RECENT DEVELOPMENTS IN COAL PREPARATION AND UTILIZATION

By A. C. FIELDSER

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The first annual review of this series (Minerals Yearbook 1932–33, pp. 433–445) presents the background for the new developments discussed in the subsequent years. Readers unfamiliar with the subject will find it helpful to read the above initial review and the following one in the 1934 Yearbook.

COMPOSITION, PROPERTIES, AND TESTING OF COAL

Tentative specifications for the classification of coals by rank and by grade were adopted by the American Society for Testing Materials in 1934.1

Microstructure and petrography.—Stopes 2 has expanded her original classification 3 of the banded constituents of coals to include vitrain showing microscopic plant structure (Thiessen’s anthraxylon), which is given the name “pro-vitrain”; structureless vitrain is called “Eu-vitrain.”

The importance of determining the composition and properties of the constituent types of coal in a given bed, as exemplified by the bright and dull bands, is receiving the increased recognition it deserves.4 5 6 These layers often show wide variations in composition and coking properties. The bright bands are lower in ash and higher

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in coking properties than the dull bands. The differences between dull and bright coals become greater as the rank decreases.

The friable constituents of coal, such as fusain, concentrate in the coal dust which settles in mines, imparting a different degree of inflammability to these dusts than that of a representative pulverized sample of the lump coal.

The temperatures at which initial melting of certain constituents of coal takes place were determined at the Bureau of Mines by observing under the microscope thin sections of coal heated to various temperatures.

Chemical constitution.—Work with solvents has contributed further evidence of the presence of 6-atom carbon rings in the coal substance. The method of “rational” analysis, which depends largely on solvent extraction, did not prove useful as a test for predicting gas-, coke-, or byproduct-making properties of coals, when applied by the Bureau of Mines in its survey of coking coals. Teskey believes that during coal formation the humic acids pass through a series of compounds, each containing less oxygen than the preceding ones.

The Coal Research Laboratory of the Carnegie Institute of Technology, in its study of the constitution of coal, has developed equipment for the distillation of coal at temperatures up to 620° C. under a vacuum of 10⁻² to 10⁻³ mm of mercury with minimum decomposition of products, and for the pyrolysis of coal at controlled rates of heating to fixed maximum temperatures. It was found that the mechanism of coking involved competition between distillation and decomposition and that differences in the magnitude of their temperature coefficients were responsible for the increase in tar yield as the rate of heating was increased.

Decomposition temperatures and plastic properties.—Hibbott and Wheeler have described a method for estimating the decomposition temperature of bituminous coal, which involves raising the temperature of 1-gram samples of finely divided coal at the rate of 0.5° per minute and measuring periodically the volumes of gases withdrawn continuously by a vacuum pump. A sudden change occurs in the quantity of gases yielded by a coal when the decomposition point is reached. Lignites do not give a sudden evolution of gases at the decomposition point, but significant changes occur in the character of the gaseous and liquid products and in the solid residues. Kreulen

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determined the rate of increase in evolution of volatile matter for each 10° rise in temperature from 200° to 650° C. for 23 coals. The temperature of maximum evolution of gas varied with the volatile matter content of the ash- and moisture-free coal, irrespective of the degree of coalification. Shimomura developed an apparatus for the continuous measurement of the weight of volatile matter evolved on heating coal and applied this measurement, together with determinations of contraction or swelling in the plastic range, to determine the effect of blending coals.

The development of plasticity in coal on heating and its relation to coking have continued to interest European investigators. Bunte and Lohr, using the Layng-Hathorne modification of the Foxwell method involving resistance to the flow of nitrogen, conclude that the plastic behavior of a blend can not be predicted from that of the constituent coals. Scheutzenko describes an automatically registering apparatus for determining the swelling pressure and the upper and lower levels of the plastic zone of coal during coking. Arnv made further study of the dilatometer method of Audibert and Delmas and concludes that the method gives virtually all the properties necessary to determine the suitability of a coal for coking purposes. On the other hand, recent research by the Bureau of Mines, wherein plastic properties and extractability were determined for 30 coking coals which were tested at the same time as to carbonizing properties, indicates that none of these tests can replace carbonization tests in predicting the quality of coke obtainable from a given coal.

Ignition temperature and oxidation.—Although coal has no definite ignition temperature from the physicochemical point of view, investigators have continued to devise apparatus for measuring so-called ignition temperatures. Low-temperature (100°–120° C.) oxidation raises the ignition temperature, modifies the agglutinating power, changes the reactivity, and decreases the gas yield. The addition of moisture to coal accelerates the absorption of oxygen. The tendency of lignites to ignite spontaneously is related to the content of humic substances. Lignites which contain least humic materials approach bituminous coals in their resistance to spontaneous com-

20 Discussion of Plasticity in Industry: Ibid., pp. 2471-2477.
28 See footnote 8.
bustion. The average reducing power of nearly 50 anthracite samples between 900° and 950° was 57 percent, with an initial reaction temperature of 572° C. The average reducing power of five coke samples under the same conditions was 22 percent, with an initial reaction temperature of 715° C.\textsuperscript{32}

**Analytical and testing methods.**—Holmes\textsuperscript{33} has reported the results of sampling experiments which showed that serious errors are produced by segregation of pieces of different sizes and densities.

