Patent 1951703, Mar. 20, 1934.

⁵⁴ Wallace, Frederick J. (to Robeson Process Co.), Preserving Coal: United States Patent 1910975, May 23, 1933 (uses a dilute solution of black-strap molasses). Odell, B. F. J., Method of Producing a Prepared Fuel: United States Patent 1922391, Aug. 15, 1933 (uses an oil-water emulsion). Spencer, Geo. P., Process of Treating Coal and Coke: United States Patent 1916539, July 4, 1933 (uses an aqueous ligno-sulphuric acid solution, with coloring matter if desired). Standard Oil Development Co., Process and Product for Treating Solid Fuels in a Way to Reduce Their Tendency to Produce Dust: French Patent 746567, March 14, 1933 (uses an aqueous solution of sodium sulphamate or other sulphonic compound derived from petroleum). Fife, Harvey R., Method of Treating Coal: United States Patent 1912697, June 6, 1933 (uses paraffin wax).

Research Laboratory. Their method, after use over a period of years, was published in 1933.⁵⁵

Processes have been proposed for improving the ignitability of coke by coating it with a film of coal dust, using tar as an adhesive⁵⁶; also for giving it a distinctive appearance by quenching it in water containing coloring materials or even electroplating the coke with copper or nickel.⁵⁷

Flocculation of slurries.—Improvement in the clarification of washery water and increased rate of settling of solids have been obtained at several washeries in the United States through the use of lime as a flocculating agent. In Belgium further development in the use of frozen starch grains for this purpose has been made by M. R. A. Henry, managing director of a large colliery.⁵⁸ This process, or a modification of it, has been examined by several coal companies in the United States. In this process lime, starch, and caustic soda solutions are added to slurry water in the proportion of 9 ounces of lime, ¼ ounce of starch, and ½ ounce of caustic soda per ton of slurry water.

An anthracite colliery in Wales found ammonium and calcium hydroxides very satisfactory for clarifying washery water and preventing the adsorption of clay on the surface of the finer commercial sizes below 1 inch.⁵⁹ In Germany the use of colloids instead of electrolytes is favored. Protective colloids, particularly those of vegetable origin, such as swollen potato starch, were found to increase the settling rate greatly.⁶⁰ Successful, practical results were obtained in five Ruhr washeries.⁶¹ Five to thirty grams of starch were added to each cubic meter of slurry per 100 grams of solids in the slurry. The larger amounts of starch were required for high-volatile low-rank coals; the smaller amounts for medium- or low-volatile coking coals. The clarified water contained less than 1 gram of solids per cubic meter.

Studies at the British Fuel Research Station show that the best treatment varies with the local condition at each washery.⁶²

BRIQUETTING

The Illinois State Geological Survey has made briquets satisfactory with respect to hardness and friability from certain Illinois bituminous coals without the addition of binding materials.⁶³ One-tenth of a pound of coal, crushed to pass a ¼-inch to ⅜-inch screen and pre-heated 10 minutes at 300° C. in an oven, was briquetted by the impact of a 500-pound weight dropped 4½ feet. No information on the commercial success of the experimental Apfelbeck press for briquetting German bituminous coals without binder, referred to in last year's

⁵⁵ Powell, A. R., and Russell, C. C., Method for Determining the Dustiness of Coal and Coke: Ind. and Eng. Chem., Anal. Ed., vol. 5, 1933, pp. 340-341.

⁵⁶ Hodsmann, H. J., Coke for Open Fires: Gas Jour. (London), vol. 201, 1933, p. 737.

⁵⁷ Sperr, F. W., Jr. (to Koppers Co.), Coke Treatment: United States Patent 1928214, Sept. 26, 1933.

⁵⁸ Gifford, R. D., The Clarification of Colliery Waste Water: Coll. Guard, vol. 148, 1934, p. 350.

⁵⁹ Samuel, J. O., The Flocculation of Washery Water: Coll. Guard., vol. 145, 1932, pp. 939-941, 985-987.

⁶⁰ Petersen, W., and Gregor, F., The Clarification of Coal Washery Slimes: Glückauf, vol. 68, 1932, pp. 621-630.

⁶¹ Peterson, W., Works Experiments on the Clarification of Slurries from Bituminous-Coal Washerries: Glückauf, vol. 70, 1934, pp. 125-131.

⁶² The Institution of Mining Engineers, Utilization of Coal Committee, Slurries: Mem. 14, March 1934, 3 pp.

⁶³ Piersol, R. J., Briquetting Illinois Coals without a Binder by Compression and Impact: Illinois State Geol. Surv., Rept. of Investigations 31, 1933, 70 pp.

report, has been published, but the Coppee Co. is working on a similar process in France and Belgium.⁶⁴

COMBUSTION

One of the outstanding papers of the year on underfeed combustion was contributed by the Pittsburgh Experiment Station of the United States Bureau of Mines. It showed that the rate of ignition is much more important in underfeed burning than it is in overfeed fuel beds and that it fixes limits to the outputs that can be obtained.⁶⁵

Activity is continuing in the development and installation of automatic domestic stokers. Domestic pulverized-coal burners are being tried out in Ohio, and the Anthracite Institute's "heat machine" was exhibited at the Century of Progress. The Philadelphia & Reading Coal & Iron Co. has developed a house-heating furnace for anthracite which automatically feeds the fuel from a storage bin and removes the ash to a receiver. It also provides hot water and may be combined with air-conditioning equipment for cooling the house in the summer. A commercial machine of this type has provided the world's first coal refrigerator in a Pottsville (Pa.) meat-storage warehouse.

