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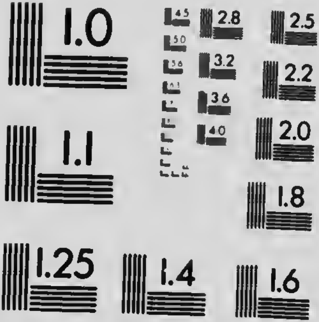

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Government of the Province of Saskatchewan

The Carbonizing and Briquetting of Lignite

Report of Investigations carried on by the Government of the Province of Saskatchewan with a view toward better methods of utilizing Lignite, by way of Drying, Carbonizing, and Briquetting it: to determine its value as a source of Power, Domestic and Furnace Fuel and Hydro-Carbon and Ammonia Byproducts

S. M. DARLING

Printed by order of the Legislative Assembly

REGINA:
J. W. Reid, Government Printer
1915

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and
Briquetting of Lignite

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1915

Regina, December 23, 1914.

THE HON. WALTER SCOTT,

President of the Executive Council,

Regina, Saskatchewan.

Sir, I have the honour to transmit to you herewith the report of the investigation carried on by Mr. S. M Darling for the Government of the Province with a view toward discovering better methods of utilizing Saskatchewan lignite.

The features of the report to which I would especially direct your attention relate to:

	Page
DRIED LIGNITE, for use on automatic stokers and in fuel-gas producers, and, when pulverized, as a powdered fuel	10
DRIED LIGNITE BRIQUETTES, for use in large, hand-fired furnaces.	13
CARBONIZED LIGNITE, for power-gas producers.	26, 29, 30
CARBONIZED LIGNITE BRIQUETTES, as a domestic fuel.	32, 41
GAS, to be sold as a "town gas," or used for the production of cheap electrical power or for burning clay products.	26, 32
BYPRODUCTS, from the hydrocarbon and ammonia compounds.	27, 28

Respectfully submitted,

Your obedient servant,

H. S. CARPENTER,

Acting Chairman, Board of Highway Commissioners.

Regina, December 1, 1914

F. J. ROBINSON, ESQ.

Chairman of the Board of Highway Commissioners,
Regina, Saskatchewan.

Sir, I have the honour to transmit to you herewith my report on lignite, following the work I have done during the past year under the auspices of the Government of the Province.

I take this opportunity of recording my appreciation of the assistance rendered me in this work by Dr. G. A. Charlton, provincial analyst, R. N. Blackburn, chief inspector of steam boilers, B. M. Smyth, chief engineer Parliament building power plant, J. D. Peters, superintendent Moose Jaw power plant, E. W. Bull, superintendent Regina power plant, and E. A. Sturley, engineer Leader Publishing Company, Regina.

I am,
Your obedient servant,
S. M. DARLING.

THE CARBONIZING AND BRIQUETTING OF LIGNITE

REPORT OF INVESTIGATION CARRIED ON BY THE GOVERNMENT OF THE PROVINCE OF SASKATCHEWAN WITH A VIEW TOWARD BETTER METHODS OF UTILIZING L[illegible]TE.

The lignite which is the subject of this investigation is that embraced in what is known as the Souris River coal field, in the vicinity of Estevan, in southern Saskatchewan. It is of late Cretaceous formation. The details as to geological history and geographical distribution have been ably dealt with by representatives of the Bureau of Mines, Ottawa, and therefore need not be discussed here.

In *quantity* there are not millions but billions of tons. The principal seam being mined lies about 80 feet below the level of the plain, and varies in thickness from 7 to 20 feet. There are numerous smaller seams above and below this one, the lowest within the personal knowledge of the writer being 456 feet down. It is reported by well drillers that there is a seam of coal at 900 feet. Several of these minor seams are in places of minable thickness.

In *quality*, this fuel is [illegible] typical xyloid lignite. The biochemical processes operating in the tr[illegible]formation of peat into coal were cut short before the decomposition of the vegetal matter had proceeded very far, hence the woody structure is very marked. The field is, broadly speaking, a level plain, cut by the Souris river; the seams are all practically horizontal and comparatively near the surface; the dynamo-chemical process, induced and controlled by geo-dynamic influences, which is the principal factor in the compression and devolatilization of the vegetal material comprising coal seams, ceased early and while the deposit in question was still in a comparatively unsatisfactory condition from a fuel standpoint. Judging from the fact that no gas is encountered in the lignite mines in this field, it is not operative in an appreciable degree at the present time. It is interesting to note, however, in this connection, that the "law of Hilt" is exemplified in some degree in the progressive increase of fixed carbon found in the successively lower lignite seams.

These brown coal deposits are of inestimable value to Saskatchewa[illegible] and Manitoba, fo[illegible] aside from a small quantity of Tertiary ligni[illegible] in the Turtle Mountains in Manitoba, and some scattering deposits in the Willow Bunch and Dirt Hills districts west of the Estevan field, they are the only proved source of fuel in the vast territory between the head of the Great Lakes and the Alberta coal fields in the Rocky Mountain region. It is, of course, trite to say that cheap fuel and power are essential to a country's industrial development.

Present Status of the Industry.

The tonnage mined annually in Saskatchewan has aggregated about 200,000 tons for several years. Despite the large increase in population the output does not increase. Indeed, of late, there has been a slight decrease. This falling off in tonnage is due entirely to the encroachment upon the lignite territory of eastern and western coals. A large tonnage of Pennsylvania anthracite is annually marketed in this region in spite of the excessively high price of $10 per ton in Winnipeg to $14 per ton in some parts of Saskatchewan.

The reason this lignite is not able to hold its own, with the result that millions of dollars are annually sent out of these two provinces in payment for eastern and western coals, is found in some of its physical characteristics.

A large number of samples averaged:

Moisture	26.13
Volatile hydrocarbons	28.11
Fixed carbon	38.16
Ash	6.86
Sulphur	.74

This large percentage of moisture has not been absorbed from extraneous sources, but is the portion remaining from the great amount of water present in the peat from which the lignite was formed. The necessity for the evaporation of this water in the furnace is, of course, an enormous handicap upon the fuel. When the lignite is mined and exposed to warm air and sunlight, the evaporation of the water causes the coal to disintegrate or slack very rapidly; it also fires very quickly from spontaneous combustion; hence it is not practicable to ship it long distances or to store it. Its light gases distil before the fixed carbon reaches the temperature of ignition and, in the ordinary furnaces, escape unconsumed. The lignite has no "coking" quality whatever, and when thrown onto the fire crumbles very quickly, giving rise to difficulties in firing and substantial loss through the grate bars.

The fact that the percentage of sulphur is small is a good feature. There is an almost entire absence of the corrosive acid resulting from the combination of sulphur with water when the lignite is burned. Further, should the lignite gas ever be used as a "town gas" for heating, cooking and illuminating purposes, there will be almost no sulphuretted hydrogen to be removed by means of hydrated oxide of iron purifiers.

Apparatus Designed to Burn Raw Lignite.

In Germany a sort of "stair" or "step" grate has been developed upon which to burn lignite.

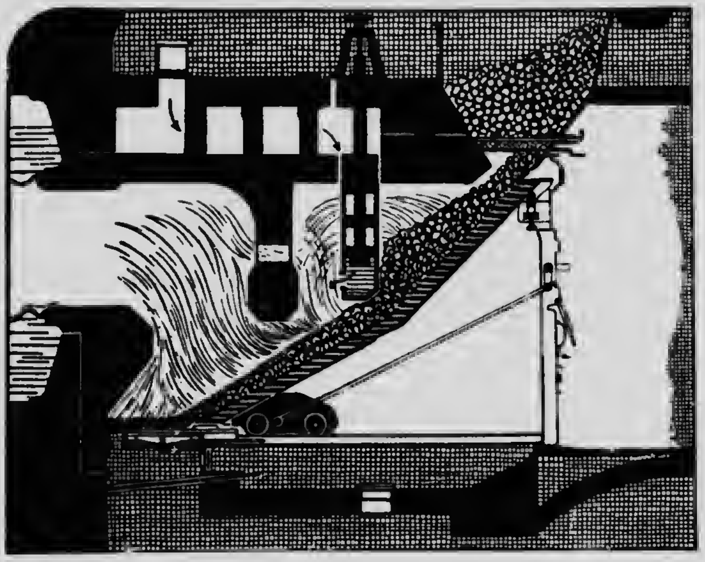


Plate 1.

German "Stair" Grate.

In America, a good type of furnace is that in use at the power plant of the United States Reclamation Service, Williston, North Dakota. (Plate 2, page 8.) This installation is fully described and illustrated in bulletin No. 2 of the Bureau of Mines, Washington, D.C.

The furnace is of the semi-gas producer type and has an external resemblance to the so-called Dutch oven. The solid fuel is gasified on the grate and the gas passes through the space under the arch into the combustion chamber, where most of the gaseous combustible burns. The necessary air for combustion is added through the openings A in the bridge wall. This air is preheated to 200 or 300 degrees Fahrenheit in coils P and forced into the furnace under a pressure of 0.5 to 1 inch of water. Owing to the location and direction of these air openings, the air is blown in jets into the comparatively slow-moving body of combustible gas, thereby causing considerable stirring, so that the gases and the air form a fairly homogeneous mixture. Although there is some combustion above the fuel bed, the greater part of the gases burn below the contracted arch and back of the bridge wall, after air has been added through the openings A and R.

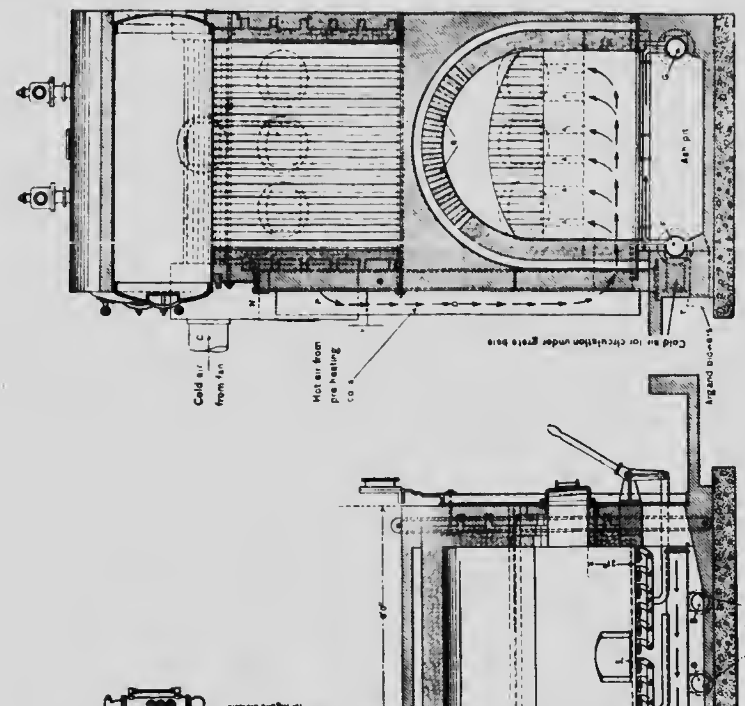


Plate 2.

Vertical section showing details of boiler setting. United States Reclamation Service, Williston, N.D.

The furnace is operated with "balanced draft" that is, the ash pit is kept under pressure higher than the atmospheric and the uptake under a pressure a little below atmospheric; the furnace is, therefore, just about at atmospheric pressure. This condition permits the opening of the fire doors when firing without allowing outside air to enter.

In Texas, a somewhat unique type of grate for burning lignite has been developed and is in extensive use, in connection with a Dutch oven form of furnace.

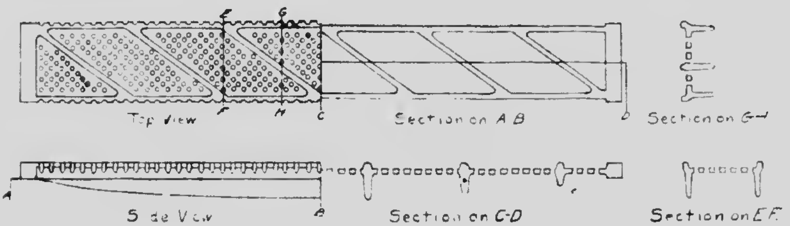


Plate 3.

"Velvet" Grate Bar: used in Texas to burn lignite.

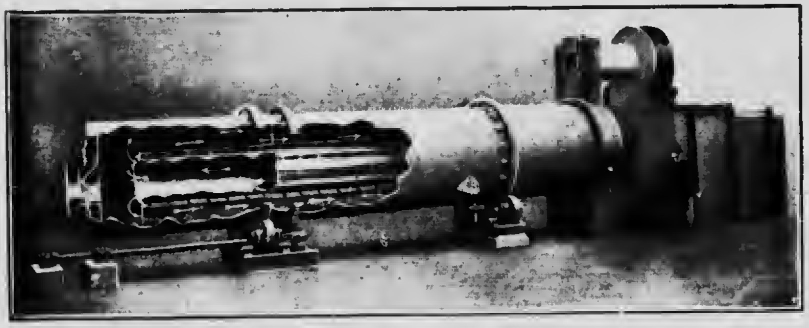
This so-called "velvet" grate bar, in its general outline, is like the ordinary grate bar commonly used in boiler furnaces, being approximately rectangular in cross-section, and wider at top than bottom. It is provided on its top face with marginal ribs and transverse ribs or partitions, forming a plurality of individual fuel pockets adapted to retain fine fuel, and on its bottom face with recesses forming air pockets corresponding to the fuel pockets. These fuel pockets are about one-half to five-eighths of an inch deep. The fuel pockets are connected with the air pockets by ventilating holes, tapering, and largest at their lower ends, being about three-eighths of an inch in diameter at the top and 50 per cent. larger at the bottom.

