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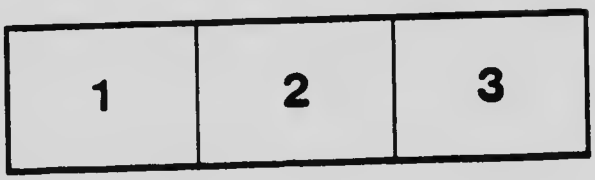

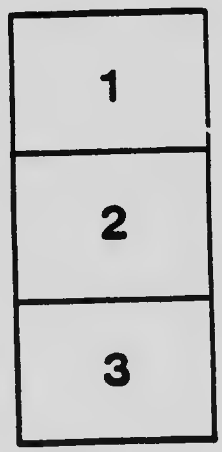

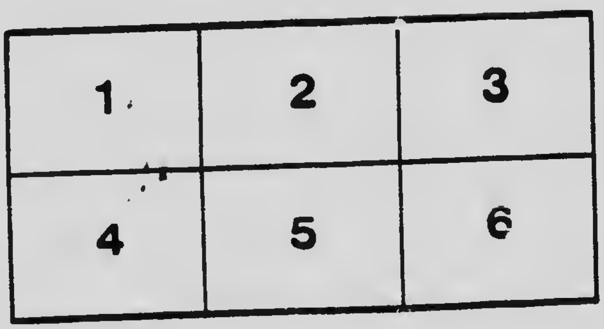

REPORT

ON

COAL AND POWER INVESTIGATION

BY

R. O. WYNNE-ROBERTS, M. INST. C.E.

Printed by Order of the Legislative Assembly

REGINA:
J. W. CRAM, Acting Government Printer.
1913

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REGINA, *November 23, 1912.*

HON. GEORGE BELL, M.L.A.,
Provincial Treasurer,
Regina, Saskatchewan.

SIR,—I have the honour to transmit to you herewith the report of an "Inquiry into the Practicability of producing Power at Coal Centres and distributing it throughout the Province," as provided under vote number forty, miscellaneous, 1912 estimates, and pursuant to an order of His Honour the Lieutenant Governor in Council of date April 25, 1912.

The inquiry from the nature of the case was confined to a great extent to the collection of scattered data the result of experiment on the part of a great many practical and scientific bodies and carried far afield wherever there was a likelihood of finding information that would help towards a solution of the problem, and but very little actual experimenting was done. The results are a compilation of this data and the conclusions that have been drawn therefrom.

The inquiry naturally divided itself into various parts and investigation was made of each of these as far as information could be obtained.

The following is a schedule roughly outlining an analysis of the problem and showing the various parts of the investigation as above with the pages set opposite where the date and the discussion thereon will be found.

I beg to especially call your attention to page 90, where the conclusion is arrived at as to the most promising method of treating the lignite in transforming it into power ready for transmission, where it is shown to be by means of producer plants and the use of the gas in the gas engines with steam engines as auxiliary to carry part of the load. It would seem that further investigation and experiment following this line is exceedingly desirable.

An important finding of the inquiry is also included on page 127, which deals with the commercial possibility of the manufacture of lignite coal gas and its distribution through gas mains to the various centres.

An important point worthy of special attention is found on page 126 which shows a comparison between the cost of power generated at a distance from the possible market so far away as Estevan and the cost where generated at a point much closer.

A synopsis of the data collected as to the use of lignite for power will be found on pages 93 and 94 and the conclusions and recommendations on the last four pages of the report.

Respectfully submitted,

Your obedient servant,

A. J. MCPHERSON,

Chairman of the Board of Highway Commissioners.

REGINA, *November 15, 1912.*

A. J. MCPHERSON, ESQ.,
Chairman Board of Highway Commissioners,
Parliament Buildings,
Regina, Sask.

Lignite Investigations.

SIR,—I beg leave to submit the following report on the investigation, which I made on your instruction, into the question of developing power at the lignite coal fields of Saskatchewan.

INSTRUCTION.

I am informed that early this year an appropriation of $3,000 was voted by the Legislature "To provide for Inquiry into the Practicability of producing Power at Coal Centres and distributing it throughout the Province."

It will be observed that the inquiry according to the above wording is limited to practicability, but there is no doubt that this is not to be interpreted in its literal sense but from a financial and commercial point of view as well.

PRELIMINARY REMARKS.

In accordance with your instructions I commenced making investigations in the Province and collecting data from other parts of the world where lignite is found, as to what is being done and the methods adopted to utilise such fuel for power and other purposes, so as to be in a position to assimilate the information obtained and to present the same in a concentrated form for your perusal and consideration.

It is desirable at the outset to state that although several individual and spasmodic efforts have been made during the last few years to utilise inferior coals in Canada, reliable particulars to be obtained as to the results are meagre: moreover until the Canadian Department of Mines made investigations at McGill University, Montreal, under the direction of Messrs. Porter, Durley and others, no scientific tests had been made with local lignites to ascertain what results could be expected, and even these investigations were not comprehensive so far as the Saskatchewan fuels are concerned.

The same remarks can be made with reference to United States lignites, for until 1904, with the exception of Texas investigation, no comprehensive investigations were made relating to the value of inferior coal. Since then the United States Government has voted several annual appropriations to enable the Geological Survey Department, and later, the Bureau of Mines to conduct many experiments, reference to which will be made in another part of this report. The Texas State Government in 1890 authorised investigations to be made into the use of lignite which were conducted by Mr. E. T. Dumble, the State Geologist; these also will be dealt with later on. The North Dakota State Government in 1909 made an allowance to the University of North Dakota for investigations into the best methods of using lignite, the result of which were reported upon by Prof. E. J. Babcock in 1911 and will be discussed in the appropriate part of this report.

The Victorian Government some time ago had a report prepared by a London Engineer on the use of lignite for development of power.

The principal countries where lignite has been utilised are Italy, Austria, Hungary and especially Germany. Some literature has been received from the last named country and in the short time which has elapsed since they were received the more salient facts contained therein have been translated and will be incorporated in this report.

The work entailed in the assimilation of the information acquired, in collecting further data and in analysing the same so as to be presented in the following pages has been one of considerable labour but of great interest and pleasure to the writer.

CHEAP FUEL AND POWER.

It would seem superfluous to postulate that cheap power and fuel are very important factors in the industrial and commercial development of any country. There are abundant examples to show that such is the case. Still it is desirable to refer to a few points in this connection before discussing the situation as it concerns the Province of Saskatchewan.

Industrial progress is largely dependent on the cost of production, and in this respect the cost of power and fuel plays an important part. There are, of course, several other factors which have a large influence on the development of industry and commerce, such as cost of raw material, labour, transportation, etc., but it will not be possible in this report to analyse the relative value of these, excepting in an incidental manner.

The industrial development of Great Britain is mainly due to the cheapness of fuel, raw material, labour and transport. The coal production in 1911 amounted to about 300,000,000 tons. The coal is anthracite and bituminous and as the deposits to be found in Great Britain are being gradually exhausted, attention is being paid to the use of coal wastes, etc., which were formerly dumped over the tip as worthless. The cost of coal is low at the pit mouth, despite the enormous expenditure involved in the machinery, deep shafts and an increasing labour bill, yet the most inferior of slack and washery-refuse are now being consumed in considerable quantities for the development of cheap power. As one instance of the influence of cheap fuel and power the North-East Coast (England) Power system may be referred to. There are seventeen generating stations belonging to this Company, of which six are coal-fired stations and the remainder waste heat stations, where steam for generating the electricity is obtained either from exhaust steam that has already done work in blowing or other engines or by steam raised by blast furnace gas or from the waste heat and gas from coke-ovens; the total horse power connected amounts to nearly 200,000. The engineer in his description of the work pointed out that cheap fuel is of paramount importance and expressed his opinion that the future of electricity supply lies in the very large stations employing very big units of plants and established at the coal-fields. The above electrical installations have afforded facilities which have attracted several new industries to be located within the area of supply. The same remarks are applicable to the manufacture and distribution of gas, which is being adopted more generally each year.

In Germany, the supply of high class coal is not so well distributed as in Great Britain, but there is a plentiful supply of inferior fuel such as lignite, etc., and here science and art have been so developed in the utilisation of poor fuel that immense power plants are now in operation, and others projected. The production of coal in Germany has in thirty years increased from 68,000,000 tons to 245,000,000 tons. In the same period development of water power has also been great and the transmission of gas under high pressure is rapidly becoming a feature in up-to-date methods of cheap fuel and power distribution.

The United States, being so near, is perhaps better known to the general public. It is noticeable that the value and conservation of cheap fuel and power in the States are being more fully appreciated each year. When it is borne in mind that coal in the States of Illinois, Ohio, Pennsylvania, Virginia and Alabama, during the year 1910 averaged in price $1.08 per short ton at the mines, it will be better understood why these States occupy such prominent positions in the industrial world. The cost of transport in these States is not a serious item, for the cost of bituminous coal according to quality purchased, ranges from $1.50 to $3.00 per ton f.o.b. New York Harbour. Coal in large quantities can be had in Pittsburg for $1.00 a ton, but even in remote parts of the above-named States the cost averages under $3 per ton. The supply of natural gas was at one time abundant and cheap, but extravagant waste has led to serious depletion and increase in price. Waterpower has been developed in some of these States with the result that the cheap electrical power which is available, has contributed considerably to the development of the country around. As already stated the movement in the United States towards the utilisation of poor fuel is becoming stronger each year, and the result is the establishment of power plants where formerly it was not thought possible, and this is opening out new industrial centres to the advantage of all concerned. As an indication of the magnitude of the use made of cheap gas in the States the following figures may serve to emphasise the foregoing statements.

1909	
Producer gas for gas engines, heating open-hearth furnaces, and gas retort benches	
for power only	35,000,000,000 cubic feet
for heating only	100,000,000,000 cubic feet
Blast furnace gas	2,900,000,000,000 cubic feet
Natural gas	480,707,000,000 cubic feet

The coal production in the States has in thirty years increased from 86,000,000 tons to over 500,000,000 tons. The use of anthracite coal is not increasing and is rapidly being replaced by cheap bituminous coal, except for domestic use.

DEVELOPMENT AND NEEDS OF SASKATCHEWAN.

The Province of Saskatchewan has developed in a remarkable manner during the last few years and there is every prospect for a continuation of its development in the future. There are, however, conditions which will tend to retard its progress and development and those are mainly the cost of fuel and therefore power, and cost of living and therefore labour. The extraordinary expansion of agricultural industry and the great extension of railways now create an increasing demand for labour but in time this will be adjusted. The natural sequence to railways expansion and Provincial progress will be the establishment of mills, factories, electro-chemical works and other forms of enterprise which will need cheap fuel and power. Where industries are located these elements must be found or such enterprises will decay, to the great disadvantage of the community. A growing population necessarily calls for various local industries to provide for its daily wants, and at the cheapest rate, and this tends to make the variety of local industrial enterprises interdependent and mutually helpful.

The cost of imported fuel renders it commercially difficult to run industries in this Province unless the price of the products are high and this directly or indirectly reacts on every other form of provincial enterprise. Virginia coal which costs less than $1 per ton at the mine, costs about $8 per ton in Regina. Pennsylvania anthracite costs about $2 at the mine, whereas in Regina it costs $12 per ton. More or less the same costs are prevalent through the Province. Alberta coal, of course, costs less, but more must be consumed to obtain similar results. The cost of railroad transportation constitutes the bulk of the increase in the price of coal in this Province.

As is well known Saskatchewan has no local supply of bituminous coal and up to the present by far the greater part of fuel consumed is imported either from the States or from the vicinity of the Rocky Mountains, both of which entail long haulage and heavy freightage.

It is, however, an interesting coincidence and a consideration of great economic importance that in those parts of North America and more particularly the central Prairie Provinces, which are so remote from the fields of superior coal, lignite—and in some parts peat also —is found in large quantities; and it needs only to ascertain the best method of utilising them to obtain the best results, when the absence of superior coal will be compensated by the presence of fuel which will cost less for equal power.

Before entering on this phase of the report it will be necessary to discuss one or two matters, which have a bearing on the problem under consideration.

GEOLOGY OF WEST CANADIAN COAL FIELDS.

Early pioneers in their travels across the plains and down the rivers discovered coal in different parts of the country now included in the Province of Saskatchewan, but the information is somewhat indefinite as to the localities referred to.

In 1857 Sir James Hector found coal at Souris River near the present mines.

A most interesting report on the lignite deposits is that prepared by Dr. G. M. Dawson in 1875 in connection with the International Boundary Commission.

Since that time much investigation has been made which is covered by a report prepared by Mr. D. B. Dowling on "The Coalfields of Manitoba, Saskatchewan, Alberta and British Columbia," dated 1909.[1]

Mr. Dowling in his report made the following statement concerning the geological formation of the Prairie Provinces:

"The geological structure of the area was roughly outlined by Sir James Hector, but to Dr. G. M. Dawson, R. G. McConnell, and J. B. Turrell fell the lot of making the detailed examinations which gave us a true insight into the structure and a real distribution of the measures. The coal is found in three distinct horizons in the Cretaceous, separated by shales of marine origin. The lowest is practically the base of the formation, and is considered Cretaceous from its fossil flora; though it lies just above the Fernie shale, now understood to be of Jurassic age. The line of demarcation is not very sharp, as the shales in their upper part become interstratified with sands, and gradually pass into a sandstone formation containing coal seams—called by Dawson the Kootanie. The age of the Kootanie, if not Jurassic, must be early Cretaceous. Above this the Dakota does not appear to be coal-bearing in an economic sense, and not until near the top of the Belly river or Judith river formation is reached does there appear to have been land conditions of sufficiently long duration for the growth of material to form coal beds. The coal horizon in the Belly river contains but a few workable seams; but its areal distribution makes it important. The third coal horizon is at the top of the Cretaceous, and includes part of the old Laramie formation. The upper part in Alberta is a fresh-water deposit, and is classed as Tertiary, under the name of Paskapoo formation, and is not distinctly coal-bearing. What is believed to be the same horizon as the lower Laramie, bears many lignite seams, and in Alberta is given the name of Edmonton formation, the highest member of the Cretaceous."

LIGNITE FIELDS IN SASKATCHEWAN.

The following notes are taken from Mr. D. B. Dowling's report already mentioned:

"The three provinces to the east of the mountains although generally called plains, are in reality undulating table-lands, which may be divided roughly into four topographic divisions:

"The first consists of a plain lying upon the Archean floor, from which all but the Palæozoic rocks have been removed; and in Manitoba this is smoothed over by deposits of glacial drifts and by the sediments laid by the glacial lake Agassiz.

"The second is a plateau which has for its eastern edge the northeastern escarpment of the Cretaceous shaly deposits.

"The third division is more diverse in character; but is roughly outlined on its eastern edge by the elevation known as the Coteau. The rocks which are exposed throughout this division have a larger proportion of sandstones among them than in the second. To this, no doubt, is due the greater relief in the topography.

[1] Canada Department of Mines, Ottawa.

"The fourth division may be called the foothills area, and the character of its topography is due more to the structure than to drainage denudation. The foothills consist generally of ridges of inclined strata running parallel to the Rocky Mountains, cut through at intervals by stream valleys."

TABLE OF FORMATION.

	Groups.	Saskatchewan.	Kind of Rocks.	Character of Fossils.
Tertiary	Miocene Eocene	Miocene Laramie	Conglomerates and sandy clays	Land and fresh water
Cretaceous	Montana	Pierre-Foxhill Belly River	Sandstone and clay shales Sandstones	Land plants Brackish water Marine Brackish and fresh

"The lower Cretaceous consists of sandstones, and brown and black shales in which are numerous coal seams. These rocks do not appear east of the foothills.

"The middle part of the Cretaceous, consisting of shales of marine origin, forms the plateaus extending from the mountains to within the borders of Manitoba. The general topography, with its deeply incised valleys, is derived mainly from the erosion of these soft rocks.

"The upper part of the Cretaceous section, although for the most part marine shales, grades upward to sandy measures of brackish water origin. The harder beds of this upper part form many of the stronger topographic features, both of the foothills and plains. Few exposures are to be found in the mountains, where they have been almost entirely removed by erosion.

"The Tertiary rocks are littoral deposits—sandstones with some shales and conglomerates. Exposures are to be found in the higher plateaus such as the Cypress Hills and Wood Mountain, and in the trough which extends North from the international boundary in the foothills, including the Porcupine Hills, and the sandstones of Calgary. The northern extension crosses the Saskatchewan west of Edmonton.

"The later deposits such as the glacial till and the Saskatchewan gravel, will be but briefly mentioned. The glaciation of the mountains spreads a mantle of till through the foothills. The till of the Keewatin glacier does not always reach the eastern margin of the Rocky mountains till, and they are possibly of two distinct periods. The eastern derived till is thin on the uplands, and often appears to have been rearranged by deposition in water. Morainic deposits occur on the Coteau in eastern

Saskatchewan, and in Manitoba. Glacial lake phenomena have been observed at several parts; but the Lake Agassiz beaches of Manitoba, and the upper Red River, have formed the subject of several interesting reports.

"The economic value of the rocks of the Cretaceous, exposed as they are over an enormous area, lies chiefly in their coal-bearing beds. Although mainly sea deposits, there are three horizons which show land conditions and evidences of plant life, and in these beds coal seams have been found.

"A marine invasion of the central part of the continent during Cretaceous time was preceded in the then existing low trough of the present Rocky Mountain area, by an abundant flora, so that the early Cretaceous was coal-bearing.

"These beds—known as the Kootanie series—were subsequently covered with a series of marine shales deposited by an invasion of the sea; but a shallowing of this sea over the western part also brought about land conditions again in later Cretaceous times and vegetation spread eastward; which was in turn buried by shales in the last invasion by the sea.

"This second flora is reserved in the beds of the Belly River formation, and in places forms important coal deposits.

"At the close of the Cretaceous times, when the continent finally emerged from this sea invasion, and while the land surface oscillated slightly at or near sea level, another mantle of vegetation covered the low ground.

"Coal seams were then formed, and in the rocks which succeed these coal beds, impressions of leaves, stems and petrified wood, show an increasingly changeable climate, and probably an increasing altitude.

"The last deposits of the Cretaceous and the early ones of the Tertiary form the third coal horizon, and include the Edmonton and lower Laramie."

"The three coal horizons thus found are:

Edmonton-Laramie formations.
Belly River formations.
Kootanie formations.

"The second coal horizon lies above the Kootanie, and is separated from it by dark marine shales, which represent a period of depression in which this part of the continent was below sea level. The rise which followed was arrested when the surface of this deposit reached sea level, and vegetation again spread over the plain. The remains of this vegetation, compressed to coal, form an important field; for although the seams are not thick, the quality in the western portion of the exposed part is above the general average of lignite, and approaches true coal. In Saskatchewan it has so far been found to contain very thin seams of inferior coal in the northern part of the area, and possibly a 4 foot seam in the southern border.

"The principal exposures of coal in this formation are on the Belly River near Lethbridge. The coal is of a better grade than in beds above it in the same vicinity.

"The continuation of the beds eastward under the rocks of the plains can only be conjectured, but it is thought that they may thin out considerably and lose their coal-bearing character. Such occurrences as the drift coal below Prince Albert and coal in the drift near Souris, Manitoba, are possibly evidences of this continuation.

"In Saskatchewan the Laramie formation occupies the summit of some of the plateaus, and portions of elevations such as the Cypress Hills. It is quite evident, that from a great portion of the plains these rocks have been worn away, and what remains is merely the lower portion of the formation which is generally coal-bearing.

"The exposures of Laramie coal are mainly in the southern portions of Saskatchewan and Manitoba. Besides the areas shown on the map, it may be noted that, others in the north, especially on the summits of the more elevated portions, may be found by boring through the surface soil and the possibilities of supplying the northern parts of the treeless country with serviceable fuel will be much increased. Reports of coal seams having been found in well borings near Prince Albert, have also been heard, but no definite information is at hand.

"In the Cypress Hills, and on the Coteau, these beds occur in the elevated portions of the country; but east of the Coteau there seems to be a basin in which they dip down to the east, and so underline the area traversed by the Souris River. The erosion of the valley of this stream in its great bend south into Dakota has separated the Souris area from its continuation in southern Manitoba, which is found again in Turtle Mountain.

"The area that is best known is the vicinity of Estevan on the Souris. Mining has been carried on here for several years. The seams are found exposed on the river banks, and located elsewhere by boring. Over a large part there are, per section, at least 7,000,000 tons of lignite available. Eight townships of this vicinity would, therefore, have a possible 2,000,000,000 tons. Coal will be found north to near Weyburn station, and west of this outcrops have been recorded on the Souris in township 3, range 15. Along the international boundary, in about the same longitude, seams are exposed on Big Muddy creek, draining Willow Bunch Lake. These are of low grade lignite, and the seams are respectively 3 feet and 5 feet in thickness. At the crossing of Popular River in township 1, range 29, west of the second meridian, there is an exposure of an 18 foot seam of lignite of about the same quality of coal as at Souris River.

"Near the old Mounted Police post at Wood Mountain, seams of 6 and 5 feet respectively have been opened, and have proved good domestic fuel. The same may be said of exposures at Willow Bunch settlement, west of this the lignite beds underlie portions of the Swift Current plateau. In the Cypress Hills a 4 foot seam is recorded at the head of Lodge Pole creek; so that, with the scattered areas in which coal seams have been found, exclusive of the Souris area, there are nearly 4,000 square miles on which there is good chance of finding coal. This area is capable of producing, for every foot thickness of coal worked, 3,7[illegible]00,000 tons, which, with the smallest workable thickness of 4 feet, m[illegible] 5,000,000,000 tons.

"The south-eastern or Laramie format[illegible] extends along the international boundary from the Manitoba boundary to Wood Mountain, and according to the map issued by the Geological Survey Department the lignite area lies west of a line drawn from the international boundary to Oxbow, thence to Lampman, Weyburn, Forward, Avonlea, and east of Johnston Lake, Lake of the Rivers, Twelve-mile Lake to Wood Mountain. There is a narrow strip extending from Wood Mountain west and another from near Lake Johnston north-west.

In the course of these inquiries information was received as to deposits lying outside the above area, but owing to other more important matters in this connection there has been no opportunity of confirming the reports, but there appears to be no doubt that the distribution is even greater than as above stated.

Moreover, deep wells have been sunk in Estevan and at Taylorton and the strata gone through show that lignite is to be found at considerable depths. The boring in Estevan town shows 8 feet of soft coal at 41 feet below the ground surface, and 4 feet of harder coal at 45 feet depth, but no further deposits were found down to 874 feet. At Taylorton a 7 feet 9 inches seam of coal was found at 64 feet below the surface; 1 foot 6 inches thick at 77 feet depth; 3 feet 3 inches at 199 feet below the surface; 6 inches at 275 feet; 7 inches at 303 feet; 1 foot 6 inches at 488 feet; 2 feet at 593 feet; 4 feet at 623 feet; 1 foot 4 inches at 698 feet.

In another instance it is reported that a well was sunk at the Estevan Coal and Brick Company's yard where a lignite bed 9 feet thick was found at 10 feet below the surface; 3 feet thick at 20 feet depth; 5 feet thick at 53 feet depth, and 10 feet bed at 570 feet depth.

At Ogema 6 inch seam was found at about 250 feet depth. At Oxbow 6 inch seam at 300 feet, and in other places in same area at about similar depths.

There are a number of mines being worked and several which have been opened by local farmers for a supply of fuel, whilst the bulk of the area remains untouched. In Bienfait mine on section 19, township 2, range 6 west of the second meridian, the seam is 14 feet thick, whilst a little over one mile east it is said to be 22 feet thick. About 20,000 tons are produced per annum at this mine, but the capacity, of the plant is stated to be equal to a much larger output. At the Manitoba and Saskatchewan mine the seam is from 10 to 15 feet thick at a depth of about 86 feet. The output last year was slightly under 80,000 tons. The seam of lignite at the Western Dominion Mine at 90 feet deep is 7 feet 6 inches thick. The output in 1911 was slightly over 100,000 tons. The Consumers' Coal Mine on section 36, township 10, range 28 west of the second meridian, was opened last year. The seam outcrops on the east bank of the Lake of the Rivers and is 6 to 8 feet thick.

Time has not sufficed to enable a careful survey being made of the southern part of the province, but there is no doubt that the deposits of lignite extend more or less toward the border of Alberta.

Mr. Rand carried out some prospecting work on Mr. A. S. Porter's lan near the international boundary and south-west of Estevan. He found seams of coal ranging in thickness from 1 foot to 4 feet 8 inches, but in his report he did not express any conclusive opinion as to the probable areal extent of the deposits. A sample of lignite was sent to the University of Illinois and a report by Mr. Ralph K. Huish, dated March 23, 1912, was sent by him to Mr. Porter giving the results of laboratory tests, which were as follows:

	As Rec'd	Dry coal
Moisture	22.58	——
Volatile Matter	35.44	45.79
Fixed Carbon	37.04	47.84
Ash	4.94	6.37
Sulphur	0.33	0.43
British thermal units	8,570	11,069

Mr. Huish in his report on the clay and [illegible] expressed his opinion that "As shown by the analysis the lignite is of very good quality with a low ash and sulphur content and a good heat value. It compares very favourably with some of the steaming coals in this section and is a good fuel for general use. The proximity of the fuel to the clay in this case makes an excellent proposition for development. The cost of mining will not be high and the clay is necessarily removed to get the coal."

The above analysis is somewhat similar to those obtained from other lignites in the district (see table on page 18) and the remark that, "it compares very favourably with some steam coals in this section," requires some qualification.

The Belly River formation on the north-west of the province, according to the map issued by the Canadian Geological Survey, extends along the Alberta frontier from Walsh (20 miles west of Maple Creek) in the south to about 18 miles north of Macklin in the north. The eastern boundary is roughly from Walsh to South Saskatchewan River about 15 miles east of Saskatchewan Landing) thence to White Bear Lake; it approaches near Perdue, Wilkie and Swinburne and then turns West to the Alberta Boundary. This comprises an area of about 1500 square miles and the deposits of lignite have been computed by Mr. Dowling to be about 3,000,-000,000 tons. There are indications that the distribution of lignite may extend outside this area also, but unfortunately careful records have not, in most cases, been kept by well-sinkers, and in some cases the information obtained by sinking is not made available. At Salvador lignite beds 6 feet thick were found at a depth of 200 feet and 3 feet thick at 300 feet deep. Although many letters were addressed to persons resident within this area inquiring for information as to discoveries of lignite, as a rule the replies were negative but this is by no means conclusive evidence, for in some cases data was obtained from railway officials and others which evidently indicate that there are deposits of lignite which are workable. Prospecting and development will no doubt reveal more lignite beds, and until this takes place it will be difficult to fix on a location for the establishment of power-plant for the northern parts of the province.

Since writing the foregoing, a copy of the report of the Canadian Geological Branch of the Department of Mines for 1911 has been received and in it there is a paragraph with reference to lignite deposit found in the Belly River formation in the vicinity of Brock on section 22, township 28, range 20 west of the third meridian. A well was sunk on the top of a hill and coal from 7 to 10 feet thick was found at a depth of 130 feet. A sample was analysed and the results were:

Moisture	25.70	per cent.
Volatile matter	26.95	per cent.
Fixed carbon	28.42	per cent.
Ash	18.93	per cent.
	100.00	

Mr. Dowling states that it is quite evident "that if only samples of the solid coal were taken the ash content would be much reduced. The locality is on the unforested area, and this field although of about the grade of Souris coal, would be valuable to the surrounding district. Mining would be expensive on account of the lack of timber, but as the country is dry there seems to be no great need for expense in drainage, and the roof, although clay, stands up well.

This coal find is about 100 miles south-west of Saskatoon and is the nearest present exposure of coal to that city. It is about 90 miles south west of Battleford.

The southern lignite field of Saskatchewan is fairly well intersected by railroads. The Canadian Northern Railway from Moose Jaw to Forward runs almost parallel with the eastern outskirts of the lignite regions. The Canadian Northern and Canadian Pacific Railways from Avonlea and Lampman and from Weyburn and Estevan respectively cross the field east to west. The Grand Trunk Pacific will cross the southern portion and be in direct communication with Regina. These railways will no doubt do much to open out new mines, if the demand for lignite should increase.

The western lignite field is also provided with railroad facilities. The Canadian Northern Railway from Alsask to Saskatoon, Grand Trunk Pacific from Swinburne to Saskatoon, Canadian Pacific from Macklin to Saskatoon, and Macklin to Rosetown and other lines which are projected and will soon be built within this area.

