FUEL BRIQUETTING

R. A. STRONG, E. SWARTZMAN, AND E. J. BURROUGH

BUREAU OF MINES
DEPARTMENT OF MINES AND RESOURCES
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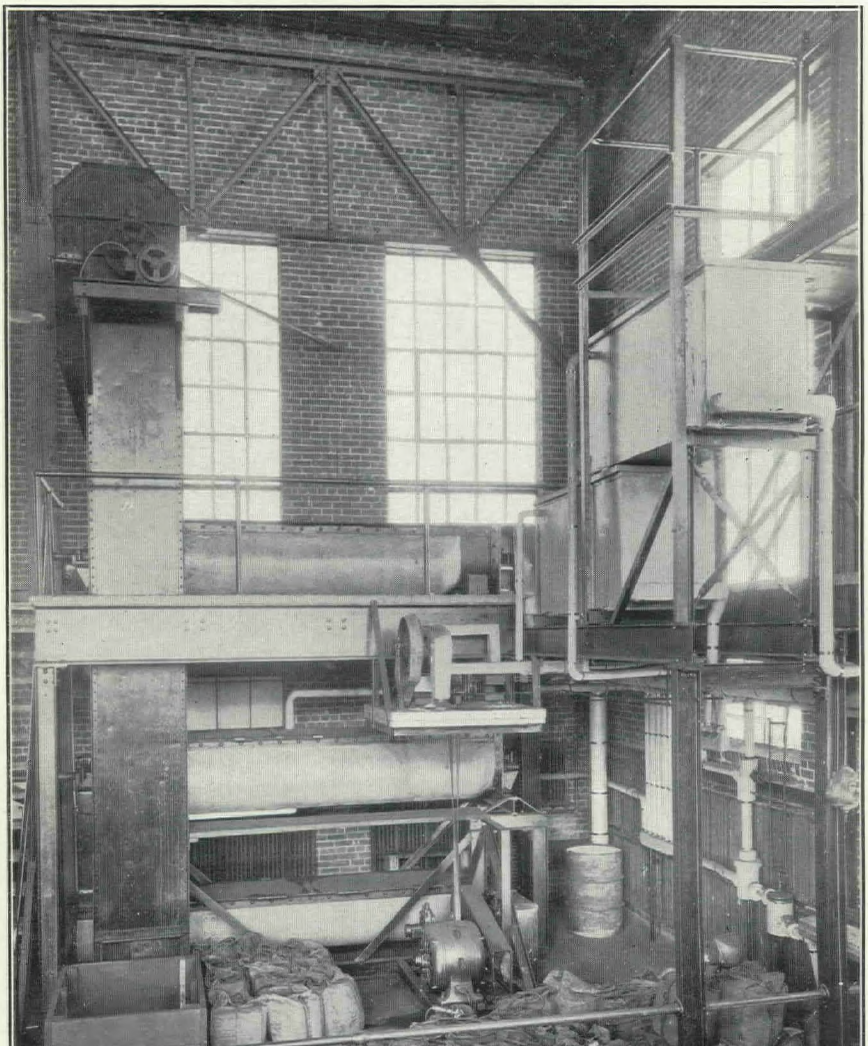

Briquetting equipment at Fuel Research Laboratories: mixing equipment and binder tanks.

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BY

R. A. Strong, E. Swartzman, and E. J. Burrough

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CONTENTS

PAGE

CHAPTER VI

TABLES

ILLUSTRATIONS

Photographs

Drawings

FOREWORD

This report presents an outline of the fuel briquetting industry, the information given being meant primarily for those interested in the history, the present status, and the possibilities of fuel briquetting in Canada.

The results of recent briquetting tests conducted at the Fuel Research Laboratories of the Department of Mines are included in Chapter V. These tests have been made on Welsh anthracite fines, wood charcoal breeze, petroleum coke breeze, high-temperature by-product coke oven breeze, and the fines from Canadian bituminous coals using as binders petroleum asphalt, coal-tar pitch, asphalt from Alberta bitumen, flour, and sulphite liquor. With the exception of the investigations just mentioned the report is largely a review of the literature on the subject. The literature that has been consulted is designated in the list of references, which it is to be noted is comprised of articles from various technical journals, government reports, publications of the manufacturers of briquetting equipment, and standard text books.

"A Handbook of Briquetting" by Franke, and "Briquetting" by Stillman, have been repeatedly cited. To these and to all other sources of information due acknowledgment is herewith made. A comprehensive review of the patent literature, comprising more than two hundred patent abstracts on the different binders and binder mixtures for briquetting fuels, is included in the report as an Appendix.

Fuel Briquetting

INTRODUCTION

The briquetting of coal has been the subject of much investigation both by individuals and research organizations for a number of years, and while an industry of importance has been established in several countries of Europe, the same degree of success has not materialized in North America. This is mainly due to the difference in the available fuels and their method of utilization. In Europe, the industry was established on the basis of converting the fines resulting from the mining of industrial coal into a more usable form, whereas in North America the manufacture of briquettes has been confined almost entirely to the production of domestic fuels in competition with prepared anthracite. This difference in markets indicates the reason for the indifferent success of the industry in North America as the standards and specifications for domestic fuel differ considerably from those for industrial fuel.

The desire to produce briquettes that would have approximately the qualities of anthracite, the outstanding one of which is smokelessness, has led to an intensive study of binders, and literally hundreds of patents have been granted for various processes and binders for the production of a smokeless briquette.

Interest in briquetting in Canada has been spasmodic. A number of plants have been erected, most of which for various reasons have subsequently been closed. No complete publication has been issued of the briquetting investigations conducted by the Federal Department of Mines and the Alberta Research Council in co-operation with the Lignite Utilization Board during the period 1918 to 1924, and in their respective laboratories at Ottawa and Edmonton since that time. Accordingly the present report is intended to give in one publication a summary of the available information on the subject, which it is hoped will find a ready and valuable use in response to the many requests for information from various interested parties, particularly as regards Canada.

CHAPTER I

HISTORY OF BRIQUETTING

The briquetting or compressing of finely divided coal or other fuel probably developed from the old, simple ball-shaping and hand-moulding, first practised in China, in which loam or clay moistened with water was used as the binding medium. The first published specification relating to fuels of this character in the English Patent Office records was dated April 1773. Franke (1) in his Handbook of Briquetting gives the following data with respect to the historical development of the briquetting industry in Europe.

In the year 1789, Chavanne obtained an English patent for the preparation of pressed coals in the form of cakes. The sifted slack coal was intimately mixed with earth, clay, cow-dung, tar pitch, broken glass, sulphur, sawdust, oil cake, tan, wood, or other vegetable matter, placed in water, dried in drained pits, and finally moulded into cakes of convenient size. (Knight—The Practical Dictionary of Mechanics, page 921). In the year 1832, E. Marsais of St. Etienne, France, patented a method of pressed coal briquetting, using a mixture of coal tar and coal slack, but the briquettes were not sufficiently strong. In 1842, Marsais took out a patent for the application of soft coal-tar pitch (brai gras) as a bond, and opened the first briquette factory at Berard, near St. Etienne, a second factory being opened at Givors four years later. In 1843, Wylam applied the use of hard coal-tar pitch in England. In 1848, H. Dobrée introduced in England the use of steam for heating the pressed coals made with tar in order to strengthen them, and to soften mixtures made with hard pitch previous to pressing. After the establishment of the first briquette factory in France, similar factories were gradually opened in other countries: in 1846 at Newcastle in England; in 1852 at Montigny-sur-Gambre in Belgium; in 1858 at Brandeisl near Prague in Czechoslovakia; in 1861 at Mulheim on the Ruhr in Prussia.

The production of briquettes in European countries developed very rapidly until there were in 1867 thirty-one factories in France with a total production of over 1,000,000 tons of briquettes; and in 1869 Belgium possessed nine factories, with a yearly production of 515,000 tons; while England produced some 200,000 tons.

The first attempt to carry on this industry in America, according to Stillman (2), was started in 1870 by E. F. Loiseau at Port Richmond, Philadelphia, Pa., which, incidentally, marks the first commercial application of the roll press. The briquettes made were egg-shaped, weighing seven to eight ounces each. The material briquetted was anthracite culm with a clay binder, and the resulting briquettes were waterproofed with a resin varnish dissolved in benzine. The plant was unsuccessful, both mechanically and commercially.

A similar type of improved plant was built in 1876 by Loiseau, making smaller briquettes and using gas-house coal tar, also coal tar imported from England, as the binding medium. Two other plants of similar design were built but neither of them was successful, with the result that operations were abandoned in 1885.

In 1890, the Anthracite-Pressed Fuel Company built a plant at Mahanoy City, Pa., installing a Stevens press of the plunger type, made in England. This plant produced a 2-pound briquette, using imported coke oven tar pitch as the binder. The briquettes were too smoky and too high in ash and the plant was closed after two years' operation.

In 1892 a Loiseau plant was erected at Gayton, Va., to process Virginia semi-anthracite slack, using coal-tar pitch as a binder. This plant was evidently fairly successful and similar plants were erected at Milwaukee, Wis., and Chicago, Ill. All of these plants were later abandoned, the trouble apparently being the unsuitability of the machinery.

In the same year an attempt was made by the National Eggette Coal Company of New Jersey to briquette a mixture of Arkansas semi-anthracite and bituminous coal using hard pitch and coal tar as a binder. The plant was not a financial success owing to the high cost of binder and to price competition of other fuels.

In 1896 a small briquetting plant was erected at Rockdale, Texas, for utilizing Texas lignites. A special process was employed in preparing the lignite, and hard pitch was used as a binder. The failure of this plant was due to the difficulty of securing the requisite quantity of pitch and to difficulties in drying the lignite.

In 1901 a plant was erected at Stockton, California, by the San Francisco and San Joaquin Coal Company, to briquette a high-grade lignite. This plant employed asphalt as a binder and mixed a certain proportion of bituminous coal with the lignite to prevent disintegration during burning. The process was apparently a success but the plant was destroyed by fire in 1905 and was not rebuilt.

In 1904, E. B. A. Zwoyer and Rolland Zwoyer built a plant at Brooklyn, N.Y., which was later moved to Perth Amboy, N.J., to briquette anthracite culm from the mines of the Lykens district. Coal-tar pitch was used as a binder to the extent of 6 to 7 per cent and between 6 and 10 per cent of bituminous coal was mixed with the anthracite. The plant was in operation for several years and although partly destroyed by fire in 1909 was rebuilt and continued operation until 1911.

In 1905 the Semet-Solvay Company constructed a small plant at Del Ray, Michigan, using the revolver type press. This plant was later enlarged and employed a rotary press of 15 tons per hour capacity, making 3-ounce briquettes. A mixture of coal and coke breeze was used with coal-tar pitch as a binder. A larger plant was later built by this company at Detroit. The price of the product, however, was not commensurate with the difficulties of making the briquettes, and the plant was closed after one year's operation.

In the same year three plants were erected in California to briquette coalyard screenings and lignite with California asphalt as a binder. Most of these plants were, however, destroyed by fire the following year. A plant was also erected by the Los Angeles Gas and Electric Corporation to briquette oil carbon. This plant employed the Fernholtz process and produced a satisfactory domestic fuel. Operating records do not extend beyond 1927.

Two attempts at briquetting North Dakota lignite were made during the years 1905 and 1906. Senator Washburn erected in Minnesota an experimental plant of small tonnage for briquetting lignite without any binding material and the American Briquette and Manufacturing Company attempted to briquette lignite using 6 per cent of flax syrup and rosin as the binding medium. Both experiments resulted in failure.

In 1906 the United Gas Improvement Company built a plant to briquette coke breeze mixed with anthracite coal using coal-tar pitch as a binder. The briquettes were used for water gas manufacture and for this purpose were quite satisfactory. In the same year the Scranton Anthracite Briquetting Company built a plant at Dickson City, Pa., to briquette anthracite culm from the washery of the Lackawanna Coal Company. This plant is still in operation using asphalt as a binder and producing 20 tons of 2-ounce briquettes per hour.

In 1907 two plants were established, the first being built by the Western Coalette Fuel Company of Kansas City, Mo., to briquette Arkansas semi-anthracite screenings with coal-tar pitch and the second by the Rock Island Coal Mining Company at Hartshorne, Oklahoma, where briquettes were made from bituminous slack bound with water-gas pitch. The first plant closed shortly after starting, but the second operated for a period of three years and was termed a commercial success. A strike and economic features affecting the raw material were the cause of its being abandoned.

In 1908 the Lehigh Coal and Navigation Company started operations at Lansford, Pa. Three plants have been built and operated by this company: the first being an experimental unit which was destroyed by fire in 1909; the second was built in 1911 and operated, with certain changes in the process, until 1918 when by reason of the demand for the product an entirely new plant was installed. The plant was designed to briquette anthracite culm using asphalt as a binder. The method employed is known as the Dutch process involving the use of a masticator which is described in Chapter IV. No operation is recorded beyond 1926.

In the same year the Indianapolis Pressed Fuel Company erected a plant at Indianapolis, Indiana, to briquette the slack from Indiana coal with coal-tar pitch. The plant was destroyed by fire in 1911 but was rebuilt in 1912 and operated for a short time.

In 1909 the Coal Compress Company installed a plant operating under the Giles patent which involved the use of a hot paste of flour and water in a solution of iron sulphate as a binder. The plant was used for demonstration purposes only and commercial exploitation did not materialize. The Detroit Coalette Fuel Company established a plant at Detroit to briquette Pocahontas coal using a hard pitch binder mixed with the coal in the pulverized state. The plant produced 8½-ounce briquettes and operated until 1915. The Staunton Coal Company established a plant at Livingstone, Illinois, to experiment with the then recently invented Rutledge press of Gustave Komarek. The press, producing cylindrical-shaped briquettes weighing 16 ounces and having a capacity of 32 tons per hour, was reported as successful but no record of the operation of the plant is available. In this year the Standard Briquette Fuel Company established a plant at Kansas City, Mo., to briquette Arkansas semi-anthracite screenings using coal-tar pitch as a binder. The original plant contained a Misner press of the Couffinhal type, but in 1912 the plant was redesigned by the Malcolmson Briquette Engineering Company and a Rutledge press was installed. This plant has been considered a success, technically and financially. The Coal Briquette Machine Company at Oshkosh, Wis., also put a plant into operation in 1909. This plant appears to have been a characteristic Couffinhal system and its operation was in accordance with the best German practice, briquetting anthracite dust mixed with 4 per cent of coking coal slack using a hard coal-tar pitch as binder. Operation is not recorded beyond 1910. An important operation starting in 1909 was that of the Stott Briquette Company at Superior, Wis. The plant was designed by Mashek using the Zwoyer method to briquette anthracite and bituminous slack obtained from the coalyards and docks at Lake Superior. The pillow-shaped briquettes, which weigh 2¼ ounces, are bound with asphalt. The plant has been in continuous operation since its beginning.

In 1910 the Coal Boulet Company established a plant in New York City using a French process. The venture proved unsuccessful owing to the high handling costs caused by the location of the plant, and it was closed in 1914. The Tepper Fuel Company attempted to operate the plant using sulphite pitch binder followed by carbonization, and although excellent briquettes were made the venture was not commercially successful. In this year an attempt was made to briquette the Rhode Island anthracites which are highly graphitic in nature and, as mined, are not suitable for domestic fuels. The Rhode Island Coal Company installed a plant which was designed by both Mashek and the Zwoyer brothers and an excellent fuel was produced which found a ready sale. Operations were discontinued, however, in 1912 owing to litigation regarding the ownership of the mine.

In 1911 the United Collieries Company installed a plant at Seattle, Washington, to briquette Washington bituminous slack coal mixed with certain available lignites. The binder used consisted of coal-tar pitch and flour waste in the proportion of about 5 per cent of the former and 1 per cent of the latter. The briquettes, which were made in a roll press, weighed about 4½ ounces and were of "eggette" shape. Operations ceased in 1915.

In the same year the American Coal Boulet Company established a plant at Phoenix, Md., to briquette Georges Creek coal with an asphaltic binder. The briquettes were made on a Devilliers press and weighed 1½ ounces each. In 1915 the plant was taken over by the Belgian Coal Fuel Company and was closed in 1917.

In 1912 the Berwind Fuel Company erected a plant at Superior, Wis., to briquette coal screenings with petroleum asphalt. Two sizes of briquettes were made; the larger, which was 13 ounces in weight, being manufactured in a Rutledge press and the smaller in a Komarek press. The latter were sold to the domestic trade and the excellence of the product led to a large and increasing business which continues to the present day.

In the same year the Eggette Coal Company of Trenton, N.J., established a plant to operate under the Giles patents. A unique feature of the process was that the briquettes were pressed cold. They were subsequently treated at a temperature of 200°F. to dry and waterproof them. The plant operated until 1915. This plant was later taken over by the Fuel Briquette

Company and briquettes were manufactured using sulphite liquor as a binder. After pressing, the briquettes were treated at 600°F. to render them waterproof. The plant operated successfully until 1921.

In November of 1912 the Virginia Coal Briquetting Company began operations in Richmond, Va., using the Hite process. The fuel consisted of 75 per cent of Virginia semi-anthracite and 25 per cent of Pocahontas coal. The binder was crude oil with a small percentage of starch emulsified by water, this being the original Hite formula. The briquettes were waterproofed by a baking process carried out at slightly over 200°F. The plant ceased operations about 1915 owing to technical and financial difficulties.

In 1913 the American Coalette Company established a plant at Philadelphia for the manufacture of anthracite briquettes. They employed a secret binder during the first stage of their operations but later changed to hydrolene.[1] The plant continued operations until 1917.

In 1913 the Portland Gas and Coke Company established a plant to briquette oil carbon by the Fernholtz process.

In 1914 the Pacific Coast Coal Company established a plant at Briquetteville, Washington, near Seattle, to briquette the lower grade Washington coals. Asphalt is used as a binder and the briquettes are produced in a Rutledge press. The plant has been successful and is still in operation.

In 1915 the Delparen Anthracite Briquetting Company established a plant at Parrott, Va. The plant was designed to produce briquettes from Virginia semi-anthracite coal. A vegetable binder was first employed that was later changed to coal-tar pitch, and still later to asphalt. The plant was successful and operated until 1929.

In 1915 another plant for briquetting oil carbon was established by the Pacific Gas and Electric Company, and the International Fuel Products Corporation started their experimental plant at Irvington, N.J., to carbonize bituminous coal at low temperatures, briquette the residue and carbonize the briquettes to produce a smokeless fuel. This plant was established to exploit the Smith patents and after several years of experimental operation work was discontinued.

In 1916 the Gamble Fuel Briquette Company established a plant at Harrisburg, Pa. The plant was designed to use the Gamble patented binder which was essentially sulphite liquor waterproofed by asphalt. It was intended to carbonize the briquettes but this part of the process was abandoned and the briquettes were sold as they came from the press. The plant discontinued operations in 1919.

In 1916 a similar plant under the same process was erected at Richmond, Va., but was burnt down shortly after erection and the machinery was taken over by the Anthracite Briquette Company of Sunbury, Pa. The quantity of sulphite liquor used in the process was gradually decreased until it was eliminated entirely, asphalt alone being used as a binder. The plant discontinued operations in 1929.

The Virginia Navigation Company established a plant in 1916 to briquette Pocahontas slack for export only. It was the largest plant up

[1] This is a specially prepared petroleum residuum.

to that time in the United States and was intended to have a capacity of 300,000 tons per annum. The plant has only operated intermittently since it was constructed.

In 1918 the American Briquette Company installed a plant at Lykens, Pa., using Lykens Valley coal dust and the Hite binder. This company had been experimenting for several years on this process and had produced briquettes successfully in a small experimental plant located at Philadelphia, using only 2½ per cent (on the dry basis) of the emulsified asphalt-starch binder. This plant has been a commercial success and is still operating.

In 1920 the Burnrite Coal Company established a plant in Newark, N.J., to briquette anthracite coal with a secret binder. The briquettes were 2 ounces in weight and pillow-shaped. They were submitted to a baking operation to make them smokeless and waterproof. The plant discontinued operations in 1923.

The first record of briquetting in Canada is that at the Bankhead Collieries, Ltd., Bankhead, Alberta. The entire plant was designed and built by the Zwoyer Fuel Company of New York in 1907, for the Canadian Pacific Railway Company, to manufacture railway and domestic fuel. The pillow-shaped briquettes were made from semi-anthracite screenings and coal-tar pitch in roll presses and weighed 2½ ounces. The plant operated successfully until the mine was closed in 1921.

In 1916 the Colonial Coal Company of Sydney, Nova Scotia, erected two plants, about ten miles apart, near Sydney. Machinery was imported from England and the hard pitch method used. The coal and hard pitch were pulverized, mixed, fluxed, and pressed in Belgian eggette presses. These plants are no longer operating.

In 1918 a plant was established in Montreal, Canada, under the auspices of the Aetna Briquetting Company, but never operated.

In the same year a plant was established by the Anthracite Briquette Company in Toronto, under the Gamble process, very similar to the one at Sunbury, Pa. In 1920 this plant was acquired by H. F. Slater, President of the Nukol Company. It closed in 1928 and was dismantled in 1931.

In 1919 a Dutch process[1] plant was established in Toronto by the Nukol Fuel Company, Ltd. Anthracite culm, obtained from the river coal operators of Pennsylvania, was briquetted with an asphaltic residuum manufactured by the Imperial Oil Company at their Montreal refinery. The plant is described in the first general report of the Lignite Utilization Board. The company ceased manufacturing in 1921.

In 1921 a plant using the Dutch process and similar in all essential details to the Nukol Company's plant in Toronto, was installed by the Port Stanley Nukol Company at Port Stanley, Ontario, but this plant ceased operations soon after its completion.

In the same year the Lignite Utilization Board completed their plant at Bienfait, Saskatchewan, to carbonize and briquette the lignites of this district. The plant has been described in the first general report of the Lignite Utilization Board and elsewhere. It was operated intermittently under various organizations until 1931, since which time it has been closed.

[1] The Dutch process, invented in Holland, is a method whereby the mixture of coal and binder is thoroughly kneaded in a masticator.

In 1924 the British Columbia Electric Company established a plant in Vancouver, B.C., to briquette the breeze from their coke plant. A mixture of breeze and non-coking bituminous coal was briquetted using coal-tar pitch as a binder. This plant has been operated intermittently since its installation.

In 1925 the Canmore Coal Company installed a plant at Canmore, Alberta, to briquette the fines resulting from screening their coal for railway use. The plant was built by the Komarek Company of Chicago and is capable of producing 15 tons of briquettes per hour. The coal is semi-bituminous, with slightly agglomerating properties, and petroleum asphalt is used as a binder. The plant is still operating.

Since 1925 considerable interest in the briquetting of fuel has been indicated and several unit type plants using tamping presses have been installed in storage yards by retail dealers, a list of these being given in Table VII, page 62.

CHAPTER II

PROCESSES FOR BRIQUETTING VARIOUS CLASSES OF FUEL

BRIQUETTING OF WOOD WASTE

The problem of making wood waste briquettes without carbonization has received a great deal of attention in the past. Because of the low fuel value of waste wood, binder and preparation costs must be very low, and in view of this most of the experimental work has had for its objective the briquetting of waste wood without the use of binders. In order to produce a briquette which will withstand handling and transportation, the elasticity of the wood must be destroyed either by high pressure or heat treatment. Stillman (2) and his associates, experimenting along these lines, found that the roll press was not suitable for briquetting wood waste, as in this type of press there is no continuous pressure applied simultaneously on all parts of the raw material, a condition necessary to overcome the resilient properties of the wood particles. Good briquettes have, however, been made with the piston and mould type of press, such as the modified Exter press of Arnold, and the Gilmore horizontal hydraulic press. Probably the most successful process is that of Arnold, controlled by Ganz and Company, of Ratibor, Upper Silesia. In this process sawdust is first preheated, with the aid of steam, to a temperature sufficient to remove the moisture, release the gases and resins without destruction, and destroy the elasticity of the wood particles. The heated material is then fed to the above-mentioned Arnold "rope" press, where briquettes are formed. This process produced strong, dry briquettes with a fuel value approximately one-fifth higher than the original wood.

In the United States the Pacific Coal and Wood Company of Los Angeles briquette wood shavings in a special brick press. The pressures used are light and to ensure coherence the briquettes are bound in wire. They are cylindrical in shape, being about 3 inches in diameter and 10 inches long. No wood waste briquetting enterprises in Canada are known to the authors.

In all cases, briquettes made in the above manner are low in heat value, and result in a fuel which can only compete with cord wood. A more profitable and better fuel can be prepared by carbonizing the waste wood and briquetting the resultant charcoal with the aid of binders such as pitch or starch, or by carbonizing waste wood briquettes. The fuel produced by the first method is light, has a high heat value, and is a much cleaner and stronger fuel than the usual block charcoal. However, when the charcoal is produced in the comminuted form and then briquetted, hardwood pitch or tar to the extent of approximately 30 per cent is necessary as a binder, and, in order to produce a fuel suitable for domestic use, distillation of the briquette is imperative. This method, invented by S. J. Seaman, has been employed by the West Virginia Waste Wood Company at Gauley's Mills, West Virginia. The preparation of a smokeless briquette from charcoal for domestic purposes, without the necessity of distillation, has been accomplished by the use of 10 per cent of flour or starch in the form of paste as a binder. Due to the large quantity of water necessary for the preparation of the binder a drying process for the briquettes must be included in the plant. This method is used by the Ford Motor Company in their plant at Iron Mountain, Michigan. The briquettes made by this process are not waterproof, whereas those made by the Seaman process are. Several processes for the production of charcoal briquettes by first briquetting the waste wood without a binder and then carbonizing under pressure have been developed, but without commercial success.

BRIQUETTING OF PEAT

Many attempts have been made both in Europe and in Canada to utilize peat deposits by preparing a fuel superior to that produced by cutting and air-drying the resultant peat bricks. The success achieved in Germany in the briquetting of brown coals without a binder led to the attempted application of similar processes for the manufacture of peat briquettes. However, according to Haanel (3), "The great economic differences between the handling of raw material such as brown coal, wth 50 to 60 per cent of water, and peat, which usually had a water content of 85 to 90 per cent or upwards, and especially—the peculiar properties of peat which render extraction of water from it by mechanical means very difficult and even impossible, beyond a certain extent," led to the failure of applying brown coal briquetting methods to peat. Several companies were formed in Canada to manufacture fuel from raw peat by the process of drying and briquetting (4). The first plant was built in 1901 at Welland, Ontario. The peat after being air-dried for about 2½ hours to a moisture content of approximately 45 per cent, was subjected to artificial drying to bring the moisture down to 25 per cent. The peat was then disintegrated and pressed in the Dickson press which was of the vertical open-tube type, and operated similar to the Exter press. On account of the high cost of drying and the inefficiency of the pressing operation, the plant was finally abandoned.

The second attempt at briquetting peat in Canada was in 1902 at Beaverton, Ontario, by the Dobson process. The raw peat was air-dried for a period of from 2 to 3 hours and after disintegration was artificially dried to about 16 per cent of moisture in a shell dryer. The dried peat was briquetted in the Dobson press, which was of the resistance block type, in which the moulds were swabbed with oil to prevent sticking.

None of the attempts to manufacture briquettes from peat passed the experimental stage owing mainly to the high cost of artificially drying the peat, which is necessary in order to produce satisfactory briquettes. An added cause of failure was the character of the product. The briquettes made from peat without the use of a binding material were hygroscopic, and rapidly disintegrated when exposed to moist air, and even when freshly made suffered considerable loss in transportation and handling.

In 1908 the Canadian Government made a thorough investigation of the peat industry, and the results of this work are embodied in a report by E. Nystrom (5). In concluding—Nystrom remarks as follows:

> The manufacture of peat briquettes, which are preferable for domestic use on account of their higher fuel value and cleanliness, is, as far as can be judged in Europe, not a very lucrative undertaking—the increased fuel value does not cover the extra expense of artificial drying and briquetting.

As the cost of dehydrating the peat is the main obstacle to the economic briquetting of this fuel many processes have been developed with an attempt to reduce this initial cost. Probably the most notable experiment was that of the Wet Carbonizing Process invented by Dr. Martin Ekenberg in London, England, in 1904 (3). In this process the peat as obtained from the bog is charged into retorts and heated to 150°C. under pressure. The peat loses its gelatinous colloidal property, facilitating the removal of the larger portion of the water by pressing. A slight charring or coking of the peat takes place, without liberation of gases, as in dry distillation, and the resultant char can be easily briquetted in an open mould press. Several attempts were made in Sweden and in England to demonstrate the commercial possibilities of the Ekenberg process, but, due to technical difficulties in operation, the extremely poor production efficiency obtained in relation to the heat consumption, the complexity of the process, the very high capital costs involved, and the cost of the operation, the process was proved to be uneconomic.

Recent work on peat briquetting in the United States includes the application of the Zwoyer "Universal" roll press. In 1920 Mr. M. G. Ewer of the Peat Products Corporation, in conjunction with the General Briquetting Company, conducted a series of tests whereby peat, air-dried to 35 per cent of moisture, was masticated while hot and pressed in a Zwoyer "Universal" press. The briquettes produced were weak and soggy but they shrank, without breaking, to a fairly hard product which it was claimed, while not immediately weatherproof, became so with time. A small plant was erected at Eastern Rapids, Michigan, to use this process and for a short time peat briquettes were manufactured for local consumption only. Peat fuel whether manufactured according to the air-dried machine-peat process, or briquetted by any of the previously mentioned methods, is unsuitable for many industrial purposes, and also as a competitive domestic fuel in most countries. In order to extend its field of usefulness, carbonizing at low temperatures with the resultant production of peat charcoal might be resorted to. Carbonizing and coking processes not only involve very heavy capital expenditures and complicated costly operations, but owing to the high volatile content of peat, the resultant fuel production is very small in proportion to the quantity of raw material handled. (3) The devising of a process which would economically remove the water content of the peat by pressure, carbonize the dewatered substance and briquette the carbonized residue, has been frequently attempted. The Schoening and Fritz Process (5) developed in Germany for this purpose was tried out on a capacity basis of 3 tons of briquettes per hour. According to this process the disintegrated peat was passed through a series of horizontal retorts heated to a maximum temperature of 250°C. in 30 minutes, which resulted in partial carbonization. The hot semi-char was then conveyed to the dies of a heavy hydraulic press, the plungers of which were heated to 200°C., and submitted to a sustained pressure of 300 atmospheres for 12 seconds. The briquettes produced were heavy and strong, and burned with a long flame. According to Stillman, however, "It is very evident that unless fuel made in this manner can command a substantial premium over coal prices, it will not pay to install such a factory in the United States". The same remarks apply to Canada. According to J. G. Mashek (6) to make a briquette that will stand transportation and handling, and be comparatively weatherproof, it is necessary with most peats to use a binder of some type to briquette the material properly. A search of the patent literature has revealed several suggestions with respect to preparing peat briquettes with the aid of binders. According to these patents peat alone, or in admixture with other fuels, may be briquetted with the aid of the following binders: coal-tar pitch, asphalt, tar, rosin, mineral oil, naphthalene, sulphite liquor and lime, either alone or in various mixtures. These have been referred to and summarized in Chapter III. A thorough search of the literature has, however, not revealed any reference to the commercial application of briquetting peat with the aid of binders, and, as Mashek states, "The cost of manufacture of peat briquettes using some form of binder is about twice as much as making briquettes from anthracite or bituminous coal." It does not seem probable, therefore, that the use of binders in peat briquetting will ever be seriously considered for commercial purposes.

BRIQUETTING OF LIGNITE

There are extensive fields of lignite in many countries, and although these are often so distributed that competitive coal beds are not located in their neighbourhood, the use of raw lignite both for domestic and industrial purposes has been comparatively limited. The physical and chemical properties of raw lignite are such that competition with higher grade fuels is very difficult and in most cases impossible. The most serious drawbacks to the use of raw lignite are its disintegration on weathering and combustion, and its low calorific value and high moisture content. Many attempts have been made to produce a fuel from lignite by briquetting, which overcomes the above-mentioned drawbacks, and these have resulted in the development of three different methods, viz.:

(1) The German "Braunkohle" method, whereby the lignite is dried to a proper consistency and briquetted, without a binder, in an Exter type press;

(2) The method whereby the lignite is mixed with a binder and briquetted by ordinary coal briquetting methods; and

(3) The method involving carbonizing the lignite and briquetting the char by standard coal briquetting methods.

The German "Braunkohle" Method of Briquetting Lignite

This process involves the pressing of the dried lignite into blocks without the aid of a binder, and seems to be applicable only to the earthy type of brown coals which are abundant in Germany. The application of this method to Canadian and United States earthy lignites has so far been unsuccessful, the reason assigned by various experimenters being, that the lack of sufficient natural bitumen was responsible for the failures. Recent work by Dr. J. L. Blum (7) tends to show that "The specific property of lignite, that permits briquetting without a binder at a pressure of 1200 to 1500 kilogrammes per square centimetre", is not due to the presence of benzine soluble bitumen, but to the presence of free humic acids in sufficient quantity. It is the opinion of the authors that in all probability Dr. Blum's conclusion is correct, but that a sufficient quantity of bitumen is also necessary to produce a briquette that will withstand weathering and will not disintegrate in the fire.

Where suitable lignite is available, the raw material containing from 45 to 60 per cent of moisture after being crushed to the proper size, is dried in either a steam table oven, or steam drum tube dryer, or both, to a moisture content of from 12 to 18 per cent. As the temperature of the lignite rises rapidly during briquette formation it is essential, in order that good briquettes may be made, that the lignite be cooled, before pressing, to about 100° to 150°F. The dried and properly tempered lignite is thoroughly mixed and pressed in the heated open-mould Exter press. For complete information with respect to "Braunkohle" briquetting, G. Franke's "Handbook of Briquetting" should be referred to.

