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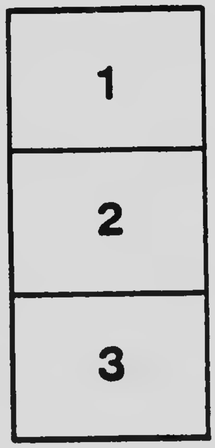

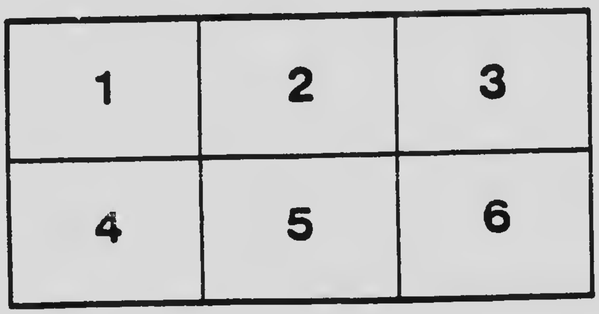

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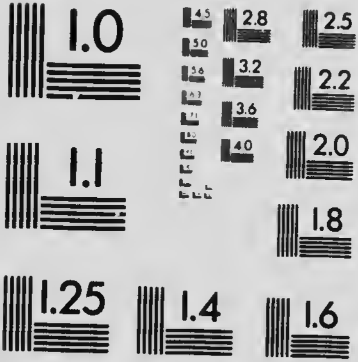

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DOMINION OF CANADA

THE HONORARY ADVISORY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

REPORT No. 1

THE BRIQUETTING OF LIGNITES

BY

R. A. ROSS, E.E.

Canada

Published by the authority of the Sub-Committee of the Privy Council for Scientific and Industrial Research

OTTAWA, 1918

THE BRIQUETTING OF LIGNITES.

Introduction.

Although the fuel resources of Canada are enormous and varied, their geographical distribution is such as to leave the region between the Atlantic bituminous coal deposits and the lignite deposits of Saskatchewan destitute of all natural fuels save peat and wood.* Hence the Provinces of Quebec, Ontario and Manitoba must be supplied in large part by importations from the United States, supplemented by shipments from the Eastern and Western Canadian coal areas. High freight rates are an inevitable concomitant of this condition.

As more than half the coal used in Canada is imported from the United States, and as nearly all is used in this naturally coal-less region, our dependence upon the United States constitutes at once an industrial menace and a national problem. Fortunately this problem is capable of solution. Superabundant unutilized water powers can provide ample energy for industrial requirements in Eastern and Central Canada. Farther west the feasibility of meeting requirements in Saskatchewan and Manitoba by utilizing prepared lignites and sub-bituminous coals is the subject of this report.

Throughout the West, and especially in Saskatchewan, the domestic fuel situation is difficult. Either the householder must use the native lignite and sub-bituminous coals of the district, which would be unacceptable to the householder in the East, or he must pay even in normal times, from $10.00 to $15.00 a ton for anthracite coal from Pennsylvania. As a matter of fact, the westerner does use about 500,000 tons of anthracite per year in this district at a cost of about $6,000,000.

In addition to this coal imported for household use, a large amount of the native coal is used on account of its cheapness; but as it is dirty, friable, and disintegrates rapidly, it presents no advantage for domestic purposes other than cheapness.

*Natural gas and petroleum are relatively of minor commercial importance.

Underlying the province of Saskatchewan are immense deposits of very poor lignites. Better lignites and bituminous coals occur in Alberta. For the utilizing of these fuels in the most effective way for both domestic and commercial purposes, commercial preparation is necessary. For years past, Germany has burned practically no raw coal of any description; the raw product when mined being either briquetted or coked; the by-products together with the resulting fuel being of more economic value to the community than if the coal were burned without recovery processes, as is the practice on this continent.

When the Honorary Advisory Council for Scientific and Industrial Research was formed about a year ago, one of the first problems to attract attention was that of fuel. The situation in the North West in winter time, complicated as it is by stoppages of mines due to strikes, shortages of fuel due to lack of transportation, storms, etc., presented a field for useful work.

A review of the records of the Dominion Mines Branch and various Provincial departments, and of the reports made from time to time by Commissions and individuals both in this country and in the United States, indicated the commercial possibility of transforming the lignites of Saskatchewan into a marketable equivalent of anthracite coal.

Analysis of recorded facts demonstrated that preliminary carbonizing treatment, by which two tons of the raw lignite was converted into one ton of coke and then briquetted under pressure with the aid of a binder, gave better results than any attempt to briquette the raw material itself.

It may be stated in passing that some of the German brown coal can be, and is, briquetted without binding material; but it has been found that this is not possible in the case of the lignites of Saskatchewan and North Dakota. What little pitch they contain has to be supplemented by some effective binder to produce a sound briquette.

During the carbonizing process, the moisture is first driven from the coal, then the gases, and, still later, distillates which yield ammonia, oils, aad pitches, all valuable products, so valuable, in fact, that for years past Germany has coked all her coal and saved the distillates and gas.

While these by-products are valuable, their value has not been considered in this respect as it was felt that the quantities which might be recovered would depend upon how far it is advisable to lessen the fuel efficiency of the briquetted product.

The Fuel Committee of the Council was fortunate enough to secure the hearty co-operation of the Department of Mines and of the Commission of Conservation, through their Engineers, Mr. Haanel and Mr. Dick, to whom they desire to extend thanks for their efforts.