When the western lignite field is more fully prospected and market found for the fuel, these and new railways will afford the necessary facilities for transport.

DESCRIPTION OF COAL.

The various kinds of coal to be found in Canada and elsewhere are divided by many authorities into several classes according to their composition, without regard to the geological age to which they belong, although such classification nevertheless bears some relation to the formations in which they are found. In general terms coals may be classified according to the geological period during which they were formed:

(1) Recent fossil coal, such as peat and lignite.

(2) Older fossil coal, such as bituminous coal and anthracite.

As the dividing line between the different coals is in many cases most difficult to define, the United States Geological Survey in their report on "Coal Testing Plant" 1906 endeavoured to establish some ratio as to quality, such as "Fuel Ratio," "Fixed Carbon," "Calorific Value," "Hydrogen," "Carbon," but finally provisionally proposed "The Carbon-Hydrogen Ratio" as the basis of a new "Scientific classification of coals which is applicable to all, from the highest class of anthracite to the lowest grade of brown lignite and peat." The percentage of hydrogen decreases as the percentage of carbon increases, and both are valuable as fuel elements.

This ratio is $\frac{C.}{H.}$

C = percentage of Carbon.

H = percentage of Hydrogen.

The British classification is a ratio between oxygen and hydrogen together with that of carbon contents of coal. To arrive at the above ratios it means that ultimate analyses must be made of coals to ascertain the proportions of hydrogen, carbon, nitrogen, oxygen, sulphur and ash contained therein. But these particulars are not always available and some other ratio is required so as to correlate the relative value of local coals.

A large number of proximate analyses have been made by different authorities to obtain the proportions of fixed carbon, volatile matter, moisture, sulphur and ash. Proximate analyses are more readily made and do not require as great skill or knowledge of chemistry.

Mr. D. B. Dowling has suggested another ratio which is based on proximate analysis, which is—

$$\frac{\text{Fixed carbon plus } \frac{1}{6} \text{ volatile combustible.}}{\text{Moisture plus } \frac{1}{2} \text{ volatile combustible.}}$$

This formula as will be perceived takes into reckoning the quantity of moisture in coal which is an important factor when contrasting lignite with other coals.

Adopting Dowling's ratio the classification of coal will be as follows:

Anthracite	Dowling's ratio	15 up
Semi-anthracite	"	13 to 15
Anthracite coal	"	10 to 13
High carbon bituminous	"	6 to 10
Bituminous	"	3.5 to 6
Low carbon bituminous	"	3 to 3.5
Lignitic coal	"	2.5 to 3
Lignite	"	0.75 to 2.5
Peat	"	below 0.5

Peat is partly decomposed and disintegrated vegetable matter that has accumulated in any part where the ordinary decay or chemical decomposition of such material has been more or less suspended, although the form and a considerable part of the structure of the plant organs are more or less destroyed.[1]

Peat varies in colour from brown to black and in texture from light, spongy, friable, fibrous matter to forms that are nearly or quite devoid of structure and when wet are as plastic as clay and when dry form dense, hard masses resembling lignite. Peat in its raw condition contains upwards of 80 per cent. of water.

Lignite or brown-coal whether considered physically or chemically may be justly regarded as a substance intermediate between peat on the one hand and bituminous coal on the other. There are no hard and fast lines of division between these substances, but each grades into the other by such small differences that it cannot be said where one ends and the other begins. Indeed, so closely do certain varieties of each simulate the other, that there is no test which can decide between them as to which is bituminous coal and which is brown coal and the determinations can only be made by their geological relations.[2]

Lignite varies in texture from the appearance of undecomposed wood to tough structureless coal, and in colour from brown to pitch black lustre.

There are several varieties of lignite which are generally named according to appearance, structure and fracture. Such as pitchy coal (pich-Kohle), slaty coal (Schuler Kohle), earthy, slab lignite (platteau-Kohle) and it is probable that Saskatchewan lignites are similar to the German and Austria pitchy coal. Cannel coal which is valuable for manufacture of rich gas, and jet which is often worked up into articles of ornaments belong to species of lignite.

[1] Bulletin 16, "Uses of Peat," U.S. Bureau of Mines, 1911.
[2] Brown Coal and Lignite, Edwin T. Dumble, Texas, 1892.

The character of coal changes with the age of formation and the thickness of the overlying material, but there is another important element which contributes to the changes and that is the lateral disturbance and pressure which took place in the physical features of the country. This upheaval which caused the formation of Rocky Mountains produced such a disturbance and pressure as to alter the character of the coal and thus cause it in the vicinity of the mountains to grade from lignite to true coal. "In the undisturbed regions the coals are lignites but grade from those bordering on true coals in the west to poor lignite." The Belly River coals are generally of better quality than the Edmonton-Laramie class.

Bituminous coal constitutes the world's most valuable class of fuel, owing to its wide distribution and use. It is not particularly hard and as a rule is brittle, causing a considerable proportion of fine coal or slack to be produced when mined. There are several varieties of coal of this class, and these have their special application in connection with industries. Non-caking coal, caking coal, gas coal, etc., have each their own adaptability for various purposes.

Anthracite coal forms a transition stage between the bituminous and true anthracite. The latter represents the last step in the formation of coal.

The changes from woody tissue to anthracite will be shown by the following table.[1] 100 parts of carbon in each class of fuel is taken as the basis of comparison.

	Carbon	Hydrogen	Oxygen
1. Wood, average of 6 analysis	100	12.18	83.07
2. Peat . . .	100	9.85	55.67
3. Lignite average of 15 varieties	100	8.37	42.42
4. Staffordshire coal	100	6.12	21.23
5. Steam coal from South Wales	100	5.91	18.32
6. Semi-anthracite from South Wales	100	4.75	5.25
7. Pennsylvania anthracite	100	2.84	1.74

It is evident from the foregoing that as the change from wood to coal progresses the value of the product as a fuel increases. "The gradual elimination of the hydrogen and oxygen of the plant tissue out of contact with air would, if it proceeded regularly and naturally for a length of time sufficiently great, cause the wood fibre to pass successively through the stages of peat, brown coal, bituminous coal, and anthracite. This process may be accelerated by heat, moisture and pressure, or it may be impeded or entirely stopped by exposure to atmospheric agencies or oxidation.[2]

As confirmatory evidence it may be stated Dr. Berguis, of Hanover, read a paper before the Inorganic Chemistry Section of the Association of German Chemists at a meeting held in June, 1912, and in it he referred to a laboratory method of producing coal. The experiment consisted in heating organic substance—such as wood, cellulose or peat—with water under high pressure. For instance, peat as dug, containing some 85 per cent. of water was heated to 660 degrees Fahrenheit in the bomb, super-heating being avoided. Thus carbonisation was prevented, the heat liberated, which would otherwise cause carbonisation being absorbed by the water. But since the vapour pressure of water at temperature above 570 degrees Fahrenheit is upwards of 100 atmospheres, a pressure exceeding the latter

[1] Grove & Hoop, Chemical Technology.
[2] Bro— Coal and Lignite, Edwin T. Dumble, Texas.

was employed. Coal precisely similar to natural bituminous coal, was thus obtained from peat, with the simultaneous liberation of gases consisting chiefly of carbonic acid and methane. The composition of the coal produced varied with the temperature and duration of the heating. The carbon in the artificial coal was higher and the oxygen and hydrogen lower with the increase in the time and temperature of heating.[1]

According to Mr. D. B. Dowling the coal fields of Canada may be grouped roughly into four great divisions:

	Tons estimated
1. The Maritime Provinces, Nova Scotia and New Brunswick:	
Bituminous coal only . .	3,500,000,000
2. Central Plains and Rocky Mountain, Manitoba, Saskatchewan, Alberta and British Columbia:	
Anthracite.	400,000,000
Bituminous.	30,000,000,000
Sub-bituminous and lignite. . .	100,000,000,000
3. Pacific Coast and Western Mountains:	
Anthracite. . .	61,000,000
Bituminous.	40,000,000,000
Lignite.	500,000,000
4. Arctic-Mackenzie basin:	
Lignite only. .	190,000,000
Total.	174,951,000,000

Lignites and sub-bituminous coal therefore constitute 57 per cent. of the whole of the coal in Canada.

As the quality of the fuel available for use has a most important influence on the results to be obtained in the development of power it was necessary to collect the results of analyses made by various authorities and to carry out some independent tests.

In this case, owing to the delay in the delivery of a calorimeter and other appliances necessary for this purpose, the number of such tests are comparatively few.

The quality of a fuel depends on its calorific value, proportion of impurities and moisture content. Its hardness, liability to weather, transportability and the effect of handling are also important factors when evaluating coal for industrial and domestic use. The following analyses of local lignites have been collected together so as to afford some means of comparing the results obtained.

[1]Journal fur Gasbeleuchtung and Journal of Gas Lighting.

ANALYSES OF LIGNITES IN BELLY RIVER FORMATION

	Proximate					Ultimate						
Source of Lignite	Dowling's Ratio	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulphur %	Hyd'gen %	Carbon %	Nitrogen %	Oxygen %	Calorific Value B.T.U.	Authority
Taber Coal Mines, Alta.	2.46	7.21	39.18	46.36	7.22	....	....	....	....	....	....	Dowling
South Saskatchewan River 10½ miles above Medicine Hat	1.94	17.70	29.96	48.56	[illegible].81							Dowling
South Saskatchewan River 10 miles above Medicine Hat	1.83	16.82	31.90	43.98	7.30						9,259	Dowling

Selection of Coals from other formations, for the purpose of comparison

Source of Lignite	Dowling's Ratio	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulphur %	Hyd'gen %	Carbon %	Nitrogen %	Oxygen %	Calorific Value B.T.U.	Authority
Hill Crest Mine, Edmonton	....	2.00	21.50	64.50	12.00	....	....	....	....	....	13,197	Parsons
Clover Bar Mine, Edmonton	1.55	19.60	31.12	39.02	10.26	0.34	....	....	....	....	8,870	Parsons
Honour Banner Mine, Edmonton	1.60	18.35	35.15	39.92	10.28	0.32	....	....	....		9,010	Parsons
Dawson Coal Mine, Edmonton	1.59	19.39	33.62	40.59	8.61	....	....	....	....		8,900	Parsons
Twin City Mine, Edmonton	1.60	16.79	37.71	38.04	7.46	0.36					9,460	Parsons
Pocahontas, Virginia	7.00	3.0	31.65	60.82	4.48	0.67	5.17	80.35	1.59	7.74	14,470	U.S. Geo.Sur.
Wilton Mine, N. Dakota	.778	35.90	31.92	24.37	7.75	1.15	6.54	41.43	1.21	41.92	7,069	U.S. Geo.Sur.
Cedar Coulee Mine, N. Dakota	.87	36.13	29.28	29.55	5.01	.59	6.60	42.00	0.73	45.04	7,326	U.S. Geo.Sur.
Hoyt, Texas	.95	33.85	27.50	31.35	7.30	.51	6.68	43.12	0.71	41.68	7,497	U.S. Geo.Sur.
Alba, Texas	1.92	10.85	37.82	38.21	12.35	.77	....	....	....	....	....	Dumble
Italian Lignite	dried	....	37.60	61.85	.55	6.12	....	....	....	....	....	..
Italian Lignite	dried	....	39.00	53.68	7.32	1.00	....	....	....	....	....	

ANALYSES OF LIGNITES

Source of Lignite	Proximate					Ultimate						
	Dowling's Ratio	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulphur %	Hyd'gen %	Carbon %	Nitrogen %	Oxygen %	Calorific Value B.T.U.	Authority
Nicholson's Mine, Estevan.	1.13	30.	29.32	35.92	4.71						7,900	...
Porter's Mine, near Estevan .	1.36	22.5	35.44	37.04	4.91	0.33					8,570	R. A. Huish
Porter's Mine, near Estevan .	dried coal	. .	45.79	47.81	6.37	0.43					11,069	R. A. Huish
Taylorton Mine, Estevan	dried coal	.	49.00	42.90	8.10	0.6					10,692	Montreal Rpt
Eureka Mine, Estevan	dried coal	. .	40.00	43.20	16.80	0.5					9,648	Montreal Rpt
Consumers' Mine, S. of Moose Jaw	0.973	32.42	28.29	31.32	7.97						10,000	B. F. Haanell
Wood Mountain, lower seam	1.93	12.26	11.51	43.07	3.16							Dowling
Wood Mountain, thick seam.	1.49	18.61	39.11	37.57	4.71							Dowling
M. & S. Mine, Estevan	1.18	23.70	29.90	30.90	15.50						7,880	Blackie
M. & S. Mine, Estevan	1.12	25.10	25.00	29.50	20.40						6,700	Blackie
Western Dom. Mine, Estevan	1.46	24.80	23.55	41.45	10.20						6,680	Blackie
Western Dom. Mine, Estevan	1.29	25.40	22.60	36.00	16.00						6,490	Blackie
Roche Percee .	1.43	17.80	31.55	32.00	18.65						7,038	Blackie
Bienfait.	1.49	19.53	38.12	38.12	9.90							H. B. Lake
Sutherland Tunnel, Souris River												
1 mile south of Roche Percee	1.42	21.84	35.12	38.61	4.40							Dr. Hoffman
St. Peter's Gully, Sec. 6-2-5-2	1.68	17.78	32.70	41.17	8.35							Dr. Hoffman
Carrols, Sec. 14-1-6-2	1.70	13.91	41.92	38.35	5.79							Dr. Hoffman
Carrols, Sec. 14-1-8-2	1.50	14.73	48.40	34.07	2.80							Dr. Dawson

ANALYSES OF LIGNITES—*Continued*

Source of Lignite	Dowling's Ratio	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulphur %	Hyd'gen %	Carbon %	Nitrogen %	Oxygen %	Calorific Value B.T.U.	Authority
Wood Mountain, nr 3rd Meridian	1.80	16.51	31.17	43.62	5.69							Dowling
Wood Mountain, Hay Flat....	1.72	13.73	38.91	38.51	8.82							Dowling
Wood Mountain, Poplar River	1.49	11.16	43.90	2.66	8.97							Dowling
Big Muddy Creek, at Boundary	1.31	15.51	51.33	28.41	4.72							Dowling
Big Muddy Creek, at Boundary	1.31	16.28	50.26	29.18	4.28							Dowling
Big Muddy Creek, at Boundary	1.30	15.20	51.27	27.61	5.92							Dowling
Big Muddy Creek, lowest seam	1.27	18.74	16.19	30.04	5.03							Dowling
Dirt Hills	1.87	15.50	35.96	11.78	3.76							Dowling
Souris River	2.15	13.85	30.95	17.90	7.30							Dowling
Souris River	1.28	17.97	47.32	30.10	4.61							Dowling
Souris River	1.58	14.90	43.24	36.68	5.18							Dowling
Souris River....	1.38	12.67	53.90	28.01	6.42							Dowling
Souris River, 22-1-8-2.....	1.77	15.11	38.66	41.67	4.56							Dowling
Souris River, W. of Short Creek	1.76	12.07	46.28	38.90	2.75							Dowling
Souris River, nr Roche Percee	1.30	20.29	31.41	31.35	16.95							Dowling

It is evident from the foregoing figures that the different samples of lignites were not tested under similar conditions, otherwise it is difficult to account for the difference in the ratio. Unless the samples are taken at the mines and immediately hermetically sealed up it is impossible to make a fair comparison, but when such precaution is taken Dowling's formula offers a useful indication as to the position each sample occupies in the scale. It is highly essential that tests and analyses of all Saskatchewan lignites should be made under standard conditions so as to arrive at their relative values as fuel.

In the absence of data obtained by ultimate analyses the best that can be done under the present condition is to calculate the water-free composition of a few representative samples from the foregoing figures, and this will give an idea of their relative values so far as their fixed carbon, volatile matter and ash contents.

COMPOSITION OF WATER-FREE-LIGNITE, ETC.

Origin of Coal	Volatile matter %	Fixed Carbon %	Ash %
Porter's Mine, near Estevan	45.79	47.84	6.37
Taylorton mine, near Estevan	49.0	42.9	8.1
Eureka Mine, near Estevan	40.0	43.2	16.8
Consumer's Mine, south of Moose Jaw	42.0	46.2	11.8
M & S Mine, near Estevan	39.3	40.6	20.3
Dirt Hills	42.6	53.4	4.16
Taber Mines, Alberta	42.3	50.0	7.8
S. Saskatchewan R., near Medicine Hat	38.3	53.0	8.8
Hill Crest Mine, near Edmonton	24.8	66.0	12.3
Twin City Mine, near Edmonton	45.3	45.6	9.0
Wilton Mine, N. Dakota	50.0	38.0	12.2
Cedar Coulee, N. Dakota	45.8	46.2	7.88
Hoyt, Texas	41.5	47.4	11.0
Alba, Texas	42.3	42.7	13.9
West Virginia Coal	37.0	63.0	4.65
Italian lignite	37.6	61.85	0.55
Italian lignite	39.0	53.68	7.32

It will be observed that according to the foregoing figures the lignites in this province which contain the highest percentage of fixed carbon and lowest percentage of ash are those obtained from the Dirt Hills, but the difference is small. It is noticeable that the contents of water-free lignites are much more uniform than would appear from the complete proximate tests. A small percentage of moisture may tend to help combustion, but the large proportion of water contained in lignite has the effect of lowering the efficiency of operation of a steam plant. "The harmful effect of moisture in coal on steam boiler operation is due to the fact that a large part of the heat held by the moisture is below the temperature of the water in the boiler and hence is not available for making steam."[1]

As some steam is required in connection with the gasifying of lignite in gas producers, moisture in the fuel, within certain limits, is not a detriment. In the manufacture of gas by dry distillation the coal must be as dry as possible.

[1] Bulletin 2, United States Bureau of Mines "North Dakota Lignite as a Fuel for Power Plant Boilers"

The conversion of lignite into briquettes requires a certain amount of moisture, indeed in Germany those lignites which contain about 40 per cent. of water prove to be the most satisfactory for this purpose.

The above points will be more fully dealt with later on.

With regard to liability of lignite to weather, its transportability and the effect of handling; all these may be dealt with together. This fuel when exposed to the atmosphere, disintegrates or crumbles; although this crumbling propensity probably does not cause the fuel to deteriorate, but rather to improve, it nevertheless tends to result in greater waste as the smaller particles cannot be retained on the firebars under steam boiler. Furthermore, lignite in its disintegrated condition entails more labour if hand firing is adopted.

Lignite is usually transported in box cars, so as to minimise the slacking process, and the coal is used as soon as practicable after its arrival. The stock of lignite kept at any works is comparatively small, owing to the above defect, and this necessarily means that lignite mining is at present more or less a winter industry, whereas in the interest of the community generally, it is highly desirable that it should afford continuous instead of intermittent employment for the workmen.

Regular operation of the mines means that the plant is more fully utilised and the return on the capital invested is greater. The workmen will be more efficient and probably a greater output per man will be the result.

The question as to how these conditions can be attained is one for further investigation, as it is not included in the instructions issued for the present inquiries and report.

By virtue of the fact that this province possesses large tracts of lignite-bearing strata such fuel has the advantage of freight rates over the imported and higher grade coals. Lignite, however, contains a large proportion of hygroscopic water, which is in great part readily dissipated on exposure to air, and to this fact is due, to a large measure, the defect which it possesses of slacking or crumbling when so exposed. Even after long exposure to the air, lignite often contains over 15 per cent. of moisture, which can only be driven out by suitable heating. On an average 30 per cent. of raw lignite consists of water, but assuming that the colliery companies supplied only air-dried lignite, containing say 15 per cent. of moisture, it will be seen that out of every dollar paid in freight, 15 cents will be for conveying water.

Pennsylvania coal contains from 2 to 6 per cent. of moisture of which at least one-half is lost by air drying, in which case only about 1 to 3 cents out of each dollar is paid for a commodity which is worse than useless.

The cost of transport, as has already been pointed out in this report, constitutes the largest single item in the cost of local fuel, and favourable or unfavourable freight rates are sufficient to develop or destroy the prosperity of the mining industry.

A high grade coal can legitimately stand a higher freight charge than inferior coal, and when regard is paid to the development of home industries, it will doubtless be recognised that some differentiation should be made in the scale of freight rates. At present, freight rates on lignite are the same as on anthracite imported from the States. Estevan lignite at the mine costs under $1.50 per ton and freight to Regina is $1.80; the distance is

172 miles. The rates in Texas for 100 miles is 90c for coal and 60c for lignite, for 200 miles $1.40 for coal and 91c for lignite. In some parts of Texas lignite, despite its inferiority, is purchased in preference to bituminous coal.

Another feature under this head is the time taken for the delivery of lignite to the consumer. It was stated by an engineer in Winnipeg that one reason for discontinuing the use of lignite was that delays took place on the railways, and as a large stock could not be kept, it was impossible especially in winter time to assure a constant supply. In the event of snow storms, for instance, the main lines receive first attention by which imported coal could be delivered, but the Souris lines were left uncleared for a longer time. Furthermore, it was stated that even in good weather deliveries were uncertain and therefore lignite was abandoned.

As lignite is one of Saskatchewan's products it would appear reasonable that some consideration should be given these points by the authorities, whereby a prosperous mining industry could be built up, the local freight traffic increased and cheaper fuel made available to the mutual advantage of all concerned.

PRODUCTION AND CONSUMPTION OF LIGNITE.

The production of lignite in Saskatchewan in the year 1911 was 206.779 tons, of which approximately one-half was shipped to towns in Manitoba, about 104,000 tons therefore being consumed in this province. The quantity of coal imported from foreign countries into Saskatchewan during the year ending March 31, 1912, was as follows:[1]

Anthracite	663 tons
Bituminous round and run of mine	302,942 tons
Bituminous slack, such as will pass through a ¾″ screen	29 tons
Total	303,634 tons

This does not include coal brought from Alberta, etc., so it appears safe to estimate a total consumption of 500,000 tons of imported coal, to which must be added 104,000 tons of lignite making a total of about 604,000 tons of coal consumed in Saskatchewan.

Lignite therefore represents on the above conservative basis only 17 per cent. of the total consumption. The population is estimated at 500,000, so on this basis the coal consumption per capita in 1911 was one ton of imported coal and 0.21 ton of local lignite. There is ample scope for the lignite mining industry to develop when means are found to improve this fuel for general use.

Lignite beds are to be found in the United States of America. North Dakota, the nearest State, possesses about 35,000 square miles of lignite-bearing beds, which are reputed to be capable of producing 500,000 000,000 tons. In 1910, 400,000 tons of lignite were mined giving employment for 534 men. Until 1906 mining operations were carried on in a small way, principally for the purpose of supplying ranchmen with fuel. "Since that time, however, production has been stimulated somewhat through the act of the North Dakota Legislature which compelled the use of North Dakota lignite in all state buildings and institutions."[2]

[1]Statement supplied by the Commissioner of Customs, Ottawa.
[2]"Coal Production in 1907," U.S.A. Report by Mr. E. W. Parker.

Lignite is found in Montana, Wyoming, Colorado, New Mexico, Washington, California, Oregon and other States, but mining operations are not on an extensive scale. Probably the largest producer and consumer of lignite in the United States is Texas, where 1,130 men are employed in mining the same, producing 881,000 tons in 1910 at an average price of 87 cents per ton at the pit mouth. The known lignite areas in Texas cover about 2,000 square miles, while there are about 53,000 square miles which may contain workable beds of lignite. The estimated original supply of lignite is placed at 23,000,000,000 to 30,000,000,000 tons of which only 0.1 of 1 per cent. has been mined.

There are also lignite beds in Tasmania, New Zealand, Australia, India and on the European Continent.

The production of lignite in Austria-Hungary was over 20,000,000 tons in 1911. It was 16,000,000 tons in 1891.

Italy has extensive deposits of lignite, but no particulars are available at present to show what is produced, but in 1891 it amounted to 400,000 tons.

In Germany statistics show that the lignite mining industry has developed to a much greater extent than in any other country. In 1881, 10,412,000 tons were produced, in 1891, 16,818,000 tons, and from 1902 to 1911 the following table will speak for itself:

Year	Prussia only tons	Whole Germany tons
1902	36,228,000	43,126,000
1903	38,463,000	45,819,000
1904	41,154,000	48,635,000
1905	44,149,000	52,512,000
1906	47,912,000	56,415,000
1907	52,674,000	62,319,000
1908	55,457,000	67,615,000
1909	56,046,000	68,253,000
1910	56,573,000	69,105,000
1911	60,594,000	73,517,000

To the above must be added about 8,000,000 tons of lignite imported from Austria, as well as a large quantity of lignite briquettes.

Of the above quantity of lignite about 30,000,000 tons[1] were in 1911, converted into briquettes, which form the chief household fuel in many large cities.

Berlin alone consumes an average of over 100,000 tons of lignite, and to show its popularity as fuel the following figures have been extracted from "Braunkohle" for August, 1912.

	Berlin		Leipzig		Dresden	
	1910 tons	1911 tons	1910 tons	1911 tons	1910 tons	1911 tons
Total bit. coal and lignite	3,333,722	3,339,707	1,683,476	1,722,274	979,050	1,102,411
Austria brown-coal	0.1%	0.1%	2.1%	1.9%	35.1%	33.6%
German brown-coal	35.2%	38.2%	74.9%	76.8%	20.8%	23.0%
Other brown-coal	.....	.....		.....	1.7%	1.8%
German bit. coal	39.5%	37.4%	23.0%	21.3%	42.4%	41. %
English bit. coal	25.2%	24.3%	.....	.....	.....	.....

[1] Bergwirtschaftliche Mitteilungen. Jan.-Feb., 1912

From the foregoing table it will be observed that from one-third to three-quarters of the total coal consumed for city use is lignite, either in its raw condition or as briquettes. Although no differentiation is made above as to the class of lignite used it will be well to remember that in Germany there are several kinds, but at present no data is available as to the kind most used.

USES OF SASKATCHEWAN LIGNITE.

The number of large consumers of lignite in this province is comparatively small. The Robin Hood Mills, Limited, Moose Jaw is probably the largest consumer. They have four 170 H.P. 20 feet by 6 feet return tube boilers, the furnaces are fitted with rocking bar grates and lignite is hand fired. The new boilers will shortly be fixed in place and provided with another type of furnace; an induced draught and economisers will also be in working operation.

Lignite has occasionally been used at Moose Jaw power house, but the equipment was not adapted for this fuel. The same remark is applicable to Regina power house.

The Western Dominion Coal Company have at their mine at Taylorton, four return tube boilers developing a total of 350 H.P. The grates are fitted with herringbone firebars, which were stated to give good results. The fuel used consisted of fine lignite slack from the screening machines.

At the Manitoba and Saskatchewan Mine, near Taylorton, two 90 H.P. boilers are in use which are hand-fired with fine lignite slack.

Lignite is consumed at the Estevan power house where two 125 H.P. Robb return tube boilers are installed, to which reference will be made later on.

At Weyburn, lignite is consumed for raising [illegible] d at Rouleau it is used in connection with a Smith's 200 H.P. suction gas producer to operate one 172 brake H.P. gas engine for generating electricity and pumping water. Another gas producer plant is also in use at Swift Current. This was built by Messrs. Crossleys, Manchester.

The Eureka Coal and Brick Company, Estevan, use run of mine lignite obtained on the site for raising steam and for burning brick.

At the Bienfait (C.P.R.) Mine near Estevan, there are two (one 150 H.P. and one 50 H.P.) boilers and the fuel is lignite slack.

With the exception of Estevan and Weyburn, where special tests were made by Mr. R. N. Blackburn, Wh. Sc., provincial chief boiler inspector, and which will be dealt with hereafter, it was not possible to obtain any statistics as to the results secured as to efficiency and economy, but in each case the persons in charge generously supplied what data they had in this respect.

The Consumer's Coal Company of Moose Jaw, this year sent eleven tons of lignite to the Mines Department at Ottawa to be tested in the producers. The department conducted the test for the purpose of ascertaining its usefulness.

Eleven tons proved to be insufficient for the determination of the volume of gas in cubic feet produced per ton of lignite gasified.

Mr. B. F. Haanel the chief of the division of fuel and fue testing, in his report dated July 12, 1912, made the following observations:

"The lignite was burned in the Westinghouse double-zone bituminous gas producers. The producer was first built up with Pittsburg bituminous slack coal, with which the staff of the fuel division had previous knowledge and experience, when this was partly run through, the producer was fed with lignite. For the purpose of ascertaining the efficiency of any fuel in a producer of this type and capacity (125 H.P.) and the volume of gas produced per ton of fuel, it was necessary first, that the producer contained no fuel other than the sample to be tested at the time the test commenced and, second, that the test was continuous and of sufficient duration to ensure that the condition and the amount of the fuel in the producer at the end of the run was the same as at the beginning and such test is generally of 60 or more hours' duration.