Although some method for briquetting certain Canadian lignites without the use of a binder, may be developed, it does not seem probable that such a fuel will be capable of competing in the domestic market with anthracite or by-product coke. However, where that market is predominantly bituminous and sub-bituminous a raw lignite briquette may satisfy the domestic requirements.

Briquetting Raw Lignite with a Binder

The unsuccessful attempts to briquette American and Canadian lignites without the use of a binder has led to comprehensive investigations of methods and processes involving the briquetting of raw lignite with the aid of binders. The U.S. Bureau of Mines carried out many experimental tests using various types of lignite and such binders as coal-tar pitch, asphalt, resin, and lime, but in no instance were they able to produce a satisfactory briquette. Several plants (2) were constructed throughout the western section of the United States with a view to briquetting lignite with a binder, but in all cases the operations were discontinued because of the poor quality of the product. It may be concluded that, up to the present, no method has been developed for the commercial briquetting of raw or dried American lignite, by the addition of a binder. The admixture of a substantial proportion of bituminous or anthracite coal, or coke, renders it possible to produce a fairly satisfactory briquette, but the price factor in such cases is practically prohibitive. With respect to lignite alone, Mashek states that:

In order to make raw lignite briquettes that will stand the weather, a large percentage of binder such as coal-tar pitch or asphaltum must be used so that all coal particles are covered in order to prevent further air-slacking and disintegrating. The results obtained during combustion, however, are very little, if any, better than when attempting to burn raw lump lignite, and in addition there is the smoke and fumes from the binder to contend with. In no part of the country can such fuel be sold at a profit in spite of the high prices of eastern fuels.

Briquetting Carbonized Lignite with a Binder

The raw lignites of Canada and the United States have not been successfully briquetted by either the "Braunkohle" method, or by methods using binders. In both cases the fuel produced is dirty, smoky, non-weatherproof, and does not stand up in the fire, and added to all these physical disadvantages the fuel is high in moisture and low in heat value. Such a fuel under average conditions has no possibility of competing, in either Canada or the United States, with any of the higher price, higher grade fuels. In view of this, a tremendous amount of research work has been carried out both in Canada and the United States with the object of producing a high-grade fuel, by carbonizing lignite at a low temperature and briquetting the resultant finely divided char.

The greatest difficulty encountered in the low-temperature carbonization method was in the design of a suitable retort, but after many attempts apparatus were designed and constructed which can economically produce suitable lignite char. This is discussed more fully in Chapter V. The lignite char, which is low in moisture and high in heat value, is briquetted with a binder such as coal-tar pitch, petroleum asphalt, or lignite-tar pitch, it being necessary to use approximately 10 to 12 per cent of binder for satisfactory results. Due to the high porosity and absorptive power of the char the use of a secondary binder such as flour, appears to be advisable, because it not only acts as a filler but also allows for a decrease in the amount of bituminous binder required, and gives added strength to the briquette. Investigations have shown that within certain limits, one part of flour will replace two parts of pitch, in the production of a strong, clean, hard, weatherproof briquette.

Several plants have, from time to time, been operated for the production of carbonized lignite briquettes, but it seems that in every case the projects were unsuccessful for financial reasons rather than mechanical.

BRIQUETTING OF BITUMINOUS COALS

These coals include fuels of widely varying properties and rank. They range from the high-volatile, non-agglomerating, sub-bituminous coals to the low-volatile, highly swelling, semi-bituminous coals. Extensive research on the classification of coals has resulted in the general acceptance that the bituminous coals may be divided, either according to their ultimate elemental composition or to their calorific value and volatile matter content, into the following more or less well defined groups.

(1) Sub-bituminous { non-agglomerating / agglomerating }
(2) Para-bituminous { pseudo gas coals / true gas coals }
(3) Ortho-bituminous—natural by-product coking coals
(4) Meta-bituminous —blending coals
(5) Semi-bituminous —both highly swelling, Pocahontas type, blending coals and weakly swelling coals.

Each one of these groups contains coals which are similar in many of their physical and chemical properties, such as friability, slacking characteristics, heat value, volatile content, oxygen, carbon, and hydrogen contents, and coking properties. The relationship of the rank of a coal to its coking properties has been fairly well established. Sub-bituminous coals may be divided into two groups, non-agglomerating and agglomerating, both of which are non-coking in so far as standard by-product practice is concerned. The para-bituminous or gas coals may be divided into pseudo-gas and true gas coals, the latter being the coals most suitable for gas works' practice because they result in the production of the largest thermal yield of gas, together with the finest type of gas coke. The ortho-bituminous coals are those coals most suitable for by-product coke practice when used alone. Meta-bituminous coals are coking coals used only in admixture with higher volatile gas coals, while the semi-bituminous coals contain those highly swelling, Pocahontas type coals, used so extensively in the United States for blending with lower rank bituminous coals in the production of the highest quality of by-product coke. Recent investigations, especially in the Fuel Research Laboratories, Department of Mines, Ottawa, definitely indicate that the briquetting amenability of a bituminous coal bears a similar relationship to its rank as does the coking property. It is shown in Chapter V that those coals which are considered to have the optimum coking properties for by-product use, also result in the production of the best briquettes from the standpoint of strength, weathering and burning properties. The sub-bituminous coals however, especially those which are non-agglomerating, require the addition of approximately 15 to 25 per cent of a strongly coking coal in order to produce a briquette of optimum quality, capable of resisting disintegration while being burned. It is, therefore, evident that blending is as equally necessary for the production of a good briquette from bituminous coals as it is for the production of the best quality coke.

In order to produce briquettes of optimum quality from those bituminous coals either lower or higher in rank than the ortho-bituminous coals, it is necessary to use increased quantities of binder, roughly in proportion to the deviation in rank from the ortho-bituminous coals, irrespective of whether a single or mixed binder is used.

The binders commonly used for briquetting bituminous coals are coal-tar pitch and petroleum asphalt with or without a secondary binder, such as flour or starch. The pitch binders are added to the dried and preheated coal, either in the pulverized or molten state. The secondary binder, which may be introduced as a paste, or in the dry state, and cooked with the coal in a preheater, allows for an appreciable reduction in the quantity of bituminous binder, with a resultant decrease in the smoke nuisance. It is even more interesting to note that the introduction of a secondary binder results in the production of a briquette which is stronger, less easily abraded and cleaner, than when pitch alone is used. Several processes have been developed, especially the Hite process[1] used by the American Briquette Company, which employs flour as the primary binder and pitch as the secondary binder. In these processes the binder is prepared in the form of an emulsion, the pitch being in a very finely divided state and acting as a weatherproofing material only, flour in itself not being a weatherproof binder. The use of a very small quantity of this binder produces a briquette of such strength that it can only be duplicated by the use of an excessive quantity of pitch.

Sulphite liquor is also used as a binder for bituminous coal, but to a lesser extent, however, than pitch. Although briquettes made with this binder are strong and non-abradable, producing a minimum amount of smoke, the great drawback is their non-waterproof characteristics. Baking at a temperature of about 600°F. for approximately 20 minutes will carbonize or char the sulphite liquor and result in a weatherproof briquette which, however, is somewhat weaker than the unbaked briquette. Various patents have been taken out for the production of a waterproof binder from sulphite liquor by the precipitation of the binding material with various inorganic materials such as lime. No commercial process has, however, been developed using the above method. Sulphite liquor in conjunction with flour is probably a better binder than sulphite liquor alone, but in this case waterproofing is also necessary.

The ultimate aim in briquetting bituminous coal for domestic use is to produce a clean, smokeless lump fuel from fines. The use of pitch binders adds to the smokiness, whereas the use of flour does not, but in either case there still is the smoke due to the volatile content of the coal itself. In view of this, considerable investigational work has been done on carbonizing or coking bituminous coal briquettes that have been made either with or without binders, at either high or low temperatures.

Recently, attempts have been made to briquette bituminous coals without the aid of a binder, by making use of the property of plasticity which all coking coals possess to a greater or lesser degree.

Investigations in Europe by Swietoslawski and co-workers, and in the United States by Piersol have demonstrated that by preheating bituminous coal, either in a mould or independently, to its plastic state, briquettes can be formed either by compression or impact. This work is still in the laboratory stage but it may have economic value. In view of the fact that no binder is required, and no complex expensive carbonization systems seem necessary, the method merits serious consideration, and it should result in the solution of the problem of producing clean, smokeless briquettes equal to anthracite, from bituminous coals.

[1] *See* Chapter III—Binders for Briquettes.

BRIQUETTING OF SEMI-ANTHRACITE AND ANTHRACITE

The briquetting of the fines resulting from the mining and preparation of both anthracite and semi-anthracite has been the chief aim of the industry in North America and the majority of the briquetting plants which have been established were for this purpose. Both of these fuels are low-volatile, non-coking coals which are practically smokeless, and the main problem in briquetting them is to keep the resultant fuel as nearly smokeless as possible. The use of coal-tar pitch and petroleum asphalt alone, as binders, requires such quantities as to make the fuel very smoky, and therefore inferior to the original coal. Recent developments indicate the use of flour-bitumen binders, such as the Hite binder, in which case the flour is the primary binder, and only sufficient bitumen is added to ensure a weatherproof briquette. This binder is best made up in the form of an emulsion resulting in the production of very fine particles of pitch so that only a small quantity need be used to ensure effective surface covering. Due to the use of a large quantity of water in preparing the flour paste, drying of the briquettes at a temperature of about 250°F. is necessary before they are satisfactory for marketing.

The use of sulphite liquor, either alone or with flour and/or pitch, has been attempted from time to time but without much success, it being necessary to subject the briquettes to either a heat treatment or some other waterproofing process such as coating with bitumen.

Briquetting of semi-anthracite and anthracite without a binder is impossible, because the coals are non-coking and do not become plastic when heated, and in order to produce a briquette which will stand up in the fire without any disintegration whatsoever, it is advisable to add at least 5 per cent of good coking coal.

The type of equipment used for briquetting anthracite with the aid of a binder is the same as that used for bituminous coal and is discussed in Chapter IV.

BRIQUETTING OF COKE BREEZE AND PETROLEUM COKE FINES

The fines resulting from the preparation of domestic coke are usually difficult of disposal. Many attempts have been made to briquette this waste product in order to enhance its value and to produce from it a satisfactory fuel. The briquetting of coke breeze alone is, however, difficult, owing to the porosity and absorptive power of the material which makes it necessary to employ a large quantity of binder. In addition, the coke fines are very abrasive and as a consequence repairs and replacements of machinery are greater with this material than with coal. Coke breeze has, however, been successfully briquetted by mixing it with coal, in which case a low-volatile, strongly coking coal is preferable as it not only improves the quality of the fuel but enhances its physical properties as well. A briquette of this type is freer burning than one made from coke breeze alone, and does not disintegrate so readily in the fire. Any binder which is satisfactory for other fuels can be used to briquette coke breeze, but it is considered that a flour-pitch emulsion is the most preferable. If, however, pitch alone is used, experience indicates that a smaller quantity is required and a stronger briquette is produced when the binder is added as a liquid rather than in the pulverized form.

The application of low-temperature carbonization to the lower rank non-coking bituminous coals results in a char or non-coherent residue somewhat similar to coke breeze, inasmuch as it is porous, but it is not similarly abrasive. Many attempts have been made to produce briquettes from this material with more or less success. With this type of fuel it is advisable to add approximately 5 per cent of a strongly coking coal in order to prevent disintegration during burning. Any of the binders suitable for coal may be used for briquetting low-temperature char.

Petroleum coke, which is the carbon residue from the distillation and refining of mineral oil, has been briquetted for industrial and domestic use. This material is similar to low-temperature coke breeze in its briquetting properties, with the exception that, because of its very low ash content and the oily smell of the smoke liberated it is usual to mix these fines with low-volatile coking coal. The resultant briquettes make a splendid fuel.

Carbon black or oil carbon has been briquetted in California and Oregon in the United States by the Fernholtz process (2) using a special press with 50 moulds. No added binder is used, the small amount of oil tar in the carbon being sufficient to act as a binder. This process has a very limited application.

CARBONIZED BRIQUETTES

The principal objection to briquettes on the part of the domestic consumer, especially where the standard fuel is either anthracite or coke, is the smoke resulting from the binder. A large amount of experimental work has been done and a number of processes tried out commercially, with both organic and inorganic binders, to overcome this disadvantage, but in the majority of cases the result was unsuccessful either owing to the briquette being insufficiently strong to withstand normal handling or that the increase in ash, due to the binder, lowered the quality of the fuel to such a degree as to render it unpopular. Experimental work has demonstrated that coal-tar pitch and asphalt are the most economical binders but as they both impart a certain smokiness to the resultant briquette, carbonization has been attempted to overcome this objection, especially when high-volatile smoky coals are processed to compete with anthracites.

Considerable work along this line has been done in France, and several plants are in operation producing carbonized briquettes. The Compagnie des Mines de Vicoigne, Nœux, et Drocourt, carbonize the pitch-bound briquettes in a series of fixed retorts, which are heated progressively with steam, superheated to about 650°C. The fuel is sold under the trade name of "Anthracine." The Purified Combustibles Company in their factory at Lapagnoy, France, use the Trent process for cleaning their coal, briquetting the resultant oil-coal paste, and then subjecting the briquettes to a low-temperature carbonization with the aid of superheated steam. Their fuel is sold under the name of "Trenthracite." Neilsen (8), who developed the "L & N Low Temperature Carbonization" process in England has applied it to fuel preparation of non-coking, high-volatile coals. In this process the non-coking coal is first carbonized at a low temperature, and the char is washed by gravity in troughs of running water. The cleaned char is briquetted with a binder prepared from the low-temperature tar, and the resulting briquettes are carbonized in "L & N" retorts.

The systems of carbonization used for briquettes are usually rather complicated, and as difficulty has been experienced due to the briquettes sticking together during carbonization, various processes have been patented for preventing this by embedding the briquettes in sand, coke breeze, etc. It is doubtful whether these suggestions are practicable.

Although a good smokeless briquette may be produced by carbonization, the combination of the use of a binder for briquetting, and the final carbonization, usually makes the process too expensive for most localities. Paul Weiss (9) states that the cost of production would not exceed $3.50 per ton of saleable briquettes, from coal containing less than 18 per cent of volatile matter.

The review of some of the patent literature on this subject, given at the end of this report in patents Nos. 189 to 210, indicates the tremendous interest in all countries in processes of the above nature.

BRIQUETTING WITHOUT BINDERS

The primary purpose of briquetting is to increase the value of the fuel, and it is only by this means that certain fuels can be utilized. This is particularly true of the brown coal (lignite) deposits of Germany, which in their natural state can only be utilized in the immediate vicinity of the deposits owing to the rapid disintegration of the fuel when exposed to the atmosphere. Experimental work on these fines demonstrated that a solid domestic briquette, which was capable of withstanding the handling necessary in transportation and which was weatherproof, could be produced without the addition of any binding material. This was accomplished by drying the lignite to a predetermined moisture content and moulding it at pressures of from 1,200 to 1,500 atmospheres in an Exter press. The success of the process apparently depended on the quantity of natural bitumen in the fuel, and the deposits which are utilized in this manner contain a high percentage of this particular constituent. The success of this process was so marked and its development so rapid that at the present time practically 80 per cent of the world production of briquettes is produced from German brown coal.

Many attempts have been made to produce similar strong weatherproof briquettes from Canadian and United States lignites, but without success mainly because of the lack of sufficient natural bitumen content. The process has, however, been successful with Australian lignites.

Because of the success of the German brown coal briquetting industry, and because binders add to the smokiness of the fuel, many experimenters have attempted to produce briquettes from higher rank coals without the use of a binder. The "Pure Coal Briquette" process of Sutcliffe and Evans

(10) in Leigh, England, which was practically the earliest attempt, consisted of briquetting a moistened coal and coke mixture without a binder, in a specially developed press, at 20,000 pounds per square inch, and carbonizing the briquettes at temperatures from 600° to 1000°C., in order to give them strength and make them smokeless. The "Delkeskamp Briquetting" process (2) developed in 1926 in Germany, consisted in mixing coal with 6 to 20 per cent of a colloidal dispersion of coal in water, and briquetting the mixture at pressures of 2,000 to 4,000 pounds per square inch. The resultant briquettes were carbonized at either high or low temperatures. In 1931, Hardy (11) in Belgium attempted to briquette coal in a roll press at temperatures between 350° and 400°C., and then carbonize the resulting briquette. The success of the process depended on the subsequent carbonization of the product to produce strong smokeless briquettes.

Other attempts have been made to produce briquettes without a binder or subsequent carbonization. Swietoslawski, Roger, and Chorazy (12) in Warsaw, Poland, in 1929 and 1930 carried out a comprehensive series of laboratory tests on coals of various ranks, in an attempt to make use of the property of plasticity of coal to produce briquettes, without the aid of a binder, employing pressure and temperature only. Their investigations led them to devise three methods for producing a strong briquette from coking coals at a pressure range of from 2,800 to 4,300 pounds per square inch. In the first method the coal is heated to the temperature of incipient plasticity, and produces briquettes having a granular structure. In the second method the coal is heated for the necessary length of time at the temperature of greatest plasticity in order to reduce the "bituminous matter" to the critical proportion. The third method consisted of heating the coal at the upper temperature limit of plasticity in order to decrease the time of treatment. The laboratory tests also showed: (1) that anthracite coals cannot be briquetted at any temperature without the use of binders, even at pressures up to 40,000 pounds per square inch; and (2) that the greater the caking power, plasticity, and volatile matter of semibituminous coals, the better the briquettes. The above investigation is still in the laboratory stage.

R. J. Piersol (13) of the Illinois State Geological Survey, in 1933 reports an investigation on "Briquetting Illinois Coals Without a Binder by Compression and Impact." The results of his compression experiments were as follows:

1. Compression tests indicated that fairly good briquettes can be formed at a temperature of approximately 300°C from coal heated in the mould or preheated to the above temperature.

2. A pressure of at least 15,000 pounds per square inch applied for not less than 15 minutes was effective. The time element is the most serious obstacle to the commercial application of the compression process of briquetting without a binder.

The results of the experiments using the impact method were as follows:

1. The double impact method produced good briquettes when 45 grammes of coal was impacted in a cylindrical die, by two blows of a 250-pound weight from a height of 6 feet upon coal heated for 10 minutes at 300°C.

2. The single impact method produced somewhat better briquettes when 45 grammes of coal was impacted by the blow of a 500-pound weight from a height of 4½ feet upon coal heated 10 minutes at 300°C.

3. Equally good briquettes were obtained by the single impact method if the coal was pre-heated externally.

This investigation, although still in the laboratory stage, seemed promising enough for the inventor to patent the process.

From the foregoing it is evident that although a certain amount of work has been done on briquetting coals, other than brown coals, without the aid of a binder, no commercial process has as yet been evolved. The recent thorough work of Swietoslawski and his co-workers in Poland, and of Piersol in Illinois, indicates, however, that in the near future a commercial process of this type may be evolved.

A review of some of the patent literature with respect to briquetting without binders is given in patents Nos. 211 to 224.

SHAPE, SIZE, AND WEIGHT OF BRIQUETTES

Coal briquettes are produced in a variety of sizes, shapes, and weights, and these three factors are largely governed by the purpose for which they are intended. In Europe, where briquettes are used extensively for industrial purposes, blocks of varying sizes and weights are preferred.

According to Franke (1) briquettes of the following shapes and weights are used on the German railways:

(*a*) Elongated, brick shaped, 220 x 110 x 105 millimetres, weight 3 kilograms.

(*b*) Quadratic, flattened, cube shaped, 160 x 160 x 105 millimetres, weight 3 kilograms.

(*c*) Elongated brick shaped, 280 x 150 x 110 millimetres, also cubical 185 x 185 x 135 millimetres, or 200 x 150 x 155 millimetres, weight 5 kilograms.

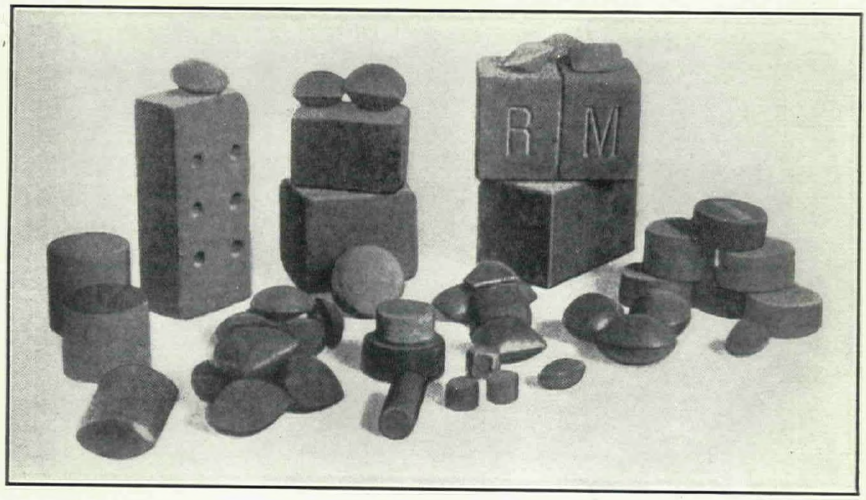
These forms are preferred as they can be stored in the coal storage space of the tender to better advantage than any other shape. They have to be broken before being charged but this disadvantage is tolerated owing to their other superior properties. In Belgium, briquettes of 4 kilograms, and in England of 9 pounds' weight are supplied to the railways.

The preparation of small briquettes for industrial purposes has not attained much importance in Europe, owing to the competition of natural coals which have been screened to the desired size.

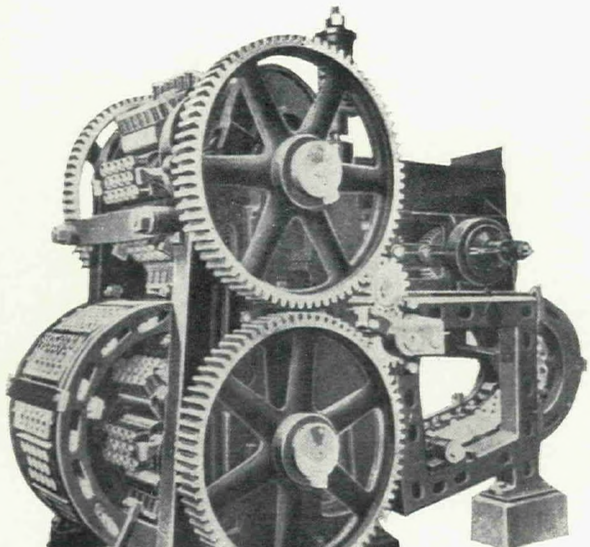
In America briquettes are primarily produced for the domestic trade and must, therefore, "be of a size from which the same results can be obtained as from the prepared sizes of fuel the public is in the habit of using" (6)

A briquette must be of such form or shape that it can be spouted, the same as ordinary coal, shovelled from the top of a pile, handled by clam shell buckets, elevators, etc. The important point that must be considered with any shape of briquette is the right size to give the best results with any particular coal, and the purpose for which the fuel is intended. At the present time the prevailing size that the public demand after considerable experience in different parts of Canada, United States, and the tropics, varies from 1⅝ ounces up tu 2½ ounces for domestic use, and from 2½ ounces up to 5½ ounces for steam and furnace use. The larger size is only suitable for steam boilers and large furnaces, for instance, it has been found in burning briquettes in locomotives that about a 2-ounce to 2¼-ounce briquette made from so-called semi-anthracite, low volatile, and high carbon coal dust, gave the best results and produced the smallest percentage of carbon monoxide, as compared with briquettes weighing 3¼ ounces (6).

The various shapes of briquettes which are ordinarily produced both in Europe and America are shown in Plate II A.



A. Various types of briquettes.



B. Rutledge press.

CHAPTER III

BINDERS FOR BRIQUETTES

Since the early days of the briquetting industry, a large number of different materials have been suggested as binders, many of which have been applied on either an experimental or manufacturing scale. A large number of patents have been issued; and in practically all cases the object is to produce a smokeless, odourless, and waterproof binder which would be cheaper than coal tar, pitch, or asphalt.

Binding materials may be divided into organic and inorganic substances. The organic binders are the most suitable in that being combustible, they usually do not contribute to the ash. These binders for best results should have the following properties:

1. On combustion, little or no objectionable odour or smoke should be produced.

2. On heating, the binder should not soften to such an extent as to allow the fine coal to fall away in the fire. It should, therefore, preferably be a coking material, so that on ignition it will coke and agglutinate the fine coal, which may be of a non-coking variety. In every case a binder should fulfil the following requirements:—

It should permit of the preparation of briquettes which conform to the following specifications:

(*a*) The strength of the briquettes shall be at least equal to that of good coal;
(*b*) The loss by abrasion and shattering during ordinary handling and transport should not exceed 5 per cent;
(*c*) The apparent specific gravity should not be much below 1·20;
(*d*) The ash should not exceed 10 per cent;
(*e*) The moisture content should not exceed 5 per cent, neither should the briquettes absorb water, nor fall to pieces on standing in water; and
(*f*) The calorific value should be at least equal to that of the coal with which it is intended to compete.

It should be obtainable in large quantities of uniform quality and at a reasonable price.

The following list includes most of the binders employed. A few comments have been made and a review of the patent literature applying to each is included in the Appendix.

ORGANIC BINDERS

Coal-tar Pitch

This material was almost exclusively used in Europe as a briquette binder, and until about 1912 was the only binder used in America, since which time it has been almost entirely replaced by asphaltum. The most suitable coal-tar pitch is that made from coke oven, gas works, and carburetted water-gas tar. Blast furnace and producer-gas tars yield unsuitable pitch. According to Grounds (14) a satisfactory coal-tar pitch for briquetting should have the following properties:

(*a*) The pitch should be " medium soft " to " hard."

(*b*) "Twisting point"—50°C to 55°C.

(*c*) Softening point by ring and ball—140° F. to 225°F.

(*d*) Free carbon should be low—70 to 80 per cent soluble in carbon bisulphide.

(*e*) Coke button in platinum crucible should be quite flat and greyish black in colour, a swollen button indicating an unsatisfactory pitch.

The coal-tar pitch when used in the liquid state for briquetting may have a melting point varying from 140°F. to 175°F., but when introduced in the dry pulverized state the melting point should be between 160°F. and 225°F. It should not exceed the latter temperature as sufficient heat for melting and spreading the binder over the coal will not be available if the process is to be maintained on an economic basis. The amount of pitch necessary to make suitable briquettes is between 6·5 and 9 per cent, depending on the properties of the coal to be bound.

Petroleum Asphalt

This material is used more extensively than any other as the binding medium in briquetting plants in America. When properly prepared from suitable oils it possesses several advantages over coal-tar pitch. Inasmuch as it contains no cresols it is practically odourless and, in addition, by reason of its low free carbon content a smaller quantity is required for the manufacture of briquettes of equivalent hardness. Asphalt does not produce so much smoke as coal-tar pitch on burning, and, as less is required, briquettes made with this binder are more acceptable to the consumer. However, although the required melting point is practically the same, more efficient pulverizing, mixing, and heating are required than with coal-tar pitch. The asphalts produced for paving and waterproofing are not the most suitable for briquette binders, since larger quantities of these are required to produce briquettes of the proper hardness. Special asphalts of the proper melting point are produced for briquetting, which are tough and hard when cold, and yet possess the properties of adhesiveness and stickiness. This type of asphalt has a low viscosity and is almost as fluid as water when heated above its melting point. Such asphalts are usually residues from the cracking coils and may be used either in liquid state or pulverized and mixed with the coal before heating. Petroleum asphalt as a briquette binder has not been adopted to any extent in Europe owing to its scarcity.

At the end of the report will be found a list of some of the patents issued for the use of coal-tar pitch and asphalt as briquette binders.

Bituminous Emulsions

These are prepared for the purpose of reducing the quantity of pitch used in briquetting, and the claim is made that, by their use, it is possible to manufacture a briquette of better quality requiring less total binder. Most of these patent binders contain a fairly large proportion of water, with an emulsifying agent such as flour, alkali, clay, tannic acid, or sulphite liquor, and therefore the finished briquettes must be dried before being shipped or stored. Some of the emulsions are so made that the starch acts as the main binder, and the pitch only as a waterproofing agent and secondary binder. In the list of patents, those worthy of note are Nos. 25, 28, and 32, the first two pertaining to the starch-asphalt emulsion as developed by Charles E. Hite, which has been applied so successfully to the briquetting of Pennsylvania anthracite.

Mixed Binders for Coal using Coal-tar Pitch or Asphalt as a Base

In order to decrease the quantity of coal-tar pitch or petroleum asphalt necessary for the production of briquettes of suitable strength, many experimenters have tried mixing substances of widely varying types with the base binder. These secondary binders include inorganic materials such as lime, clay, sulphur, calcium chloride, magnesium chloride, etc., and organic materials such as tar, resins, oils, flour, blood, etc. The former are objectionable because they increase the mineral content of the briquettes without suitably compensating for the increased ash by providing a better or cheaper binder. The organic binders are, however, of greater value, especially the starch binders, as it has been demonstrated that one part of starch replaces practically two parts of pitch. There is a limit, however, to which pitch may be replaced by starch, depending upon the desirability to produce a waterproof briquette. Starch alone produces strong briquettes which, however, are not waterproof.

Under the heading of mixed binders should be included those processes which involve the briquetting of oil-coated fines, resulting from either oil flotation processes or the Trent process. In this case pitch is used as the binding medium and in order to reduce the smokiness the briquettes are usually carbonized. For greater detail see patents Nos. 41 and 42.

Generally speaking, it is questionable whether any of the proposed mixtures of binders may be considered as either economic or practical, with the single exception of flour and pitch. The patents which have been issued under this heading include Nos. 34 to 45.

Mixed Binders for Peat, Lignite, etc., using Coal-tar Pitch and Petroleum Asphalt as a Base

Binders of this type are largely confined to the briquetting of peat, lignite, low-temperature chars, coke breeze, and vegetable materials. Fuels of this nature are usually quite porous and possess a high absorptive capacity, which makes it necessary to use a very large quantity of bituminous binder for the production of a satisfactory briquette. In order to reduce the quantity of this type of binder, it is customary to add a material to the fuel which will act as a filler, thus reducing its porosity and making it possible to briquette with a reasonable quantity of pitch. These fillers are either inorganic or organic, the former including lime, clay, water-glass, etc., and the latter, flour, blood, or other albuminous or farinaceous material. The inorganic substances are objectionable inasmuch as they tend materially to increase the ash in the briquettes. The organic fillers are preferable, especially those containing starch. Many of the materials used as fillers require the addition of large quantities of water, and consequently a drying process is usually necessary, and must, therefore, be included in the plant equipment. Direct-fired dryers are the type usually employed for this purpose as they are the most efficient for driving off the large quantity of moisture involved, but considerable difficulty is encountered in the use of these owing to the low ignition temperature of peats and lignites which results in spontaneous combustion of the material being dried.

A large number of patents have been issued on binders of this type, Nos. 46 to 60 inclusive indicate the wide variety of binders suggested.

Coal Tar, Petroleum Oils, Rosin, Naphthalene, etc.

Coal tar has been employed as the binding material for the production of briquettes but it possesses several objectionable features in that it is too sticky, softens too easily, and produces large quantities of objectionable smoke. Distillation of the briquettes has been attempted, but the quality of the finished product is not so good as when pitch is used. Coal tar has a limited use in admixture with harder pitches. Some of the older briquette factories in central France melt the pitch and add about 15 per cent of tar, and in some cases the coal tar is treated with approximately 5 per cent of sulphur in order to increase its binding power and viscosity.

Rosin. Many of the factories in lower Rhenish Westphalia use a certain proportion of rosin when the price of pitch becomes unduly high. Rosin is the residue from turpentine distilleries, and is a crude brown resin with a melting point of about 120°C. It must be finely ground, and in this fine state is much more liable to spontaneous combustion than pitch. Rosin cannot be used alone as the resulting briquettes are weak and fall to pieces in the fire, but as its binding power is from 2 to 3 times that of pitch, it enables a substantial saving to be made when the price of coal-tar pitch is excessive.

Naphthalene. Experimental briquettes made with this material are of very low strength, and hence the binder is unsuitable.

Paraffins, such as acid sludge and tallow, have also been suggested, but their successful use as binders is very doubtful.

Heavy petroleum oils have been suggested for briquetting coal in a similar way in which coal tar is used. The various processes of solidifying petroleum or other oils, however, do not add to their binding qualities and these oils are usually unsuitable for briquetting coal.

Hydrogenated products, such as those of coal, have also recently been suggested as binders. No commercial application of this process has been noted, although it appears to have possibilities.

For greater detail on the above binders, *see* patents Nos. 61 to 85, inclusive.

Vegetable Binders

These include farinaceous material such as flour, cornstarch, and dextrin; fermented and chemically treated vegetable material; paper pulp, peat, and brown coals, etc. Of these, the most important are the starches and the treated vegetable material.

Flour, Starch, etc. When these are used it is necessary to convert them into a paste either before or after addition to the coal. This entails the use of a large quantity of water and hence a drying process for the briquettes must be included in the equipment of a plant. Starch alone does not, however, produce a waterproof briquette and therefore is unsuitable for commercial purposes. The use of flour also necessitates the introduction of a chemical to prevent fermentation and moss growth which would soften and weaken the briquette. (*See* patents Nos. 95, 98, and 100.)

Fermented vegetable material has been employed as a binder and methods have been devised for its production which are claimed to be commercially successful. One process developed by C. J. Goodwin and G. N. White of Wales (15) consists of the bacterial fermentation of vegetable matter such as grass, beet waste, etc., to form a humus material which when ground with from 1 to 6 per cent of its weight of soda, a gelatinous binder is formed. It is claimed by the inventors of this process that briquettes made with this binder, when properly dried, are weatherproof and smokeless. (*See also* patents Nos. 93 and 94.)