It was known that the United States Government and certain northern universities had done some work in the way of carbonizing; that briquetting of coal was comparatively common; that the use of binders was fairly well understood; and, in short, that much experimental work had been done, not only in the laboratory, but in a commercial way.

It was found, however, that much of this experimental and investigatory work was rendered inutile because of a marked lack of sequence and articulation. No attempts had been made to co-ordinate complete manufacturing processes for handling such lignites as those of Saskatchewan and North Dakota, these being practically identical in composition.

Investigations were conducted among machinery manufacturers and briquetting plants in operation, to determine the possibility of obtaining adequate machinery. A final report suggesting action was then presented to the Research Council by the Lignites Committee. As this report contains all the details of the project, it is considered desirable to add it to this general statement.

After due consideration by the Council [illegible] report was accepted, and representations were thereupon made to the Government requesting an appropriation of $400,000 to be expended on a plant of about 30,000 tons capacity of briquettes [illegible] year; the whole to be handled as a company on a commerc[illegible]ring both construction and operation, raw materials [illegible]ased, and the finished product sold with reference only [illegible]mercial results, but without profit to the directorate.

It was anticipated that about one year would be necessary to complete the plant, and that thereafter possibl[illegible] months would be required for adjusting machinery, experim[illegible]g with various binders and mixtures, determining suitable [illegible] for distillation under commercial conditions and the qu[illegible] and distillates to be driven off.

At the expiry of this period it was expected that the project would be on a commercial basis and that finally the equipment would be operated by the Dominion Government as a producing plant or sold to the Provincial Government or to private individuals, or used as an experiment station for briquetting other fuels.

Briefly, summarizing the report, the financial aspects of the proposition are as follows:

Total capital invested in lands, buildings, machinery, interest and management during construction, etc.	$[illegible]0,000.00
Cost per ton of briquettes at the mine, including all fixed charges, amounting to 20% on the capital per ton.	7.00
Cost of anthracite coal f.o.b. cars Estevan during normal times.	$10.00 to $12.00

The above estimates imply that briquettes can be profitably manufactured in Saskatchewan, on a relatively small scale, without taking into consideration the value of by-products, at from $3.00 to $5.00 per ton less than the cost of Pennsylvania anthracite at the same spot.

It may be fairly expected that in the future, with larger plants in operation, profiting by the experience gained in this proposed establishment, briquettes will be produced at a very considerable reduction of the estimates there presented.

This project having been approved by the Research Council, was in June, 1917, presented to the Government with the request for official sanction. After a full consideration of this report the Privy Council recommended on March 20th, 1918, that this project be undertaken by the Government in co-operation with the Governments of the Provinces of Manitoba and Saskatchewan on the conditions that the two Provincial Governments together contribute half of the amount to be expended and that the direction and management of the undertaking be vested in a commission appointed to that end by the three Governments.

Memorandum Concerning Briquetting of Lignites.

At the first meeting of Council there was constituted a committee to deal with the utilization of lignites, which committee, added to from time to time, has made interim reports to the Council. It is now possible to make definite recommendations on the situation.

In the meantime your committee, consisting of: Dr. F. D. Adams, Dr. W. C. Murray, Dr. A. S. Mackenzie, and Mr. R. A. Ross, Chairman, has reviewed the general fuel situation throughout the Dominion, and having concluded that the domestic fuel problem of the North West presented the best field for immediate results, thereafter confined its attention to the briquetting of the lignites of the North West for domestic purposes.

Your committee in carrying out this study has availed itself of all the literature and information in the hands of the Dominion Government, and all the public records of the United States Government, relating especially in the latter case to the lignites of North Dakota, and through the good offices of the Mines Branch, and the Commission of Conservation, has had the benefit of the co-operation of Mr. B. F. Haanel and Mr. W. J. Dick.

A considerable amount of literature exists, published chiefly through Government agencies, covering the coal briquetting problem; but there is very little information extant regarding the briquetting of carbonized lignites. Fortunately, however, such information as does exist concerns the lignites of Southern Saskatchewan.

As regards this memorandum, the idea is to present in as concise form as possible the facts and conclusions under suitable heads, placing all statistics and figures in tables at the end.

The Situation.

1st. The fuel resources of the Dominion of Canada are second only to those of the United States, the greatest coal country in the world.

2nd. In spite of this fact, Canada imports at present and always has imported—50% of her fuel from the United States. (See Table 3.)

3rd. Canadian efficiency in this regard is, therefore, about 50%.

4th. Under these conditions the problem must be attacked, preferably by the Government, and not by isolated commercial agencies working in competition with each other.

5th. An examination of the map attached will show the Canadian territories supplied by coal distributed from various centres and indicate an immense area whose requirements are met from American sources.

6th. The province of Saskatchewan, as will be seen, is the balancing point for fuel from the East and from the West, and for this reason fuel prices are the highest, although underlying a great part of this province are immense deposits of lignite awaiting use.

7th. We, therefore, recommend that the attack on the fuel problem of Canada be concentrated first on the production of domestic fuel from the lignites of Saskatchewan for the following reasons:

(*a*) Because the price of anthracite coal in normal times in this district is the highest and runs about $15.00 per ton.

(*b*) Because successful briquetting of the lignites of Southern Saskatchewan will also solve the problem of briquetting the higher grade lignites of Alberta.

The Lignites.