The following points were observed:

1. The behaviour of the fuel in the producer.
2. The most efficient method of operation.
3. The suitability of the gas generated for burning in the gas engine.

Conclusions:

1. The lignite can be fed into the producer in the condition it is unloaded from the car, it being unnecessary to submit it to crushing, the larger pieces being broken when deemed necessary with a sledge.

2. The fuel burned uniformly without the formation of troublesome clinker, and when the attendant had acquired the method of operation, but little attention other than feeding the fuel and poking the fires of the two zones twice a day was required.

3. The gas generated was tar free and the heating value satisfactory.

4. The engine was operated at a load of 50 brake H.P. for about 40 minutes, and when examined at the termination of the run, the valves were found to be exceptionally clean.

5. As a result of this test, this lignite may be pronounced as an excellent fuel for the production of power when utilised in a producer gas plant, the fuel as it arrives from the mine requiring no further treatment, such as crushing. The tendency moreover to the lignite to disintegrate into small fragments on exposure to the air, does not in any way interfere with its operation when burned in a gas producer.

Proximate analysis of the lignite by fast coking:

	per cent.
Moisture	32.42
Volatile combustible matter	28.29
Fixed carbon	31.32
Ash	7.97
	100.00
Coke	39.29
Fuel ratio	1 to 1.10

Calorific value of moisture free fuel 10,000 British thermal units per pound.

Average effective calorific value of gas per cubic feet, 115 British thermal units per pound.

The volume of gas generated per ton of lignite and the thermal efficiency were not determined. The indications, however, are that they would have been satisfactory if the test could have been run for 60 hours.

In the autumn of 1906 the Canadian Government, through Dr. A. P. Low, Director of the Geological Survey, decided to undertake a study of the fuels of the Dominion, somewhat on the lines of the fuel tests which have already been commenced by the United States Geological Survey.

But inasmuch as the government had not, at Ottawa, any suitable mechanical laboratory, and as research work had already been done by the Mining Department of McGill University on a number of Western coals, Dr Low invited Dr. Porter, the head of the department, to undertake the large investigation.

This was agreed to by the University Governors provided the Government would pay for supplementary equipment and all additional expenditure. The railway companies agreed to convey the coal free of charge. When the Canadian Mines Branch was established under Dr. Eugene Haanel, the above arrangement was adhered to.[1]

The series of tests commenced with the Western lignites to which the down-draft producer seemed well suited, practically no tar being found in the gas as it left the producer. With these coals, in fact, the scrubber seemed to take little or no tar out of the gas and the same remark applied to the washer, and in some trials with these coals the latter apparatus was not used at all.

The methods adopted in making these tests are fully described in the report to which reference should be made for fuller particulars.

Only two samples of Saskatchewan lignites were tested in the gas producer and these were from Western Dominion mine, Taylorton.

The following results were obtained:

Western Dominion Mine

Run of mine lignite:		
Duration of trial in hours	24	19
Proximate analysis of coal as charged:		
Fixed carbon, per cent.	36.7	32.2
Volatile matter, per cent.	32.8	43.3
Ash, per cent.	7.2	11.1
Moisture, per cent.	23.3	13.4
Calorific value of coal as charged, B.t.u.	8,300	9,370
Weight of coal charged	1,625	1,475
Weight of dry coal charged	1,247	1,278
Refuse removed during trial		
Prox. analysis, fixed carbon	not	38.0
Volatile matter, per cent.	taken	9.8
Average depth of fuel bed above orifice in inches	35.0	34.0
Total gas as metered during trial cubic feet	71,595	59,200
Average temperature of gas		
Leaving producer in degrees Fahr.	529	529
Average higher calorific value of gas (as metered) by calorimeter in B.t.u. per cubic foot	118	124.2
Average higher calorific value of gas at 60 deg. Fahr. and 14.7 lbs. sq. in. by calorimeter in B.t.u. per cubic foot	122.4	128.3
Average lower calorific value corrected from gas analysis in B.t.u. per cubic foot	112.7	117.4
Average analysis of gas by volume:		
Carbon dioxide, CO_2 per cent	11.7	11.6
Oxygen, O_2 per cent	0.9	1.0
Carbon monoxide, CO per cent	15.05	13.3
Hydrogen, H_2 per cent	11.48	14.0

[1] Investigation of the Coals of Canada by Dr. Porter and Mr. Dursley. Vol. 1, 1912.

	Western Dom.	Mine
Methane, CH_4 per cent. . .	3.75	3.6
Ethylene, C_2H_4 per cent. .	0.00	0.1
Nitrogen, N_2. .	57.12	56.4
Average suction at producer in inches of water	3.3	1.7
Average mean eff. pressure gas engine cylinder (indicator) pounds per square inch .	65.2	73.2
Average B.H.P. corrected for gas blown off. . .	29.7	31.3
Average B.H.P. net, less power for auxiliaries.	26.2	28.8
Coal charged per hour, lbs. . . .	67.7	77.7
Coal charged per square foot fuel bed per hour in lbs. .	16.9	19.4
Coal per B.H.P. (gross) per hour, lbs.	2.28	2.48
Coal per B.H.P. (net) per hour, lbs. .	2.58	2.70
Standard gas at 14.7 lbs. square inch and 60 deg. Fahr. per hour, cubic feet	2,875	3,019
Standard gas per lb. of coal cubic feet	42.5	38.8
Steam used per lb. of coal. . .		0.0
Water used per lb. of coal, in lbs. . . .	16.3	11.1
Efficiency of producer based on calorific value of gas and coal charged, per cent. . . .	57.8	48.8
B.t.u. in coal charged per B.H. P.H. . . .	18,924	23,240

An ideal producer gas should contain approximately one-third carbon monoxide and two-thirds nitrogen, but in practice it is impossible to obtain such results because carbon dioxide is always found in greater or less volume depending on the temperature of the heat within the producer, and other conditions.

The quantity of coal charged per brake horse power hour in many of the bituminous class, such as those from Nova Scotia, Alberta and British Columbia exceeded that in the case of the Souris lignite; and the efficiency obtained with Souris lignite was only excelled by some of the better bituminous coals.

The Montreal report states that lignite and lignitic coals from Saskatchewan and Alberta proved excellent for use in the down draft producer, most of them required no steam at all, and some of them gave so little tar that the washer could be dispensed with. They all have low calorific values, are moderately high in ash, and contain much intrinsic moisture. They weather rapidly and break up in the producer. Good efficiencies were obtained in each case, with gas of high calorific value and uniform in quality. Very little attention to the fire was needed and with most of the samples the producer could have been run without the exhauster as a suction producer.

In connection with Taylorton lignite it should be noted that seven weeks (during which the fuel was kept in bags in a dry store) elapsed between the two trials. The change in the composition of the lignite during this time is well shown, but the ageing process did not seem to make it less suitable for use in the producer.

The following table is an extract from the Montreal report and will be useful to compare the results obtained with various lignites:

PERFORMANCE WITH LIGNITE AND LIGNITIC COALS.

DESCRIPTION	Lignite from Western Dominion Collieries, Ltd., Taylorton, Sask. Trial 1	Lignite from Western Dominion Collieries, Ltd., Taylorton, Sask. Trial 2	Lignite from Parkdale Coal Co., Edmonton	Lignite from Standard Coal Co., Edmonton	Lignite from Strathcona Coal, Strathcona	Lignitic Coal from Canada West Coal, Taber	Lignitic Coal from Alta. Ry. and Irr. Co., Lethbridge
Volatile matter, per cent.	32.8	13.5	28.7	31.2	30.9	26.6	35.2
Ash, per cent.	7.2	11.1	11.2	7.5	11.9	16.3	9.1
Moisture, per cent.	23.3	13.4	17.3	15.3	16.1	12.6	7.8
Cal. value, coal B.t.u.	8,300	9,370	8,910	9,640	9,010	9,650	10,800
Cal. value, gas per c. ft. B.t.u.	112.7	117.1	119.5	118.6	119.0	120.0	122.4
Producer efficiency	0.578	0.488	0.514	0.566	0.657	0.531	0.522
Coal per B.H.P. per hour, lbs.	2.28	2.18	2.61	2.13	1.83	2.12	2.13
Caking	none	none	none	none	none	none	very slight
Average interval between poking	5 hrs.	6 hrs.	2¼ hrs.	5 hrs.	12 hrs.	2¼ hrs.	1¾ hrs.
Clinker	very slight	none	none	slight	slight	slight	none
Tar	none	gas washer not used. No tar.	none	none	none	very little from scrubber	none
Uniformity in gas	very uniform	very uniform	very uniform	fairly uniform	fairly uniform	very uniform	fairly uniform
Amount of steam used	very little	none	none	none	very little	small amount	small amount
Combus. in refuse	(not analysed)	moderate	moderate	(not analysed)	little combus.	rather rich in combustible	little combus.
Remarks	very suitable fuel for producer easy to work	very suitable for producer easy to work no trouble	very suitable for producer easily worked	very suitable for producer easily worked	very easy to work in producer	very little trouble, easy to work	good for producer work very little trouble

The following table is also taken from the Montreal report, and is self-explanatory.

Heat value of coal charged per B.H.P. per hour. (Coals arranged in order of apparent economy.)

Description of Coal	B.t.u. per B.H.P. P.hr.
Lignite, Strathcona Coal Co., Edmonton, Alta.	16,490
Lignite, Western Dom. Collieries Ltd., Taylorton, Sask	18,924
Coal, Crow's Nest Pass Coal Co., Fernie, B.C.	20,460
Lignite, Standard Coal Co., Edmonton, Alta.	20,470
Coal, Crow's Nest Pass Coal Co., Fernie and Michel, B.C.	20,780
Coal, King's Mine, Minto, N.B.	21,497
Coal, Nicola Valley Coal Co., Coutlee, B.C.	22,200
Coal, Intercolonial Coal Co., Westville, N.S.	22,493
Coal, H. W. McNeil Co. Ltd., Canmore, Alta	22,566
Coal, Bankhead Mines, Ltd., Bankhead, Alta.	23,000
Lignitic Coal, Alberta Ry. & I. Co. Ltd, Lethbridge, Alta	23,000
Coal, Nova Scotia S. & C. Co., Sydney Mines, N.S.	23,200
Lignite, Parkdale Coal Co. Ltd., Edmonton, Alta	23,330
Lignite, Canadian West Coal Co., Taber, Alta.	23,350
Coal, Acadian Coal Co., Stellarton, N.S.	23,650
Coal, Western Fuel Co., Nanaimo, B.C.	23,760
Coal, Canada Coal & Ry. Co. Ltd., Joggins, N.S.	23,840
Coal, Inter. Coal & Coke Co., Coleman, Alta.	24,800
Coal, Cumberland Ry. & Coal Co., Springhill, N.S.	27,160
Coal, Crow's Nest Pass Coal Co., Fernie, B.C.	29,730
Coal, Dominion Coal Co., Ltd., Glace Bay, N.S.	30,500
Coal, Dominion Coal Co., Ltd., Glace Bay, N.S.	30,690
Coal, Western Fuel Co., Nanaimo, B.C.	30,790
Coal, Acadia Coal Co., Ltd., Westville, N.S.	31,010
Coal, Richmond Coal Co., Ltd., Port Hood, N.S.	31,703
Coal, Dominion Coal Co., Ltd., Glace Bay, N.S.	32,450
Coal, Leitch Colliers, Ltd., Passburg, Alta.	33,210
Coal, Dominion Coal Co., Ltd., Glace Bay, N.S.	36,030

Perhaps the most striking result of the series of tests is the excellent performance of the lignites, which is well seen in this table, all the lignites taking good places. The Crow's Nest Coals, and Alberta Anthracite are also seen to have given good results. The lower places in the table are taken (generally speaking) by coals whose caking qualities render them difficult to handle in a gas producer of small size.

Reference might with advantage be here made to the results of a number of tests made at St. Louis by the United States Geological Survey, and the Bureau of Mines Departments. Lignite from Texas, Dakota, Montana and other States were tested under somewhat similar conditions as at Montreal, but the results obtained at St. Louis were still more favourable. A first class gas engine should operate on 10,000 B.t.u. per one brake horse power per hour, but even allowing for contingencies and increasing these figures to 15,000 B.t.u. at Montreal, 16,490 to 36,030 B.t.u. were required per one brake horse power per hour, whereas at St. Louis it ranged from 9,970 to 13,770 B.t.u.[1] as will be seen later on.

The Montreal Steam Tests of 1908 include one lignite from the Western Dominion Collieries, Taylorton. The following particulars have been taken from Volume II.[2]

Duration of trial	8.70 hours
Proximate analysis	
Fixed carbon	42.9 per cent.
Volatile matter	49.0 per cent.
Ash	8.1 per cent.
Moisture in coal as fired	29.7 per cent.
Weight of coal as fired	4,580 lbs.
Weight of dry coal	3,219 lbs.
Weight of clinker	152 lbs.
Weight of ash	113 lbs.
Ash and clinker in dry coal	8.2 per cent.
Weight of feed water	15,164 lbs.
Dry coal per hour	370 lbs.
Dry coal per hour per square foot of grate	22.1 lbs.
Coal as fired per square foot grate per hour	31.5 lbs.
Steam per hour corrected for moisture	1,736 lbs.
Equivalent evaporation per hour from and at 212 degrees Fahr.	2,061 lbs.
Steam pressure	117.1 lbs.
Barometer	29.79 inches.
Temperature of feed water	73 degrees Fahr.
Pressure draft between ash pit and damper	0.90 inches water.
Moisture in steam	0.6 per cent.
Boiler horse power	59.7
Water apparently evaporated per lb. of coal	3.31 lbs.
Equivalent evaporation from and at	
212 deg. F. per lb. of coal as fired	3.91 lbs.
212 deg. F. per lb. of dry coal	5.57 lbs.
212 deg. F. per lb. of combustible	6.33 lbs.
Calorific value of coal as fired per lb.	7,520 B.t.u.
Calorific value of dry coal as determined	10,690 B.t.u.
Boiler efficiency based on combustible consumed	52.5 per cent.
Boiler efficiency based on dry coal	50.3 per cent.
Dry flue gas per lb of dry coal	12.2 lbs.
Heat of fuel in dry flue gas	13.5 per cent.
Temperature of escaping flue gas at damper	578 Fahr.

REMARKS,—Fire seemed to be most intense at edge of grate. Difficulty in getting air through body of fire; clinker hard, but easy to remove, no smoke.

Professor Durley adopted as a standard the result obtained by using George's Creek coal from West Virginia and to it correlated the results obtained on testing Canadian Coals. This, of course, had no refer-

[1] Resume of Producer Gas Investigations, 1904-1910, United States Bureau of Mines, 1911.

[2] An Investigation of Coal of Canada Canada Department of Mines, 1912.

ence to the economic value of the different coals, for poor lignite at a comparatively low price is often cheaper than superior steam coal at a high price.

The following table is copied from the report on Montreal tests:

EVAPORATION FROM LIGNITE AND LIGNITIC COAL.

	Calorific value per lb. of coal as fired	Moisture coal as fired %	Ash and clinker from dry coal %	Index No.	Equiv Evap. per lb. as fired
Western Dominion Collieries, Taylorton	7,520	29.7	8.24	48.1	3.91
Parkdale Coal Co., Edmonton	8,760	19.7	11.1	62.7	4.98
Canada West Coal Co., Taber	5,790	14.3	17.3	57.2	4.91
Galt Colliery	10,740	8.3	10.4	68.7	5.92

It might be stated that these lignites were partly air dried owing to the time which had elapsed between mining and testing and the above result therefore will differ from those obtained in this province.

A sample of local lignite was sent to St. Louis for testing purposes to Messrs. Evans & Howard Fire Brick Company, a firm of gas work constructioners and they handed the same over to the chief gas engineer of that city. The results obtained are reported to be as follows:

PROXIMATE ANALYSIS OF LIGNITE

Moisture	29.78%
Volatile matter	33.67%
Fixed carbon	30.20%
Ash	6.35%
Sulphur	0.50%
Calorific value	8,790 B.t.u.

Two tests were made—one in the ordinary way, the other having the retort cold at the beginning of the test, and gradually heating it to the temperature attained in the first test (1,900 deg. F.). By the second method it was thought that it might be possible to reduce the percentage of CO_2 in the gas by distilling water off at a low temperature, but the results do not show such an improvement.

	Ordinary way	Distilling at low temperature
Yield of gas per pound	10.58 c.ft.	7.12 c.ft.
Residue	28.8%	37.0%
Calorific value per cubic foot	371 B.t.u.	388 B.t.u.
Analysis of gas:		
Carbon dioxide	14.8%	14.0%
Illuminants	1.8%	2.0%
Oxygen	0.4%	0.7%
Carbon monoxide	28.4%	19.5%
Methane	9.3%	11.2%
Hydrogen	42.4%	47.7%
Nitrogen	2.9%	4.9%

Illuminating power of this gas was about 0.4 of a candle.

SPECIAL TEST MADE AT ESTEVAN AND WEYBURN.

After making many personal inquiries and inspecting many power plants in the province the writer was unable to secure reliable data as to the results obtained with local lignite as fuel for steam raising or producing gas. Although some information was available regarding the Montreal tests, and others made at St. Louis and elsewhere, it was felt by the writer that local tests under normal working conditions would be more valuable, as showing the results obtained with ordinary workmen instead of by specialists.

Having regard to the importance of this subject to steam-users generally, and also to those interested in the lignite mining industry, you were good enough to agree that such tests should be made.

As the general investigations, however, were assuming a rather comprehensive character, the writer approached Mr. R. N. Blackburn, Wh. Sc., and requested him to undertake the work. Mr. Blackburn with the consent of Mr. H.S. Carpenter, Deputy Minister of Public Works, agreed to do so.

Mr. Blackburn's report is both comprehensive and instructive and should be read by every steam user in this province, as it constitutes a valuable feature of the present general lignite investigation.

It is to be regretted that time precluded the test being made on the gas producer at Rouleau, but if the Government decide in continuing these inquiries, it will be highly desirable that it should be done, and furthermore tests of other power plants should be made, as they will doubtless afford the operating engineers a fund of data on which to work with the view of procuring increased efficiency and in that manner popularise the use of lignite.

As Mr. Blackburn's report is self explanatory it will be unnecessary to do more than refer to one or two points.

The efficiencies of Estevan and Weyburn steam plant are comparatively low, the losses are high. Any steam plant that gives a thermal efficiency of 70% is considered good; few exceed this. Accepting seventy per cent. efficiency as a standard, and assuming it has a value of say $100, then 50% efficiency has a value of only $70, that is, out of every $100 the steam user loses $30. It is therefore palpable that it is worth some capital expenditure to secure increased efficiency.

Mr. Blackburn refers to the possible methods of increasing this efficiency, some of which are adverted to by the writer, and it is to be hoped that steps will be taken to improve the present methods of consuming lignite.

The following diagrams (plate 1)* have been prepared to illustrate the losses mentioned by Mr. Blackburn as taking place at Estevan and Weyburn and the third (plate 2) illustrates the results of a test made elsewhere.

Mr. Blackburn's report is inserted in full.

*[illegible]

REPORT OF TESTS OF LIGNITE AS FUEL FOR STEAM BOILERS

By R. N. BLACKBURN, Wh.Sc., Chief Inspector of Steam Boilers

REGINA, *November 7, 19*

SIR, I beg to submit the following report of tests of lignite as f for steam boilers.

Two tests were made, the first at Estevan Electric Power pla t September 11, 1912, and the second at Weyburn Electric Power and September 22, 1912.

The objects of the tests were: First, to ascertain the condition which lignite is at present being used as fuel in steam power plants and economic results obtained. Secondly, to obtain information and d which would indicate the economic possibilities of lignite as fuel for ste power plants and the probable lines on which improved results might obtained.

Permission to make the tests was readily granted, and I take opportunity of acknowledging the courtesy of the town council Estevan and Weyburn and the assistance given by Mr. Smith, the engineer at Estevan Electric Light plant, and by Mr. Reed, elect superintendent at Weyburn.

DESCRIPTION OF ESTEVAN ELECTRIC LIGHT PLANT.

The plant at Estevan comprises two 110 horse power horiz return tubular boilers, 72 inches diameter by 14 feet long, built by Robb Engineering Company of Amherst, N.S. The boilers are se brickwork and are bricked over the top to lessen radiation. Ther 88 flues in each boiler, each flue being $3\frac{1}{2}$ inches external diameter. heating surface of each boiler is 1,330 square feet. The grate bars a the ordinary herring-bone pattern, the grate area being $33\frac{1}{2}$ square The products of combustion are carried by a sheet iron uptake to a chimney about 80 feet high.

The right-hand boiler only was used for the test. This boile washed out on the Saturday prior to the test and was fairly clean a time the test was made. There was a thin film of scale about 1-32 thick on the inside of the boiler. The flues were cleaned with a s blower immediately before the test. The brickwork setting was o fair condition, there being several air leaks in the brickwork. M these were stopped before the test was made.

The engines are of the cross-compound receiver type with aut cut-off valves, the high pressure cylinder is 16 inches diameter, t pressure cylinder 22 inches diameter. The stroke of each engine inches. The engines are worked non-condensing.

The horse power of the engines is in excess of the present requir and the high pressure engine only is used. The slide valve of the lo sure engine has been removed and the exhaust steam from the hig sure cylinder passes freely through the receiver and the low p cylinder to the atmosphere. The exhaust steam is bye-passed t a feed water heater of the closed type.

A water softening tank is ordinarily used for treating the feed water, but it was not used during the test, in order to facilitate the measurement of the feed water.

The lignite used during the test was from Parkinson's Mine, Estevan, and costs $1.60 per ton, delivered at the plant. The coal was delivered a few hours before the trial commenced, it was not weathered and appeared to have been recently mined.

The electrical equipment comprises a three-phase alternating current generator, the field-exciting current being supplied by a belt-driven dynamo. I was informed that the watt-meter was inaccurate and it was cut out of the service during the test. The electrical power delivered at the switchboard has been computed from reading of the voltmeter and ammeter which were taken every fifteen minutes during the run. There was no means of ascertaining the power factor, but I was informed that there were no motors on the line, the whole power being used or lighting incandescent lamps. The load may therefore be presumed to be practically non-inductive, and a power factor of .95 has been assumed in calculating the electric power generated.

DESCRIPTION OF WEYBURN ELECTRIC LIGHT PLANT.

The plant at Weyburn consists of two Robb-Mumford boilers and one Babcock and Wilcox Water tube boiler. The latter boiler alone, was used for the test. It had been recently installed and, with the exception of a preliminary run a week previous to the test, had not been used. It was therefore quite clean inside and the brick-setting was quite air-tight, conditions favourable to good results. The upper portion of the steam drum, however, was not lagged and the steam main had not yet been covered with non-conducting material. The boiler is built up of nine sections each having 10 tubes 4 inches diameter by 18 feet long. The steam drum measures 4 feet diameter by 21 feet 3 inches in length. The total heating surface is 2,010 square feet. The boiler is provided with a Dutch oven which is fitted with Neem's shaking grates. The total grate area is 39½ square feet. The flue gases are carried by an iron uptake to a main flue common to the three boilers and leading to an iron chimney 4 feet diameter. The height of the latter above the grate is approximately 100 feet.

The lignite used during the trial was supplied by the Manitoba and Saskatchewan Mines, Taylorton, and costs $2.40 per ton delivered at the plant, made up as follows:

Cost per ton F.O.B. at mine	$1 35 per ton
Freight to Weyburn	90 per ton
Delivery charges	15 per ton

The engines are of the cross-compound jet condensing corliss type. Diameter of high pressure cylinder 15 inches. Diameter of low pressure cylinder 30 inches. Stroke 30 inches. The engines were built and installed by The Goldie & McCulloch Co. of Galt, Ontario. There is also a smaller high pressure corliss engine, direct acting fire pumps, etc., neither of which were used during the trial.

The electrical power is generated by a three-phase alternator the field current being furnished by a belt driven dynamo.

The condensed steam and injection water are pumped into a hot well from which the feed water is pumped into an open heater, which raises its temperature to about 190 deg. Fahrenheit, at which temperature it is delivered to the boilers.

It was not found practicable to measure the feed water after leaving the feed heater, and as the steam condensing in the heater would introduce an error in the measurement, which could not readily be computed, it was decided to cut out the feed heater during the trial and feed the boilers with cold water direct from the town mains. While this reduces the apparent evaporation, the required correction in the result is easily made and the equivalent evaporation from and at 212 deg. Fahrenheit, which is the real basis of comparison, can be accurately determined.

The load was applied by a water-rheostat which was adjusted so as to give the boiler a full load, but without requiring the fires to be unduly forced. Voltmeter and ammeter readings were taken every fifteen minutes during the trial from which the power delivered at the switch board has been calculated. The load being non-inductive, the power factor is taken as unity. The kilowatts delivered, as thus computed, were compared with the reading of a continuously recording watt-meter with which they closely agree.

Both in this trial and the trial at Estevan, indicator diagrams were taken from the engines every half hour.

The feed water in each test was measured in barrels which were calibrated before the trials. A 2 inch hole was bored in the upper part of each barrel used for measuring the feed water, the lower half of which was closed by a thin iron plate. The barrels were filled up until the water flowed over the plate and as soon as the overflow ceased the contents were run into a feed tank, from which the water was pumped into the boilers. The method ensured that the barrels were filled each time to *exactly the same height* and the capacity of each barrel thus having previously been ascertained by weighing, the quantity of feed water used could be readily and accurately measured.

A hole was drilled in the feed line close up to the boiler, in which was placed a thermometer for measuring the temperature of the f[illegible]r enter-ing the boiler. Care was taken to ascertain that there were [illegible] in the feed line or at the blow-off cock, which would impair the corr[illegible] of the results obtained.

The level of the water in the water gauge glass was measured at the beginning of each trial, and at the close of the trial the water was brought to the same level as at the commencement.

The fuel was filled into sacks before the trials and weighed. A small shovelful for a sample was taken from each sack before being weighed. After the trial these samples were crushed and well mixed and a small sample taken for analysis by the usual method of quartering. The sample for analysis was put into a sealed jar which was not opened [illegible] the sample was required for analysis. The analysis may therefore [illegible] taken to accurately represent the average quality of the lignite used for the test.

The "alternate" method of starting and stopping the test was adopted—that is to say, the fires were allowed to burn clear before the commence-ment of the trial and the trial was stopped when the fires were burned down to the same condition, as nearly as could be judged, as at the commence-ment of the trial. The fires were cleaned out during each trial. The amount of clinker removed was not excessive. A calorific test was made of the clinker, by plunging a large piece taken directly from the furnace into a weighed quantity of water and noting the rise in temperature, the clinker being afterwards dried and weighed. Samples of clinker and ash were taken by mixing and quartering, as in the case of the fuel used.

The temperature of the flue gases was measured by a steel cased mercury thermometer, readings of which were taken every half hour. A hole was drilled in the uptake close to the boiler to insert the thermometer.

A hole was also drilled in the uptake for measuring the draught. The latter was measured by a Schaeffer & Budenberg differential draught gauge, readings being taken every half hour.

A sampling tube was inserted in the uptake near to the boiler and a continuous stream of flue gas was drawn off by an aspirator. Samples were taken from the pipe through which the flue gas was flowing, in glass jars, by displacement of water. The jars having been first completely filled with water, the latter was syphoned off through a rubber tube provided with a screw pinch cock by which the flow could be regulated and which was adjusted so as to empty the jar in about one hour. Four samples were taken at regular intervals during each test and as each sample required about one hour to collect, the mean of the four samples represents a fair average of the flue gas during the trial. In order to prevent any change in the composition of the samples collected, due to the solubility of some of the constituent gases, the water used for collecting the samples was thoroughly saturated with the flue gases before using, by drawing a continuous stream of flue gas through the water by means of the aspirator.

An Orsat apparatus was used for analysing the samples of flue gas, the carbon dioxide, oxygen and carbon monoxide being absorbed respectively by solutions of potassium hydrate potassium pyrogallate and cuprous chloride dissolved in hydrochloric acid. The volume of gas remaining after each absorption was measured in a water jacketted burette, difference in volume being taken as the volume of gas absorbed. After the absorption of the CO_2 O_2 and CO the remaining gas was mixed with a measured volume of air and passed through a gently-heated tube containing palladium asbestos, two-thirds of the loss in volume being computed as hydrogen. The remainder after allowing for the added air was considered as nitrogen. The flue gases would probably contain small percentages of sulphurous anhydride and hydrogen sulphide together with traces of methane, ethylene and other hydrocarbons. For the purpose of this preliminary inquiry it was not considered necessary to determine the percentages of these gases, which would in any case be very small and would not materially affect the results of the tests. In a systematic research for improved methods of utilising lignite, the presence of comparatively small quantities of hydrocarbons in the flue gases is nevertheless of considerable importance as indicating incomplete combustion, and their presence should not be overlooked. From the volumetric analysis of the flue gases thus obtained, the percentage composition by weight was calculated.