Chemically treated vegetable materials for binders usually employ seaweed, moss, etc. These materials are boiled in water to which alkali has been added, the resulting gelatinous mass possesses good binding properties, but produces briquettes which are not waterproof. Incidentally, this process is an expensive one. (*See* patents Nos. 91, 92, 95 and 101).

Paper Pulp (Cellulose and Sawdust). These have been used as binder, experimentally, either in the finely divided state or chemically treated with water and alkali to form swollen hydrated jelly-like products. They are expensive and do not yield waterproof briquettes.

Peat, Brown Coals, etc. These are quite good binders for coals, but can be used only where the material is available at a very low price.

With all the above binders, drying of the briquettes is absolutely necessary, and in most cases they are expensive and the resulting briquettes not weatherproof. (*See* patents Nos. 86 to 103 inclusive).

Miscellaneous Organic Binders

Organic materials of widely varying origin, both alone and in combination, have been experimented with as binders for the manufacture of briquettes. These include such substances as gums, vegetable extracts, glue, casein and other milk products, albuminates, molasses, scrap leather, etc. Certain of these substances possess merit as a binding medium, but their production is insufficient to satisfy more than local demands and should a widespread market develop for these products they would not be available. A further disadvantage of the use of this type of binder is that it is necessary to add some inorganic material such as lime or cement and, in addition, some chemical to act as a preservative. The use of binders of this type involves the addition of fairly large quantities of water and as a consequence a drying process is usually necessary which adds to the cost of the plant. Although a large number of patents have been issued on binders of this type it is doubtful whether any of them have attained commercial success.

Greater detail as to the types and uses of the above-mentioned binders may be obtained by reference to patents Nos. 104 to 122.

Sulphite Liquor

The liquor obtained from sulphite cellulose factories has been the starting point of various more or less valuable briquetting materials. "Sulphite Pitch" is a concentrated sulphite liquor which has been neutralized with lime. The pitch is of about 32° Bé. or heavier, and contains approximately 50 per cent of solids. It is used extensively in America under the trade names of "Glutrin" and "Binderine" in foundries for core work. Under the name of "Cell Pitch" it is sold in the dry powdered form and must be dissolved in water before it can be used as a binder. The objections to this binder are: its high sulphur content which produces obnoxious fumes when the briquettes are burned, and the non-waterproof nature of the briquette, the binder being very hygroscopic. To overcome this latter objection a great many processes have been patented, based on using some waterproof materials such as pine tar, coal tar, asphalt, coal-tar pitch, oils, etc., which are mixed with the sulphite pitch. Some processes use a bituminous emulsion to give the briquettes a waterproof coating. In every case the briquettes must be dried in order to produce a product which will handle easily and store well. The best method of waterproofing is baking at a temperature of about 600° F., at which temperature the sulphite pitch is carbonized, forming a strong waterproof binder. This process requires expert control and adds appreciably to the expense of manufacturing briquettes.

The use of sulphite liquor as a binder has not been very successful, one of the main reasons being the difficulty experienced in producing well formed briquettes continuously. Rigid temperature and moisture control of the briquetting mixture is imperative, otherwise, sticking in the rolls or moulds results. Several methods have been developed for producing an adhesive from sulphite liquor, which would be waterproof in itself, without the addition of a secondary waterproofing material and without the necessity of carbonizing. According to Mitscherlich(1) such a binder is prepared as follows:

The liquor is treated with lime until it is very faintly alkaline or with chalk until it is practically neutral. In this way calcium sulphite is caused to separate out. The liquor is then introduced into an osmosis apparatus. The liquid flowing from the apparatus carries with it most of the inorganic materials, fermentable bodies, etc., while the residual material contains the real adhesive substances in combination with lime. This is treated with sodium carbonate until the precipitation of the calcium carbonate is complete.

This adhesive substance does not absorb moisture and can be obtained at a very low cost. A cheaper binder may be made as above by using only lime and eliminating the sodium carbonate. The binder prepared thus has, however, a tendency to absorb moisture. *See* patent Nos. 123 to 167 on sulphite liquor.

INORGANIC BINDERS

The use of inorganic materials, such as are employed in the clay and building industries, as binders for fuel briquettes, probably had its origin in the first attempts at briquetting which consisted of moulding, by hand, lumps of fuel with moist clay. Inorganic binders have the disadvantage of appreciably increasing the ash content of the briquetted fuel and must therefore be added in small quantities. As a result, for a binder of this type to be successfully employed, it must have a very high adhesive power and should set quickly. The inorganic binders usually employed are clay, Sorel cement, Portland cement, and lime.

Clay

This material makes a weak briquette which does not stand up to handling and storage, and hence it can only be used locally for immediate consumption.

Magnesia or Sorel Cement

The high binding power of a mixture of magnesium chloride solution and ignited magnesia was discovered by Sorel and it was first used in the briquetting industry by A. Gurlt in 1880 (1). A satisfactory mixture can be made from 30 parts of a 45 per cent solution of magnesium chloride, 30 parts of 93 per cent magnesia, and 60 parts of water. The briquettes are supposed to be weatherproof, store well, and behave well in the fire, but are quite brittle. The cement is quite expensive and adds appreciably to the ash of the coal.

Portland Cement

This material is less expensive than magnesia cement, but does not possess the binding power, and a longer time is necessary for complete setting and hardening of the briquettes. When made with this cement briquettes do not fall apart in the fire, but disintegrate in water. It requires 10 per cent in order to make a good strong briquette.

Lime

This material necessitates the ready access of carbon dioxide in order that it may be converted to calcium carbonate for optimum binding action. For this reaction an outside source of carbon dioxide is necessary which makes the process expensive.

Other inorganic binders suggested from time to time, are water glass (sodium silicate), plaster of Paris, magnesia, etc., but they are all unsuitable except when used in large quantities. (*See* patents Nos. 168 to 188.)

CHAPTER IV

EQUIPMENT USED IN BRIQUETTING

The briquetting of coal is carried on in the following manner: The material to be briquetted, which is usually washed or unwashed fines, is first dried to the desired moisture content. The binding material, which is usually hard or medium-hard pitch, is, depending on the melting point of the pitch used, either pulverized and intimately mixed with the coal in predetermined ratios or is added in a molten state by spraying on to the previously heated coal. In either case the coal and binder are thoroughly mixed in heated mixers after which the plastic mass is fed to a briquetting press. The resultant fuel briquettes are cooled and conveyed to storage.

From the above it is evident that a briquetting process is roughly divided into six separate operations:—

1. Preparation and conveyance of coal.
2. Preparation of binder and feeding.
3. Drying and preheating.
4. Mixing and kneading of coal and binder.
5. Pressing of plastic mixture.
6. Cooling, screening, and storage of finished briquettes.

Flow-sheets of the two types of briquetting plants are shown in Figure 1.

PREPARATION AND CONVEYANCE OF COAL

If the coal is not fine enough when received at the plant, the material is usually screened over a $\frac{1}{4}$-inch mesh screen and the oversize crushed in suitable equipment, usually swing-hammer pulverizers or roll crushers. Care must be taken to maintain uniform and proper screen analysis, as an excess of large particles tends to result in weak and easily abraded briquettes, whereas too great a proportion of fines increases the binder requirements to such a degree as to be both uneconomical and objectionable to the consumer. The prepared coal is then delivered by a system of conveyers, either belt or elevator, to a suitable feeding bin, from which the coal is measured by the use of a table, plunger, or worm feeder. It is absolutely necessary to have a flexible coal feeding device of some sort, in order to enable the proper mixing ratio of coal to binder to be maintained continuously, and to enable a change in the ratio to be made in a very short time during operation.

PREPARATION OF BINDER AND FEEDING

As approximately 95 per cent of the binder used in the briquetting industry is either hard or medium-hard pitch, the preparation of these is important. Hard pitch is usually received in large blocks or lumps, which must be broken down by hammers and then crushed in a pitch cracker down to $\frac{3}{4}$-inch pieces. It is further reduced in size in specially designed pitch pulverizers in order to obtain a uniformly sized fine product which can be easily mixed with the crushed coal in the dry state. If the particles of crushed pitch are too large, difficulty will be experienced in obtaining a uniform mixture with the coal and a much larger quantity of binder

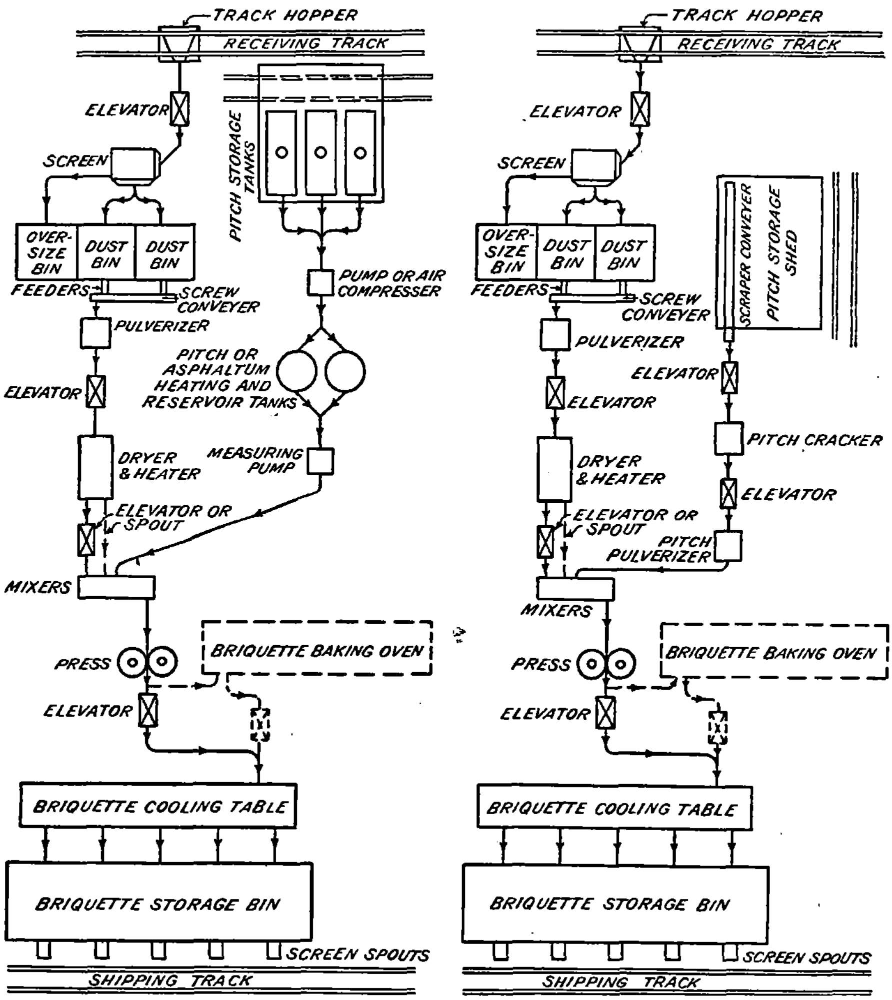


Figure 1. Flow-sheets of two types of briquetting plant.

will be necessary to produce briquettes of suitable strength. Also, much more superheated steam and larger mixers would probably be necessary if the pitch is not crushed uniformly fine. The common types of pitch pulverizer are the centrifugal disintegrator, and the impact mill operating on the percussion principle. Roll mills are unsatisfactory because of the sticking of the pitch to the rolls. After the pitch is ground to from 30 to 60 mesh, it is stored in bins from which it is delivered in measured quantities, by means of a suitable device such as a table or screw conveyer, to the mixers where it is mixed with the coal and heated.

Where a medium-hard pitch, i.e. having a melting point below 150° F., is used the binder is supplied to the coal in the liquid state. To handle binder of this nature most economically it should be delivered to the briquetting plant in tank cars, equipped with heating coils, from which it is pumped into large storage tanks where it should be kept at a constant temperature. For smaller plants the pitch is usually received in drums. The liquid binder is most readily mixed with the coal in definite predetermined quantities, continuously, by means of a rotary binder pump of the positive-pressure type, having a slow speed and equipped with a variable speed drive so as to allow for a rapid change in the rate of feeding. An alternative method for mixing the liquid binder with the coal, is by means of a steam-jacketed valve operating under constant head conditions. A satisfactory arrangement consists of a small overhead tank, which is fed continuously from storage, and is maintained at a constant head by a return overflow. The binder is usually sprayed on the coal by means of steam or air.

DRYING AND PREHEATING

If excessively moist coal is received at a briquetting plant it is necessary, especially if pulverized pitch is used, to dry the product before crushing to the proper size. Two types of equipment are used for this purpose—table dryers, and rotary dryers.

(1) *Table Dryers.* These are steam-heated, and consist of a system of hollow iron plates arranged one above the other, with a clear space in the centre and discharge openings either at the inner or outer edges. The tables are provided with revolving shovels which move the thin layer of coal from one side to the other, and discharge the coal from one table to the other.

(2) *Rotary Dryers.* These are of two kinds, direct-fired and steam-heated. They are inclined horizontal cylinders, being either mounted on a central shaft or rotating on steel tires and rollers. The steam-heated dryers are jacketed, and are so constructed that live steam does not come in contact with the condensed water. Steam dryers are not so efficient as properly designed direct-fired dryers, especially where very high moisture coals are treated.

MIXING AND KNEADING OF COAL AND BINDER

Proper mixing of coal and binder is accomplished with the aid of mixers of which there are three main types.

(1) *Horizontal Mixers.* These are of the paddle or ribbon blade type, and are so constructed as to enable both good mixing and conveyance to be accomplished. Some manufacturers include "pugging" blades to ensure efficient mixing. The mixers are supplied with or without steam jackets, and with bottom or end discharge.

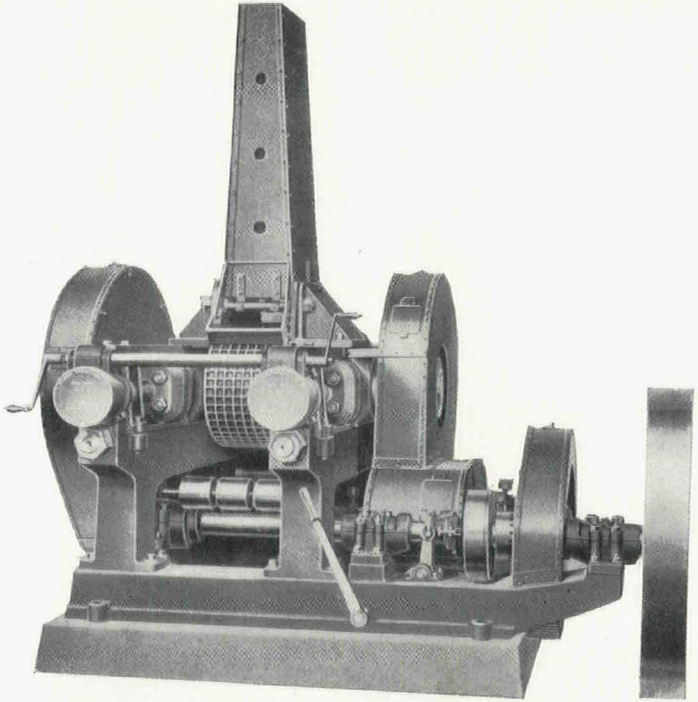
(2) *Vertical Mixers.* These are of two distinct types, one having fixed blades and a single rotating shaft equipped with arms, the other having two rotating shafts with arms arranged to give a cutting action. These mixers are made with or without steam jackets.

(3) *Masticators.* The Chilean mill type masticator, which is a modified edge runner, is sometimes used. The rolls are not heated but the base plate is so constructed to allow the introduction of steam, which serves to form a heated surface for the mixture. The use of this equipment is the basis of the "Dutch" process.

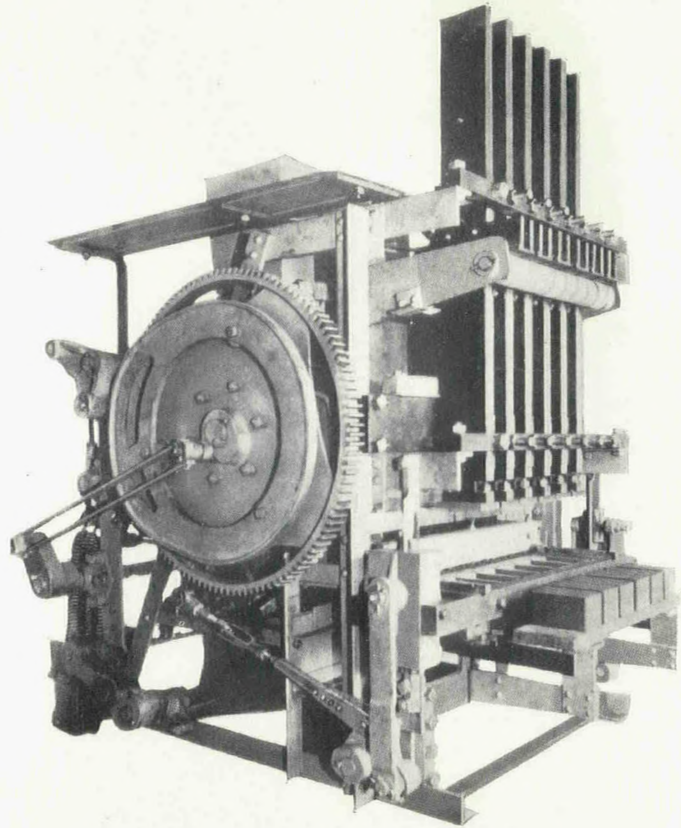
The use of either dry pulverized pitch or liquid pitch necessitates different arrangements of mixing equipment. Where dry pulverized pitch is used the coal need not be preheated, the binder being mixed with the coal while both are cold. They are introduced together into a heated mixer, usually with the addition of live steam. After a thorough mixing, the plastic mass is discharged into a second mixer, called a temperer. This mixer is either water-jacketed, or the material may be cooled by a stream of air passing through it. The mass is then discharged through a suitable feeding device to the press.

When liquid binder is used the process is slightly different. The coal must first be heated in a mixer, called the preheater, in order to get the coal to a suitable temperature for the introduction of the binder. The preheater may be either steam-heated or direct-fired. This mixer may also be used to explode starch granules and form a starch paste, when it is desired to employ this material as a secondary binder, in which case live steam is usually introduced into the mixer. From the preheater the coal is discharged into the mixer or kneader, where the liquid binder is sprayed on the coal, and thoroughly mixed with it. A fairly high temperature must be maintained in the mixer, in order to enable the binder to coat all the exposed surfaces of coal. These mixers are usually steam-jacketed. The plastic mass is then discharged into a cooling mixer called a temperer. Here the mixture is cooled either by air, or by water-jacketing the equipment, to a temperature suitable for pressing.

In both the above processes the three types of mixers referred to previously may be used alone or in conjunction with each other, the most common combinations being either horizontal mixers alone, or a horizontal mixer for preheating and tempering and a vertical mixer for fluxing.



A. Typical roll press.



B. Kleen-Blox press.

PRESSING OF PLASTIC MIXTURE

The development of briquetting necessarily depended on the availability of suitable apparatus for forming the briquettes. The presses used in the industry may be divided into four classes: —

Plunger Presses. In which the pressure is applied to one side of the briquette only, of which the following are representative: Mazeline, Steven, Crozet, Exter, Revollier, Dupuy, Detombay, etc. This type of press was introduced about 1850, and only a very limited number are now found in use, mainly at the oldest plants in Europe. Briquettes made in these presses are not uniformly dense throughout their whole mass, and do not possess uniform strength.

The following are a few representative types of plunger presses in which the pressure is applied on two sides of the briquettes: Bretrux, Couffinhal, Veillon; the revolver presses of Middleton, Yeadon, Yeadon-Busse, etc.; and the toggle-joint presses of Schuring, Tigler, and others. These include the most widely used plunger press systems of the present day in Europe. They were first introduced in the late 70's. The Couffinhal press, manufactured in Germany, is the most popular in Europe, and the most suitable for making large briquettes of square or prismatic shape, weighing from 2 to 20 pounds. It is capable of a maximum throughput of 20 tons per hour. In this machine both pressing jaws have a stamp, while the upper pressing jaw also carries the discharging stamp. The pressing operation commences by filling from the distributing head during the revolving of the moulding table. The sequence of pressing is so arranged that the initial compaction is carried out by the movement of the upper stamp and as soon as the briquetting material offers a certain resistance to further compression, the lower pressing stamp is raised so that the final pressure on the briquette is effected equally from both sides. This type of press produces uniformly dense and strong briquettes.

The Yeadon press manufactured in England since 1877, is of the revolver type; so called because of the mould disk turning in a vertical plane on a horizontal axis similar to a revolver. These presses are built in various sizes up to an output of 20 tons per hour, making briquettes weighing from 1½ to 20 pounds.

Another type of plunger press in which the pressure is applied on two sides is the rotary Rutledge press (Plate IIB) developed by G. Komarek in the United States. It consists of a chain of moulds or die plates, passing under a feeding hopper and between two revolving drums that carry punch rams. The lower punch rams enter the dies again, after compressing the briquettes, and eject them. The briquettes fall from the press to a perforated chute, which delivers them to the cooling conveyer. The briquettes are cylindrical in shape and weigh 10 to 16 ounces. The press makes about 32 tons of briquettes per hour. This press was installed by the Malcolmson Briquette Engineering Company, at the plants of the Standard Briquette Company, Kansas City, Mo., the Pacific Coast Fuel Co., Seattle, Wash., and the Berwind Fuel Company, Superior, Wis. The upkeep of these presses is likely to be very high as compared to ordinary roll presses.

Extrusion Presses. These presses include those in which one briquette is formed against the back of another, i.e. rope and sausage presses of Evrard and Bouriez. The principle of these machines depends on the plastic briquetting material being pressed into an elongated channel, open at both ends, by a pressure stamp which is moved to and fro. The material is briquetted in the form of a rope, which when it emerges is cut into briquettes of uniform length. This process leaves much to be desired in so far as good strong briquettes and ease of operation are concerned.

Presses with a Tangential Action. These are presses in which the pressure is produced by means of a pair of rolls such as those of Loiseau, Gilly, Maison de Beer, Zimmerman, Fouquenberg, Bilan, Mashek, Komarek, Zwoyer, etc. In these machines the rolls are horizontally arranged and revolve in opposite directions. The faces consist of exchangeable shells provided with moulds having the shape of half an egg, or pillow, etc. The first "egg"-briquette press used was that of Loiseau, and it was put into operation in 1870 in the briquette factory built by him at Port Richmond, Philadelphia, Pa. The first American roll press produced was constructed by G. J. Mashek in 1905. Roll presses in general are built with capacities of from 4 to 30 tons per hour and make briquettes weighing from $1\frac{1}{2}$ to $5\frac{1}{2}$ ounces. (Plate IIIA).

Tamping Presses. Machines of this type employ stamping to consolidate the briquette, the Kleen-Blox press (Plate IIIB) being an example. These are recent American developments and are made in various sizes from that suitable for small retail dealers, having a capacity ranging from 2 tons an hour, to 40 tons. The material to be briquetted, which need not be crushed finer than through a $\frac{3}{4}$-inch screen, is fed into moulds, and tamps of approximately 500 pounds in weight deliver several blows compressing the material into a block, varying from 3 by 3 by $3\frac{1}{2}$ inches to 5 by 5 by 8 inches. The blocks are stripped from the moulds and moved forward on conveyers. These presses are simple in design, and should be comparatively inexpensive. Very little experimental work has been done on processes using these presses, and hence it is not possible to predict whether they will achieve a wide adoption.

COOLING, SCREENING, AND STORAGE OF FINISHED BRIQUETTES

The pressed material as delivered from the press usually contains a varying quantity of fines which are immediately screened out on either a cascade screen or mesh conveyer, and returned to the plant. Briquettes must be cooled before being stored in bins to prevent any possibility of spontaneous combustion, and to allow the briquettes made with pitch to harden. The time for cooling usually varies from twenty minutes to one hour, depending on the size of the briquettes, the coal from which they are made, the binder used, and the heat necessary to briquette the fuel properly. When a baking oven is used to produce a smokeless or partially carbonized product, the briquettes are passed through the oven immediately after being pressed, after which the hot briquettes are cooled. Two types of equipment are used for cooling, namely, *Cooling tables*, consisting of a series of endless steel plate conveyers upon which the briquettes are evenly distributed, and *Conveyer belts*, which are made of a suitable length to allow for sufficient cooling time. A slow cooling process is preferable to sudden chilling, as in the latter case the rapid contraction produces fine cracks and thereby weakens the briquette.

The cooled briquettes are conveyed to storage bins or piles, or loaded into cars, etc., by means of adjustable belt conveyers and chutes. In order to prevent excessive breakage in loading, care should be taken not to subject them to too great a drop.

NORTH AMERICAN PRACTICE

Standard practice in North America is to use roll presses for the manufacture of briquettes, employing various arrangements of the auxiliary equipment described above. A few exceptions to this practice, however, may be noted inasmuch as the heavy pressure presses of the German type described, have been tried, without success, in an attempt to briquette raw lignite. The Rutledge plunger press has also been used to a minor degree.

The tamping presses described and illustrated in Plate IIIB are being installed in the yards of retail coal dealers in order to briquette the "fines" resulting from the preparation of various coals sold on the domestic market. Two such plants exist in Canada at present, but insufficient experience has, so far, been obtained to predict whether this type of briquetting will result in its general adoption.

CHAPTER V

INVESTIGATIONS ON BRIQUETTING IN NORTH AMERICA

EXPERIMENTAL WORK IN UNITED STATES

The first briquetting plant in America was erected by E. F. Loiseau in 1870, but after a short period of operation it was closed owing to the process being neither mechanically nor commercially sound. After Loiseau's failure several other unsuccessful attempts were made to briquette fuels on a commercial scale, and according to C. L. Wright (16) these failures were due mainly to the following causes:

1. Plants were poorly situated for marketing the briquettes.
2. The briquettes produced were of inferior quality. They contained an excessive amount of smoke-producing pitch binder which resulted in heavy soot formation, thus creating a public prejudice against this type of fuel.
3. An uncertainty existed as to the supply of raw fuel and binder.
4. Lack of proper technical supervision. (The making of satisfactory briquettes involves more than the possession of suitable machinery.)
5. Attempts were made to develop a new binding material or a new press, without proper appreciation of the principles of briquetting.

Partly because of the large number of failures and partly because the high cost of coal-tar pitch, which was one of the main barriers to the development of the briquetting industry in the United States, the American government began a series of briquetting investigations in its fuel testing plant at St. Louis, Mo., in 1904. This plant was finally transferred in 1908 to the Pittsburgh Experiment Station where the investigation was continued.

One of the main purposes of this investigation was to discover, if possible, some cheaper binding material than coal-tar pitch, and with this in view a large number of tests both in the laboratory and on a plant scale were conducted, which were ultimately published in collected form by C. L. Wright of the Bureau of Mines in 1912. The results of these investigations on binders included the work of J. H. Pratt, J. E. Mills, and C. L. Wright; and may be summarized as follows:

1. Different binders require different methods of heating to obtain the best results.

2. The various classes of fuels require different methods of treatment to produce the best briquettes.

3. Lignites, to produce the strongest briquettes, generally require drying before being mixed with binder, but for the best results some moisture must be allowed to remain in the fuel.

4. Six per cent of water-gas pitch made satisfactory briquettes from Pittsburgh slack, Texas lignite, Philippine lignite and Washington sub-bituminous coal; 7 per cent was sufficient to briquette Utah sub-bituminous coal satisfactorily.

5. Three per cent of wheat flour made satisfactory briquettes from samples of Texas and North Dakota lignite; 4 per cent made satisfactory briquettes from undried Philippine lignite; and 5 per cent was more than sufficient to make satisfactory briquettes from Washington sub-bituminous coal. The briquettes held together in the fire but deteriorated when exposed to the weather.

6. Almost the same results were obtained with cornstarch as with wheat flour.

7. Four per cent of hardwood-tar pitch made strong briquettes from Pittsburgh bituminous slack. The strong characteristic odour of this material, however, was considered an objection to its use.

8. Two per cent of cell pitch made strong briquettes with Pittsburgh bituminous slack; 8 per cent was required to briquette Texas and North Dakota lignite, and 4 per cent was sufficient for Utah sub-bituminous coal. The briquette having the greatest compressive strength was made from Pittsburgh slack and 6 per cent cell pitch. These briquettes were, however, not waterproof.

9. Three per cent of sulphite liquor was sufficient to briquette Pittsburgh slack, but 5 per cent was necessary for anthracite culm. Lignite, however, could not be briquetted although 9 per cent of this binder was tried. The briquettes made with sulphite liquor were not weatherproof.

10. The use of inorganic binding materials was considered as unlikely to prove practicable under ordinary conditions. *Clay, lime,* and *cement* as binders were found to be entirely unsatisfactory, as they added considerably to the ash content of the briquettes. Briquettes made with these binders disintegrated on exposure to water and weathering. Waterproofing by soaking in oils, etc., was found to be both difficult and expensive. *Water glass* (sodium silicate) was also unsuitable as a binder, in quantities even as great as 12 per cent. *Magnesium oxide* as a binder in quantities up to 6 per cent resulted in briquettes which disintegrated on wetting, but retained their shape in the fire. Briquettes made with *plaster of Paris* were hard and brittle, and would not stand handling unless at least 12 per cent of the binder was used. The briquettes did not disintegrate in the fire, but were not waterproof. *Magnesia cement* (30 parts of 45 per cent magnesium chloride, 30 parts of 93 per cent magnesium oxide, and 60 parts water) briquettes containing 3 per cent of this binder retained their shape in the fire but disintegrated in water.

11. Few of the wood products, when used alone, were regarded as satisfactory. *Rosin* can be used either alone, or in combination with lime or pitch, or both, to make good briquettes. Rosin in combination with pitch reduced the total quantity of binder required and also reduced the smokiness of the resulting briquette. *Wood tars* were found to be unsatisfactory, but the pitch prepared from the tars made fairly satisfactory briquettes. *Wood pulp* was unsuitable.

12. Sugar factory residues were not considered satisfactory as a binding material, as the briquettes were not weatherproof.

13. The tests with coal-tar pitches indicated that this product was a satisfactory binder for the manufacture of briquettes, both as to price of binder and the general properties of the briquettes.

14. Petroleum residuum proved to be a successful binding material, four to six per cent being sufficient to produce excellent briquettes.

15. Acid sludge, asphalt tar and Pintsch gas tar were unsatisfactory.

The large number of tests conducted, using different coals and binders during a period of eight years, both in the laboratory and in the plant, employing various types of commercial presses, indicated that petroleum residua (asphalts) were the most satisfactory materials for binders both as to price and quality of briquettes produced. Water-gas tar pitch was given second place and coal-tar pitch third.

The utilization of the vast deposits of lignite in the United States, which occur mainly in North Dakota, Montana, Wyoming, Colorado, and Texas, has been given a great deal of attention by the U.S. Bureau of Mines, and especially by the School of Mines of the University of North Dakota. The co-operative work undertaken by these two organizations has been published by J. E. Babcock and W. W. Odell (17) and may be summarized as follows:

Preliminary tests definitely showed that American lignites could not be satisfactorily briquetted in the raw state without the use of binders, as are the German brown coals, because of their low percentage of matter soluble in carbon bisulphide (bitumens). Briquettes prepared from American raw lignite without a binder, although sufficiently strong for handling will not usually withstand outside storage. The briquettes, in addition, disintegrate in the fire, the evolution of gas causing them to expand and fall to pieces. Lignite briquettes possess a further disadvantage in that their heating value has been increased only in proportion to the amount of moisture driven off.

For the above reasons investigations were carried out to evolve new methods for the preparation of a superior fuel from the raw lignite. This entailed the manufacture, by either high- or low-temperature carbonization on an economic basis, of a char suitable for the preparation of briquettes with the aid of a binder. The production of carbonized lignite necessitated the testing of various types of ovens, such as modified beehives, and shaft ovens of different designs and sizes. As a result of these tests an inclined retort was designed, which was operated at a low temperature and which seemed, at the time, to give the desired char, at an economical price, suitable for the preparation of high-grade briquettes.

An investigation on the briquetting of carbonized lignite, conducted at Hebron, N.D., resulted in the successful production of good briquettes. It was determined that well made briquettes from carbonized lignite with a binder composed of flour ($\frac{3}{4}$ to $1\frac{1}{2}$ per cent) and pitch (7 per cent) hold their shape and do not disintegrate in the fire. They are capable of being stored with but small loss; are reasonably strong to withstand handling and shipment; are fairly high in heating value; and in general are of such quality as to fulfil satisfactorily the general market and commercial requirements. However, the results of the experiments conducted at Hebron, up to 1921, pointed to certain deficiencies in the carbonizing process, which were as follows:

1. The cost per ton-day of char made was too high with the inclined retort used to carbonize lignite for briquetting.

2. The depreciation of the carbonizing apparatus was too heavy.

3. The carbonizing apparatus could not be operated intermittently without seriously damaging it.

Due to the above reasons further experimental work was conducted in order to design a carbonizer which would overcome the above deficiencies. A vertical shaft type of oven heated by internal combustion was designed by Hood and Odell (18). This retort in its final commercial form was simple in construction and operation, and its "first cost" was relatively low.

Despite the fact, however, that a tremendous amount of experimental work has been done on the utilization of lignite by carbonization and briquetting, up to the present time, only one commercial undertaking has been attempted, and this has resulted in financial failure.

Recently, the subject of briquetting certain American coals without the use of a binder has been given consideration by R. J. Piersol of the Illinois State Geological Survey. The results of a laboratory study of some Illinois coals is reported by him under the title "Briquetting Illinois Coals Without a Binder by Compression and by Impact"—Report of Investigations No. 31—Illinois State Geological Survey, 1933. As previously stated, this investigation is still in the laboratory stage, but shows definite commercial promise.