In ordinary grates, especially where a forced or induced draft is used, there is a tendency of the air to rush through the weakest places in the fire. In the "velvet" grate the individual air pockets underneath form separate sources of supply to the separate groups of ventilating holes and cause an even distribution of the air to the fuel pockets in the top of the bar throughout the grate surface. A steam blower is used with these grates. (Bulletin of the University of Texas No. 307.)

Because of the large water content and rapid slacking characteristics of the lignite, it is not likely that much of it will ever be used in the natural state, hence no emphasis is put upon methods or apparatus to consume the raw lignite.

DRIED LIGNITE.

The first step in the treatment of the lignite with a view to the better utilization of it is to crush it to about 2 inches and *dry* it. The best kind of dryer is the well known double cylinder rotary (Plate 4, page 10). The lignite is fed at a measured rate into the upper end of the dryer and passes down between the shells of the two cylinders. Vanes on the inside of the outer cylinder carry it up and cascade it down upon the outside



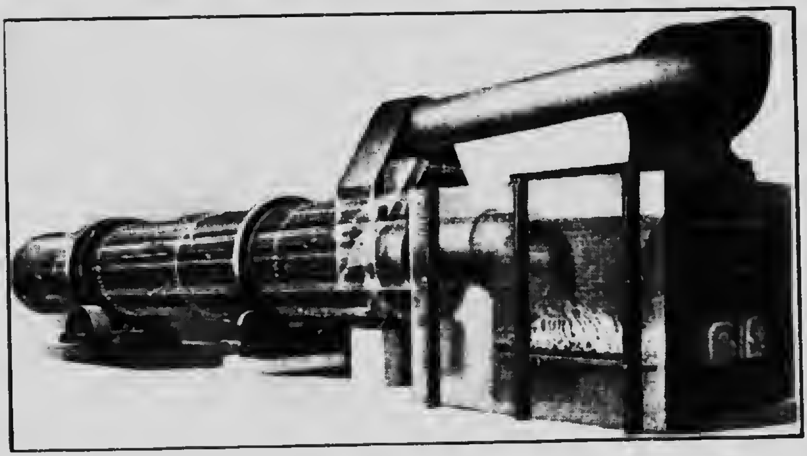


Plate 4.

Illustrations of Rotary Dryer, showing principle of operation.
Ruggles-Coles Co., New York.

of the inner cylinder, through which are passing the flue gases from the furnace in their initial travel through the dryer. The flue gases return between the two shells of the dryer in direct contact with the descending fuel and pass off with the moisture evaporated. A dryer of this type having a capacity of 20 tons per hour, including crusher, necessary elevators, screen and bins would cost $15,000.

The cost of drying the lignite, aside from the loss in weight due to the extraction of the 25 per cent. of water, is but a few cents per ton. One pound of fuel is required to evaporate six pounds of water. The dissipation, therefore, of the 500 pounds of water per ton of lignite requires 85 pounds of fuel. The cost of supplying from the central power plant the additional power required to actuate the crusher, dryer, screen and elevator is small. The labour item involves only part of the time of one man. There is to be added interest at 6 per cent. and depreciation 10 per cent. This cost, as well as the reduction in weight, is more than taken care of in the increased value and serviceability of the fuel.

The dried lignite dust is very explosive, and explosion safeguards must be provided in any drying plant and the temperature in the dryer carefully watched. In the form of dryer mentioned, the flue gases, steam and dust are withdrawn together. This dust can be reclaimed by means of the well known cyclone air separation device and either used as a powdered fuel or incorporated into the briquettes described later.

After being dried the fuel will be screened into three sizes: (1) dust to 1/8 inch, (2) 1/8 to 1/2 inch, and (3) 1/2 to the maximum size, about 2 inches.

All of size No. 1 that cannot be marketed as a powdered fuel will be passed directly to the briquetting section. All of size No. 2, and such portion of size No. 3 as does not find a market for use on automatic stokers and in fuel-gas producers, will be conveyed to the carbonizing ovens to be carbonized and briquetted.

The raw lignite, with its large content of water, cannot be burned successfully on the stokers in use in the city power plant at Moose Jaw. (Plate 5, page 12.) Because of the necessity of evaporating this water, ignition of the fuel does not occur until it is too far out under the ignition arch to maintain that arch at a sufficiently high temperature. Also, the carbonized lignite, being without volatile hydrocarbons, does not ignite readily enough. But a mixture of 30 per cent. bituminous coal and 70 per cent. carbonized lignite carries the load very well, and several carloads of the screenings from the carbonizing plant were burned in this way. Whether the type of automatic stoker (Plate 6, page 12) installed in the new Regina city power plant will burn raw lignite advantageously can only be determined by test. But both of these types of stokers will burn *dried* lignite with good efficiency.

There is no waste: every pound of lignite broken from the seam in mining, from the largest size down to the finest dust can be utilized in one or another of the different ways. Under the present practice, when shipping screened lump, about 15 per cent. is screened out in the shape of "fines." About one-third of this is wasted and the balance sold at from 50 to 90 cents per ton, which is less than the present actual cost of mining.

The drying process, besides supplying the demand for powdered fuel and dried lignite for automatic stokers and fuel-gas producers, speeds up the carbonizing process to the extent of the water removed before the lignite reaches the carbonizing retorts. It has the advantage, too, of removing a substantial amount of disagreeable lignite dust, preventing it from reaching the carbonizing oven and choking the gas off-take pipes.

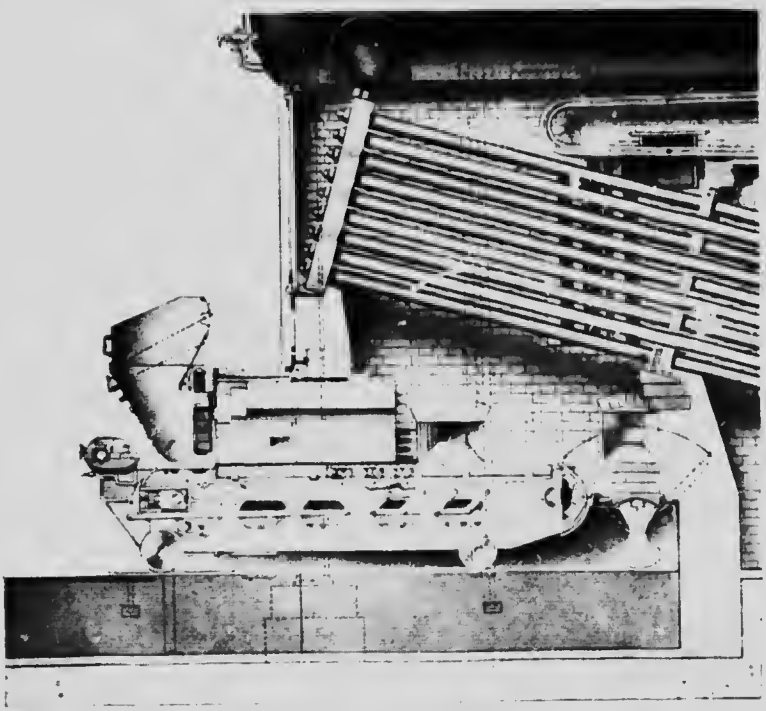


Plate 5.
Type of Chain Grate Stoker in service in Moose Jaw city power plant.

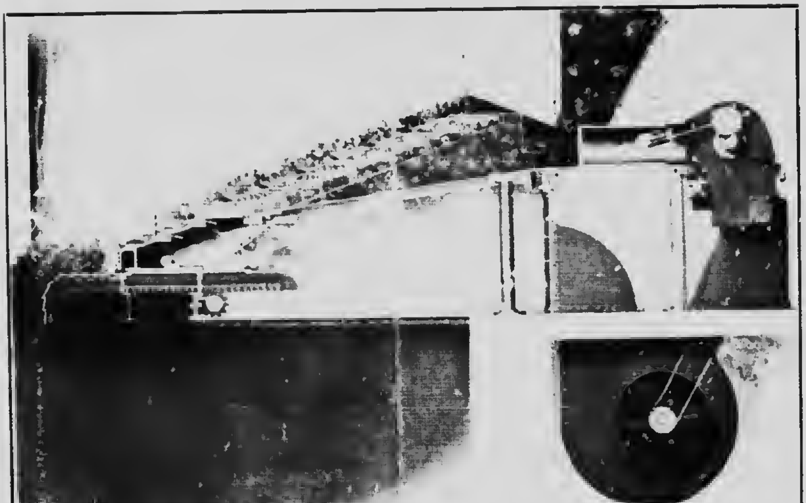


Plate 6.
Type of Stoker in service in Regina city power plant.

Boiler Test of Dried Lignite Briquettes.

The nearest dryer of the type above mentioned is in the coal briquetting plant of the Berwind Fuel Company, Superior, Wisconsin. This plant consists of two drying and briquetting units, each having a capacity of 40 tons per hour (Plate 7, page 15). In it are briquetted the Pocahontas screenings that accumulate on the company's coal docks at Superior. This company magnanimously placed one of these units at the service of the writer.

A carload of lignite, crushed to 2 inch size, was shipped to Superior and dried. The drying equipment was not provided with explosion safeguards, and, not wishing to risk an explosion, the moisture content was reduced only to 10 per cent. In a plant equipped especially to dry lignite, this moisture could and should be almost entirely extracted.

Part of the dried lignite was set aside for a powdered fuel test, and the remainder divided into two portions and briquetted on two different plans.

In briquetting the first portion, only the usual coal tar pitch was used as binder. Upon trial it was found that these briquettes, because of the rapid evolution of the gases and the comparatively severe usage to which a furnace fuel is subjected, disintegrated in the furnace when the melting point of the pitch was reached.

A bituminous coal briquette holds together in the fire because of the fact that it "cokes" (Plate 20, page 40). Since the lignite has no "coking" quality whatever, some ingredient must be put in that will retain its binding properties until it is burned. In this country the most available materials of this nature are starch, in the form of cheap flour, and coking coal.

In briquetting the remainder there was incorporated 15 per cent. of a coking coal. These briquettes stood up splendidly in the fire. A portion of them was shipped to Regina and a boiler test made at the Parliament building power house.

The following statement gives the prir ·ipal items of steaming tests made on raw lignite, dried lignite briquett and four samples of western coal found on the Regina market.

	Raw Lignite	Lignite Briquettes	Alberta Coal	Alberta Coal	Alberta Coal	Alberta Coal
Coal consumed, lbs.	6,747	11,909	14,490	13,568	12,420	12,491
Water evaporated, lbs	23,220	75,791	87,882	77,445	86,070	91,035
Temperature of feed water deg. Fahr.	56.3	57.82	48.12	48	48	48
Average steam pressure, lbs. per square inch	106	107.58	108.58	108.24	108.32	109.87
Water evaporated per lb. of coal as fired, lbs.	3.44	6.36	6.07	5.7	6.93	7.29
Equivalent evaporation per lb. of coal from and at 212° Fahr., lbs.	4.13	7.63	7.35	6.89	8.38	8.82

The test on the raw lignite was made on Babcock & Wilcox water tube boilers at the city power plant, Weyburn, Saskatchewan, by R. N. Blackburn, chief inspector of steam boilers, and the other tests on the horizontal return tubular boilers in the power plant at the Parliament buildings, Regina, under the supervision of B. M. Smyth, chief engineer

As noted above, the lignite briquettes were under the handicap of a 10 per cent. content of water, which, with drying and briquetting equipment designed specially to treat lignite, would be reduced to 2 or 3 per cent.

It was evident, too, from the knurling of the briquettes when burning, that a greater percentage of coking coal was used than was necessary. Subsequent tests showed that not more than 8 per cent. of bituminous coal is required.

Estimate of cost of dried lignite briquettes.

In considering this estimate of cost, and those appearing later in this report, it must be borne in mind that one power plant will be common to the mining, drying, carbonizing and briquetting divisions of the work; that the several departments will be grouped practically under one roof; and that all will be under one management.

A dryer, mixer, press and auxiliary equipment with a capacity of 200 tons per day, or a minimum of 50,000 tons per year, would cost $40,000.

LIGNITE, 56,667 tons at 90 cents	$ 51,000.00
DRYING, including fuel, labour, etc.	5,000.00
BINDER, 7 per cent. coal tar pitch, 3,500 tons at $15.00	52,500.00
BITUMINOUS COAL SLACK, 8 per cent, 4,000 tons at $4.50	18,000.00
LABOUR, 25 cents per ton of briquettes	12,500.00
INTEREST, 6 per cent. on $40,000.00	2,400.00
DEPRECIATION, 10 per cent. on $40,000.00	4,000.00
POWER (portion chargeable to)	5,000.00
INCIDENTALS, oil, waste, etc.	2,000.00
GENERAL OFFICE (portion chargeable to)	1,200.00
Gross cost, 50,000 tons	$153,600.00
Net cost, 1 ton	3.08

These dried lignite briquettes are serviceable in hand fired furnaces. Having a large volatile content, they burn fiercely, with a long flame, very much like wood. They are excellent as a locomotive fuel, and in the territory adjacent to the lignite fields will compete with eastern and western coals brought in by the railroads for their own use. They are not so serviceable in house-heating stoves and furnaces as the carbonized lignite briquettes, which burn more like anthracite.