In addition to the several constituents above mentioned a large quantity of water vapour was present in the flue gases which does not appear in the analysis of the dry flue gases. The amount of water vapour present has been separately computed from the percentage of moisture and hydrogen in the fuel, and has been taken into account in determining the heat balance.

The calorific value of the fuel was determined by means of an Abady calorimeter in which the fuel is burned with sodium peroxide. Apparatus for making a complete analysis of the fuel was not available and the percentage of carbon in the fuel was determined by the loss in weight of the residue from the combustion of a sample of the fuel in the calorimeter, after treatment with hydrochloric acid. As the combustion of the fuel in the calorimeter takes place in an airtight bomb in the presence of a large excess of sodium peroxide, the whole of the carbon in the sample may be assumed to be present in the residue in the form of sodium carbonate. This residue being dissolved in water and the carbon dioxide being driven off by the addition of hydrochloric acid, with due precautions to prevent loss of water vapour, the loss in weight gives the amount of carbon dioxide from which the percentage of carbon in the fuel may be calculated. While this method is not as good as the usual method of analysis of coal it appeared the best method available with the appliances at hand, and the results obtained are believed to be sufficiently correct for the purpose of this investigation.

A throttling calorimeter was used for determining the quantity of moisture present in the steam, readings being taken every half hour and the quantity of water evaporated has been corrected for priming in accordance with the readings.

Detailed particulars of the trials and the economic results obtained are tabulated in parallel columns.

PARTICULARS OF BOILERS, ETC.

	ESTEVAN	WEYBURN
Type of boiler	Horizontal Return Tubular	Babcock & Wilcox Water tube
Heating surface, square feet	1,330	2,010
Grate area, square feet	33.5	39.5
Width of air spaces in grate, inches	7-16	5 16
Ratio of air spaces in grate to total area, per cent.	35	42
Ratio of heating surface to grate area	39.7 to 1	50.9 to 1
Ratio of flue area to grate area, per cent	15.2	
Ratio of area over bridge to grate area, per cent	23.5	
Height of chimney above grate (approximate feet)	80	100
FUEL		
Total weight of coal, as fired, lbs.	5,725	6,747
Amount of moisture in coal, as fired, per cent.	31.3	31.3
Total weight of dry coal consumed, lbs.	3,933	4,635
Total weight of ash and clinker, lbs.	441	532
Duration of trial, hours	6	5¾

Particulars of Boilers, etc.—*Continued*

	Estevan	Weyburn
Coal consumed per hour		
As fired, lbs.	954	1,173
Dry coal, lbs.	655	805
Coal consumed per hour per square foot of grate area, as fired, lbs.	28.4	29.7
Dry coal, lbs.	19.5	20.4
Proximate analysis of coal, as fired		
Moisture, per cent.	31.3	31.3
Volatile matter, per cent.	18.8	20.4
Fixed carbon, per cent.	38.9	37.1
Ash per cent.	11.0	11.2
	100.0	100.0
Total carbon referred to dry coal (separately determined) per cent.	67.3	64.2
Gross calorific value of dry coal per lb (as determined) B.T.U.	10,439	10,366
Gross calorific value of coal, as fired (calculated) B.T.U.	7,171	7,121
WATER		
Total weight of water fed to boiler, lbs.	19,453	23,220
Moisture in steam, per cent.	0.4	0.2
Water evaporated per hour (corrected for moisture in steam) lbs.	3,229	4,030
Water evaporated per square foot of heating surface per hour (corrected for moisture in steam) lbs.	2.43	2.00
AVERAGE PRESSURES		
Height of barometer, inches	28.12	27.68
Steam pressure (by gauge) lbs. per square inch	89.7	106
Steam pressure (absolute) lbs. per square inch	103.5	119.6
Draught in uptake, inches of water	0.22	0.30
AVERAGE TEMPERATURES		
Temperature of boiler room, deg. F.	83	74.5
Temperature of wet bulb hygrometer, deg. F.	74	63
Temperature of steam, deg. F.	330	340.7
Temperature of feed water entering boiler, deg. F	143	56.3
Temperature of flue gases in uptake, deg. F.	617	425
POWER DEVELOPED		
Indicated horse power	73.75	147.3
Kilowatts delivered at switch board (average)	19.6	86
Total kilowatt hours	118	495

PARTICULARS OF BOILERS, ETC.—*Continued*

	ESTEVAN	WEYBURN
ANALYSIS DRY FLUE GASES		
Percentage composition by vol. (as determined)		
Carbon dioxide, per cent.	7.35	5.87
Carbon monoxide, per cent.	.50	.17
Oxygen, per cent.	10.75	14.38
Hydrogen, per cent.	none	.25
Nitrogen, per cent.	81.40	79.33
	100.00	100.00
Percentage composition by weight (calculated)		
Carbon dioxide, per cent.	10.92	8.77
Carbon monoxide, per cent.	.47	.16
Oxygen, per cent.	11.62	15.62
Hydrogen, per cent.	none	.02
Nitrogen, per cent.	76.99	75.43
	100.00	100.00
Weight of air passing through furnace per pound of carbon in fuel (calculated) lbs.	31.44	39.81
Weight of air passing through furnace per pound of coal as fired (calculated) lbs.	14.55	17.55
Humidity of atmosphere (saturation = 100)	69	52
Weight of moisture in one pound weight of air lbs.	.0169	.0092
ECONOMIC RESULTS		
Equivalent evaporation from and at 212 deg. Fahrenheit per hour (corrected for moisture in steam) lbs.	3,582.9	4,844.4
Water apparently evaporated under actual conditions per pound of coal, as fired, lbs.	3.39	3.44
Equivalent evaporation from and at 212 deg. Fahrenheit per pound of coal as fired (corrected for moisture in steam) lbs.	3.76	4.13
Equivalent evaporation from and at 212 deg. Fahrenheit per pound of dry coal (corrected for moisture in steam) lbs.	5.47	6.02
Equivalent evaporation from and at 212 deg. Fahrenheit per square foot of heating surface per hour (corrected for moisture).	2.69	2.41
Thermal efficiency of boiler and furnace (the percentage of the total heat in the fuel, actually utilised in generating steam) per cent.	50.85	56.01

NOTE.—In the Estevan test there was very little load on the engine during the latter part of the run and the mechanical efficiency of the plant is much lower than if a full load had been carried.

The above figures may be taken as fairly typical of the economic results at present obtained with lignite as fuel in steam plants. In the Weyburn plant an equivalent evaporation from and at 212 deg. Fahrenheit of 4.13 pounds of steam per pound of fuel consumed was obtained. In a steam boiler working at 125 pounds per square inch pressure and taking its feed water at 180 deg. Fahrenheit one pound of lignite would therefore under the above conditions evaporate 3.85 pounds of steam. A simple non-condensing corliss engine, similar to those in general use in small plants, working at about 125 pounds steam pressure usually consumes from 25 to 35 pounds of steam per indicated horse power per hour, the steam consumption depending upon the size and type of engine. The coal consumption on the above basis would therefore range from about $6\frac{1}{2}$ to 9 pounds of lignite coal per indicated horse power per hour. In a larger plant with a compound condensing corliss engine using from 15 to 20 pounds of steam per horse power hour, a coal consumption of from 4 to $5\frac{1}{2}$ pounds of lignite per indicated horse power hour might be expected.

In order to compare these figures with the results obtained from other coals used in the province it would be necessary to conduct a series of trials with various fuels, *under test conditions*. Many of the figures given me relating to other fuels have been obtained under conditions absolutely precluding accurate results and comparisons based thereon are quite unreliable. The results obtained in the tests at Estevan and Weyburn would appear however, to warrant a more extensive use of lignite than at present obtains. It will be noted, however, that the thermal efficiency of the boiler and furnace is only 50.85% in the Estevan boiler, and 56.01% in the Weyburn boiler, or in other words very little more than one half the heat in the fuel utilised. As the thermal efficiency of steam boilers is frequently over 70 per cent. the results obtained in these trials are not entirely satisfactory.

From the data given in the above tables a heat balance has been computed, which shows the average distribution of the heating value of each pound of coal used during the tests. The heat losses per pound of coal due to various causes are given in British thermal units and are also expressed as percentages of the total heat generated by the combustion of one pound of coal. The heat balance, therefore, not only shows the actual result obtained and the amount of heat lost in various ways, but also indicates the economic possibilities of lignite as fuel and the percentage of saving possible under improved conditions.

Heat Balance	Estevan		Weyburn	
	B.T.U.	per cent.	B.T.U.	per cent.
Debit—				
To total heat generated by the combustion of one pound of coal as fired.	7171		7121	—
Credit—				
By heat usefully expended in making dry steam.	3617	50.85	3989	56.01
By loss due to evaporation of the moisture in the fuel and heating the vapour to the temperature of the escaping flue gases	401	5.61	377	5.30
By loss due to evaporation of moisture formed by the burning of the hydrogen in in the fuel and heating the vapour to the temperature of the escaping flue gases (approximate)...	320	4.46	120	1.49
By loss due to the heat carried away by the dry flue gases escaping up the chimney.	1860	25.96	1530	21.48
By loss due to incomplete combustion of carbon burned to CO instead of CO_2 ..	292	4.07	125	1.76
By loss due to unconsumed hydrogen			188	2.64
By loss of heat due to removal of clinker in cleaning fires.	23	.32	10	.14
By loss due to heating the aqueous vapour in the air supplied to the furnace	63	.86	27	.38
By loss of heat due to unconsumed carbon in ashes	380	5.30	392	5.51
By loss of heat due to radiation and unaccounted for	182	2.54	163	2.29
Total	7171	100.00	7121	100.00

The above heat balance shows that a large proportion of the heat generated by the coal is lost by escaping up the chimney, the loss from this cause amounting to nearly 26% of the total heat of the coal in the Estevan test, and over 21% at Weyburn. A considerable loss from this cause is unavoidable but the loss under this heading should not exceed from 12 to 15% of the total heat generated by the combustion of the coal, and is therefore, much in excess of what is absolutely unavoidable and might be considerably reduced. It will be seen from the tabulated report of the tests, that the weight of air passing through the furnace per pound of fuel amounts to 14.55 pounds at Estevan and 17.55 pounds at Weyburn. While in the case of bituminous and anthracite coals this proportion of air conforms with good practice, it would appear from a consideration of the chemical analysis of lignite to be much in excess of what is required in the case of lignite fuel. The weight of air theoretically required to completely burn one pound of coal depends upon its chemical composition and for bituminous and anthracite coals, averages about 12 pounds of air per pound of coal. In actual practice on account of the impossibility of ensuring a perfect admixture of air with the products of combustion, an excess of at least 50% above the theoretical amount of air is required.

The amount of air theoretically required to burn one pound of lignite may be calculated as follows. As each pound of carbon requires for its complete combustion 11.6 pounds of air, and each pound of free hydrogen in the coal requires 34.8 pounds of air it follows that the lignite used in the tests, averaging (as fired) 44 to 46% of carbon, and, say 1.6% of free hydrogen would theoretically require for its complete combustion very nearly 6 pounds of air, or allowing 50% excess, say (in practice) 9 pounds of air. Any air supplied in excess of this amount causes a loss of fuel and it is evident that the loss under this head might be considerably reduced.

In most plants where lignite is used in the province the air supply to the furnace is usually greatly in excess of what is actually required. It appears to be the general practice to carry a very thin fire, and the fresh fuel is spread evenly over the fire, the grate area is generally large in proportion to the heating surface of the boiler, and in order to ensure complete combustion and to prevent smoke escaping from the chimney, a large proportion of air is allowed to pass through and over the fire. The high percentage of volatile matter usually present in lignite tends to produce considerable smoke from the chimney, and to prevent excessive smoke, with its consequent waste of fuel, the fireman goes to the other extreme and permits an excess of air to pass through the fire which may cause almost as great a waste of fuel, but the loss from which cause is not so apparent. It is no doubt difficult to burn lignite with the maximum of economy in the ordinary type of furnace, and to obtain the best results, a type of furnace specially adapted for burning lignite would probably be required.

In order to encourage the use and development of the coal deposits of the province, further investigation on these lines is very desirable. It is probable that better results would be obtained by using a smaller grate area and a much thicker fire, with alternate side firing. A thicker fire would tend to raise the temperature of the furnace and to increase the efficiency of the boiler, while alternate side firing would tend to promote more complete combustion of the volatile matter in the coal. In order to ensure complete combustion of the volatile matter a limited supply of air could be admitted above the grate, and it might be found advisable to admit a further supply of air behind the bridge. This air could be previously heated if found desirable. In any case, care should be taken to provide an ample combustion chamber, as it is essential that the volatile matter should be completely burned before the furnace gases enter the boiler tubes; and this would be especially necessary if thicker fires are used.

The higher temperature of the furnace would perhaps increase the tendency to form clinker, on account of the ash fusing more readily with the greater heat, and it might be found desirable to adopt some form of stepped fire bar to prevent the air spaces in the grate becoming choked. I am not aware the lignite causes any great amount of trouble in this respect under present conditions, but with higher furnace temperature it may be found that the formation of clinker is detrimental and a special form of grate may be required. Tests should also be made under various draft pressures, etc. It is possible that furnaces of the down-draft type may be found especially suitable for burning lignite. Furnaces of this type do not appear to have been tried in this province hitherto. I understand that two boilers equipped with down-draft furnaces are shortly to be installed in the province, and if a careful test can be arranged, the results obtained should be of considerable interest to steam users. The most efficient type of furnace can only be ascertained by actual trial and by a close investigation of the results obtained under different conditions, and as steam users generally have neither the facilities nor the inclination to carry out experiments of this kind, lignite fuel has not been used to the best advantage, and the development of the lignite deposits in the province has consequently been retarded.

It will be noticed from the tabulated results of the tests that the evaporation per square foot of heating surface in the boiler is low, being only 2.00 pounds of water evaporated per square foot of heating surface in the Weyburn test, and 2.43 pounds with the Estevan boiler. Many steam users who have tried lignite as boiler fuel have found it difficult to keep up the required steam pressure, and have consequently abandoned its use. In plants where the boiler capacity is greater than is actually required to meet the demands for steam, a reduction in the rate of steaming is not of very great importance, provided no actual increase is required in the boiler-room staff on account of the extra fires needed; but where the boilers must be operated at or near their full capacity as is usually the case, any considerable reduction in the rate of steaming practically prohibits use of lignite, unless more boiler capacity is provided which the steam user is not generally willing to install. Higher furnace temperatures would in great measure overcome this objection and an increase in the rate of evaporation of at least 50% without material loss in efficiency, does not appear unattainable. This would place lignite, so far as the rate of steaming is concerned, on an equality with the best coals imported into the province.

A factor which reduces the value of lignite as fuel for power plants is the presence of moisture in the fuel. In the tests under consideration, the moisture in the coal amounted to 31.3 per cent. of the total weight of the fuel. As the fuel used in both tests was freshly delivered, the percentage of moisture would presumably be at a maximum. The loss in efficiency caused by this moisture is computed at 5.29% of the total heat value of the fuel in the Weyburn test, and 5.63% in the Estevan test. It may be pointed out that the presence of [illegible]ture constitutes what may be termed a first charge upon the heat valu[illegible]d, and that of the total heat generated by the combustion of fuel, a portion must inevitably be expended in evaporating the moisture contained in the fuel itself. After the moisture is evaporated, a further portion of the heat generated is expended in heating the water vapour to the temperature of the escaping flue gases and only that portion of the heat remaining in the fuel after evaporating the moisture and raising the temperature of the vapour to that of the flu gases, is available for generating steam in the boiler or for other external use. When fuel can be obtained at a low cost, as in the neighbourhood of th mines, a loss of say 5 or 6% in the heat generated may not appear a ver serious matter, but it must be remembered that freight charges are base not upon the heating value of the fuel but upon the total weight. Whe the amount of moisture present in the fuel amounts to nearly one-thir the total weight of the fuel, as was the case in the fuel tested, and remember ing that this moisture not only reduces the total amount of combustibl matter in the fuel, but also causes a portion of the heat value of the con bustible to be wasted, it is evident that in cases where the freight charg form a large proportion of the cost of the coal delivered, the presence of large percentage of moisture is a serious handicap in competition wit coals higher calorific value. The gross calorific value of *dried* lignite was found by experiment to be 10,439 British thermal units per pound, for the coal used in the Estevan trial, and 10,366 British thermal units per pound, for the coal used in the Weyburn trial.

Owing to the presence of moisture the actual calorific value of coal was only 7,171 B.T.U. and 7,121 B.T.U. respectively. Of these 404 B.T.U. and 377 B.T.U. respectively were expended in evaporating the moisture in the coal itself, so that the available calorific value amounted to only 6,767 B.T.U. for the Estevan coal and 6,744 B.T.U. for the coal used at Weyburn.

The cost of lignite at the Estevan mines is about $1.35 per ton and the freight to Regina is $1.80 per ton, making the total cost of lignite free on rails at Regina $3.15 per ton. As lignite loses weight in drying the cost of a ton of dried lignite at the mines would be somewhat higher, and may be taken at about $2.00 per ton. Adding $1.80 per ton for freight charges this would make the cost F.O.B. Regina of dried lignite $3.80 per ton. A ton of raw lignite, however, contains only 13,534,000 available B.T.U. whereas a ton of dried lignite would contain 20,878,000 B.T.U. The cost of raw lignite at Regina (for example) per million B.T.U. would therefore be about 23¼ cents and the cost of dried lignite at Regina per million B.T.U. would be about 18½ cents. A comparison may be made with a well known Alberta coal largely used for power purposes, which costs in car loads at Regina $6.50 per ton. This coal averages 12,160 B.T.U. per pound and therefore costs a little over 26 cents per million B.T.U. Another Alberta coal costing at Moose Jaw in car loads $5.65 per ton has a calorific value of 12,380 B.T.U. per pound. Its cost per million B.T.U. is therefore very nearly 23 cents. A further comparison may be made with Pennsylvania coals, e.g. Youghiogheny coal costing in Regina about $8.50 per ton and having a calorific value per pound of from 12,000 to 13,000 B.T.U. The cost of this coal per million B.T.U. is therefore from 32½ to 35½ cents.

Many other examples might be given showing the economic possibilities of lignite, especially when dried before shipment. The calorific value of anthracite coal varies usually from 13,600 to 14,000 B.T.U. per pound.

It may be mentioned here that it is the practice of the British Admiralty, The United States Navy Bureau, and many other large consumers of coal, to purchase their coal supplies on a B.T.U. basis and this standard of comparison is considered to be the correct method of estimating the relative value of various fuels.

To ascertain the amount of moisture lignite loses by air drying two small samples were coarsely crushed and exposed to the air in a room. The results obtained were as follows:

	Sample No. 1		Sample No. 2	
	weight grains	loss per cent.	weight grains	loss per cent.
As taken	174	.	179.6	....
After 2 days	128	26	133.2	25.8
After 4 days	127	27	129.5	27.9

It will be noted that after a period of four days the loss in weight averages 27.5% of the original weight. As the amount of moisture originally present amounted to 31.3% of the total weight, it will be seen that the lignite lost in four days 90% of its original moisture.

A further experiment was made by taking a small lump of lignite weighing 270.7 grains. The drying was naturally somewhat slower, the reduction in weight being as follows:

Original weight of sample	270.7 grains	
Weight after 2 days	216.7 grains	loss in weight 20%
Weight after 4 days	203.7 grains	loss in weight 23%
Weight after 6 days	200.0 grains	loss in weight 25.5%

In this case it will be noted that the loss in weight after six days amounted to 25.5% of the original weight of the sample or 81.7% of the total moisture. In dealing with large quantities a longer time would be required to air-dry the lignite, probably several weeks.

The above experiments, however, and the preceding comparison of lignite with other fuels on a B.T.U. cost basis, sufficiently indicate the value of lignite as a fuel for power purposes. Unfortunately, as lignite loses its moisture, the coal becomes slacked, in which condition it is difficult to burn to advantage in an ordinary grate. An obvious method of using the dried lignite to good advantage is in the form of briquettes. As I understand, however, that the question of briquetting lignite is already being dealt with, this method of utilising dried lignite is merely mentioned.

Attention has already been drawn to the necessity of special treatment to obtain the highest possible economy in the combustion of raw lignite and the economical utilisation of dried lignite in a furnace specially adapted to consume slacked fuel does not appear to present any difficulty. It may be pointed out that by using air-dried lignite without further treatment, the cost of briquetting, etc., is saved and this method of utilising lignite as fuel for steam boilers has the initial advantage of the lowest possible fuel cost. Several types of furnaces for burning slacked fuel are already on the market and have met with considerable success. Some of these are especially adapted for burning colliery refuse, coke breeze and other low grade fuels. The methods adopted vary considerably. In some furnaces the fuel is burned on an ordinary or special grate, under air pressure obtained by fans or steam jets, in others the pulverised fuel is projected by an air blast through a nozzle into a combustion chamber where it ignites and so on.

As an illustration of the results obtained by a furnace especially adapted to the fuel to be burned the results obtained in burning low… slack may be cited. This fuel contains from 8 to 12% of moisture an… frequently from about 28 to 32% of ash. It is claimed that this low grade fuel which is much inferior to lignite, and which, when burned in the usu… manner, gives an over-all thermal efficiency of about 40%, is successfull… burned in a special furnace, with an over-all thermal efficiency of from 5… to 60%, giving an equivalent evaporation from and at 212 deg. F. of 4… pounds of water per pound of coal.

Producer gas engines also appear to offer a promising field for th… economic utilisation of lignite as fuel for power plants, and very litt… work appears to have been done hitherto in this direction. Permissio… was obtained to conduct a test of a producer gas plant using lignite fu… The information and data obtained from a carefully conducted test wou…

probably be of value, and I regret that the time at my disposal did not permit the test to be made.

The trials dealt with in this report, however, clearly indicate the value of lignite as fuel and a more rapid development of the lignite deposits of the province for power purposes will undoubtedly follow the general adoption of improved methods of utilising this fuel to the greatest advantage.

Your obedient servant.

R. N. BLACKBURN,
Chief Inspector of Steam Boilers.

SASKATCHEWAN LIGNITE USED OUTSIDE THE PROVINCE.

The Brandon Electric Light Company have 13 return-tube boilers, each 125 H.P. and two water-tube boilers each 250 H.P. Until recently Bienfait run of mine lignite was used as fuel and the experience of 13 years obtained at this installation was stated to be that only two-thirds the rated capacity of the boilers was secured when lignite was used, whereas with Pocohantas slack coal full capacity was got. In other words the calorific power of lignite is only two-thirds of that of good coal. Lignite costs $3.50 and Pocohantas coal $6.40 per ton. It was stated that one indicated horse power was obtained with a consumption of 7 pounds of lignite. Owing to the increased consumption of steam, superior coal is now used so as to secure the full capacity of the boilers.

The manager of the Brandon Steam Laundry was good enough to give the following data:

Lignite net cost..	$0.75 at mine
Freight ..	1.60
Unloading .	0.30
	$2.65, of which 8 tons per day were

used costing $21.20.

Pocohantas coal cost	$2.75 at mine
Duty	0.14
Freight	3.50
Unloading	0.30
	$6.69 of which three tons per day

were consumed, costing $20.07. The saving in cost of fuel by using the latter was therefore $1.13 per day, apart from labour, etc.

Owing to the increasing demand for steam the use of lignite was discontinued.

The Brandon water pumping plant is operated on lignite of which about 10 tons per day are consumed. The boiler capacity is 300 H.P. The engines are compound condensing.

Mr. Shaw, the engineer, gave the results of a test which he carried out in January, 1907, which are as follows:

TEST

Duration of test.... . .	10 hours.
Water pumped	853,340 gallons.
Average water pressure... ..	91 18 lbs. sq. in.

Average steam pressure	93.5 lbs. sq. in.
Coal burned	5,102 lbs.
Total water evaporated	22,903 lbs.
Average water evaporated per pound of coal	4.49 lbs.
Average temperature of feed water	90.9 deg. Fahr.
Average vacuum reduced to sea level	25.9 ins.
Temperature of city water	36 deg. Fahr.
Steam consumed per horse power hour	21.6 lbs.
Coal used per horse power hour	4.81 lbs.
Gallons water pumped per pound of coal	166.9

A week's test was also made April 14, 1912, when 67.79 gallons of water were raised from each pound of coal when consuming lignite and on April 21–27, 1912, 98.27 pounds of water were pumped per pound of Pocohantas coal. Lignite cost $3.00 and Pocohantas coal $6.39, both delivered. The extra cost of labour when using lignite is stated to be about 16 cents per ton. On the basis of the above figure the cost of lifting 1,000 gallons was 2.33 cents with lignite, including extra labour, and 3.23 cents with Pocohantas coal.

The Winnipeg high pressure fire pumps are operated by four 450 H.P. and two 250 H.P. Crossley's gas engines, which are supplied with producer gas from two 1,000 H.P. and two 500 H.P. generators. About 1,000 tons of lignite were used, but the plant was apparently not designed for such fuel. Trouble was experienced with clinker which formed in the producer and difficulty was found in the disposing of the tar. The heat value of the gas from lignite was about 150 B.T.U. per cubic foot, Pennsylvania bituminous slack is now used and the gas has a calorific of about 125 B.T.U. per cubic foot. It was stated that two pounds of lignite were consumed per brake horse power as compared with about 1¼ pounds of Pennsylvania coal. Lignite cost about $3.10 and Pennsylvania coal $5.80 per ton. So on the above results one brake horse power cost for fuel only, lignite 0.31 cents and bituminous coal 0.36 cents.

At Eaton's department store there is a steam plant consisting of Heines safety boilers, and here some tests were made to ascertain which fuel gave the most satisfactory results per dollar.

RESULTS OF TESTS made at Messrs. Eaton Co.'s Power House—Winnipeg

	1	2	3	4	5	6	7	8	9
Name of Engineer	Struther	Clark	Bonner	Hawkes	Struther	Bonner	Bonner	Bonner	Bonner
Date of Test	April 29	May 1	April 27	April 28	April 28	April 27	April 25	April 25	April 26
Duration of Test	4 hrs.	4 hrs.	4 hrs.	2 hrs.	4 hrs.	4 hrs.	4 hrs.	4 hrs.	4 hrs.
Kind of fuel used	4 H'd Screen 1 Soft	4 H'd Screen 1 Soft	4 H'd Screen 1 Soft	4 H'd Screen 1 Soft	40% Lignite 40% Hard 20% Soft	40% Hard 40% Lignite 20% Soft	100% L'nite	50% Lignite 50% Hard	30% Lignite 30% Hard 30% Coke 10% Soft
Amount of fuel used	7,600	8,000	9,000	4,800	8,800	11,700	14,000	8,000	10,600
Value of fuel used	$17 49	$17 98	$20.36	$10.95	$17.95	$24 21	$21.35	$14 80	$19 40
Quantity of water evaporated	49,050	43,650	50,850	27,000	29,250	56,250	54,900	30,600	54,000
Water evaporated per lb. coal	6.45	5.45	5 65	5 62	3 32	4 80	3 92	3 825	5.09
Water evaporated per $1.00	2,804	2,427	2,492	2,472	1,629	2,323	2,571	2,070	2,783
Horsepower developed	408.75	363	423.75	450	243.4	468 75	457	255	451
Number of boilers	1	1	1	1	1	1	1	1	1
Rated horse power	370	370	370	370	370	370	370	370	370
Temperature of feed water	147	147	147	147	147	147	147	147	147
Steam pressure	130	130	130	130	130	130	130	130	130

The principal reason for now using anthracite and bituminous coal instead of lignite was stated to be the uncertainty of having a regular supply of 50 tons per day.

OTHER USERS OF LIGNITE.

ALBERTA.

At the Edmonton power house, 1,000 tons of local lignite are consumed per week under water-tube boilers, having a total capacity of 6,000 H.P. There are also one 9 feet by 15 feet and one 8 feet by 14 feet down-draft Loomis-Pettibone gas producers and one 1,000 H.P. gas engine built by Allis Chalmers & Co. There are also scrubbers, etc., and a gas holder, the capacity of which is 26,000 cubic feet. The producer gas has practically a uniform calorific value of 125 B.T.U. as recorded by an automatic recording calorimeter. The consumption of lignite is 2 to 2.25 pounds per kilowatt hour exclusive of steam generation or 2½ to 3 pounds including same. A considerable quantity of water is required to wash and scrub the gas and to cool the cylinders. The latter in particular can be re-used when cooled.

