By Arno C. Fieldner

RECENT DEVELOPMENTS IN COAL PREPARATION AND UTILIZATION

SUMMARY OUTLINE

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The first annual review of this series (Minerals Yearbook 1932–33, pp. 433–445) presented the background for the new developments discussed in the subsequent years. Readers unfamiliar with the subject will find it helpful to read this initial review and those following in subsequent yearbooks.

The steady progress of coal research in the United States during 1936 is one of the gratifying features of the uplift from the depths of the depression. Fundamental and applied research in coal technology is now being conducted at a number of centers. Bituminous Coal Research, Inc., reports some 40 laboratories as engaged to some degree in research on coal and coal utilization. At least 10 of these laboratories may be considered major contributors to our knowledge of coal and advances in coal technology. This is a good start, but much remains to be done, as indicated by the report of the Committee on Bituminous Research Planning.

COMPOSITION, PROPERTIES, AND TESTING

Approval of the Tentative American Standard for classification of coal according to rank and grade has provided authoritative boundary lines between anthracite, semianthracite, low-, medium-, and

high-volatile bituminous coals, subbituminous coal, and lignite. Investigations on progressive changes in the properties of coal in relation to rank have shown that the amount of moisture retained by typical banded coals, after drying under standardized conditions (25° C. with air of 50 percent relative humidity), and the ease of chemical oxidation of the coals, as measured by standard potassium permanganate consumed, increases while the angle of polarization of light reflected from polished surfaces of vitrain decreases.

Several publications give analyses, petrographic composition, and carbonizing properties of North American coals and W. A. Bone's comprehensive revision of his pioneering book on the constitution and uses of coal were issued in the past year. Hoffmann has attempted to correlate the various systems of nomenclature used in coal petrography. Microscopical studies by other investigators have shown that vitrain (anthracyxylon) tends to go into the smaller sizes of coal and fusain concentrates in the fine dust. In several instances, the fusain contained considerably more phosphorus than the associated coals. Examination of the splint coals of the Upper and Lower Cedar Grove beds of West Virginia indicated that the granular opaque matter which characterizes thin sections of splint coals is derived from coniferous wood fibers. Further progress has been made in the correlation of coal beds by identification of spores and in the "float-and-sink" separation of the banded constituents of coal beds. About 1 percent germanium has been found in the ash of several Donetz coals.

Chemical constitution.—The Coal Research Laboratory of the Carnegie Institute of Technology continued its study of the constitution of coal by extracting with solvents and chlorination of a

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Pittsburgh bed coal; the close agreement between the properties of corresponding products of the benzene-pressure extract and the residue, and of the hydrogenation products of extract and residue, indicates that these materials are very similar in their essential chemical structure; and it was concluded that the coal structure is made up of fundamental units with an average molecular weight of about 300, held together in larger aggregates by some relatively weak type of linkage. These aggregates can be depolymerized or peptized and put into colloidal solution by the action of benzene, quinoline, aniline, anthracene, or certain heavy oils heated under pressure to temperatures well above their boiling points. Such solutions are especially suitable for the production of synthetic gasoline by the hydrogenation process. The various so-called "colloidal fuels" are stable suspensions of finely powdered coal in oil rather than colloidal solutions. Russian chemists have identified thioether sulphur as one of the organic sulphur compounds in coal.

Gas evolution in coal mines.—Mine-air samples taken automatically at 1-hour intervals over 24-hour periods in a number of Belgian mines showed that methane was evolved not only from the face but from fissures behind the face and from the waste. Some seams yielded no methane, whereas others gave off 6,000 cubic feet of methane per ton of coal mined. Breyre believes that these large amounts are difficult to explain on the hypothesis of adsorption by the coal, and Audibert, on the basis of experimentally determined sorption isotherms of methane in coal at 4°C and up to 150 atmospheres pressure, concludes that practically all the methane contained in coal is dissolved rather than adsorbed. (See Bureau of Mines Report of Investigations 3233, The Occurrence of Gases in Coals, by R. F. Selden, 1934, 64 pp.) Hoffmann found that the amount of methane evolved from boreholes decreased with descending rank of coal, and that the amount was greater for dull coal than bright coal in high-rank coals and the reverse in low-rank coals. Leprince-Ringuet has summarized recent researches, and others have discussed carbon dioxide and methane outbursts.

Spontaneous ignition and effect of low-temperature oxidation.—A Bureau of Mines investigation of the causes of anthracite mine fires found a direct correlation between the spontaneous ignitability of carbonaceous matter and the rate of carbon monoxide formation when the sample was heated in a stream of air.31 Studies of the oxidation mechanism and peroxide formation of two hydrocarbons which are components of tars and oils showed that the determination of double bonds in a fuel by means of the bromine or iodine number is not necessarily a measure of self-ignitability.32 For a given bituminous coal, allowed to heat spontaneously in an oxygen atmosphere,33 it was found that both the rate of oxygen adsorption and temperature rise were nearly linear functions of time, therefore, one may be predicted from the other with considerable accuracy. Mild oxidation of Pittsburgh bed coal34 was found to increase the strength of coke and to decrease the yield of tar very appreciably, long before any changes could be detected in proximate and ultimate analyses, heating value, and agglutinating value. The amount and rate of oxidation increased with descending rank of the coal, and fresh coal oxidized more rapidly than stored coal.35 Treatment of coking coals with oxygen at higher temperatures, up to 300° C., increased the rate of oxidation and the amounts of carbon monoxide, carbon dioxide, and water formed but decreased the amount of oxygen fixed in the coal.36