Of course, no byproducts are obtained when the lignite is merely dried.

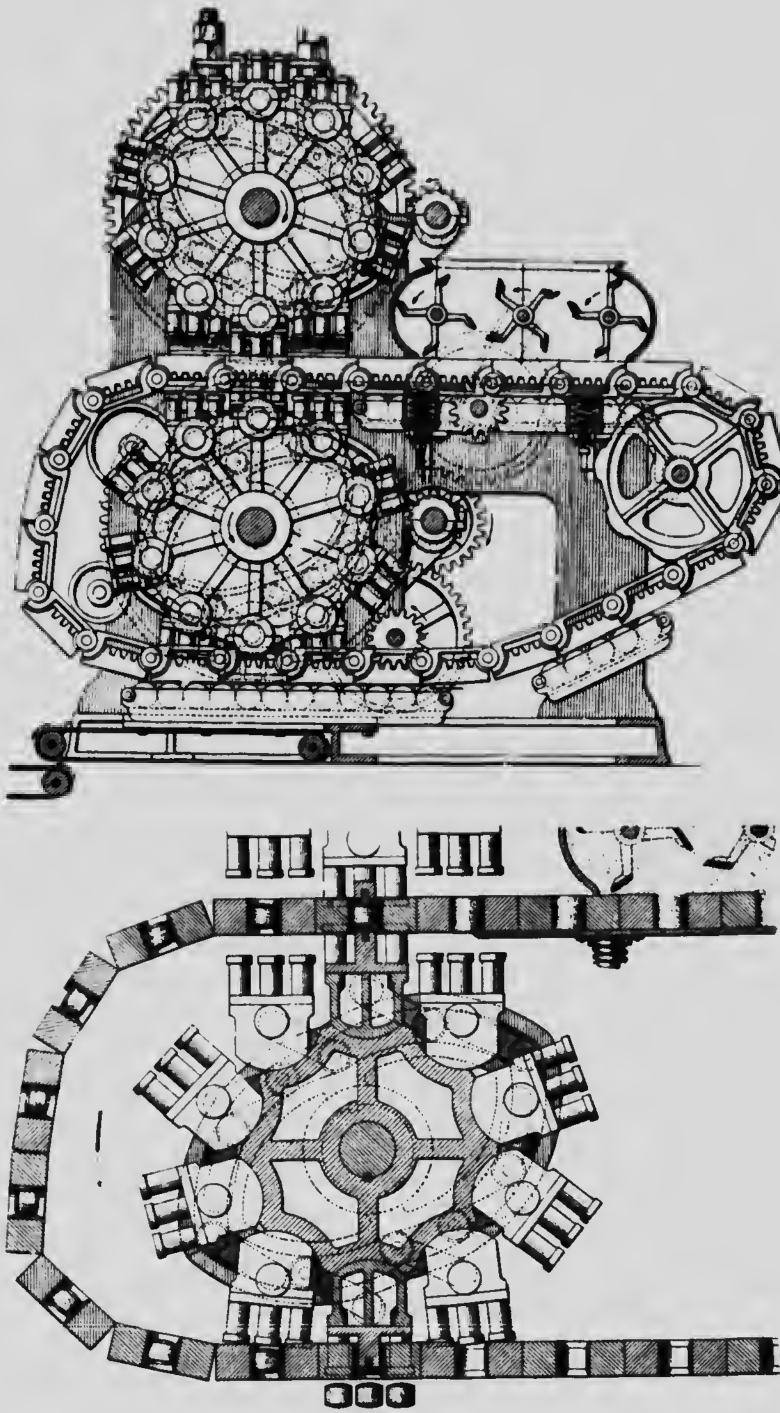


Plate 7.
Briquette Press in service at plant of Berwind Fuel Co., Superior, Wisconsin.
Malcolmson Briquette Engineering Co., Agents, Chicago.

Briquetting without a Binder: German Practice

While a more or less satisfactory briquette can, in a laboratory by the use of excessive pressure, be made from the raw Saskatchewan lignite without the addition of any binding material, it has been found impracticable to do so on a commercial scale. A great deal of time and money have been expended in an effort to accomplish this, following the practice in some parts of Germany, quite disregarding the difference in physical and chemical characteristics between the two lignites.

The lignite, or "braunkohle," of Germany is largely of Tertiary formation, and more nearly resembles peat than does the Saskatchewan lignite. Much of it contains 50 to 60 per cent. of water. Some of the beds are 300 feet thick. In many places the relatively thin burden of gravel and clay is removed by means of steam shovels and the lignite hoisted into cars by excavating machines of the chain and bucket type. In a number of plants additional water is added and the mixture macerated into the consistency of mud, which is then consolidated by being forced through a rectangular die having a contracting channel and cut into brick-shaped briquettes by means of wires, precisely as is done in making wet-pressed, wire-cut clay building bricks. The briquettes so fashioned are then piled up to air dry.

In other places the lignite is dessicated to the required degree of fineness and dried, until the water content is down to 15 per cent., in large rotating steam tubular dryers. After being cooled somewhat the comparatively dry powdered lignite is fed positively into the briquette press mould. This mould also has a contracting channel, affording a high compression on the stream of material forced through it by the reciprocating plunger of the press (Plate 8, page 17). It is claimed that as high a pressure as 18,000 to 20,000 pounds per square inch is used. The heat developed by this high pressure and friction liberates a certain amount of pitch or tarry matter from the coal, and no additional binder is required. The plunger of the press is actuated by a steam engine. One briquette is formed with each forward stroke of the piston. After being discharged from the mould, they are pushed along in a steel trough two or three hundred feet, when they are sufficiently cool to be stored. They weigh about $1\frac{1}{2}$ pounds each.

In other plants, again, are made large rectangular briquettes, which must be broken up before being thrown into the furnace.

As indicating the magnitude of this briquetting industry, it may be stated that about four millions of short tons of brown coal briquettes are annually marketed from the mines in the vicinity of Cologne.

It will be apparent to any one at all familiar with the physical characteristics of the Saskatchewan lignite which is very much harder and more nearly true coal, that our problems, both from mechanical and chemical viewpoints, are different from those in Germany and must be resolved in different ways. Our lignites lie in solid seams, and are mined by the

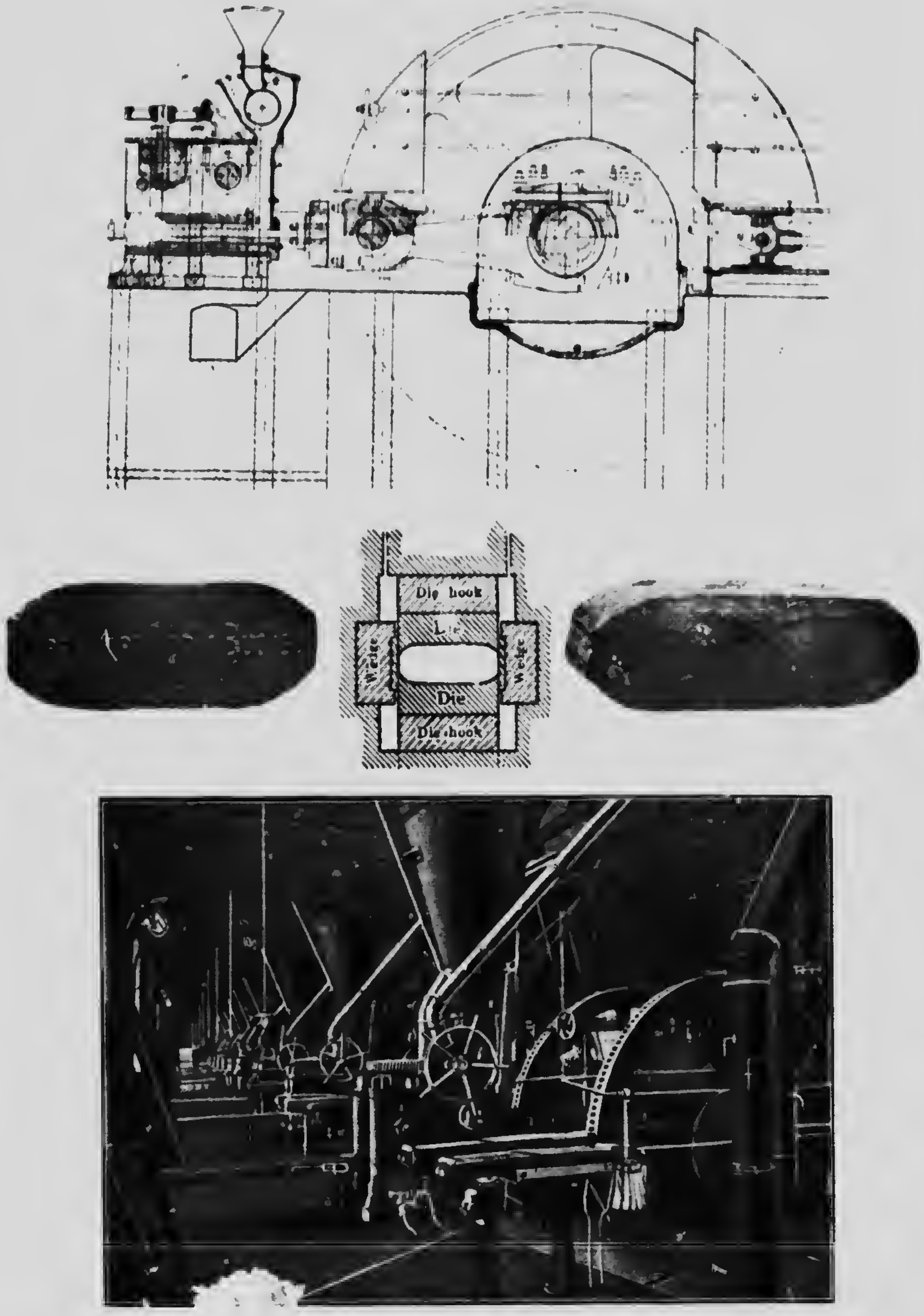


Plate 8.
German Type of Briquette Press and Briquette.

shaft and room and pillar system, like true coal. Again, the trade here demands a small ovoid briquette that will roll and which is hard enough to be handled mechanically. The average German briquette would not be tolerated on this market.

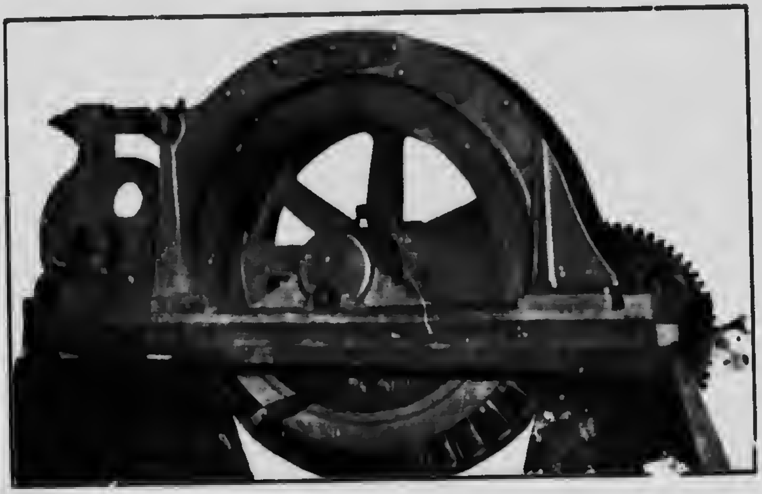


Plate 9.

Briquette Press of rotary plunger type.
Robert Schorr, San Francisco, California.

Powdered Fuel.

Tests were made of pulverized lignite as a powdered fuel in a Bettington boiler in service at the plant of the Dominion Coal Company, Cape Breton (Plate 10, page 19), in the powdered fuel burners supplied by the Aero Pulverizer Company, New York, used in connection with the cement kilns of the Manitoba Gypsum Company, Winnipeg, and by the Quigley Furnace Company, Springfield, Massachusetts. It was discovered that because of the tough, woody character of the lignite, it could not be pulverized to a sufficiently fine powder with the facility that bituminous coal can. The apparatus, therefore, that with bituminous coal gave a clear, homogeneous sheet of flame, with the lignite afforded a beautiful galaxy of sparks. Before the lignite can be used as a powdered fuel, therefore, it must be subjected to more vigorous pulverizing than is necessary with bituminous coal. Then, with its high volatile content and explosive character, it will make an excellent powdered fuel.

When drying the lignite a substantial portion of fine dust is produced by reason of the cascading of the material as it passes through the rotary dryer. This, if collected in a dust collector, will afford a small supply of powdered lignite without further pulverizing.