At the Calgary power house about 30 tons of Taber lignite slack are consumed in 24 hours under water-tube boilers having a total capacity of 5,000 H.P. As the installation [illegible] e completed, the engineer could give no statistics as to the res[illegible] ob[illegible] d. At the time of inspection very wet lignite was fed into the f[illegible] s, but it was not possible to judge the effects, yet apparently ample steam power was maintained. Induced draft was in operation reducing the gas pressure in the uptake of the boilers by 0.8 inch. The consumption of lignite was stated to be about 5 to 6 pounds per kilowatt hour and about 9 pounds of coal was burned per square foot of grate area.

The Lethbridge power house is located on the north bank of the South Saskatchewan River, and within about one-half mile from the lignite mine which is at the base of the steep slope. The coal as soon as mined is conveyed on a narrow gauge-line to the power house and discharged into a hopper, whence it is elevated to the bunkers over the boilers. When the present installation is complete the total capacity of water-tube boilers will be 2,500 H.P. On a special test one pound of coal evaporated 7½ times its weight of water, but during 1911 the average was 6.15 times from and at 212 deg. Fahr. The engineer (Mr. Reid) supplied the following figures:

ANALYSIS OF COAL

Moisture	6.00%
Vol. matter	39.80%
Fixed carbon	48.42%
Ash	5.78%
Sulphur	0.96%
B.T.U.	10.000

RESULTS of Operation.

	Jan., 1912	Feb., 1912	Mar., 1912	Apr., 1912	May, 191
Total Coal consumed lbs	1,484,000	1,476,200	1,364,190	1,311,750	1,233,090
Total Water evaporated	8,512,180	7,856,570	9,237,688	8,187,554	8,263,80
Total Output K.W.	158,700	143,590	137,270	127,740	126,80
Total Water pumped gals.	29,391,000	26,713,000	28,518,000	28,938,000	35,978,00
Water evaporated per pound of coal	5.75	5.7	6.75	6.24	6.7

Feed water average temperature 200 deg. Fahr. Green and Sturtevants economisers and induced draft fans are in use.

In the three foregoing stations chain-grates and mechanical stokers are used.

DAKOTA.

At Hebron mining experiment station,[1] experiments have been carried on for about three years in the manufacture of gas from lignite by dry distillation or, using the more precise chemical term, "thermalysis," that is, out of contact with air, and in the briquetting of the lignite-coke residue. These experiments are interesting and instructive, inasmuch as they were made in an ordinary full-sized retort, with charges ranging round 400 pounds of air-dried lignite, containing a small percentage of moisture. The periods of c ation were about three hours' duration.

Dakota lignite is somewhat similar to that found in Saskatchewan, as will be seen by the following proximate analyses.

AIR-DRIED COAL.

	Moisture	Volatile Matter	Fixed Carbon	Ash
Average of 25 samples of Dakota lignite	29.0%	39.40%	52.00%	8.60%
Average of 6 samples of Saskatchewan lignite	....	43.26%	45.64%	11.29%

Prof. E. J. Babcock, Dean of the College of Mining Engineering of the University of North Dakota, stated in his report, dated Feb. 1, 1911,[2] that the legislative session of 1909 made an appropriation to carry on scientific investigations, inter alia, to arrive at practical methods of utilising and developing the mineral industries.

The phraseology used by the legislature in this connection was "Investigations and practical tests shall be made to obtain a cheap and efficient method of lignite coal briquetting, to show by actual tests the best methods of burning lignite and to determine the possibility of using lignite as a gas producing material."

At first, laboratory investigations were made at the University and then to prove it possible to manufacture gas and make briquettes in a commercial manner, gas making and briquetting plants were erected at Hebron.

The equipment of this experimental gas plant consists of one retort, one condenser, one exhauster, two scrubbers, one purifier, one meter, all full sized and in proportion, one gas holder, etc. The more essential particulars as to dimensions are as follows:

Ordinary fire-clay retort 15 inches x 26 inches x 9 feet, 4 inches thick, built in a bench and provided with an ordinary furnace connected to flues which surround the retort; the fuel being raw or "green" lignite which is mined a short distance away.

[1] C. E. Munroe, By-Product in gas manufacture, "Progressive Age," Oct. 1, 1912.
[2] "Investigations of lignite coal relative to the production of gas and briquettes."

The steam arising from the burning of fresh-mined lignite had a cooling effect on the hot fire-clay retort and caused it to crack. To avoid the cost of replacing the same, which might also be cracked in a similar manner, a cast-iron retort was slipped into the existing clay-retort.

The retort is fitted with a self-luting cast-iron mouthpiece connected by an ascension pipe to the hydraulic main, where tar and water are collected and removed at will.

The water-tube condenser which condenses the tarry vapours and moisture, is 3 feet in diameter and 11 feet high and contains 21 water tubes, 3 inches by 8 feet, through which water flows to cool the gases.

The exhauster is a steam driven No. 1 Root with 3 inch inlet and outlet. When lignite or other coal is being distilled or carbonised the gases are driven out and as they accumulate a certain amount of back-pressure tends to be created within the retort and this affects the quality and quantity of gas made, so this pressure is reduced to a minimum by means of the exhauster.

The two cylindrical tower scrubbers are 24 inches in diameter and 8 feet high and remove the remaining tar, ammonia, etc., whilst the purifier, which is a steel cylindrical box 4 feet in diameter and 2 feet 6 inches deep filled with lime or oxide resting on trays, removes the carbonic acid, sulphuretted hydrogen, etc.

The gas is measured by means of a Westinghouse meter and the gas holder 9 feet 9¼ inches diameter and 13 feet 6 inches high, stores the gas produced. It is advisable to explain that some coals when burned in retorts or ovens, cake or lute together and thus form a coke which is valuable as a fuel for a variety of purposes. There are also coals which under similar treatment will not cement together to form a coherent mass or coke but more or less retain their original shape and condition. Prof. Vivian B. Lewes expresses his opinion that "there is no doubt that it is the resin bodies and their derivatives—the hydrocarbons—in [illegible] that form the tar, which yields the pitch that lutes the coke, and [illegible] the resin bodies play a very important if not the chief part in the weathering of coal."[1]

In the first kind of coal "the proportion of resin and hydrocarbon bodies has reached the right ratio as compared with humus and residuum and the best coking coal is obtained." But in the latter kind "the humus-like bodies are still present in much larger quantities than the resinic compounds and hydrocarbons and as on distillation they leave no binding material in the residue, the resinic bodies cannot supply enough to give more than a friable mass."

Many bituminous coals produce good coke while lignites as a rule do not, but nevertheless, lignite-coke is amenable to treatment as will be explained. Charges of about 400 pounds of air-dried lignite from different mines were put into retort, the mouthpiece lid made gas tight, and the furnace beneath kept at a good temperature. The heat required at ordinary coal gas works to distil the coal is about 2,300 deg. Fahr., but during the experiments made at Hebron "it was found that the gas distilled freely at 900 deg. to 1,000 deg. Fahr., while the proper temperature to give the maximum quantity and quality of gas seemed to be between 1,200 and 1,400 deg. Fahr." This indicates that less fuel is required to carbonise lignite than in the case of coal and therefore less wear and tear and cost.

[1] "Carbonisation of Coal" Cantor Lectures, Royal Society of Arts, 1911.

As the gas passed through the various parts of the plant, observations were made as to its rate of production and also that of tar and liquor.

The coke residue is, as already explained, an incoherent friable mass.

The gas was analysed daily and the average standard results of same unpurified, are stated by Prof. Babcock to be as follows:

Sample Series	Illuminants	Carbon M'oxide	Hyd'gen	Ethane	Methane	Nitrogen	Oxygen	Carbon-Dioxide
A.......	3.11	17.24	45.16	0.14	15.59	5.49	1.76	11.51
B..	2.10	19.24	41.26	0.39	16.31	4.30	1.00	15.40
C.......	2.35	18.70	45.45	1.02	14.42	5.31	1.21	11.51
Average	2.52	18.73	43.96	0.52	15.41	5.04	1.32	12.77
(The following is inserted for purposes of comparison)								
Purified Gas from Standard gas coal (average) American	5.50	11.50	13.50		35.00	2.00	0.50	2.00

It will be observed that the illuminating power of the gas is low—illuminants and methane—and the carbon dioxide is high, but the latter can be reduced and the quality of the gas thereby improved.

The volume of gas obtained per ton (2,000 pounds) of air-dried lignite and the calorific value is reported by Prof. Babcock to be as below:

Sample Series	Unpurified		Purified from Carbon Dioxide and air	
	Yield cu. feet	Calorific value in B.T.U.	Yield cu. feet	Calorific value in B.T.U.
A.......	10,663	400.07	8,523	500.00
B.......	11,306	406.60	9,347	491.80
C.......	11,801	399.80	9,416	501.1
Average	11,257	402.20	9,095	497.6

It is understood that the lignite in these last tests contained about 15 per cent. moisture, in which case the raw lignite yielded 9,569 cubic feet of unpurified gas and 7,730 cubic feet of purified gas, but if the lignite had only 4 per cent. moisture, then the figures would be about 10,806 and 8,731 respectively.

With improved and larger equipment these results could, doubtless, be much exceeded.

The gas is stated to produce "a clear smokeless flame, easily regulated and with proper adjustment the light is equal to that prod ced from any city gas." This does not conform with experience gained in Texas, Ann Arbor and elsewhere. The analysis of the gas does not indicate high illuminating power; but the heat value, in view of the developments which are now taking place in ordinary gas manufacture, will be approximately equal to about four-fifths of coal gas. The general use of incandescent mantles with coal gas renders it almost unnecessary to supply high quality and high priced gas, as with the calorific values reported by Prof. Babcock, mantles will yield a medium lighting power. But in view of the fact that most towns have electric power plants available for lighting purposes, there is no need at the present juncture to discuss the lighting phase of the problem. According to the results of the Hebron experiments lignite gas can be used for heating, cooking and for power.

Besides gas, lignite also produces coke, tar and ammoniacal liquor. The average production of coke amounted to 1,143 pounds per ton of air dried lignite (containing about 15 per cent. moisture) or about 1,340 pounds per ton of dried coal. From 20 to 40 pounds of tar and 14 to 15 pounds of sulphate of ammonia were also produced.

The coke is pulverulent—non-caking—and must therefore be briquetted before it is available for sale and use.

The briquetting plant at Hebron has been somewhat improved since the publication of the report. The coke and about four per cent. of soft-caking coal are conveyed by a Loudin litter carrier to a bin and then conveyed by a drag-chain to a screw conveyor and then elevated to a Raymond cyclone disintegrator where the coke is broken up into small particles. Then it is conveyed and elevated to Sturtevant plain balanced rollers where the coke is crushed so as to pass through a screen having 20 meshes to a lineal inch, and from there falls into a bin. The coke is fed therefrom by an automatic worm-feeder into a steam jacketted conveyor where it is heated to about 250 degrees Fahr. and here 2 per cent. of flour is added. From the steam heated conveyor the coke and flour is discharged into a mixer where 6 per cent. of hot pitch is sprayed under steam pressure and the whole mixed together by puddling paddles. On its way the mixture receives 12 to 16 per cent. of hot water, after which it is discharged into a hopper fixed over a Mashek roller briquetting press where the briquettes are made and immediately cooled and conveyed by a belt to a storage bin. The pitch is heated in a steel sheathed tank by steam coils to 250 degrees Fahr.

As the Hebron plant is essentially experimental it would be unfair to base any estimates as to cost on what is done there. The initial expenditure and the cost of operating a lignite gas plant together with briquetting coke will be discussed later on, when dealing with the general question of power development.

The relative value of lignite coke briquettes and raw lignite and imported coal may be judged by the following figures obtained by analysis

	Taylorton Lignite	Dakota Lignite-coke briquettes	Latta Raw-lignite briquettes	Banff Coal briquettes	Virginia Coal	Taber lignite (Galt)
Moisture .... "	28 6	8 44	16.4	0.55	3.05	13.0
Volatile Matter .... "	49 00	32 50	47.8	8.50	31.65	36.0
Fixed Carbon .... "	42.9	58 50	62.60	67.5	60.82	49.9
Ash .... "	8 1	16 0	9 6	15.0	4.48	14 1
Calorific value B.T.U	10,692	11,050	12,100	12,800	14,470	11,72
Cost per ton, del'd Regina..	$6.00	$8.00	$8.50	$9 00	$12.00	$8.0

Another experiment is now being made at Hebron and that is carbonise lignite in a beehive coke oven. This oven is 6 feet in diamet and 8 feet high internally, it has a hearth sloping towards the door and domed roof. Fire is first kindled on the hearth and when it is permanent established lignite is added to it until the bottom of the oven is fille The furnace door is then closed and the oven is filled to the base of t domed roof. The lignite remains in the oven for three days and is th drawn out. The next charge does not require a fire kindled, as a pa of the old charge is left in. The third and subsequent charges are ignited by the heat retained in the brickwork. About 4 tons of lignite in one charge can be carbonised with the minimum of labour, but at the present time no reliable data is available as to the results obtained.

It is stated that raw lignite produced by carbonisation in this oven about 9,000 cubic feet of gas and about 40 per cent. by weight of coke.

WILLISTON, N. DAKOTA—STEAM PLANT.[1]

The United States Geological Survey in 1908 conducted tests at Williston irrigation pumping station with brown lignite under steam boilers.

The lignite is mined on an adjacent government land, the analysis of which was as follows:

Average of 16 tests	In moist coal	In combustible
Proximate—Moisture	42.61	
Fixed Carbon	26.27	52.81
Volatile Matter	24.10	41.15
Ash as fired	7.03	12.26 (dry)
Sulphur	1.04	1.24 (dry)
Ultimate—	Dry	Combustible (moisture and ash free)
Carbon	61.92	67.56
Hydrogen	4.07	4.94
Oxygen	21.05	24.01
Nitrogen	1.07	1.22

The furnace was of the semi-gas-producer type and had an external resemblance to the so-called Dutch oven. The setting is shown on the drawing. The solid fuel was gasified on the grate and the gas passed through the space under the arch into the combustion chamber, where most of the gaseous combustible was burned. The necessary air for combustion was added through the openings (A) in the bridge wall. The air was preheated to 200 to 300 deg. Fahr. in coils (P) and forced by a fan blower into the furnace under a pressure of 0.5 to 1 inch of water.

The furnace was equipped with a rocking grate consisting of two rows of bars connected to two shaking levers so as to operate alternately. (See plate 3.)

The pressure in the ashpit, varying from 1 to 2 inches of water, was maintained by argand blowers using superheated steam supplied from an independent steam boiler so as to ascertain the amount of steam consumed.

The following table gives the principal dimensions of the furnace, the boiler and the grate:

[1] Bulletin 2. North Dakota lignite as a fuel for power plant boilers. U.S. Bureau of Mines.

PRINCIPAL DIMENSIONS.

Furnace		
Width in front	feet	6 6
Width back of bridge wall	"	7.5
Length	"	8
Height	"	7
Roof of Furnace		
Length (straight portion)	"	8 5
Length at sides	"	15 8
Length in middle	"	15.3
Height in rear above bridge wall	inches	23
Number of openings		16
Size of openings	inches	2x1.5
Width of partitions	"	2
Bridge Wall		
Width at base	feet	5
Width on top	"	3
Height	inches	40
Number of openings		6
Size of openings	inches	5x25
Side Door		
Lower edge above grate	inches	7.5
Height	"	17
Width	"	19
Firing Door		
Lower edge above grate,	inches	21
Height	"	14.75
Width	"	19 75
Chimney		
Height above grate	feet	155
Diameter	inches	51
Boiler		
Builders' rating	H.P.	258
Water heating surface	sq. ft.	2587
Dia. of steam drums	inches	42
Length of steam drums	feet	10.33
Dia. of mud drums	inches	42
Length of mud drums	feet	8.83
Number of tubes		209
Diameter of tubes	inches	3 25
Grate		
Width	feet	6 6
Length	"	8
Width of grate bars	inches	7.4
Width of rib	"	.44
Width of air space	"	.44
Depth of air space	"	1.75

Careful observations were made by the staff employed as to the behaviour of the lignite and the results obtained, and the usual methods were adopted in weighing and sampling the fuel; measuring the feed water; sampling flue gas; taking temperatures; recording the steam pressure and measuring the drafts, all of which are fully set forth in the bulletin.

The following tables give the average results obtained, and as these tests were made on a practical scale with lignite very similar in composition to that found in South Saskatchewan, the results are given in full.

Summary of average observed data and calculated items of 15 steaming tests made with North Dakota lignite, October 8th to 29th, 1908.

CONDITIONS OF FUEL

	Fresh
Average pressures	
Barometer (inches of mercury)	28.00
Steam above atmosphere (in pounds square inch)	
(1) At gauge	135.4
(2) To ash pit	60.2
Draft (inches of water)	
Below atmosphere	
(1) Stack	.266
(2) Furnace	.19
Above atmosphere	
(1) Ash pit	1.56
(2) To bridge wall	.35
Average temperature (F) of	
Atmosphere	
(1) Outside	49.4
(2) Fireroom	72.7
Preheated air to bridge wal	232.3

Average temperature (F) of—*Continued*	
Steam to ash pit blowers	453
Feed water in tank	50.4
Calorimeter	287
Flue gas	492.4
Furnace	2,107
Fuel (total weight in pounds)	
As fired	26,459
Dry	16,170
Ash and refuse	1,465
Total combustible consumed (pounds)	14,000
Fired per hour (pounds)	
Dry fuel for grate	1,432
Dry fuel per square foot of grate	25.25
Combustible	1,115
Refuse in dry fuel (per cent.)	9.61
Proximate analysis (per cent.)	
Fixed carbon	
(*a*) In moist coal	26.27
(*b*) In combustible	52.81
Volatile matter	
(*a*) In moist coal	24.10
(*b*) In combustible	41.17
Moisture in fuel as fired	42.61
Ash in fuel	
(*a*) As Fired	7.03
(*b*) Dry	12.26
Sulphur, separately determined (per cent.)	
In moist coal	1.04
In dry coal	1.24
Accompanying 100% combustible	1.35
Ultimate Analysis (per cent.)	
Carbon	
(*a*) Dry coal	61.92
(*b*) Accompanying 100% combustible	67.56
Hydrogen	
(*a*) Dry coal	4.07
(*b*) Accompanying 100% combustible	4.92
Oxygen	
(*a*) Dry coal	21.05
(*b*) Accompanying 100% combustible	24.11
Nitrogen	
(*a*) Dry coal	1.07
(*b*) Accompanying 100% combustible	1.22
Water fed to boiler (pounds)	
Total	78,800
Equivalent evaporated from and at 212 deg. F.	
Total	94,95[illegible]
Per hour	8,21[illegible]
Accompanying 100% combustible	3.17
Into dry steam	94,396

Equivalent evaporated from and at 212 deg. F.—*Continued.*	
Per pound of fuel	3.50
(*a*) As fired	5.09
(*b*) Dry	6.67
(*c*) Moisture and ash free	
Actually evaporated	77,048
Total	6,750
Per hour	
Evaporation	2.77
Apparent, per pound of coal as fired	1.2153
Factor of	
Composition of refuse (per cent.)	19.33
Carbon	79.33
Earthy matter	44.10
Clinker	
Heat Value per pound (B.T.U.)	10,363
Dry fuel	11,799
Combustible	.91
Steam (per cent.)	99.47
Moisture in	
Horse power developed	237.6
In boiler	95.03
Per cent. of rated	
Efficiency (per cent.)	
Of boiler and furnace	59.32
(*a*) Alone	45.88
(*b*) Including grate	53.79
Over all	20.1
Average thickness of fuel beds (inches)	4.24
Average intervals between firings (minutes)	
Dry chimney gases	14.94
Per pound of combustible (pounds)	
Analysis (per cent.)	11.16
CO_2 (Carbon dioxide)	7.66
O_2 (Oxygen)	.45
CO (Carbon Monoxide)	80.68
N_2 (Nitrogen)	11,587
Heat value of 1 lb of combustible (B.T.U.)	
Heat Balance	7,163
Absorbed by boiler (B.T.U.)	
Heat lost in dry flue gases	1,486
B.T.U.	12.6
Per cent.	
Loss due to moisture in the fuel	1,06
B.T.U	9.1
Per cent.	
Loss due to moisture forming by burning of hydrogen	
B.T.U.	55
Per cent.	4.7
Loss due to incomplete combustion of carbon	23
B.T.U.	1.9
Per cent.	

Loss in escaping hydrocarbons, radiation and unaccounted for	
B.T.U.	1,382
Per cent.	11.91
Boiler supplying steam to ash pit	
Time used (hours)	10.68
Used for Argand blowers—Steam (pounds)	
(*a*) Total	5,893
(*b*) Per hour	552
Heat in form of steam (per cent.)	3.27
Evaporation (per cent.)	8.12

"*Density of Smoke.*—The visible smoke during all the tests was very light and appeared to be composed mostly of water vapour. At the top of the stack hardly any smoke was discernible, the colour of the smoke becoming apparent only at a distance of 15 to 30 feet from the top of the stack, where a density was observed that would be denoted on Ringelmann's chart as between Nos. 0 and 1.

"Test 1, October 8.—Test 1 was short and for that reason is not considered accurate. The fuel bed at the start was comparatively thin (about 6 inches) and when thickest was only 9 to 10 inches. Samples of coal and ash of this test were not sent for chemical analysis.

"Test 2, October 10.—Test 2 was run with superheated steam in the ash-pit blowers. Fire was run at low rate of combustion two days before starting the test and the fuel bed was apparently in good condition when the test was started. The fuel bed at start was about 17 inches thick; average for the test about 20 inches. The grates were shaken eleven times during the test. The fire had burned down at the close to the same level as at the start. In computing results 650 pounds were added to the weight of coal as correction for the clinkers in the fuel bed at the end of the test. Fairly uniform conditions prevailed during the test.

"Test 3, October 11.—Test 3 was run with superheated steam in the ash-pit blowers. Fire was cleaned about 1 or 2 o'clock in the morning and the boiler was run at 60 to 75 per cent. of rated capacity until test started. The fuel bed was about 13 inches thick at the start and 18 inches at the close; average for the test about 20 inches. During the test about 165 pounds of coal was fired at intervals of two or three minutes, spreading the coal over the entire fuel bed. The grate was shaken ten times during the test. Uniform conditions prevailed during the entire test.

"Test 4, October 12.—Test 4 was run with superheated steam in the ash-pit blowers. The fuel bed was about 16 to 17 inches thick at the start and about 20 to 21 inches at the close; average during test about 20 inches. The grate was shaken eight times during the entire test. Coal was fired in charges of 160 pounds at intervals of four or five minutes spreading it over the entire grate area Uniform conditions prevailed during the entire test. Clinkers were more troublesome than in tests 2 and 3 This was probably due to the fact that the coal contained about 30 per cent. of slack. The fuel was apparently of inferior quality as compared with that of tests 2 and 3. Clinkers were heavy and fused to the brick on the sides of the furnace.

"Test 5, October 14.—Test 5 was run with superheated steam in the ash-pit blowers. Coal used on this test was crushed by hand and contained very small percentage of slack; it was mostly in pieces 3 to 6 inches through. Sulphur appeared, distributed in thin layers. The fuel bed was about 15 inches thick at the start and about 18 inches at the close. The grate was shaken eight times during the test. Fire was apparently in good condition during the entire test. Coal was fired in charges of 165 pounds at 15 minute intervals. From 3.30 to 5 o'clock the fan forcing the air into the furnace through the bridge-wall opening was out of repair and ran too slowly, so that not enough air was supplied to burn the gases; this resulted in high CO content in the flue gases.

"Test 6, October 16.—Test 6 was run with superheated steam in the ash-pit blower. Coal used on this test was crushed by hand and was wet from rain when fired. Sulphur appeared in rather large quantities, distributed in thin layers. The fuel bed was about 17 inches thick at the start and about 20 inches at the close; average during test about 22 inches. The grate was shaken five times during the test. Until about 3 o'clock the test was somewhat irregular, after that it ran smoothly. The grates were not shaken after 1.35 o'clock and the fire remained in good condition. Coal was fired in charges of 165 pounds at 4 minute intervals. The percentage of CO in the flue gases, as shown by analysis, is high when the air pressure to bridge wall openings are low; when the pressure is increased CO drops.

"Test 7, October 17. Test 7 was run with superheated steam in the ashpit blowers. Coal was crushed by hand. Sulphur appeared in large quantity distributed in thin layers. The fuel bed was 17 inche thick at the start and 22 inches at the close; average for the test about 2 inches. The grate was shaken four times during test. Little free ash wa found in the ash-pit at the end of the test. The grate seemed to be entirel covered by clinkers, and no more ash could be shaken down by rocking it When pulled the clinkers had a very strong SO_2 odour. The fire wa unmanageable during the last one and one-half hours, and the test coul not have been run much longer.

"Test 8, October 19.—Test 8 was run with saturated steam in th ashpit blowers. Coal was crushed by crusher, was very wet and con tained 20 to 30 per cent. of slack. The fuel bed was about 16 inches thic at the start and about 20 inches at the close; average for the test 18 to 2 inches. The grates were shaken five times during the test. Attemp to shake clinkers through the grate resulted in shaking a large amount fine coal into the ashpit. In cleaning after closing, large and thick piec of clinker were found on the grate.

"Test 9, October 20.—Test 9 was run with saturated steam in t ashpit blowers. Coal was crushed by crusher, was wet from rain a contained about 20 per cent. slack. The fuel bed was 15 inches thick the start and 20 inches at the close; average for the test 20 to 22 inche After 5 p.m. the fire seemed to be in bad condition on account of clinke preventing free passage of air through the fuel bed.

"Test 10, October 21.—Test 10 was run with saturated steam the ash-pit blowers. Coal was crushed by crusher. Fire was started 3 a.m. with the burning coal left of the grate after cleaning. The fu bed was 18 inches thick at the start and 22 inches at the close; avera for the test about 20 inches. Coal was fired in charges of 165 pounds 5 minute intervals.

"Test 11, October 22.—Test 11 was run with superheated steam the ashpit blowers. Coal was crushed by crusher; the appearance of coal was good. The fuel bed was 14 inches thick at the start and 18 inches at the close; average for the test 20 inches. The grates were shaken eight times during the test. Strong SO_2 odour came out of the ash-pit when grates were shaken. Coal was fired in charges of 165 pounds at 3 minute intervals. This test represents the highest capacity which can be developed with this apparatus and fuel without great decrease of efficiency.

"Test 12, October 23. Test 12 was run with saturated steam in the ash-pit blowers. Coal was crushed by crusher. The fuel bed was 14 inches thick at the start and 18 inches at the close; average for the test was 18 to 20 inches. The grates were shaken five times during the test, only very little at a time so that not much fine coal was shaken into the ash-pit. Coal was fired in charges of 165 pounds at 3 minute intervals.

"Test 13, October 26. Test 13 was run with superheated steam in the ash-pit blowers. Coal was crushed by crusher. The fuel bed was 14 inches thick at the start and 18 inches at the close; average for the test 18 to 20 inches. The grates were shaken six times during the test. One of the ash-pit blowers was stopped during the first three hours of the test.

"Test 14, October 27. Test 14 was run with superheated steam in the ash-pit blowers. Coal used had been exposed to sun and wind for 24 hours; the portion fired after 5.30 contained about 20 per cent. of slack. The fuel bed was 13 inches thick at the start and 18 inches at the close, average for the test 21 inches. The grate was shaken four times during the test. Coal was fired in charges of 165 pounds at 4 minute intervals.

"Test 15, October 29.- Test 15 was run with superheated steam in the ash-pit blowers, steam being supplied for this purpose by the main test boiler. One object of this test was to determine whether the clinkers could be made to fall into the ash-pit by frequent shaking of the grate and the fire thereby continually maintained in good running condition. At 9.45 a.m. one of the shaking bars on the left side of the grate became disconnected from the grate bars, and after that only the other (alternate) grate bars on the left side could be shaken. As a result of the frequent shaking of the grate much fine coal fell into the ashpit and the amount of refuse was increased considerably. At 6.30 p.m. the fire became unmanageable on account of clinkers on the grate, and the test had to be stopped. The fuel bed was 18 inches thick at the start and 22 inches at the close; average for the test 22 inches.