Colloidal fuel.—No continuous practical use of oil-coal mixtures has been made since the trip of the Cunard liner *Scythia* across the Atlantic nearly 2 years ago. Patents⁶⁶ issued to this company indicate that they used a mixture of 180-mesh coal with a hydrocarbon oil having a fixed-carbon content of at least 5 percent without a stabilizer.

The British Fuel Research Station found that a suspension of 40 percent coal dust in a Persian fuel oil that had been converted to a dilute gel by the addition of 0.5 percent sodium stearate showed no appreciable separation after standing for 5 months at atmospheric temperature, whereas without the stabilizer the mixture began to separate after 20 days.⁶⁷ Benthin obtained stable mixtures of pulverized lignite and oil using stabilizers of 1.5 percent soap or creosote oil and small amounts of alkali soaps.⁶⁸ From 70 to 80 percent thermal efficiencies have been reported in tests on stationary boiler furnaces.⁶⁹ Several interesting reviews of the subject have appeared within the year.⁷⁰

Coal-dust engines.—The fuel economy obtained by the direct combustion of coal dust in the cylinders of internal-combustion engines continues to attract discussion. It is reported that a Government committee of experts is looking into the subject in Germany.⁷¹

⁶⁴ Colliery Guardian, A New Method of Upgrading Slack Coal: Vol. 148, 1934, pp. 352-353.

⁶⁵ Nicholls, P., and Eilers, M. G., The Principles of Underfeed Combustion and the Effect of Preheated Air on Overfeed and Underfeed Fuel Beds: Combustion, vol. 4, no. 12; vol. 5, no. 1, 1933, pp. 15-23; Trans. Am. Soc. Mech. Eng., vol. 56, 1934, pp. 321-336.

⁶⁶ Adam, R. A., Holmes, F. C. V., and Perrins, A. W., The Cunard Steam Ship Co., Ltd., Improved Dispersion of Coal in Oil: British Patent 396,432, Aug. 2, 1933.

⁶⁷ Wigginton, R., Oil-Coal Fuels: Fuel, vol. 12, 1933, pp. 291-292; Suspension of Coal in Oil: Report of the Fuel Research Board, Dept. Sci. and Ind. Research, H. M. S. Office (London), 1933, pp. 115-116.

⁶⁸ Benthin, G., Flow Coal from Lignite: Ztschr. angew. Chem., vol. 46, 1933, pp. 742-744.

⁶⁹ Schultes, W., Combustion Experiments with Flow Coal: Glückauf, vol. 68, 1932, p. 1198; German Trials with Coal Oil Fuel: Steam Eng., vol. 2, no. 5, 1933, p. 203; A New High Pressure Steam Generator: Eng. and Boiler House Rev., vol. 46, 1933, pp. 511-512.

⁷⁰ Brownlie, David, Colloidal Fuel: A Survey of the Present Position: Steam Eng., vol. 3, 1934, pp. 183-184. Tollemache, H. D., Pulverized Coal and Colloidal Fuel: Proc. South Wales Inst. Eng., vol. 49, 1933, pp. 163-198.

⁷¹ Maercks, J., The Use of Pulverized Fuel in Diesel Engines: Glückauf, vol. 69, 1933, pp. 1016-1023; Coll. Guard., vol. 148, 1934, p. 259. Martin, W. H., Comparative Costs of Rupa Coal-Dust Engine, Diesel Engine, and Coal-Fired Steam Power: Internal Combust. Eng., vol. 1, 1934, pp. 137-138; Marine News, vol. 20, no. 7, 1933, pp. 67-70; abs. in Mech. Eng., vol. 56, 1934, p. 170.

COMPLETE GASIFICATION

Oxygen enrichment.—Oxygen enrichment again is being tested for the production of producer gas. At the Tegel works in Berlin, Germany, a gas plant of commercial size has been operated under atmospheric pressure on brown-coal briquets and oxygen saturated with water vapor at 91° C. The Lurgi Gesellschaft has operated a test plant continuously for several months. At a gas pressure of 20 atmospheres 184 pounds of fuel per hour per square foot cross-section of shaft was gasified. The fuel column was 10 feet high. It is claimed that the advantages of the process more than outweigh the cost of the oxygen at a price of 5¼ d. per cubic foot.⁷²

HIGH-TEMPERATURE CARBONIZATION

The present low ebb in the construction of new coke ovens has not favored new developments of design. However, an interesting new idea is the "Still" process recently described by Dean.⁷³ The Still oven is provided with 10 or 12 gas-collecting pipes inserted into the middle of the charge from the top of the oven at equidistant intervals. Suction on these pipes maintains a pressure slightly below atmospheric. The gases and vapors evolved in the plastic layer are drawn through the uncoked coal instead of passing outward through the hot coke to the oven walls. Decomposition of liquid products is minimized, and the yields and quality of light oil and tar are said to be improved considerably. Results from commercial plants at Wolfsbank and Achenbach, Westphalia, Germany, indicate 30- to 40-percent increase in benzol, 10- to 20-percent increase in tar, and 15- to 25-percent reduction in ammonia.