The American Society for Testing Materials has published a pamphlet containing the various methods of testing, definitions, and specifications for coal and coke, as approved by the society.\textsuperscript{34} The German Standards Committee has published a similar pamphlet.\textsuperscript{35} New methods or modifications have been proposed for determining sulphur,\textsuperscript{36} nitrogen,\textsuperscript{37} phosphorus,\textsuperscript{38} and ash in coal and coke. Fluorine was added to the list\textsuperscript{39} of elements found in coal by Lessing;\textsuperscript{41} it was collected in the ammonia liquor in a certain gas works where it corroded the porcelain tower fillings. Iodine originating from Ostrava coal was found in the blast-furnace dust at the Witkowitz iron and steel works in Czechoslovakia.\textsuperscript{42}

Methods for determining fusion temperatures of coals also have been studied by several investigators.\textsuperscript{43} Ternary diagrams have been developed by means of which approximate softening temperature may be predicted from the ash analysis.\textsuperscript{44} A chart showing the relation between the chemical composition of slags and their fluidities, data on samples from stations operating slag-tap furnaces, and tests for the disposal of fly ash by returning it to the slag bed have been published by the Bureau of Mines in cooperation with the American Society of Mechanical Engineers.\textsuperscript{45}

A simple roll test for determining the grindability of coal,\textsuperscript{46} based on the principle of increase of new surface measured in accordance with Rittinger's theory of crushing, has been proposed. Particle-


\textsuperscript{34} American Society for Testing Materials, Standards on Coal and Coke: September 1934, 108 pp.

\textsuperscript{35} German Standards Committee, Testing of Fuels: German Standards Publication 5011, 1934, pp. 1-22.


\textsuperscript{37} Raskin, L. D., Simultaneous Determination of Sulphur and Ash in Nonbituminous Coal: Fuel and Coke, 1934, pp. 201-204.


\textsuperscript{44} Thilo, E., Results of Analysis of Two Coal Ashes. Ztschr. anorg. allgem. Chem., vol. 218, 1934, pp. 201-209; Chem. Abs., vol. 28, 1934, p. 5960.


size distribution of the finer sizes is determined by the sedimentation-velocity method.

Small-scale laboratory-assay tests for determining the yields of coke, gas, and byproducts of coal have been in general use during the year for studying the suitability of coals for coking and for estimating probable yields to be expected in large-scale operation. The Bureau of Mines has published the results of a comprehensive investigation of the yields and properties of gas, coke, and byproducts obtained in the carbonization of 30 coals and blends of coal carbonized at temperatures from 500° to 1,100° C.  

**PREPARATION OF COAL**

**General features.**—Competitive conditions and code regulations gave added impetus to the installation of improved equipment for preparing and cleaning coal in 1934. Facilities for mechanical handling of anthracite and bituminous coal underground and the use of methods designed to improve preparation at the face increased. New or improved mining machines suitable for cutting thinner kerfs either horizontally or vertically, with refinements in methods for breaking down the coal, probably resulted in an increased size and a better quality of mine-run coal reaching the surface preparation plants.

The capacity of surface plants for preparing anthracite and bituminous coal by screening methods installed or contracted for during the year was reported to be about 7,800 tons per hour and that for mechanical cleaning equipment about 5,500 tons per hour. New preparation facilities were installed at 69 plants during the year, and 38 of these included units for cleaning part or all of the mine product; most of these involved only additions to existing plants. The new installations of washing and cleaning equipment included wet and dry units, with jigs of the Baum type apparently predominating in number. In addition 2 conical-type separators, 2 jigs, 1 air lauder, and 1 air-sand separator were installed. Hand-picking methods were replaced by treatment of coal up to 7 inches in size by jigs and up to 8 inches by cone separators.

The demand for smaller sizes of coal for use in small, automatic stokers increased. According to the United States Census Bureau sales of stokers by 83 manufacturers totaled 21,253 units compared with 14,810 stokers sold in 1933 and 9,571 in 1932. Seventy-eight percent of the sales in 1934 were domestic units, with a capacity of 100 pounds or less of coal per hour.

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70 See footnote 24.
Equipment for crushing coarse coal to meet the demand for smaller sizes and vibrating screens, with and without dedusting units, were installed at a number of preparation plants. In a new-type crusher coarse coal is broken with a minimum production of finer sizes by the application of pressure at selected points with a series of long, sharp-pointed rods or picks.