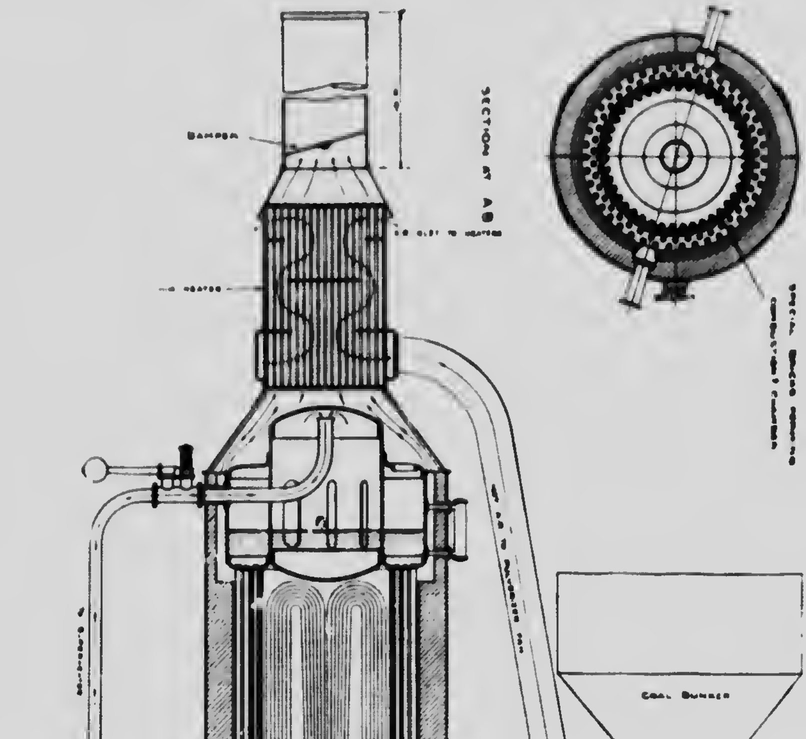


Plate 10.

Bettington Boiler; designed to burn powdered, liquid or gaseous fuel.
Fraser & Chalmers, Montreal.

CARBONIZED LIGNITE.

The next step, looking toward the more efficient utilization of the lignite, is to carbonize it; that is, by means of destructive distillation, to extract all of the volatile matter naturally in the lignite, and utilize the resulting gas, ammonia compounds, liquid hydrocarbons and residual carbon or coke in the various ways for which they are best adapted.

The problem of an efficient lignite carbonizing oven has not been an easy one to solve. Elaborate and very efficient devices have been evolved to carbonize or coke bituminous coal. In all of these, however, the work is done at high temperatures, to get a large yield of gas, rather than at low temperatures, with a view to an increased amount of hydrocarbon byproducts.

Then, too, because of the fact that bituminous coal *cokes*, very different apparatus is necessarily needed to handle it from that required for lignite, which has no coking or intumescing quality whatever, but instead crumbles when carbonized.

Early Efforts to Carbonize Lignite.

So far as the writer's knowledge goes, the first lignite carbonizing in America was done in Camden, Arkansas, about thirty years ago, using the canneloid lignite found in that vicinity, near Lester. The device used was simply a couple of iron pipes, about 15 feet long and 12 to 15 inches in diameter, laid horizontally in a brick furnace. One end of these pipes was permanently closed; the other had a removable cap and a 2 or 3-inch gas off-take and cooling pipe a couple of hundred feet in length. A darkey would fill the pipes with lignite in the morning, put on the cap and fire away all day. The oil or tar that condensed in the cooling pipe was collected in a bucket. The gas escaped. The "carbonizing bench" was allowed to cool off over night and in the morning the cap was removed, the carbon residue raked out and the performance repeated. The carbon was pulverized, mixed with some of the oil and other ingredients and the mixture sold as a rough black paint, which was used principally on iron and steel.

Some of the oil or tar was used for preserving fence posts, etc., and there were posts that had been soaked in this tar in existence there until recently in a good state of preservation.

Subsequently a more pretentious carbonizing bench, containing five inclined cast iron retorts, was erected near Lester, but financial difficulties shortly engulfed the enterprise.

Some years later, a firm in Poplar Bluff, Missouri, built a small bench of three regular horizontal ◯-shaped fireclay retorts such as are used in small coal gas plants supplying illuminating gas to cities. (Plate II, page 21.) The output of this plant also was used in paint manufacture.

In 1905, the writer did some laboratory work on Arkansas lignite, and in the fall of 1906, not then knowing of any previous installation for a similar purpose, built at Chicago a bench containing one coal gas retort of the type installed by the Poplar Bluff concern. This retort carbonized a charge of 300 pounds of lignite in four hours. Two carloads were carbonized in this bench. The resulting carbon was sold as a paint pigment.

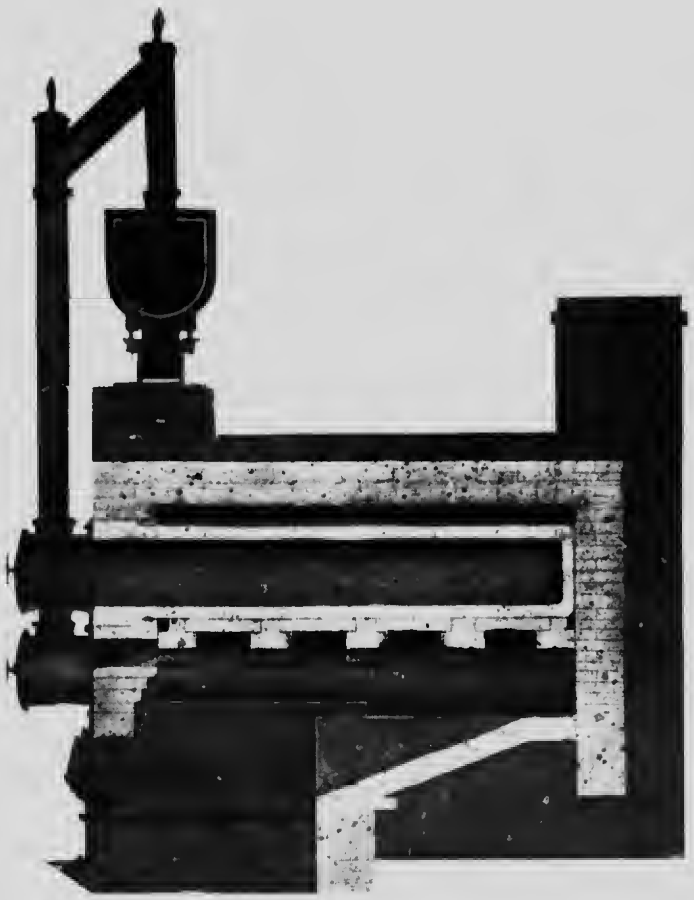


Plate II.
Small bench of three Coal Gas Retorts.

Then, in the summer of 1907, the Laclede Gas Light Company, St. Louis, Missouri, equipped an experimental bench of four similar retorts. Under the writer's direction, twenty carloads of Arkansas lignite were carbonized in this bench. The object of this test was to determine whether or not the gas was of sufficiently good quality to be used as illuminating gas in the city.

It was found that the gas contained a very large percentage of carbon dioxide, about 16 per cent. by volume. This almost entirely destroyed the value of the fair percentage of illuminants present. The standard method of removing the carbon dioxide is to pass the gas through a layer of lime. The volume to be extracted, however, was so large as to make this too expensive for commercial application.

A comparative analysis is:

	Lignite gas	Coal gas
Carbon dioxide	15.9	1.34
Illuminants	3.5	4.42
Oxygen	0.2	.03
Carbon monoxide	19.5	6.75
Methane	16.1	34.60
Hydrogen	43.9	50.19
Nitrogen	0.9	2.67
Candle power	3.2	5.00
British thermal units per cubic foot	440.0	[illegible]0.00

While the lignite gas, therefore, has little value when burned as an open flame, it gives good results when burned in a mantle, and is very serviceable for fuel and power, in furnaces and gas engines.

The work with these two benches of horizontal retorts showed conclusively that if lignite is to be carbonized on a large scale some different type of apparatus must be used. These retorts were, of course, always kept at a high temperature, but even then the process was too slow. When one charge was carbonized the end door was opened and the residual carbon raked out. This was red hot and in a more or less fine state of division. It burned immediately upon contact with the air, and water thrown onto the hot pile would not penetrate the mass as in the case of bituminous coke. It was necessary almost to saturate the material before it could be handled. It was plain that this carbon must be discharged from the retorts mechanically and kept out of the presence of air until cooled to the point where it would not burn.

Again, in carbonizing the lignite, it is desirable that as large a yield as is possible of the hydrocarbon byproducts be obtained. This necessitates that the lignite must not be subjected to a high temperature until most of the volatile is distilled. Of course, throwing the lignite directly into a red hot retort, as is done in coal gas practice, produces a larger volume of gas and a smaller yield of oil or tar. If the retorts were carried along at a much lower temperature there would be a larger yield of oil and a smaller volume of gas. But this would make the process so slow as to be unprofitable.

The fact that the lignite crumbles on being carbonized makes possible a continuous carbonizing process, thus obviating the laborious and expensive charging and drawing of retorts as practised in coal gas plants.

Following the work in St. Louis, therefore, the writer built a carbonizer in Chicago, the essential feature of which was an inclined, slowly rotating, cylindrical iron retort, 14 inches in diameter and 15 feet long. This cylinder passed through a stationary combustion chamber, the highest temperature being maintained at the lower, or discharge, end of the retort and the flue gases escaping at the upper, or feed, end. The motion of the retort drew the lignite continuously out of a hopper at the upper end and discharged the carbonized material into a cooling device at the lower end. As the lignite passed through this rotating retort it encountered a gradually increasing temperature until it was finally discharged red hot into the cooler. This resulted in a large yield of oil or tar, averaging upwards of 20 gallons per ton of Arkansas lignite. A small roll or Belgian type of press (Plate 17, page 38) was set up and the carbon residue briquetted (A Plate 22, page 41). The tar was distilled and the products tested in various ways. While this was a very efficient type of carbonizing device, the iron retort deteriorated very rapidly under the high temperature. There are also many mechanical obstacles in the way of constructing and operating a large installation on this plan.

The writer then built a third carbonizing oven, using as retorts vertical cast iron tubes, the lower portions of which were protected with fireclay tile. Here, too, the maximum temperature was at the bottom, the flue gases escaping at the top. Continuously fed and discharged, this also gave the essential progressive carbonization, and did the work very satisfactorily in every respect. In operating this oven the writer used lignite from Williston, North Dakota, which is in all respects like the Saskatchewan product.

In 1909 the state of North Dakota made an appropriation to cover the cost of some lignite development work, to be carried on under the supervision of Prof. E. J. Babcock, Dean of the School of Mines of that state. A carbonizing bench of one horizontal coal gas retort (Plate 11, page 21), with the necessary auxiliary equipment, was installed at Hebron. The result of this work is published in a bulletin issued by the University of North Dakota, entitled "Investigations of Lignite Coal relative to the Production of Gas and Briquettes," and is referred to at more length in this report (page 37) in connection with one of the briquetting tests.

The Saskatchewan Experimental Carbonizing Oven.

At this stage the Saskatchewan Government commissioned the writer to erect and operate at Estevan a small lignite carbonizing and briquetting plant. The idea was not so much to do fine-drawn laboratory work as to actually treat the lignite on a sufficiently large scale as to be able to use the products in every day commercial work.

The carbonizing bench erected may be described as a *vertical chamber oven* (Plate 12, page 24). In principle it is the same as the large horizontal byproduct chamber ovens, which are the most efficient devices for the coking of bituminous coal, except that it is vertical instead of horizontal and is charged and discharged continuously instead of intermittently

Plate 12.

Saskatchewan Lignite Carbonizing Oven.

The lignite is unloaded from the cars into a bin in the bottom and extending the length of the building, passed as required through the crusher, elevated to the top of the oven and distributed to the several retort sections. It passes down through and is discharged red hot from the bottoms of the retort sections into a hopper, from which it is conveyed and elevated to the screen in the peak of the building, which separates it into three sizes and deposits them into their respective bins above the raw lignite bin. The discharge hopper, conveyor trough, elevator leg and the bins are kept charged constantly with exhaust steam from the gas-exhauster engine. The lignite carbon or coke is therefore kept in an atmosphere of steam until it will not burn on exposure to the air. The portion that is briquetted need never get cold.

The inside dimensions of the oven are 8 feet by 9 feet 7 inches by 12 feet high. The rectangular retort sections are 12 feet high, 6 inches wide and 8 feet horizontally, and alternate with series of combustion flues. Each layer or column of lignite is but 6 inches thick and has a heating flue on either side of it. Thus the heat is driven into the midst of the slowly descending body of lignite. These retort sections hold in the aggregate 4 tons of lignite. This oven carbonizes 24 to 36 tons of raw lignite per day of 24 hours.

The gas generated in the retorts is withdrawn by an e[illegible] and passed through cooling and washing apparatus, where the hydroc[illegible]bon and ammonia compounds are precipitated, and then on to the gas burners located at the bottoms of the retorts. The flue gases are discharged at the top of the bench.

It will be noted that the lignite is started in at the top of the retorts under a low temperature. As it descends slowly it encounters a gradually increasing degree of heat until it is discharged from the bottom of the oven red hot.