The increasing demand for benzol in Germany has stimulated efforts to increase yields by decreasing decomposition of light oils in the hot space above the oven charge. Thau⁷⁴ describes two modifications of ovens in which collecting channels built into the tops of the ovens facilitate the rapid removal of benzol vapors from the hot space above the charge. Decomposition is reduced, and the yields of benzol are said to be increased 8 to 10 percent.

The Pittsburgh Experiment Station of the United States Bureau of Mines has continued at a restricted rate its studies of the gas-, coke-, and byproduct-making properties of American coals. Splint-coal bands from the Elkhorn bed in western Kentucky gave a higher yield and a stronger coke than was obtained from bright coal bands in the same seam. However, the yield of tar from the bright coal was greater than from the splint. The yield and quality of the gas from the two types of coal was nearly the same.⁷⁵

Properties of coke.—The Midland⁷⁶ and Northern⁷⁷ Coke Research Committees of England have continued active work on blending coals and determining the properties of the coke produced in small experimental ovens.⁷⁸ The Northern Committee has designed a new

⁷² Drawe, Gasification with Oxygen: Gas Jour., vol. 203, 1933, p. 95.

⁷³ Dean, H., The "Still" Process: Fuel, vol. 13, 1934, pp. 112-115.

⁷⁴ Thau, A., Increasing Benzol Yields from Coke Ovens: Brennstoff-Chem., vol. 15, 1934, pp. 41-45.

⁷⁵ Fieldner, A. C., Davis, J. D., Reynolds, D. A., and Holmes, C. R., High-Temperature Carbonizing Properties of Coal: Ind. and Eng. Chem., vol. 26, 1934, pp. 301-303.

⁷⁶ Midland Coke Research Committee, Report of Progress during 1933: Fuel, vol. 13, pp. 51-54.

⁷⁷ Annual Report of the Northern Coke Research Committee, Solving Problems by Cooperation: Gas World, Coking Sec., vol. 99, 1933, pp. 75-76.

⁷⁸ Mott, R. A., The Evaluation and Blending of Coals for Coke Making: Fuel, vol. 12, 1933, pp. 13-25.

apparatus⁷⁹ for the laboratory determination of combustibility in air of small samples of 10–20 mesh coke. The measure of combustibility is the minimum air current through the apparatus in cubic feet per minute that will maintain combustion in the sample for 20 minutes or more after it has been ignited by means of an electrical heater under standardized conditions.

Other investigators have continued their efforts to find chemical substances that can be added to the coal before coking to increase the combustibility or lower the ignition temperature of the resultant coke. Experiments at Leeds University⁸⁰ show that sodium carbonate lowers the ignition temperature of cokes prepared above 600° C. but has no effect on those made below 600°. Sodium carbonate, calcium carbonate, or iron oxide increased the reactivities of the cokes. Similar results were obtained by German investigators.⁸¹ White and Fox,⁸² of the University of Michigan, found that less than 10 percent of a sodium compound, such as sodium carbonate, mixed with carbonaceous fuel in a gas generator substantially decreased the amount of carbon dioxide in the producer gas and permitted a reduction of the operating temperature to about 925° C.⁸³

Light-oil recovery.—The activated-carbon light-oil recovery plant at Beckton, England, the largest in the world, is producing 3,000,000 imperial gallons of benzol annually, or 3. imperial gallons per long ton of coal coked.⁸⁴ The extraction efficiency is usually over 92 percent. The average over-all steam consumption has been 36.6 pounds per gallon, and the average rate of carbon replacement, 7.1 pounds per 1,000 pounds of benzol. Virtually all the organic sulphur is removed.

Parallel tests of oil absorption and activated carbon processes at Frankfurt-am-Main, Germany, showed higher recoveries and greater removal of organic sulphur compounds, hydrocyanic acid, naphthalene, and other undesirable impurities⁸⁵ by the activated-carbon process. Activated charcoal also is being used in Germany for the removal of phenols from crude gas liquors but does not appear as promising as the tricresyl phosphate process developed by I. G. Farbenindustrie. Tricresyl phosphate has 8 times the solvent power of benzene for phenol and 30 times the solvent power for the higher tar acids.⁸⁶

The direct recovery of commercial fractions of tar at coke ovens, using the sensible heat of the oven gases, has made further growth in Great Britain, where this process has been installed at several plants for the production of standard road tars.⁸⁷

⁷⁹ Blayden, H. E., Noble, W., and Riley, H. L., A Simple Laboratory Method for the Assessment of the Combustible Nature of Coke: *Gas World*, vol. 100, 1934, pp. 106–110.