Coals for commercial purposes are arbitrarily grouped as follows: Anthracite, semi-anthracite, bituminous, semi-bituminous, and lignite. All of these are available in this country in greater or less degree.

The manufacture of the lignites into briquettes in the manner proposed constitutes an artificial method of raising a very low grade fuel to the highest grade with the production of gas and other valuable by-products, no allowance for which is made herein.

1st. Various grades of coal, from anthracite in the Rockies to poor lignites in Southern Saskatchewan underlie a large part of the provinces of Alberta and Saskatchewan, whereas further East we have no coal deposits until the Maritime Provinces are reached.

2nd. The raw lignites of Southern Saskatchewan when taken from the ground contain about 40% of water which must be eliminated by air-drying, or evaporated in the furnace at the expense of the heat value of the fuel.

3rd. This condition renders the raw fuel unsatisfactory for domestic use, both on account of the cost of transporting the water and of its evaporation. The fuel is impure, falls to pieces if stored, and can only be utilized when freshly mined.

4th. An examination of Table 8 will indicate the relative positions of lignite as mined, briquettes of carbonized lignite, and anthracite, in the scale of heating values. When the other factors of operation, such as loss through grates, etc., are considered, it is safe to say that the heating value of the lignite as mined is increased 100% by carbonizing and briquetting.

5th. Raw lignites are briquetted commercially in Germany, but so far it has not been found possible to handle the lignites of North Dakota and Saskatchewan in this way, nor in view of the situation to-day is it advisable to do so even if it were possible.

6th. By carbonizing the lignite a coke or charcoal is obtained which briquettes readily, has a high heat value, and by-products such as tar, ammonium, sulphate, gas, etc., are recovered.

7th. Without consideration of the by-products the result has been to turn two (2) tons of poor fuel into one (1) ton of fuel approximating anthracite in caloric value with practically the same actual heating value in the domestic furnace as the two (2) original tons from which it was made.

8th. After carbonizing, briquetting can only take place through the agency of a binder for which coal-tar pitch and sulphite pitch have been successfully used. Sulphite pitch, a waste product from pulp mills, is available in immense quantities. The only purpose which it subserves at the present time is that of poisoning fish in the various waters near which pulp mills are situated.

9th. After carbonizing and briquetting, the fuel must be waterproofed. This is accomplished by a simple heat process resulting in the coking of the binder.

Present State of the Art of Producing Carbonized Lignite Briquettes.

The processes involved in the manufacture of carbonized lignite briquettes have all been carried to a stage beyond that of the laboratory. The next step forward involves commercial methods of production on a scale sufficient to demonstrate the best production methods and the costs.

1st. Briquetting of the raw lignites of Central Europe, especially those of Germany, has been carried on successfully for years past, the output for 1913 in Germany being 20,000,000 tons.

2nd. The briquetting of bituminous slacks and small sizes is carried on in several parts of the United States in a commercial way at the present time.

3rd. The briquetting of anthracite slack in British Columbia has been a practical success for some years past, both for domestic and locomotive fuel.

4th. The carbonizing of North Dakota lignites has been carried on at Hebron, N.D., in a semi-commercial way, and carbonized Souris lignite has been produced at Estevan on a small scale.

5th. The briquetting of these lignites, however, has not been carried on in a commercial way, any briquettes made being produced sporadically in carload lots, sufficient in amount only to demonstrate that briquetting is practicable.

6th. Carbonizing is a simple process and sufficient information and experience has been obtained to warrant commercial production.

7th. Briquetting and suitable binders require study upon a commercial scale in order to determine temperatures, pressures, mixtures and results in actual practice.

8th. The necessary waterproofing, which is obtained by a heat treatment of the completed briquettes, presents no difficulty whatever, being a simple matter of coking the binder at a low heat.

9th. Summing up, the producer must face the difficulties inherent in commercial production which are approximately of the same order as those met in other industrial establishments. The problem has been solved; it remains merely to overcome the incidental difficulties.

10th. The road to success in the briquetting problem is strewn with the wrecks of ill-conceived attempts to do this apparently simple thing—failure resulting from either lack of knowledge of what had been done, lack of technical experience, or shortage of money.

11th. For the above reasons, amongst others, private capital is chary of such enterprises. It is argued that the chances of failure are great, and, as the market cannot be cornered, any process when successfully developed will be utilized without cost by competitors. The situation in Saskatchewan, therefore, should be grappled by the Government.

12th. Thereafter the business may be continued by the Government as a public utility, or, as demonstration having been made and results shown, private investors may confidently venture.

Equipment Recommended.

To carry out on a commercial scale the carbonizing and briquetting of lignites, a considerable amount of equipment is required, and it appears that suitable machinery is obtainable at the present time. In this connection your committee had, through Mr. Haanel, and also individually, the advantage of the advice of mechanical specialists. The following recommendations are submitted:—

1st. By establishing a plant in the Souris coal fields in the neighbourhood of existing mines, the demonstration when made will have covered the treatment of the most difficult material on the American continent, and therefore, success with other and better fuel will be comparatively easy.

2nd. Having passed the laboratory stage, it becomes inadvisable to consider the establishment of a plant of less than 100 tons per day, as the problems involved are not technical so much as commercial, covering such questions as operating temperatures, mixtures, binders, percentages of binders, wages, cost of supplies and repairs.

3rd. We have estimated upon a briquetting press with a capacity of 10 tons per hour, operated 10 hours per day, and producing 100 tons.