"Test 15 has been separated into two parts. The first 4 hours have been considered as preliminary. The intention was to run ten hours after that, but clinkers so accumulated on the grate that the second part of the test had to be stopped at the end of eight hours. The date of the two parts appear separately in Table 3. The whole test, including the preliminary part, is represented in the line opposite test number 15; the data of the last eight hours (omitting the preliminary four hours) are given in the line opposite 15A.

With regard to the effect of high moisture content on the temperature of products of combustion in a furnace employed to heat a steam boiler it is exceedingly important that this factor should be clearly understood and this is the excuse for making rather copious extracts from Bulletin 2 as it will have a tangible influence on the results to be expected at a central steam power plant if solid fuel is used.

In coals having high moisture content, such as the lignite used during the tests reported in this bulletin, the heat required to evaporate the moisture is taken from the highest temperature of the products of combustion, thereby reducing the heat available for absorption by the boiler and thus reducing the useful effects of the coal This is shown in plate 4, illustrating the results of test 4, in burning coal with varying supplies of air. The coal used during test 4 contained 44.26 per cent. of moisture. Calculations were made on the basis of one pound of combustible; moisture formed by the burning of hydrogen was added to the moisture in coal. Specific heat of water was taken as 1; latent heat of steam as 965; specific heat of steam as 0.48 constant at all temperatures; and specific heat of the gaseous products of combustion as 0.24, constant at all temperatures. The heat value of 1 pound of combustible, determined by calorimeter, was 11,567. The same calculations were made for coal with the moisture reduced to 20 per cent. and for coal chemically dry. In all computations it was assumed that the combustible was completely burned, a condition which in practice would be difficult to obtain, especially with the low supply of air.

It was found that the ash from lignite fused at a comparatively low temperature so that clinker was easily formed in the fuel bed. The engineers had hoped that a semi-producer type of furnace would eliminate this trouble. Shaking the grate bars helped a little but the pieces of clinker were large enough to extend over two or three bars and frequently retained their position despite the shaking. Inadequate provision in the design of the furnace was made to remove the clinker, but this of course can be remedied in future construction.

The conclusions arrived at by the authorities were as follows:

"The combination of boiler and furnace setting described gives good results with the North Dakota lignite. Steam can be made with a fuel efficiency of 55 to 58 per cent. of the heat in the coal and no difficulty is experienced in obtaining the full capacity of the boiler. The authors are of opinion that equally good or perhaps even better results can be obtained with mechanical stokers.

These results compare very favourably with the results obtained in the average plant using a good grade of bituminous coal when the heat available to the boiler is considered.

Little, if any, advantage is gained by crushing the coal by hand instead of in a power crusher. To reduce the moisture in the coal by weathering seems to improve the economy, but these tests are not sufficient in number to determine definitely the condition of the fuel and the time required for weathering to insure the best results The steam blower for the ash-pit is inefficient and there is no gain in supplying superheated steam to it. A considerable saving in steam and equally good results could probably be obtained by substituting for the steam blower a fan such as commonly used for forced draft."

St. Louis, Mo., Fuel Tests, 1904.

In 1904 the United States Congress set aside $60,000 "for analysing and testing at the Louisiana Purchase Exposition, the coals and lignite of the United States in order to determine their fuel values and the most economical method for their utilisation for different purposes."

Under the act all the testing machinery and all the coals had to be furnished to the government free of charge, but the operating plant was purchased. Buildings were erected and a chemical laboratory equipped so that the testing station was available for various investigations which were considered necessary to arrive at a reliable result. The report on the operations fully describes the plants which were contributed and installed and also the results, and the following notes have been taken from the same [1]

A large number of coals and lignites were tested for raising steam, producing gas, development of power and generation of electricity, briquetting experiments were also made; in short, the work done was to ascertain scientifically and on a practical scale, the possibilities of each fuel brought from various parts of the United States to the testing station. The report on this work is contained in three large volumes

Lignite and lignitic coals from Colorado, North Dakota, Texas and Wyoming were tested, the results of which are interesting and instructive but before the general details are given, it will be important to establish a standard for comparison.

West Virginia (Pocohantas) Coals "are high grade steam coals,— in fact, they are decidedly in the lead in this respect of all coals tested" (page 137.) The results show that for the production of one electrical H.P. hour developed at the switchboard in the producer gas plant, there were required from 1.15 to 1.60 (average 1.37) pounds of dry coal, while to produce the same result in the steam plant it took from 3.39 to 3.90 (average 3.61) pounds of dry coal. In other words it took 2.6 times as much coal in the steam plant to produce the same power as in the gas producer plant. The standard for comparison will be the above average, namely, 1.37 and 3.61 pounds respectively per electrical H.P hour.

Colorado coal is essentially lignitic, has a tendency to slack when exposed to the weather, and is available only for use in near-by localities. The results with this coal gave one electrical H.P. hour by steam plant for 4.85 pounds of dry coal as compared with 1.45 pounds (or 1.82 pounds as fired) by gas producer and engine.

North Dakota lignite, which is very similar to South Saskatchewan fuel, in the gas producer and engine produce one electrical H.P. hour with consumption of 2.07 pounds of dry lignite, or 3.42 pounds lignite as fired.

Texas lignite, like most lignites, disintegrates under the influence of the atmosphere which makes long shipments and storage impossible. This lignite produced one electrical H.P. hour on a consumption of 1.54 to 1.99 pounds of dry coal (average 1.76 dry or 2.66 pounds as fired).

Wyoming coal is a shiny black lignite and in the steam plant gave one electrical H.P. hour for every 4.99 pounds of dry coal and in the producer plant 1.82 pounds dry or 2.00 pounds as fired.

[1] Report on the operations of the Coal Testing Plant of the Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. United States Geological Survey. Professional Paper 48.

Tabulating the foregoing results, the contrast may be seen more clearly.

	Pounds dry coal to develop 1 E.H.P. in gas producer and engine	Pounds dry coal to develop 1 E.H.P. in steam plant	Rates of coal required in steam plant as compared with gas producer and engine to obtain same power
West Virginia Steam Standard	1.37	3.61	2.6
Colorado Lignite Coal	1.45	4.85	3.35
North Dakota Lignite	2.07	..	..
Texas Lignite	1.76	..	..
Wyoming Lignitic Coal	1.82	4.99	2.75

It must, of course, be borne in mind that these results were obtained on a practical scale, and with a constant load. The boilers were two 210 H.P. Heine boilers. One 100 H.P. Frost fire tube boiler, with plain grates and hand fired. One 250 H.P. Allis Corliss simple non-condensing engine rated at 26.3 pounds of steam per H.P. hour. One Frost 50 H.P. slide valve engine. One Taylor 250 H.P. gas producer with rotative ash-table, and continuous automatic feed. One Westinghouse 235 boiler H.P. gas engine and several electric generators.

The mechanical efficiency of the Corliss engine and the electric generator was 81 per cent.

It must also be understood that these tests were conducted by specialists, under favourable conditions, yet the experience with lignite was necessarily new and limited, as no previous comprehensive or practical tests had been made in the States.

On page 110 of Part I of the report there will be found the following statements which are especially interesting.

"How better to utilise the brown lignite deposits of this country (North Dakota) has been a question that has long attracted attention, but very little progress had been made toward its solution.

"The lignite disintegrates so badly that it can not be stored or shipped for any great distance, and in order to fit it for shipment many have been working along the line of briquetting and with fair success so far as manufacture of briquettes is concerned, but in every case the expense of the operation and the cost of the binder have been prohibitive.

"When the first car of brown lignite was received at the testing plant, experiments were made on the briquetting machines but with little success. A test was attempted under a steam boiler, but the equipment of the testing plant was not designed for this class of fuel and no satisfactory results were obtained. At this time it was not thought possible to use such fuel successfully in the gas producer, but by the time the second carload had been received at the plant the opinion had gained ground that producer gas could be made from this lignite, and a trial run was made. The expectations were of so doubtful a nature in the mind of the superintendent of the producer plant that the gas engine was run on a two-thirds load as it was feared that the product of gas would not be sufficient to enable the engine to operate at its full capacity. To the surprise of everyone the lignite worked well in the producer and the gas had a higher calorific value than that of any other coal tested. Altogether the trial was highly satisfactory; it seemed to solve the question of the production of power in North Dakota and eastern Montana.

"The result of the steam tests was so unsatisfactory that there is nothing by which a direct comparison can be made of the efficiency of the fuel in the producer plant as compared with the efficiency developed in the steam plant. Nevertheless a comparison of the results obtained on other coals under the steam boiler is instructive.

"The table shows that to produce one electrical H.P. hour in the producer gas plant required 2.29 pounds of dry North Dakota lignite, whereas, to produce the same result in the steam plant required 3.39 pounds of the best Virginia coal.

"This means that North Dakota lignite with the moisture eliminated, will do more work when used in a producer gas plant than the best coal in the country will do in a steam plant.

"These results are startling, but they are full of promise to the owners of lignite deposits and to the users of power in North Dakota, Montana and Wyoming.'

On page 29 and 30 of the same, where a summary of the resu ts are given, the fo lowing paragraphs appear

"Probably the most important of the results accomplished has been the demonstration that bituminous coal and lignite can be used in the manufacture of producer gas and that this gas may be consumed in internal combustion engines for the development of power, with a fuel economy of over 50 per cent. The use of the producer gas made from anthracite coal, from coke or from charcoal or power purposes and of producer gas from bituminous coal in steel works etc., is no new story; but the demonstration of the possibility of utilising bituminous coal and lignite in the gas engine is a decided advance in the economica combustion of coal for power.

"Of scarcely less importance are the results obtained in the use of lignite in the gas producer plant. It has been shown that a gas of higher quality can be obtained from lignite than from high grade bituminous coals, and that one ton of lignite used in a gas producer plant will yield as much power as the best Pennsylvania or West Virginia bituminous coals used under boilers. It appears, in fact, that as coals decline in value when measured by their steam raising power, they increase in value comparatively as a fuel for the gas producer.

"The brown lignites on which tests were made at the coal-testing plant were North Dakota and Texas and the unexpectedly high power producing qualities developed by them in the gas producer and gas engine give promise of arge future developments in these and other States in the far West where extensive but a most untouched beds of lignite are known to exist."

The loss due to moisture in the fuels when used under the steam boiler is most striking, for instance the loss of heat due to moisture in Illinois coal, averaged under 1½ per cent of the total heating value of the combustible constituents; with Virginia coals it was under ½ per cent., but with No th Dakota lignite it was 6.70 per cent. and Texas lignite 3.37 per cent.

Whilst the steam plant and gas producer plant were not the most efficient available, there is no doubt that during the nine years which have elapsed since these tests were made, both types of power plants have passed through many stages of improvements, so that with improved fire grates and other appliances, together with the knowledge and experience gained since 1904, probab y better results can now be obtained with ignite under boilers and furthermore with the development of gas producers suitable for lignite and the great progress made in the construction of reliable and efficient gas engines it is possible that superior results are now obtainable.

In part 3 of the report, page 1000, Prof. Robert H. Fernald, an eminent specialist in gas producer work, states that in comparing the results, "it should be borne in mind that in these preliminary tests, the object has been to demonstrate the possibility of using these coals in a producer, and not to show how efficiently they could be burned. Although the results in many cases have been highly satisfactory, there is no question that in second series of tests upon the same coals, made with the idea of showing the greatest economy, the amount of coal used per H.P. per hour will, in the majority of cases, be much less."

It will be desirable to note that according to the above report the Colorado lignite clinkered badly in the producer and required frequent poking, but the clinkers were not large and could be broken from the tops of the producer. Montana lignite also clinkered badly causing the blast to break through the bed in two or three places. North Dakota lignite is an ideal gas producer fuel but for its tendency to clinker. It yielded a rich gas, very uniform throughout the test, which was not the case with other lignites. The heat value of the gas from North Dakota lignite was higher than that from any other fuel tested (page 1200); it was 188.5 British thermal units per cubic foot of gas, whereas the next highest was Texas lignite with 169.7 British thermal units, but the yield of gas per pound was lower than any other coal.

In 1905 the gas producer plant was increased by installing another gas producer with economiser; the object of the latter was to preheat the air for the blast, but the results of the experiments made showed that it did not add to the efficiency of the producer, so it was discarded.

The following lignites were tested and the results obtained per one electrical H.P. per hour are shown below:

Lignites	In gas plant		Under boiler	
	Lignite as fired pounds	Dry lignite pounds	Lignite as fired pounds	Dry lignite pounds
Tesla, San Francisco	2.88	2.38		
Lehigh, North Dakota	2.82	1.90		
Cedar Coulee, North Dakota	2.83	1.80		
Wilton Mine, North Dakota	3.24	2.08	8.46	5.41
(For comparison)				
West Virginia Coal Standard		1.37		3.61

Take Wilton mine lignite and West Virginia coal results, and it will be seen that the ratio of consumption is:

	In producer lignite	Under boiler
Wilton	1.52	1.50
West Virginia as	1.00	1.00

But, expressing the results in another way, 2.08 pounds of Dakota lignite produced the same power by means of producer gas, as 3.61 pounds of Virginia coal did under a steam boiler.

The United States Government in 1905 voted $202,000.00 and in 1906 another $250,000.00 to continue the testing of fuel.

Lignite from Lester, Arkansas, used under a boiler developed 1 E.H.P. with a consumption of 9.72 pounds coal as fired or 5.96 pounds dry coal; in the producer the results were 4.07 pounds and 2.46 pounds respectively for same energy obtained.

Lignite from Fromberg, Montana, developed 1 E.H.P. under boiler for each 5.04 pounds coal as fired or 4.87 pounds dry coal, as compared to 2.25 pounds, and 2.06 pounds in the producer, whilst another sample from Montana gave 1 E.H.P. for each 5.04 pounds and 4.58 pounds as compared to 1.74 pounds and 1.59 pounds respectively.

The work of testing American fuels was removed from St. Louis and is now being carried on in Pittsburg. The results obtained at St. Louis by the use of lignites have been dealt with; it will be desirable to refer to further tests made at Pittsburg so that the information as to the data obtained on the value of American lignites may be made complete.

Test 179. Texas lignite gave some trouble, as it did not ignite readily, tar accumulated and a large amount of clinker was formed.

Tests 180 and 181 were also on Texas lignite, the experience was similar to No. 179. Test 183 was with washery refuse from Texas lignite. It contained 30 per cent. of ash and as fired had a heat value of about 9,900 British thermal units per pound. "This refuse burned readily in the producer, but with a tendency to cake necessitating poking of the fuel bed at frequent intervals."

Test 184 was made on North Dakota lignite which had a moisture content of 35 per cent. and for this reason it ignited slowly, when the fire was first kindled. After the fuel bed was burning well, however, the lignite ignited readily and produced a very satisfactory gas. Throughout the test the plant was shut down each night and during the day it was operated for a period of about 9 hours. The results of the test are based upon the total quantity of fuel used, no allowance being made for stand-by losses. The fire held in the producer over night remarkably well, and usually not over 10 to 15 minutes each morning were required to get the plant in operation. Throughout the entire test the resistance of the fuel bed was exceptionally low and but few shots were made; the amount of clinker which formed during this test was small, and in no way interfered with the operation of the producer.

Test 185 was on California lig[illegible] which contained 38 per cent. moisture, and had a heat value of 6,3[illegible] British thermal units per pound. This lignite did not ignite readily or produce gas of uniform quality and clinker gave trouble.

Test 188 California lignite briquettes were tried and it was found that they gave better results.

The general results obtained were as follows: 19.6 to 33.6 pounds of lignite were consumed per square foot of fuel bed area per hour. North Dakota lignites averaged 28.5 pounds.

The gas produced had a heat value ranging from 91.6 to 126.7 British thermal units per cubic foot. North Dakota lignites averaged 113.5 and 10,800 British thermal units produced one brake H.P. hour.

The economic results with North Dakota lignites were 2.17 to 2.36 pounds dry lignite per electrical H.P. hour or 3.36 to 3.62 pounds as fired.

For the remainder of the statistics given, reference should be made to Bulletin 13.[1]

To convert the above quantities of lignite consumed per electrical H.P. per hour to that required per brake H.P. per hour it is necessary to multiply the figures by 0.85.

The results of tests made by the United States Geological Survey and latterly by the United States Bureau of Mines with many kinds of American coals during the years 1904-1910 in gas producer plants, and under steam boilers afforded an excellent opportunity to contrast the same with the results obtained at McGill University, Montreal, with Canadian coals in a smaller producer plant.

Both results have been plotted in on squared paper (see plate 5) the horizontal lines (abscissae) represent heat values in British thermal units = "x" and the upright lines (ordinates) represent the quantity of coal consumed to develop one brake H.P. per hour = "y". The curve obtained showing the average of American results is a straight line which may be expressed in the form of y = mx plus c (m and c being constant). The following is the approximate formula for the curve:

Pounds dry coal per B.H.P. hour = 2.75—.00012 British thermal units.

As shown by the chart some of the lignite points lie off the curve and consequently the above formula will not apply in all cases.

The results of Montreal tests are also plotted on the same sheet and are indicated by triangular spots, but they are not sufficiently uniform to permit an average curve being drawn and a formula to be deduced. It is difficult to account for the difference in the results obtained for in both cases the tests were conducted by trained experts, and it would be reasonable to expect approximately comparative results under these conditions.

The tests on lignite are marked "L" and it will be observed that in some instances the coal consumption per brake H.P. hour is greater and in others less than the mean. The principal drawback in all the tests is their comparatively short duration, and as they were not conducted under normal working conditions, under inferior supervision and with the losses due to banking of fires, irregular loads, repairs, etc., the foregoing results may probably be regarded as the "topnotch" mark to be expected in ordinary practice.

The actual results obtained under usual working conditions will be dealt with later on in the following pages. As explained when discussing Pittsburg test the consumption of lignite included that required for banking fire for 15 hours out of 24, and the quantity consumed under these conditions was 3.10 pounds of coal as fired per brake H.P. per hour.

GAS TO BE OBTAINED FROM LIGNITE, ETC.

"Peat is capable of producing excellent illuminating gas by distilling it in cast iron retorts, heated from the outside." "The distillation of peat for illuminating gas manufacture must be carried on at a red heat, or higher, in order to decompose the heavier hydro-carbons into permanent

[1] Bulletin 13. "Resume of Producer Gas Investigations." United States Bureau of Mines, 1911.

gases that will furnish substances to brighten the flame when the gas is burned." "If distillation is carried on at temperatures that are too low the gas contains much more carbon dioxide and gives a colourless flame when burned. The percentage of carbon dioxide may reach 25 to 30 per cent. and even more if the peat used is not thoroughly dried when it is put into the retort. The evaporation of the water present lowers the temperature of the gases formed so much that the carbon dioxide developed is not decomposed." The quantity of time necessary for the removal of carbon dioxide is great, and this has operated against the use of peat as a source of illuminating gas. Peat is stated to be capable of yielding from 8,900 to 10,400 cubic feet of gas per ton of 2,000 pounds. "That it might be used in properly designed and constructed plants in regions remote from supplies of suitable coal and where peat is common is clearly indicated."[1]

Lignite has already been described as a substance intermediate between peat and bituminous coal, and what is claimed producible from peat may be reasonably claimed for lignite.

AMERICAN GAS COAL TESTS.

In reply to a letter addressed to Prof. Alfred H. White, of the University of Michigan, who with Mr. Perry Barker conducted comprehensive tests on "Coal, available for the manufacture of illuminating gas,"[2] he referred to a full-sized test on lignite from Carbon County, Wyoming.

Fifty-nine sacks of this coal as it left the tipple were tested to ascertain the results to be obtained from such highly oxygenated coals.

The following figures have been extracted:

Wyoming Lignite	Coal as Received	Dry coal	Moisture and ash-free coal
Proximate analysis			
Moisture	22.56	.....	.....
Ash	5.81	7.50	.....
Volatile Matter	32.26	41.66	45.04
Fixed Carbon	39.37	50.84	54.96
Sulphur	0.36	0.46	0.50
Heat value, British thermal units	9,592	12,386	13,390
Ultimate analysis			
Hydrogen	.....	5.03	5.41
Carbon	.....	68.80	78.05
Nitrogen	.....	1.08	1.16
Oxygen	.....	17.58	18.93
Sulphur	.....	0.42	0.45
Ash	.....	7.09	.....

Coke from Wyoming Lignite	Coal as received	Dry coal	Moisture and ash-free coal
Proximate analysis			
Moisture	16.25	.....	.....
Ash	11.49	13.72	.....
Volatile matter	1.06	1.27	1.47
Fixed Carbon	71.20	85.01	98.53
Sulphur	0.31	0.41	0.48
Heat value, B.T.U.	10,447	12,474	14,458

[1] Bulletin 16, "The Uses of Peat," United States Bureau of Mines, 1911.

[2] Bulletin 6, United States Coals available for Manufacture of Illuminating Gas, Bureau of Mines, 1911.

Screenings	Coal as received	Dry coal	Moisture and ash-free coal
Moisture	11.45	......	......
Ash	6.13	6.92	......
Volatile Matter	37.06	41.85	44.96
Fixed Carbon	45.36	51.23	55.04
Sulphur	0.32	0.36	0.39
Heat value, B.T.U.	10,939	12,353	13,271

Retort operations

Charge of Wyoming lignite as received	400 pounds
Charge of lignite, dry	309 pounds
Production of coke	201 pounds
Dry coke, percentage of coal charged	50.2 per cent.
Dry coke, percentage of dry coal charged	64.9 per cent.
Breeze (small coke)	88.4 per cent.
Period of carbonisation	4.25 hours
Yield of gas per pound of coal as charged	5.4 cubic feet
Yield of gas per pound of dry coal as charged	7.0 cubic feet
Calculated average heat value, gross	564 B.T.U.
Calculated average heat value, net	502 B.T.U.
Average candle power	8.8
Calculated average gas analysis per cent.	
Carbon dioxide (CO_2)	7.6
Illuminants (C_nH_{2n})	4.9
Oxygen (O_2)	0.2
Carbon monoxide (CO)	14.4
Methane (CH_4)	29.0
Hydrogen (H_2)	40.2
Nitrogen (N_2)	3.7
Yield of tar, ammonia.	
Tar per ton of coal as charged	14.4 gallons
Tar per ton of dry coal	18.6 gallons
Ammonia NH_3 per ton of coal as charged	3.77 pounds
Ammonia NH_3 per ton of dry coal	4.88 pounds
Heat value of gas per pound of coal	3,046 B.T.U.

When the retort was opened at the end of the run the coke was so fine that it flew in sparks all over the retort house.

It will be useful to compare the tests made as already reported.

	Wyoming lignite	Dakota lignite	Texas lignite	Italian lignite
Cubic feet of gas produced per pound of dry coal	7.0	4.0	3.6	3.7
Analysis of g[illegible]r cent.				
Carbon di[illegible]	7.6	12.77	....	....
Illuminants	4.9	2.52	....	....
Oxygen	0.2	1.32	....	....
Carbon Monoxide	14.4	18.73	....	....
Methane	29.0	15.44	....	....
Ethane	....	0.52	....	....
Hydrogen	40.2	43.96	....	....
Nitrogen	3.7	5.04	..	....

The equipment at Ann Arbor was more complete than at Hebron and the advice of various members of the Michigan Gas Association and the practical assistance of the engineers of the Detroit City Gas Company probably rendered it possible to obtain better results.

The temperature required to produce the maximum quantity of gas from lignite, is, according to Prof. Babcock's test between 1,200 degrees and 1,400 degrees Fahr., whereas with bituminous coal the heat ranges about 2,300 degrees Fahr.

Coalite process. The coalite process, which was carried on in England, required a low temperature of 800 degrees Fahr., and this produced gas of high illuminating and calorific value, as well as "coalite," which was coal from which the volatile components had been extracted. This process was not a commercial success, mainly because of the difficulty of disposing of the gas, but it is understood that further steps are being taken to resuscitate the industry and that the process has been much improved. Smokeless free burning and hard fuel is now producible, as well as a large quantity of gas, but of a slightly lower heat value. The plant required for this process consists of narrow oval vertical retorts, which are filled almost full with coal. The coal is carbonised under relatively low temperature for about 7 hours. By this method, producing power by this method on a large scale at the lignite mines may not be economically applicable, yet the product "coalite" when made from bituminous coal is a valuable domestic fuel for raising steam and for use in gas producers. It is very probable that with lignite this product would have to be briquetted, and in that form would be more marketable than raw lignite. The gas could be used for heating the retorts operating gas engines, raising steam, etc.

Illinois experiments. Before disposing of the methods of gas production, etc., it will be useful to refer to experiments which were made by Messrs. Parr and Olin at the University of Illinois.[1]

These experiments have developed three lines of industrial interest.

"First, the possibility of developing smokeless fuel of good texture and admirably suited to domestic as well as to general industrial use, where the absence of smoke is essential.

"Second, they suggest a possible method for the manufacture of producer gas which would be free from present difficulties attending the use of bituminous coal, and would convert a much higher percentage of the fuel into gaseous form.

"Third, there are opened up interesting possibilities in the production of coke, briquettes or other forms of fuel."

The heat employed was low, the gas produced had a very high calorific value,—equal to natural gas,—and the coke owing to its freedom from tar, etc., was excellent for gas producers.

For further particulars reference should be made to the bulletin. The coal was bituminous but the test suggests a line of experiments which might prove advantageous to the development of lignite mining in this province.

Texas. Texas possesses large tracts of lignite deposits and also bituminous coal, and many efforts have been made to utilise the former as the use of the latter was better understood. In 1877 Mr. Edwin T.

[1] "Coking of Coal at Low Temperature," University of Illinois, Bulletin No. 60, June, 1912.

Dumble, the state geologist was requested by the secretary of the Houston and Texas Railway to make a study of lignite with a view to their preparation in some way as fuel for use in their locomotives. In 1881 Prof. H. H. Dinwiddie, then president of the Agricultural and Mechanical College of Texas, recommended the use of lignite by converting some into water gas.

Under an act of the Legislature passed in or about 1890, Mr. Dumble was instructed to make "Comprehensive investigations into the question of utilising lignite." He visited Germany and Austria so as to compare the different varieties of lignite, used in those countries with those found in Texas, and also examined the various methods of utilising them. The results of these investigations are contained in a printed report published in 1892 consisting of 230 pages which is now out in print, but fortunately an old copy was found for the writer. It has been a most interesting and instructive study, and before describing what is done at the present time it will be well to refer to parts of Mr. Dumble's report.

In Germany stepgrates—treppenrost—were used in 1890 and are today under steam boilers. These grates were arranged somewhat similar to a stairway leading downwards from the furnace door or hopper to the back of the grate (hence the name stair-hearth given it in some cases). There were openings between each step and these were designed to suit the size and nature of fuel used. The slope ranged from 40 degrees above horizontal for slack-coal passing through three-eighths mesh to 28 degrees for lump coal. The openings between the steps were kept clear by the firemen.

Brown coal was then used on railroad locomotives in Austria and Germany, but no information has been received as to whether this obtains today.

Producer gas was made from lignite for metallurgical operations and many kinds of manufacturing requirements, and in concluding the chapter on the use of lignite as fuel under boilers and in producers, Mr. Dumble, twenty years ago, stated that "the use of raw brown coal, either direct or gas firing, has been proved not only possible, but economical as well for all industrial purposes for which bituminous coal is applicable."

The dry distillation of gas was in vogue in Bohemia in 1890, for Teplitz was lighted by gas made from the brown coal of the vicinity, enriched with a small percentage of Reichenau brown coal to produce 12 to 14 candle power. The gas produced was similar in every respect to that got by carbonising bituminous coal, except that instead of allowing the waste heat to pass away into the chimney shaft it was made to pass under a floor to dry the lignite for the next charge. The gas gave perfect satisfaction. The yield was about 3 cubic feet per pound of coal.

Further on in his report Mr. Dumble stated that in Italy an experiment made for producing illuminating gas from Italian brown coal has been extremely satisfactory, and shows that it can be done not only to the entire satisfaction of the consumers, but at a much greater profit to the producer than is possible with bituminous coal. In September, 1891, the city of Spezia entered upon some experiments, being incited thereto largely by the patriotic motive of assisting in bringing into use the deposits of brown coal of the neighbourhood in place of coal imported from England. These experiments included not only the production and sale of illuminating gas, but a briquetting of the resulting coke for steam purposes. 29.04 tons of brown coal were subjected to destructive distillation—4 tons of lump coal, 20.04 tons small coal and 5 tons slack. "The ordinary method of coal carbonisation was followed, a charge of 234 pound of lignite was carbonised in 4 hours, whereas it took 6 hours to carbonize 270 pounds of bituminous coal. The plant therefore was capable of dealing with a greater quantity of lignite than coal in a given period. The yield of gas was 7,500 cubic feet per ton, practically the same as at Hebron, assuming the lignite was "green." The gas was used for lighting, for gas engines, and for producing steam, and in each and every instance gave as good satisfaction as the coal gas and nowhere was there any dissatisfaction found among the consumers."