⁸⁰ Parker, A., Kerr, H., and Marson, C. B., Influence of Various Factors on the Ignition Temperature, Reactivities, and Structure of Coke: *Trans. Inst. Gas Eng.*, vol. 78, 1928–29, pp. 240–248; vol. 79, 1929–30, pp. 50–103, 143–55.

⁸¹ Neumann, B., and van Ahlen, A., Influencing Reactivity of Pure Coke by the Addition of Certain Inorganic Substances likely to Occur in the Ash: *Brennstoff Chem.*, vol. 15, 1934, pp. 61–64.

⁸² White, A. H., and Fox, D. A., Producer-Gas Process using Sodium Carbonate: United States Patent 1948085, Feb. 20, 1934.

⁸³ Weiss, C. B., and White, A. H., Influence of Sodium Carbonate upon the Producer-Gas Reaction: *Ind. and Eng. Chem.*, vol. 26, 1934, pp. 83–87.

⁸⁴ Hollings, H., and Hay, S., The Recovery of Benzole by Active Carbon: *The Gas World*, vol. 100, 1934, pp. 189–193; *Chem. and Ind.*, vol. 53, 1934, pp. 143–55.

⁸⁵ Engelhardt, A., and Rüping, H., Improving the Purity of Manufactured Gas by Recovering Light Oils with Active Carbon: *Gas u. Wasserfach*, vol. 76, 1933, pp. 478–84; abstracted in *Gas Jour.*, as Recovering Benzole with Activated Carbon, vol. 203, 1933, p. 154.

⁸⁶ Tupholme, C. H. S., Tricresyl Phosphate as Solvent for Phenol Recovery from Gas-plant Effluents: *Ind. and Eng. Chem.*, vol. 25, 1933, pp. 303–304.

⁸⁷ Cooke, F., Progress in the Direct Recovery of Standard Road Tars and Other Tar constituents from Vertical Retort, Coke Oven, and Other Producing Plants: *Gas World, Coking Sec.*, vol. 93, 1933, pp. 50–56; *abs. in Ind. and Eng. Chem., News Ed.*, vol. 12, 1934, p. 16.

Gum deposits.—No entirely satisfactory method has yet been put into practice to eliminate completely the formation of gums in manufactured-gas distribution lines. Research over the last decade has shown that the sources of these gums are unsaturated hydrocarbons, such as styrene, indene, etc., which, in the presence of small amounts of oxygen and even smaller concentrations of nitric oxide, oxidize and polymerize to form gums or resins, which plug up pilot lights and make meters run slow.⁸⁸ In order more readily to study the effect of small percentages of nitric oxide in gases, Fulweiler developed an apparatus in which oxygen and gas are mixed in equal proportions by volume, and the NO₂ thus formed is determined colorimetrically.⁸⁹

Sulphur recovery processes.—The substitution of ammonia from the weak ammonia liquor for soda in the Thylox process for gas purification at Racine, Wis., has made it possible to dispose of the sulphur as a profitable byproduct.⁹⁰

In England the decline in the returns from ammonia stimulated Imperial Chemical Industries, Ltd., to the development of the "Auto" process, which simultaneously removes hydrogen sulphide, hydrogen cyanide, and over half of the ammonia from coke-oven gas.⁹¹ The process depends on the reduction and oxidation of iron ammonium ferrocyanide, which is formed by scrubbing the gas initially with a solution of ferrous sulphate. Free sulphur is recovered by flotation. The total costs, estimated on the basis of an experimental plant, are reported as about 0.41 d. per 1,000 cubic feet of gas.

Recent German developments in dry purification, using towers and extracting the sulphur at the plant, are reported to have economic advantages over wet-purification methods.⁹² Of special interest in this connection is the Raffloer dry purification process described by Thau.⁹³ Specially prepared iron hydroxide is formed into strong porous balls about five-eighths to seven-eighths of an inch in diameter. These balls are packed into cylindrical towers, thus permitting high gas velocities with very low back pressure. The sulphur-saturated balls are removed from the towers, the sulphur leached out and recovered for the market, and the regenerated balls returned to the towers. An experimental plant is located at the Concordia colliery near Oberhausen on the Rhine.

Gas as motor fuel.—The use of compressed gas as motor fuel continues to receive active support from the manufactured-gas companies in England.⁹⁴ Several gas filling stations have been established, and certain bus and trucking lines are using gas for demonstration or

⁸⁸ Brown, R. L., Gum- and Resin-Forming Constituents in Artificial Gas: Proc. Am. Gas Assoc. Monthly, vol. 4, 1922, pp. 435-436; Gummy Deposits in Gas Meters: Proc. Am. Gas Assoc., vol. 6, 1924, pp. 1353-1411; Some General Considerations of the Gummy Meter Problems in the Gas Industry: Am. Gas Assoc. Monthly, vol. 5, 1923, pp. 309-316. Ward, A. L., Jordan, C. W., and Fulweiler, W. H., Gum Deposits in Gas-Distribution Systems: I, Liquid-Phase Gum: Ind. and Eng. Chem., vol. 24, 1932, pp. 969-977; 1238-1247; vol. 25, 1933, pp. 1224-1234.