Flaky, bony material can be eliminated by properly operated tables provided the coal is coarser than 100-mesh; the material finer than 100-mesh is responsible for low table efficiencies. At the Sophia-Jacoba mine, Hückelhoven, Germany, coal sized between 3/8 and 3/4 inches is treated in a bath of heavy liquid, specific gravity 1.47, made by suspending a mixture of fine barite (barium sulphate) and clay in water. Heating to 35°C. reduces its viscosity and permits rapid settling and a sharp separation of impurities. The average yield by the process approaches float-and-sink yields closely and is about 4 percent higher than that given by jig-washing. The cost is slightly less than jigging.

Dewatering and drying.—A number of washeries installed heat driers, centrifugal driers, and dewatering screens during the year. The No. 11 mine washer, United Electric Coal Cos., Fidelity, Ill., installed vibrator screens to remove through 48-mesh undersize from the ¾-inch feed to centrifugal driers. The heat driers included a type in which a heated current of air is passed down through a bed of coal as it travels forward on a perforated endless conveyor. High-speed, short-stroke, horizontal vibrating screens equipped with wedge wire were used for dewatering washed coal.

Dedusting.—Several additional pneumatic dedusting plants were put in during the year. The contract has been awarded for a new installation at the Champion No. 1 mine, Imperial, Pa., of dedusters of English design, with a capacity for treating 150 tons per hour of through ¾-inch coal. The separation in the deduster will be made at about 48-mesh. Utilization of the dust produced by such units is still a problem at some plants. A survey at 20 mines in England showed that the dust was used for pulverized-fuel firing for power stations or at the mines, for which it is suitable after further pulverization or mixed with washed small coal and washery sludge for coking or combustion.

Flotation.—Several coal-mining companies continued semicommercial experimentation on froth flotation for cleaning coal sludge. At a washery of the Pittsburg & Midway Coal Mining Co., near Pittsburg, Kans., the process has been applied ingeniously to yield (1) cleaned coal for the market, and (2) cleaned clay tailings for use in supplying the heavy suspension required in the primary cone separator cleaning process. Research at the Northwest Experiment Station of the Bureau of Mines showed that under proper conditions ferrous and ferric sulphates were effective in depressing pyrite in the coal-flotation circuit and that the recleneing of coal froths for reduction of ash content was much more economical than dilution of the original feed sufi-
ciently to give a cleaned product of the same ash content by a single-pass treatment. 67

The first commercial installation of the vacuum-flotation process was made at a colliery in England, 68 in which the dust from a pneumatic deduster will be cleaned. Further studies made by the Fuel Research Board in England 59 showed that the process was not suitable for treatment of coals containing soft fireclay, which disintegrates readily in water, without preliminary decliming to remove the major portion of the clay before treatment; however, in some cases the clay can be flocculated with the aid of size or glue. 69

"Pressure flotation" 70 without reagent has shown some promise in laboratory-scale experiments; dry coal in air or other gas is subjected to 20 to 60 pounds per square inch pressure, water is added, and the pressure is released.

Flocculation and settlement of solids in washery water.—In a few instances lime has been added to the water in coal washeries in the United States to increase the rate of clarification of wash water, to prevent the loss of fine material, and to obviate the possibility of stream pollution. The Pacific Coast Coal Co., in Washington, recently has adopted this procedure at another one of its mines after obtaining satisfactory results in full-scale trials. An increased recovery of fine coal has resulted.

Further study and use of various flocculating agents have continued abroad. 62 Small-scale trials of a new filter, in which the filtering medium consisted of a layer of canvas stretched on porous rubber have proven highly successful. Raybould 63 recommends conditioning the washery water with electrolytes to reduce the slinging of clay particles and flocculation of the residual colloids to promote rapid settling in the cone. He states that the cost of reagents for treatment by the lime-starch-caustic soda process is about 21 cents per 1,000 gallons, or 16 cents per ton of dry recovered solids.

The Fuel Research Board, England, 64 in experimental work using gelatin in the form of a glue as a flocculating agent found that of 3 different washery slurries treated 2 showed an increased rate of settlement on the addition of small quantities of gelatin but with the third the addition was disadvantageous. These results show that the best flocculating agent must be determined at each washery. After 12 and 24 hours of operation 65 of a semilarge-scale experiment with glue in a continuous washery circuit the flocculated slurry contained 0.1 and 1 percent solids. Flocculated slurry forms a porous filter cake

70 Department of Scientific and Industrial Research, work cited, p. 41.
61 See footnote 60.
which promotes high capacity and facilitates removal of the cake from the filter fabric.\textsuperscript{66}

The Fuel Research Board has continued its studies of the settlement of washery slurry without the addition of flocculating agents. Using a tank of rectangular section with the feed admitted at one end they were able to reduce the size of the tank to less than one fifth by installing a system of inclined baffles. Moreover, by using 4 sludge hoppers instead of 1 they were able to obtain rough classification by size into four products.\textsuperscript{67}