The essential feature of this type of oven is that of *progressive distillation*, passing the lignite gradually from an atmospheric temperature to a zone of red heat. This results in the same substantial increase in the yield of hydrocarbon byproducts obtained when carbonizing at low temperatures, and yet the work can be carried on with the same speed as is possible with a high degree of heat.

The entire process is mechanical. The fuel need not be handled by manual labour from the time the lignite is loaded by the miner into the mine car until the briquettes are in the hands of the consumer. The costly element of labour is reduced practically to that required for merely watching the operations.

The lignite carbonizes much more readily than bituminous coal. Further, since the object of carbonizing the lignite is simply to extract the volatile constituents, rather than to produce a commercial coke, it is not necessary to subject the lignite to the high temperature required to produce commercial coke from bituminous coal. The gas is practically all driven off from a coking coal while the charge is still a black, intumescent mass, but it is necessary to carry the temperature several hundred degrees higher in order to procure a firm, hard coke. This increase in temperature is not necessary with the lignite; the process can be stopped as soon as the volatile has been extracted. The most rapid evolution of lignite gas is between 700 and 900 degrees Fahrenheit. The gas is practically all off at 1000 degrees Fahrenheit.

On carbonization, the products, in round numbers, are:

(1) Gas, per ton of lignite	10,000 cubic feet.
(2) Oil or tar (water free)	15 gallons
(3) Ammoniacal liquor	65 gallons
(4) Carbon residue	955 pounds

These are the proportions obtainable in good commercial practice. In the laboratory tests the yields of gas exceeded 11,000 cubic feet per ton of lignite, with practically no increase in the amount of tar, as the last 1,000 cubic feet of gas contains very little condensable hydrocarbon.

The Gas.

The heating value of the gas averages above 400 British thermal units per cubic foot. As shown earlier in this report, it is not good illuminating gas, unless burned in a mantle, but makes a good "town gas" for heating and cooking, and is very serviceable for industrial fuel and power, in furnaces and gas engines.

There is more gas in one ton of lignite than is required to carbonize the next ton. In practice only sufficient gas would be removed to supply the requisite fuel to carry on the carbonizing process, the remaining portion being left to add heating value to the carbon residue; or all may be extracted and the surplus used in a gas engine to generate power, or for burning tile, pottery, brick, etc., or the entire yield may be so used, or sold as a "town gas," and the carbonizing carried on by means of lignite producer gas.

This surplus gas has a very direct bearing upon the matter of cheap power for distribution throughout southern Saskatchewan and southwestern Manitoba, from a central station located at the mine or near one or more large centres of population. 6,000 cubic feet of the gas yield per ton is required to carry on the carbonizing, leaving a surplus, costing nothing, of 4,000 cubic feet per ton to be used for power. This 4,000 cubic feet of gas, of 400 British thermal units per cubic foot, yields 1,600,000 British thermal units. The average gas engine uses 10,000 British thermal units per horse power hour. This gives 160 horse power hours from the surplus gas per ton of lignite carbonized. This power is comparable in cost with that derived from natural gas. It is cheaper than water power. This cheap power, of course, is limited to the quantity of lignite carbonized. But the first need of the people in this rigorous climate is domestic fuel, and hence the demand for fuel in these two provinces is large.

In addition to the 200,000 tons of Saskatchewan lignite annually marketed in Saskatchewan and in Manitoba as far east as Winnipeg, there is imported into this territory each year upwards of 2,000,000 tons of eastern and western coal. To supply only 20 per cent. of this demand with carbonized lignite, in the form of briquettes and gas producer fuel, would require the carbonization daily of at least 2,000 tons of lignite, yielding 320,000 horse power hours per day of this cheap gas power.

The total output during 1913 of the Regina city power plant for lighting and power, including that used by the electric railways, was 8,120,810 kilowatt hours, or about 29,800 horse power hours per day. This represents about 75 per cent. of the entire consumption in the city, making Regina's total for that year approximately 40,000 horse power hours per day. The 320,000 horse power hours per day derived from this surplus gas is therefore *eight* times Regina's present requirements.

The only other large power user in the southern part of the province is the city of Moose Jaw, which consumes about three-fourths as much power as Regina. There is, therefore, ample power left to supply the smaller towns and villages in the territory within range of power transmission lines from a central station at the mines. As the population and the demand for power increase, the demand for this carbonized fuel will increase apace. Further, if necessary, this amount of power can be readily and cheaply augmented by the use of carbonized lignite in gas producers.

There is available, therefore, in this lignite, all the electrical power that will ever be required in southern Saskatchewan, on the switchboard at not to exceed Niagara rates, $8 per horse power year.

The Oil or Tar.

There is not the large yield of oil or tar from the xyloid Saskatchewan lignite that there is from the more amorphous lignite mined near Lester, Arkansas, from which the writer has obtained as high as 25 gallons per ton. The Lester lignite probably represents a stage in the formation of cannel coal. The biochemical or putrefaction process has proceeded further with it than with the Saskatchewan lignite.

On distillation the fractions are:

1. Light oils, benzine, etc.	11.5 per cent.
2. Carbolic oils, some napthaline	13.5 per cent.
3. Creosote oils	34.1 per cent.
4. Anthracene oils, some paraffin	16.4 per cent.
5. Pitch, hard	24.5 per cent.

The simple distillation products of this oil can be put to many uses fuel oil for furnaces and internal combustion engines, creosoting oils for the preservation of timber, waterproofing and preserving oils for leather and cotton and other fabrics, tar paper, roofing pitch, etc.

The pitch makes an excellent binder for the briquettes, and will go far toward reducing the cost of this item, if more valuable uses are not found for it. The anthracene and creosote oils will without doubt find a ready market as wood and leather preservatives. The first two fractions make a good fuel oil and can, of course, be used in internal combustion engines of the Diesel type.

From these several fractions, upon exhaustive distillation and treatment, are derived hundreds of synthetic products in the way of paraffin, acids, antiseptics, photographic chemicals, aniline dyes, perfumes, drugs, preservatives, etc.

From the light oils come benzol, aniline dyes, photo-chemicals, benzoic acid, certain drugs, and many other chemical products. From the carbolic and creosote fractions are derived carbolic acid, creosote, lysol, creoline, salycilic acid, asperine, oil of wintergreen, picric acid phenacetin, photo-dyes and chemicals, indigo and other colouring materials, and numbers of perfumes. The anthracene oils give, among other things, alizarin, a valuable acid used in the production of dyes, and carbolineum, used as a wood preservative. This latter product is analogous and equal in value to the carbolineum derived from European lignite, which is imported in large quantities and retailed at 65 cents per gallon.

At first, of course, the simple distillation products will be procured and marketed as such. But, as opportunity affords, each of these primary byproducts will be taken up and synthetic chemical products manufactured. The exact course of this development is a matter to be determined by a commercial company after an exhaustive study of the market.

Almost all of these tar products have heretofore come from Germany. In 1913 the United States imported coal tar products of the value of $11,000,000 at initiating points and when they reached the consumer probably cost double that amount. Millions of gallons of creosoting oils for preserving timbers have been imported annually. That supply is now cut off and the market value of these commodities on this continent greatly enhanced. It is not unreasonable to expect that in the future a large part of this demand for tar products will be supplied from these immense stores of lignite.

The Ammoniacal Liquor.

The market here for anhydrous ammonia is limited. This byproduct will therefore be recovered and marketed as sulphate of ammonia, a valuable fertilizer, selling for 3 to 3½ cents per pound. There are about 15 pounds of sulphate of ammonia per ton of lignite. It is easy of recovery, by passing the gas, after the tar has been extracted, through a sulphuric acid solution. Ammonium sulphate crystallizes out and is raked out and dried, when it is ready for the market. There is bound to be a large demand for this fertilizer in this agricultural empire.

The Carbon or Coke.

The lignite on being carbonized does not coke in the sense that bituminous coal cokes. It does not even intumesce in any degree. It simply crumbles, making possible a comparatively inexpensive continuous carbonizing process.

When carbonized, the lignite is practically charcoal. It has about the same analysis as anthracite and has about the same heating value, but it is not so dense in structure and therefore has more bulk per ton than anthracite.

After passing through the carbonizing bench, the lignite is screened into several sizes. The dust and smaller sizes must be briquetted; the larger lumps, somewhat above the size of "pea" anthracite, are available for use in gas producers for the production of power.

The Gas Producer.

Raw lignite, or any other substance containing carbon, can be utilized to advantage in a gas producer to produce gas for *fuel* purposes, and an enormous tonnage of the cheaper grades of fuel are consumed in this way.

But the use of producer gas in a gas engine to produce *power* is quite a different matter. This gas must be clean and free from tar. The standard fuels for this purpose are anthracite coal, bituminous coke, charcoal and (permit the writer to add) carbonized lignite. These have little or no volatile matter in their composition and hence the gases derived from them are practically free from tar.

Very determined efforts have been made by governments, gas producer manufacturers and others to utilize bituminous coal, lignite and other fuels containing a substantial amount of tar-producing volatile matter in gas producers for the production of power. The feasibility of this rests upon the successful extraction of the tar from the gas or the destruction of it in the producer itself. Few, if any, engineers at the present time have the temerity to affirm that this goal has been reached. The difficulty will be apparent when one takes into consideration the fact that a substantial portion of the tar fog carried by the gas is so fine that it will readily pass through a couple of thicknesses of filter paper.

Some hope in this direction is afforded by the results of some recent experiments in the way of precipitating this tar mist by means of a high tension, direct current, silent electrical discharge. This system has been successfully employed to precipitate the objectionable acid fumes from smelters and the dust from rotary kilns of Portland cement plants. Efforts to apply the process to the extraction of the tar particles from coal gas and producer gas have been made by Herbert A. Humphrey, Prof. Alfred H. White and Prof. F. W. Steere of the University of Michigan, and Prof. J. G. Davidson of McGill College, Vancouver. Mr. Steere reports (October, 1914) that this electrical process was put into commission

January 21, 1914, at the Ford Motor plant, Detroit, Michigan, to detar the producer gas driving their large gas engines; that it has been in continuous and successful service ever since, and that "all the difficulties which were in any way due to tar have been entirely eliminated."

But the problem does not vitally concern us, because of the availability of an enormous tonnage of carbonized lignite, yielding in the producer a clean, practically tar-free gas.

Carbonized Lignite as a Gas Producer Fuel.

This carbonized lignite is the ideal gas producer fuel. The amount of gas is equal to that from anthracite, pound for pound, but the gas is richer, it has less tar and less clinker, it burns more freely, and hence starts and picks up increased loads more quickly.

The 100 horse power Ruston-Proctor producer gas plant in The Leader Building, Regina, has to date used eight carloads of this carbonized lignite. On anything approaching a full load they get a horse power hour from each pound of fuel. This is the experience also of the power plants at Melville and Strassburg, which have used this fuel in carload lots.

There are two dozen gas producer plants in this territory, now operating on anthracite coal, that will use the carbonized lignite when it can be supplied in sufficient quantities. This serviceable and cheap fuel will bring many other similar installations. It means a reduction of at least 50 per cent. in their fuel bills. For instance, pea anthracite costs The Leader Publishing Company, Regina, $9.50 per ton. This carbonized lignite can be delivered there at $4.25, including a profit to the manufacturer. It will, for this purpose, entirely supersede anthracite in the territory tributary to these lignite fields.

Until an electrical power distributing system from a central station shall be established the cheapest way in which the various towns and manufactories in this territory can get their power will be to transport the carbonized lignite from the carbonizing plant to their individual power plants and there, by means of the gas producer and gas engine, generate the electrical power required for local consumption.

Producer Gas: What It is.

Plate 13, page 31, illustrates the generation of producer gas, showing the *combustion zone* where the burning of the fuel is complete, two atoms of oxygen uniting with one of carbon to form the waste gas carbon dioxide (CO_2). Each pound of carbon in this reaction liberates 14,500 British thermal units. This carbon dioxide passes up into the *decomposition zone*, where it encounters incandescent carbon without any increase in the supply of oxygen. The chemical reaction of the combustion zone is therefore reversed; the molecule of carbon dioxide picks up another atom of carbon and yields two molecules of carbon monoxide ($CO_2+C=2CO$).

absorbing in the reaction 10,080 British thermal units per pound of carbon and hence reducing the temperature. This carbon monoxide passes through the *distillation zone* above, carrying off with it the volatile gases, if any, distilled from the fuel. The carbon monoxide is then conveyed to and burned in a furnace or gas engine cylinder where the molecule of carbon monoxide unites with an atom of oxygen from the air and becomes

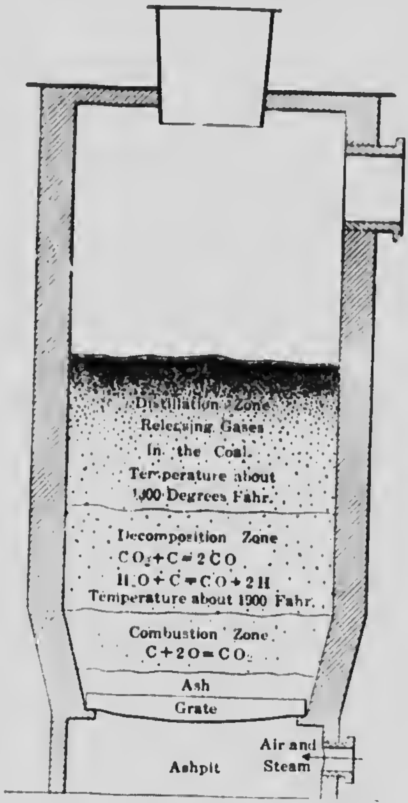


Plate 13.