⁸⁹ Fulweiler, W. H., The Gum Problem; Recent Developments: Proc. Am. Gas Assoc., 1933, pp. 829-846. McBride, R. S., Making Sulphur in City Gas a Profitable Byproduct: Chem. and Met. Eng., vol. 40, 1933, pp. 398-401. Denig, Fred, Gas-Purification and Ammonium-Sulphate Manufacture: Proc. Am. Gas Assoc., 1933, pp. 903-912; New Ideas on Gas Purification and Sulphate Manufacture: Gas Age Record, vol. 71, 1933, pp. 593-596, 604. Denig, Fred, and Powell, A. R., Liquid Purification of Gas and Some Recent Developments: Proc. Am. Gas Assoc., 1933, pp. 913-925.

⁹⁰ Smith, Frank F., and Pryde, D. R., A Wet Process for the Removal of Hydrogen Sulphide from Coke-Oven Gas: Gas World, Coking Sec., vol. 100, 1934, pp. 44-46.

⁹¹ Rettenmaier, A. R., Economics of Dry and Wet Gas Desulphurization: Glückauf, vol. 70, 1934, pp. 228-232.

⁹² Thau, A., Dry Gas Purification with Sulphur Recovery: Coll. Guard., vol. 148, 1934, pp. 151-153; New Process for Gas Desulphurization: Gas u. Wasserfach, vol. 77, 1934, pp. 33-35.

⁹³ Walter, C. M., Town's Gas for the Running of High Speed Internal Combustion Engines: Gas World, vol. 99, 1933, pp. 87-91; Coll. Guard., vol. 147, 1933, pp. 53-55; Gas for Internal-Combustion Engines: Gas Jour., vol. 203, 1933, pp. 302-304; The Possibilities of Compressed Gas: Indust. Gas Supp.; Gas World, vol. 100, 1934, p. 22.

experimental purposes.⁹⁵ Usually the gas equipment on a bus or truck consists of 6 to 8 steel containers of gas at 3,000 pounds per square inch pressure giving a cruising range of 60 to 70 miles.

LOW-TEMPERATURE CARBONIZATION

Foreign developments.—After a few years of comparative indifference increasing interest is being shown in the upgrading of low-ash, fine sizes of coal by low-temperature carbonization at the mine. The Utilization of Coal Committee of the British Institution of Mining Engineers, after consideration of the economics of the situation and assuming that a suitable technical process is available, concludes that the manufacture of a low-temperature coke of good quality from cheap small coal should prove a profitable undertaking for coal companies but that, with future growth of the industry, the profits might decrease because of the equalizing of prices of small and lump coal.⁹⁶ In general, the low-temperature plants operating at present are situated at mines and working under the conditions prescribed by the committee.

The three Coalite plants⁹⁷ of Low Temperature Carbonization, Ltd., at Barugh, near Barnsley, Doncaster, and at the South Metropolitan Gas Works in London are operating at full capacity. The Bussey plant at Glenboig near Glasgow has been started up again by another company.⁹⁸ A 50-ton capacity battery of Hird retorts is being installed at the Nostell Colliery, Ltd., near Wakefield. The retorts, of cast-iron heat-resisting metal, have a capacity of 2¼ tons of coal and operate on the intermittent, externally heated system.⁹⁹

Although the first Illingworth plants in England failed to operate successfully owing to faulty design, these defects have been corrected in later plants erected in France and Italy. During the year the plant at Courrières has been doubled in size to give a capacity of 250 tons a day. Another 250-ton plant was started up in September 1933 at Maubeuge, and the plant in Italy is in operation.¹

Because of the lack of home supplies of anthracite many French low-temperature processes are directed toward the production of so-called artificial anthracite made from washed bituminous fines. In several of the processes, the material is briquetted with pitch binder and recarbonized at low temperatures. Most of the processes mentioned in the 1932-33 Minerals Yearbook, as well as several new ones, are operating at various mines.²

The outstanding new process of the year is the Koppers mid-temperature or high-temperature (as desired) coking plant at the

⁹⁵ Gas Age-Record, Operating Motor Vehicles with Compressed Coal Gas: A Report on Experiments Carried Out by the Newcastle-upon-Tyne and Gateshead Gas Co., England, vol. 72, 1933, pp. 503-504. The Length of England on Compressed Gas-Converted Larry's Journey: Gas World, 670-Mile Test by Whitewood Chemical Co., and New Gas Filling Stations Established: Ind. Gas. Suppl., vol. 100, 1934, p. 22; Gas Journal, Wallasey Adapts Gas for Road Vehicles: Vol. 205, 1934, p. 299.