\textit{Dust-prevention treatment and dyeing}.—Additional sprays to be applied to coal and coke for prevention of dustiness, for providing pleasant odors, and for identifying trade products have appeared.\textsuperscript{68}

Meredith considers that oil emulsified with sodium resinate is the best dust preventive.\textsuperscript{69}

Coryell has described the coke-dust-proofing equipment of the New York & Queens Gas Co. at the Flushing coke station.\textsuperscript{70}

**BRIQUETTING**

The marketing of coal and of sawdust briquets in paper-wrapped packages and cartons is attracting attention in some sections of the United States. A number of small coal-briquetting plants are now operating in distribution centers somewhat remote from coal-mining areas. The briquets are made in cubical shapes with a plunger-type press using \(\frac{3}{4}\)- or \(\frac{1}{2}\)-inch screenings and about 1 percent binder.\textsuperscript{71}

A machine for wrapping the briquets ordinarily is installed as a part of the equipment. Construction of a plant to make coal briquets in 3-inch cubes was started late in the year at Paris, Ark.\textsuperscript{72}

Another plant at Renton, Wash., is making briquets of coal and of coal-tar coke in the shape of common brick. Two timber companies, one in Washington and the other in Idaho, are compressing kiln-dried Douglas fir and white-pine sawdust and shavings into 7- to 8-pound cylindrical log-shaped briquets and marketing them in paper cartons containing 6 to 12 briquets.

The manufacture of briquets without binder has been receiving much attention.\textsuperscript{73}

The Rtanj Collieries in Yugoslavia is using the Apfelbeck briquetting press for this purpose.\textsuperscript{74}

A rather novel method for mixing petroleum pitch with coal to be briquetted is used at the Petrosani mines in Rumania. The liquefied pitch is atomized by pumping it under pressure through a fine orifice.
into a revolving horizontal mixing crum containing the coal.\textsuperscript{75} It is claimed that only 5 percent of binder is required with this process compared with 8 percent with the usual methods. The strength of the briquets is about 30 percent greater than of those in which coal-tar pitch is used as a binder.

**COMBUSTION**

Sales of domestic stokers have continued to increase. The sprinkling-type overfeed stoker which has proved successful with large boilers has been adapted to domestic use. Several stoker companies have brought out pulverizer units suitable for small boilers. The Anthracite Institute Laboratory has developed a new horizontal-combustion magazine-type heater which has no combustion space above the fuel bed or air openings in the solid grate underneath.\textsuperscript{76} Advantages claimed are no clinking, less than 5 percent combustible in the ash, and usually more than 16 percent CO\textsubscript{2} in the flue gas. The furnace requires no blower and but little attention.

Mayers has reviewed\textsuperscript{77} the theory of combustion of carbon and has measured the rate of reduction of carbon dioxide.\textsuperscript{78}

Installation of Cottrell precipitators for the removal of fly ash at the new Buzzards Point plant of the Potomac Electric Power Co., Washington, D. C., has given a clear stack at all times when the precipitator was in operation.\textsuperscript{79} Means for removal of sulphur dioxide, smoke, and dust has been of particular interest in London, England. A process for removing the sulphur from flue gas has been installed at the Battersea power station. Recently the Imperial Chemical Industries has developed to the pilot-plant stage a wet-lime washing process which has no effluent and therefore has a wide application.\textsuperscript{80}

Interest in colloidal fuels\textsuperscript{81} continues, but practical use has been confined to demonstration tests.\textsuperscript{82}

**COMPLETE GASIFICATION**

Terres\textsuperscript{83} and associates in Germany, on the basis of a critical review of the literature and new experimental work on water-gas reactions, find that the reactivity of graphite, lampblack, bituminous-coal coke and semicoke, wood charcoal, and brown-coal coke and semicoke increase in the order given. The speed of the water-gas reaction with North Dakota lignite is governed chiefly by the velocity of the chemical


reaction rather than by diffusion. However, the rates of gasification may be increased by the use of oxygen and fine sizes of solid fuel in a bed maintained "in teeter" by an upward current of water gas produced in the same apparatus. Portable producer-gas plants for busses, tractors, and trucks continue to interest European countries. Tests show 77.5 percent savings in fuel cost over ordinary gasoline; 1.25 kg of charcoal is equivalent to 1 liter of gasoline and superior to wood gas, although the latter has been used satisfactorily.

HIGH-TEMPERATURE CARBONIZATION

The carbonization of coal by electrical heating, which was tested on a small scale at Lecco, Italy, in 1910 and recently in a 30-ton experimental retort by the Detroit Edison Co., has been repeated on a small scale (700 pounds) at Baden, Switzerland, and Reggio, Italy. The current required for continuous operation was 440 kilowatt-hours per net ton of coal. Assuming that the carbonization of a coal with 3-percent moisture requires 650 B. t. u. per pound Foxwell calculates the electrical energy required as 427 kilowatt-hours per ton of coal; hence, cheap off-peak power would be required, such as may become available in the Tennessee Valley.