EXPERIMENTAL WORK IN CANADA

Lignite Utilization Board

Although briquetting has been conducted on a commercial scale in Canada since 1897, the first experimental work undertaken was in conjunction with the utilization of Saskatchewan lignite. In this connexion on October 1, 1918, the Lignite Utilization Board of Canada was created under the jurisdiction of the National Research Council. The immediate objective of this board was the carbonizing and briquetting of lignite in southern Saskatchewan for use as domestic fuel in this province, and in Manitoba. Previous to this, in 1917, E. Stansfield (19), of the Mines Branch, Department of Mines, had conducted some thorough laboratory tests on Saskatchewan lignite. The yield of carbonized residue, gas, and tar under different heat treatments was studied and the heating values of the gas and residue determined. The laboratory tests yielded such promising results that a design of a commercial-size carbonizer was made, and a plant according to these designs was built by the Lignite Utilization Board at Bienfait, Saskatchewan. The carbonizer consisted of a number of slot ovens or retorts inclined at an angle of 45 degrees from horizontal, similar in many respects to that designed by E. J. Babcock at the School of Mines in North Dakota. The results of the tests on this carbonizer, after many attempts at redesigning, indicated that although the method was theoretically sound, the mechanical difficulties were too great to be overcome and still retain a simple retort which would produce char on an economical basis. This carbonizer was finally abandoned, and a Hood-Odell oven was erected, similar in design to that used in the joint investigation of North Dakota lignite by the U.S. Bureau of Mines and the University of North Dakota.

TABLE I

SUMMARY OF LABORATORY BINDER EXPERIMENTS

Minimum binder ratios given below are comparative only and are not to be construed as representing possible commercial practice

Material briquetted	Volatiles, %	Hardwood tar, etc			Coal tar and pitch				Asphalt and pitch			Sulphite liquor		"Hite" binder; flour and lignite pitch, 1 to 1 ‡
		Soft tar	Pitch, 392°F. up, m.p. 140°F.	Pitch and lignite oils †	Soft tar	Pitch, m.p. 145°F.	Pitch, m.p. 190°F.	Pitch and lignite oils †	Soft (liquid) asphalt	Oil pitch, m.p. 172°F.	Oxidised oil pitch, m.p. 200°F. and lignite oils †	Liquor, 50% solids	Liquor and lignite oils †	
Heat treated – smokeless and non-softening														
Anthracite	4·3		5·5-6		35+	5·5-6·5				6-7		10-12		3·7-4·5
Lignite air dried		20-25	20+		30-35		30-35							
" oven dried	38·5	18-20	18-19											Neg
" residue 662°F.	27·5	15-18	16-18											Neg
" " 842°F.	17·0		14-15			16+								Neg
" " 1050°F.	9·5	13-14	11	8-10	18-20	13-13·5	11-12	9-10	20+	12·5-13	9-10	18-22	10-15	7·3-7·7
" " 1430°F.	4·5		8·5-9·5			12-13								6-6·5
" " 1700°F.	2·5		8·5-9·5			11-13	10·5-11·5							
Not heat treated – smoky and softening														
Anthracite						4·5-5·5				5-7				3-3·5*
Lignite residue 1050°F.	9·5	12-13*	10	8-8·5		11-12	10·5-11	8·5-9		11-11·5	8·5-9	15-18*	9-10*	6-7*
" " 1430°F.	4·5		8-9			11-12								
" " 1700°F.	2·5		8-9			11-12	10-11							5-5·5*

†Binder ratios do not include lignite oil ‡Binder ratios based on flour plus pitch *Not waterproof

The experimental work on the briquetting of lignite char was conducted mainly at the laboratory briquetting plant constructed at the Fuel Testing Station of the Department of Mines at Ottawa. This work was undertaken by Stansfield and Gilmore. Prior to the creation of the Lignite Utilization Board they had carried on a series of tests using a small hand plunger press, and although these preliminary experiments were confined to a laboratory scale and not directly translatable into results which would be obtained in a commercial plant, enough work had been done by the Department to determine the capacity as binding agents of hardwood-tar pitches, coal-tar pitches, and sulphite-liquor pitches. (*See* Table I.) At the conclusion of this work the Lignite Utilization Board decided to continue the tests by means of a co-operative agreement with the Department of Mines and suggested that the scope of the experiments be enlarged to that of a semi-commercial scale. For this purpose a plant was installed consisting of a type Y-1 three-pocket Mashek roll press, and subsidiary equipment such as crushers, mixers, and dryers. The results of this investigation on briquetting of carbonized lignite may be summarized as follows (20):—

1. As a result of researches as to the relative suitability for briquetting of lignite carbonized at different temperatures, it developed that carbonization at 600°C. yielded a residue having the highest heating value (11,100 B.T.U.), and that no difficulty was experienced in briquetting a product prepared at that temperature.

2. The investigation to determine the best sizing of the carbonized lignite for briquetting was not completed owing to the fact that fineness is not an independent variable, but is intimately connected with the binder discussed. It was found, however, that material which passed through a ⅛-inch screen with about 18·0 per cent passing through a 40-mesh screen, resulted in the production of excellent briquettes.

3. A large number of binders were thoroughly investigated and of those studied the most suitable were coal-tar pitch, petroleum pitch, sulphite-liquor pitch, starch, gluten, and straw jelly. The last three were considered only as auxiliary binders. By a process of elimination, due to prohibitive costs at Bienfait, petroleum pitch and sulphite liquor were not considered, leaving only coal-tar pitch which was investigated alone and in combination with waste flour screenings. The result of this work indicated the minimum amount of coal-tar pitch necessary to make a commercial briquette to be 13 parts of the binder to 100 parts of the lignite, i.e. a mixing ratio of 13. Within certain rather narrow limits 1 part of waste flour screenings will replace 2 parts of coal-tar pitch, and it was found that a good briquette could be made using these binders in the following proportion—coal-tar pitch, mixing ratio 9; and flour, mixing ratio 2. The incorporation of lignite-tar pitch as a substitute binder was not successful.

A plant was erected by the Lignite Utilization Board in Bienfait, Saskatchewan, for the production of carbonized lignite briquettes. Experimental work was conducted at this plant for a period of approximately three years without success, owing mainly to mechanical difficulties, and ultimately the work was abandoned. The plant was later taken over by the owners of the Western Dominion Collieries who installed a system of carbonization similar to the Hood-Odell, i.e. that of the Lurgi Gesellschaft, and briquettes were produced in commercial quantities. This venture did not result in financial success and the plant was ultimately closed.

Industrial and Scientific Research Council of Alberta

Further experimental work in Canada was begun under the direction of E. Stansfield in the laboratories of the Scientific and Industrial Research Council of Alberta at the University of Alberta, Edmonton, in 1922. A summary of the more important investigations conducted on the briquetting of Alberta coals has been made by Stansfield and Lang (21) in their paper presented to the Second International Conference on Bituminous Coals.

For the greater part of the work a small experimental horizontal double plunger press was used, although comparative tests were made on a type Y-1 three-pocket Mashek semi-commercial roll press. The investigations resolved themselves mainly into three parts:

1. Material briquetted.
2. Binders.
3. Factors in operation.

MATERIAL BRIQUETTED

A study was made of the influence of the chemical and physical properties of the material on the briquettes produced and the following conclusions were made:

Coals high in moisture are not satisfactory for briquetting unless first dried, as they disintegrate readily and will not stand firing or handling. When dried, however, they become porous and require more binder.

Ash is undesirable as it wastes binder; clean coal requires less binder than does dirty coal per ton of effective fuel.

A coking coal not only requires less binder than a non-coking coal, other things being equal, but the briquettes are superior in the fire. This disadvantage with non-coking coals can be partly overcome by the choice of a suitable binder, or by the addition of some coking coal.

The extent to which a coal will crush during mixing and pressing is related to the hardness of the coal, and must be considered in deciding the original sizing of the coal best suited for briquetting. Research along these lines showed that the sizing of the coal has a material effect on the quantity of binder used, as the area to be coated by binder increases extremely rapidly as the size of the particles is decreased. On the other hand, the voids to be filled are reduced by a suitable proportioning of the different sizes. Crushing during mixing and especially during pressing produces fresh surfaces which are not coated with binder, resulting in weakness in the final briquette.

BINDERS

The investigation of the properties (melting point, penetration, viscosity, etc.) of typical binders has indicated that it is not as yet possible to make such rigid specifications that the more closely the binder conforms to the specifications the better are its binding qualities.

The amount of binder required varies with its nature; with the strength and density of material bound, strong particles requiring less, weak and porous particles more; with the size of the material to be bound; with the pressure employed; with the thoroughness of the mixing; and with the uniformity of feeding and the skill of the operator.

A large number of varying types of binders were tested, but the binders found to be most useful were petroleum asphalt and coal-tar pitch. The asphalt gave a less objectionable smoke than coal-tar pitch, but the briquettes were weaker when heated in the furnace.

Preliminary experiments with Alberta coals using the Von Delkeskamp process of colloidal briquetting were unsuccessful.

Investigations were made on the production of binders from straw, sawdust, and other waste materials. The cellulosic substances were converted to a jelly-like mass by cooking with a dilute solution of caustic soda at a temperature of 180° C. in an autoclave and then pulping the mass in a ball mill. Briquettes made with these cellulosic binders were not waterproof, and would not withstand weathering.

Starchy materials were found suitable as binders, with the exception that the briquettes are not waterproof. Bituminous material serves to waterproof the briquettes, and very promising results were obtained by the use of flour and McMurray bitumen. Experiments using bituminous emulsions were not very encouraging.

FACTORS IN OPERATION

Blending of coals has been found useful when utilizing non-coking coals in order to improve their burning qualities. Non-coking coals which do not swell when heated were found to require about 10 per cent of a good coking coal to make them satisfactory in the fire, whereas non-coking coals which swell require a much higher percentage of coking coal.

The conclusion arrived at as to sizing of coal for briquetting was that the best screen analysis was one which approaches a straight line when the screen sizes are plotted on a logarithmic basis, always provided there was not too much coarse or too much fine coal present; coarse coal causing a rough briquette from which there is a high loss by abrasion, and fine coal requiring considerably more binder than is economically possible.

Experiments indicated that there is little advantage to be gained by prolonged mixing when the temperature is sufficiently high. The temperature of mixing must be varied with each binder to give the desired low viscosity.

The density, and consequently the strength, of a briquette can be increased by decreasing the viscosity of the binder in the mix as it goes to the press, by increasing the pressure employed, and by increasing the time the pressure is maintained. An increase of pressure is probably the most satisfactory method for increasing the density, but a point is soon reached where the increased cost of pressing is not commensurate with the increased strength.

SUMMARY OF RESULTS

The results of the investigation of several Alberta coals are given in the Eighth Annual Report of the Scientific and Industrial Research Council of Alberta, 1927 (pages 32-33) and may be summarized as follows:

Semi-bituminous Coal

Canmore Coal. The use of asphalts with a melting point of 55° to 65° C., and a mixing ratio of 5 to 6 produced good briquettes with a loss due to shattering and abrasion (tested by the A.S.T.M. D-294-29 tumbler) of from 3·0 to 13·7 per cent.

Bituminous Coal

Greenhill Coal. Asphalts with a mixing ratio of 4 to 7, resulting in good briquettes with a tumbler loss of from 2·3 to 15·7 per cent. Soft coal-tar pitch (melting point 54° C.) and a mixing ratio of 7 gave good briquettes. Crude McMurray bitumen mixing ratio 4, and flour 1½ resulted in good briquettes, better than those using soft coal-tar pitch and flour in the same proportions.

McGillivray Creek Coal. Asphalt and a mixing ratio of 6, produced good briquettes with a tumbler loss of from 6·6 to 9·9 per cent. Hard coal-tar pitch and a mixing ratio of 6 produced inferior briquettes with a tumbler loss of 19·9 per cent.

Sub-bituminous Coal

Coal Valley Coal. Asphalt with a mixing ratio of 5 to 8 produced good briquettes, with a tumbler loss of 1·7 to 8·5 per cent. However, the briquettes are not satisfactory in the fire unless the coal is blended with 10 per cent of coking coal, e.g. McGillivray Creek.

Sterco Coal. Asphalts with a mixing ratio of 6 and sawdust binder mixing ratio 1·5, produced strong briquettes with a tumbler loss of 2·8 per cent—but are not satisfactory in the fire unless the coal is mixed with a coking coal.

The final investigation on briquetting by the Alberta Research Council was an attempt to briquette coking coal without the use of binder, depending solely on the plastic state of coal at raised temperatures. The results were discouraging and further investigation along this line was abandoned.

Stansfield and his co-workers under the Alberta Research Council have, up to 1931, contributed the greater part of the experimental work on briquetting in Canada. Although these investigations have materially contributed to the solution of briquetting problems peculiar to certain lignites, sub-bituminous and bituminous coals of Alberta, no direct commercial application has resulted.

Ontario Research Foundation

In 1930 C. Tasker, of the Ontario Research Foundation, undertook a technical and economic investigation of the extensive Onakawana lignite deposits of Ontario, which are situated near Blacksmith rapids on the Abitibi river, 60 miles south of Moosonee. The early work on the nature of the lignite deposits was conducted jointly by the Fuel Research Laboratories of the Department of Mines, Ottawa, and by the Chemical Branch of the Ontario Department of Mines, the results of the analytical work being published by Dr. W. S. Dyer (22). This was a very limited study and hence the investigations of the Ontario Research Foundation (23) necessitated an extensive chemical and physical survey of the lignite deposits, before the various methods for the processing of the raw lignite could be explored. On completion of this study, the problem resolved itself into the utilization of a fuel which contains 50 per cent moisture, is low in heat value as mined (about 5,200 B.T.U. per pound), is not homogeneous in character (i.e. contains three physically different types: wood, peaty, and earthy materials), and which disintegrates on exposure to the atmosphere.

Accordingly, three methods of processing the raw lignite were investigated:

1. Drying with or without attempting to minimize disintegration.

2. Carbonization followed by briquetting of the char or semi-coke produced.

3. Drying followed by briquetting without the addition of binder.

This investigation was conducted at existing test plants in Europe, and may be summarized as follows:

(*a*) The drying of Ontario lignite with saturated steam by the Fleissner process resulted in the production of a lump fuel, containing 20 per cent moisture and 9,000 B.T.U. per pound, which could be transported without excessive breakage losses. On the other hand, drying of the lignite by flue gas gave a disintegrated slack suitable only for powdered fuel equipment. The earthy lignite was not amenable to these processes.

(*b*) Extensive tests in Germany in semi-commercial equipment and laboratory tests at the Ontario Research Foundation have shown that the woody and peaty constituents of Ontario lignite are not amenable to briquetting without a binder, but that the earthy portions seem to offer a material which could be briquetted by the above method, although the briquettes made weathered rather badly in open storage and were not waterproof as are the European brown coal briquettes similarly made. This was traced, as had been done previously with other lignites, to the low bitumen content (0·6 per cent) of the Ontario lignites.

(*c*) The lignite was successfully carbonized at low temperatures by the Lurgi system which uses internal heating, and the K.V.G.[1] system which employs external heating. The char is soft and porous and in a finely divided state; it must be briquetted to give a saleable product. Briquettes were made with various quantities of pitch, with or without the addition of sulphite liquor. The best briquettes made from the Lurgi char contained between 9 and 10 per cent pitch and 4 per cent sulphite liquor, and with K.V.G. char, 10 per cent of pitch. Burning tests showed that the briquettes held together well in the fire. The earthy lignite could not be economically treated by carbonization to produce high-grade briquettes.

Experimental work by the Ontario Research Foundation is continuing in the hope that some method or combination of methods will be evolved to utilize this deposit which is the only native fuel so far located in the province of Ontario.

Fuel Research Laboratories, Department of Mines, Canada

The Fuel Research Laboratories of the Dominion Department of Mines followed the work of Stansfield very closely with the object of launching a more extensive investigation of all the coals of Canada, as well as the fines of certain imported high-rank coals. Accordingly, with this in view, in 1931 there was begun the construction of a small commercial-size briquetting

[1] Kohlenveredlungs Gesellschaft.

plant at the Fuel Research Laboratories. This plant, in order to be both commercial and experimental, must of necessity be constructed with the maximum amount of flexibility to enable a thorough study of all the various types of coal either mined or imported into Canada. The construction of such a plant entailed a great deal of preliminary experimental work to determine the design for maximum flexibility. The plant in its final form may be described as follows:

In view of the importance of both the size of the coal particles and the uniformity of the screen analysis for the production of the best quality of briquettes, the crushing plant has been designed to obtain any desired screen size. It consists of a rotary crusher for primary reduction and two sets of rolls for the final crushing. A double deck screen is placed between the rolls to allow of the removal of a definitely sized material to which the requisite quantity of fines can be added. Thus, after determination of the most suitable screen analysis for any coal to be briquetted a uniform product can be consistently produced.

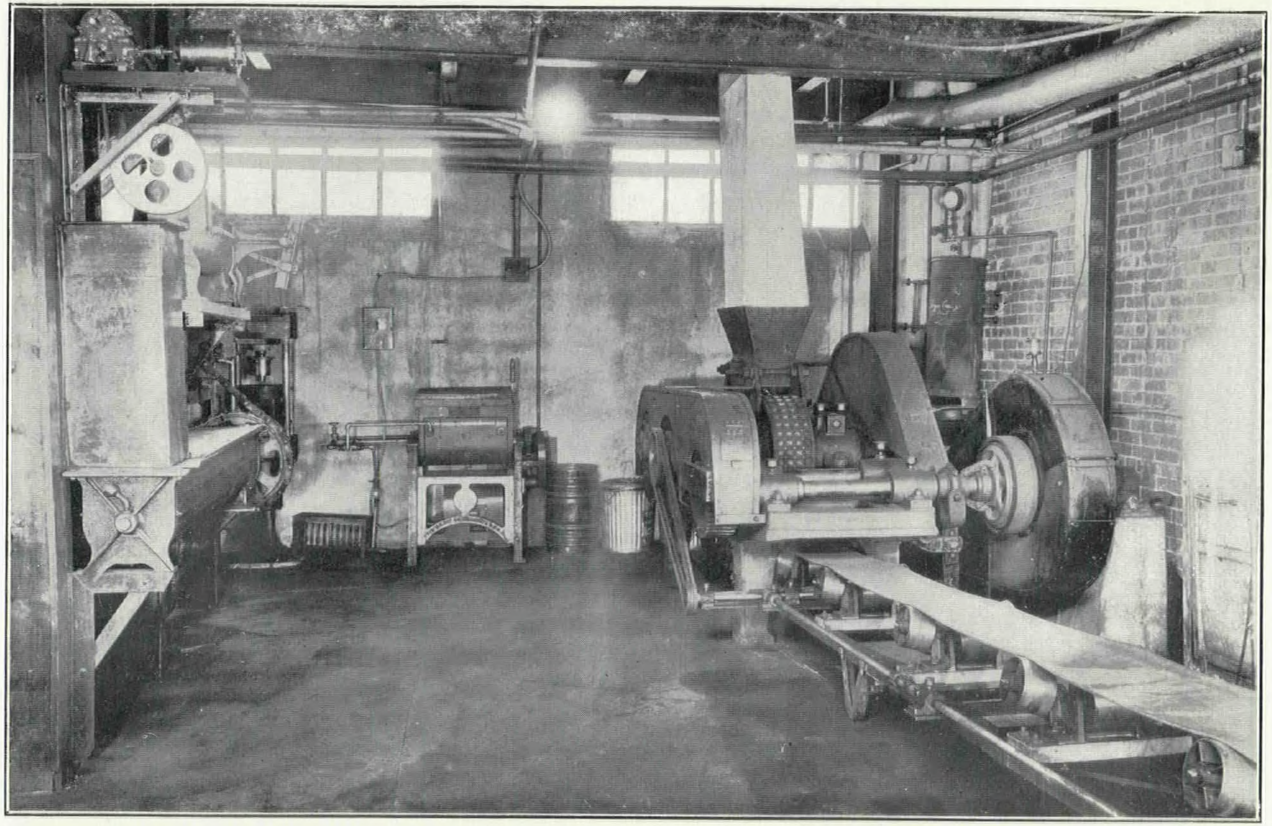
The mixing equipment consists of three horizontal mixers equipped with adjustable blades in order to effect possible variations in the time and thoroughness of mixing. The first two mixers are steam-jacketed and equipped with jets for the introduction of live steam into the coal mass. The final mixer is not equipped with a jacket and provision is made to allow a current of air to be passed over the heated coal in order to reduce it to the proper temperature for briquetting.

Provision is made to introduce flour or starch binder into the coal as it enters the first mixer where the temperature is raised to the desired degree and the requisite quantity of moisture added. Bituminous binder is added in the second mixer from heated tanks through a constant volume rotary pump operated through a variable speed mechanism.

The mixture is briquetted in a Mashek roll press capable of producing 4½ tons of 2½-ounce pillow-shaped briquettes an hour. These are received on a belt conveyer as they leave the press and distributed on a receiving floor, no provision for storage or screening out of the fines being provided owing to the experimental nature of the plant.

The crushed coal to be briquetted is stored in a bin which is equipped with a screw conveyer operated through a variable speed drive for feeding control. The flour or starch binder is added to the moving stream of coal in the conveyer by means of a feeder also equipped with variable speed control. The mixture of coal and flour is elevated to the primary mixer where the mixture is preheated to the proper temperature for the introduction of the bituminous binder, and the starch is converted into a paste. The three mixers are located one immediately above the other and are chain-driven by a separate motor. The feeding mechanism is also driven by an individual motor, as is the press.

During the construction of the experimental plant several briquetting investigations were conducted. These consisted of small-scale tests, using a steam-jacketed batch mixer, of the bread mixer type, with a capacity of from 50 to 75 pounds of material, and the type Y-4 Mashek roll press for the actual pressing. The results of these tests may be summarized as follows:—



Briquetting equipment at Fuel Research Laboratories: roll press and conveyer.

BRIQUETTING TESTS ON WELSH ANTHRACITE SCREENINGS

Tests were made on both the crushed and uncrushed material using various types of binders. The binders experimented with consisted of sulphite liquor, flour, coal-tar pitch, petroleum asphalt, and blown bitumen asphalt prepared from the McMurray bituminous tar sands. The effect of the addition of bituminous coking coal to the anthracite was also determined.

Sulphite Liquor Binder (Glutrin). This binder is a sulphite cellulose waste concentrate having a specific gravity of 1·275 and containing 46·6 per cent of solids. In order to prepare briquettes of suitable strength using sulphite liquor, alone, as a binder, it required, with the coarse anthracite screenings tested, approximately 8 parts of binder solids to 100 parts of coal, and with crushed anthracite screenings, 10 parts of binder solids. Glutrin binder contains over 50 per cent of water, and in order to obtain 8 to 10 parts of solids in the finished briquettes the mixture of coal and binder is so moist as to require excessive heat for moisture evaporation during mixing. This is necessary in order to avoid sticking in the rolls during processing. An added disadvantage of this binder is the necessity for rigidly controlling the briquetting temperature between 150° and 155° F., since departure from these temperatures also introduces the difficulty of sticking in the rolls. The experimental briquettes were not waterproof, disintegrating when immersed in water, but could be burned without either swelling or cracking, providing there was no agitation when freshly charged. To prevent the briquettes from disintegrating on agitation in the fire the addition of at least 5 per cent of a good coking coal was necessary.

Flour alone with an approximate mixing ratio of 5 made a strong briquette, no difficulty being experienced in pressing. The briquettes, however, were not waterproof. Flour mixed with sulphite liquor in the proportion of 4 parts of flour and 2 parts of liquor to 100 parts of anthracite, resulted in a good strong non-abradable smokeless briquette which offered no briquetting difficulties. The product, however, was not weatherproof and attempts to waterproof the briquettes by the addition of pitch were unsuccessful.

Coal-tar Pitch, Petroleum Asphalt, and McMurray Asphalt. To make briquettes of suitable strength with these binders a mixing ratio of 6 to 8 was found sufficient. The briquettes were waterproof, did not disintegrate in the fire, but emitted objectionable smoke, the petroleum asphalt and McMurray asphalt being the least objectionable in this latter respect. The substitution of flour for a portion of the pitch, e.g. pitch (mixing ratio 4) and flour (mixing ratio 2) resulted in a stronger waterproof briquette with less objectionable smoke.

The tests on these binders indicated that at least 5 per cent of a good coking coal seemed necessary to ensure that the briquettes held together properly in the fire.

BRIQUETTING TESTS ON CHARCOAL BREEZE

A series of tests was conducted with charcoal fines using the following binders: flour, sulphite liquor, sulphite liquor and flour, asphalt, asphalt and flour, hardwood tar, hardwood pitch and sodium silicate. By reason of the porous nature and absorptive capacity of the charcoal, sulphite liquor, asphalt, hardwood tar and pitch, and sodium silicate were found to be unsuitable binders. Flour, however, was found to be entirely satisfactory, requiring 10 parts to 100 parts by weight of charcoal, with the addition of 38 per cent of water to ensure the formation of a suitable binding starch paste. The briquettes while satisfactory for the type of trade using this fuel are not waterproof and must be dried before being marketed. Charcoal briquettes made with hardwood pitch (mixing ratio 41·5) as a binder and subsequently carbonized at 300° C. compared favourably with ordinary charcoal, but could not be considered comparable to the briquettes made with flour.

BRIQUETTING TESTS ON PETROLEUM COKE BREEZE

Several tests were made on petroleum coke breeze alone and mixed with bituminous coking coal using a blown asphalt binder with a melting point of 140° F. The results of this investigation showed that petroleum coke, being quite porous, required an excessive amount of pitch binder to make satisfactory briquettes. The addition of a coking coal materially improved the strength and burning qualities of the briquettes, and aided in the reduction of the quantity of binder used. A mixture of 70 per cent of petroleum coke breeze and 30 per cent of coking coal with a mixing ratio of 8 parts of asphalt resulted in satisfactory briquettes from the standpoint of strength, weatherproof and burning qualities.

BRIQUETTING TESTS ON BRITISH COLUMBIA COALS

Eight representative coals were tested using coal-tar pitch, petroleum asphalt, and flour as the binding media. The coals were all screened through a ¼-inch screen, the sizing being adjusted for optimum results.

These coals ranged in rank from lignitic to high rank bituminous, their analyses and classification being shown in the following table:—

Proximate Analysis and Classification of British Columbia Coals

Coal	Moisture	Analysis (dry basis)			S.V.I. rank of coal
		Volatile matter	Fixed carbon	Ash	
	per cent	per cent	per cent	per cent	
Pleasant Valley, Princeton, B.C.	24·2	34·4	48·1	17·5	110·3—A ortho-lignitous
Tulameen, Princeton, B.C.	21·1	36·6	52·2	10·9	118·1—A ortho-lignitous
Coalmont, Coalmont, B.C.	7·7	36·8	49·1	14·1	136·1—B sub-bituminous
Middlesboro, Merritt, B.C.	9·5	39·8	48·3	11·9	140·6—B sub-bituminous
Reserve, Nanaimo, B.C.	6·7	38·4	46·9	14·7	150·8—C sub-bituminous
Comox, Union Bay, B.C.	5·3	31·1	53·9	15·0	162·2—E true gas coal
Michel, Michel, B.C.	1·9	28·4	65·4	6·2	178·1—F ortho-bituminous
Corbin, Corbin, B.C.	5·0	23·2	60·2	16·6	175·6—G ortho-bituminous

The coals were briquetted under identical conditions using the same kind and quantity of binder and thus an opportunity was afforded of comparing the briquetting properties of coals of different rank under similar conditions. The results indicated that these properties are dependent on the rank of the coal, and, generally speaking, the lower the rank the more difficult it is to briquette the coal. Judging from the evidence of a ball mill test,[1] the shatter index increases and the dust due to abrasion and shatter decreases with increasing rank. This is demonstrated in the following table which shows the coals tested, arranged according to rank in ascending order, together with the results of the ball mill test on the briquettes. In all cases the briquettes were made using coal-tar pitch as a binder with a mixing ratio of eight.

Name of Coal	S.V.I.	Rank	Ball mill test	
			Shatter index	Dust due to abrasion and shatter
			per cent	per cent
Pleasant Valley	110·3	A—ortho-lignitous	11·6	64·6
Tulameen	118·1	A—ortho-lignitous	23·8	62·5
Coalmont	136·1	B—sub-bituminous	61·7	36·0
Middlesboro	140·6	B—sub-bituminous	69·3	30·7
Reserve	150·8	C—sub-bituminous	73·7	25·6
Comox	162·2	E—true gas coal	70·9	25·5
Michel	178·1	F—ortho-bituminous	53·6	36·6
Corbin	175·6	G—ortho-bituminous	82·7	17·3

It will be noted that the Shatter Index of the briquettes increases with increase in rank and that the dust due to abrasion correspondingly decreases in all cases with the exception of Michel coal. In this case the coal was so friable that it was further broken during mixing and passage through the rolls, thus exposing coal surfaces which had not been coated with the binding medium.

The relationship between the rank of the coal and the quality of a briquette capable of being made from it is indicated by plotting the rank of the coal against the physical properties of the briquettes as determined by the ball mill test. The curves in Figure 2 have been prepared by plotting the Specific Volatile Index (24) against both the shatter index and the dust due to abrasion and shatter. It will be noted that the two curves practically unite in the section indicated by C, delimiting the agglomerating coals. This section divides the coking coals from those which do not coke and the coincidence of the two curves at this point indicates that the change in the property of the coal from coking to non-coking coincides with its briquetting properties. Thus, coals which rank above those delimited by Section C make satisfactory briquettes, whereas those of lower rank are not so amenable to briquetting. The addi-

[1] In this test 1,000 grammes of briquettes are placed in a laboratory ball mill jar fitted with iron frames upon which are strips that project about 1¼ inches from the walls of the jar. The ball mill is revolved at a speed of 40 r.p.m. for a period of one-half hour, after which the briquettes are screened over a 1-inch screen and a 1/10-inch screen. The material over the 1-inch screen is the "shatter index," and the material through the 1/10-inch screen is the dust and fines due to abrasion and shattering.

tion of a coking coal to the non-coking coals has been found to be beneficial and from previous experiments conducted it has been determined that with the low rank lignites the quantity necessary is at least 25 per cent, whereas with high rank non-coking coals such as anthracites only 5 per cent is necessary. In the case of the low rank coals the addition of the

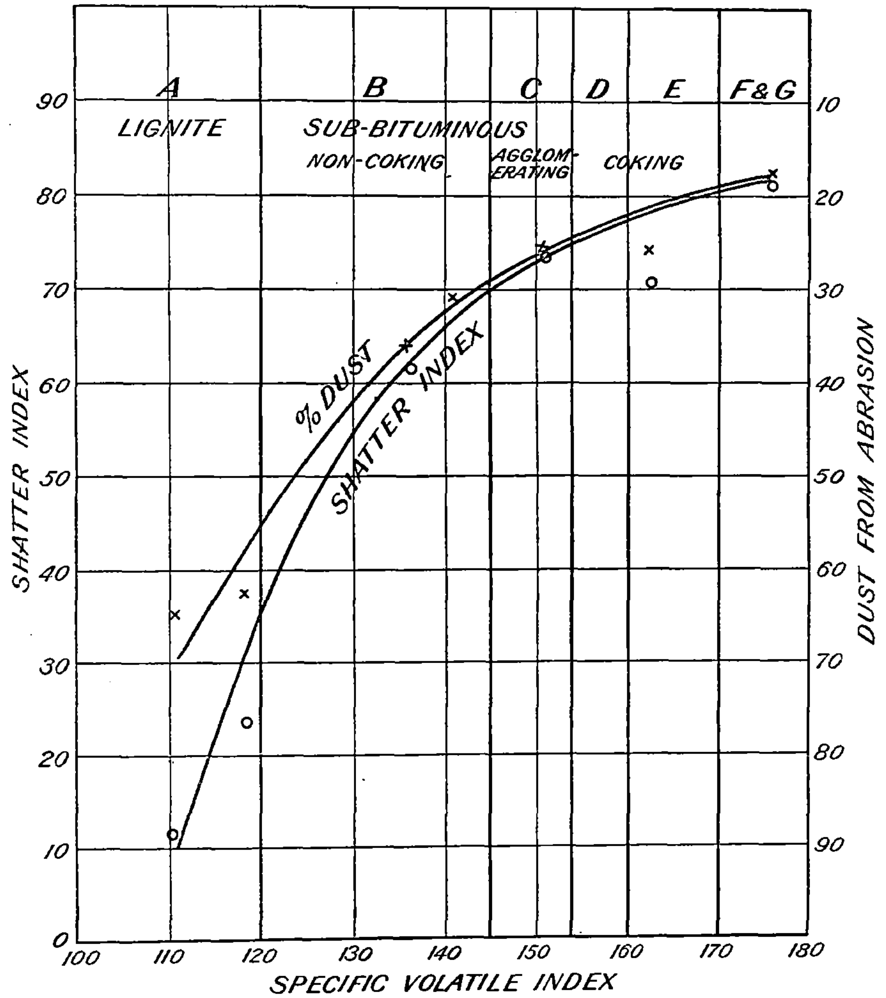


Figure 2. Curves showing relationship of the rank of coal to the strength of the resultant briquette.

coking coals improves the briquetting properties and also influences the burning properties of the briquette, whereas in the case of the high rank coals it mainly affects the burning properties. The burning characteristics are usually judged by the ability of a briquette to hold together in the fire until completely consumed. Briquettes made from non-coking low rank coals, which usually are high in volatile matter, tend to disintegrate during the evolution of the volatile matter and hence are not the most desirable fuel. The addition of a coking coal as mentioned above appears to eliminate this weakness and should therefore always be employed in this type of briquette.

Method of Testing Briquettes

A standard method of testing briquettes for physical properties has not as yet been accepted, although the drop test is used by most manufacturers. This test has been varied by different producers in accordance with the kind of briquette manufactured. An abrasion test of one form or another has also been used and one manufacturer has developed a compression test.

Before deciding on a method of testing for the briquettes made in the experimental plant of the Fuel Research Laboratories samples of various types of commercial briquettes were obtained and were subjected to certain physical tests.