Plasticity and coking properties.—Measurement of the plastic properties of coal and their relation to coke formation have received considerable attention.37 From observed characteristics of the "transient" fusion of coal, together with its agglutinating index with sand, when coked under specified conditions, Gillet,38 claims a satisfactory means of predicting the mechanical properties of the coke to be expected in practice. Agde and Hubertus postulated from numerous extraction and microscopic studies that the colloidal structure of bituminous coal causes plasticity, swelling, and caking.39

Comparison by the Bureau of Mines of the Davis plastometer, Agde-Damm dilatometer, and the Layng-Hathorne gas-flow methods show that the plastometer gives the best data for the plastic range and the dilatometer for the preplastic period. A fairly good prediction of coke quality may be made from the plastometer results.40 Others report that dilatometer methods correlate well with the behavior of coals on both low- and high-temperature carbonization.41

Weathering, admixture of inerts, and variation of rate of heating produces a greater effect on the swelling, plasticity, and rate of decomposition of poorly coking coals than on good-coking coals.\textsuperscript{42} The best cokes are produced from those coking coals which give off the largest amount of gas throughout the plastic range.\textsuperscript{43} Poor coke may be caused by: (a) A large percentage of volatile matter at the end of the plastic range, and (b) a deficiency of plastic material to bind the coal particles sufficiently to give a nonabradable coke.\textsuperscript{44}

\textit{Ask fusion and clinkering}.—Although the direct determination of ash-softerning temperature is cheaper and more accurate than estimation from ash analysis, investigators continue to obtain data on the relation between the composition of ash and its fusibility.\textsuperscript{46} Combustion tests of anthracite in furnace equipment indicated that ash-softerning temperatures corresponding to various degrees of clinker formation were, respectively: 3,000° F., none; 2,810° F., small; 2,460°–2,550° F., bad.\textsuperscript{47} Ash-softerning temperatures are functions of compositions in terms of alumina, silica, lime, and ferric oxide on a sulfur trioxide-free basis. These are derived from detrital clay, kaolinite, calcite, and pyrite, as shown by petrographic examination of the separable mineral matter from Illinois and western Pennsylvania coals.\textsuperscript{48}

Different types of refractories have been found to have the following relative order of resistance to erosion by coal-ash slags: Forsterite, silica, chromite, magnesia, high alumina (diaspore type), high alumina (electrically fused type), high mullite (bonded type), cast mullite, and silicon carbide, no erosion occurring until the temperature of the refractory face exceeds the ash-softerning temperature.\textsuperscript{49} The DeGraaf micropyrometer method has been modified so as to furnish a permanent photographic record of the changes in the coal ash during the fusion interval.\textsuperscript{50}

\textit{Sampling}.—Mechanical methods for the collection of gross samples and their reduction\textsuperscript{51} to laboratory size are being more widely used and application of the theory of probability to coal sampling is resulting in a better understanding and interpretation of sampling problems\textsuperscript{42} and laboratory analyses.

\textsuperscript{45} The Carbonization of Vitrains and Their Mixtures: Fuel, vol. 15, 1936, pp. 43-47.
\textsuperscript{47} Davidson, W., \textit{Coke Research: Jour. West Scotland Iron Steel Inst.}, vol. 44, 1936, pp. 117-128.
\textsuperscript{56} Grumell, E. S., and Dunningham, A. C., \textit{The Sampling of Small Coal}: Fuel, vol. 15, 1936, pp. 55-59.
\textsuperscript{57} Guy, T. W., \textit{A Control Chart for Interpretation of Coal-Sampling Data}: Combustion, vol. 7, December 1935, pp. 32-33.
PREPARATION

Increased stripping and mechanical loading activities and more exacting market requirements necessitated further expansion of mechanical cleaning facilities despite further improvement in preparation at the face.

A new plant for recovering pyrite and coal from coal-washery refuse, employing ore jigs and concentrating tables, with a capacity of 75 tons of feed per hour, was put into operation at Mineral, Kans. About one-third of the waste from picking tables at Illinois mines can be recovered as marketable coal and a central Baum-type jig washery has been erected near Kincaid, Ill., to recover coal and pyrite from picking-table refuse produced at four nearby mines.

Differences in electrical conductivity and reflecting power of light of coal and refuse are being tried as substitutes for hand picking.

Drained high-ash washery sludge, containing 18 percent moisture and dry dust from dedusting plants, is used for generating power at mines in Indiana and Illinois. Experimental work in England indicates that the size composition of slack coal, and even of crushed coal, follows the Rosin-Rammler law of size distribution.

By means of this law, it is possible to express the size distribution of coal by two numbers instead of the many required in the conventional method of reporting screen analyses.