Although experiments of the type were proposed years ago by Sir William Ramsey, Soviet Russia has reported the first tests ever undertaken to gasify coal underground. Leakage and lack of control of the process lead to poor quality of gas and incomplete combustion of the coal. Further experiments will be made in other districts.

New coke plants.—The continued depression in the iron and steel industry and the increased supply of natural gas have not favored the construction of new coking plants, the only American projects being (1) a contract let by the Public Service Co. at Camden, N. J., for a 37-oven battery of improved Becker ovens and (2) a battery of 10 Knowles ovens built for the Radiant Fuel Corporation at West Frankfort, Ill. The Becker ovens will have an average width of 16 inches, coal line 8 feet 7 inches, and length 31 feet 3½ inches. The Knowles ovens are 7½ feet wide, 30 feet long, and about 4 feet high to the center of the arched top. The coal charge is 10 inches deep
and lies in a horizontal layer heated from beneath through a silica or carborundum floor. The special advantages claimed for this type of oven are low investment cost in small units suitable for installation at coal mines and ability to make coke from poorly coking coals, from mixtures of coal and tar or oil, and from pitch and petroleum residues. A battery of Knowles ovens has been constructed at the Corby Iron Works near Kettering, Northamptonshire, England, for the production of metallurgical coke from mixtures of pulverized noncooking coal and heavy tar or petroleum residues.95

Increasing benzol yield.—Foreign demand for benzol has maintained interest in coke-oven modifications which favor increased yields of light oil. The Goldschmidt top channel, which increases the yield of benzol about 10 percent has been adapted to some 200 ovens in Germany,97 and also in the new battery of "Kogog" ovens installed at the Cargo Fleet Iron Works of the South Durham Steel & Iron Co., Ltd., in England.

Recent investigations98 show that the pyrolysis of benzol proceeds simultaneously with its production by the pyrolysis of other higher hydrocarbons. Under the conditions of most coke ovens the increased yields of benzol by the Goldschmidt process may be due to increased rather than decreased cracking. These findings agree with those of Davis and Auvil99 of the Bureau of Mines, who observed an increase in the yield of light oil resulting from increase in time of exposure of the gases and vapors to a temperature of 900° C. in the free space above the charge in the Bureau of Mines-American Gas Association test retort.

The growing demand for motor benzol in England has led to a number of new and improved light-oil installations at horizontal and vertical retort plants.1 Although light-oil removal reduced the calorific value of the gas about 26 B. t. u. per cubic foot at the North Shields Station2 this loss was more than compensated by the value of the recovered benzol and by the removal of the organic sulphur and naphthalene3 from the gas.

The Instill process for refining light oil has been simplified and improved with respect to removal of thiophene and reagents required.4

Purification of gas.—Gas purification by sulphur-recovery methods has continued to make progress. A new type of pressure thionizer has been installed at the "Thylox" purification plant of the Laclede Gas Light Co., St. Louis, Mo., and a large Thylo recovery plant for

purifying blue water gas has been installed by the Du Pont Co. at Belle, W. Va. A pilot plant of the Rostin process for catalytically purifying manufactured gas and light oil from sulphur and also catalytically converting CO to CO₂ has given satisfactory results at the Tegel plant of the Berlin Gas Works.

The dehydration of gas by glycerin at the Luton Gas Works in England reduced materially the formation of rust, and the stoppages caused by it.

Fulweiler and associates found that nitric oxide must be removed entirely to prevent formation of gum in manufactured gas; it can be done by special working of iron oxide purifiers. The gum particles, when first formed, probably are of molecular size. They coalesce and remain dispersed in the gas until the particles grow to about 1.5 μ when they deposit on the walls of the pipes and on the burner orifices; 0.3 mg of gum plus the associated dirt is enough to stop a pilot-light orifice. A survey of the British gas industry showed that 50 percent of the companies experienced gum trouble.

The Metallgesellschaft A. G. of Frankfurt-am-Main has developed a process for manufacturing sulphuric acid from the devil gases (20 to 30 percent H₂S) of the ammonia saturator, equal to one-fifth of the daily acid requirement for sulphate manufacture.

Tar recovery and utilization.—Electrostatic tar precipitation has become standard practice at most new coke-oven plants in England. Power consumption is 1 to 1.5 kilowatts per 100,000 cubic feet of gas. The capital cost is about $9,600. The efficiency is over 99 percent, and the tar content of the crude gas is reduced to about 1 grain per cubic foot.

The Institution of Gas Engineers finds a great diversity of opinion on the nature of tars most suitable for use in Diesel engines and on the degree of satisfaction realized by users. Fuel cost is considerably less than that of gasoline, but more skillful attention is required. In general, tar-oil fuel has been employed only for running, gasoline being used for starting up and idling. In stationary engines of the spark-ignition type results are much more promising. Tar oils are inherently unsuitable for use in the standard types of compression-ignition engines. The exhaust gases contain very little carbon monoxide, but complaints have been made of a creosote odor. Engine tests are being carried out by Gewerkschaft Matthias Stinnes in the hope of finding a suitable catalyst for use in front of the combustion chamber, to reduce the ignition temperature of the tar oils.