4th. We recommend installing one (1) carbonizing oven with a capacity of 2½ tons per hour, operated 24 hours per day, total capacity say 50 tons.

5th. Also a waterproofing plant of a capacity of five (5) tons per hour, for 24 hours, or say 100 tons total capacity.

6th. Also conveying and power plant for 100 tons capacity.

7th. Also complete buildings for covering the 100 ton plant.

8th. By the above arrangement there will be no immediate purchase of the second carbonizing oven, which will be necessary to complete the plant, until full commercial tests are made upon the one unit provided.

9th. An inspection of table No. 1 will show that the capital cost of the above with a production of 15,000 tons per year will be $320,000, and yet with this partial equipment all problems may be worked out on a commercial basis.

10th. For the full plant of 30,000 tons per year capacity, an additional carbonizing unit will have to be added. The capital cost of the completed plant as per table No. 1 being $370,000.

11th. From table No. 2, wherein detailed figures are given, it will be seen that the production costs at the plant for carbonized and briquetted fuel, covering operating costs and fixed charges will not exceed per ton $7.00.

12th. An inspection of the figures upon which the results are based will indicate that in every case a most conservative view has been taken. The capital costs are high, labor is allowed for with liberality, percentages for depreciation, repairs, etc., are high and the costs of materials also. As a matter of fact, the estimated costs herein given are much in excess of those put forward in any other estimate of which we are aware. It can, therefore, safely be predicted that no probable combination of prices could exceed the aggregation here given.

Commercial Conditions.

Having dealt with the technical aspects of carbonizing and briquetting, it is now appropriate to discuss the handling and marketing of the finished product. This involves commercial handling which is equally important as production. As notes on the above remarks, the following are presented:

1st. The plant in contemplation will be constructed as a unit to which other units of similar size can be added, or established elsewhere. A similar plant of this size would not supply more than a local market. If constructed at Estevan for example, it would have its market only in Regina, Moose Jaw, and the intervening country, as the tonnage of 30,000 per year of domestic fuel would only supply the requirements of a population of 20,000 people.

2nd. Assuming a cost of $7.00 per ton at the plant, and a transportation cost of $1.50 to Moose Jaw, with a dealer's profit and delivery cost of $1.50, the total price to the consumer at Moose Jaw would not exceed $10.00 per ton. It would be less at Regina, and still less in the intervening country districts where it would not be sold to a dealer or delivered by him, but would be unloaded by the farmers from their own cars. This price at Moose Jaw, however, under the worst conditions would be two to five dollars less per ton than present prices paid.

3rd. While the present costs of coal have been referred to above, it must not be supposed that these will continue, for recent past records indicate an increased cost of 50 cents per ton per year. As a matter of fact, the rate of increase may be expected to be considerably higher than this, leading eventually to the elimination of anthracite altogether on the score of price, with the imminent prospect of an embargo being placed on the export of this coal from the United States in the not distant future. In short, the costs of anthracite must go up, and the costs of briquettes will go down with larger production, and the spread, therefore, becomes continually greater.

4th. Using present figures for one year's operation, the annual saving of a minimum of $2.00 per ton to the people of this district would total $60,000.

5th. Even if no saving were made, and the selling costs of briquettes were as high as that of anthracite coal at present, there would be kept in the country the sum of $360,000 per year.

Procedure.

If the suggestions made be considered adequate to establish the advisability of the construction of such a plant as is indicated herein, other questions will immediately arise which should be looked at in advance.

1st. Contracts will have to be entered into for all kinds of machinery without restriction as to where it is produced or by whom it is produced, but considering only its demonstrated suitability for the work in hand.

2nd. The question of the site of the plant will have to be decided on with a view not only to proximity of supplies, but also of alternative supplies from whatever mines are available, or, possibly, from a Government-owned mine, which should be situated as closely as possible to the site of the plant, thus providing a supply in case of trouble with other mines.

3rd. Contracts will have to be entered into with an existing mine or mines for such material as the waste fines. In this connection it may be stated that usually the mines only operate in winter when lignite is used, as it cannot be stored, whereas a briquetting plant would purchase all the year round and use what is now practically waste material.

4th. A staff will have to be appointed consisting of manager or superintendent, chemist, etc., on the basis of fitness for this particular class of work, as the character of the work implies a certain degree of special training.

5th. Arrangements will have to be made with dealers or otherwise for the distribution of fuel in competition with coal. With a small plant such as here indicated there should be little trouble with this aspect of the case, while the product would be of sufficient volume to give a demonstration of commercial costs.

6th. An office system will have to be installed by means of which accurate costs of raw materials entering into the product, the labour costs and the tonnage output costs may be found, and the whole lead up to something that might be presented to the Government in a general report covering results.

7th. A review of the above activities does not indicate that they are such as could best be carried out under Departmental control. The whole project is a commercial one, which will have no justification for its existence if it does not give commercial results, and this involves commercial handling. It is imperative, therefore, that the construction and operation of this plant be placed in the hands of a Board constituted of technical and business men whose hands are not tied in any way.

Summing Up.

In view of the discursive nature of this report a summing up may be advisable.

1st. The necessity exists for the development of all our fuel resources.

2nd. The best immediate returns will be secured by the development of lignite briquetting processes.

3rd. The country has the raw materials, the brains and the command of money for such national work.

4th. Leaving the problem in private hands will result in long delays during which we must buy our fuel abroad.