Wöhler, H., Theory of Photo-Electric Cells and Their Possible Applications in Mining in Germany: Kohle und Erz., vol. 33, 1936, pp. 155-164.


Dedusting, dewatering, and drying.—At the new cleaning plant of the Bell & Zoller Coal Mining Co., near Zeigler, Ill., which has a capacity of 1,000 tons per hour and uses the sand-floatation cone for coarse coal and pneumatic launder-flow tables for fine coal, the dust is removed during the latter operation and shipped separately or in combination with other sizes. The Pittsburgh Coal Co. dedusts through 3/4-inch pulverizer coal by aspiration after washing and heat drying. The Chicago, Wilmington & Franklin Coal Co. also dedusts pneumatically at 48 mesh and ships this product separately or in combination with other sizes. Dedusting is also being done wet by means of sprays on vibrating screens.

The Willow Grove No. 10 cleaning plant of the Hanna Coal Co. (Neffs, Ohio), the Delta Coal Mining Co. (Carrier Mills, Ill.), and the Roslyn-Cascade Coal Co. (Ronald, Wash.), among others, installed rotary-kiln-type heat-drying plants. The first two installations, although of the common rotary-kiln type, admit the hot gases through louvers around the periphery of the shell. A drier of similar design has been used previously in Sweden for drying charcoal.

In Germany a Government commission reviewed the physical and technical problems encountered in drying coal as bearing on the processes of briquetting, carbonization, hydrogenation, and pulverization. The Fleissner process for dehydrating lignite by heating with steam under pressure is being used in Germany and Austria.

Flocculation and settlement of solids in washery water.—One American washery is using lime and another is using amyleneaceous materials as flocculating agents to increase the rate of clarification of washery water. Although coal slurries contain very little material of colloidal dimensions, flocculation may be brought about by lyophilic colloidal-type flocculators such as starch and glue, but not by electrolytes. Certain slurries not amenable to such flocculents can be made amenable by prior treatment with very small quantities of wetting agents.

Numerous patented flocculating agents are being marketed in England, and considerable research on this problem is being carried out in England and in Germany.

Dust-prevention treatment.—Rapid growth occurred in the practice of treating coal with oil, calcium chloride, and other agents to render it dustless. Experiments in the firing of coals sprayed with oils

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indicated that ignition is attained more easily but that too much oil decreases air penetration through the fuel bed; efficiency was about 3.9 percent higher with oiled coal. The Interborough Rapid Transit Co. reported that there is no difficulty in grinding oiled coal for pulverized fuel but that no advantage is gained in ordinary firing operations.\textsuperscript{15}

\textit{Briquetting}.—Quite a number of retail coal dealers handling friable, low-volatile coals have installed “packaged-fuel” or other briquetting plants to dispose of fine coal;\textsuperscript{76} plants also have been built for anthracite fines,\textsuperscript{77} lignite,\textsuperscript{78} and bituminous coal.\textsuperscript{79} The Pierson process of making low-volatile coal briquets by impact without binder is to be tried on a commercial scale at Collinsville, Ill.\textsuperscript{80} In Germany and Austria, the Afpelbeck high-pressure roller press is used for making briquets without binder from brown coal and bituminous coal\textsuperscript{81} Krupp and the Lurgi Co. also have developed a “ring roller” press which subjects the powdered fuel to a pressure of 2,500 atmospheres, making firm briquets without binder. The Canadian Bureau of Mines has published a comprehensive review of history, commercial processes, research, and present status and costs of briquetting in North America.\textsuperscript{82}

\textbf{COMBUSTION}

\textit{Theoretical studies}.—From a mathematical analysis of fuel-bed reactions, Mayers concludes that the coefficient of heat transfer between the solids of the fuel bed and the air or gas stream, the thermal conductivity of the fuel bed, and the specific rate of the combustion reaction appear to depend almost entirely on the physical characteristics of the fuel bed and will be affected more by the size, size distribution, and porosity of the fuel in bulk than by its chemical characteristics. Ignition temperature and possibly coking reactions are the only properties characteristic of a particular fuel that are important in combustion calculations.\textsuperscript{83} With the aid of models, Rosin has made extensive studies on the effect of relative motion between fuel, air, and combustion gases on the speed of combustion, both for pulverized coal and for combustion on grates.\textsuperscript{84} Here again, physical considerations, such as size of fuel and turbulence of air current were dominating factors in speed of combustion. New methods of determining\textsuperscript{85} and interpreting the ignition temperatures of solid fuels have been advanced. Furnas\textsuperscript{86} proposes to measure reactivity in terms of the


\textsuperscript{78} Coal Age, Anthracite Industry Presses Drive on Cost and Product: Vol. 42, 1937, pp. 53–56.