Illustration of reactions taking place in a gas producer.

again carbon dioxide, liberating in this reaction the 10,080 British thermal units absorbed in the decomposition zone of the producer.

Some of the nitrogen in the air drawn into the producer unites with hydrogen to form ammonia (NH_3) and the remainder passes along inert. The steam (H_2O) passing into the producer with the air is broken up at about 1,800 degrees Fahrenheit into its component parts of hydrogen and oxygen, the latter uniting with carbon to form carbon monoxide and the former (except such as unites with nitrogen to form ammonia) passing along unchanged and forming a valuable constituent of the gas produced in the process, which has come to be designated "producer gas."

Power Distribution.

The largest centres of population and power and fuel demand in the territory in question are Moose Jaw and Regina. The question arises as to the practicability of drying the lignite at the mines, shipping it to one or both of these cities, and there carrying on the carbonizing and briquetting industry, supplying cheap power from a central station over transmission lines radiating in all directions, and selling the lignite gas as a "town gas." This is a subject for further elucidation from the commercial standpoint.

It is not deemed pertinent at the present moment to discuss any general power distribution plan. That the time will come when cheap electrical power will be distributed over the southern half of the province from a central station or stations goes without saying. But for the present, since this is as yet mainly an agricultural country, the population is too sparse, and hence the demand for power too small, to warrant such a project. When a lignite carbonizing and briquetting industry is established and power at Niagara rates is available (pages 26 and 27), transmission lines will begin to radiate in the several directions required by commerce, and the power system will evolve naturally, step by step, in consonance with the industrial development of the province. Any other method would be commercially illogical.

The Briquettes.

The carbonized lignite "fines" or screenings and that portion of the lumps which is not marketed for gas producer purposes must be briquetted.

As noted above, it has been found impracticable to briquette the raw lignite without the addition of a binding material. Since the carbonizing process removes all of the volatile hydrocarbons, leaving nothing but residual carbon or coke, this statement applies with greater force in respect to the carbonized material.

The best available binders are coal tar pitch and lignite tar pitch. As in the case of the dried lignite, the briquette is improved by the addition of 7 per cent. of coking coal or 2 per cent. of flour, the binding ingredient of which, of course, is the starch which is turned into a form of dextrin by the heat employed in preparing the mixture for the press.

While the addition of the starch or coking coal may be necessary in a briquette which is burned in a large industrial furnace, because of the severe usage to which the fuel is subjected, it is not absolutely necessary in a briquette used in domestic service house heating furnaces, fireplaces and cooking ranges. When a briquette in which pitch alone is used is thrown onto the fire, it is quickly warmed to the melting point of the pitch and if it is poked at that particular time, it will go to pieces. But if it is not disturbed for a few minutes longer it becomes sufficiently hard to withstand rough handling, and may even be withdrawn red hot from the fire and dropped into water without disintegrating.

All of the carbonized lignite turned out by the experimental oven at Estevan that was large enough for use in gas producers was used for that purpose at the three plants above named. Five carloads of the screenings were burned in the Moose Jaw power plant and the remainder were used in briquetting tests. Most of the briquettes were used in various burning tests at the points of manufacture. The balance were distributed in small lots among several hundred families in the province to be tested in domestic service. They gave universal satisfaction.

There are quite a number of types of coal briquetting presses on the market, and it was felt that before any one was selected for installation at Estevan, tests should be made on these presses at the places where they were already in operation. Consequently, quantities of the carbonized lignite fines were shipped to various points and briquetting tests made. The results have been so satisfactory as to demonstrate conclusively the commercial feasibility of the process and to render unnecessary the installation of experimental briquetting equipment at the Estevan plant.

These briquetting tests were not made in a laboratory, but in commercial plants used to briquette bituminous and anthracite coal, and the fuel came through the different presses at the rates of from five to forty tons per hour.

Briquetting Tests.

A. Page 41 shows briquettes made from carbonized Arkansas lignite in Chicago on a Belgian or roll type of press (Plate 17, page 38). These briquettes contained as binder 8 per cent. pitch and 2 per cent. flour. The pitch was the asphaltum residue procured upon the distillation of a crude petroleum. The briquettes contained 11,500 British thermal units per pound, did not disintegrate in fire, were very hard and withstood rough handling. The British thermal units were low because of high ash content, about 20 per cent. The briquettes weighed 2 ounces each.

D. Page 41 shows ovoid briquettes made from Saskatchewan carbonized lignite at the experimental plant of Armstrong-Kerr Company, Vancouver, on a roll type of press (Plate 14, page 34).

Several trials led to the use of 7 per cent. of coal tar pitch and 2 per cent. of flour or corn meal. Good results were obtained with this mixture. The briquettes were sufficiently hard to meet the requirements of shipping, and they held together well in the fire. They weighed 5 ounces each.

It was clearly evident from these two tests that the carbonized lignite required more pressure in briquetting than would a bituminous coal. Of course, with this roll type of press the mould is never quite closed and the material escapes upwards as the rolls rotate. This makes it impossible to get a positive pressure of known quantity upon the briquette, which is possible only with what might be called a closed mould type of press, where the die is filled with a fixed quantity and plungers enter from both ends, giving a known pressure. Mr. Armstrong uses only 6 per cent. of pitch in the manufacture of coke breeze briquettes, and is of the opinion that by using the positive pressure type of press the percentage of pitch required to briquette lignite carbon could be reduced to 5 per cent.

The Berwind Fuel Company, Superior, Wisconsin, in briquetting the screenings from Pocahontas coal, uses 5 to 5½ per cent. of coal tar pitch.

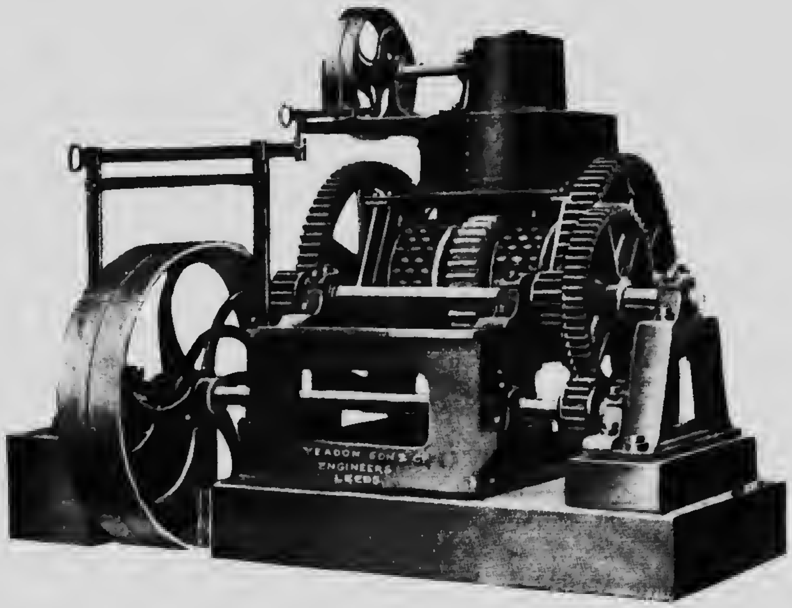


Plate 14.

Ovoid Briquette Press.
Armstrong-Kerr Co., Vancouver, B.C.

G. Page 41 shows a briquette made from Saskatchewan carbonized lignite on a small brick press at the plant of Chisholm, Boyd & White, Chicago. The binder used was 8 per cent of asphaltum pitch. The pressure exerted was 5,000 pounds per square inch. The briquette was very hard and of fine texture. Its density was much greater than is possible to obtain on the roll type of press. Briquettes of this type make an excellent fuel for the foot warmers used by people making long drives in cold weather. They burn like charcoal—indeed the carbonized lignite is nothing more nor less than charcoal. Once ignited, the briquette burns slowly until entirely consumed. This briquette weighs 10 ounces.

A small briquette, weighing 2 to 4 ounces, is the most desirable size for domestic use; and this is the large demand in this territory. The roll type of press gives a much larger output of these small briquettes than any other type and is a desirable machine for this reason. But because of the impracticability of getting a high pressure, it is necessary to increase the percentage of pitch. A substantially less percentage of pitch is required when using a positive pressure press, giving five to six thousand pounds pressure per square inch. The latter type of press undoubtedly makes a much better briquette with a lower percentage of pitch, but on the other hand its output in tons per hour when making a small briquette is substantially less than is possible with the roll press. In making a large

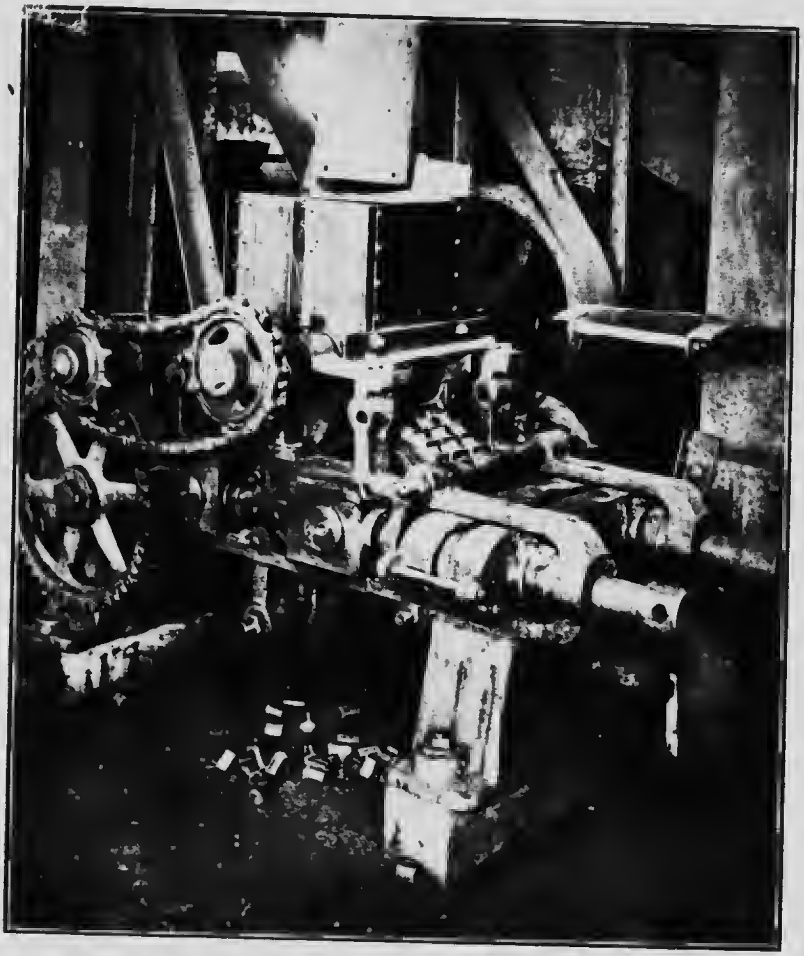


Plate 15.

Experimental Briquette Press.
St. Louis Briquette Machine Co., St. Louis, Mo.

briquette for use under boilers and in large heating furnaces, one of the positive pressure, reciprocating plunger types of press is unquestionably the more efficient.

C. Page 41 shows briquettes made from Saskatchewan carbonized lignite at the briquetting plant of the Standard Briquette Fuel Company, Kansas City, Missouri, on an experimental press built by the St. Louis Briquette Machine Company, St. Louis, Missouri. (Plate 15, page 35). This is a modification of the roll press designed to give greater pressure and a more perfect discharge from the moulds. It will be noted that the briquette moulds are not contiguous, as in the Belgian press, but are separated by "liners" which remain stationary in the mould-feeding zone of the press. This small experimental press gave sufficient promise to warrant the builders in constructing a large commercial press having an output of 25 tons per hour. This press is now being installed at Kansas City. A carload of carbonized lignite is there, and will be briquetted in the near future.

As a binder there was used 8 per cent. of asphaltum pitch only. These briquettes were hard and stood shipping very well. They weighed 2 ounces. In burning, if not disturbed until they were approaching a red heat, they gave good service. Of course, since there is no coking element in this briquette except the pitch binder, when the melting point of the pitch is reached the briquettes if poked go to pieces, but if left undisturbed a little longer the briquette will withstand rough usage. It is therefore seen that, while the addition of flour (starch) or coking coal adds somewhat to the serviceability of the briquette, they are not absolutely essential where the fuel is used in domestic service.

F. Page 41 is a photograph of briquettes made from Saskatchewan carbonized lignite by Sutcliffe, Speakman & Co., Leigh, England, on a German type of press, the material being forced through a tube under heavy pressure by a reciprocating plunger, one briquette following another. These briquettes are four inches in diameter, 3 inches thick and weigh 1½ pounds. They are composed of

15 per cent. of fine coking coal.
7 per cent. coal tar pitch.
2 per cent. coal tar.
76 per cent. carbonized lignite.