⁹⁶ The Institution of Mining Engineers, Utilization of Coal Committee, The Economics of Low-Temperature Carbonization at Collieries: Mem. 12, 1933, 7 pp.

⁹⁷ Fuel Economist, Progress of New British Industry; Smokeless Fuel: Petrol and Fuel Oil, vol. 9, December 1933, pp. 134-141.

⁹⁸ Iron and Coal Trades Review, Bussey Coal Distillation Co., Ltd.: Vol. 127, 1933, p. 1006.

⁹⁹ Chemical Age, The Hird Low-Temperature Carbonization Process: Vol. 30, 1934, pp. 246-247.

¹ Colliery Guardian, Illingworth, L. T., Plants: Vol. 143, 1934, p. 97.

² Colliery Guardian, Synthetic Anthracites: Vol. 146, Feb. 3, 1933, p. 209. Berthelot, Ch., The Present Technique of Low Carbonization in France and England: Génie civil, vol. 103, 1933, pp. 513-518, 543-545. Colliery Guardian, The "Thermax" Low-Temperature Carbonization Process: Vol. 147, 1933, pp. 254-255. Berthelot, Ch., Modern Methods of Carbonization at Low Temperature and of the Preparation of Synthetic Anthracite: Chim. et ind., vol. 23, 1933, pp. 18-44; Present Tendencies in Industrial Low-Temperature Carbonization of Coal: Chim. et ind., vol. 31, 1934 (in press).

Bruay mines near Bethune, France.³ Fifty ovens produced 130,000 tons of this coke in 1933. The process resembles that of the late Professor Parr,⁴ in that it is carried out in two stages, and the final carbonization is conducted at a medium temperature (700° C. inside oven wall) in existing types of high-temperature ovens.

The ovens at Bruay are of the H. Koppers hairpin type, each about 12 inches wide and 120 cubic feet capacity. The coking time is about 18 hours. The oven charge consists of a carefully mixed blend of dry-cleaned raw coal and low-temperature coke, each pulverized to particles not exceeding 1 millimeter in size. The low-temperature coke is made in rotary kilns at 475° C., after suitable roasting at 350° C. to reduce the caking properties of the coal.

Successful operation of the ovens at these lower temperatures is due to the improved heating system, which provides very uniform temperatures on all sides of the oven.

The product, called Carbolux, is discharged from the oven in massive single pieces. There is no central seam to break them in two. It is free from fissures, resistant to breakage, and almost as reactive as charcoal. The volatile matter ranges from 8 to 12 percent; the ignition temperature is 450° to 460° C. The shatter index over 1½-inch screen is 86 to 88 percent.

The fuel seems ideal for domestic use, but one wonders if a process that has a roaster and low-temperature carbonizer superimposed on an ordinary coke oven can compete with the coke oven alone making ordinary byproduct coke.

The Lecocq Co. has designed and built a full-size oven for mid-temperature carbonization at the Montrambert collieries.⁵ Ten to twenty percent of coke dust is blended with the raw coal charge. The coke produced at 700° C. inside oven-wall temperature contains 4 to 6 percent volatile matter, is easily ignited, and burns well in open grates. About twice as much tar is produced as with high-temperature carbonization. The gas, after being scrubbed for light oil, has a calorific value of 750 B.t.u. per cubic foot. A battery of these ovens is being built at Montrambert and at the New Brancepeth Colliery Co., Durham, England.

The British Fuel Research Station likewise is investigating carbonization at midtemperatures (600° to 800° C.). New brick F vertical retorts are being put into operation on such a research program on various coals.⁶ These retorts are 21 feet high, 6 feet 6 inches long, and 7 inches wide at the top, widening uniformly to 11 inches at the bottom.

American developments.—During the summer of 1933 the Pittsburgh Coal Co., through a controlled subsidiary, the Pittsburgh Coal Carbonization Co., constructed a plant for the production of low-temperature coke adjacent to the Champion No. 1 cleaning plant of the coal company at Champion, Pa., about 20 miles west of Pittsburgh. The process used is a modified form of the Wisner. The coal is oxidized on rectangular multiple hearths and carbonized in a rotor 6 feet inside diameter by 84 feet long. The capacity of

³ Koppers, Heinrich, Recent Developments in Coking Practice: Coll. Guard., vol. 147, 1933, pp. 724-728, 770-773, 825-827; Jour. Inst. Fuel, vol. 7, 1933, pp. 13-28; discussion, pp. 57-66; Gas Jour., vol. 204, 1933, pp. 267-272. Topholme, C. H. S., Free-Burning Domestic Coke from Coke Ovens: Ind. and Eng. Chem., News Ed., vol. 11, 1933, p. 342.

⁴ Parr, S. W., Low-Temperature Carbonization of Coal: Ind. and Eng. Chem., vol. 21, 1929, pp. 164-168.

⁵ Cerkel, H. O. H., The Manufacture of Household Coke in Coke Ovens: Gas Jour., vol. 204, 1933, pp. 831-833.