5th. In view of the broad national importance of the field the actual capital necessary is of secondary importance only.

6th. Full success will mean the stoppage of millions of outgo to the United States and its expenditure in wages in Canada.

7th. If only a partial success be secured a step shall have been taken in a problem which must be solved ultimately.

8th. A complete failure is unthinkable, but granted that outcome, the money if judiciously spent will have demonstrated the uselessness of further trials, and will lay a ghost which otherwise will be continually in evidence.

ACTION.

If this report be found convincing and be adopted by the Council prompt action will be necessary as the season is advancing.

It is estimated that a year will be required to construct and equip the plant, owing to existing conditions in Canada and the United States.

Further, a period of six months may elapse before the plant in operation will have so adjusted its processes as to turn out a uniform product at a commercial cost.

In order, therefore, that the plant should be in operation by this time next year and delivering its output by the winter of 1919, the buildings must be erected during the coming summer or within a period of six months. During the ensuing winter the machinery may be installed.

Within the next six months therefore the Government's approval must be given, a Board constituted, a manager appointed, plans made and contracts let for equipment, and the buildings designed. For these buildings contracts must be let and construction completed before December next. Any failure in this programme means the loss of a year.

TABLE No. I.

BRIQUETTING PLANT.

CAPITAL COSTS

Malcolmson letter of date May 21st, to Mr. Haanel.

	YEARLY OUTPUT	
	15,000 tons	30,000 tons
	$	$
Materials only, for buildings	20,000	20,000
Briquetting Press	15,000	15,000
Waterproofing Oven	15,000	15,000
Dryer and Carbonizing Kilns	28,000	56,000
Power Plant, Motors and Wiring	32,000	32,000
Conveyors, Mixers, Track Hoppers, Bins, Storage, etc.	40,000	45,000
Fuel Gas and Pitch Recovery Plant	23,000	23,000
Shop Tools, Laboratory, etc.	10,000	10,000
Labour on all above	50,000	55,000
Engineering and Travelling expenses, Freight and Insurance	27,000	30,000
Total	260,000	301,000
15% for Engineering and Contracting	39,000	45,150
Grand Total	299,000	346,150
Interest on above—6 months at 6%	8,970	10,384
Expenses of operation for 6 months of adjustment	10,000	10,000
Total	317,970	366,534
Fixed Charges: Interest = 6%; Depreciation = 10%; Repairs = 4%:—Total = 20%	63,594	73,307
Per ton of output	4.24	2.44

Table No. II.

COST OF BRIQUETTING.

Production Costs	15,000 tons per year		30,000 tons per year	
	Total	Per ton	Total	Per ton
Lignite as mined:				
Residue from carbonization—Darling 955 lbs.				
Residue from carbonization—Babcock 47%				
Allow 2 tons of lignite per ton of briquettes at $1.00	$30,000	2.00	$60,000	2.00
Binder—with allowances:				
Darling—P-22 to 44 allows from 5 to 8%.				
Allow for estimate 10% of binder at $15.00	22,500	1.50	45,000	1.50
Labour—both carbonizing and briquetting:				
Darling—P-45 allows per ton 25c.				
Mills—P-12 briquetting only 20c.				
Wright—P-14 briquetting only 60c.				
Malcolmson Letter carb. and briq. 60c.				
Allow per ton for carbonizing and briquetting	15,000	1.00	18,000	.60
Supplies—Oil, waste, small tools, etc.:				
Allow per ton as a pure estimate..	3,000	.20	4,500	15
Superintendence and Management:				
1 Superintendent, $2,000.				
1 Manager, $4,000.				
Office expenses at works, $2,000...	8,000	.53	9,000	.30
Total production costs	$78,500	5.23	$136,500	4.55
Fixed Charges (see capital sheet):				
Interest 6%, Depreciation 10%, Repairs 4%	63,594	4.24	73,307	2.44
Total Operating and Fixed Charges...	$142,094	9.47	$209,807	6.99

TABLES OF INFORMATION.

Table No. III.

CONSUMPTION OF COAL IN CANADA.*

Calendar Year.	Canadian.	Imported	Total.	Percent'ge Canadian	Percent'ge Imported	Con-sumpt'n per Capita
	Tons	Tons	Tons			
1886	1,595,950	1,884,161	3,480,111	45.9	54.1	0.758
1887	1,848,365	2,192,260	4,040,625	45.7	54.3	0.871
1888	2,013,925	3,314,353	5,328,278	37.8	62.2	1.137
1889	1,992,988	2,490,931	4,483,919	44.4	55.6	0.946
1890	2,360,196	2,581,187	4,941,383	47.8	52.2	1.031
1891	2,606,490	2,980,222	5,586,712	46.7	53.3	1.153
1892	2,464,012	3,082,429	5,546,441	44.4	55.6	1.133
1893	2,823,187	3,110,462	5,933,649	47.6	52.4	1.198
1894	2,743,376	2,917,818	5,661,194	48.5	51.5	1.130
1895	2,467,109	2,933,752	5,400,861	45.7	54.3	1.066
1896	2,639,055	3,206,456	5,848,511	45.1	54.9	1.140
1897	2,799,977	3,124,485	5,924,462	47.3	52.7	1.143
1898	3,023,079	3,274,981	6,298,060	48.0	52.0	1.200
1899	3,631,882	4,092,361	7,724,243	47.0	53.0	1.454
1900	3,989,542	4,361,563	8,351,105	47.8	52.2	1.561
1901	4,912,664	4,810,213	9,722,877	50.5	49.5	1.310
1902	5,376,413	5,165,938	10,542,351	51.0	49.0	1.927
1903	6,005,735	5,491,870	11,507,605	52.2	47.8	2.055
1904	6,697,183	6,909,651	13,606,834	49.2	50.8	2.346
1905	7,232,661	7,343,880	14,376,541	48.9	51.1	2.362
1906	7,927,560	7,398,906	15,326,466	51.7	48.3	2.425
1907	8,617,352	10,549,503	19,166,855	45.0	55.0	2.947
1908	9,156,478	10,195,424	19,351,902	47.3	52.7	2.820
1909	8,913,376	9,711,826	18,625,202	47.9	52.1	2.682
1910	10,532,103	10,438,123	20,970,226	50.2	49.8	2.960
1911	9,822,749	14,424,949	24,247,698	40.5	59.5	3.384
1912	12,385,696	14,549,104	26,934,800	46.0	54.0	3.596
1913	13,450,158	18,132,387	31,582,545	42.6	57.4	4.071
1914	12,214,403	14,637,920	26,852,323	45.5	54.5	3.325
1915	11,500,480	12,406,212	23,906,692	48.1	51.9	.....
1916	12,348,036	17,517,820	29,865,856	41.3	58.7	.....