The physical tests applied to the samples, in addition to the usual chemical analysis, consisted of bulk density, shatter test, abrasion test, compressive strength, ball mill test, and apparent specific gravity. These tests were performed as follows:

Bulk Density, or weight per cubic foot, was determined by filling a box having dimensions equal to 2 cubic feet, with the briquettes to be tested, the quantity being weighed and calculated to the basis of weight per cubic foot.

Shatter Test. The standard method for conducting a shatter test on coke was used in the case of the briquettes to be tested, and is outlined in the proceedings of the A.S.T.M., serial designation 141-23. The method consists of dropping a 50-pound sample of the briquettes, four times from a height of 6 feet. The product is then screened over a $1\frac{1}{2}$-inch screen and the percentage remaining on the screen is considered the *Shatter Index.* The fines resulting from the shattering are also measured by screening the product over a $\frac{1}{2}$-inch screen and this result is also reported.

Abrasion Test (Sheffield). This test is made by placing 2 cubic feet of briquettes in a drum 18 inches in diameter and 18 inches long, which is revolved at a speed of 23 r.p.m. for 30 minutes. The briquettes are then screened over a $1\frac{1}{2}$-inch screen and a $\frac{1}{16}$-inch screen. The quantity of material remaining on the $1\frac{1}{2}$-inch screen is reported as the *Abrasion Index* and the material through the $\frac{1}{16}$-screen as *Dust due to Abrasion.* This test was developed by the Midland Coke Research Committee for testing coke and is described in their report.

Compressive Strength (Komarek-Greaves Test). The briquette tester built by the Komarek-Greaves Company consists of a calibrated spring attached to a threaded plunger by means of which the small pillow-shaped type briquette is compressed between two flat surfaces. The compression of the spring is recorded on a gauge marked in pounds and thus the pressure required to break the briquette is recorded. Briquettes which break at less than 130 pounds are not considered sufficiently strong to withstand normal handling. This test was applied to the various samples of briquettes received.

Ball Mill Test (F.R.L.). This test, which was originally devised to determine the friability of coal, was used to compare the briquettes. It consists of placing 1,000 grammes of briquettes in a laboratory ball mill jar fitted with iron frames upon which are strips projecting about 1¼ inches from the walls of the jar. The jar is revolved at a speed of 40 r.p.m. for a period of one-half hour, after which the briquettes are screened over a 1-inch and a $\frac{1}{16}$-inch screen. The advantage of this test is that it can be used when only a small supply of the briquettes to be tested is available. From results obtained to date the test appears to combine the results obtainable from the shatter test and the abrasion test, inasmuch as the material over 1-inch in size appears to conform closely with the shatter index, and the material through the $\frac{1}{16}$-inch screen approximates both the breakage from the shatter test (i.e. material —½-inch) and the dust due to abrasion as obtained from the Sheffield abrasion test. The test is, however, only applicable to briquettes of 2 to 3 ounces in weight owing to the small size of the apparatus.

Apparent Specific Gravity. This test is made in accordance with the standard method outlined in the transactions of the A.S.T.M. serial designation D 167-24 which was designed for the determination of the apparent specific gravity of coke. It is, however, applicable to briquettes or other solid fuels and was used to determine this property of the briquettes examined.

Table II gives the chemical analyses and Table III the physical properties of the various briquettes tested. It will be noted that the Shatter Index varies from 53 to 98 per cent and the breakage due to shatter from 1 to 26 per cent. The Abrasion Index varies from 44 to 97 per cent and the dust resulting from abrasion, from 2 to 38 per cent. These two tests are apparently a very good indication of the strength of a briquette and its ability to withstand handling. The compressive strength varies from 125 pounds to 210 pounds but it is not related to the other two tests. From the tests made it would appear that the compression machine is better adapted to testing for the maintenance of a standard quality in any one plant than for comparing briquettes manufactured under widely varying processes. The ball mill test, as indicated, is quite comparable to the shatter and abrasion test and is suitable only where small samples are available. The apparent specific gravities vary from 0·584 for the charcoal briquettes to 1·25 for a briquette made from semi-bituminous coal, and the bulk densities from 22 to 45 pounds per cubic foot.

The results indicated that, with certain limitations, the tests used in the survey were suitable for the determination of the quality of a briquette and they were, therefore, adopted tentatively as a standard by the Fuel Research Laboratories for the comparison of briquettes made experimentally with those produced commercially.

TABLE II

Chemical Analyses of Various Types of Briquettes

—	Analysis							
	Moisture	Ash	Volatile matter	Fixed carbon	Sulphur	Calorific value, B.T.U./lb.	F.P.A. °F.	Coking properties
	per cent	per cent	per cent	per cent	per cent			
Ford Briquettes	2·8	5·4	19·7	74·9	0·1	13,410	2,640	N.C.
Ambricoal Briquettes	1·3	10·6	13·3	76·1	0·8	13,730	....	N.C.
Berwind Briquettes	1·2	6·9	22·2	70·9	0·8	14,790	2,330	Fair
{Diamond Briquettes	4·6	12·5	37·1	50·4	0·7	13,060	....	Fair
{Sunglo Koalets	8·1	11·9	40·8	47·3	0·7	12,690	....	Poor
Canmore Briquettes	1·1	9·6	18·9	71·5	0·9	14,191	....	Poor
{"Welscot" Briquettes	1·7	8·6	17·1	74·3	0·9	13,900	....	N.C.
{"Burnrite Specials" No. 2	1·9	6·1	16·1	77·8	0·9	14,720	....	Good
{"Burnrite Specials" No. 3	1·8	8·7	17·3	74·0	0·9	13,870	....	Fair
"Thermets"—B.C. Electric	4·1	16·4	26·5	57·1	0·7	12,180	2,325	N.C.

N.C. = Non-coking.

TABLE III

Physical Properties of Various Types of Briquettes

—	Ford Briquettes	Ambricoal Briquettes	Berwind Briquettes	Diamond Briquettes	Sunglo Koalets	Canmore Briquettes	"Welscot" Briquettes	"Burnrite Specials" No. 2	"Burnrite Specials" No. 3	B.C. Electric "Thermets"
Fuel	Charcoal	Anthracite and coking coal	Semi-bituminous	¾ bituminous, ¼ sub-bituminous	Sub-bituminous	Semi-bituminous	Welsh and Scotch anthracite	Pocahontas slack	Pocahontas slack and coke	70 per cent coke breeze, 30 per cent non-coking slack
Binder	Starch	"Hite"	Oil-pitch and coal-tar pitch	Petroleum asphalt	Petroleum asphalt	Petroleum asphalt	Petroleum asphalt	Petroleum asphalt	Petroleum asphalt	Coal-tar pitch
Quantity used ... per cent	7	8-10	6·5 M.R. 1·1 M.R.	6	6	8	....	....	....	10
Physical Tests—										
I. *Shatter*—Index ... per cent	97·6	96·0	75·0	72·5	52·5	69·0	....	....	....	78·5
Fines ... per cent	1·3	1·0	12·0	11·3	26·2	12·0	....	....	....	7·0
II. *Abrasion*—										
Index ... per cent	96·2	97·1	94·4	67·9	48·9	90·6	....	....	....	43·5
Dust ... per cent	2·79	2·33	3·33	29·80	37·80	8·23	....	....	....	16·4
III. *Compressive Strength*—										
Komarek-Greaves ... lb.	130	130	230	....	125	175	175	210	150	....
IV. *Ball Mill Test (F.R.L.)*—										
Index ... per cent	96·9	94·9	91·3	....	81·5	92·5	98·4	93·9	97·9	73·6
Dust ... per cent	1·40	5·10	8·11	....	18·20	7·34	1·6	6·1	2·1	23·0
V. Apparent Specific Gravity	0·584	1·21	1·25	1·125	1·143	1·23	....	....	....	....
VI. Bulk Density (wt. per cu. ft.-lb.)	22·40	43·0	45·0	42·0	44·3	42·5	....	....	....	40·3
VII. *Weatherproof Qualities*	None	Good	Good	Good	Good	Good	Good	Good	Good	Good

CHAPTER VI

ECONOMICS OF BRIQUETTING

The brief outline of the history of the briquetting industry in North America reproduced in Chapter I indicates that most of the plants established failed for one reason or another and that the number of successful plants has been comparatively few. In the United States only twenty-six plants reported production of briquettes on a commercial scale in 1932. During the period 1907 to 1932 fifty-four briquetting plants were abandoned, which is approximately 68 per cent of the number established. In Canada a very similar record is indicated inasmuch as out of a total of fourteen plants erected up to the year 1929, two are in operation at the present time. The Bankhead plant must not, however, be included in the list of failures as it operated successfully for a period of 16 years and was only closed owing to the exhaustion of the mine. Including this operation in the list of successful plants, the percentage of failures is approximately 79 per cent of all the plants erected. Of the eight plants at present operating in Canada only two can be considered as being successful, as the remaining six have been put into operation since 1932 and are either reconstructed brick plants in which brick presses have been adapted to the manufacture of cubical or cylindrical briquettes, or unit type plants installed in retail dealers' yards for recovery of fines.

According to Stillman the most common causes for failure of briquetting plants were as follows:—

Lack of Technical Knowledge. In the early days, before the briquetting of fuel became a standard industry, many failures occurred owing to the industry being in an experimental stage. It necessarily follows that, in determining the proper course, developments were made with difficulty and loss.

Lack of Study of Markets. It has always been characteristic, unfortunately, of briquetting companies, newly founded, to build plants without taking into consideration the adaptability of their product to the market they expected to serve. Fuel markets in the United States vary widely in character with the locality. In the east, along the Atlantic seaboard, the people are accustomed to Pennsylvania anthracite, properly sized —one of the best household fuels. Only the very best of fuel briquettes can compete with the mined coal to which these people are accustomed. They will not tolerate smoky fuel; they insist upon excellent binding quality; and demand a fuel in briquette form at a lower price. It has not been easy to produce an answer to such demands, but today a large tonnage of anthracite briquettes of high quality is being distributed in the Eastern States. In the west, the problem is somewhat different; the people have been accustomed to burning sized soft coal and are eager to obtain a superior fuel. The briquetting of soft coal has been recognized as materially improving the character of bituminous coal from the domestic standpoint. The population is ready to pay a premium for briquettes over domestic soft coal. The problem is in keeping that premium within bounds, and supplying the briquetted soft coal at a price the public is willing to pay. This problem has been solved of late years, particularly in the Lake Superior district. In certain cases, also, the briquetting of soft coal slack has been found to be of great advantage for industrial as well as domestic purposes.

Foreign Technique not Always Adaptable to American Conditions. It was considered, in the early efforts to briquette American coals, that successful European practice could be applied without change. In the case of both bituminous and anthracite coal, methods very popular in England and Germany produced large briquettes weighing from one to twenty pounds. With few exceptions, such briquettes have not proven adaptable to the American market. It is now universally recognized that the ideal briquette for America is the one which can be handled with a fire shovel. The use of foreign binders (and in Europe coal-tar pitch is almost universal) has produced a briquette which for America is too smoky and has too strong an odour of acid vapours to be successful. The most successful plants have taken the best practices of Europe and adapted them to American conditions.

Insufficient Financing. With the single exception of improper estimation of markets prior to placing briquettes on sale, the insufficient financing of proposed plants has been the most frequent cause of failure. Briquetting, unfortunately, appears considerably easier of accomplishment, economically, than is actually the case. Cheap plants, faulty in design, inadequate in performance, and incapable of producing a good product, have often resulted, owing to either the original estimate of cost being too low or through complete lack of knowledge of the problems involved.

Wood Construction. Wood construction has been a cause of failure in many cases. The fire toll of briquetting plants has been extremely heavy, and it is, at present, considered essential that where so much high temperature work is done, fireproof construction is necessary. The record of many plants is: "Burned down—never rebuilt."

Although the reasons given above were written to account for the failure of briquetting plants in the United States, they may be considered equally applicable to Canada, as practically all the failures here have been due to one or more of the above causes. It would appear essential that the successful establishment of a briquetting industry, in addition to the above, is dependent on a knowledge of (1) the present status of the industry, (2) the conditions of the market, and (3) the cost involved in producing a satisfactory briquette.

PRESENT STATUS OF THE INDUSTRY

Information regarding the present status of the briquetting industry is not readily available, although several publications contain certain data on the subject. The authors have attempted to present the existing position of the industry in the following tables which have been compiled from several sources. In Table IV the world production of briquettes from 1928 to 1934 by countries is shown with a differentiation being made between briquettes made from high rank coals and those made from lignite. Table V contains a list of the briquetting plants operating in Canada during the year 1934, showing the location of the plants, the date on which they were put into operation, and the kind of fuel briquetted. Table VI contains a similar list of plants operating in the United States during the year 1934, and Table VII a history of the briquetting plants established at various times in Canada. It will be noted that a serious decline in the production of briquettes in practically all countries since 1929 is shown, and also, that while Germany leads the world in this industry, over 80 per cent of her production is from brown coal. In the United States the production in 1932 was less than half of the quantity produced in 1929, and in Canada the decline was even greater. It is, therefore, indicated that very careful consideration is necessary before a decision is made to establish a briquetting plant and that only under special conditions has it a chance to succeed.

TABLE IV

World Production of Briquettes*

(In metric tons)

Country	1928	1929	1930	1931	1932	1933	1934
Algeria	33,767	101,552	96,812	73,828	71,000	19,689	**
Australia: Victoria	....	420	184,000	296,000	325,000	315,754	**
Belgium	1,959,130	2,018,110	1,875,210	1,850,360	1,316,990	1,384,000	1,350,800
Czechoslovakia:							
Coal	214,613	270,294	239,080	285,782	400,574	396,840	386,463
Lignite	241,174	256,111	180,718	209,435	202,003	199,653	197,434
France	5,885,616	6,670,000	6,810,000	7,185,830	7,537,000	7,530,000	7,635,000
Germany:							
Coal	5,375,842	6,059,195	5,176,628	5,186,566	4,375,512	4,863,940	4,819,171
Lignite	40,157,264	42,136,834	33,988,162	32,422,214	29,752,172	30,064,899	31,418,809
Saar	....	....	....	1,178	6,939	**	**
Great Britain	1,151,270	1,394,898	1,149,114	883,498	923,048	940,723	**
Hungary:							
Coal } Lignite }	56,165	109,570	101,009	184,544	414,421	371,550	**
Indo-China	127,000	113,225	144,000	134,000	97,406	73,219	**
Italy	....	6,716	2,002	2,450	2,414	4,926	**
Netherlands:							
Coal	785,829	958,186	945,939	1,212,621	1,170,930	1,102,551	**
Lignite	69,091	54,498	48,868	40,892	44,025	35,641	**
Netherland East Indies	82,629	64,099	52,292	17,418	6,967	32,948	**
Poland	264,362	354,783	234,123	300,999	222,246	221,911	**
Rumania	**	**	**	30,400	43,019	127,274	**
Spain	846,645	921,906	929,736	914,117	785,703	801,953	**
United States	859,483	1,099,879	933,366	633,498	426,923	481,195	639,431
Venezuela	1,232	1,691	524	**	555	**	**
Jugoslavia	27,582	51,477	32,413	41,083	29,851	24,015	**
Canada‡	**	65,764	33,027	18,260	†25,912	†15,886	†15,028
	58,138,694	62,709,208	53,157,023	51,924,973	48,186,610	49,008,567	**

*"Fuel Briquettes" by W. H. Young and J. B. Clark—Chapter from Mineral Resources of United States, 1935. Part III, pages 711-718. United States Bureau of Mines.

**Data not available.

†Approximate production.

‡Data from Memorandum of J. M. Casey, Statistician, Mineral Resources Division, Mines Branch, Department of Mines, Ottawa, Canada, dated September 25th, 1933. Does not appear in U.S. Bureau of Mines Publication.

TABLE V

Briquetting Plants Operated in Canada in 1934*

Province	Name and address of operator	Location of plant	Date put in operation	Raw fuel used, as reported by producer
Quebec...........	Shawinigan Chemical, Ltd., Shawinigan Falls, Que.	Shawinigan Falls.	1933	Coke breeze.
Ontario...........	Burn-Rite Fuel Company, Ltd., 366 Rogers Rd., Toronto, Ont.	Toronto.......	1933	Welsh and Scotch anthracite fines. Pocahontas slack coke and Pocahontas screenings.
"	Dibble Coal Company, 398 Eastern Ave., Toronto. Ont.	Toronto.......	1932	Petroleum coke.
"	Economy Fuel Company (E. J. Shepard, Ltd.), 636 Ottawa St. N., Hamilton, Ont.	Hamilton.....	1933	Pocahontas slack and coke.
"	Imperial Coal Company, 426 Vidal St., Sarnia, Ont.	Sarnia........	1933	Pocahontas slack and petroleum coke.
"	Nicholas Coal Company, Ltd., Tecumseh Rd. at Janette, Windsor, Ont.	Windsor......	1932	Pocahontas slack.
"	Packaged Fuels, Ltd., Hamilton, Ont.	Hamilton.....	1934	Bituminous coal.
"	Waterloo Coal Company, Ltd., 86 Erb St. W., Waterloo, Ont.	Waterloo......	1933	Pocahontas coal and petroleum coke.
"	Windsor Ice and Coal Company, Ltd., Windsor, Ont.	Windsor......	1934	Pocahontas slack.
Alberta...........	Canmore Coal Company, Ltd., Canmore, Alta.	Canmore......	1925	Semi-bituminous slack.
British Columbia	British Columbia Power and Gas Company, Ltd., Hastings and Carrall Sts., Vancouver, B.C.	Vancouver....	1924	Coke breeze and non-coking bituminous coal.

* Survey conducted in 1933 by J. M. Casey of the Mineral Resources Division, Mines Branch, Department of Mines, Canada.—Reported as a memorandum to Director of Mines Branch, September 25, 1933.

TABLE VI

Briquetting Plants Operated in the United States in 1934*

Province	Name and address of operator	Location of plant	Date put in operation	Raw fuel used, as reported by producer
State *Eastern States*				
Massachusetts....	American Briquette Co., 1505 Philadelphia Bank Bldg., Philadelphia, Pa.	Charlestown..	1929	Anthracite.
"	Staples Coal Co., 80 Federal St., Boston, Mass.	Fall River....	1932	Anthracite and bituminous slack.
New Jersey.......	Navicoal Corporation, 1421 Chestnut St., Philadelphia, Pa.	Keasbey......	1925	Anthracite and bituminous slack.
Ohio.............	Trustees of the Consolidation Coal Co., Debtor, 811 Race St., Cincinnati, Ohio.	Cincinnati....	1932	Semi-bituminous slack.
Pennsylvania.....	American Briquette Co., 1505 Philadelphia Bank Bldg., Philadelphia, Pa.	Lykens.......	1920	Anthracite.

TABLE VI—Concluded

Province	Name and address of operator	Location of plant	Date put in operation	Raw fuel used, as reported by producer
Pennsylvania	Henriette Coal Mining Co., 15 Moore St., New York, N.Y.	Dunlo	1929	Bituminous slack.
"	Atlantic Refining Co., 260 S. Broad St., Philadelphia, Pa.	Philadelphia	1933	Petroleum coke.
West Virginia	Berwind Fuel Co. of W. Virginia, 122 S. Michigan Ave., Chicago, Ill.	Berwind	1929	Bituminous slack.
"	Raleigh-Wyoming Mining Co., 230 S. Clark St., Chicago, Ill.	Glen Rogers	1932	Bituminous slack.
"	Winding Gulf Collieries, P.O. Box 30, Bluefield, W. Va.	Davy	1930	Bituminous slack.
Central States				
Colorado	Acme Smokeless Fuel Co., 212 Davidson Bldg., Bay City, Mich.	Salida	1931	Anthracite culm and bituminous slack.
Missouri	Standard Briquette Fuel Co., 818 Security Bldg., St. Louis, Mo.	Kansas City	1909	Arkansas anthracite and semi-anthracite slack.
Nebraska	Christopherson-Renstrom Co., Thirty-first Avenue and Sahler St., Omaha, Nebr.	Omaha	1932	Petroleum coke.
North Dakota	Lehigh Briquetting Co., Fargo, N.D.	Lehigh	1929	Semi-coke.
Oklahoma	Covington Coal Co., 411 First National Bank Bldg., Fort Smith, Ark.	Tahona	1934	Semi-bituminous slack.
"	Superior Smokeless Coal and Mining Co., 20 N. Wacker Drive, Chicago, Ill.	Tahona	1933	Semi-anthracite
Texas	Magnolia Petroleum Co., P.O. Box 798, Beaumont, Tex.	Beaumont	1930	Petroleum coke.
Wisconsin	Berwind Fuel Co., 122 S. Michigan Ave., Chicago, Ill.	Superior	1912	Semi-bituminous slack.
"	Panda Briquet Co., 1011 Froshay Bldg., Minneapolis, Minn.	Ashland	1931	Semi-bituminous slack.
"	Stott Briquette Co., First National Bank Bldg., St. Paul, Minn.	Superior	1909	Anthracite fines and bituminous slack.
"	United Coal and Dock Co., 102 W. Walls St., Milwaukee, Wis.	Milwaukee	1928	Semi-bituminous slack and high-temperature coke.
"	C. Reiss Coal Co., Reiss Bldg., Sheboygan, Wis.	Sheboygan	1933	Semi-bituminous slack.
Pacific Coast States				
California	California Fuel and Utilities (Inc.), Box 735, Compton, Cal.	Dominguez	1931	Petroleum coke.
"	Los Angeles Briquet and By-Product Co., 6623 McKinley Ave., Los Angeles, Cal.	Los Angeles	1933	Petroleum coke.
Oregon	Portland Gas and Coke Co., Public Service Bldg., Portland, Ore.	Portland	1913	Carbon from oil gas.
Washington	Pacific Coast Coal Co., Smith Tower, Seattle, Wash.	Renton	1914	Bituminous slack.
"	Calkins Pressed Fuel Co. of Renton, Renton, Wash.	Renton	1934	Bituminous slack and black lignite.

*Young, W. H., and Clark, J. B., "Fuel Briquettes in 1934", Chapter from Mineral Resources of the United States, 1935. Part III, pages 711-718—United States Bureau of Mines.

TABLE VII

Briquetting Plants—Past and Present in Canada

Date put in operation	Name and address of operator	Raw fuel used	Binder used	Date operation ceased	Type of press	Shape and size of briquettes	Remarks
1892	The Patent Fuel Co., Ltd., Gowrie Mines, N.S.	Bituminous slack	Coal-tar pitch	1893	Yeadon plunger.	Blocks 11 ½ lb.	
1897	..............Port Morien, N.S.	Bituminous slack	Coal-tar pitch	1899	Yeadon plunger.	Blocks 12" x 6" x 4".	
1907	Canadian Pacific Railway Co., Bankhead, Alta.	Semi-anthracite fines	Coal-tar pitch	1921	Zwoyer rolls	Pillows	Closed down on account exhaustion of mines.
1912	..............Inverness, N.S.	Bituminous fines	Coal-tar pitch	1913	Yeadon rolls	Ovoids 3" x 2".	
1914	Oakoal Company, Ltd., Toronto, Ont.	Garbage and coal fines	Gas-tar pitch	1914	Brick press	Blocks	Plant built, but not seriously used.
1916	Colonial Coal Company, Sydney, N.S.	Bituminous coal	Coal-tar pitch	1919	Belgian rolls	Eggette 7 oz.	Two plants erected.
1918	Aetna Briquetting Company, Montreal, P.Q.	....	....	1918	....	....	Never operated.
1918	Anthracite Briquette Company, Toronto, Ont.	Anthracite culm	Gamble-sulphite liquor and oil.	1928	Belgian roll	Eggette 2 oz.	
1919	Nukol Fuel Company, Ltd., Toronto, Ont.	River anthracite culm	Petroleum asphalt	1921	Belgian roll	Eggette 7 oz	Financial and internal trouble.
1921	Port Stanley Nukol Company, Port Stanley, Ont.	Anthracite culm	Petroleum asphalt	1921	Belgian roll	Eggette 7 oz	" "
1921	Lignite Utilization Board, Bienfait, Sask.	Lignite char	Coal-tar pitch	....	Belgian roll	Eggette 2 oz.	Operated intermittently until 1931, first by L.U.B., and then by West. Dom. Collieries.
	Western Dominion Collieries, Bienfait, Sask.		Coal-tar pitch	1931	Belgian roll	Eggette 2 oz.	
1924	British Columbia Power and Gas Company, Ltd., Vancouver, B.C.	Coke breeze and non-coking bituminous fines.	Coal-tar pitch	In operation.	Belgian roll	Ovoids 3 oz.	
1925	Canmore Coal Company, Ltd., Canmore, Alta.	Semi-bituminous fines	Petroleum asphalt	"	Belgian roll	Pillows 2½ oz.	
1932	Nicholas Coal Company, Ltd., Windsor, Ont.	Pocahontas slack	Portland cement	"	Eberling tamp press.	Cubes 3" x 3" x 4"	1½ lb. package fuel.
1932	Dibble Coal Company, Toronto, Ont.	Petroleum coke	Portland cement	"	" "	Cubes 3" x 3" x 4"	2 lb. package fuel.
1933	Burn-Rite Fuel Company, Ltd., Toronto, Ont.	1. Welsh and Scotch fines. 2. Pocahontas slack. 3. Coke and Pocahontas screenings.	Petroleum asphalt.	1934	Reconstructed rotary brick press.	Cylinder— diameter: 2 1/16 height: 1 3/16 weight: 3½ oz.	
1933	Economy Fuel Company, Hamilton, Ont.	Pocahontas slack and coke.	Cement	In operation.	Brick press	Cubes 4" x 4" x 4"	Package fuel.
1933	Imperial Coal Company, Sarnia, Ont.	Pocahontas slack and petroleum coke.	Cement	"	Brick press	Cubes 4" x 4" x 4".	
1933	Waterloo Coal Company, Ltd., Waterloo, Ont.	Pocahontas slack and petroleum coke.	Cement	"	Viking hand-operated tamping press.	Sectional block 16" x 8" x 5".	
1933	Shawinigan Chemicals, Ltd., Shawinigan Falls, P.Q.	High temperature coke.	Grain flour	"	Belgian roll	Pillows 2½ oz.	Used for carbide manufacture.
1934	Windsor Ice and Coal Co., Ltd., Windsor, Oat.	Pocahontas slack	Starch	"	Tamp press	Cubes 3" x 3" x 4"	Package fuel.
1934	Packaged Fuels, Ltd., Hamilton, Ont.	Bituminous slack	Portland cement	No information.	Eberling tamp press.	Cubes 3½" x 3½" x 3½".	

CONDITION OF MARKETS

The market for fuel in Canada has been fairly thoroughly surveyed, and a number of organizations present annual statistics on the subject. The following tables, taken from various statistical sources, present the pertinent data with regard to the quantity of coal produced and consumed within the Dominion. In Table VIII is shown the production of coal and the types produced in the various provinces during the year 1935. Table IX shows the coal available for consumption in 1935 by provinces. From these two tables it will be seen that Canada produces approximately only 50 per cent of her requirements, and that of the coal produced practically 26 per cent is lignite and 70 per cent bituminous, the remainder being sub-bituminous coal. It will be noted, also, that anthracite represents 12·9 per cent of the total fuel consumed and that the greater part of this quantity is distributed in central Ontario and Quebec. Table X indicates the quantity of domestic fuel consumed in the provinces of Quebec, Ontario, and Manitoba for the year 1932. It also shows the various kinds of fuel used under this classification and the amount of each imported as compared to that produced within the country. This information is not available for the other provinces, nor has it been collected since 1932, but it may be assumed that bituminous coal is largely used for domestic heating in the Maritime Provinces, and lignite, sub-bituminous, and bituminous coal for the same purpose in the Western Provinces. In Tables XI and XII, the shipments of coal from Canadian mines by grades and destination, and the average price of each grade at the mines is shown. From these tables the quantity of slack in the various provinces is indicated together with its average price at the mine. In Table XIII is given the yearly average retail prices of coal in Canada, by provinces, for the year 1934.

TABLE VIII

Production of Coal in Canada by Provinces and Kinds in 1935

(Short tons)

Province	Lignite	Sub-bituminous	Bituminous	Total
Nova Scotia			5,808,420	5,808,420
New Brunswick			342,333	342,333
Manitoba	3,106			3,106
Saskatchewan	919,477			919,477
Alberta	2,645,917	566,425	2,248,685	5,461,027
British Columbia			1,329,379	1,329,379
Yukon			835	835
Total	3,568,500	566,425	9,729,652	13,864,577
Per cent of total	25·7	4·1	70·2	100·0

TABLE IX

Coal Available for Consumption in Canada in 1935, by Provinces

(Short tons)

Province	Lignite	Sub-bituminous	Bituminous	Anthracite	Total
Prince Edward Island	....	....	77,803	10,710	88,513
Nova Scotia	....	....	2,890,795	66,639	2,957,434
New Brunswick	....	....	659,791	101,750	761,541
Quebec	....	....	3,807,827	1,965,997	5,773,824
Central Ontario	32,392	20,357	8,535,389	1,377,911	9,966,049
Manitoba and Head of Lakes	589,495	70,980	958,899	14,020	1,633,394
Saskatchewan	1,437,074	14,165	75,773	....	1,527,012
Alberta	1,095,026	404,805	1,700,107	....	3,199,938
British Columbia	51,258	27,170	1,330,410	282	1,409,120
Yukon and Northwest Territories	....	31	659	....	690
Total	3,205,245	537,508	20,037,453	3,537,309	27,317,515
Per cent of total	11·7	2·0	73·4	12·9	100·0

TABLE X

Consumption of Fuel Distributed for Domestic Heating in Canada in 1932*

Province		Lignite and sub-bituminous	Bituminous	Anthracite	Coke	Charcoal, peat and briquettes	Total
Quebec	Imported	....	147,290	1,314,584	28,196	301	1,490,371
	Canadian	102	266,834	....	153,723	17,561	438,220
Total		102	414,124	1,314,584	181,919	17,862	1,928,591
Ontario	Imported	....	1,164,103	1,653,408	461,911	....	3,279,422
	Canadian	25,613	60,324	....	761,232	15,178	862,347
Total		25,613	1,224,427	1,653,408	1,223,143	15,178	4,141,769
Manitoba	Imported	....	91,690	11,698	49,857	4,371	157,616
	Canadian	576,793	98,622	....	41,920	485	717,820
Total		576,793	190,312	11,698	91,777	4,856	875,436

*Extracted from Survey by J. M. Casey. Issued by the Dominion Fuel Board in co-operation with the Mines Branch, Department of Mines, Ottawa.

TABLE XI

Shipments of Coal from Canadian Mines by Grades and by Destination, 1934

(Short tons)

Destination	Run-of-mine	Screened	Slack	Total
Prince Edward Island	5,748	59,670	10,270	75,688
Nova Scotia	124,542	418,916	625,418	1,168,876
New Brunswick	135,069	117,653	249,606	502,328
Quebec	121,709	1,308,956	1,453,944	2,884,609
Ontario	5,273	53,025	20,613	78,911
Manitoba	70,541	304,460	499,551	874,552
Saskatchewan	239,046	721,074	511,582	1,471,702
Alberta	190,133	393,206	480,629	1,063,968
British Columbia	18,095	465,874	167,133	651,102
Yukon and Northwest Territories	....	222	....	222
Total domestic shipments	910,156	3,843,056	4,018,746	8,771,958
Railroads	2,477,052	607,940	93,709	3,178,755
Ship's bunkers	234,910	105,243	330	340,483
Total	2,711,962	713,183	94,039	3,519,184
External shipments	6,851	154,345	53,626	214,822
Total	3,628,969	4,710,584	4,166,411	12,505,964

TABLE XII

Average Price per Short Ton of Canadian Coal at the Mine by Grade for each Province, 1934*

Province	Run-of-mine		Lump		Egg		Nut		Pea		Slack	
	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts.	$ cts	$ cts.
Nova Scotia—												
Bituminous	4 17	3 60	4 75	4 12	5 75	5 25	5 23	4 32	3 35	2 80	2 54	2 00
New Brunswick—												
Bituminous	3 17	2 87	4 10	3 70	......	......	3 86	3 53	......	......	2 71	2 30
Manitoba—												
Lignite	......	......	2 25	2 25	......	......	......	......	......	......	0 80	0 80
Saskatchewan—												
Lignite	1 61	1 51	1 69	1 47	1 50	1 33	1 30	1 16	1 06	1 01	0 96	0 78
Alberta—												
Bituminous	3 83	3 12	4 56	4 14	4 50	4 50	3 89	3 76	3 75	3 00	2 34	1 83
Sub-bituminous	3 22	3 00	4 10	3 64	4 07	3 33	2 59	2 09	1 80	1 64	1 25	1 05
Lignite	2 34	2 10	3 07	2 65	2 64	2 20	1 91	1 56	1 57	1 35	0 90	0 71
British Columbia—												
Bituminous	4 50	4 07	4 97	4 49	4 88	4 36	3 93	3 72	3 18	2 90	2 77	2 05

*Extract from "Coal Statistics for Canada, Calendar Year 1934." Dominion Bureau of Statistics.

TABLE XIII

Yearly Average Retail Prices of Coal in Canada by Provinces, 1934

Province	Anthracite	Bituminous
	$ cts.	$ cts.
Prince Edward Island	....	9 07
Nova Scotia	....	9 14
New Brunswick	....	10 12
Quebec	14 41	....
Ontario	14 48	....
Manitoba	....	10 68
Saskatchewan	....	8 62
Alberta:		
Calgary	....	7 00
Edmonton	....	4 00
British Columbia	....	10 77

COSTS

The cost of briquette manufacture is dependent on a number of factors, in addition to the cost involved in the purchase of coal and binder and the cost of processing. The location of the plant is of prime importance and in this connexion the U.S. Bureau of Mines (26) states that "as the successful operation of a briquetting plant depends upon its ability to meet in competition other forms of fuel, it is apparent that plant locations must fulfil certain requirements. Briefly, these are, a readily available supply of low priced raw fuel, an accessible market that demands high-grade fuel, and lower transportation costs than those prevailing on the principal competitive coals. For these reasons most of the briquetting plants now in existence have been located in towns near coal fields that are close to well populated areas."