\textsuperscript{79} Coal Age, Bituminous Preparation Registers Gains in Capacity and Methods: Vol. 42, 1937, pp. 72.


reaction-rate constants for the two equations: \( \text{C} + \text{O}_2 = \text{CO}_2 \) and \( \text{CO}_2 + \text{C} = 2\text{CO} \). Mayers\(^7\) suggests that the results of the measurement of the reactivity of carbonized materials to oxidizing atmospheres over a wide range of temperatures can be reported in terms of the two parameters \( b \) and \( E \) of the Arrhenius expression for reaction rate. An ingenious method for studying the combustion rate of carbon has been developed which involves the microanalysis of small gas samples withdrawn from the carbon surface inside the "film" overlying the carbon, whereby the variation of gas composition through the film may be determined.\(^8\)

Residential stokers.—Sales of small stokers increased considerably during 1936, and the studies sponsored by Bituminous Coal Research at Battelle Memorial Institute\(^9\) have shown that the two principal characteristics of a coal that determine its performance on small stokers are its caking and coking tendencies and its size range, and these are closely related. Relative total costs of coal, coke, oil, and natural gas, based on tests and survey conducted in Columbus, Ohio, were found to be in the following order: Oil, 177; natural gas, 151; bituminous coal (stoker-fired), 119; bituminous coal (hand-fired), 100; semibituminous coal (hand-fired), 97; coke (hand-fired), 95.\(^0\)

The Anthracite Institute Laboratory has developed a new furnace design in which the usual "combustion space" has disappeared, the combustion being complete within the bed of glowing coals. Further application of water-cooled surfaces in the fuel bed for the prevention of clinkers is being studied.\(^1\)

Large power plants.—Improvements in the quality of heat-resisting steel and the purity of feed water have permitted increase of superheated steam temperatures up to 950°-1,000° F., and steam generating pressure up to 2,000 pounds per square inch. Such a plant recently has been completed by the I. G. Farbenindustrie at the Leverkusen works. Pulverized coal is burned under the boilers, and the flue gases are cleaned free from smoke and fly-ash by electrical precipitation. The same effective cleaning of flue gas is done at the new Federal Central Heating Plant, situated adjacent to the fine Government buildings in Washington, D. C.\(^2\) At the new Fulham power station in London, sulphur compounds are removed from the flue gases with a lime treatment. The slag-tap furnaces, which are designed to remove ash as molten slag, are meeting expectations in the United States and are arousing the interest of German engineers.\(^3\) The Trinidad power station of the Texas Light & Power Co. has operated successfully for the past 10 years, using 100-percent lignite in pulverized form. Operating costs are said to have been favorable compared with fuel oil and natural gas during a period when there has

been a very large flush production of each within the State.\(^4\) Piersol\(^5\) has reviewed previous methods of smoke determination and has devised a new method, based on measuring the absorption of a standard beam of light with a Weston photronic cell and a galvanometer. He found a direct proportionality between the smoke index and the percentage of volatile matter in the Illinois and West Virginia coals investigated.

**Coal-dust engines.**—The high thermal efficiency of the Diesel-type engine has continued to interest German engineers in solving the problems of abrasion by the ash of the coal dust\(^6\) and the introduction of the fuel into the cylinders.\(^7\) Although extremely fine grinding of brown coal is not considered essential by Schor,\(^8\) Pawlikowski\(^9\) proposes to grind especially prepared very low ash coal in a liquid medium until the maximum diameter of the grains of ash-forming material is no greater than the film thickness of the lubricating oil on the cylinder walls. This pulp is then injected into the engine cylinder.

**COMPLETE GASIFICATION**

The production of carbon monoxide and hydrogen for the synthesis\(^1\) of motor fuels and chemical products has led British and European investigators to study gas-producer and water-gas reactions and equipment with a view to speeding up these processes by increasing gas velocity through the producer,\(^2\) slugging the ash and operating at higher temperatures,\(^3\) enhancing the reactivity of the fuel by adding sodium carbonate,\(^4\) and enriching the air with oxygen\(^5\) with or without increasing the pressure. Experiments in which powdered coke treated with 5 percent sodium carbonate was gasified in a stream of steam-oxygen mixtures led to the conclusion that at 1,000° C. and 5 seconds contact time, practically complete decomposition of steam is obtained.\(^7\) Impregnation of granular coke with 2 percent sodium

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carbonate and passing steam and oxygen, preheated to 700°, through it at atmospheric pressure gave a fuel-bed temperature of 1,070° C. and an oxygen consumption of about 35.5 cubic feet per therm of gas produced. Increasing the pressure of the steam-oxygen mixture to 20 or 30 atmospheres increased the methane content of the gas to about 15 percent, thus giving a calorific value to the gas, scrubbed free from carbon dioxide, of about 450 to 500 B. t. u. per cubic foot. A semicommercial plant, using this process (Lurgi) on brown coal, has been furnishing town’s gas at Zittau, Germany.

Underground gasification.—Results of the much-publicized Russian experiments on the underground gasification of coal have appeared in English. According to the authors, successful exploitation has proceeded underground at the Gorlovka mine (Donetz Basin), since August 1935, producing gas at the face of the coal by means of periodical blows of air with admixture of oxygen up to 35 percent. A typical composition of the gas obtained, in percent, is given as: Carbon dioxide 18, carbon monoxide 15, hydrogen 20, methane 3, and nitrogen 44; heating value, 150 B. t. u. per cubic foot. Water gas was made by alternately blowing with air and steam or steam and oxygen. Other underground gasification plants are to be established at various mines.