Gas utilization.—The municipal gas works at Hameln near Hanover, Germany, has installed the first and only plant in the world for rendering coal gas nonpoisonous by the catalytic conversion of the carbon

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monoxide to carbon dioxide and hydrogen, using steam at 400° C. Other beneficial effects are reduction of organic sulphur to 0.5 grain per 100 cubic feet, hydrogenation of the naphthalene to tetralin, and quantitative removal of tar fog and oxygen. The treatment cost is estimated at about 3 cents per 1,000 cubic feet.\textsuperscript{14}

Interest in the use of compressed gas and volatile hydrocarbons has spread from England\textsuperscript{15} to France, Germany,\textsuperscript{16} and South Africa.\textsuperscript{17} Thirty-one gas-driven vehicles, mainly busses, trucks, and tractors, were operating in France in 1934,\textsuperscript{18} and new compressing stations were installed in Lyons\textsuperscript{19} and Cambria.\textsuperscript{20} The technical problems in the use of coal gas for motor transport have been solved;\textsuperscript{21} 250 cubic feet of 500-B. t. u. gas gives mileage equivalent to an imperial gallon of gasoline.

\textbf{Properties of coke.}—The South Metropolitan Gas Co. of London has published its investigations over a period of years on the evaluation of the burning properties of high- and low-temperatureokes in domestic fires by means of laboratory ignition and reactivity tests.\textsuperscript{22}

The ignition temperatures of cookes increased from 470° to 626° C. as the carbonizing temperature was increased from 650° to 900° C. The combustibility, reactivity, and electrical resistivity decrease with the carbonization temperature, the change being greatest at about 700° C. It is concluded that to obtain a smokeless solid fuel, readily ignitable and freely burning in the ordinary domestic grate, the coal must be carbonized below 700° C. However, Mitchell reports obtaining easily ignitable high-temperature coke in horizontal-retort practice by using suitable blends of coking and noncoking coales.\textsuperscript{23}

The Midland\textsuperscript{24} and Northern\textsuperscript{25} Coke Research Committees of England have continued their studies of the effect of blending coales on the strength and combustibility of cookes made in an experimental oven. Motte reports that as much as 30 percent of durain (equivalent to our American splint coal), which usually is poorly coking, may be blended with bright coal and yet obtain a satisfactory coke, provided the charge is well mixed and crushed all through a ½-inch and 90 percent through an ⅜-inch sieve. That the addition of up to 8 percent of pulverized fusain or coke dust improves the quality of coke from highly fusible coales has been confirmed in full-scale oven tests at Clairton, Pa. The best results were obtained with 6 percent of —20-mesh coke dust.\textsuperscript{26}

\textsuperscript{18}Gas Times, vol. 2, 1935, p. 36.
\textsuperscript{22}Chemical Department, South Metropolitan Gas Co., The Solid Products of the Carbonization of Coal: London, 1934, 125 pp.
The cokes made in narrow ovens were darker, smaller, and more uniform in size than those from wide ovens, but there was no difference in the shatter indexes or combustibility of the coke. experiments on the influence of grain size and moisture on the bulk density of coke-oven charges showed that blends of three different grain sizes gave higher bulk densities than mixtures of two sizes. compression of the charge due to dropping the coal 11 feet materially increased the density of charge.

At Leeds University the reactivity of coke to carbon dioxide was increased on carrying the temperature up to 1,500° C., although there was but little increase in the case of petroleum coke and retort carbon.

low-temperature carbonization

Foreign developments.—Announcement of a 3-percent dividend by the Low-Temperature Carbonization, Ltd., and the addition of 72 retorts (making 288 in all) at the Doncaster Coalite plant indicates progress in establishing a commercial low-temperature-carbonization industry in England. the three English plants at Doncaster, Barugh, and the South Metropolitan Gas Co. have a total of 628 retorts with a total capacity of 370,000 gross tons of coal per annum. A Coalite plant was started at Lens, France, in july, and other plants are proposed at Lievin and at Bethune. other British processes remain in the experimental stage. Il lingworth has operated at Pontypridd, an 8-ton per day oven of improved design which can be used for swelling or noncaking coals.

The official report of tests by the Fuel Research Station on the l. and n. process shows that an internally heated type of rotary retort produces considerable dust which contaminates the tar and gas. When operated at the stated capacity of the retort (100 tons of coal per day) the tar was not entirely eliminated from the coke, which still retained 19.1 percent volatile matter.