While the cost of production of briquettes is naturally not available for any particular plant, an analysis of the various plants operating in the United States has been made by the U.S. Bureau of Mines (27). In this publication the principal expenses, value of products, and value added by the manufacturer is given for sixteen fuel briquetting plants during the year 1927. As these plants represent 93 per cent of the total production in the United States and may, therefore, be considered a reliable guide to the average costs of briquetting coal in the United States, the table is reproduced below.

Item	Total	Per ton
		$ cts.
Number of establishments	16	....
Production (net tons)	905,601	....
Principal expenses:		
Salaries	$ 149,598	0 17
Wages	426,584	0 47
Materials (coal, binder, and plant supplies)	4,609,988	5 09
Power and fuel used for power at plant	236,411	0 26
Total	$5,422,581	5 99
Value of product (f.o.b. plant)	7,116,710	7 86
Value added by manufacturer	1,694,129	1 87

The figures shown in the above table have been averaged for the entire country, although a considerable variation in prices exists in the different sections. In the following table, which has been taken from the same source, is shown the value of briquettes per ton f.o.b. plant compiled as above for Pennsylvania, as compared with the Central States, and the change in this value over a period of years.

—	Average value per ton f.o.b. plant	
	Pennsylvania	Central States
	$ cts.	$ cts.
Yearly average—		
1912–1915	2 68	4 62
1916–1920	4 17	7 48
1921–1925	6 04	9 07
1926–1930	6 42	8 36
Year		
1928	6 38	8 38
1929	6 22	8 13
1930	6 22	8 13
1931	5 90	8 11
1932	5 21	7 60

In addition to salaries, wages, raw materials and power, many other items of expense enter into the cost of producing a ton of briquettes. These include insurance, taxes, interest on investment in the plant, charges for depreciation of equipment, etc. Considering a 30,000-ton per annum plant to be valued at $100,000, and overhead, i.e. interest, depreciation, etc., at 15 per cent, the cost of overhead charges is 50 cents per ton. This figure added to the cost shown above, will make the total cost for a ton of briquettes, at the plant, $6.49 ($5.99 + 0.50).

On this basis the cost of processing a ton of briquettes, exclusive of binder and coal, is as follows:

	$ cts.	
Salaries	0 17	
Wages	0 47	
Power and fuel	0 26	
Overhead	0 50	
Plant supplies, etc	0 05	(assumed)
Total	1 45	

The total cost of production depends upon, and varies with the prices of both coal and binder. The cost of pitch binder ranges from $10 to $20 per ton, depending upon the quantity purchased and the freight haulage, but an average cost, for purposes of estimate, may be considered as $15 per ton. The average quantity of coal-tar pitch used for briquetting purposes in Great Britain is 9 per cent, whereas the average quantity of pitch binder used in the United States is 6 per cent. For practical purposes it may be considered that an average consumption of pitch binder is 7½ per cent of the briquettes produced, and at $15 per ton the cost of binder per ton of briquettes would be $1.13.

On this basis, the binder cost practically equals the cost of processing and it is, therefore, quite evident that fluctuations in the price of binder have a greater effect on the economical operation of a briquetting plant than any other individual item. The smaller the quantity of binder used, the less is the effect on the price of binder, as demonstrated in the following table.

Quantity of binder used per cent	Price of pitch—per ton of briquettes										
	$ cts. 10 00	$ cts. 11 00	$ cts. 12 00	$ cts. 13 00	$ cts. 14 00	$ cts. 15 00	$ cts. 16 00	$ cts. 17 00	$ cts. 18 00	$ cts. 19 00	$ cts. 20 00
5·0....................	0 50	0 55	0 60	0 65	0 70	0 75	0 80	0 85	0 90	0 95	1 00
5·5....................	0 55	0 61	0 66	0 72	0 77	0 83	0 88	0 94	0 99	1 05	1 10
6·0....................	0 60	0 66	0 72	0 78	0 84	0 90	0 96	1 02	1 08	1 14	1 20
6·5....................	0 65	0 72	0 78	0 85	0 91	0 98	1 04	1 11	1 17	1 24	1 30
7·0....................	0 70	0 77	0 84	0 91	0 98	1 05	1 12	1 19	1 26	1 33	1 40
7·5....................	0 75	0 83	0 90	0 98	1 05	1 13	1 20	1 28	1 35	1 43	1 50
8·0....................	0 80	0 88	0 96	1 04	1 12	1 20	1 28	1 36	1 44	1 52	1 60
8·5....................	0 85	0 94	1 02	1 11	1 19	1 28	1 36	1 45	1 53	1 62	1 70
9·0....................	0 90	0 99	1 08	1 17	1 26	1 35	1 44	1 53	1 62	1 71	1 80
9·5....................	0 95	1 05	1 14	1 24	1 33	1 43	1 52	1 62	1 71	1 81	1 90
10·0....................	1 00	1 10	1 20	1 30	1 40	1 50	1 60	1 70	1 80	1 90	2 00

The cost of manufactured briquettes with varying cost of raw materials, assuming a processing cost of $1.45 per ton of finished briquettes and the use of 7 per cent binder, is as follows:

Cost of fuel per ton	Cost of binder per ton				
	$ cts. 10 00	$ cts. 15 00	$ cts. 20 00	$ cts. 25 00	$ cts. 30 00
$ cts.					
1 50....................................	3 55	3 90	4 25	4 60	4 95
2 00....................................	4 01	4 36	4 71	5 06	5 41
2 50....................................	4 48	4 83	5 18	5 53	5 88
3 00....................................	4 94	5 29	5 64	5 99	6 34
3 50....................................	5 41	5 76	6 11	6 46	6 81
4 00....................................	5 87	6 22	6 57	6 92	7 27
4 50....................................	6 34	6 69	7 04	7 39	7 74
5 00....................................	6 80	7 15	7 50	7 85	8 20

From the above two tables it is seen that if the average quantity of binder used is decreased from 7·5 to 5·0 per cent the price which could be paid for binder could be raised from $15 per ton to approximately $22.50, and still maintain the cost of binder per ton of briquettes at $1.13, i.e. a 33⅓ per cent reduction in the quantity of binder used will balance a 50 per cent increase in the price of the binder. By reducing the binder from 7·5 to 5·0 per cent the cost of binder per ton of briquettes (at $15 per ton of binder) is reduced from $1.13 to $0.75, i.e. a saving of $0.38 per ton of briquettes is made, which is 14·7 per cent reduction in processing costs. In order to effect a similar reduction in costs without reducing the quantity of pitch used, it would be necessary to obtain pitch at $10 per ton instead of $15, which is a 33⅓ per cent reduction in the price of the pitch. It does not seem logical to assume that manufacturers of pitch could concede such a reduction, unless very large quantities were consumed, and hence it would appear that reduction in the quantity of binder used is the logical objective. This has been accomplished by certain manufacturers using the Hite binder, who claim to require as little as 2½ per cent of binder in the preparation of anthracite briquettes. Incidentally, these briquettes are practically smokeless, and as to strength and cleanliness are the best briquettes which have been examined by the authors.

In the light of recent experimental work with bituminous coals there is the possibility of dispensing with the use of binders entirely in the production of smokeless fuel. While the proposed methods are more expensive than the standard methods now employed, the high cost of binder entering into the manufacture of a briquette allows of considerable increase in the cost of production where no binder is used.

Capital Cost of Plants. Data on the cost of briquetting plants are difficult to obtain and such estimates as are published vary widely. It is obvious that both the location of the plant and its size will, to a great degree, determine the cost. Recently a publication (28) was issued by the New Zealand Department of Scientific and Industrial Research on the Briquetting of New Zealand Coals in which the authors indicated the cost of a 10-ton an hour plant, or, based on eight hours of operation daily and five days per week, 20,000 tons per annum. As this is a plant of average capacity, and as the estimates used are based on quoted prices from reliable manufacturers, the costs are reproduced below.

*Cost of Briquetting Plant 10 Tons Per Hour Capacity***

(20,000 tons per annum)	$* cts.
Cost of plant, f.o.b. Liverpool	12,710 70
Freight and insurance	1,948 00
Freight to site	487 00
	15,145 70
Foundations for plant	1,461 00
Erection of plant	1,948 00
Steam boiler (erected)	1,704 50
Service hoppers	974 00
Complete plant (erected)	21,233 20
Building	5,600 50
	26,833 70
Contingencies—15 per cent	4,334 30
	31,168 00
Briquette storage bins (steel) 250 tons capacity (erected)	3,896 00
Total cost of plant ready for working	35,064 00

* Converted from pounds to dollars at par of exchange.

** Such items as freight to site, costs of material, etc., will vary according to the locality in which the plant is to be situated. The costs of the briquetting plant were obtained by the authors from Wm. Johnson & Sons, Ltd., England.

From the above figures the authors estimated the cost of briquetting on this production basis. Their conclusions are shown below.

Cost of Manufacture of Briquettes (20,000 tons per annum)

	$* cts.
Interest on capital at 8 per cent..	2,922 00
Depreciation, machinery only, 10 per cent..	2,435 00
Upkeep on plant..	1,217 50
Upkeep on building..	487 00
Office and staff..	2,191 50
Labour:	
6 men at £3.10.0 per week =$5.113.50	
1 foreman £250 per annum=$1,217.50..	6,331 00
Power, 120,000 k.w.h..	2,922 00
Steam for process 1,200 lb. per hour..	730 50
Incidentals..	1,948 00
	$21,184 50
Manufacturing cost of briquettes per ton (approximate)	$1.06

* Converted from pounds to dollars at par of exchange.

It is thus evident that the overhead expenses are $7,061.50, i.e. 35 cents per ton. This does not include insurance, taxes, and rentals. Salaries amount to 11 cents per ton and wages 32 cents per ton, whereas power and fuel are 18 cents per ton and incidentals 10 cents.

In the same publication a quotation was given from the Komarek-Greaves Company for a 3½ ton per hour unit type plant (Plate V). This unit was quoted by the above company at $5,730, F.A.S. Vancouver, without motors or boilers. The authors estimated that this plant was capable of producing 7,000 tons of briquettes per annum and could be delivered and erected in New Zealand, exclusive of buildings, at a price of $17,045. From the previous calculations it is reasonable to assume that this plant could be erected, including buildings, at a cost of $20,000. On the basis of the quantity of briquettes produced per annum and the figures used above the cost of manufacture without including the buildings, would be $1.18 per ton and on the basis of the assumed cost of buildings it would be approximately $1.35 per ton of briquettes.

This plant would cost considerably less to erect in either the United States or Canada, as, according to information received from the Komarek-Greaves Company, the equipment can be purchased for $5,800, f.o.b. cars in Chicago, including all motors.

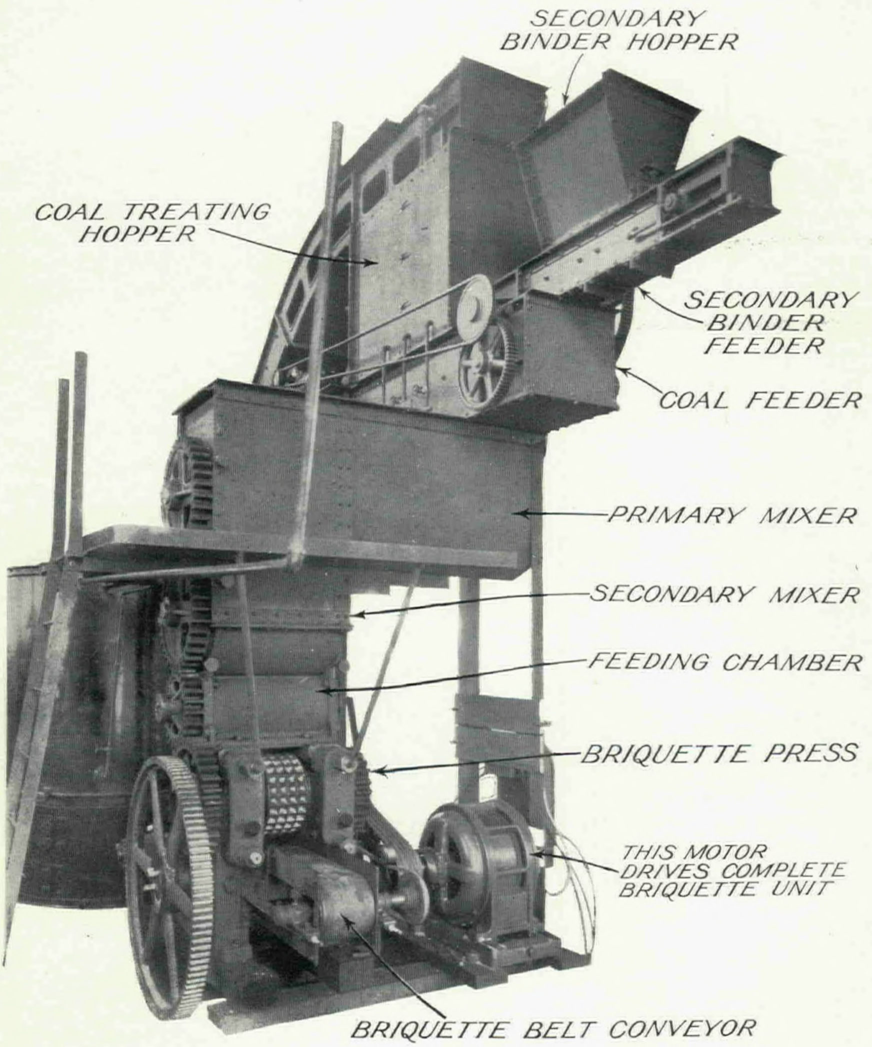
Several estimates have been published for the cost of plants and of operation for the production of carbonized lignite briquettes.

E. J. Babcock and W. W. Odell(17) estimated a cost of $100,000 for a briquetting plant capable of producing 100 tons of briquettes per 8-hour day, i.e. 12½ tons per hour.

Costs of briquetting are given as follows:

Power..	$0.30
Labour and workmen's compensation..	0.27
Depreciation, interest or investment at 6 per cent, supplies, repairs, etc..	0.65
	$1.22

PLATE V



Komarek-Greaves unit type of briquetting plant.

This figure does not include salaries, which may be taken as 17 cents, making a total cost per ton of $1.39.

In a further publication O. P. Hood and W. W. Odell (18) quote $30,000 as the cost of a carbonizing plant for treating 240 tons of raw lignite a day, the lignite containing 28 to 33 per cent of moisture. Assuming a cost of $1.50 a ton for raw lignite, and a 40 per cent yield of residue, the cost of producing a ton of residue is as follows:

Lignite $\left(\frac{100}{40} \times 1.50\right)$ and oil, etc.	$3.75
Labour.	.51
Depreciation, 15 per cent interest on investment at 7 per cent, supplies, repairs, etc.	.49
Cost per ton of char.	$4.75

Cost per ton of Briquettes

Char in 1 ton briquettes at $4.75 per ton.	$4.20
Binding mixture (7 per cent pitch at $30 net ton) (1–1½ flour at $25 per ton).	2.47
Power.	.30
Labour, supervision, workmen's compensation.	.35
Depreciation, interest at 7 per cent, repairs, etc. (based on 68 cents per ton for full time operation).	.85
Cost per ton.	$8.17

It is evident from the above survey of the economic factors affecting the briquetting industry, i.e. (1) the cost of fuel, (2) the cost of binder, (3) the capital cost of plant, and (4) the processing costs, that in order to achieve success it is necessary to select a location which offers the most favourable conditions in respect to these factors. In addition the fuel market in the locality selected must be carefully studied to determine the type of substitute fuel that will be acceptable.

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APPENDIX

REVIEW OF PATENT LITERATURE ON BINDERS

Briquetting Patents *re* Coal-Tar Pitch and Petroleum Asphalt

(1) *W. P. Frey, Bull. Amer. Inst. Min. Eng. 1918, 143-9.* The Lehigh Coal and Navigation Company of Lansford, Pa., manufacture an anthracite briquette with the use of 7 per cent of heavy petroleum residue known as Hydrolene (melting point 160° F.) as binder. This briquette has a heat value of 12,385 B.T.U., contains 12 per cent volatile matter, and 16·5 per cent ash, and is tough, hard, and waterproof. Total cost of manufacture is $3.35 per ton including $1.25 for the binder and $1 for the silt, delivered. The layout and operation of the plant are described—Chem. Abs. 12:528.

(2) *W. Anderson, British 114,371, November 24, 1917.* Briquettes are formed by mixing powdered coal-tar pitch with peat cut from the bog and containing about 80 per cent water, in the proportion of 20 parts of pitch to 100 parts of peat. The mixture is mechanically stirred, and is pulped and projected from the pulping machine in the form of a ribbon. This is cut up into blocks, dried in a stove by a current of hot air, and then carbonized in a retort —Chem. Abs. 12:1509.

(3) *C. Michel and V. Raskin, British 134,887, November 2, 1918.* Briquettes of artificial fuel, containing sawdust, coal dust, etc., pitch, and a mineral substance, are made by heating the mixture in a closed vessel and moulding the hot mass: the water vapour released from the sawdust, with disintegration of the sawdust fibres softens the pitch, which then penetrates the sawdust. The mineral addition employed is lime, cement or dry clay, or a mixture of these. The temperature in the closed vessel may be 150° to 180° F.

(4) *C.M.C. Hughes, British 136,584, August 17, 1918.* Coal or coke, in a finely subdivided state, and pitch, with or without other materials, are mixed with water to form a plastic mass, which is moulded to form fuel briquettes; the mixing is effected cold or at a temperature below the melting point of the binder. The briquettes are subjected to the action of an increasing temperature, which at first is sufficient to drive off the water from the briquettes, but is not sufficient to melt the binder, and later is high enough to melt the binder. On completion of the heating process the briquettes are allowed to cool and harden. The composition of the briquettes by weight may be as follows: fine coal 90 parts, pitch 6 parts, and filter-cake from sugar refineries 4 parts; or coke dust 80·5 parts, pitch 12·5 parts, filter-cake 5 parts, and iron oxide 2 parts; or anthracite duff 92·5 parts, pitch 5 parts, and filter-cake 2·5 parts—Chem. Abs. 14:1752.

(5) *W. W. Stenning and W. H. Beasley, U.S. 1,560,116, November 3, 1925.* Finely divided coal is suspended in water, mixed with a binding medium such as coal tar or pitch and subjected to heat and agitation without aeration, in order to effect agglomeration of the particles and prepare them for briquetting—Chem. Abs. 20:106.

(6) *S. C. Davidson, U.S. 1,384,012, July 5, 1921.* Wet peat as obtained from the bog is stirred into a putty-like consistency, mixed with powdered pitch and powdered dry peat to form a homogeneous mass, and the mixture is pressed into blocks—Chem. Abs. 15:3738.

(7) *R. Bowen, U.S. 1,397,571-2, November 22, 1921.* Artificial fuel mixtures such as those formed of coal or coke dust and pitch, are pressed out through the orifices of a heated die chamber, to form the mixture into superposed layers, and the layers are pressed together to effect slight bonding only—Chem. Abs. 16:822.

(8) *S. M. Darling, U.S. 1,382,629, June 28, 1921.* Lignite is mixed with about 10 to 12 per cent its weight of pitch and the mixture is formed into briquettes, which are heated to a temperature of about 370° F. and then cooled in the presence of the volatilized products evolved by the heating. About 12 per cent of coal may also be used in the briquettes—Chem. Abs. 15:3551.

(9) *L. Liais, U.S. 1,603,961, October 19, 1926.* Gas is introduced into melted petroleum tar to cause it to foam and the material is suddenly cooled to produce a porous solid mass. The product is divided and used as a binder for making briquettes with coal dust or other fuels—Chem. Abs. 21:168.

(10) *A. L. Stillman, U.S. 1,664,998, April 3, 1928.* Bituminous coal is mixed with asphalt or pitch or other bituminous binder heated to a molten condition and the mixture is subjected to an intense grinding action in the presence of water vapour and at a temperature above the melting point of the binder until volatile constituents of the coal are liberated and passed into solution in the binder—Chem. Abs. 22:1842.

(11) *J. C. Lüchinger, Swiss 75,536, August 16, 1917.* In the manufacture of briquettes from coal dust, coke breeze, flue ash, quenched locomotive cinders, sawdust, peat, and like combustible materials, in the dry way and without pressure, the specified materials are first mixed with finely pulverized hard gas pitch and the resulting mixture is placed in forms and heated therein in order to bind the mass by the softening of the hard pitch and rehardening upon cooling. —Chem. Abs. 12:219.

(12) *F. E. Hobson, British 233,463, February 22, 1924.* Mechanical features of forming scored bars from mixtures such as distilled coal residue 67 per cent, distilled sawdust refuse 23 per cent, and asphaltic binder 10 per cent—Chem. Abs. 20:659.

(13) *W. C. Cash, British 132,183, March 4, 1919.* Palm-kernel shells or shells of similar nature, coal refuse, and pitch are mixed in about the following proportions: shells 53 per cent, coal refuse 25 per cent, and pitch 22 per cent, and formed into briquettes—Chem. Abs. 14:341.

(14) *Donald D. Andrews, U.S. 1,793,833, February 24, 1931.* In making fuel briquettes with an anthracite base, culm 85-90, asphalt 5-10 and pulverized bituminous coal about 5 per cent are used together. The asphalt is rendered freely fluent by heating, the culm is heated to about the same temperature and mixed with the asphalt and the bituminous coal is then added and intermixed—Chem. Abs. 25:2272.

Briquetting Patents *re* Bituminous Emulsion

(15) *A. Tapping, Canadian 268,394, February 15, 1927.* A binder for finely divided substances is manufactured by the incorporation into a homogeneous mixture of a solid bituminous substance and an aqueous pulp of starch-bearing vegetable material under a vapour pressure higher than atmospheric and at a temperature above the melting point of the bituminous substance—Chem. Abs. 21:2377.

(16) *Asphalt Cold Mix, Ltd. and F. Levy, British 246,907, November 3, 1924.* Mexican asphalt or other bituminous material is mixed with up to about 10 per cent of an emulsifying agent comprising tannic acid or a synthetic tanning substance and hot water, with or without a dilute aqueous alkali solution, to prepare a binding material for use in road making, preparing fuel briquettes, etc.—Chem. Abs. 21:492.

(17) *J. A. Montgomerie, U.S. 1,643,675, September 27, 1927.* Mexican asphalt which is solid at ordinary temperatures is melted and poured into a dilute caustic alkali solution at a temperature of about 216° F. and the mixture is stirred to effect reaction between the alkali and a portion of the ingredients of the asphalt—Chem. Abs. 21:4060.

(18) *H. A. MacKay, British 202,231, May 9, 1922.* An aqueous emulsion of bitumen of the kind artificially prepared from petroleum, e.g. Mexican asphalt, is used as a binding medium in the manufacture of briquettes of coal, lignite, peat, etc. The emulsion is prepared by melting the bitumen and adding, with agitation, first about 2½ to 5 per cent of a higher fatty acid, and a dilute (1 to 2 per cent) solution of potassium or sodium hydroxide or carbonate at a temperature of 215° to 225° F., the heating and agitation being maintained until emulsification takes place, and the agitation preferably continued during cooling. Unsaturated fatty acids such as oleic acid may be used. One of the provisional specifications states that the fatty acid may be wholly or partly replaced by a resin or a resin oil. The emulsion is preferably diluted with water before use, and the powdered fuel may be moistened with water before mixing with the emulsion. The briquettes are moulded in a press in the usual manner, and may afterwards be dipped in an emulsion of the same kind as the binding agent. They may finally be dusted over with powdered fuel—Chem. Abs. 18:322.

(19) *A. D. Parker, U.S. 1,564,890, December 8, 1925.* Starch and borax are heated in water and emulsified with hot asphalt to form a binder for culm or other material to be briquetted—Chem. Abs. 20:495.

(20) *J. C. Morrell, U.S. 1,440,355, December 26, 1922.* A light coloured solution formed from tannic acid and ammonium hydroxide is used to produce a suspension of hard pitch and an emulsion of heavy coal-tar oil which may be used together as binders with fuel briquette materials in which the pitch and oil are proportioned as desired, or may be used for preparing electrode mixtures or for absorbing charcoal—Chem. Abs. 17:1312.

(21) *H. A. MacKay, British 229,361, September 19, 1923.* An emulsifying agent such as trimethylamine or other aliphatic amine is used with hot water for emulsifying bituminous materials, or for coating wood, stone, metal, felt, etc. The amine-containing mixture resulting from dry distillation of beet sugar residues may be used, with or without fatty acids and alkalies—Chem. Abs. 19:3159.

(22) *C. Demoulin, British 332,815, September 23, 1929.* Wood charcoal is used with a binder of wood-tar pitch emulsified with a heated alkaline solution such as sodium carbonate—Chem. Abs. 25:399.

(23) *Otto Reynard and Frank F. Tapping, German 508,570, April 3, 1928.* Solid bituminous binding material in the form of an aqueous emulsion dispersed in oil is used. Examples mention petroleum asphalt, Mexican burning oil and potassium hydroxide—Chem. Abs. 25:798.

(24) *Otto Reynard, U.S. 1,825,756, October 6, 1931.* Briquettes are formed by heating and pressing a mixture formed from finely divided pulverulent material such as coal, solid bituminous material such as petroleum asphalt and an added emulsion of the water-in-oil type comprising an oil such as Mexican fuel oil having an affinity for the bituminous material and an emulsifying agent such as sodium caseinate or alginate capable of forming stable emulsions with the oil—Chem. Abs. 26:581.

(25) *Clayton S. Wolf (to American Briquet Co.), U.S. 1,851,689, March 29, 1932.* An emulsion of material such as petroleum asphalt or coal-tar pitch with a carbohydrate paste, such as cornstarch, tapioca, or rice, is mixed with a small percentage of pulverized coking coal, and this mixture is then mixed with a larger percentage of pulverized non-coking coal for making briquettes—Chem. Abs. 26:3091.

(26) *H. A. MacKay, British 236,641, April 8, 1925.* Sulphonated fatty oils are used in preparing emulsions of Mexican asphalt, pitch, or other bituminous substances—Chem. Abs. 20:1321.

(27) *S. R. Wagel, U.S. 1,596,218, August 17, 1926.* Fine coal is bound by an emulsion of asphalt and clay stabilized by a blending agent such as acidified oil—Chem. Abs. 20:3345.

(28) *C. E. Hite, U.S. 1,290,992, January 14, 1919.* Coal is formed into briquettes with a binder produced by mixing starch, 0·5 per cent, with water 6 per cent, heating and stirring to form a paste and then mixing and emulsifying with 1 per cent of petroleum residuum (the proportions being based on the weight of coal).

(29) *C. E. Hite, Canadian 203,325, August 24, 1920.* Powdered coal is formed into briquettes with a binder made by heating one part starch to 12 parts water to a temperature sufficient to burst the starch granules and adding to the paste thus formed residuum from petroleum distillation, and thoroughly incorporating the mixture—Chem. Abs. 14:2981.

(30) *R. Illemann, British 107,344, January 2, 1917.* In a process of manufacturing briquettes, clay is mixed with water and the mixture is poured into melted pitch. Coal dust, wood chips, coke, peat, or sawdust is then added and, after mixing, the mass is pressed or moulded into blocks. In one example, 10 pounds of pitch, 6 pounds of clay, 6 pounds of water, and 112 pounds of coal dust are used—Chem. Abs. 11:3422.

(31) *E. Edser and Minerals Separation, Ltd., British 235,634, March 18, 1924.* Finely divided carbonaceous fuel suspended in water is agitated with an emulsion of residuum from distillation of Mexican fuel oil or other bituminous material preferably heated to 140° to 212° F. to cause flocculation, and pressed to remove water and form briquettes—Chem. Abs. 20:982.

(32) *F. A. Vogel, U.S. 1,212,291, January 16, 1917.* A binder for making fuel briquettes is produced by heating petroleum residuum or other similar oily material at about 248° F. or higher and gradually stirring waste sulphite pitch into it to form an emulsion—Chem. Abs. 11:883.

(33) *Charles E. Hite, Burlington, N.J., U.S. 941,454, November 30, 1909.* An emulsion of flour paste with linseed oil or other fixed oil or fatty acid or petroleum, with a preservative as calcium chloride, is employed as a binder—Chem. Abs. 4:508.

Briquetting Patents *re* Mixed Binders using Coal-tar Pitch or Asphalt as a Base

(34) *D. J. Davis, J. T. Armstrong, J. Mordan and Petroleum Solid Fuel Company, British 22,738, October 8, 1913.* A binder for fuel or other briquettes consists of gilsonite mixed with an untreated heavy hydrocarbon oil or tar. Hardening agents such as ferric chloride may be added. The binder is either poured while hot or sprayed by means of steam or compressed air. The proportions may be 18 ounces gilsonite, 34 ounces bituminous oil, and 34 pounds coal. For hardening 3 per cent of the binder may be ferric chloride—Chem. Abs. 9:860.

(35) *George F. Sheehan, U.S. 1,682,195, August 28, 1928.* Briquettes are formed of coal 90, crude oil 2, sulphur 2, and a suitable binder such as asphalt, tar, pitch or gilsonite 6 per cent.—Chem. Abs. 22:3978.

(36) *G. W. Love, U.S. 1,488,606, April 1, 1924.* Briquettes are formed of coal dust 93, asphalt 4·5, charcoal 1, Epsom salt 1, and sulphur 0·5 parts—Chem. Abs. 18:1899.

(37) *Aktieselskab De Forenede, Kulhandleres Briketfabrik, Norway, 30,374, May 25, 1920.* For the manufacture of briquettes in which tar is used, unslaked lime is added to the powdered fuel, and the heat liberated upon the slaking of the lime with the moisture of the fuel or of specially added water used to render the tar thinly liquid, so that in the subsequent compression of the mass to briquettes it will be forced in between the particles of fuel and bind them—Chem. Abs. 15:2174.

(38) *Gustave Komarek (to Berwind Fuel Company of Delaware), U.S. 1,860,743, May 31, 1932.* A finely divided dry carbonaceous material such as coal or coke fines is mixed with a binder such as pitch, and a hygroscopic salt such as calcium chloride or magnesium chloride is added in dry form (suitably in the proportion of about 1 per cent) and the mixture is moulded—Chem. Abs. 26:3904.

(39) *K. Woitschek and A. Kubler, Swiss 78,070, November 1, 1918.* The briquette material is composed of fine coal 87 per cent, pitch 3 per cent, unslaked lime 5 per cent, blood 2 per cent, and water 3 per cent—Chem. Abs. 13:2435.

(40) *J. Hani, French 481,207, November 14, 1916.* In the manufacture of briquettes or blocks from fine anthracite, the powder is dried and heated, then the briquetting ingredients are added and mixed therewith, and finally moulded at elevated temperature. The powdered anthracite comprises about 95 per cent of the product; the remaining 5 per cent consists of the agglutinating ingredients especially powdered silica (about 2 parts) and pitch or other bituminous material (about 3 parts) intimately mixed—Chem. Abs. 11:2958.

(41) *W. Broadbridge, British 155,875, August 26, 1919.* Coal briquettes are made from coal concentrates, which may be obtained by treating impure coal, coal dumps, etc., by froth-flotation processes, by obtaining a suspension of the powdered concentrates in water and subjecting to agitation with a liquefied binding agent, whereby the coal particles are coated with binding medium and flocculated so as to be readily separable from the water. A flocculating agent, such as slaked lime, or sodium silicate, may be added to the pulp of coal concentrates in water and may act also as an auxiliary binding agent. The liquefied binding agent may be melted pitch, with or without tar, resin, etc. When the concentrates are obtained by froth-flotation processes a liquid agent which contains or yields both a frothing agent and a binding medium may be used. The agitation of the coal-water pulp with the binding agent is carried out with a greater or lesser degree of aeration. The concentration of the coal by the froth-flotation process and the coating of the coal particles with the binding medium may be combined into a single operation, which may be continuous. The amount of pitch used may be 7 per cent of the weight of the coal reckoned dry, or 5 per cent of pitch may be used together with cresol and kerosene oil—Chem. Abs. 15:1614.

(42) *W. Broadbridge, E. Edser, and W. W. Stenning, U.S. 1,504,860, August 12, 1924.* In the manufacture of briquettes from impure bituminous coal or like materials the finely divided material is purified by froth flotation and selected purified material, in the form of a freely flowing pulp, is mixed with pitch or other binding material having an affinity for the purified particles sufficient to effect agglomeration but insufficient to flow on the surface of the particles after coating them. The agglomerates thus formed are separated from the pulp liquid and briquetted. U.S. 1,504,861 specifies a somewhat similar process in which the flotation is effected with frothing, binding, and flocculating agents, e.g. pitch, cresol, and kerosene, so that the desired particles are selectively floated, coated and flocculated to form agglomerates which are supported by bubbles. These agglomerates are then separated and briquetted —Chem. Abs. 18:3267.

(43) *G. F. Sheehan and H. A. Gilen, U.S. 1,461,322, February 20, 1923.* A vulcanized binder formed of bitumen 4 and sulphur 1 part is used with lignite in forming briquettes—Chem. Abs. 17:1543.

(44) *Henri Liesens, French 637,396, July 9, 1927.* Coal briquettes which do not smell or smoke and are non-friable are made from a mixture of coal dust, flour of manioc 3, bitumen tar 2, and chalk 1 to 1·5 per cent—Chem. Abs. 23:504.

(45) *O. Meyers, U.S. 1,305,392, June 3, 1919.* Fuel briquettes are produced by heating tar or similar material to render it fluid, adding powdered limestone, marble or cement and comminuted coal, wood, straw, or other carbonaceous fuel, cooling the mixture by the addition of water, and moulding.—Chem. Abs. 13:2125.