⁶ Fuel Research Board Report: Dept. Sci. and Ind. Research, H.M.S. Office, (London), 1933, pp. 70-72.

this unit is 95 tons of raw coal per day, dry weight. Operation was begun on November 1 and has been continuous throughout the winter. The fuel produced is a low-temperature coke of 12 to 14 percent volatile matter. The production passing over $\frac{3}{4}$ -inch square-hole trommel screen is marketed. The minus $\frac{3}{4}$ -inch material is pulverized in a hammer mill and recirculated through the carbonizer. The gas produced is used in roasting and carbonizing and for the operation of a tar still. The only byproducts now produced are tar and products obtained from the distillation of this tar. The raw coal used in the process is cleaned fine coal from the Champion No. 1 cleaning plant. The coke produced is a strong, dense, and easily ignitable smokeless fuel. It is on sale in Pittsburgh, Pa., Washington, D.C., and certain other cities under the name of Disco.

The Hayes process has been operated intermittently at the mines of the Ben Franklin Coal Co., Moundsville, W.Va., to supply low-temperature char as needed for the reduction of zinc ore at a near-by smelter.

The Lurgi plant of the Lehigh Briquetting Co. near Dickenson, N.Dak., is operating at a capacity of about 80 tons of briquets per day, using 250 tons of raw lignite, including that used for power and distillation of the tar. Eight to ten gallons of tar are recovered per ton of briquets made. The tar contains 50 to 60 percent of tar acids suitable for wood preserving and disinfecting. During the first 3 months of 1934, 6,300 tons of briquets were made.

HYDROGENATION AND LIQUEFACTION OF COAL

The commercial large-scale production of gasoline from bituminous coal is now assured in England. Fortified by a Government guaranty of continuation of the present preference in tax of 8d. per gallon for the next $4\frac{1}{2}$ years, or for 9 years if the tax is reduced to 4d., Imperial Chemical Industries, Ltd., has begun erecting a commercial plant at Billingham at an estimated cost of \$11,000,000. The plant is expected to produce 100,000 tons (37,000,000 United States gallons) of gasoline annually by treating 400 long tons of coal per day. Including the coal used for power, steam, and hydrogen production, the total coal consumption will be 1,000 long tons per day,⁷ or 3.15 tons of moisture- and ash-free coal per ton of gasoline produced. The over-all thermal efficiency is 40 to 45 percent, and the cost at the plant (including fixed charges and depreciation), based on coal at \$3.10 per ton, is estimated at 11 to 12 cents per United States gallon of gasoline.

The vertical converters of the new plant are to be double-walled, consisting of an inner electrically heated thin-walled tube, in which the reaction is carried on, and an outer thick-walled pressure-resisting tube. The space between is insulated so that the temperature of the outer tube does not exceed 150° C., above which hydrogen would weaken the tube. The working pressure is maintained on both sides of the inner tube. The most effective catalyst in the

⁷ Tupholme, C. H. S., Progress in Production of Motor Spirit by Coal Hydrogenation: *Ind. and Eng. Chem., News Ed.*, vol. 12, 1934, p. 107. *Petroleum Times, Oil from Coal Plant*: Vol. 31, 1934, p. 112. Ormandy, W. R., and Burns, J., *Oil from Coal*: *Jour. Inst. Fuel*, vol. 7, 1933, pp. 71-84; *Coll. Guard.*, vol. 147, 1933, pp. 749-751. Gordon, K., *The Hydrogenation of Bituminous Coal, The Billingham Process*: *Abstract, Coll. Guard.*, vol. 147, 1933, p. 156. Lessing, R., *The Future for Oil-Coal Fuel*, Discussion at the World Petroleum Congress, London: *Chem. Age*, vol. 29, 1933, pp. 128-129.

first, or liquid phase, is a tin salt; in the second, or vapor phase, molybdenum impregnated on a carrier gives best results.

The Leuna Works of the German I. G. Farbenindustrie now has a capacity of producing 350,000 tons of gasoline per year from brown coal and brown-coal tar, and additions are contemplated for the hydrogenation of bituminous coal.⁸

It is reported that the Korea Nitrogen Co. is planning to erect a plant for coal hydrogenation in Japan with the aid of a State subsidy. It is to be completed in 1935 and will have a capacity of 500,000 tons of gasoline annually.⁹

The Australian Government likewise is considering the question of financial assistance to companies wishing to engage in the manufacture of oil from coal or shale.¹⁰

Much research on the hydrogenation of coal and tar has been conducted in various countries during the past year. The British Fuel Research Station¹¹ continued its studies on the fundamentals of coal hydrogenation, particularly the effect of temperature, dispersion media, catalysts, and stirring. In the absence of a liquid medium, compounds of germanium, tin, and lead greatly increased the degree of liquefaction by increasing the speed of the reaction at lower temperatures.