* John McLeish, loc. cit., p. 13.

Table No. IV.

ANNUAL PRODUCTION OF COAL IN SASKATCHEWAN.*

Calendar Year.	Short Tons.	Value.	Average Value Per Ton.
		$	$
1890	200	200	1.00
1891		...	
1892	5,400	9,325	1.73
1893	8,325	12,485	
1894	15,051	15,153	
1895	15,769	31,538	
1896	16,706	25,059	
1897	25,000	37,500	
1898	25,000	37,500	
1899	25,000	37,500	
1900	40,500	60,750	[illegible]
1901	45,000	72,000	[illegible]
1902	70,400	112,640	[illegible]
1903	116,703	169,618	1.45
1904	124,885	187,021	1.50
1905	107,596	152,334	1.42
1906	108,398	164,146	1.51
1907	151,232	252,437	1.67
1908	150,556	253,790	1.69
1909	192,125	296,339	1.54
1910	181,156	293,923	1.62
1911	206,779	347,248	[illegible]
1912	225,342	368,135	[illegible]
1913	212,897	358,192	1.68
1914	232,299	374,245	1.61
1915	240,107	365,246	[illegible]
1916	281,300	441,836	1.57
Total	2,824,126	4,476,960	.....

*John McLeish, loc. cit., p. 27.

Table No. V.

AVERAGE COMPOSITION OF A LARGE NUMBER OF SAMPLES OF SASKATCHEWAN LIGNITES.*

Moisture	26 13
Volatile hydrocarbons	28 11
Fixed carbon	38 16
Ash	6 86
Sulphur	.74

PRODUCTS OF CARBONIZATION.†

Gas, per ton of lignite	10,000 c.f.
Oil or tar (water free)	15 gallons
Ammoniacal liquor	65 gallons
Carbon residue	955 pounds

The lignite carbonizes much more readily than bituminous coal. The most rapid evolution of gas from the lignite takes place between 700 and 900 degrees Fahrenheit. The gas is practically all off at 1,000 degrees Fahrenheit.

The heating value of the gas averages above 400 B.T.U's. per cubic foot. There is more gas in one ton of lignite than is required to carbonize the next ton. 6,000 feet of the gas produced would be sufficient for this purpose, leaving 4,000 cubic feet per ton to be used for other purposes, such as the production of power.

The average gas engine uses 10,000 B.T.U's. per horse power hour. This gives 160 horse power hours from the surplus gas per ton of lignite carbonized.

‡In addition to the 200,000 tons of Saskatchewan lignite annually marketed in Saskatchewan and Manitoba, as far east as Winnipeg, there are 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.

*S. M. Darling, loc. cit., p. 6.
†S. M. Darling, loc. cit., p. 26.
‡S. M. Darling, loc. cit., p. 27.

TABLE No. VI.

"ECONOMIC METHODS OF UTILIZING WESTERN LIGNITES."*

The average composition of many a series of Western lignites when dry:

Fixed carbon	51 per cent.
Volatile matter	39 per cent.
Ash	10 per cent.
Moisture as mined	15 to 40 per cent.

Average composition of North Dakota dry lignite is probably about as follows:

Fixed carbon	49 per cent.
Volatile matter	43 per cent.
Ash	8 per cent.
Moisture in the lignite as mined	25 to 35 per cent.

"ECONOMIC METHODS OF UTILIZING LIGNITES"†

RESULTS OF EXPOSURE OF LIGNITE TO WEATHER.

Condition of Lignite	Moisture	Volatile matter.	Fixed Carbon.	Ash.
	per cent	per cent	per cent	per cent
As mined	33.5	25.5	35	6
After 14-day exposure	12.52	34.83	46.05	7.6

*E. J. Babcock, loc. cit., p. 8.
†E. J. Babcock, loc. cit., p. 10.

Table No. VII.

"ECONOMIC METHODS OF UTILIZING WESTERN LIGNITES"*

Average of results of a number of tests chiefly with North Dakota lignites but others from Montana, Colorado and Texas:

Average yield per ton of air-dried lignite—unpurified gas	11,038 c.f.
Average calorific value of above	396 B.T.U.
Retort temperature for above—averaged	1,498 degrees
Residue after gas driven off per ton—averaged	1,092 pounds
Proportional amount of residue to total	54 per cent.