Briquetting Patents *re* Mixed Binders for Peat, Lignite, etc., using Coal-tar or Petroleum Pitch as a Base

(46) *O. Walter, British 104,865, December 29, 1916.* Briquettes are made from peaty earth, humus, swamp ground, or other earth, together with pitch, coal tar, or wood tar. Cinders, ashes, scoria, coal or coke dust, or sawdust may also be added together with sulphuric acid or nitric acid. In one example, 100 kg. of cinders are mixed with 10 kg. of pitch. The mixture is heated and 3 kg. of coal tar and 800 grammes of sulphuric acid added. The mixture is then moulded and pressed into briquettes. In another example, 66 kg. of cinders are mixed with 34 kg. of turfy earth, 10 kg. of pitch, 3 kg. of coal tar and 800 grammes sulphuric acid. In a further example, 50 kg. of peaty earth is mixed with 35 kg. of sawdust, 8 kg. of coal tar, 3 kg. of pine resin, 500 grms. of nitric acid, and 400 grms. sulphuric acid—Chem. Abs. 11:2039.

(47) *J. W. Leadbeater, British 160,042, January 17, 1926.* Peat from the black or lower strata of the bog is finely disintegrated by any ordinary machinery and thoroughly mixed with ground lime or slaked lime or one or more alkalies having similar properties; the peat may be used in its ordinary undried state or water may be added to it. The mixture of peat and lime is then mixed with fine ground pitch or tar or with both and with an oil, such as tar oil, mineral oil, or fuel oil, or a mixture of such oils—finally, small or finely ground coal is added. The proportions of the materials used may be 168 pounds of peat, 4 pounds of lime, 8 pounds of pitch or tar, or both, 2 to 3 pounds of coal, and 10 per cent of oil—Chem. Abs. 15:2351.

(48) *J. T. Setchell, U.S. 1,479,747, January 1, 1924.* Compressed briquettes are formed from a mixture of lignite 2000, tar pitch 55, rosin 40, and glucose 4 pounds—Chem. Abs. 18:747.

(49) *V. Von Porten, U.S. 1,572,909, February 16, 1926.* A fuel for household use comprises manure, garbage, or other animal or vegetable refuse 75, a hydrocarbon distillate such as kerosene 2, a combustible binder, e.g. tar oil and pitch 18 and clay 5 per cent—Chem. Abs. 20:1316.

(50) *Suckichi Nagata, Japan 36,893, August 9, 1920.* Saturated calcium chloride solution, 700 kg., is boiled with 300 kg. pitch to a homogeneous sticky paste. Powdered coal, coke or sawdust is added, heated under agitation, and the product is made to a definite form—Chem. Abs. 15:3738.

(51) *K. Kurg, Swiss 73,177, September 1, 1916.* A briquette is made from a mixture of peat, tar pitch, benzine, and turpentine. The benzine and turpentine are added to the mixture of peat and tar pitch made over a fire, e.g. a product may consist of peat 50, tar pitch 3, benzine 0·05 and turpentine 0·06 part by weight—Chem. Abs. 11:95.

(52) *E. J. Babcock, U.S. 1,130,564, March 2, 1915.* Briquetted fuel, formed of the residue of lignite after heating to drive off moisture and volatile matter mixed with 4 to 10 per cent of fine coking coal, 4 to 8 per cent pitch and 1 to 2 per cent flour—Chem. Abs. 9:1108.

(53) *J. H. Hislop, British 160,083, March 16, 1920.* Dead leaves, wood in the form of chips or sawdust, or other combustible vegetable substance, such as bracken, peat, heather, etc., are soaked in any inflammable oil or spirit; sand may be added to the vegetable material; the mixture is preferably briquetted. Finally, the fuel is coated with pitch or tar, to which sand has been added. The amounts of the various materials may be 15 parts of pitch or tar, 65 parts of wood, vegetable matter, etc., 10 parts of oil or spirit, and 10 parts of sand. Chem. Abs. 15:2351.

(54) *Thomas A. Laughlin, Canadian 292,421, August 20, 1929.* A briquette consists of asphalt 10 to 15 per cent, pitch 5 to 10 per cent, coal dust 15 per cent, crude petroleum 5 to 10 per cent and the remainder peat—Chem. Abs. 23:5306.

(55) *J. Miller, U.S. 1,241,648, October 2, 1917.* Combustible refuse such as vegetable parings or refuse wood is ground and mixed while heated with crude oil 20 per cent, pitch 20 per cent and 10 per cent of a mixture of rosin, charcoal, and gasoline, and the mixture is moulded into blocks for use as fuel—Chem. Abs. 12:219.

(56) *Hans. Neilsen, Norway 31,291, October 25, 1920.* Coal dust 49, peat slime 49, pitch 0·5 per cent and tar 1·5 per cent are mixed by stirring, while heated at 104° C., until the mass is practically free from water. While hot it is briquetted at a pressure of 60 to 70 kg. per cm.—Chem. Abs. 15:2174.

(57) *O. F. Werner, U.S. 1,274,480, August 6, 1918.* Fuel briquettes are formed of a compressed mixture of lampblack 70, comminuted charcoal, sawdust, peat or similar combustible material 30, asphalt binder 5, and lime dust 2 parts—Chem. Abs. 12:5050.

(58) *C.M.C. Hughes and R. G. Lovell, British 127,024, March 17, 1917.* Fuel is made from waste carbonaceous materials such as house refuse, destructor ash, coal or coke dust, sawdust, peat, etc., by the addition of a small quantity of a hydrocarbon such as pitch, or a carbohydrate such as molasses or glucose, together with soot or charcoal, in the proportion of 4 parts of soot to 8 of the hydrocarbon or 10 of the carbohydrate. The fuel is moulded without pressure and then broken into pieces—Chem. Abs. 13:2435.

(59) *P. Fallet, Swiss, 75,222, June 16, 1917.* Sawdust is mixed intimately with clay and tar or a residue from the distillation of tar, this mixture being then compressed and moulded in the form of briquettes. The mixture may consist of sawdust 200, clay 300, tar 100 parts by weight—Chem. Abs. 12:91.

(60) *J. Gerlach, Swiss, 76,172, November 1, 1917.* A mixture of petroleum and lime is mixed with the combustible waste, and compressed in moulds to briquettes—Chem. Abs. 12:1117.

Briquetting Patents *re* Use of Coal Tar, Petroleum Oil, Naphthalene, Etc.

(61) *O. Walker, Swiss, 73,269, February 16, 1917.* A carboniferous and earthy material is mixed with coal tar and sulphuric acid with heating, and subsequently compressed to briquettes, e.g. 100 kg. granular culm is mixed, with heating, with about 10 kg. pulverized coal tar, and about 3 kg. coal tar and about 800 grammes sulphuric acid are added to the mixture with constant stirring and heating.—Chem. Abs. 11:2040.

(62) *C. E. Hite, U.S. 1,224,641, May 1, 1917.* Dry pulverized coal or culm mixed with 2 to 17 per cent of crude petroleum is heated to about 200° F., mixed with sufficient water to stiffen the paraffin or asphaltic constituents of the oil, formed into blocks or briquettes and heated to about 260° to 310° F.

(63) *C. Parisi, French 480,555, August 24, 1916.* Briquettes are made from a homogeneous mixture of vegetable ligneous materials such as sawdust, cork powder or like material, and solid hydrocarbons such as paraffin. A kindling element is inserted in a groove provided in the briquette.—Chem. Abs. 11:1288.

(64) *W. Kuhn, M. A., Van Roggen, and J. G. Hopper, French 484,463, October 9, 1917.* Peat is mixed with tar, allowed to stand for a while, then heated after the addition of lignite, and worked up with rosin, the whole being agglomerated by pressure in the form of briquettes or the like.—Chem. Abs. 12:1119.

(65) (Above) French, 484,461, October 9, 1917. The product obtained according to 484,463, is coked in the usual form of coke oven.—Chem. Abs. 12:1119.

(66) *W. Kennett and E. I. Krebs, U.S., 1,273,619, July 23, 1918.* Fuel briquettes are formed of comminuted oil shale with a binder of heavy crude oil and rosin.—Chem. Abs. 12:1922.

(67) *W. W. Blair, U.S. 1,394,713, August 17, 1920.* Freshly dry peat is macerated, pressed into blocks, dried and impregnated with fuel oil.—*U.S. 1,349,714* relates to a similar process in which the preliminary maceration of the peat is omitted.—Chem. Abs. 14:3314.

(68) *Toichiro Sirai, Japan, 41,601, January 30, 1922.* The briquette is a compressed mixture of 35 parts of powdered coal, 5 parts of sulphuric acid, residue obtained in washing of Mond gas, and 7 parts of peat.—Chem. Abs. 17:3952.

(69) *R. Ilemann, British 206,889, July 12, 1922.* Peat containing 3 times its weight of water, or peat together with water, is ground and agitated so as to break up the fibres in the presence of oil, or greases, etc., reduced to a liquid state, in greater proportion than the amount of dry peat, so that the mass when subsequently dried has over 50 per cent and may have up to 75 per cent of oil. The oil becomes emulsified and combines with the broken fibres forming a homogeneous mass, which under continued agitation becomes stiff and is then moulded by extrusion or otherwise into briquettes, etc. To expedite drying the mass may be heated during agitation and before moulding. In an example 16 ounces of black wet peat were agitated with 4 ounces of crude mineral oil and formed a briquette containing 3 ounces dry peat and 4 ounces of oil.—Chem. Abs. 18:1191.

(70) *R. Tormin, British 226,567, December 21, 1923.* Low-grade fuels such as coke breeze or coal slack are impregnated with hot products of coal distillation or similar materials, countercurrentwise, and then briquetted while plastic. —Chem. Abs. 19:2123.

(71) *R. Tormin, British 234,805, May 28, 1924.* Coal or coke or similar material to be briquetted is treated with 1 per cent or more of benzene, toluene, CS_2 or similar solvent which is partially recovered in the pressing operation and causes the bitumen content to be distributed in the fuel mass. Pitch or other bituminous material may be added to "poor coal."—Chem. Abs. 20:814.

(72) *L. A. E. Irazusta, British 139,106, August 7, 1919.* An agglutinant for use in making coal briquettes is composed of approximately 970 kg. of tar and 30 of tallow or the like.—Chem. Abs. 14:2101.

(73) *J. S. Robeson, U.S. 1,667,358, April 24, 1928.* Tubular briquettes are formed of fine coal, oil, and lignone; the outer portions are harder than the inner portions and contain less volatile matter.—Chem. Abs. 22:2048.

(74) *L. Martel, British 218,391, April 6, 1923.* Medium or heavy oil from the distillation of coal tar or petroleum is atomized upon ground coal and ground pitch which are to be briquetted and the mixed ingredients are then formed into briquettes. The oils may be heated and may be atomized by compressed air or steam.—Chem. Abs. 19:572.

(75) *C. E. Turnbull, British 157,380, January 8, 1921.* To the pitch used for briquetting coke are added thin liquid coal tar or the oils obtained from tar distillation or both. Brown coal or lignite tar or the tar obtained from water gas, oil, or rich gas, and the primary coal tars or the primary tars from brown coal and pitch tar, or the oils from the distillation products of these tars may be added, provided they become very liquid when heated. The binder completely displaces air and water from the pores and it cokes during burning, causing the briquette to harden and retain its shape.—Chem. Abs. 15:1987.

(76) *R. Lessing, British 286,336, November 3, 1926.* For briquetting coal, ores, metal scrap, etc., or for treating "red metal," the material is coated with coal tar or other liquid containing pitchy and oily fractions. An oil solvent containing little or no aromatic constituents such as petroleum distillate is then used to extract the oily portion and precipitate the pitch in a homogeneous coating on the solid particles to be briquetted. Extraction of the tar oil is facilitated by addition of sulphuric acid, an acid solution of iron sulphate or chloride, or spent liquor from pickling steel.—Chem. Abs. 23:85.

(77) *Soc. De Recherches et De Perfectionnements Industriels, French 669,075, May 29, 1928.* A binding agent for making coal briquettes, etc., is made by heating to a high temperature in the presence of less than 5 per cent of sulphur, a tar or petroleum or coal oil; thus its viscosity and adhesiveness are increased and the sulphur is eliminated—Chem. Abs. 24:1725.

(78) *Ralph T. Goodwin (to Standard Oil Development Co.), U.S. 1,749,378, March 4, 1930.* Briquettes are formed containing anthracite fines and about 5 to 15 per cent of carbonaceous material precipitated by addition of a small quantity of sulphuric acid to a heavy residue of oil cracking (this material being fusible and partially soluble in carbon bisulphide)—Chem. Abs. 24:2273.

(79) *Josef Schümmer, German 527,031, November 20, 1927.* A binder for briquetting coal, etc., is prepared by adding finely powdered bituminous coal to tar, or to soft pitch obtained from tar, and distillating the mixture until a hard pitch, not becoming tacky below 122° F. is obtained.—Chem. Abs. 25:4691.

(80) *Marie E. McCarron, U.S. 1,914,271 June 13, 1933.* Material such as waste coal, screenings, refuse, rice coal, or buckwheat coal is used with a binder comprising a finely divided pulverized hard coal, a drying oil such as linseed oil, and glue. —Chem. Abs. 27:4379.

(81) *Jakob Buss and Carl Fohr, Germany. British 28,576, December 14, 1906.* Process of manufacturing briquettes of coal and peat consisting in using naphthalene alone or naphthalene and pitch as binding agents, and raising the mixture of fuel and binder to a temperature above the boiling point of naphthalene by means of superheated steam injected into it.—Chem. Abs. 1:2522.

(82) *Imperial Chemical Industries, Ltd., and R. E. Slade, British 322,194, July 31, 1928.* In forming briquettes from composition fuels or friable semi-coke, a binder is used consisting of the pitch-like products obtained by an incomplete hydrogenation of a paste of coal and oil in which the coal takes up only 2 to 3 per cent of hydrogen. A temperature of 770° F. and pressure of 200 atmospheres may be used, or a shorter treatment is effective at a temperature of 896° F.

(83) *Gustav Hilger, German 494,085, September 3, 1926.* Bituminous fuels are treated with hydrogen at a raised temperature and pressure until sufficient fuel to act as binder for the remainder has been converted into a pitchy mass. The material is then compressed. To prevent explosion, the fuel is preliminarily treated to displace entrained air, etc., by inert gas, and access of air during the operations is prevented by an inert protective gas—Chem. Abs. 24:2864.

(84) *P. W. Kunze, U.S. 1,547,252, July 28, 1925.* A binder for making combustible briquettes is prepared by adding lime to acid resin, heating to 200° to 250° F. for several hours and treating the mass with air during this time—Chem. Abs. 19:2874.

(85) *W. Schumacher, U.S. 1,146,455, July 13, 1915.* Briquettes are manufactured with a binder of wood tar 5 per cent and $Ca(OH)_2$ 1 per cent of the total weight of material—Chem. Abs. 9:2376.

Briquetting Patents *re* Vegetable Binders

(86) *Gebr. Bühler, Swiss 73,900, December 1, 1916.* Fuel is combined with peat, and pressed to briquettes, employing wet peat and a screw press.

(87) *T. Kashiwara, Japan 31,450, August 30, 1917.* Solid hydrocarbons, powdered, soft carbon dust, the dry distillation residue of sawdust, and indigo sediment are briquetted with a suitable binder, e.g. charcoal powder 1·5, soft charcoal powder 1, sawdust distillation residue 1, indigo sediment 1, are mixed with wood pulp and sea-weed slimes (shofu solution) and the mixture is compressed to briquettes—Chem. Abs. 12:91.

(88) *A. Anselmini & Cie., Swiss 76,173, April 1, 1918.* Coal dust is briquetted with loam as a binder—Chem. Abs. 12:2124.

(89) *W. Merz and A. Zollinger, Swiss 77,500, September 2, 1918.* Bituminous fuel is added to non-bituminous fuel, and the mixture is briquetted dry by means of a very high pressure and a temperature sufficient to decompose the bituminous substances, e.g. a mixture of 80 per cent anthracite coal dust and 20 per cent sawdust is heated to 482° F. (at which temperature the wood begins to decompose), and compressed under 6,000 atmospheres. A waterproof product is obtained, suitable for transportation. The properties of the constituents may be varied with suitable variations of pressure and temperature. A mixture of 60 per cent coal dust and 40 per cent peat may, for instance, be briquetted at 4,000 atmospheres and at 302° F.—Chem. Abs. 13:1387.

(90) *K. Jacobs, British 180,661, May, 1922.* In briquetting materials such as coal, coke, brown coal, peat, etc., a portion of the material to be briquetted, or a similar material, is ground to colloidal fineness in water and thoroughly mixed with the raw material. As an example, after the moisture of raw peat is reduced to 60 per cent a portion of the peat is ground with water to form a completely smooth slime. With the mass to be agglomerated, which may consist of 79 parts of peat and 15 of small coke, are mixed with about 6 parts of slime, calculated on the dry peat, and the mixture is pressed. The moulds may be slightly heated as by exhaust steam. The briquettes contain about 35 per cent of moisture which may be reduced to 20 to 25 per cent by a natural or artificial drying—Chem. Abs. 16:3541.

(91) *F. W. Jameson, British 226,344, November 14, 1923.* A binder for use in briquetting coal or other fuels is prepared from grasses, marsh weeds, rushes, cactus, etc., by crushing with 2 to 5 per cent caustic alkali to form a slimy pulp. Chem. Abs. 19:2123.

(92) *Masasuke Mitsunaga and the Mitsubishi Kogyo Kabushike Kaisha, Japan 41,237, December 22, 1921.* By mixing with about 10 per cent hydroxides of alkaline earth metals, especially calcium hydroxide, soy bean refuse acquires a large volume and powerful combining power, the fact of which is utilized for the manufacture of briquettes. Fifty kilograms of soy bean refuse are immersed in 200 litres of water and mixed well with 5·5 kg. of calcium hydroxide; then the mixture is completely mixed with 1,000 kg. of powdered coal. It is pressed into moulds by a pressure of 150 kg. per sq. cm. and dried. Arsenious acid, naphthalene, or camphor oil may be used as antiseptics. The product is very hard and waterproof.—Chem. Abs. 17:2495.

(93) *G. B. Damon, U.S. 1,503,304, July 29, 1924.* Coal fines are mixed with corn cob pulp or other vegetable binder containing digested vegetable material of approximate sawdust size. Briquettes are formed from the moist mixture and are subjected to pressure to force colloidal adhesive material from the vegetable matter into the spaces between the coal fines.—Chem. Abs. 18:2955.

(94) *S. W. Carpenter and G. N. White, British 244,517, September 16, 1924.* A binder is prepared by subjecting vegetable materials (such as straw, "water weeds," cactus, prickly pear, rushes, grass, bagasse, beet sugar residues, sisal, hemp, flax, residue, soy bean residues and leaves or stems of bracken, banana, maize and potato) to aerobic fermentation with retention of the non-gaseous fermentation products. Alkali is added to the material before, during, or after the treatment and a small quantity of calcium sulphate or other fungicide may be added after the fermentation (which may be allowed to continue for 24 days).—Chem. Abs. 21:314.

(95) *S. Shimanoto, British 273,556, October 30, 1926.* Sawdust or other pulverized vegetable fuel is steeped in slaked lime while still hot and may be formed into briquettes with various additions such as coal, wood chips, starch paste or heavy oils.—Chem. Abs. 22:2048.

(96) *Maschinenbau-Anstalt Humbolt (Robert Ganssen, inventor), German 482,123, September 5, 1925.* Briquettes are made from lignite, in which the humic acid and humin content is partly saturated with bases, by mixing with neutral salts of the alkaline earth metals, drying and pressing.—Chem. Abs. 23:5307.

(97) *Arthur D. Little (to Arthur D. Little, Inc.) U.S. 1,809,245, June 9, 1931.* Coal fines are formed into a plastic mass with cellulose hydrate dispersed in an excess of water; briquettes are formed from the mass, and the water is evaporated to a content productive of irreversibility in the cellulose.—Chem. Abs. 25:4387.

(98) *J. B. Cann, U.S. 1,121,325, December 15, 1914.* Coal, charcoal, etc., are mixed with a binder such as flour, starch or dextrin, treating the mixture with steam carrying vapours of oil, tar or fatty acid, agitating the moistened mixture, and finally pressing and drying.—Chem. Abs. 9:369.

(99) *F. Meyer, U.S. 1,129,109, February 23, 1915.* Making fuel briquettes of coal or coke dust, etc., with a binder of cactus extract.—Chem. Abs. 9:1108.

(100) *W. R. Ormandy and A. V. Board, British 205,865, July 21, 1922.* A binder for anthracite, lignite, or other fuel dust comprises cassava starch prepared by a dry milling process together with at least an equal amount of pitch, bitumen, resin, etc. A small quantity of sodium sulphate, sodium chloride, sodium carbonate or like salt or mixture of salts may be added to improve the hardness and quality of the briquette, and copper sulphate amounting to about ½ per cent of the starch used is preferably added during the milling to prevent mould growth.—Chem. Abs. 18:1191.

(101) *F. C. Thornley, F. F. Tapping, O. Reynard, British 211,174, August 19, 1922.* Fresh seaweed is ground wholly or in part to colloidal fineness and mixed with a small proportion of a water soluble alkaline material or with the oxide, hydroxide, or carbonate of an alkaline earth or heavy metal. The pulp produced may be used directly as an agglutinant, e.g. for briquetting powdered fuel or, in admixture with asbestos, for producing a heat insulating material.

(102) *H. A. Mueller, Canadian 214,251, November 15, 1921.* Superheated steam is supplied to the pulverous material such as sawdust, coal dust, etc., to expel the air; and pressure is applied until the steam is condensed and the particles of the mass are brought into intimate contact.—Chem. Abs. 16:823.

(103) *O. A. Tollefsen, British 112,514, January 17, 1917, French 484,316.* Briquettes are made from waste material such as paper by first reducing it to small pieces, softening the mass with water and then adding a binder of resin glue or flour mixed with water at 140° F. Other waste materials such as sawdust, tanning bark, fir and pine cones, fruit rinds, matches, haulm cork, linoleum, foliage, and peat, previously softened in water, are then added and worked into the mass till the whole is reduced to a paste suitable for moulding.—Chem. Abs. 12:1117.

Briquetting Patents *re* Miscellaneous Organic Binders

(104) *H. J. Pooley and J. L. Strevens, British 160,080, March 12, 1920.* The exhausted residues from the outer part of grass trees, after the extraction of resins, can be used directly as briquetted fuel.

(105) *E. Röthlisberger, Swiss 76,064, November 1, 1917.* The sawdust is mixed with a binder, consisting of walnut extract, dried, and slaked lime, and the resulting mass is pressed in forms.—Chem. Abs. 12:1117.

(106) *W. Presscott and D. F. Worger, U.S. 1,554,462, September 22, 1925.* Small coal 90 per cent or more is mixed with less than 0·25 per cent of lime, 1 per cent of glue and 6 per cent of water and there is added to the mixture a 40 per cent formaldehyde solution in the proportion of not more than 0·20 per cent immediately before pressing and moulding.—Chem. Abs. 19:3582.

(107) *R. A. Kratochwill, U.S. 1,376,706, May 3, 1921.* Briquettes are formed of coal dust bonded with gum arabic and coated with varnish.—Chem. Abs. 15:2714.

(108) *H. Roin, Swiss 77,220, March 16, 1918.* Coal tar, glue, magnesite, water-glass, and sawdust are mixed and the mixture is compressed in moulds to briquettes. —Chem. Abs. 12:2124.

(109) *J. Sevditch and D. Dinitch, French 486,557, April 18, 1918.* Briquettes are formed from a mixture of 30 parts of stearic acid or spermaceti or oleic acid, or paraffin or the like, or a mixture of these; 15 parts of petroleum, naphtha, or denatured alcohol, 3 parts of cotton, 7 parts of magnesium chloride or sodium chloride, 8 parts potassium chlorate, 5 parts of gum arabic or the like, and 1 part of vegetable carbon.—Chem. Abs. 14:116.

(110) *A. M. Hart, British 188,807, August 24, 1921.* The carbon produced by the carbonization of peat, lignite, etc., may be worked up into briquettes for fuel by the use of a binder such as gluten, molasses, or casein treated with formaldehyde.

(111) *C. H. Thompson and W. J. McGivern, British 262,371, August 6, 1925.* Paraffin, ceresin or similar non-saponifiable material is mixed with a fatty acid or resin, the mixture is melted and emulsified with an aqueous solution of an organic colloid such as glue, albumin or casein and alkali.—Chem. Abs. 21:3718.

(112) *A. L. Stillman, British 208,135, November 27, 1933, and U.S. 1,487,764, March 25, 1924.* Peat or humus is dried in the sun for 1 to 6 weeks and is then subjected to wringing pressure and briquetted. The soggy briquettes are preliminarily dried and then exposed to the sun whereupon they shrink and harden, a hydrolyzed cellulose being formed which acts as a binder.—Chem. Abs. 18:1562.

(113) *T. Nagel, British 229,905, May 5, 1924.* A binder for briquettes is prepared by mixing 1-10 parts of phosphoric acid and 6-30 parts of blackstrap molasses or similar material. An acid phosphate may be used instead of the phosphoric acid.—Chem. Abs. 19:3157.

(114) *H. Debauche, British 271,713, October 11, 1926.* Kauri gum and a mineral oil are used as a binder. The impure residue of Kauri gum is suitable for this purpose.—Chem. Abs. 22:1672.

(115) *Wilhelm Groth, German 467,274, January 1, 1925.* Damp crude lignite is prepared for fuel by treating it with colloidal mucilage, pressing and drying. —Chem. Abs. 23:689.

(116) *Soc. Des Etablissements Terray and Co., French 485,103, December 13, 1917.* Hydrogen chloride, together with scrap leather, are added to the powdered fuel in suitable proportions, for the purpose of agglomerating the mass as it is mixed.—Chem. Abs. 13:1921.

(117) *A. Meiro, Belgian 351,793, July 31, 1928.* The fines are worked into a paste with cereals, boiled vegetable oils and water, are pressed into briquettes and dried. According to Belgian 351,794, the fines are mixed with sodium silicate, powdered asbestos and water, pressed into briquettes and dried.—Chem. Abs. 23:2556.

(118) *A. Meiro and E. Cailleaux, Belgian 359,718, May 31, 1929.* A paste is formed of the solid fuel dust, glutin or chondrin, alum, or an oxidized iron salt, and water, and is briquetted in a press.—Chem. Abs. 24:948.

(119) *H. Liesens, Belgian 377,713, March 31, 1931.* The following products are mixed with coal dust, preferably in the proportions indicated: seaweed waste 1·3, manioc 1·3, asphalt or pitch 2, lime 1 to 1·5.—Chem. Abs. 26:1421.

(120) *Isidor Rosenwald, U.S. 1,924,457, August 29, 1933.* Skimmed milk is used as a binding material with lime and water for making coal briquettes, etc.—Chem. Abs. 27:5518.

(121) *Alphonse Exbrayat, France, U.S. 849,058, April 2, 1907.* Lichens are boiled with water to a gelatinous pulp, to which sodium oxide, lime and cement are added, and finally a mixture of formaldehyde and an alkaline silicate.—Chem. Abs. 1:1784.

(122) *I. Michel., Swiss 75,752, February 1, 1918.* An agglomerated carbon product which remains firm during handling, resists moisture, and does not break down to powder instantly upon heating, contains powdered coke, gas tar, a starchy material, a magnesium salt, copper sulphate and tallow. The liquid agglomerant is prepared by boiling together for about 25 minutes, a mixture of water 100 litres, gas tar 20 kg., starch or rye flour 6 kg., magnesium salt 300 grammes, copper sulphate 200 grammes, ordinary tallow 250 grammes, glycerol 400 grammes, and gum arabic 300 grammes. After cooling, this liquid is stirred into powdered coke, contained in a mechanical mixing machine, in the proportion of 40 kg. of the liquid to 500 kg. powdered coke. After the mass is homogeneous, it is moulded under a pressure of 200 to 300 kg. per sq. cm., employing a hydraulic press. The bricks so obtained are removed from the moulds, dried for 4 to 5 hours at 100° to 150° F. and placed upon the market.

Briquetting Patents *re* Use of Sulphite Liquor

(123) *C. Ellis, U.S. 1,246,806, November 13, 1917.* Unstable acid waste sulphite, after concentration is used as a binder with coal dust and fragments and a small amount of lime.—Chem. Abs. 12:306.

(124) *C. Ellis, U.S. 1,246,807, November 13, 1917.* A solution is formed from dried atomized water-soluble solids of sulphite waste liquor and a mixture of this solution with lime is used as a binder in making fuel briquettes or for binding other materials.—Chem. Abs. 12:306.

(125) *C. Ellis, U.S. 1,246,808, November 13, 1917.* Briquettes of coal dust, ore, sawdust or other materials are formed with a binder composed of magnesium oxide and waste sulphite liquor solids.

(126) *A. W. Goulding, U.S. 1,305,209, May 27, 1919.* A fuel mixture for briquettes is formed of coal 2,000 pounds mixed with about 70 pounds each sulphite pitch and clay.—Chem. Abs. 13:2124.

(127) *L. A. Kingkinney, U.S. 1,359,074, November 16, 1920.* A mixture formed of sulphite liquor 8 gallons, gilsonite 20 pounds, and a jelly made from kelp 4 gallons, is used as a binder with 2 tons of wood fibre in making fuel briquettes.—Chem. Abs. 15:307.

(128) *Carleton Ellis, Canadian 209,629, March 22, 1921.* Finely divided fuels or other material are briquetted by mixing with them the solids of waste sulphite liquor together with lime and sufficient water to cause a reaction between the liquor solids and lime.—Chem. Abs. 15:1196.

(129) *C. Jaeger and H. W. Erickson, Canadian 225,510, October 31, 1922.* A binder of condensed sulphite liquor and a small amount of calcium hydroxide is thoroughly mixed with finely divided fuel; the mixture is formed into briquettes under high pressure and temperature.—Chem. Abs. 17:202.

(130) *Andrews Co. Ltd., and A. M. Duckham, British 197,433, February 18, 1922.* In briquetting ore or fuel with waste sulphite liquor the formed briquettes are preferably dried and warmed and are then immersed, e.g. for 5 minutes, in a bath of molten metal, such as lead maintained at 797° F. to 887° F. Apparatus is described.—Chem. Abs. 17:3673.

(131) *Soc. Dite L'Avébène, British 197,901, January 29, 1922.* Anthracite, coke, etc., in powder form is mixed with the pulverized mass obtained by concentrating bisulphite lye after complete neutralization of sulphurous acid (free or in part combined) contained therein. Water is added if the fuel material is not sufficiently humid to form a plastic mixture. The fuel is compressed into briquettes which are baked up to about 392° F. for 20 to 40 minutes. In an example 100 parts of material are mixed with 3 to 3½ parts of solidified lixivium.—Chem. Abs. 17:3779.

(132) *F. A. Vogel, U.S. 1,481,942, January 29, 1924.* Material briquetted with molasses, sulphite pitch or other water-soluble binder, dried and carbonized. —Chem. Abs. 18:896.

(133) *E. S. Smallwood, British 211,528, July 2, 1933.* Finely divided material is mixed with sulphite waste liquid and briquetted, the briquettes being preheated at 220° F. and then baked at 650° F.—Chem. Abs. 18:1810.

(134) *T. Nagel, U.S. 1,507,673, September 9, 1924.* An organic binder containing phosphorus in inorganic combination, e.g. blackstrap molasses mixed with phosphoric acid, which is capable of hardening on heating, is used to effect agglomeration of fine coal which is to be briquetted and the binder is hardened by heating. U.S. 1,507,674 specified the similar use of sulphite pitch together with phosphoric acid. U.S. 1,507,676 specifies a binder which is rendered hard and water-insoluble on heating and which may be formed of sulphite pitch mixed with about 16 to 33 per cent of phosphoric acid. U.S. 1,507,678 specified briquetting with a binder which is rendered hard, water insoluble and non-volatile on heating and which is formed by mixing sulphuric acid or zinc chloride with sulphite pitch or a similar water-soluble organic adhesive material (50 per cent sulphuric acid).—Chem. Abs. 18:3471.

(135) *H. de Boistesselin, British 222,449, September 28, 1923.* A binder for small coal or other powdered fuel is formed by treating, reducing or hydrolyzable sugars or materials containing them, e.g. an aqueous dextrin solution, with sulphuric acid. The briquettes are heated to a temperature below the coking temperature of the binder. Glucose, molasses and cellulose wastes may be employed and iron sulphate may be used as a hardening agent.—Chem. Abs. 19:1045.

(136) *E. Piron, U.S. 1,537,190, May 12, 1925.* Briquettes formed of pulverized coke with a binder of sulphite liquor are enclosed in a layer of carbonized tar.

(137) *J. P. Delzeit, U.S. 1,596,239, August 17, 1926.* Briquettes are formed of fine coal associated with a binder of sulphite liquor or the like and a small addition of sulphur, subjected to a carbonizing heat treatment at a temperature of about 600° to 698° C.—Chem. Abs. 20:3345.

(138) *P. E. Welton, U.S. 1,572,629, February 9, 1926.* Coal culm is mixed with a binder such as waste sulphite liquor in plastic form and then with a waterproofing material such as asphalt in granular form, shaped and then heated to drive off moisture and liquefy the waterproofing material so that it serves also as a binder.—Chem. Abs. 20:1316.

(139) *E. Pollaesek, British 157,907, January 10, 1921.* An adhesive compound is made from waste sulphite cellulose lye by neutralizing the liquid with slaked lime, concentrating the filtrate until a sample sets on cooling, and then adding a heavy mineral oil in such quantity that a further sample remains liquid on cooling. The resulting liquid is of use as a binder in the manufacture of briquettes of coal and ore.—Chem. Abs. 15:1995.