Dr. Wm. B. Phillips, Ph.D., assisted by Mr. S. H. Worrell, B.S. Chemist, and Mr. Drury, McN. Phillips, in July, 1911, prepared a bulletin on the Composition of Texas Coals and Lignites and the use of producer gas in Texas. The production of lignite has increased from 303,000 tons in 1901 to 979,000 tons in 1910. Dr. Phillips stated that during the last few years there has been a marked increase in the use of lignite in gas-producers for power, lime burning, etc. The consumption of bituminous coal has increased about 200 per cent. in 15 years whilst that of lignite has increased about 700 per cent. The average price of coal at the mines in 1910 was $2.51 per ton and lignite 96 cents.

The composition of Texas lignite sampled at the mines by University Mineral Survey, 1901-2, analysed by Messrs. O.W. Palm and S.H. Worrell, may be set forth in the following summary, being average of 15 samples:

Proximate Analysis	*Natural Condition*	*On Dry Basis*
Moisture	33.77	
Volatile Matter	40.39	60.61
Fixed Carbon	17.21	25.88
Ash	9.00	13.51
Sulphur	1.12	1.68
Ultimate Analysis		
Carbon	40.13	60.23
Hydrogen	3.03	4.55
Oxygen	12.29	18.45
Nitrogen	1.18	1.47
Heat Value B.T.U.	7,611	11,427
Specific Gravity		1.33
Weight per cubic foot		lbs. 83.1

ANALYSIS OF TEXAS LIGNITE,

Company samples by S. H. Worrell, 1910-1911

Proximate Analysis	*As Received*	*(Averages) Dry Basis*
Moisture	25.17	
Vol. Matter	37.59	58.48
Fixed Carbon	28.45	37.81
Ash	8.79	11.71
Sulphur	0.65	0.90
Ultimate Analysis		
Carbon	44.08	58.85
Hydrogen	3.35	4.48
Oxygen	16.49	22.20
Nitrogen	1.47	1.86
Heat Value in B.T.U.	7,661	10,212

The total producer gas horse power operating on lignite in Texas is now about 13,000. In such use of lignite, Texas exceeds all other States combined: of this power two installations are large and the rest about 4,000 horse power are included among 21 plants.

Dr. Phillips states that in North Texas where natural gas is available some of the larger establishments prefer lignite, and in a letter Dr. Phillips writes, "In competition with natural gas as low in price as 16 cents per thousand cubic feet, lignite producer gas is more than holding its own, the cost of lignite delivered being $1.65 per ton of 2,000 lbs."

One paragraph in the report points out that "If there is one thing that stands out more prominently than others as the results of observations and investigations, it is that the best results in producer gas engine practice are likely to follow from a consideration of a plant as a compact unit, a unit in which the producer is a part of the engine and the engine a part of the producer."

About 90 per cent. of the gas producer plants in Texas are operated on lignite exclusively.

As already stated, when dealing with the results of fuel testing at St. Louis, a few Texas lignites were investigated. Lignite from Hoyt, the physical composition of which was as follows:

Moisture	33.71 per cent.
Volatile Matter	29.25 "
Fixed Carbon	29.76 "
Ash	7.28 "
Sulphur	0.53 "
Heating power, as fired in B.T.U.	7,348 per lb.
Heating power, as fired dry in B.T.U.	11,086 "

The producer gas had a calorific value of 156.2 B.T.U. per cubic foot and 1.46 pounds of lignite were consumed per brake horse power developed at the engine. This engine required 10,570 B.T.U. per B.H.P.

Another lignite from Crockett had the following composition:

Moisture	33.50 per cent
Volatile Matter	32.34 "
Fixed Carbon	23.80 "
Ash	10.36 "
Sulphur	0.63 "
Heating power, as fired in B.T.U.	7,183 per lb
Heating power, as fired dry in B.T.U.	10,928 "

The gas from this lignite had a heat value of 169.7 B.T.U. per cubic foot and 1.99 pounds were required to develop 1 B.H.P. 12,230 effective heat units were consumed to develop one brake horse power.

The following description of representative gas producer plants in use in Texas will doubtless be interesting and useful. These are obtained from Dr. Phillips' report, together with what has been collected by personal inspection or correspondence.

The Standard-Tilton Milling Company have three 200 H.P. Smith suction down draft producers, one Buckeye twin tandem, two-cylinder, double-acting horizontal gas engines direct connected to a 500 kilowatt Westinghouse alternator. This plant is now operated on natural gas conveyed by a company 110 miles and the engine develops 720 H.P., consuming 250,000 cubic feet of gas and generating 8,000 kilowatt hours. Assuming the price of this gas is 16 cents per 1,000 cubic feet, each kilowatt hour therefore costs one-half a cent. Larger cylinders have been ordered and the engine is to be again operated on producer gas, as the company is enthusiastic over this form of power.

The South-Western States Portland Cement Company at Eagle Ford have six Harvey up draft pressure-producer and three 750 kilowatt Allis-Chalmers horizontal two cylinder tandem double acting gas engines with 2,300 volt generators on the main shafts. The demand for increased power rendered it necessary to either instal additional plant or use natural gas. The company, owing to a number of circumstances, decided on the latter. When operating on producer gas 235,920 pounds of lignite were consumed in the development of 66,710 kilowatt hours or 89,411 horse power hours; 3.6 pounds of lignite were consumed per kilowatt hour, or 2.7 pounds per horse power in the first test and 3.2 pounds and 2.4 pounds respectively in the second. The average of the two tests was 3.5 pounds per kilowatt hour and 2.6 pounds per horse power hour.

Lignite cost $1.62 per ton delivered and therefore the fuel cost was 0.283 of a cent and 0.214 of a cent per kilowatt hour and horse power hour respectively. This does not include the cost of labour, capital charges, etc.

The Granville Electric Company found it necessary to either increase their steam plant or install producer plant. They adopted the latter course as an auxiliary to steam, but the economy in fuel was such that now steam is the auxiliary.

The Texas Portland Cement Co., have the largest producer gas plant in Texas. There are three series of Loomis-Pettibone, 1,000 horse power down draft producers and one 850 horse power Bethlehem Steel Co.'s up draft producer. Three Bethlehem horizontal gas engines each 1,200 horse power, and two Snow Steam Co. 800 horse power horizontal engines driving A.C. generators 440 [illegible] 25 cycle, and generating about 55,000 kilowatt hours per d[illegible] [illegible] age consumption of lignite for all purposes in the produc[illegible] ar was 4 pounds per kilowatt hour.

The cost of electrical energy, in[illegible] except depreciation and interest, cost 0.725 cents p[illegible] r at switchboard. Fuel only last year cost 0.299 cents per kilowatt hour.

At the Houston Cotton Meal Mill the[illegible] number 7 Woods Water-sealed suction up draft producers, gasifying lignite screenings of the following proximate analysis:

Moisture	31.10 per cent.
Volatile Matter	30.80 "
Fixed Carbon	25.60 "
Ash	12.50 "
Sulphur	trace
Heat Value	6,440 B.T.U.

The lignite screenings represent the particles between 2 inches and 3/4 inches that are screened out of lump lignite when mined, for which 35 cents per ton at the mine is paid. There is one Rathbun-Jones 21x24 four cylinder, 500 H.P. gas engine belted direct to lay shaft and to main line shaft with metal to metal friction clutches. The heat value of the gas is stated to be from 140 to 160 B.T.U. In a letter from Mr. Harry Hedenband he stated that they "had considerable trouble in operating the producers owing to formation of clinkers. However, this has all been eliminated and now they have no trouble in this regard. They use steam in their blast pipe and the intelligent use of the steam keeps the temperature of the fuel bed at such a point that ash is not allowed to fuse and clinker."

The People's Light Co., of Corpus Christi, have installed two Woods suction producers, with usual accompanying washers, scrubbers, etc., and two vertical three cylinder Rathbun-Jones gas engines one rated at 125 H.P. and the other 300 H.P., and two two-phase current 2,300 volt generators. At first one producer was found to be inadequate and clinkered badly, but by installing an additional one, using better grade of lignite with a small percentage of shell from the beach, it is reported (by letter) that they are now having not much trouble caused by clinker. The larger engine does not appear to have developed power equal to its rated capacity, but no reason is given for this.

When summarising the results of the investigation, Mr. Phillips draws the following conclusion. "The seemingly analogous case of steam boilers and engines does not apply to gas producers and engines. Steam is steam, whether generated in the fire-tube or water-tube, horizontal or vertical, coal fired or oil fired boilers and the sole requisite made by a steam engine is that its working medium be under pressure and dry.

In the gas plant, engine performance is generally based on effective heat units delivered to the engine a common guarantee being a brake horse power for each 10,000 effective heat units. By effective heat units is meant those which actually contribute to the development of power; part of the hydrogen, for instance, when ignited in the presence of oxygen (in the air mixed with the gas in the cylinder) forms steam and is lost with the exhaust.

As these effective heat units are to be supplied by combustion of gases, which vary with the composition of the fuel and therefore with the constituents of the gas produced, it will be observed that there is a closer relation between the producer and gas engines than between the steam boiler and engine. The closer the relationship approaches that, of say, a gasoline engine and carburettor where they are mutually dependent, the better will be the efficiency secured.

Dr. Wm B. Phillips and his staff are now investigating the use of lignite for production of gas by the ordinary process of dry distillation, and during the period of inspection carried out one complete test at the Austin University in the presence of the writer. A sample of lignite weighing two pounds was dried in a desiccator and afterwards placed in a cast iron pot fitted with an air tight lid. This was connected by a wrought iron pipe to condensers, scrubbers and glass washers, a meter and gas holder. The whole apparatus, except the meter, was built up of parts which were available or purchased locally, and consequently the apparatus was not equal in construction to others seen, although it answered its purpose efficiently.

The retort was heated with a large gasoline blow lamp, temperature of gas produced was observed, quantity of gas noted, and at completion when the coke was cool, it was weighed. The following are the results obtained. The experiment was started at 2.50 p.m., the barometer pressure was 744.5 m.m. Temperature 37.2 deg. Centigrade.

Time	*Retort Temperature*	*Gas Temperature*	*Cubic feet of Gas Produced*
3.35	125 deg. C	95 deg. C	1
3.56	175 deg.	96 deg.	2
4.12	225 deg.	97 deg.	3
4.29	250 deg.	98 deg.	4
4.48	250 deg.	98 deg.	5
5.20	275 deg.	98 deg.	5.8

As the lignite contained about 20 per cent. moisture, there were 1.6 pounds of dry lignite in the charge $\frac{200 \times 5.8}{16} = 7.25$ cubic feet of gas or 3.6 cubic feet of unpurified gas per pound of dry coal. Dakota production averages 5.86 cubic feet of gas per pound of dry coal. The results at Teplitz already referred to was 3 cubic feet per pound.

The coke residue amounted to about 43.7 per cent. of original charge of lignite. It was incoherent and had practically the same appearance as raw lignite. It burned in a gas flame without smoke and developed incandescence in similar manner to charcoal.

The gas was tested four times to ascertain its calorific value, the chemist reported it to be 556, 606, 580, 580, the average being 580.5 B.T.U. per cubic foot. This is much higher than was expected. The Dakota results averaged 402.2 B.T.U. for similar gas.

Taking into consideration the quantity of unpurified gas made per pound of dry lignite and its average calorific value it will be found that the total heat units available from the gas produced per pound of dry lignite were, Dakota 2,356.89 and Texas 2,078 B.T.U.

The gas was tested on a bar photometer, the light given in ordinary Argand burner was about 3 candle power, but when burned within an incandescent mantle and consuming at the rate of 5 cubic feet per hour, the illuminating power was 23.75 candles, but as the flame in this test rose above the mantle some of its value was therefore lost. Another test was made, keeping the flame within the mantle when the quantity of gas consumed was at the rate of 4.7 cubic feet per hour, and the illuminating power was then 33.1 candle power; correcting this consumption to the usual standard of 5 cubic feet per hour the candle power would be 36.4

The results obtained show that lignite is capable of yielding gas of considerable value by ordinary process of dry distillation. Whether Saskatchewan lignite will give approximately similar results can be ascertained by experiment only. The composition of local lignite is very similar to those in Dakota and Texas, but this must not be accepted as conclusive evidence, because in the case of bituminous coals having almost identical compositions (on laboratory analysis) they do not produce the same quality of gas, tar, etc.

Mr. J. P. Greenwood, M.E., of Dallas, made a test to ascertain the efficiency of a battery of two O'Brien horizontal return tubular boilers, each 72 inch diameter and 22 feet long with 26 six inch tubes, and having a furnace grate surface of 84 square feet. The grates were of special make, built for lignite. They were four inches wide, six feet long and the width of the furnace is 14 feet, each lineal foot had 25 three-eighth inch round holes. Each furnace has an Argand steam blower. The steam entered at the centre of a ring through 18 one thirty-second inch holes. Mr.

Greenwood observed that firing by hand meant that the furnace doors were opened 20 per cent. of the time which meant that the fuel loss during that time was about 60 per cent., which proved that opening and closing of the doors should be done quickly (mechanical stocking would obviate this). The average evaporation during a ten hour test was 4.4 pounds of steam per pound of lignite. The steam pressure was 105 pounds per square inch; air temperature 80 deg F.; uptake temperature 563 deg. F.; feed water 192 deg.; fuel consumed per square foot of grate surface 36 pounds. Mr Greenwood stated that one pound of the fuel should have evaporated at least 5 pounds of water if the furnace were properly fixed.

Alabama

The Chief Assistant State Geologist (Mr. W. F. Frontz) of Alabama, stated in reply to inquiry, that there are several workable seams of lignite in that state, and that last year the Geological Survey had some lignite tested at the University by Prof. F. H. Sibley, Professor of Mechanical Engineering, with the following results:

"The Wilcox county sample based on an eight and a half hour run showed a consumption of 1.97 pounds of coal per horse power hour at the switchboard. The Pike county sample based on a 10 hour run showed a consumption of 1.82 pounds.

"The standby consumption was about 15 pounds per hour. Total number of pounds used of Pike county sample was 606, total ash of this, 165 pounds (equal to 28 per cent.). The total coal used of Wilcox sample was 506 pounds with a total ash of 182 pounds (equal to 36 per cent.). The corresponding consumption of bituminous coal in the same producer was 1.37 pounds per horse power hour at the switchboard.

"The plant operated much more smoothly with the lignite than with other fuels tried. There was no tar to give trouble in the engine parts and the labour of operating the generator was very small.

"It will be seen from the above report, which is based on a very brief period of operation, and therefore does not show the highest efficiency of the lignite, that this class is a most excellent one for use in the gas producer."

Germany.

There are several large industrial establishments in South Germany which are operated entirely by power derived from lignite or "Braun-Kohle." The "Elektrochemische Works" at Bitterfeld was established in 1895, and now produces over 7,000 tons of caustic potash and 13,000 tons of bleaching powder, as well as magnesium, and sodium by electrolytic methods. The power plant is equivalent to 5400 horse power and lignite obtained at mine close to these works is the only fuel employed for the purpose of steam raising. The calorific value of this lignite varies between 2,600 and 2,800 calories. (4,680 and 5,050 B.T.U.) The boilers are provided with step grates constructed on the Keilman and Volcker system. There are 21 boilers of the water-tube type under 120 pounds pressure and the steam is superheated to from 220 deg. C. to 260 deg. C. The efficiency of the whole boiler installation is stated to work out at 70 per cent.[1]

[1] Engineer, Sept. 5, 1912

It is proposed to convey power over a distance of 82 miles from the lignite mines in the Bitterfeld district to Berlin, to work the Berlin city and surburban railways, and in another case it is proposed to generate four million kilowatts from lignite to meet the requirements in North Germany in which case it is suggested that the local authorities, the state and financial groups should co-operate in bringing this scheme to a successful issue. Lignite must be used practically at the place of production, if it is to be used for the economical development of power on a larger scale. Lignite is used at the power station of the Bitterfeld Dessau Electric Railway.[1]

Mond gas installation has been erected at a peat bog 25 miles from Osnabruck (Hanover), to drive electric generators, and, this town is reported to have shut down its steam driven electric plant and is now taking current transmitted at 30,000 volts from the Mond gas electric station, where three 1 150 brake horse power gas engines coupled to alternators are installed and worked with gas obtained from peat containing about 60 per cent. of moisture.

Another Mond gas plant operated on peat containing 57.5 per cent. of water produced, per ton of dried peat, 100,000 cubic feet of gas, the calorific value which was 150 B.T.U., and also 40 pound ammonium sulphate.

An 8 foot 6 inch Kerpely gas producer has been installed at Dubeesko to produce gas from shale mixed with coke dust. This fuel has a calorific value of 8,300 B.T.U., and the gas 137 B.T.U., which was used under steam boilers. No particulars are available as to other results.

Step grate furnaces are largely used in Germany: a hopper is fixed on the platform level into which the fuel is fed, and owing to the inclination of the grate the fuel is more or less self-fed. There is a large space between the back of the grate and the boiler which acts as a combustion chamber. The clinker is removed by slicing and with a good draft it is stated that about 30 pounds of lignite can be consumed per square foot of grate surface.

Reference might have been made to furnaces which have been installed at German works to consume lignite, and which according to "Braun-Kohle" are reported to give good results. The Lochner boiler furnace has been installed at Carl Zeiss and at Schott & Co's works at Jena, Saxony. A sketch of this furnace is given in plate 6. Brown coal slack is discharged into the hopper whence it gravitates down a pipe or flue into the back of the furnace, which slopes downwards from the back to the front. One advantage claimed for this sloping fire-grate is that the fire can be better seen and watched. The lignite is discharged slowly into the hottest part of the fire where the gases are quickly distilled, mixed with preheated air and burned in the combustion chamber under the boiler. With this grate the chambers and ash fall towards the furnace door and by means of a mechanical contrivance near the door, is broken up and discharged into the ashpit.

The other furnace, shown in plate 7, is known as the "Muldenrost." This is also erected in front of the boilers and consists of chambers in which are placed semi-circular arches which enclose the fire. The lignite is discharged into the chamber through openings on top, and falls on a steep Λ shaped roof on the fire chamber, and as it gravitates it is dried and slowly

[1] Engineer, July 5, 1912.

heated up, so that by the time it reaches the fire on either side, the lignite is robbed of much of its moisture which ordinarily tends to reduce the heat of the furnace and its efficiency. The gases and air are burned under the boiler. Muldenrost furnaces have been installed at Frankel and Viebahn, Leipzig, and a saving of 30 per cent. of combustible is stated to have been effected [1]

There are other forms of furnaces which are successfully operated on inferior bituminous coal, but no experience has yet been had with lignites. One firm carried out tests with lignite conveyed to New Orleans with the result that they find that their ordinary type of grate and furnace will not answer efficiently with this fuel, but they are now engaged in altering their grate to suit lignite.

Austria.

The following is extracted from Messrs. Appleby's pamphlet relating to the use of Kerpely Gas Producers, with Austria lignite. Analysis of Styrian Brown coal.

Carbon	57.70 per cent.	9.720 B.T.U. per pound
Hydrogen	4.43 "	
Nitrogen	0.78 "	
Oxygen	15.54 "	
Sulphur	1.28 "	
H_2O Water	7.17 "	
Ash	13.10 "	

Analysis of gas obtained from above Kerpely Gas Producer.

	Per cent. by Volume	Weight in grams per cubic foot
CO_2 (Carbon Dioxide)	2.8	1.57
CO (Carbon Monoxide)	30.5	10.80
CH_4 (Marsh Gas)	2.0	0.401
H (Hydrogen)	14.0	0.355
N (Nitrogen)	50.7	18.080
Total combustible	46.5	

The calorific value of the above gas was:

Without tar .... 159 B.T.U. per cubic foot
With tar .... 182 B.T.U. per cubic foot

The amount of tar per cubic foot being 0.708 grams. The gas left the producer at 882 deg. Fahr. (average). The absorbed heat was calculated as follows:

Heat capacity of gas is 0.3 calories per kilogram and centigrade.

Weight of one cubic foot of gas was 34.7 grams.

The absorbed heat of one cubic foot of gas was

Heat capacity Kilos Deg. F.

$$\frac{0.3 \times .0347 \times 822\text{-}32}{0.454 \text{ Kilos per lb.}} = 18.1 \text{ B.t.u.}$$

The ash averaged 3 per cent. carbon and the loss on this account was

$$\frac{13.1\% \times 3}{100} = 0.39\% \text{ say } 0.4\%$$

[1] Braunkohle, July 19, 1912.

The weight of carbon in each cubic foot was arrived at as follows: Atomic weight; C = 12. O = 16: H = 1

	weight in grams per cubic foot	
CO_2	1.57 x 12 ÷ 44	= 0.43 grams per cubic foot
CO	10.80 x 12 ÷ 28	= 4.60 grams per cubic foot
CH_4	0.401 x 12 ÷ 16	= 0.31 grams per cubic foot
Tar	0.708 containing 78 per cent. C = 0.55	
		5.89 with tar
		5.34 without tar

Each cubic foot of gas contains 5.34 grams of carbon without tar, therefore 100 grams of coal at 57.7 per cent. carbon yields = 57.7 ÷ 5.34, equals 10.8 cubic feet of gas.

1,000 grams of coal equal 0.2202 pounds, therefore as 0.2202 is to 1 so 10 to 8 is to 49 equals 49 cubic feet of gas per pound.

B.T.U. of one pound of coal equals 9,720.

49 cubic feet x 159 B.T.U.

49 cubic feet x 18.1 absorbed heat.

49 cubic feet x 177.1 equal 8678 B.t.u. without tar.

Therefore the efficiency was $\frac{8,678 \times 100}{9,720} = 89.3$ per cent.

Correction for carbon in ash $\frac{99.6 \times 89.3}{100} = 88.9$ per cent.

Mond gas plant has been erected at a large steel works in Austrian Bohemia. The fuel is brown coal containing 35 per cent. of moisture, but particulars are not yet to be had as to results obtained at this installation.

A 7 foot diameter Kerpley gas producer has been installed at Banzallas, Hungary, to use rough lignite containing 60 per cent. of dust which has a heat value of 5,750 B.T.U. per pound. The gas produced had a heat value of 146 B.T.U. per cubic foot.

Italy.

A Mond gas installation worked on Italian peat with a moisture content of 45 per cent., produced per ton of dry peat 60.000 cubic of gas, having a calorific value of 166 B.T.U. per cubic foot. and also 115 pounds of sulphate of ammonia, which is an excellent fertiliser.

A 7 foot diameter Kerpely gas producer has been installed at Pionbino, Italy. to gasify lignite having a heat value of 9,350 B.T.U. and this produced gas possessing a heat value of 161 B.T.U. per cubic foot.

At least 250 gas producers of one make have been installed to gasify lignites in Europe.

DIFFERENT METHODS OF PRODUCING POWER.

The popular idea of transmitting energy, whether for power, light or heat is that of electric transmission lines, but as already mentioned the delivery of gas through long lengths of pipe lines is an acknowledged possibility.

Electric energy can be generated by steam boilers and engines and electric generators; by gas-fired steam boilers and steam engines and electric generators; by gas producer, engines and electric generators; by combined gas and steam plant and electric generators; and by lignite gas, gas engines and electric generators.

Gas supply can be produced by gas producers, using solid fuel only; by water-gas producers, using some form of carbon and water, and by dry distillation of coal in various types of retorts or ovens.

STEAM BOILERS AND ENGINES AND ELECTRIC GENERATORS.

It may strike some that it is almost unnecessary to discuss steam power plants because they are so familiar to the general public. The steam boiler and engine have required more than 200 years to be developed to their present stage, and yet engineers in all progressive countries are striving to perfect the designs and secure greater efficiency. The use of steam has become so general that the number of men trained to run steam plants is legion, and it is therefore not surprising that the potentiality of gas producers has not yet been fully appreciated.

The utilisation of inferior fuel was a subject little thought of a few years ago, but today it is an international topic of discussion among engineers and chemists, for now they are able to utilise combustible substances which were formerly considered as useless for the development of power.

Moreover the methods of using fuels are gradually being changed, new appliances are being invented and old systems improved, and generally the efficiency of steam plants is being gradually increased.

It will be admitted that steam power is reliable and possesses great flexibility, and there is no great difference in the efficiency of an up-to-date engine and boiler between running full load and over and partial load. The term efficiency is sometimes interpreted in different ways, but the only meaning applied in this report, and which has any commercial significance, is what proportion of the energy contained in the fuel is obtained in power.

It is recognised that the proper way of producing power is to attack the problem in a large way, and it is a well established fact that the growth of a country around a large comprehensive development is very rapid, increasing the value of property and thereby the taxable values, and it also affords a strong inducement for investments in manufacturing industries, such as are needed in this province.

The concentration of power plant at suitable centres is conducive to economy and reliability, and the conditions which effect the cost of producing power are the price of fuel delivered into store, amount of power produced and whether the load is continuous and uniform or intermittent and variable. The next important feature is the economical transmission and distribution of the power.

With regard to the price of fuel at present, the cost of producing lignite at the mine is under $1 per ton, but to allow for contingences and hauling, the price delivered into the bunkers is figured at $1.50. As the power plant should be located at the mines, and if possible over a mine, the cost of fuel will no doubt be less.

Owing to the difficulty of estimating the probable demand for electrical energy, due to the rapid development and the possibility of some industries being established when cheap power and fuel are made available, it is advisable, as a preliminary step, to arrange for say 10,000 horse power or 7,500 kilowatts plant, with ample provision made for expansion. The third condition is of great importance and that is the load factor. As stated 7,500 kilowatt plant is suggested as the basis of calculation. Such a plant will be capable of supplying this quantity of electricity at all times, day and night, throughout the year. That practically will be its maximum output, but electricity will not be required at all hours of the day during the year and therefore the cost of production must be chargeable against the reduced quantity consumed. There will be times, usually very short, when the maximum capacity of the plant will be utilised, and other times when only a fraction of the power will be required, but the expense will not be in proportion to the output, so it is evident that the more uniform and continuous the load will be, and the nearer it approaches the capacity of the plant the cheaper will be the production of power. It will not be waste of words to state that power costs more per unit when produced in small quantity and when the load factor is low. Cost of power increases with fluctuating loads.

Electrical engineers interpret the term "load factor" to mean the ratio of actual output in kilowatts delivered to the consumers to the possible output if the maximum load were constantly in use throughout the year. This interpretation will be adopted in this report. The formula may be expressed as follows:

$$\text{Load factor, per cent.} = \frac{\text{No. of Kilowatts del'd} \times 100}{\text{Maximum load in Kw} \times 8760 \text{ hours}}$$

For the purpose of calculation, a forty per cent. load factor will be assumed. This is somewhat higher than at present obtained in Regina, but having regard to the future possibilities it is believed to be a safe factor to work upon.

The foregoing remarks are equally applicable to producer gas plant or any power generator where fuel is consumed. It may not apply with equal force in the case of hydro-electric schemes because the water used does not cost dollars and cents to the same extent.

As will have been observed there are several ways of consuming lignite under steam boilers. Step grates are used in Germany. Chain grates in Alberta, semi-producer furnace in North Dakota, Jones underfeed stoker is also employed in some places. For instance at Pluma, South Dakota, a test on lignite was made in 190? which resulted in 6.83 pounds of water being evaporated from and at 212 degrees Fahr. per pound of coal, the composition of which was 21.51 per cent. of moisture, 34.63 per cent. volatile matter, 36.26 per cent. fixed carbon, and 7.60 per cent. ash. It had a calorific value of 14,987 British thermal units per pound of dry fuel.

In some places a small proportion of bituminous coal is mixed with lignite so as to increase the calorific power.

Efforts have been made to obtain particulars as to the results got by means of step grates in Germany but up to the time of writing this report none has been received.

Chain grates, together with mechanical stokers, are operated successfully with fuel containing the same high percentage of volatile matter as lignite. The coal by the above appliance enters into the coolest part of the furnace and is ignited gradually. The volatile matter is driven slowly out instead of being quickly released, as in the case of hand firing. and the gases are drawn between the hot arch and the incandescent fuel bed, mixed with air and burned before striking the boiler tubes, etc

The results obtained with lignite consumed in a semi-producer furnace at Williston have been fully described, but there is no doubt that by adopting such changes as the test suggests, better results may be got.