"ECONOMIC METHODS OF UTILIZING WESTERN LIGNITES"†

Results of tests to determine the composition of the lignite residue resulting from operation of small modified oven:

Sample	Yield of Residue.	Analysis of Residue. Moisture.	Volatile matter.	Fixed Carbon.	Ash.	Calorific value of residue per pound
	Per cent.	Per cent.	Per cent.	Per cent	Per cent.	B.T.U.
A.	53.3	0.00	20.40	69.53	10.07	12,590
B.	49.4	0.00	19.98	70.20	9.82	12,300
C.	43.3	0.00	10.42	80.90	8.68	13,200
D.	43.3	0.00	15.85	74.30	9.85	12,905
Average	47.3	0.00	16.66	73.73	9.61	12,749

There can be recovered unpurified gas with a heating value of nearly 400 B.T.U's. Furthermore, the yield of gas from partly air-dried lignites reaches 10,000 to 11,000 c.f. per ton. This quantity would, of course, be reduced if calculated on the basis of wet lignite.

*E. J. Babcock, loc. cit., p. 30.
†E. J. Babcock, loc. cit., p. 44.

Table No. VIII.

"ECONOMIC METHODS OF UTILIZING WESTERN LIGNITES"*

The table following gives the percentage of tar in the lignite used in nine tests:

TAR YIELDS IN RETORT TESTS OF LIGNITES.

Sample No.	Quantity of tar per ton of lignites as charged.	Portion of tar in lignites
	Pounds.	Per cent.
1	26.00	1.30
2	27.00	1.35
3	77.78	3.89
4	56.40	2.82
5	61 80	3.09
6	67.00	3.35
7	39.26	1.96
8	46.20	2 31
9	55.00	2 75
Average	50.72	2.54

(*a*) The lignite was partly dried, containing 8 to 27 per cent. moisture.

* E. J. Babcock, loc. cit., p. 48.

TABLE No. VIII—*Continued.*

"ECONOMIC METHODS OF UTILIZING WESTERN LIGNITES"*

Chemical analyses and calorific values of anthracite coal, lignite and carbonized lignite briquettes.

	Moisture.	Volatile Matter.	Fixed carbon.	Ash.	Heating value.
	Per cent.	Per cent.	Per cent.	Per cent.	B.T.U.
Lignite as mined........	35.01	25.11	34 67	5.21	7,000 to 7,800
Lignite briquettes carbonized..............	0 to 6	2 to 8	72 to 82	10 to 16	11,500 to 12,000
Anthracite.............	1 to 5	2 to 6	78 to 92	10 to 15	12,000 to 13,500

The lignite briquettes represented in the table were made from a good grade of lignite, low in ash, which had undergone relatively complete carbonization. It may be said, however, that in order to produce results as satisfactory, care must be exercised in selecting lignite of low ash content, for in the carbonization, the ash is concentrated along with the fixed carbon in the residue. If, therefore, the ash content in the raw lignite is high, it will be greatly increased in the residue, and may be so high in an impure lignite as to reduce materially the calorific value and efficiency of the briquettes. Therefore, the selection of low-ash lignite for briquetting purposes is of great importance.

* E. J. Babcock, loc. cit., p. 58.

TABLE No. IX.

"ECONOMIC METHODS OF UTILIZING WESTERN LIGNITES."*

The results presented in the following table may be taken as representative of the bulk of semicarbonized lignite briquettes, amounting to several hundreds of tons, produced at the experimental station, and it may be said that briquettes of the quality indicated are readily produced from most of the lignite coals. The table covers tests of briquettes made from Montana, Colorado, Texas and a large number of North Dakota lignites.

RESULTS OF TESTS OF SEMI-CARBONIZED LIGNITE BRIQUETTES

Sample No.	Calorific value per pound.	Chemical Analyses.			
		Moisture.	Volatile matter.	Fixed carbon.	Ash.
	B.T.U.	Per cent.	Per cent.	Per cent.	Per cent.
1	11,642	3.85	19.08	66.82	15.25
2	12,137	4.15	17.65	64.10	14.10
3	......	5.43	18.18	62.56	13.83
4	......	4.83	15.25	64.10	15.82
5	......	5.55	14.45	65.55	14.45
6	......	5.80	14.87	64.48	14.85
7	......	5.72	15.48	63.08	15.72
8	11,557	6.50	22.10	59.30	12.10
9	......	6.65	17.77	62.80	12.78
10	......	6.30	16.21	64.39	13.10
11	......	6.05	15.21	64.69	14.05
12	11,981	3.90	15.83	64.77	15.50
13	11,669	3.57	16.23	65.03	15.17
14	......	5.97	16.25	63.46	14.32
15	......	5.38	16.70	63.82	14.10
16	......	4.97	14.44	64.96	15.63
17	......	4.35	12.21	67.49	15.95
18	11,926	6.18	11.35	68.13	14.34
19	......	4.80	14.09	66.01	15.10
20	......	5.65	16.27	63.80	14.28
21	......	5.12	16.76	63.92	14.20
22	......	4.78	14.66	65.90	14.66
23	......	5.08	17.04	63.65	14.23
24	11,599	5.85	12.20	67.38	14.57
25	12,024	4.83	12.22	67.50	15.45
Average	11,692	5.25	15.70	64.51	14.54

* E. J. Babcock, loc. cit., p. 59.