(140) *W. P. Frey, British 219,659, July 25, 1923.* Briquettes are formed of anthracite or similar material together with 20 per cent to 35 per cent bituminous coal and starch, glutin or hot sulphite liquor as a binder and these briquettes are heated for a short time to a high temperature superficially to coke them.—Chem. Abs. 19: 722.

(141) *E. Pollaesek, Canadian 221,816, August 1, 1922.* Coal dust is mixed with alkaline sulphite waste lye and heavy mineral oil and pressed in moulds without heating.—Chem. Abs. 16: 3385.

(142) *J. F. Lovejoy, U.S. 1,366,091, January 18, 1921.* The apparatus is especially adapted for heating and drying briquettes with a binder of waste sulphite pitch.—Chem. Abs. 15: 942.

(143) *Park E. Welton and George H. Wadsworth, U.S. 1,642,055, September 13, 1927.* Granulated or shredded oil refinery residue wax, 3 parts, mixed with sulphite by-product liquor, 2 parts, to form a putty-like mixture, and this is mixed as a binder with coal culm 100 parts and with water, briquettes are formed from this mixture and are set and baked.—Chem. Abs. 21:3733.

(144) *P. E. Welton, British 244,971, March 26, 1925.* Dried coal culm is mixed with cellulose by-product in powdered form and with granular petroleum residuum or other waterproofing; the mixture is extruded in the form of a porous cylinder, the latter is broken into briquette lengths and baked.

(145) *Theodore Nagel, U.S. 1,626,208, April 26, 1927.* Alcohol slops and sulphite liquor are mixed and used as a binder for fuel which, after pressing, is heated to 250° to 500° F. to convert the binder into a hard water-insoluble smokeless material.—Chem. Abs. 21: 2058.

(146) *S. R. Wagel, U.S. 1,618,029, February 15, 1927.* Briquettes are formed of coal bonded with clay, bituminous material and other material such as sulphite liquor, molasses, alcohol slop or magnesium chloride, which serves as an effective binder at temperatures between that where the bituminous material loses its binding properties and that where the clay becomes effectively baked to hold the briquettes against disintegration.—Chem. Abs. 21:1177.

(147) *Paul C. Milligan, U.S. 1,683,094, September 4, 1928.* After heating the base material such as coal and wood charcoal it is mixed with molasses, and heating of the mixture is continued to drive off water contained in the molasses but at a temperature below that which would drive off volatiles from the fuel; the mixture is then cooled to a briquetting consistency, pressed and baked to carbonize the binder.—Chem. Abs. 22:3979.

(148) *W. T. Miller, U.S. 1,670,865, May 22, 1928.* Coal or other finely divided carbonaceous material is treated with an adhesive formed of a glutinous substance such as dextrin dissolved in water and partially thrown out of solution by a precipitant, e.g. alcohol. Sodium silicate also is used.—Chem. Abs. 22:2455.

(149) *Albert L. Stillman (to General Fuel Briquette Corp.) U.S. 1,677,994, July 24, 1928.* A mixture of coal 90, molasses lees 5 to 7 and sulphite liquor 5 to 3 per cent is ground, crushed and kneaded, moulded and carbonized.—Chem. Abs. 22:3512.

(150) *Koks and Halbkoks-Brikattierungs-Ges., British 279,020, October 14, 1926.* Finely divided bituminous coal is briquetted with water soluble or inorganic binders such as sulphite waste liquor and clay, and the briquettes are subjected to a roasting and then to a distillation at a temperature of 66·2° F. to 1202° F. (depending on the kind of coal used).—Chem. Abs. 22:2830.

(151) *F. L. Schmidt, British 294,879, July 30, 1927.* In briquetting with a binder of molasses or cellulose pitch, the sugar substances in the binder are removed at least partially by fermentation and the residue is concentrated by evaporation at a temperature of above 212° F. until a test portion sets on cooling. Acetone, acetaldehyde, alcohol, glycerol, etc., may be obtained by the fermentation.—Chem. Abs. 23:2021.

(152) *O. Reynard and F. F. Tapping, British 293,135, April 4, 1927.* Sulphite cellulose waste liquor is used with bituminous material such as coal-tar pitch, asphaltic pitch or natural bitumen after neutralization of the liquor by sodium hydroxide or other alkali and is formed into a paste with finely divided coal, peat, lignite or the like, under pressure and while heated to above 212° F. Various other materials such as oils may be added. British 293,136 described the production of briquettes with bituminous binders, together with oils and aqueous emulsifying agents such as alkali or ammonium salts or hydroxides or a caseinate, alginate, pectate, tannate, gelatin, glue or, acid or neutralized sulphite cellulose liquor or suspensions of cereal materials or potatoes or beets, marine algae, etc.—Chem. Abs. 23:1496.

(153) *F. A. Vogel, Canadian 183,261, March 26, 1918.* A mineral oil is heated to aprox. 250° F. and to it is added during agitation sulphite pitch solution. When the mixing is complete the product is mixed with fine particles of fuel and formed into briquettes.—Chem. Abs. 12:1345.

(154) *L. Rudeman, British 236,366, June 25, 1924.* The water content of peat or a mixture of peat and peat earth is reduced to 60 to 65 per cent and the material is then agitated with waste sulphite liquor containing phenols or tar oils under the action of heat and pressure and formed into briquettes, coal or dust, tar and other fuel ingredients also may be added.—Chem. Abs. 20:982.

(155) *F. M. Crossman, British 244,053, December 5, 1924.* Anthracite fines or other fuel (preferably not having over 12 per cent of volatile) is bonded with starch, sulphite waste liquor, furfurol, heavy oil residuum or pitch and a small quantity of sodium nitrate or other oxidizing agent. The nitrate may be added to a milky solution of starch and the latter heated to increase its consistency. The briquettes may be dried at 248° to 392° F.—Chem. Abs. 21:168.

(156) *S. F. Walten, U.S. 1,618,249, February 22, 1927.* Relates to briquettes which are formed with a binder of sulphite liquor and celluloid scrap solutions or similar material.—Chem. Abs. 21:1177.

(157) *E. W. Bowen, U.S. 1,667,304, April 24, 1928.* Fine dust is separated from the granular portions of fuels such as coal or coke and after the granular portion has been mixed with sulphite liquor or other binder a definite proportion of the fine dust is added to the mixture.—Chem. Abs. 22:2048.

(158) *P. Fuchs (to Friedlaender & Co.) British 281,326, November 27, 1926.* Non-caking fuels are briquetted with a binder consisting of a mixture of organic and inorganic substances, e.g. waste sulphite liquor constituents and lime or cement. Naphthalene and lime slaked with a saturated magnesium sulphate solution also may be used and mercuric oxide may be mixed with the lime before slaking in different proportions according to the hardness desired.—Chem. Abs. 22:3517.

(159) *Robert W. Strehlenert, U.S. 1,743,985, January 14, 1930.* Sawdust is mixed with a waste sulphite liquor in such concentration and proportion that the mixture on a dry basis contains about 25 to 60 per cent dry materials derived from the sulphite liquor, the mixture is partly dried, and is then treated with live steam to effect further heating and moistening. The moistened mixture is briquetted under pressure and the briquettes are dried at a temperature not substantially in excess of 392° F.—Chem. Abs. 24:1493.

(160) *Francis M. Crossman, U.S. 1,752,838, April 1, 1930.* A binder for making briquettes from pulverulent fuels such as anthracite fines comprises a mixture of sulphite cellulose waste liquor in an aqueous starch solution together with asphaltum pitch as a waterproofing material and a small quantity of sodium nitrate as an oxidizing agent.—Chem. Abs. 24:2581.

(161) *Kisomatu Hyogoya, Japanese 91,304, June 13, 1931.* Briquettes are formed from a mixture of powdered anthracite, concentrated waste sulphite pulp solution, and sodium silicate and dried. During the drying lime water is sprayed on the briquette.—Chem. Abs. 26:1756.

(162) *Gustave Komarek (to Berwind Fuel Co. of Del.), U.S. 1,860,465, May 31, 1932.* Briquettes are provided with a deliquescent abrasion-resistant coating by separately applying a deliquescent material such as calcium chloride and an abrasion-resisting film-forming substance such as sulphite liquor to the surface of the briquette to form a strong film or envelope about the briquette without substantially reducing the deliquescence of the coating.—Chem. Abs. 26:3904.

(163) *E. Pollaesek, U.S. 1,173,499, March 30, 1915.* The liquor is heated with lime until a froth forms and then heavy petroleum distillate is added drop by drop and the oily portion containing calcium compounds is separated, the remaining liquor concentrated and more oil added to the hot concentrated liquor. After cooling, lime paste and additional oil are mixed with the product and it is finally boiled.—Chem. Abs. 9:1391.

(164) *A. Richter, German 275,832, August 2, 1910.* 500 kg. creosote oil, 1,000 kg. sulphite liquor of 36° Bé., and 200 kg. sulphuric acid of 60° Bé. are mixed intimately. To this is added 8,000 kg. of fine coal, the whole intimately mixed, and briquetted. These are exposed to a temperature increasing to 518° F. whereupon all the binder decomposes, leaving a pure solid carbon skeleton which firmly binds the separated particles of the briquettes.—Chem. Abs. 9:522.

(165) *B. Grätz, German 280,455, November 21, 1913.* In the manufacture of coal briquettes, blast furnace slag powder, calcined ash, gypsum, or cement are added to the fine coal as water binding agents which retain the water at about 230° F., and the mass is then mixed with about 14 per cent sulphite-cellulose lye containing about 50 per cent water, heated, pressed in forms, and the sulphite lye in the briquettes coked. After the addition of the powdered slag, if a small excess of water (above the 3 to 4 per cent necessary for pressing) remains, it is driven out quickly at 212° F. to 221° F., e.g. 1 kg. well burned gypsum is added to 100 kg. fine coal and thoroughly mixed. This mixture is then stirred up with 14 kg. sulphite liquor of about 50 per cent water content. The gypsum takes up a large amount of water and retains it. Upon heating the briquettes to coke the sulphite cellulose, the gypsum strengthens the briquettes and renders the usual addition of sulphuric acid unnecessary.—Chem. Abs. 9:1388.

(166) *M. Platsch and Koesch and Company, French 455,099, March 5, 1913.* In a process of manufacturing water-insoluble briquettes by means of sulphite cellulose waste lyes, without resorting to carbonization, to the concentrated lyes only so much sulphuric acid is added, with cooling, as to precipitate all the lime and leave a slight excess of free acid which, upon drying the briquettes at about 212° F. separates out the binding constituents, with formation of sulphur dioxide in a water insoluble state, and allows the organic acids (formic acid, acetic acid) to escape.—Chem. Abs. 8:568.

(167) *F. H. Patch, U.S. 1,113,681, October 13, 1914.* Formed by mixing waste sulphite liquor with flour or clay, evaporating until it is thick enough to hold soap in suspension and then adding soap or alkali and fats or oil to the mixture and evaporating to dryness if desired.—Chem. Abs. 8: 3842.

Briquetting Patents *re* Inorganic Binders

(168) *F. Fallet, Swiss 76,907, February 16, 1918.* The combustible material is comminuted and the particles are agglutinated by means of clay. Powdered carbon, locomotive flue dust, and sawdust are specified as suitable combustible material.

(169) *P. Lamberty, British 119,443, May 4, 1918.* Coal dust, coke dust, and the like are mixed with lime, and the mixture is damped and moulded under high pressure into briquettes. The briquettes are exposed to the action of steam under pressure in a boiler.

(170) *J. Chappuis and C. Ortlieb, Swiss 77,340, August 16, 1918.* A combustible agglomerate is composed, e.g. of coke breeze 95 parts by weight, coal slack 5, and Portland cement 10. The gas generated by the burning of the coal facilitates the combustion of the coke.—Chem. Abs. 13:1387.

(171) *A. H. Ege, U.S. 1,357,627, November 2, 1920.* A fuel mixture suitable for manufacture of briquettes is formed of coke breeze or slack 128, Portland cement 9, magnesium oxide $\frac{1}{8}$, magnesium chloride and water.—Chem. Abs. 15: 307.

(172) *A. A. Dale, British 160,279, December 18, 1919.* Coal dust, coke, etc., are mixed with lime or other alkaline earth oxide. The mixture is allowed to stand, say, for a week, out of contact with atmospheric and other carbon dioxide and then briquetted. The process of allowing the mixture to stand may be effected in a sealed vessel, in which a vacuum is created during the whole or part of the standing period. In the process of mixing, hot water may be used and the mixture may be heated also by means of steam; the amount of hot water used in mixing the ingredients of the fuel may be 2·5 to 3 volumes of water to 1 volume of the ingredients.—Chem. Abs. 15:2351.

(173) *W. P. Taggart, U.S. 1,396,603, November 8, 1921.* In forming baked briquettes from coal, culm, etc., a binder including sodium silicate and sulphuric acid is employed in order to provide insoluble silicic acid in the briquettes which assists in preventing their distintegration during handling and in rendering them waterproof.—Chem. Abs. 16: 637.

(174) *R. Kattner, U.S. 1,562,564, November 24, 1925.* Coal fines or other fuel material is mixed with magnesium chloride, and magnesium oxide is then added and the mixture is moulded and pressed, water also being added if necessary.—Chem. Abs. 20:495.

(175) *G. E. Rice and E. J. Johnston, British 233,248, November 3, 1924.* Fuel blocks are formed with a core comprising coal dust, calcium carbonate, magnesium carbonate, or other magnesium compound, and sea water, an inner coating of the same ingredients except that the coal dust is omitted, and an outer coating of the same ingredients with the addition of ground spent oil shale and a crude petroleum jelly.—Chem. Abs. 20: 656.

(176) *Frankensteiner Magnesitwerke Akt. Ges., British 241,175, October 11, 1924.* Coal dust or similar material is first treated with ground magnesium chloride and then water is added in quantity sufficient for forming briquettes. Magnesium oxide is added immediately prior to moulding.—Chem. Abs. 20: 2577.

(177) *W. Tyrrell, U.S. 1,588,823, June 15, 1926.* Diatomaceous earth and sodium hydroxide in equal quantities are mixed with sufficient warm water to moisten, stirred, heated to about 221° F. for about 30 minutes, formed into a plastic mass with additional hot water and about 2 per cent of this product is used with finely ground combustible material such as coal or coke which is compressed into briquettes.—Chem. Abs. 20: 2577.

(178) *H. M. Spencer, U.S. 1,590,706, June 29, 1926.* Material such as culm is treated with acid phosphate and heated to about 392° F.—Chem. Abs. 20:3073.

(179) *E. C. Wallace, U.S. 1,443,105, January 23, 1923.* Partially dried peat still containing 50 to 65 per cent water is mixed with powdered coal or sawdust and cement, briquetted and dried.—Chem. Abs. 17:1322.

(180) *Bertram E. Crocker, U.S. 1,676,729, July 10, 1928.* The carbon residue obtained in the manufacture of oil gas is incorporated with a gas-liberating substance such as calcium carbonate, the mixture is formed into briquettes and the latter are heated to effect liberation of gas.—Chem. Abs. 22: 3285.

(181) *Jules Baumstümmler and Adolphe Goeppele, French 705,258, November 7, 1930.* Blast furnace dust is mixed with coke dust and agglomerated by the action of hydrochloric acid on the iron contained in the dust. The agglomerates are submitted to an appropriate pressure. An example is given in which the agglomerates are treated with a solution containing hydrochloric acid sodium silicate and powdered chalk or marble.—Chem. Abs. 25: 5275.

(182) *John A. Erickson (to Viking Mfg. Co.), U.S. 1,887,183, November 8, 1932.* Fuel fines are moistened with a solution of a hygroscopic salt such as calcium chloride and sufficient hydraulic cement is added to serve as a binder (the solution being applied in sufficient quantity to hydrolize the cement and in salt concentration merely sufficient to accelerate the setting of the cement binder). —Chem. Abs. 27:1488.

(183) *J. F. Dymond, U.S. 1,105,688, August 4, 1914.* Briquettes are formed of charcoal 200, barium nitrate 10, strontium nitrate 10, lead nitrate 5, potassium nitrate 5, and potassium chlorate 5 parts.—Chem. Abs. 8: 3233.

(184) *Ludwig Weiss, Budapest, German 183,108, February 18, 1906.* The powdered fuel or ore is mixed with calcium hydroxide and treated throughout the mass with carbon dioxide under pressure, first cooled, then warmed, with a view to transforming the calcium hydroxide into calcium carbonate.

(185) *L. Caillat, French 486,383, March 28, 1918.* A cheap fuel is prepared from vegetable materials or residues from stills or the like, twigs, leaves, and dried roots, sawdust, etc., reduced to a powder and sifted, and mixed with a priming powder of carbon, resin, sulphur, etc., moistened and agglomerated in the form of sticks or briquettes with potter's earth or clay by pressure, and then dried naturally in the air.—Chem. Abs. 13: 1920.

(186) *E. N. Pearson and L. Meredith, British 115,790, February 5, 1918.* Fuller's earth, impregnated, or saturated with oil, is mixed with coal dust, coal slack, or culm, common salt, and water, or other suitable liquid so as to form a pasty mass, which is moulded into blocks and dried more or less before use as fuel. In addition to the coal dust, coal slack, or culm, coke or coke dust, and bar or grate ash may be used. The oil saturated or impregnated fuller's earth used is a by-product of oil refineries.—Chem. Abs. 12: 1922.

(187) *W. W. Stafford, U.S. 1,430,767, October 3, 1922.* Ground anthracite, coke, or other carbonaceous material is formed into briquettes with coal dust, barium carbonate, charcoal, and tar.—Chem. Abs. 16:4052.

(188) *F. Berlin, French 485,737, February 1, 1918.* Powdered charcoal or coke is agglomerated by means of cement, sodium borate, and decoction of linseed. —Chem. Abs. 13:1922.

Briquetting Patents *re* Carbonizing Briquettes

(189) *C. H. Smith, British 11,285, August 29, 1917.* Briquettes which are adapted to burn in a smokeless manner are formed by heating to a high temperature, e.g. from 1400° to 2000° F., preferably about 1850° F., a moulded briquette which has been formed from crushed coal, coke, or partially carbonized coal, or mixtures of these with water or with a hydrocarbon binder such as tar, pitch, oil, or with raw coal, the characteristic feature of the composition being that it contains from 11 to 17 per cent of volatile matter, exclusive of water, which is partially driven off during the final heating. The invention is described in connexion with an apparatus in which coal having a higher percentage of carbon than 17 is submitted to a partial carbonizing operation in a retort in which the crushed charge is mixed and conveyed forward by overlapping blades on rotating members. The partially carbonized coal is then passed by a conveyer to a crushing apparatus and to a mixing apparatus where a binder may be added, after which the mixture is briquetted. The briquettes are then heated in a second oven, and are completed by the carbonizing received therein, which is carried to a stage in which the volatile contents of the briquettes are reduced to from 5 to 14 per cent.—Chem. Abs. 12:627.

(190) *C. H. Smith, U.S. 1,276,427, August 20, 1918.* Coal is heated to render it plastic, removed from the heating zone and mixed with coke to absorb gases and condensates contained in the coal and, after further cooling, the mixture is compressed into briquettes. U.S. 1,276,428 describes the manufacture of briquettes from coal which has been previously subjected to a partial distillation followed by a vacuum treatment for removal of entrained gases which if not removed might cause the briquettes formed to rupture. U.S. 1,276,429 describes the manufacture of briquettes from coal, coke, or partially carbonized coal or a mixture of similar material in which there is too low a volatile content for the direct manufacture of smokeless fuels. The material is pulverized and mixed with sufficient coal-tar pitch or other binder containing hydrocarbons to make the proportion of volatile substances contained in the resulting mixture 11 to 12 per cent. This mixture is then formed into briquettes, using water as a temporary binder, and the briquettes are subjected to a second carbonization in a retort heated to about 1400° to 1832° F.—Chem. Abs. 12:2124.

(191) *C. H. Smith, British 120,585, August 20, 1917.* Briquettes are made from mixtures of raw coals, raw coal and coke, or raw coals and a hydrocarbon binder such as coal-tar pitch, asphalt pitch, coal-tar or petroleum oils, the mixtures being such that the volatile matter contained therein is between 11 and 17 per cent. The mixture is made into a mash with water or by the aid of the binder, the whole being well crushed. The mixture is then moulded into briquettes and these are carbonized in a chamber which is maintained at a temperature between 1400° and 2000° F., preferably at about 1850° F. the by-products being collected. It is stated that the briquette produced is hard and porous, burns with a non-smoky flame, and has a volatile content of about 2·5 per cent.—Chem. Abs. 13:657.

(192) *G. Komarek, U.S. 1,430,386, September 26, 1922.* A mixture of coal dust and a binder such as coal tar or asphalt tar is heated in a vertical columnar chamber and the material in the lower portion only of the column is kneaded to prepare it for moulding.—Chem. Abs. 16:4052.

(193) *H. Dupuy and L. Liaris, British 192,418, January 29, 1923.* Pulverulent fuel, e.g. poor coal, anthracite, etc., is moulded with a binder of resin, etc., into briquettes which are provided with a perforation preferably along their major axis. The briquettes are distributed so as to form a smokeless fuel, the distribution products being collected.—Chem. Abs. 17:3244.

(194) *Midland Coal Products Ltd., and A. Fisher, British 198,503, March 31, 1922.* Coal of low coking index, breeze or slack, is powdered, mixed with a binding material such as pitch and pressed into briquettes which are fed into a vertical retort and carbonized by consuming a small portion of the charge in a regulated supply of air, and by the upwardly flowing hot combustion products together with steam which may be admitted.—Chem. Abs. 18:322.

(195) *S. R. Illingworth, British 212,663, December 18, 1922.* A mixture of coal and about 5 per cent pitch, of such a character that the "caking index of the mixture is 6 to 12," is pressed into briquettes and these are heated to 50° to 100° F. above the temperature of decomposition of resinous matter in the coal (not above 600° F. when a light pitch is employed, nor above 750° F. when heavy pitch is used). A final temperature of 900° to 1000° F. may subsequently be applied and pitch and hydrocarbons may be recovered during the heat treatment.—Chem. Abs. 18:2239.

(196) *T. A. Goskar, British 231,934, January 9, 1924.* Fuel briquettes for coking comprise a mixture containing 70 to 90 per cent of a non-coking coal and 30 to 10 per cent of a binder formed by grinding caking coal to a powder of 150 to 200 mesh and adding water-gas tar, etc., to form a smooth paste. The coking of the briquettes may be effected with hot producer gas.—Chem. Abs. 19:3583.

(197) *C. H. Smith, U.S. 1,334,180, March 16, 1920.* A mixture is formed of 50 to 75 per cent non-caking coal having a volatile content of 38 to 40 per cent, 22 to 30 per cent caking coal having a volatile content of about 30 to 40 per cent and 6 to 10 per cent of pitch having a volatile content of about 55 to 60 per cent, the proportions being so chosen that the caking coal and the pitch provide volatile matter equivalent to 11 to 20 per cent of the entire mixture. This mixture is briquetted and carbonized at a temperature of 800° to 1000° F. to drive off volatile matter and produce a firm, dense, coherent, smokeless fuel. Various bituminous coals and lignites may be used. The mixture may be fluxed with steam to prepare it for briquetting.—Chem. Abs. 14:1434.

(198) *S. F. Walton, U.S. 1,618,248, February 22, 1927.* Wet ground coal is mixed with an oil binder, in the approximate proportions of 90 and 10 per cent respectively, formed into briquettes and carbonized at a relatively low temperature while protected from oxidation.—Chem. Abs. 21:1177.

(199) *Compagnie Des Mines De Bruay, British 272,522, June 14, 1926.* Distillation at low temperature is effected in a mass of grains of silica or the like so that each piece is coated and prevented from fusing to the adjacent pieces. The fuel may be bituminous coal bonded with a solution of gum arabic or a sulphite cellulose composition.—Chem. Abs. 22:1842.

(200) *L. M. Johnston and J. L. Farrell, U.S. 1,655,728, January 10, 1928.* Acid tar is used as a binder in forming briquettes from petroleum-coke, coal dust, lignite or similar carbonaceous material, and the briquettes are roasted to drive off the acid.—Chem. Abs. 22:1031.

(201) *Compagnie Des Mines De Bruay, British 282,340, December 18, 1926.* Solid fuels may be mixed with powdered charcoal from sawdust, formed into briquettes and these are embedded in material such as dust or grains of coal schist, roof coal of a schistose nature, sawdust, waste peat, bark scrapings, oil cake waste or other material adapted to produce gases and oils at the distillation temperature. This entire mass is then heated to a temperature which is raised in stages from 212° to 932° F. and tar and other volatilized products are collected.—Chem. Abs. 22:3762.

(202) *M. H. Hue, British 323,698, April 16, 1929.* A mixture of crushed charcoal or half-coked peat or lignite with a binder of hard petroleum tar dissolved in fuel oil residue (mazaut) is briquetted in a press, exposed to the air, heated to 500° to 600° F. for 3·5 hours and then cooled out of contact with air for 7 hours.—Chem. Abs. 24:3345.

(203) *Charles V. McIntire (to Consolidation Coal Products Company), U.S. 1,722,189, August 5, 1930.* A pulverized solid carbonaceous fuel such as a semi-coke is mixed with a hydrocarbon binder such as coal-tar pitch to form a mixture containing about 18 to 20 per cent volatile matter, exclusive of water, which forms a coherent coke on carbonization, the mixture is briquetted and the briquettes are carbonized.—Chem. Abs. 24:4920.

(204) *Henry F. Maurel (to Maurel Investment Corp.), U.S. 1,780,205, November 4, 1930.* Fuel suitable for use in furnaces is prepared by subjecting carbonaceous materials such as pulverized coal to froth-flotation concentration, reducing the moisture in the concentrates to form a heavy paste, mixing the latter with a suitable liquid hydrocarbon material such as a heavy asphalt base oil and finally baking the mixture.—Chem. Abs. 25:192.

(205) *Henry F. Maurel (to Maurel Investment Corp.), U.S. 1,908,910, May 16, 1933.* Moisture and lower-boiling oil fractions are driven off from previously formed fuel briquettes by indirect heat and the heavier fractions are retained to serve as a binder and the briquettes are then cooled to contract the gases and vapours contained in them and are subjected to the action of oxygen or air. U.S. 1,908,911, relates to an oven with an endless conveyer for carbonizing briquettes.—Chem. Abs. 27:3805.

(206) *Henry O. Loebell (to Combustion Utilities Corp.), U.S. 1,912,002, May 30, 1933.* Briquettes suitable for use as domestic fuel are produced by low-temperature carbonization of a finely divided fuel mixture, arranged in a thin layer and containing a low-volatile fuel and a high melting pitch (having a melting point of about 150° F. or higher) while concurrently forming the heated material into briquettes under a low mechanical pressure. Apparatus is described.—Chem. Abs. 27:4059.

(207) *Edwin L. Wilson (to Lehigh Coal and Navigation Company) U.S. 1,918,162, July 11, 1933.* A layer of green briquettes is placed on a porous bed of relatively fine carbonaceous combustible material and the bed material is burned underneath the layer of briquettes and currents of air are passed upwardly through the materials to support combustion and heat the briquettes to effect their carbonization.—Chem. Abs. 27:4655.

(208) *E. R. Sutcliffe and Pure Coal Briquettes, Ltd., British 5,018-9, March 31, 1915.* Coal is briquetted under high pressure without binder and/or with dry binder, and either coked or broken up and rebriquetted.—Chem. Abs. 10:2396.

(209) *J. Armstrong, British 1,183, January 16, 1914.* In the manufacture of fuel briquettes by mixing the material with an agglomerant that will cake or coke under heat, the caking or coking is performed automatically and continuously in closed moulds out of contact with air.

(210) *Comp. D'Agglomérés D'Anthracite Pur., French 463,138, December 9, 1912.* Anthracite dust, mixed with bituminous coal (5 to 8 per cent) is briquetted with a binder (molasses, dextrin) which serves only as a temporary binder, and is then heated at 1652° to 1832° F. in the autoclave, whereby the bituminous coal, by the coking, yields a binder of great power compared with the molasses coke.—Chem. Abs. 9:145.

Patents *re* Briquetting Without Binders

(211) *E. R. Sutcliffe, U.S. 1,267,711, May 28, 1918.* Finely powdered coal or similar fuel, e.g. material which is of 200-mesh grade, is formed into blocks or briquettes by subjection to high compression in a completely enclosed mould space while permitting expansion of the compressed material in a direction transverse to the line of application of the pressure, under the interval stresses created in the block or briquette. Briquettes thus formed will burn completely in an open grate.—Chem. Abs. 12:1830.

(212) *R. Matsunaga and S. Aoki, British 157,007, March 8, 1920.* Coal dust, coke waste, brown coal, or the like is washed with water, pulverized, and mixed with caking bituminous coal, also pulverized, the pulverization being effected in such a way that both ingredients are powders of a uniform degree of fineness. The mixture is moistened with water, moulded into briquettes, and roasted in an oven. A house fuel, intended to be smokeless and odourless, is produced in the same way except that the coal dust, coke waste, etc., is roasted after being washed. The amount of coal dust, coke waste, etc., used is not more than two parts and that of the bituminous coal one part.—Chem. Abs. 15:1803.

(213) *Charles Howard Smith, Norway 31,320, November 1, 1920.* Bituminous coal is treated in such a manner that it will give off all gases and vapours volatilizing at low temperature while at the same time it swells and becomes porous. The distillation is then discontinued, the residue pressed into briquettes, after addition of a binding agent, if required, and such briquettes are distilled at higher temperature, e.g. 1382° to 1850° F., until all the gases and vapours have been driven off. The result will then be a dense connective pressed coal of a low degree of porosity.—Chem. Abs. 15:2174.

(214) *S. R. Illingworth, British 205,542, May 11, 1922.* In a plant for carbonizing coal the coal is supplied to a series of moulds, which are conveyed through a furnace on an endless chain, and is heated to form briquettes with a shell sufficiently hard to prevent fracture when they are dropped into a vertical furnace or oven in which further heating takes place.—Chem. Abs. 18:1191.

(215) *J. F. O'Donnell, U.S. 1,557,320, October 13, 1925.* About equal amounts of fine anthracite and semi-bituminous coal dust are mixed with each other, moulded under pressure and subjected to a temperature of about 1004° F. for 3 to 6 minutes.—Chem. Abs. 20:106.

(216) *J. Beaudequin, U.S. 1,597,570, August 24, 1926.* Briquettes "of anthracite quality" are made from peat, lignite, brown coal or turf or other similar materials by subjecting the raw material to predistillation to drive off water and more volatile hydrocarbons, forming briquettes of the distillation residue and forcing them successively into and through a tube in a column which tightly fits the bore of the tube. The briquettes in the forward part of the tube while under pressure are heated to a temperature sufficiently high to cause "fluescence" of the remaining hydrocarbons present, and the briquettes are cooled while still under pressure in the tube.—Chem. Abs. 20:3345.

(217) *J. F. O'Donnell, British 247,272, November 10, 1924.* A mixture of anthracite birdeye coal and anthracite dust coal with bituminous coal or similar mixture is pressed and heated to 800° to 1000° F. for 3 to 6 minutes in a metal container from which distillates may escape through perforations.—Chem. Abs. 21:643.

(218) *E. Gevers-Orban and J. Pieters, British 294,581, July 26, 1927.* Sticking together of briquettes during carbonization is prevented by embedding them in a dust which may either be that of the raw fuel or of coke breeze from a previous distillation.—Chem. Abs. 23:2020.

(219) *Chemische-Technische Ges., British 300,195, November 8, 1927.* In forming briquettes from fuels of different coking properties, the coking fuel is heated to or below the softening temperature (suitably about 572° F.) and the non-coking fuel to a higher temperature (suitably about 1112° F.) and the fuels are then mixed and briquetted.

(220) *Synthetic Ammonia and Nitrates, Ltd., and H. A. Humphrey, British 291,543, March 11, 1927.* Powdered fuel is preheated in an uncompressed state and on nearing the coking temperature is forced by pressure through a container where coking occurs and the coke takes the shape of the container, which may contain a grid for dividing up the coked mass.—Chem. Abs. 23:1254.

(221) *H. J. Phillips and A. Phillips, British 29,009, December 16, 1913.* Coal dust is made into briquettes by (1) grinding with 45 to 60 per cent water to a pulp, (2) briquetting at once without allowing settling in moulds from which the water can escape, under a pressure of 3 to 5 tons to square inch, (3) drying the briquettes by passing them through a tunnel kiln, the initial temperature of which may be 176° F. and is below boiling point to avoid cracking, and the final temperature somewhat below that at which the coal begins to decompose, ranging from 482° F. for semi-bituminous coal up to 932° F. for anthracite, and (4) further compressing them while yet soft under 5 to 15 tons to the square inch in moulds heated by superheated steam.—Chem. Abs. 9:1544.

(222) *Robert Friedlander, Berlin, Ger., British 5,051, March 1, 1906.* Briquetting coal without a binder consists of gradually compressing powdered coal, sawdust, etc., to at least 1472° F., and generally several thousand atmospheres, whereby the air is forced out completely, the final increase in pressure effecting plasticity and coherency.—Chem. Abs. 1:1789.

(223) *Alfred Uhlmann (to Albert T. Otto and Sons, Inc.), U.S. 1,768,869, July 1, 1930.* Substances such as coal dust, sand, etc., in finely divided state and under compression are placed in a high frequency electric field, so that the micro-arcing between the particles effects cohesion, without direct passage through the substances of electric current producing the field.—Chem. Abs. 24:4615.

(224) *A. Zindler, Berlin, Ger., U.S. 1,000,479, August 15, 1911.* Briquetting peat and non-briquetting material, such as anthracite, by mixing the materials, heating to a temperature sufficient to liberate bituminous binding material from the peat, and forming into briquettes.—Chem. Abs. 5:3727.

INDEX