Dispersion of the coal in a liquid medium and the use of catalysts increase the yield of oil. The Mines Department of Canada found metallic copper and molybdc oxide effective catalysts in reducing coke formation in the hydrogenation of low-temperature tar.¹² Blom recently rendered four noncoking South African coals strongly coking by hydrogenating them under pressure for 5 hours at 380° to 395° C.¹³

The Imperial Fuel Research Institute of Japan has published papers showing that methane is decomposed rapidly at 600° to 800°C. with an excess of steam in the presence of nickel catalysts promoted with various other oxides or with potassium carbonate.¹⁴ Ando gives the temperature conditions, catalysts, and products obtained in the hydrogenation of phenol and the phenolic oil in low-temperature tar.¹⁵

Bahr and Petrick¹⁶ found that the best yields of hydrocarbons from phenols, cresols, and naphthols were obtained at 360° to 380°C. with molybdc oxide catalysts. Mixtures of molybdc oxide with the oxides of zinc, aluminum, thallium, and chromium were investigated.

⁸ Institution of Mining Engineers (London), Utilization of Coal Committee, Summary of Progress no. 2: Dec. 31, 1933, 4 pp.

⁹ Iron and Coal Trades Review, Hydrogenation in Japan: Vol. 128, 1934, p. 228.

¹⁰ Jour. Soc. Chem. Ind., Oil from Coal: Vol. 53, 1934, p. 136.

¹¹ Horton, L., King, J. G., and Williams, F. A., The Progressive Action of Hydrogen on Coal: Jour. Inst. Fuel, vol. 7, 1933, pp. 85-102. Fuel Research Board, Hydrogenation of Coal Report: Dept. Sci. and Ind. Research, H.M.S. Office (London), 1933, pp. 94-103.

¹² Warren, T. E., and Williams, A. R., Report of Experimental Work on the Hydrogenation of Canadian Coal, Coal Tar, and Bitumen for the Production of Motor Fuel; I, Batch Experiments on the Hydrogenation and Cracking of Low-Temperature Coal Tar. Warren, T. E., and Bowles, K. W., II, Description of an Apparatus for Continuous Hydrogenation and Experiments on Coal Tar, Bitumen, and a Suspension of Powdered Coal in Coal Tar: Canada Dept. Mines, Mines Branch, Rept. 737-3, 1933, 31 pp.

¹³ Blom, I. J. B., The Influence of Pressure-Hydrogenation upon the Coking Constituents of Coal: Jour. Chem. Met. Min. Soc. South Africa, vol. 34, 1933, pp. 1-44.

¹⁴ Takenaka, Y., The Manufacture of Hydrogen from Waste Gas in the Hydrogenation of Coal: Jour. Fuel Soc. Japan, vol. 12, 1933, pp. 57-61.

¹⁵ Ando, S., The Catalytic Hydrogenation of Phenols under High Pressure: Jour. Fuel Soc. Japan, vol. 12, 1933, pp. 62-68.

¹⁶ Bahr, Th., and Petrick, A. J., The Catalytic Reduction of Tar Phenols to Benzene Hydrocarbons: Brennstoff-Chem., vol. 14, 1933, pp. 161-165, 187-193.

The effects of a large number of substances that have been examined for coal hydrogenation are reviewed in *Chemical Industry* for February 1934.¹⁷

The production of satisfactory lubricating oil by the partial hydrogenation of low-temperature tar has not been solved yet,¹⁸ although excellent lubricants are made by hydrogenation of petroleum.

SYNTHETIC HYDROCARBONS FROM GASES

Audibert¹⁹ has reviewed the various processes for the production of motor fuels by the catalytic hydrogenation of carbon monoxide and by the pyrolysis of methane. The Mülheim Coal Research Institute²⁰ has continued studies of the reactions involved in the production of synthetic fuels and has produced lubricating oil from a high-boiling fraction (Kogasin II) of the oil obtained in gasoline synthesis, by chlorination and condensation with aluminum chloride.²¹ The chemical utilization of coke-oven gases for the production of alcohols, ammonia, and solvent liquids is continuing at Bethune Mines in France.²² At present, the production of synthetic motor fuel from gases does not have as good commercial prospects as production from coal or coal tar by hydrogenation.

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¹⁷ Tupholme, C. H. S., *Catalysts for Coal Hydrogenation: Chem. Ind.*, vol. 34, 1934, pp. 119-120.

¹⁸ Tupholme, C. H. S., *British Fuel Research Board Investigates Production of Lubricating Oil from Low-Temperature Tars; Ind. and Eng. Chem., News Ed.*, vol. 11, 1933, p. 163.

¹⁹ Audibert, E., *Liquid Products from Coal: Rev. Ind. Min.*, 1933, pp. 444-468; 469-488; 501-508.

²⁰ Fischer, F., and Pichler, H., *The Effect of Carbon Monoxide and Carbon Dioxide on Hydrogenation in the Synthesis of Benzine: Brennstoff-Chem.*, vol. 14, 1933, pp. 306-310.

²¹ Fischer, F., and Koch, H., *Synthesis of Lubricating Oils from Kogasin: Brennstoff-Chem.*, vol. 14, 1933, pp. 463-468.

²² Vallette, F., *Synthetic Products Derived from Bethune Coals: Rev. Ind., Min.*, no. 302, 1933, p. 299.