German interest in the encouragement of the use of home-produced automotive fuel is exemplified by several informative reviews of portable gas producers, their efficiencies with various fuels, their use on boats, trucks, and buses, and the problems presented in the purification of the producer gas.

HIGH-TEMPERATURE CARBONIZATION

Continued business improvement is reflected in new oven construction in the United States and abroad. Demand for domestic coke has grown, and a number of papers have been published dealing with improvement of its combustibility by suitable blending of coals, by lowering the coking temperature, and by the addition of sodium

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4 See footnote 4.
5 See footnote 6.
carbonate, lime, or other activating agents. Addition of sufficient lime to combine with the coal ash and \( \frac{3}{4} \) to 1 percent sodium carbonate to the coal before carbonization is said to activate high-temperature coke sufficiently to ignite readily and burn freely in an open grate, but not as well as low-temperature coke. The cost is about 1.8 to 2.5 shillings per ton of coke. It is believed that no damage will be caused to the oven refractories by the alkali, but continued practical operation is required to prove this assumption. Experimental oven coking tests indicate that the addition of finely ground durain (splint) or fusain to a highly plastic coking coal increases its hardness and size-stability, whereas the addition of coke dust tends to increase the size of coke but lowers its resistance to abrasion.\(^{17}\) Bureau of Mines tests showed that the shrinkage of coke in the range between 500° and 900° C. was about the same for a number of different coking coals.\(^{18}\)

**Purification of gas.**—The Koppers two-stage thyllox process for liquid purification of gas has been installed at the Belle (W. Va.), plant of the du Pont Co.\(^{19}\) Forty-five million cubic feet of blue water gas per day are purified to a residual sulphur content of 0.2 grain per 100 cubic feet. A Koppers sodium phenolate purification plant, designed to treat 22,000,000 cubic feet of refinery gas per day at 225 pounds per square inch pressure with removal of 95 percent of the hydrogen sulphide, is being built at Philadelphia for the Atlantic Refining Co.\(^{20}\) Improvements have been made in the operation of the detoxification plant at the Hameln Gas Works. German engineers are not in agreement on the economics of the process.\(^{21}\) Bunte\(^{22}\) has developed a new method for study of fouling and revivification of oxide in the dry purification process. It consists in supplying measured volumes of the reactants, hydrogen sulphide and oxygen, to the sample maintained at constant temperature at controlled pressures; the course of the reactions is followed by pressure measurements. The method is adapted to the study of the effect of temperature, moisture content, and alkalinity on the activity and life of the purifying material.

**Recovery of benzol and tar.**—Sixty pounds of activated carbon and 30,000 pounds of steam per 1,000 gallons of crude light oil recovered

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are used at the Beckton Gas Works, probably the largest in the world using active charcoal. Three million gallons of benzol are recovered per annum. Use of activated carbon at other gas works is increasing. The direct recovery of tar, involving the spraying of hot tar into hot oven or retort gases and fractional condensation (Cooke process), has been in successful operation at three plants of the Manchester Corporation for several years. H. Koppers has adapted the pipe still of the petroleum industry to the continuous distillation of tar. Several German plants and one at Beckton, England, are being installed. The gas leaving the condensers is hot and contains a large amount of tar fog; the fog is removed by electric precipitators operating at 85° to 95° C.

LOW-TEMPERATURE CARBONIZATION

Foreign developments.—Low-Temperature Carbonization, Ltd., of Great Britain raised its dividend rate from 3.5 to 6 percent and completed a 288-retort, 500 tons coal per day “coalite” plant at Bolsover colliery. This is the world’s largest low-temperature carbonization plant for bituminous coal and the fourth operating on the Parker process. The other three are at Barugh, Doncaster, and East Greenwich (London). The total capacity is about 1,400 tons of coal per day. A process originally developed in America for the distillation of oil shale is being tried by Coal Research Syndicate, Ltd., in a pilot plant capable of carbonizing 70 tons of coal per day, at the Mansfield Colliery. The coal is heated in two vertical, firebrick-lined, steel retorts, by downward passage of hot gases produced by burning part of the enriched gases taken off from the base of the retort. After the distillation zone has reached a point about two-thirds of the way down the charge (12 hours after the retort is charged), the air supply is cut off, and the remainder of the charge is carbonized by maintaining gas circulation. None of the 15 or more processes proposed in recent years for the carbonization of mixtures of coal and oil has attained proved commercial success. Coal & Allied Industries, Ltd., operating the Stephenson-process pilot plant at Seaham Harbor, has failed financially; the National Coke & Oil Co., Ltd., which developed the “Cannock or Mitford process” at Cannock and Tipton, has built a larger plant at Erith said to have a capacity of 1,000
tons of coal per day; Blümmer has proposed a process for the production of colloidal fuel whereby equal parts of coal dust and oil are mixed and heated stepwise to 450° C. under a pressure of 25 to 30 atmospheres. Extraction, pressure cracking, low-temperature carbonization, and distillation take place simultaneously, and high yields of light oil and fuel oil are said to be obtained with but little evolution of gas.²⁵ A national drive for home-produced motor fuels in Germany has created renewed activity in low-temperature carbonization and the recovery of primary tar suitable for hydrogenation. Forty-five coke ovens in the Ruhr are being modified for exhausting gas and tar fog as soon as formed to minimize thermal decomposition.²⁶ The rotary retorts developed some 15 years ago have disappeared entirely. The present processes for bituminous coal, as described by Thau, use externally heated, intermittently charged retorts. Two Krupp-Lurgi system experimental plants, of 30 to 40 tons coal per day each, have been installed, one at the Amalie mine near Essen and the other in the Saar. These ovens are made of welded-steel plates and consist of alternating rectangular carbonizing cells and heating flues. The cells containing the coal are about 3 inches wide, 6 feet high, and 6 feet long, tapering to a greater width at the bottom. Local overheating of the steel plates is avoided by having an external combustion chamber and circulating the hot combustion gases in the flues between the cells by means of a blower. Carbonizing time is 4 to 6 hours. The BT, the Berg, and the Hinselmans processes, in which coal is carbonized under pressure, are being tried in small pilot plants. Brown coal always has been carbonized at low temperatures. Two new types of carbonizers, the Giessen and the Lurgi, were introduced after the war. In the former, the dried brown coal is carbonized while descending in a thin stream on the outer surface of a vertical, revolving, corrugated cylinder of special alloy-iron, heated on its inner surface. The distillation gases are not diluted by the combustion gases. In the Lurgi carbonizer, the brown coal is heated by direct contact with hot combustion gases circulated through the charge. Consequently, the distillation gases are diluted with combustion gases, and light-oil recovery is reduced. Some 30 Giessen retorts, each of 150 metric tons raw brown-coal capacity per day, and about 40 Lurgi units of 500 to 600 metric tons each per day are installed or under