The distillation of mixtures of coal and oil, as carried out at high temperatures in the Knowles ovens at Corby, also is being tried under conditions of low-temperature carbonization in the Cannock process at Cannock Chase, England. Powdered coal mixed with an equal quantity of oil (petroleum or tar oils from the process), 8 percent of


Brocklebank, E. w., and Mitford, W. B., Improvements in or relating to the Distillation of Solid Carbonaceous Material Mixed with Oil: British Patent 421566, Dec. 24, 1934.
which consists of industrial creosote, is treated in a revolving retort
5 feet in diameter and 50 feet long, externally heated to 600° C. The
yields from 1 long ton of coal plus 1 long ton of oil, as reported from
tests by Dr. C. H. Lander, were 15.3 imperial gallons of refined motor
spirit and 15.6 cwt. of smokeless fuel which required briquetting into
lump form and subsequent baking before selling for domestic fuel.40

In France the annual production of semi coke (not including so-
called "artificial anthracite") is approximately 180,000 long tons per
annum.41 This production is divided equally between the medium-
temperature coke known as "Carbolux" made at the Mines de Bruay 42
and low-temperature coke made at the Mines de Courrières by the
Illingworth process and various other processes at mines and gas
plants. Approximately 270,000 tons of artificial anthracite (car-
bonized briquets) were produced in 1934 by the Trent process at
Somain 43 and by the process used at the Mines de Nœux.

Medium-temperature cokes made at temperatures of 650° to 850° C.
in the Woodall-Duckham chamber ovens of the Fuel Research Station
combined high apparent density and considerable resistance to shatter
and abrasion with ease of ignition and reasonably high combustibility.44
These advantages of medium-temperature coke are confirmed by
Bureau of Mines 45 tests of cokes made at various temperatures from
30 American coals. Medium-temperature carbonization of bitumi-
nous coal is being developed further in Germany through the installa-
tion of another H. Koppers plant and a new modification of the inter-
mittent vertical chamber oven of the Didier-Werke A. G.46

No low-temperature plants for carbonizing bituminous coal are
operating commercially in Germany, but the Lurgi Co. is now con-
structing plants for the low-temperature carbonization of brown coal
and brown-coal briquets. At the Saar mines 13 to 14 percent of low-
temperature coke made by the Salerni process, blended with high-
volatile coals, improves the physical properties of the coke and is
economically feasible provided a suitable market can be developed for
the low-temperature tar.47

Several new low-temperature carbonization plants are under con-
struction in Japan as a result of a Government subsidy for a 7-year
period to all plants treating not less than 100,000 tons of coal per
annum.48

42 Farnart, Charles, The Production of the Bruay Mines Co. with Carbonization at Low and Inter-
mediate Temperatures: Chaleur et Ind., Comptes rendus du 3d Congrès du Chauffage Industriel,
44 Shaw, J. F., and King, J. G., Production of Smokeless Fuel in Chamber Ovens at Medium Tempera-
45 Same as footnote 34 on p. 693.
Manufacture of Special Metallurgical Coke at the Saar Mines under French Domination: Rev. ind. min.,
no. 319, 1934, pp. 191-211.
48 Journal of the Fuel Society of Japan, Low-Temperature Carbonization of Coal: Vol. 14, 1935, pp. 7-8; A Large Low-Temperature Carbonization Plant: Vol. 13, 1934, p. 27; New Low-Temperature Carboniza-
**American developments.—** In 1934 approximately 27,000 tons of low-temperature coke were produced in the United States by three different plants.

Current experience in 1934 in the sale and production of Disco, the trade name under which is sold the low-volatile fuel produced by the Pittsburgh Coal Carbonization Co. under the Wisner patents, was sufficiently gratifying to warrant the action on the part of the Directors of the Company to authorize, in 1935, the construction of an additional unit. The company reports that in the household and other retail markets in which Disco has been experimentally introduced, current demand indicates a promising field for this fuel in combating the competition of oil and gas.

The first commercial unit constructed in 1933 used a 6-foot-diameter by 90-foot revolving retort to carbonize. The preliminary treatment in the first unit is done in a roaster with four superimposed rectangular hearths, over which rabble is dragged by chains. The unit now under construction will have a carbonizer 8 feet in diameter by 90 feet, and the pretreatment will be done in a multiple hearth roaster of the wedge type. In this roaster, there will be nine circular hearths with outside diameter of 18 feet. The second unit will be in operation by the middle of 1935.48

The Lurgi plant of the Lehigh Briquetting Co. near Dickenson, N. Dak., operated during 6½ months of 1934 and produced 13,300 tons of briquets which were sold for household fuel and 106,000 gallons of lignite tar, part of which was sold for wood-preserving and disinfecting.

Operation of the Hayes process at Moundsville, W. Va., was limited to 5 weeks due to closing of the mine from which the slack coal was being obtained.