They were subjected to a pressure of 10,000 pounds per square inch. They are very hard, hold together splendidly in the fire and are an excellent fuel in every respect, except in the matter of shape and size. The Saskatchewan market demands a smaller briquette and one that can be more readily handled mechanically. The comparatively sharp edges, too, would give rise to a good deal of loss due to abrasion in handling. Mr. Sutcliffe is positive in his opinion that in order to get a satisfactory briquette from carbonized lignite, heavy pressure is necessary, and that the ordinary roll type of briquetting press is not suited to the work.

H. Page 41 represents briquettes made from Saskatchewan carbonized lignite at the factory of Chisholm, Boyd & White, Chicago. (Plate 16, page 37). The composition of these briquettes was

8 per cent. coal tar pitch.
92 per cent. of carbonized lignite.

They were subjected to a pressure of about 5,000 pounds per square inch. They are 3 inches in diameter, $2\frac{1}{2}$ inches high and weigh 14 ounces. They are very hard and an excellent fuel in every way. As noted above, however, they must not be disturbed in the fire until they have reached a temperature approaching a red heat. They will go to pieces if poked when they have reached the melting point of the pitch binder. In this case also the sharp edges would give rise to considerable loss in handling due to abrasion, but this objection can readily be overcome by making the ends of the plungers concave instead of flat. This briquette is a splendid fuel for boiler and other furnaces and large house heating furnaces, but it is a little large for cooking ranges, etc.

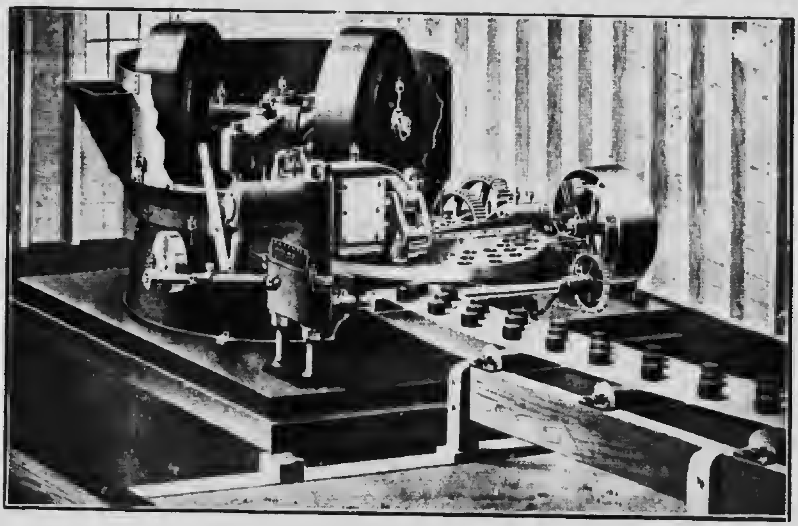


Plate 16.

Briquetting Press.
Chisholm, Boyd & White, Chicago.

B. Page 41 are briquettes made from Saskatchewan carbonized lignite on a roll type of press installed in the plant of the Northern Briquetting Company, Minot, North Dakota (Plate 17, page 38).

This plant is the outcome of experiments carried on by the State of North Dakota with a view to the better utilization of the lignites found in large quantities in that state. The work has been done under the direction of Prof. E. J. Babcock, Dean of the School of Mines. In 1909 he built at Hebron an experimental carbonizing and briquetting plant, comprising a bench of one horizontal coal gas retort (Plate 11, page 21), a small briquetting press of the roll type, and gas handling and other auxiliary equipment (Investigations of Lignite Coal relative to the Production of Gas and Briquettes, by E. J. Babcock, published by the University of North Dakota). Both Prof. Babcock and the writer were

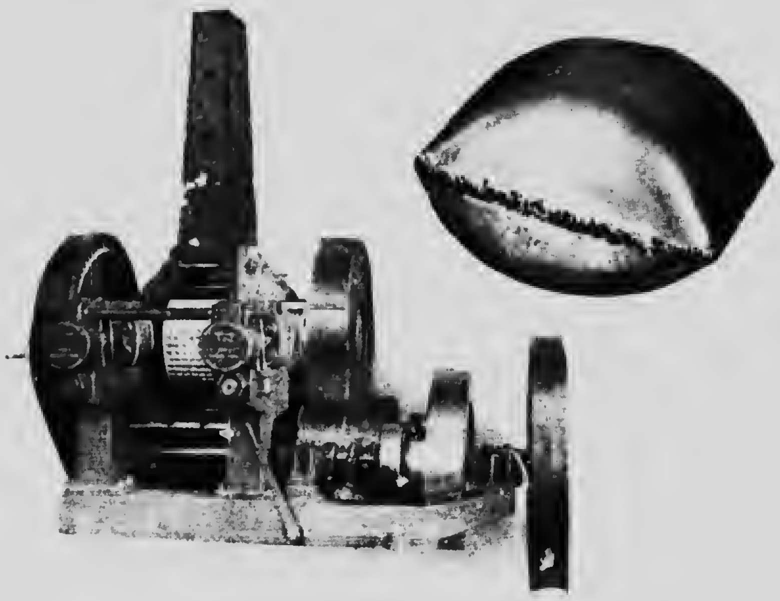


Plate 17.
Roll, or Belgian, Briquetting Press and Briquette.
Northern Briquetting Co., Minot, N.D.

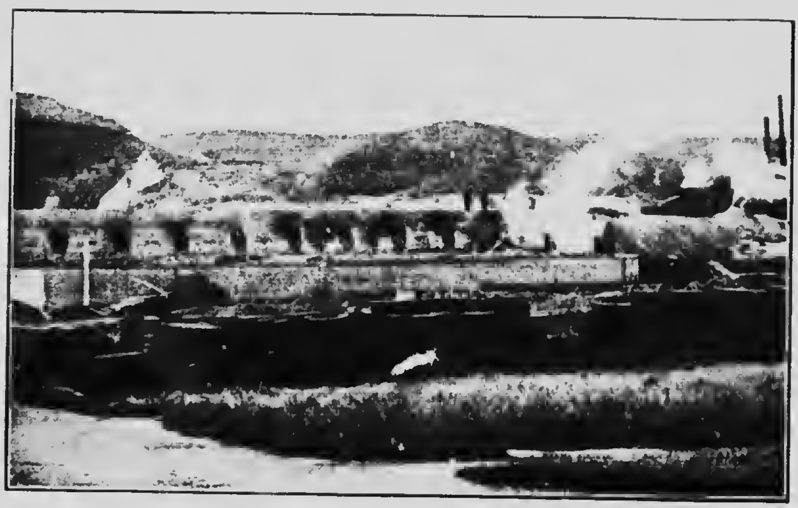


Plate 18.

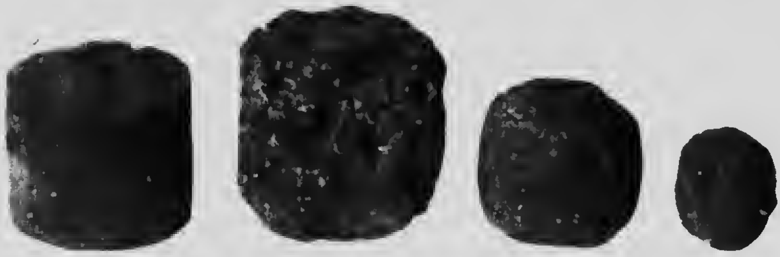
Beehive ovens where the lignite is carbonized before being briquetted.
Northern Briquetting Co., Minot, N.D.

working independently on the same problem, neither having any knowledge of the other's work. Both made satisfactory briquettes out of the carbonized lignite. Prof. Babcock, however, adooted quite a different type of carbonizing device from that evolved by the writer. His carbonizing apparatus took the form of a modified bee hive oven such as is used for coking bituminous coal (Plate 18, page 38). The main object was to get a carbonizing oven that would be inexpensive in operation and of low first cost, without reference to byproducts. The base of the oven is about ten feet in diameter and the peak of the dome approximately eight feet above the floor. Ten to twelve tons of lignite are dumped into the oven through a hole in the top. The heat remaining in the floor

Plate 19.

Briquetting Plant, Northern Briquetting Co.
Minot N.D.

and sides of the oven from the previous charge di[illegible] and ignites some of the [illegible]s, and the carbonizing proceeds without any further attention. The charge is allowed to remain thus for two to three days, when it is raked out by hand, quenched with water, and another charge dumped in. No byproducts are recovered, there is no surplus gas and at least 15 per cent. of the fixed carbon in the lignite is consumed during carbonization. Following the results obtained experimentally by Prof. Babcock at Hebron, the Northern Briquetting Company, in 1913, built a commercial lignite carbonizing and briquetting plant at Minot (Plate 19, page 39) under the direction of Prof. Babcock and the Mashek Engineering Company, New York, who had supplied the small press for the Hebron experimental plant and who were conversant with the results there obtained. The carbonizing ovens have not met expectations, and will be replaced with mechanically operated equipment, which will save the byproducts. The management of the Northern Briquetting Company very courteously permitted the writer to use its mixing and



1 2 3 4

Plate 20.

No. 1. Arkansas Coking Coal Briquette before combustion.

No. 2. Showing action of fire on briquette and commencement of coking process during combustion.

No. 3. Illustrates how, as the ashes fall away the form is retained, showing that each briquette burns as a unit.

No. 4. Same as No. 3 but at a later stage of combustion. The briquette does not break open but retains its form until consumed.

Standard Briquette Fuel Company, Kansas City, Mo.

Plate 21.

Saskatchewan carbonized lignite briquette. Progressive stages of combustion: the briquette remains intact down to the last particle.

briquetting equipment to briquette two carloads of Saskatchewan lignite which had been carbonized at the province's experimental plant at Estevan.

The briquettes made were composed of

8 per cent. coal tar pitch.
2 per cent. flour.
7 per cent. coking coal.
83 per cent. Saskatchewan carbonized lignite.

The briquettes were hard, stood shipping well and gave very general satisfaction in service. They weigh 2 ounces each. They are the ideal shape and weight for domestic use.

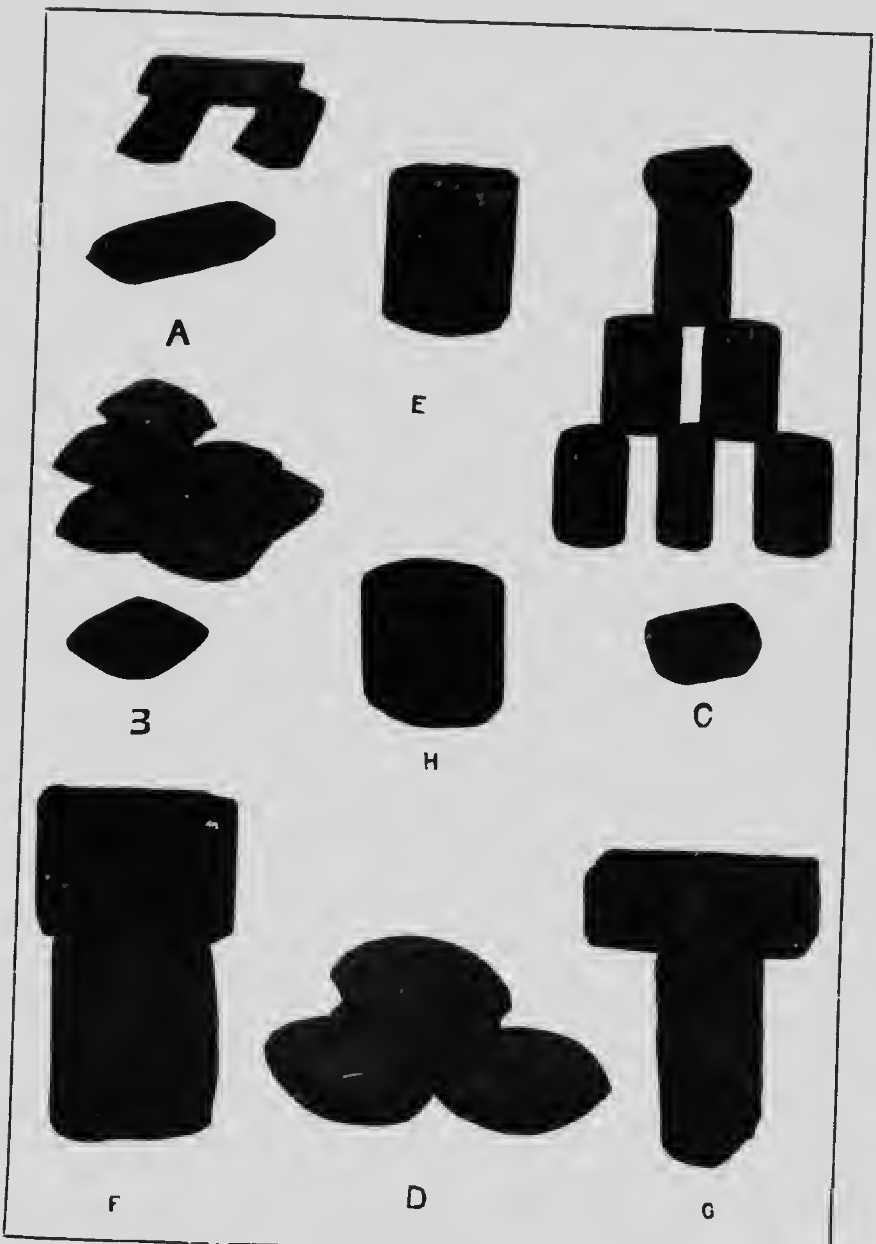


Plate 22.