construction in Germany at present. The Lurgi process also is suitable for lignite and noncaking bituminous coal, and about 15 units have been erected outside of Germany. In Japan, low-temperature coke has not been able to compete with charcoal as a domestic fuel. It has found some use for blending with coal for the production of metallurgical coke and for making water gas. Four plants have been erected. Success in the medium-temperature carbonization of coal in narrow byproduct-type coke ovens led to the construction, at the New Brancepeth Colliery in England, of an experimental battery of narrow ovens following three different designs—Kemp, Lecocq, and Cellan-Jones—which could be operated at temperatures down to 500° C. With the inside oven walls at 600° C., the coking time was 26 hours, and the coke contained about 9 percent volatile matter. On account of the long coking time and the low oven capacity, the production costs are estimated to be twice that of high-temperature coke.

American developments.—The Lehigh Briquetting Co., at Dickinson, N. Dak., has increased the capacity of its plant for the carbonization of lignite by the Lurgi process to 60,000-70,000 tons of briquets per annum. The plant of the Pittsburgh Coal Carbonization Co., at Champion, Pa., using a modified Wisner process, ran continuously during the year, producing about twice as much smokeless fuel ("Disco") and byproducts as last year.

Tar oils as Diesel-engine fuel.—Experiments with variable-compression Diesel engines by the Low Temperature Coal Distillers Association of Great Britain are said to have led to the solution of the problem of lowering the spontaneous ignition temperature of low-temperature tar without lowering the flash point. Experiments at the Bochem Mining School in Germany with various fuels led to the conclusion that the Diesel motor can be run on coal-tar oil when in hot condition, but that 100-percent coal-tar oil does not give complete combustion when the load fluctuates and therefore is not well-suited for mine locomotives. However, a mixture of refined tar oil with 10 percent paraffin oil functioned satisfactorily and gave 29 percent thermal efficiency and higher mileage per gallon than either gas oil or paraffin oil alone. For positive starting in cold weather an addition of 25 to 30 percent paraffin oil was necessary. It also is possible to use coal-tar fuel for air-cell motors by heating the entering air with a "hot-spot."

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HYDROGENATION AND LIQUEFACTION

The total German capacity for the production of gasoline by the hydrogenation of low-temperature tar, lignite, and bituminous coal was said to be about 800,000 metric tons of gasoline per annum on January 1, 1937.44 This production consisted of 300,000 tons (350,000 tons annual capacity) from tar and brown coal at the Leuna plant,45 and 150,000 tons from bituminous coal at the Ludwigs- 
haven plant, both belonging to the I. G. Farbenindustrie; 50,000 tons from bituminous coal by the Hydrierwerke Scholven, A. G., at Gel- 
senkirchen, Ruhr (ultimate capacity, 125,000 tons);46 150,000 to 170,000 tons each from brown-coal tar by two plants operated by 
Braunkohle-Benzin A. G., Brabag, one at Bohlen, near Leipzig, the 
other at Magdeburg.47 An important recent development by the Mathias Stinnes Mühlheimer Bergwerke Verein in the Ruhr is the in- 

gstallation, on an industrial scale, of the Pott and Broche process in 
which equal parts of coal and 50 percent tetralin plus 50 percent 
phenols are heated at 375°-400° C. for 3 hours under a pressure of 
about 70 atmospheres, due to gases formed in the process itself. It 
is designed for the production of 30,000 to 50,000 tons of Diesel motor 
fuel per annum.48 An alternative primary liquefaction process (Uhde) 
using tar oil as the solvent and coke-oven gas as the source of hydrogen 
(instead of obtaining hydrogen from the tetralin) is being tested on a 
pilot-plant scale.49 Laboratory studies on the extraction of coal by 
various solvents indicate that depolymerization, followed by colloidal 
solution, occurs when an appreciable fraction of the coal is dissolved 
by solvents such as tetralin or coal-tar fractions; and that liquids of 
medium dipole moment and dielectric constant produce the most 
marked solvation.50