**Research developments.—** Patents have been issued for several new modifications of low-temperature retorts or ovens 49 and for the carbonization of mixtures of coal and oil which have been heated to just below the coking temperature in coils or confined passageways and then are discharged into coking chambers.50

### HYDROGENATION AND LIQUEFACTION OF COAL

The coal-hydrogenation plant of Imperial Chemical Industries just completed at Billingham, Durham, England, has made its first shipment of gasoline—some 300,000 gallons—produced by the hydrogenation of creosote. Deliveries of gasoline from the direct hydrogenation of coal will begin about May 1. The plant is expected to produce 150,000 tons of gasoline annually at a cost of about 7d. per gallon.51

During the past year the German Government has brought strong pressure on the coal operators and chemical companies to increase the production of oil from brown coal and bituminous coal.52 The output of gasoline from lignite tar and lignite at the Leuna plant of the I. G. Farbenindustrie was increased from about 100,000 metric tons in 1933 to about 180,000 tons in 1934.53 The capacity is estimated at 350,000 tons per annum.

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48 Communication to the author.
53 Institution of Mining Engineers, Utilisation of Coal Committee, Summary of Progress 4, Dec. 31, 1934, p. 2. See also Bosch, C., Where There is a Will There is a Way: Ind. Chem., vol. 10, 1934, pp. 90-94, 115.
The experimental plant of the I. G. Farbenindustrie at Oppau, Germany, successfully hydrogenated gas-flame coal from the Ruhr, yielding 65 to 70 percent oil and 14 percent gaseous products, of which 30 to 40 percent were propane and butane. Compared with the product obtained from brown coal the bituminous product is poorer in lubricating oils and paraffins and richer in aromatic hydrocarbons. A full-size plant for the production of several thousand tons per year is under construction at Oppau.45

Hydrogenation research.—Methods, apparatus, and catalysts for the hydrogenation of coal and tar constituted the subject of considerable research,46 and innumerable patents 47 of which a few have been taken out by American investigators.48 Tar oils and colloidal solutions of coal appear to be more amenable to hydrogenation than undispersed coal. A tar oil requires only one-third of the hydrogen required for the hydrogenation of coal and the weight yield of gasoline is 80 percent compared to 60 percent for coal.49 The capital cost of a tar-hydrogenation plant is considerably less than that for coal.

The Fuel Research Station of Great Britain has given tar first and coal second place on its hydrogenation-research program.50 Experi-
ments are conducted with batch and continuous converters, the latter being heated either externally or internally. The best catalysts are the halides and sulfides of molybdenum and tungsten deposited on alumina gel operating at 450\(^\circ\) C. and 200 atmospheres pressure.60

Other laboratories also have published data on yields obtained from low,61 and high-temperature tar, phenolic oil,62 benzene,63 pitch,64 etc.,65 under different conditions of hydrogenation.

Several workers have investigated the dispersion of coals with pyridine, tetralin, aniline, quinoline, phenols, diphenyl,66 and anthracene oil at various temperatures and pressures. The extractions are hydrogenated easily and yield a large percentage of oils.67 Pott and Broche68 obtained as high as 80-percent yields from bituminous coals by stage extraction with mixed solvents, such as tetralin and low-temperature tar phenols, keeping the temperature just under the decomposition temperature of the material. The extracts hydrogenated readily.

SYNTHETIC PRODUCTS FROM GASES

A commercial-scale pilot plant, using the Fischer process69 for the production of motor fuel and lubricating oil70 from water gas, is being built by the Ruhrchemie A. G. in Oberhausen-Holten, Ruhr, Germany. The gas (1 part CO to 2 parts \(H_2\) by volume), completely

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purified from sulphur, is passed over a catalyst of nickel-aluminum-manganese on kieselguhr at 190° to 210° C. and atmospheric pressure. Motor-fuel yields are estimated at 100 to 120 grams per cubic meter of gas used and the cost of 22 pf. per kilogram.71

The Fischer process has interested Japanese chemists, who have checked many of Fischer's findings and have published considerable additional data on catalysts and the influence of various factors on the reactions.72 Secondary reactions were investigated by Simek and Kasster.73

Pyrolysis of hydrocarbons.—The obvious importance of better knowledge of the mechanism of thermal decomposition of hydrocarbons in connection with the production of synthetic fuels and useful chemical compounds has enlisted an increasing number of workers in this field, who have made important progress in the last few years. Travers and Pearce74 investigated the system ethane-ethylene-hydrogen and determined its equilibrium constant. Bunte and Lang75 reviewed pyrolysis of paraffins in general and determined the most favorable catalysts and conditions for production of methane rich gas from oil. Dunstan, Hague, and Wheeler76 present experimental data and theoretical deductions on the mechanism of thermal conversion of paraffins and olefines into aromatic hydrocarbons.

The results of research on the pyrolysis and conversion of hydrocarbons to motor fuels, lubricants, and other products, especially through the polymerization of acetylene and ethylene, have been published by the United States Bureau of Mines,77 the National Research Council of Canada,78 and others.79 A number of patents also have been granted for the conversion into liquid products of the unsaturates in still gases of petroleum refinery.