A. Arkansas Carbonized Lignite Briquette. E. Saskatchewan Dried Lignite Briquette.
All others Saskatchewan Carbonized Lignite Briquette.

The briquettes made from the Saskatchewan carbonized lignite have 11,500 to 12,000 British thermal units per pound. They burn with a short flame, no odour, no smoke (except a very little resulting from the volatilizing of some of the pitch binder when first thrown on the fire), and no clinker. They can be used wherever anthracite or bituminous coal is burned. They retain their structure in the fire until completely consumed (Plate 21, page 40). They do not disintegrate or lose value in the weather, and can therefore be stored for any length

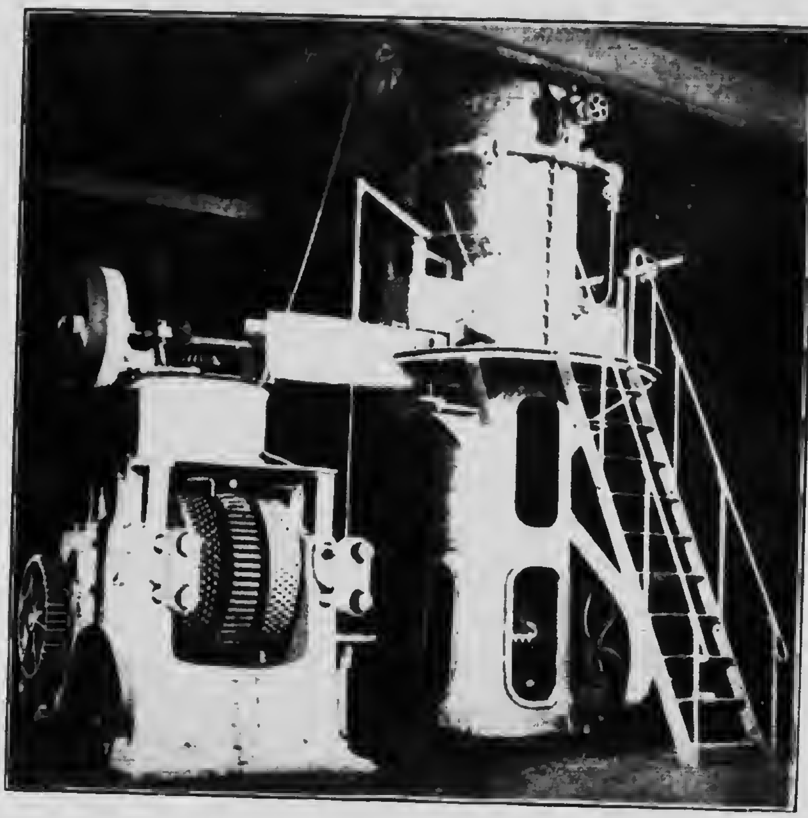
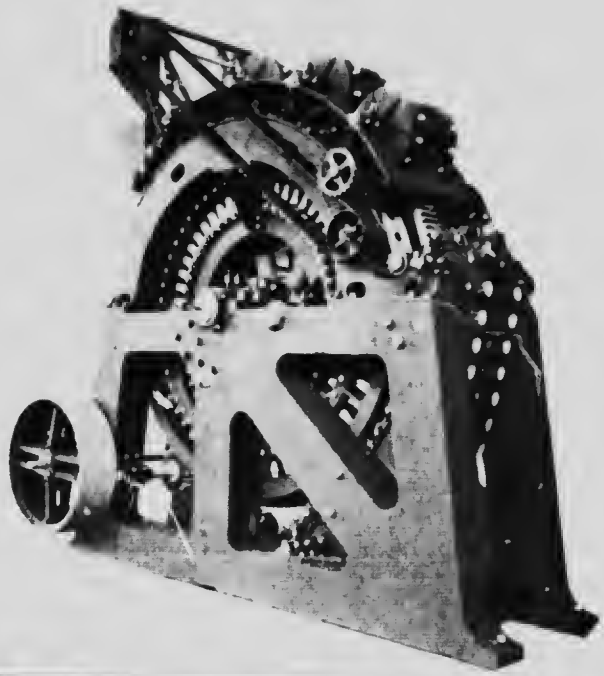


Plate 23.

Modification of roll type of press, making small ovoid briquettes.

of time and shipped any distance without loss. As a domestic fuel they are fully equal to the anthracite that is marketed here ton for ton. While the anthracite averages approximately 13,000 British thermal units per pound, a little higher than the lignite briquettes when compared in a laboratory, there is no clinker from the lignite briquettes, no loss in burning, and they can be used nicely in kitchen ranges, which is impracticable with hard coal. They make an exceptionally fine fuel for fireplaces.



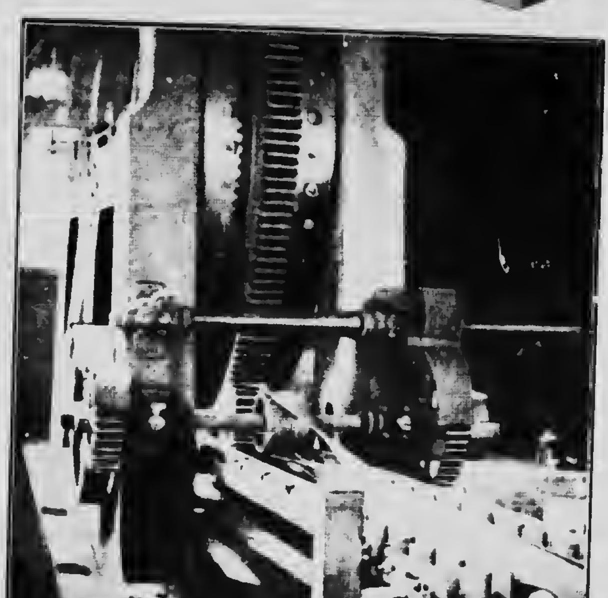


Plate 24.

Ladley Briquetting Press.
Roberts & Schaefer Co Chicago

As between the carbonized lignite briquette and the merely dried lignite briquette the question is essentially one of cost and market demand. In the latter case only the 25 per cent. of moisture is removed; while in the former the reduction in weight, in moisture and volatile is 50 per cent.; but this loss in carbonizing is more than offset by the byproducts obtained.

Plate 25.
Briquetting Press making a Rectangular Briquette weighing about 2 pounds.
Wm. Johnson & Sons, Leeds, England.

Further, some additional fuel is necessary to dry the lignite, while the carbonizing supplies all the fuel (gas) necessary to carry on the process. The dried lignite briquette makes a splendid fuel for large hand-fired furnaces, while the carbonized lignite briquette is superior for domestic service, in kitchen ranges, fireplaces and house heating plants. Doubtless both classes will be manufactured in such proportions as the market dictates,

Estimate of Cost of Carbonized Lignite Briquettes.

The estimated cost of the first unit of a carbonizing and briquetting plant, capable of turning out 200 tons per day, or a minimum of 50,000 tons per annum, is $75,000, including $15,000 for the drying equipment, consisting of a crusher, rotary dryer, necessary elevators, rotary screen and bins. This is assuming that the lignite mine is already in operation, with switching tracks, etc., and that the carbonizing and briquetting plant can be located alongside the tipple. The expenditure suggested is about as small as would be advisable from a commercial standpoint for the first unit. Additional equipment would, of course, be added as rapidly as was practicable. To quadruple the output it would not be necessary to much more than double the investment.

The estimated cost of manufacturing is:

LIGNITE, 97,383 tons, at 90 cents	$ 87,644.70
CARBONIZING portion chargeable to	11,686.00
LABCUR, at 25 cents per ton of briquettes	12,500.00
BINDER, 5 per cent. coal tar pitch, 2,500 tons at $15 per ton	37,500.00
2 per cent. lignite tar pitch produced at plant.	
INTEREST, 6 per cent. on $75,0(i0)	4,500.00
DEPRECIATION 10 per cent. on $75,000	7,500.00
INCIDENTALS, oil waste, etc.	2,000.00
FCWER (portion chargeable to briquetting plant)	5,000.00
MANAGEMENT, general office, laboratory, chemist, etc.	
Portion chargeable to briquetting plant	2,000.00
Gross cost of 50,000 tons of briquettes	$170,330.70
Gross cost of 1 ton of briquettes	3.41

As noted above, while the addition of a small percentage of coking coal or flour adds somewhat to the serviceability of a domestic fuel briquette neither is absolutely essential. The coking coal would be the cheaper, and if 7 per cent. of it were used the cest per ton would be increased 16 cents, making a total cost of $3.57 cents per ton.

There are a good many features in connection with the operation of a lignite industry as outlined in this report that make toward a reduction in this cost per ton of briquettes.

As the output increases the cost per ton will decrease.

There will likely be some demand for raw lignite for certain hand fired furnaces. A plant of this character would screen its run of mine coal and supply this demand for raw lignite with the large lumps only, thus getting an enhanced price, and pass all the rest of the mine run to the drying and briquetting sections.

The screenings would not be wasted as at present and the "nut" lignite would not be sold below the actual cost of mining, as is being done now. Every pound of coal broken from the seam will be utilized.

There is also a demand for dried lump lignite for use on automatic stokers and in gas producers where the producer gas is used as a furnace fuel, and some powdered fuel. At present the Regina power plant could use approximately 35 tons per day of dried lignite and the Moose Jaw power plant about an equal quantity. Other installations of automatic stokers will come along from time to time. The only present market for powdered fuel is approximately 10 tons per day at the plant of the Manitoba Gypsum Company, Winnipeg.

A substantial quantity of lump carbonized lignite will be sold for use in power gas producers without the expense of briquetting. There are two dozen power plants now in this territory that will use this fuel when it can be supplied in sufficient quantities. These producers, if supplied now, would use approximately 25 tons of carbonized lignite per day. And when this fuel is available the number of gas producer installations will be very largely increased, because this is the cheapest means by which towns, villages and industrial plants can secure power for local consumption until reached by transmission lines from a central power plant

The more carbonized lignite that is sold without the necessity of briquetting, the more lignite pitch there will be available to replace the coal tar pitch as a binder in the briquettes, thus reducing the cost of the item for binder. With cheap power available, it is not unlikely that the large quantity of straw grown in the vicinity of the lignite mines, which is now wasted by burning, will be made the basis of a paper industry. This would render available, at a nominal price, a substantial quantity of sulphite pitch, which makes an excellent binder for the briquettes, thus still further reducing the cost of this item.

There are 15 pounds of sulphate of ammonia procurable from each ton of the lignite. This sulphate is worth, as a fertilizer 3 to 3½ cents per pound. It should be remarked, however, that it will not be advisable to try to recover this ammonia until the plant is carbonizing at least 500 tons per day. The sulphate will then yield a very substantial revenue.

Six thousand cubic feet of the lignite gas per ton is required to carry on the carbonizing process; the remaining 4,000 cubic feet can be used to generate power for use around the plant or for sale, or it may be used for the purpose of burning brick, tile, etc.

It is deemed pertinent in this connection to mention the fact that the availability of this lignite gas as fuel for the kilns affords the opportunity for a substantial reduction in the cost of clay products, the raw material for which is present in the enormous quantities of clay, of excellent quality for building brick, hollowware and the cheaper grades of pottery, which lie in juxtaposition to the seams of lignite. While very much depends upon the character of the kilns, it may be said in a general way that the surplus gas from 3 tons of lignite is ample to burn 1,000 bricks.

If the carbonizing and briquetting plant were placed near a large centre of population, the surplus gas could be used to generate electrical power, or sold at a good price as a "town gas," or the entire 10,000 cubic feet per ton could be so used and the carbonizing carried on by means of lignite producer gas.

And then there are the hydrocarbon and ammonia byproducts, which are bound in time to become the basis of a large industry in themselves.

To summarize the products:

DRIED LIGNITE, for use on automatic stokers and fuel-gas producers, and, when pulverized, as a powdered fuel.

DRIED LIGNITE BRIQUETTES, for use in large, hand fired furnaces. These have proved equal to western coals in evaporative efficiency.

CARBONIZED LIGNITE for use in power-gas producers. Tests which consumed ten carloads of this fuel proved it equal to Pennsylvania anthracite for this purpose.

CARBONIZED LIGNITE BRIQUETTES. These have proved excellent for domestic service and are equal in fuel value, ton for ton, to the anthracite marketed in this territory.

GAS, which may be sold as a "town gas," or utilized for the production of cheap electrical power or for burning clay products.

POWER derived from the surplus gas. This gas costs practically nothing, and from it electrical power can be generated as cheaply as from natural gas It is cheaper than water power.

BYPRODUCTS, from the tar and ammonia compounds. This is an industry in itself, and, further, in view of the chaotic condition of the market following the cutting off of the supply of tar products from Germany, it is believed that the details of this phase should be left to be developed by a commercial company. The cost figures given in this report, therefore, do not take into account the revenue to be derived from these byproducts.

No argument is needed to demonstrate the value of cheap power, cheap domestic fuel, and cheap building material in the industrial development of the province.

INDEX TO TOPICS.