One hundred thousand tons of gasoline were produced from creo- 
sote oil, low-temperature tar, and bituminous coal by the hydrogena- 
tion plant of Imperial Chemical Industries at Billingham, England, 
during the first year of operation, ended May 1, 1936.51 An experi- 
mental plant for the hydrogenation of 1 to 2 tons per day of coal tar

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44 German Correspondent: Chem. and Met. Eng., Germany’s Motorization Program and Synthetic 
Motor Fuel and Rubber: Vol. 43, 1936, pp. 618-619. Wright, C. W., Germany’s Capacity to Produce 
pp. 46-50; Mineral Trade Notes, vol. 3, no. 5, Nov. 20, 1936, Spec. Suppl. 4, pp. 19-27. For recent reviews 
of methods and economics of producing motor fuel from coal by the Bergius coal hydrogenation and the 
Fischer synthetic processes, see: Berthelot, Ch., Carburants de synthèse et de remplacement, Dunod, 
92, Rue Bonaparte (VI), Paris, 1936, 330 pp.—Respective Advantages and Disadvantages of the Bergius 
and Fischer Processes Compared: Chlor. et Ind., vol. 35, 1936, pp. 762-791. Schlustmann, O., and Kop- 
penberg, H., The Industrial Production of Motor Fuels from Coal in Germany: 3d World Power Confer- 

45 Pier, M., The Manufacture of Motor Spirit by the Catalytic Hydrogenation of Lignite Under Pressure: 
Génie civil, vol. 109, 1936, pp. 7-11.

46 Zehn Schriften des Oesterreich. Vereins von Gas und Wasserfachmännern, Mar. 14, 1936, p. 73; Gas 

47 See footnote 46.

48 Petroleum Times, Diesel Oil from Coal. Is Extraction a Better Avenue than Direct Hydrogenation? 


50 Agale, G., and Huber, R., Investigation of the Colloidal Structure of Bituminous Coals: Braun- 
kohlenarchiv, no. 46, 1936, pp. 3-30. Ashbury, R. S., Action of Solvents on Coal. Extraction of a Pitts- 
burgh Seam Coal with Aniline, Tetralin, and Phenol at Elevated Temperatures: Ind. and Eng. Chem., 

51 Smith, F. E., Plant for the Production of Petrol by the Hydrogenation of Bituminous Coal: Engineer- 
152, 1936, pp. 1112-1113. Hydrogenation. Vol. 154, 1937, p. 166; Cadman, John, Coal and a Great Experi- 
Association of Hamburg, Design and Manufacture of High Pressure Forgings: Vol. 122, 1936, pp. 1063-1064; 
p. 2.
has been operated by the British Fuel Research Station. In Japan, a plant for the production of 50,000 tons of gasoline per year is being erected by the Chosen Coal Industry Co., another with 20,000 tons capacity is being constructed at Fushun by the South Manchurian Railway, a third of 10,000 tons capacity is being planned by the Japanese Electric Co. in North Sakhalin, and a fourth of 25,000 tons capacity by the Mitsui Co. at North Kiushu. In France, plants having a combined capacity of 50,000 tons of gasoline per year have been erected at Bethune and Liévin. The Vallette process used at Bethune is the same in principle that employed in England and Germany but differs therefrom in that the large reaction chamber is replaced by a number of small-diameter tubes that are easily renewed. Lignites from the Rhone delta are amenable to hydrogenation at a temperature considerably lower than that required for bituminous coal. The Audibert process is used at Liéven. The Canadian and United States Bureau of Mines is operating small experimental plants for the continuous hydrogenation of about 100 pounds of coal per day, for determining the hydrogenation properties of North American coals.

Research on hydrogenation.—The Fuel Research Station of Great Britain continues to be the principal source of research papers on coal hydrogenation. Continuously operating semitechnical-scale plants, having daily capacities of 1 to 2 tons of coal or tar, are used for studies of the effect of such variables as temperature, pressure, catalyst, time of contact, etc. Phosphorus, nickel, chromium, or silicic compounds added to the molybdenum catalyst promote its activity for the reduction of phenol to benzol. Laboratory research in various countries has shown that the composition of the coal, the degree of dispersion, and the nature of the liquid medium greatly affect the hydrogenation process. The best medium for each coal appears to be water.