TABLE No. X.

"FUEL BRIQUETTING INVESTIGATIONS"*

CONCLUSIONS FROM LABORATORY TESTS.

Following are presented conclusions derived from the tests:

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 subbituminous coal; 7 per cent. was sufficient to satisfactorily briquet Utah subbituminous coal.

5. Three per cent. wheat flour made satisfactory briquettes from samples of Texas and North Dakota lignite; (*a*) 4 per cent. made satisfactory briquettes from undried Philippine lignite; and 5 per cent. was more than sufficient to make satisfactory briquettes from Washington subbituminous coal.

6. Cornstarch gave practically the same results as wheat flour, 3 to 5 per cent. being required to make a satisfactory briquet from the various fuels.

7. Four per cent. of hardwood-tar pitch made strong briquettes of Pittsburgh bituminous slack. The strong characteristic odor of this material may be an objection to its use.

8. Two per cent. of cell pitch made strong briquettes with Pittsburgh bituminous slack. As this material is soluble in water, it would not make briquettes suitable for storage in the open but if stored under cover the briquettes will stand up indefinitely. The effect of moisture on this binder being detrimental to its binding qualities, it is not surprising that 8 per cent. was required to briquet lignite from Texas and North Dakota, whereas 4 per cent. was sufficient to briquet a sample of Utah subbituminous coal. Six per cent. was required to briquet Philippine lignite and Washington subbituminous coal. The briquet having the greatest compressive strength was made of Pittsburgh slack and 6 per cent. of cell pitch.

* C. L. Wright, loc. cit., p. 95.

The briquet broke at a pressure of 3,800 pounds per square inch, whereas a 6 per cent. water-gas pitch briquet of this coal broke at a pressure of 2,220 pounds per square inch.

9. Three per cent. of sulphite liquor was sufficient to briquet Pittsburgh slack and 5 per cent. was sufficient to briquet anthracite culm. Less satisfactory results were obtained by mixing this material with lignites. It was found that 9 per cent. of this binder was not sufficient to briquet Texas, North Dakota or Philippine lignite. The moisture in these fuels seemingly affects the binding qualities of this material.

TABLE No. XI.

SOURIS AND NORTH DAKOTA LIGNITES

	% Moisture As mined.	% Ash Dry.	% Volatile Dry.	B.T.U. As mined.
Souris—Taylorton lignite*	23.3	7.2	32.8	8,300
North Dakota lignite†	32.5	6.6	38.7	
	32.0	7.7	38.1	
	32.5	6.6	38.7	
	31.4	8.1	41.1	
	32.0	7.7	38.1	
		7.7	38.1	
		11.1	36.0	
		8.2	31.0	
North Dakota lignite‡				
Average of 5 samples—P-31	32.7	7.6	26.2	7,243
" "8 " —P-33	38	7.3	24.9	6,580
" "3 " —P-43	27.9	9.95	27.1	7,364
Average of above—Max	38	12.5	44	8,300
Min	23	6.6	25	6,580
Average	32	7.5	35	7,300

* W. J. Dick, loc. cit., p. 16.
† E. J. Babcock, loc. cit., 89B.
‡ C. L. Wright, loc. cit., 14B.

Table No. XII.

Properties of Coals.*

		Moisture	Ash.	Volatile.	B.T.U.
Peat (on dry basis)	Max.	. . .	25%	70%	10,000
	Min.	. . . .	4%	55%	7,500
	Average	. . . .	10%	60%	8,500
New England					
Lignite (as received)	Max.	42%	11%	32%	7,500
	Min.	34%	4%	24%	5,300
	Average	37%	7%	26%	6,500
Montana-Dakota-Texas					
Subbituminous Coal	Max	33%	18%	35%	11,000
	Min.	17%	3%	24%	6,000
	Average	25%	5%	30%	9,000
Rocky Mountain Field					
Bituminous Coal	Max.	10%	17%	40%	13,000
	Min.	2%	6%	29%	10,000
	Average	6%	10%	36%	12,500
Rocky Mountain Field					
Bituminous Coal	Max.	9%	12%	42%	12,300
	Min.	4.5%	7%	34%	11,200
	Average	6%	10%	39%	11,700
Illinois Field					
Bituminous Coal	Max.	5.5%	15%	40%	14,500
	Min.	1.5%	5%	30%	12,500
	Average	3%	6%	37%	13,500
Appalachian Field					
Semibituminous Coal	Max.	4%	10%	26%	14,800
	Min.	1%	3%	17%	13,800
	Average	2.5%	6%	20%	14,600
Appalachian Field					
Anthracite Coal	Max.	4%	19%	12%	13,200
	Min.	1.5%	12%	8%	11,500
	Average	3.5%	15%	9%	12,000
Pennsylvania					
Carbonized Lignite Briquettes	Max.	5.6%	1 %	19%	12,140
	Min.	3.6%	12%	12%	11,500
	Average	5.25%	14.5%	15.7%	11,700
North Dakota (Babcock, p. 59)					
North Dakota Lignites	Max.	38%	1 .5%	44%	8,300
	Min.	23%	6.6%	25%	6,580
	Average	[illegible]%	7.5%	35%	7,300
As mined—Average of all available (Table No. 11, R. A. Ross)					

* A. C. Fieldner, loc. cit., p. 39.

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