be its own liquid product.53 In the partial hydrogenation of young coals, spores and cuticles were unchanged; the hydrogenation products of the coals had a pitchy appearance and softened at temperatures well under the plastic range of the original coals.54 Russian chemists investigated the effect of various catalysts, temperatures, and pressures on the hydrogenation of primary tar, naphthalene, and tetralin.55 The best results on peat tar were obtained with molybdenum sulphide at 200 atmospheres pressure and a temperature of 430°-440° C.56 Gasolines were stabilized and completely freed from sulphur by hydrogenation at 440° C. and 20 atmospheres of hydrogen pressure in the presence of molybdenum sulphide and chromic oxide catalysts.57 The results of studies58 of the composition of hydrogenation products of primary tar and oil showing the percentages of olefins, hydroaromatics, aromatics, paraflins, and their boiling ranges, indicate that different final products such as fuel oil, Diesel oil, or gasoline may be produced according to market demands.59 A general review of the year's literature on hydrogenation leads to the conclusion that tar hydrogenation is advanced much farther commercially than coal hydrogenation, due to mechanical difficulties in dealing with solid materials.60

SYNTHETIC PRODUCTS FROM GASES

After 10 years of development work, the Fischer-Tropsch process61 for the synthetic production of gasoline from carbon monoxide and hydrogen has been placed in commercial operation in Germany. The following plants aggregating a total capacity of 115,000 metric

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tons of primary oils per annum are completed or under construction: The Rheinpreussen Colliery at Homberg, 30,000 metric tons primary products, consisting of gasoline, Diesel oil, soft and hard paraffin wax, oils for the production of domestic fats and other chemical uses, from blast furnace coke and coke oven gas; Ruhr Benzin, A. G. (subsidiary of Ruhchemie), at Oberhausen-Holten, and the Viktor Colliery at Castrop-Rauxel, each 30,000 tons of oil per year from coke; Braunkohle-Benzen, A. G., Brabag, at Ruhland, north of Dresden, 25,000 tons of primary oils from the gasification of brown-coal briquets; Mittel Deutsche Treibstoff und Oel Werke (subsidiary of Wintershall A. G.), at Kassel, 30,000 tons of primary oils from the gasification of brown coal. The Brabag and Ruhland plants were built by the Heinrich Koppers Co. of Essen. Gas containing two parts hydrogen and one part carbon monoxide by volume, suitable for the synthesis of motor fuel, may be produced (a) by converting part of the carbon monoxide in water gas with steam in the presence of activated iron oxide at 500° C., to carbon dioxide and hydrogen, and scrubbing out the carbon dioxide with water under pressure; (b) by alternately blowing steam-oxygen and steam-coal gas mixtures through an incandescent bed of coke (c) by passing natural gas mixed with steam over a nickel catalyst at 1,000° C. It is reported that the Kuhlmann Co. is erecting a Fischer-process plant in France and that the Mitsui Mining Co. is making a small commercial-scale installation at the Miike Colliery in Japan.

Research on oils and chemical products.—Japanese and other investigators have contributed a number of papers on the action of various catalysts and operating conditions on the Fischer synthesis.


75 See footnote 72.


77 Chemical Guardian, Coal Processing and Byproduct Treatment Development of the Koppers Coke-Oven Co.'s Processes: Vol. 153, 1936, p. 419.


82 Chemical Age, Oil from Coal in South Africa. Fischer-Tropsch Plant to be Erected: Vol. 36, 1937, p. 215.


and work has been done on the synthesis of lubricating oils.\textsuperscript{85} Methane and higher hydrocarbons can be formed from mixtures of carbon monoxide and hydrogen in the presence of metallic molybdenum, molybdenum sulphide alone, or a molybdenum sulphide-silica gel mixture.\textsuperscript{86} A timely and informative volume by Ipatieff,\textsuperscript{87} and other important contributions on high-pressure reactions have been published.\textsuperscript{88}

\textit{New uses for coal.}—Interesting new uses for coal proposed during the past year are use of (a) anthracite slush as the granular material that is mixed with clay and either common salt or calcium chloride for building so-called "stabilized roads"\textsuperscript{89}, (b) anthracite breaker waste as a light-weight aggregate for concrete;\textsuperscript{90} (c) production of a base-exchange material for water softening from bone coal by treating it with a sulphonating agent under the action of heat until the granules have expanded but not disintegrated, and removing the excess acid by washing;\textsuperscript{91} (d) ground coal as filler in road tars,\textsuperscript{92} and as a fertilizer ingredient;\textsuperscript{93} (e) manufacture of brick from fly-ash;\textsuperscript{94} (f) production of mellitic acid by the chemical oxidation of coal or graphite;\textsuperscript{95} and (g) production of active carbon for gas masks from durain (splint) coals.\textsuperscript{96}


\textsuperscript{89} Coal Age, Anthracite Industry Presses Drive on Costs and Products: Vol. 42, 1937, pp. 53-56.

\textsuperscript{90} See footnote 89.


\textsuperscript{92} Lougarre, J., Developments in the Use of Coal Filler in Hydrocarbon Binders: Sci. et Ind., Special Number in Route, 1936, pp. 108-109.

\textsuperscript{93} Peter, C., Soil Conditioner: U. S. Patents 2095999 and 2096900, Nov. 3, 1936.

\textsuperscript{94} The Steam Engineer, Pulverized Coal Fly-Ash for Brick Making; Vol. 5, 1936, pp. 280-281, 337-338.