There is another method which Prof. Babcock referred to in his report as "one of the most perfect methods for the combustion of highly gaseous coal," that is, by burning, pulverised or dust fuel in a draft of air. This method has not, so far as can be ascertained, been applied to the use of lignite, but a number of engineers have succeeded in obtaining excellent results with bituminous coal in burning cement by this means in rotary kilns, and good results have also been obtained under steam boilers. Probably the best known arrangement by which fuel can be consumed under steam boilers is that known as the Bettington boiler, which is a vertical one, designed to facilitate the easy removal of the burnt refuse. The coal is pulverised into dust and blown by the disintegrator fan through a central water-jacketted tuyere or gas jet where it can be ignited by a torch, and the products of combustion made to heat the boiler, by which means high thermal efficiency is stated to be obtained.

A test was made with dust fuel under a boiler supplying steam for driving a 630 indicator horse power air compressor and various other engines, the results are reported to be as follows:

Heating surface, water 2308, steam 507, total	2,815 sq. feet
Duration of test	3 hrs., 56 min.
Total coal used in pounds	4,256
Total coal used per hour in pounds	1,078
Total water evaporated in pounds	33,490
Total water evaporated per hour in pounds	8,550.8
Feed water temperature entering tuyere	143.6 degrees F.
Steam pressure, in pounds per square inch	148.2
Superheat	159 degrees F.
Temperature of air entering air heater	52.4 degrees F.
Temperature of air leaving air heater	238.7 degrees F.
Temperature of flue gases leaving boiler	543.4 degrees F.
Temperature of flue gases leaving airheater	447.8 degrees F.
Temperature of fuel mixture entering furnaces	113.2 degrees F.
Equivalent pounds of water evaporated and superheated per hour from and at 212 degrees F.	10,295.1
Equivalent pounds of water evaporated per square foot of heating surface	3.66
Power used by pulveriser as percentage of power developed	2.0
Analysis of coal used:	
Ash, per cent.	16.98
Volatile matter, per cent	27.64
Fixed carbon, per cent.	55.38
Water evaporated per pound of dry coal from and at 212 degrees F.	9.00
Calorific value of coal (dry) in British thermal units	12,120

Thermal efficiency of boiler as based on coal per cent. 76.43
Actual steam consumption per indicated H.P. in pounds.. .... 13.7

The boiler was worked at 85 per cent. its rated capacity.

It is claimed that this type of boiler is quick heating, flexible in output, no banked fires are required, radiation losses are low, and low grade fuels can be used.

The makers are prepared to guarantee 75 per cent. thermal efficiency when fired with Saskatchewan lignite containing not over 15 per cent. moisture. This, of course, means drying the fuel, which is not a difficult matter to arrange as the waste heat of about 350 degrees Fahr. from the boilers could be passed through a dryer. They state that this type of boiler would be capable of giving 50 per cent. continuous overload without difficulty. The cost of such boilers would be about the same as for water-type of equal capacity.

In this connection it may [illegible] pointed out that coal dust, and indeed dust from China beans, oil ca[illegible] and locust beans, have caused serious explosions. Lignite dust is stated to be more dangerous, as it is lighter, finer, and hangs in the air longer; but provisions can doubtless be made to eliminate this danger. Bettington boilers have been in use over six years without such occurrences. A battery of three boilers are in use at the Dominion Coal Company's power plant at Waterford Lake, Cape Breton.

The boilers now in use in this province are either of the return-tube or water-tube classes, the chief cause of inefficiency when consuming lignite is that the grates are often designed to consume bituminous coal, whereas with lignite their area should be at least 25 per cent. greater, or the fuel beds should be deeper.

The generator system of the North-East Coast power system in England are equipped with alternators driven by steam turbines of the Parsons' reaction type, and units of this class as large as 25,000 kilowatts have been installed in Chicago. The total horse power developed by Parsons' turbines is immense. Zoelly impulse steam turbines are also used in various parts of the world. These types of steam engines are very efficient. The test results obtained with a 1,700 kilowatt Zoelly steam turbine were :

Load in KW	Steam pressure at stop valve		Vacuum	Steam consumption		Thermal efficiency %, based on condition of steam	
	lb. per sq. in.	Temp. °F		Kw. Hr.*	Hp. H.	In front stop valve	Behind stop valve
1694	206.0	670.2	93.3	13.04	8.94	67.7	69.8
1366	202.3	673.5	94.2	13.77	9.18	66.5	69.2
854	205.2	662.0	95.2	15.52	9.84	64.0	66.[illegible]
457.5	208.0	642.9	94.9	18.94	10.68	57.1	[illegible]7.9

* Not including steam for condensing plant.

The ideal method of using coal for power purposes is to simplify the arrangements by which the heat involved by the combustion of the gases can be used as directly as possible in the production of power, that is, on the principle of the internal combustion engine where the ga[illegible] or alcohol, etc., is carburetted and used by as few processes as is practicable. Inferior coal requires a different treatment to that of, say, first class anthracite. In some instances coal is gasified in a producer and the gas burned under steam boilers. If the fuel is good, say, anthracite or high class bituminous coal, it is doubtful if any advantages will be derived by gasification for this purpose, but in the case of inferior fuel such as lignite, which clinkers on the fire grates causing an excessive quantity of air to be used to maintain a good draft and therefore combustion, it is possible that when converted into producer gas and burned under a boiler, lignite may give better results than when used in the solid.

GAS PRODUCERS.

The preceding observations have reference to burning solid lignite under steam boilers, in order that what follows may be clearly understood the function of a gas producer is here described. The fire grates under steam boilers hold a certain depth of fire (see sketch) the air admitted between the bars of the grate comes into contact with the fire, and the oxygen (in the air) combines with the carbon (in the coal) and forms carbon dioxide. Fresh coal is thrown on the strongly heated surface of the fire. The gases are driven out and the coal becomes partially coked. More air is admitted through the furnace door, mixes with the gases and combustion takes place, accompanied by the evolution of heat and light. The depth of fire bed in this case is usually only a few inches.

If the grate, however, is constructed so as to hold a fire-bed of, say 2 to 3 feet deep (see plate 8) then the oxygen (in the air) entering underneath the fire combines with the carbon (in the coal) and again forms carbon dioxide gas also and raises the temperature of the fire to incandescence. This gas has yet to pass through the hot fire-bed, and in doing so one-half of its oxygen component is given up to combine with more carbon, and now the gas becomes carbon monoxide, which is one of the principal gases required for power and heating purposes. The more effectual and complete the carbon dioxide gas is reduced to carbon monoxide the higher will be the efficiency of the producer.

Producers are usually built like a vertical steam boiler in appearance (see plate 9), but vary in some details and methods of working. The simplest type is a steel cylinder lined with fired-brick surrounded by a deep central fire grate. A coal hopper is placed on top, and this consists of two parts—the lid, which is sealed with some material during the working operation, and a trap door which can be opened and shut by a lever. When fuel is being charged into the producer, the hopper above the trap door is filled, the lid is closed and the trap door opened by the lever, causing the coal to fall into the fire without admitting air or causing gas to escape.

There are two kinds of producer (1) suction producers, (2) pressure producers. In the case of suction producers, once a good fire has been started the gas engine draws its supply of gas as required. In the pressure producer, the gas is manufactured independent of the engine. Suction gas plants are generally made for small works, and pressure producer plants are made in large units. So in connection with a large lignite power scheme the first kind will not be considered further. Pressure producers are made (1) up draft, (2) down draft and (3) double zone or combined up and down drafts. Each of these types is useful for particular service. In Europe, up draft producers probably predominate, whilst in America the down draft and double zone producers appeared to be the most used.

In this connection, however, up draft producers will be dealt with. Air and steam are admitted under the fire and as already explained gases are formed. When these gases are admitted from the producer they are hot (about 1100 deg. F) and in this condition could be utilised under steam boilers, etc., and so take advantage of the sensible heat, but when used in gas engines the gases have to be rid of tar, dust and vapour, and must also be cooled. This is done by driving the gases under pressure through scrubbers and washers.

In large installations it is necessary to erect a gas holder to store part of the gas made. An average composition of lignite producer gas is as follows:

	Per cent.	
Methane marsh gas CH_4	0 98	Combustible
Hydrogen H_2	14 76	
Ethylene C_2H_4	00	
Carbon monoxide CO	16 01	
Carbon dioxide CO_2	11 87	Incombustible
Nitrogen N	56 37	
Oxygen O	0 01	
	100 00	

Producer gas is used on a large scale in burning cement slurry, lime and bricks for metallurgical work, firing gas retorts, benches, etc., in which case the hot gas (1100 deg. F) as it comes from the producer together with preheated air obtained by recuperation are utilised to the fullest extent.

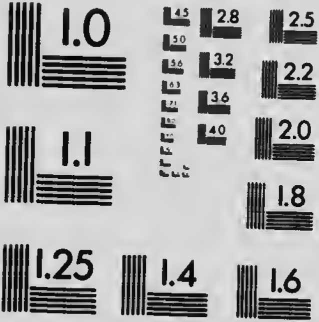
The adoption of similar methods for heating steam boilers, however, entails extra plant, such as producers, gas conduits with inherent absorption and radiation of sensible heat.

The apparent advantage of consuming producer gas under steam boilers, especially in respect to the use of lignite, are many. The sensible heat of hot gas is utilised, washing, scrubbing and cooling are unnecessary. The loss due to unburnt carbon is minimised, water is heated in producer water jackets ready for the boilers; more regular steaming is secured, the quality of air required for the complete combustion of the gas can be regulated and less quantity of inert gases such as nitrogen and carbon dioxide has to be heated up and thus a greater flame temperature is obtained.

The alternative is to use the producer gas in gas engines, which undoubtedly develops the cheapest power. The development of this type of power plant has been slower in North America than in Europe; the tendency on this continent is for mechanical engineers to be somewhat conservative in adopting other forms of power than steam or water power together with electric generation and transmission. But on the European continent the installations of large gas engine plants are numerous, and increasing in size each year. Consequently the experience there is more

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



mature. In the United States bituminous coal and anthracite are abundant and cheap, and in Canada potential water power is immense and much has been utilised. In Europe, however, competition is keener, in parts good coal is not so abundant. Inasmuch as industrial progress is largely dependent on the cost of production, fuel, raw materia and other items of expenditure are all seriously cons dered by the manufacturer, and he is generally enterprising enough to adopt new methods and machinery which will simplify his plant or result in greater efficiency and economy. Hence it is that fuels which were formerly considered as uncompromisingly poor are now being converted into producer gas.

Prof. R. H. Fernald, a recognised authority on gas producers in the States, when discussing the "Status of the Gas Producer"[1] made use of the following expression:

"Many States of the West that have no good coal are greatly benefited by the investigations which have shown the adaptability of the gas producer for the utilisation of low grade coal, lignite, peat, etc. As mined, these fuels cannot be used in boiler furnaces and will not bear long transportation, but the gas producer makes them of potential value. Thus the gas producer is an agency of conservation. It helps to keep the low grade coals from being permanently lost by being left in the mines in such condition to make their future recovery impossible. In the States in which deposits of low grade coal, lignite, and peat are found, the present cost of power, as developed in steam plants with coal that has been shipped a considerable distance, can be materially reduced by placing producer plants at the mines or bogs, so as to utilise these low grade fuels without cost of shipment by generating electric current which can be easily transmitted to desired points within a wide radius."

The United States Bureau of Mines has done much to show the usefulness and adaptability of the gas producer, and the Canadian Mines Department also has, by the tests which were being made, contributed to the knowledge on this subject.

Troubles experienced with large gas engines may be now considered as ancient history. In Germany and Great Britian gas engines are considered as reliable in operation as steam engines, and far more economical in practice. There are, according to Mr. Adolphe Greiner, now over 1,000 gas engines in Belgium, France, Germany, Russia, Spain, and Japan, each more than 1,000 H.P. in capacity. In Europe gas engines of 3,000 H.P. are being built and also several 6,000 H.P.

Producer gas has a thermal value of about 120 British thermal units and the lignite gas at Hebron 400 British thermal units, and when high power gas engines will operate with gas of as low a value as 85 British thermal units it will be seen that there should be very little difficulty to be expected with producer gas.

According to a discussion at a meeting of the Engineers Society of Western Pennsylvania, however, it would appear from the statement made by one speaker that in the States some trouble has been experienced with gas engines, owing to cylinders cracking, because of the difficulty in "not circulating the cooling water so that the cylinder will be of equal temperature in all places." Another gentleman stated that he had "spent six months in Germany studying this same question very thoroughly.

[1] Technical paper 9, "Status of the Gas Producer and of Internal Combustion Engine, in the Utilisation of Fuels," United States Bureau of Mines, 1912.

and came back with the information that the larger size gas engine was not the engine to use in the States." But Mr. Trinks (Professor of Mechanical Engineering, Pittsburg), controverted the above statement when he expressed that "in some cases equipment of doubtful engineering merit is installed and from the poor results, a whole class or type of machinery is condemned."

M. Mathol, a well known authority in Europe, gave his opinion that in the design of gas engines certain principles should be followed in respect to governing the mixture of gas and air, increased compression, scavenging of cylinders, provision for expansion, due to hot gases, regulation of cooling water, adoption of vertical types to reduce floor space, and recovery of waste heat. Some European engineering firms have introduced high power gas engines on these lines, and it will be useful to refer to one which was described by Mr. Alan E. L. Chorlton.[1] M. I. Mech. E. The "Duplex" engine is a vertical one, the cylinder walls of which are simple, the jacket is a tank so that temperature expansion of the former is allowed for, cooling is effective and uniform and no initial strains are set up, as in the inner and outer walls of the cylinders of the ordinary cylinder construction. Moreover, all working parts are enclosed, lubricating oil is supplied under pressure and increased rotational speed is obtainable, as the inertia of the reciprocating parts is balanced by a compression on each stroke.

The recovery of waste heat from the hot exhaust gas is one of importance, as will be seen later on, in connection with the proposed economical development of power from lignite. Prof. Fernald states[2] that several schemes for accomplishing this result are now commercially in use, but according to recent opinions the most efficient method of utilising the exhaust is through a combination of gas and steam engines.

Mr. Chorlton, in a paper read before the Manchester Society of Engineers, suggested the use of the steam generated obtained in cooling the gas-engine cylinder, for driving a steam auxiliary cylinder on the main engine. "He stated that this arrangement of a combined steam and gas engine is by no means a new one." He assumed a standard gas engine to use 9,500 British thermal units per brake H.P. As the engine is ordinarily arranged with jacket feed to the boilers, one may take 40 per cent. of the heat to be recoverable. From this at 80 per cent. efficiency of conversion at 100 pounds pressure, there would be recovered about 2½ pounds of steam per brake H.P. hour. In order, however to reduce the cost of the gas engine part, the compression of the gas would be lowered and with the ignition retarded, a much lower maximum pressure and temperature in the cylinders would result; the total heat units would go up, say, 12,000 British thermal units per brake H.P., but more would be rejected to exhaust, then with special arrangement of boiler, economiser pipes superheaters in exhaust, etc., 50 per cent. waste heat should be recoverable, and this would be about four pounds of steam per brake H.P. hour.

This may constitute one method of utilising the waste heat from the exhaust, but it is also possible to obtain a considerable quantity of heat for generating steam from water jackets in connection with gas producers, in which case it would be more practicable to utilise the same in independent steam turbines or engines. This will now be dealt with

[1] New Type and Methods of Construction of Large Gas Engines. Paper read before Iron and Steel Institute, England, Sept. 1912.

[2] Technical paper 9, Status of Gas Producer, etc., Bureau of Mines, 1912.

It is admitted that gas producers and engines are very economical power plants, and as lignite is eminently suitable as fuel for making producer gas, it would appear that this would be the best method of developing power. It must, however, be borne in mind that the full capacity of a 10,000 horse power plant will not be in constant demand and for this reason 40 per cent. load factor has been assumed, which means that an annual average of only 4,000 H.P. will be used, whilst to meet the maximum consumption 10,000 H.P. must be available. It is therefore evident that the economical arrangement will be to instal gas producers and engines for the average load, and to make use of the flexibility of steam boilers and engines for the remainder. Full advantage can thus be taken of the economical operation of gas plant, coupled with the utilisation of the waste heat therefrom to generate steam. It must be borne in mind that gas engines are most economical when operated at full load, their efficiency below full load diminishes at a more rapid rate than in the case of steam engines. Mr. Stott, in a paper read before an American Society of Engineers drew attention to the high economies to be obtained with a combined plant consisting of part gas and part steam equipment, so arranged that the waste heat from the gas producer could be utilised for supplying steam for the steam plant and that the gas plant could be run continuously at about full load while the steam part would handle the variable and peak loads.

Reference has already been made to the possibility of consuming producer gas under steam boilers, so it would be necessary only to have additional producers to operate the entire combined gas and steam power plant.

LIGNITE GAS AND ELECTRIC GENERATORS.

Gas manufactured by dry distillation, and gas engines to operate electric generators, constitutes another method of producing power at the mine for distribution in the Province.

Some particulars have been given of experiments made in North Dakota, Texas and elsewhere, but so far, no instance of the manufacture of gas by dry distillation from lignite on a large and practical scale has been heard of, although Dr. Swingbergen, in a paper on the utilisation of low grade fuel in the United States, mentioned that upright retorts have been in use for a long time for the distillation of lignite, of which no particulars are given. Owing to the difficulty of securing full information as to what is being done in Europe where lignites are utilised on an immense scale, this phase of the present investigations has not been fully developed. The absence of tangible examples of dry distillation of lignite on a commercial basis is not in itself an implication that it is not within the range of practicability.

As already explained lignite gas, in contra-distinction to coal gas, does not possess a high illuminating power, which today means practically nothing in view of the developments which have of late years taken place in Europe and America, but has a good heating power which means everything. The incandescent mantle was introduced in 1893 as a practical method of developing light, since when gas engineers have agitated for the removal of lighting standards, and this is recognised as reasonable by the Dominion Gas inspectors, for shortly the present regulations will be revised and heating standards substituted therefor. Lignite gas if provided, will, as a rule, be used for heating, cooking and power. Electric lighting will, as at present, doubtless, continue to be used. Lignite gas will not be subject to the regulations controlling standard coal gas, but will come under another category, namely: "prescribed gas," and this will be according to standards to be established when a scheme is being designed and a charter applied for from the Dominion Government.

The development of ordinary gas manufacture during the last ten years has been very great, the principal aim being to get the greatest production possible per ton of coal and at the same time to do it with the greatest economy. Horizontal retorts with intermittent charging have been in use for nearly a century, but the arrangement of setting and the methods of heating the same have gone through many changes. Horizontal retorts in some places have been supplanted by sloping retorts, and during late years by vertical retorts, or chambers. Continuous carbonisation in vertical retorts is now practised with excellent results. Moreover, gas is obtained from ovens which are built primarily for the production of metallurgical coke, and gas as subsidiary product. This latter product is now being supplied in many towns, and as considerable economies are effected by carbonising large quantities of coal in one operation this gas can be sold at a low rate, and this, together with the sale of tar and sulphate of ammonia recovered, constitutes a valuable income, apart from the sale of coke, which is the principal commodity wanted by the producer.

When coal is decomposed, distilled, carbonised or thermalysed (all practically synonymous terms) out of contact with air, gas and vapours are driven out, leaving behind in different parts of the plant coke, tar and ammoniacal liquor.

The ordinary method of carbonising coal is by means of a fire clay retort in which the coal is placed and the retort hermetically sealed. The only egress for the gas driven out by an externally applied heat is by means of a pipe attached to one end.

The gas and vapour pass out of the retorts into an hydraulic main where some of the tar and vapour are condensed and deposited. They then pass through a "foul" main, condensers, scrubbers and washers, where the gas is made to give up the remainder of the tar and vapours. Its passage continues through purifiers and finally into the gas holder where the purified gas is stored ready for consumption. The process is, of course, much more complex than would appear from the above elementary description, and entails considerable skill and care to obtain the best commercial results. The residue left in the retort is coke, which approximately retains the calorific value but not the weight of the original coal, and if during the process of carbonisation it has been properly cemented together it is a valuable fuel, and generally sold at a price practically equal to that paid for the coal.

As [illegible] by Hebron, Texas, Wyoming and Italian experiments, lignite [illegible] be carbonised in a similar manner to coal and the comparative average results are tabulated below:

	Lignite	Average coal
Quantity of purified gas made per ton of dry fuel	8,000 cub. ft.	10,000 cub. ft.
Gross production of coke	1,340 pounds	1,500 pounds
Tar	30 pounds	100 pounds
Sulphate of ammonia	14 pounds	28 pounds
Calorific value of purified gas	497 B.T.U.	600 B.T.U.

In the case of bituminous coal, when carbonised under the best conditions, the quantity of gas produced approaches 12,000 to 13,000 cubic feet per ton. and there is no doubt that under similar conditions lignite will also produce superior results.

Correspondence has been conducted with builders of vertical retort benches, which today are revolutionising the manufacture of coal-gas and one of them expressed an opinion that there is no reason why carbonising lignite in vertical retorts should not be successfully carried out. These retorts are used in the shale industry of Scotland where the shale is carbonised at low temperature to extract the oil.

The experience gained in the use of vertical retorts is that there is practically no difficulty in carbonising any class of coal, it being only necessary to watch the speed at which it is done.[1] Cannel coal, which is one of the lignite class, has been distilled in such retorts with good results.

So far as the data collected goes the process which promises the best results in the carbonisation of lignite is by means of vertical retorts, fired by gas supplied from an independent or attached producer, and equipped with labour saving devices for handling the lignite and coke. By using this form of retort, and especially if the sensible heat of the lower part of the charge is absorbed in heating the air for the generation of higher temperature in the combustion chamber, and incidentally also cooling the coke, the cost of operation will be less per ton of lignite than if horizontal retorts or possibly ovens were employed.

The quantity of lignite charged into the vertical retorts as well as the quantity of coke drawn out, could, within certain limits, be made to be automatic and continuous. Moreover, as moisture has an undesirable effect on the results of carbonisation, the waste heat from the flues could be used for drying the lignite and thus increase the capacity of the retort, improve the gas produced, preserve the hot fireclay retorts from damage by steam and generally give better results. Another valuable feature of the vertical retorts as compared with partially filled horizontals is the fact that the gas will not be decomposed by contact with the heat of the incandescent surfaces and therefore will not be robbed of some of its more valuable constituents.

As this gas will have a calorific value of about 450 British thermal units per cubic foot and as high class gas engines can be operated on about 10,000 British thermal units per brake horsepower hour it is easy to compute the capacity of a gas plant. With the view to providing for contingencies, such as diminished efficiency due to using the engines for under-loads, consumption of fuel in gas producers to heat retorts, and other items, it is advisable to allow, say 15,000 British thermal units per brake horse power hour. The load factor as with steam or producer gas and electric plant will be 40 per cent. and using the same interpretation as before—the ratio of actual output in cubic feet delivered to consumer to the possible maximum yearly output.

$$\text{Load factor} = \frac{\text{Number of cubic feet delivered} \times 100}{\text{Maximum daily delivery} \times 365 \text{ days.}}$$

[1] "Year's Work with Vertical Retort," Mr. Wm. Blair, "Gas World," Sept. 7, 191_.

To be able to supply lignite gas to operate 10,000 horse power maximum load means that the gas plant must have a capacity of about 800,000,000 cubic feet per annum, or a daily capacity approaching 5,000,000 cubic feet. A large gas holder would be necessary to provide for sudden demands. The consumption of coal will amount to about 100,000 tons per annum, which, [illegible] addition to gas, will also produce about 40,000 tons of coke, which must be briquetted, a considerable quantity of tar and sulphate of ammonia.

Gas, whether producer gas or lignite gas the latter of course by dry distillation, may be used by Bonecourt Surface combustion for heating steam boilers. A boiler has been installed at the works of the Skinnengrove Iron Co., Yorkshire, England. This boiler is 10 feet in diameter and only 4 feet from front to back, and containing 110 tubes each 3 inches in diameter. These tubes are packed with fragments of firebrick into which gas is admitted, and when the pieces of brick are sufficiently hot, air is mixed with the gas and a nonluminous flame is the result; but in a few moments this flame disappears and the firebrick becomes incandescent. A test was made in July, 1912, and the net quantity of heat actually used by the boiler and feed water heater was 90 per cent. of that available in the gas. For the purpose of comparison it may be stated that a test made with a water-tube boiler with all accessories fired under most favourable conditions, under good supervision, resulted in 76.4 per cent. thermal efficiency.

SYNOPSIS OF DATA RE POWER FROM LIGNITE.

As it would doubtless be unreasonable to express any opinions without giving some proofs as to the practicability of producing power from lignite, the writer considered it highly important when making these investigations, to inquire into and collect data concerning every form of power operating on lignite or other similar poor fuel.

The preceding chapter is submitted to show what is being or has been done in this direction, and the succeeding chapters will deal with the possible development of such power in this province.

The information given can now be condensed into the following brief statements:

St. Louis and Pittsburgh fuel tests clearly show that one electrical horse power per hour is to be obtained by gas producers and engines for less than 3½ pounds of North Dakota lignite. The Montreal tests resulted in a little higher consumption, but as shown by actual operation of the large Texas plant, the quantity of lignite used last year was four pounds per kilowatt hour, or, say, three pounds per electrical horse power hour.

In connection with raising steam, lignites do not show up so well. At Williston, North Dakota, the evaporation per pound was 3½ pounds of steam from and at 212 degrees Fahrenheit. At Weyburn and Estevan, under actual working conditions, the evaporation was 4.1[illegible] and 3.76 pounds respectively. At Montreal 3.91 pounds and at Dallas [illegible] pounds of steam were obtained per pound of lignite.

A compound condensing steam engine requires, say, 17½ pounds of steam per indicated H.P., then the above lignite consumption will be equal to 4 to 5 pounds per indicated H.P. hour.

On the basis that 25 pounds of steam are required per kilowatt, then the quantity of lignite will be about 5 pounds per kilowatt hour. As will be observed in Mr. Cronk's statement six pounds is allowed in the estimates for steam turbine plant.

With regard to lignite gas, it will have been noticed that there is considerable difference in the productions of gas per pound of lignite, as they range from about $3\frac{1}{2}$ to 10 cubic feet per pound, but for the purpose of this report 4 cubic feet has been adopted as a fair estimation of the probable gas production from local lignite.

The results obtained from gas producers with regard to volume of gas evolved per ton show that from North Dakota lignite 45,000 to 65,000 cubic feet were produced, and Taylorton lignite tested at Montreal yielded 80,000. The quantity of which estimates are based is 60,000 cubic feet per ton of raw lignite.

It must be appreciated in the perusal of this report that some of the lignites mentioned are not quite analogous to those to be utilised in the province. Still, it is justifiable to contend that if such inferior fuel can be used in one country, it is within the range of practical economies to do likewise here.

As is well known, Germany has during the last two decades forced her way into the front rank of industrial nations of the world. It has already been stated that German public bodies and large industrial concerns find lignite and lignite briquettes to be serviceable fuels. If conservation of power can be effected in this manner in Germany, when other and better fuels are available, it is a legitimate question to ask if there is not a good reason to warrant similar efforts being made to utilise local lignite as fuel for power and other purposes.

There necessarily are other factors which contribute to the industrial prosperity of a community, but cheap fuel and power are doubtless the most important.

LIGNITE GAS DISTRIBUTION.

Power and heat by means of gas can be produced at a central gasworks and distributed. As is probably well known it is proposed to pipe natural gas from the neighbourhood of Medicine Hat to Winnipeg and to supply the intervening towns as well. Calgary is now being supplied with natural gas obtained from Bow Island, which is about 180 miles distant. There are plenty of examples of the distribution of natural gas, the rock pressure of which is generally very great. Instances of the distribution of artificial gas over long distances are not so well known. Such gas is transmitted at St. Louis (Mo.) to supply a district comprising 120 square miles, the initial pressure is 40 pounds per square inch, and the capacity of the plant is 1,500,000 cubic feet per 24 hours.[1]

Gas is conveyed by pipe for 30 miles under an initial pressure of two atmosphere (301 pounds) from the Deutsche Kaiser blast furnace in Germany. "Seven years ago the coking plant began to furnish gas to the surrounding small towns, but it was only in 1907 that the first line was laid to the city of Mullheim, about six miles away from the plant. The system proved so excellent that some years later the distribution system was extended further to a distance of about 30 miles.[2]

[1] Progressive Age, Sept. 16, 1912.
[2] Progressive Age, Sept. 2, 1912.

Hartford City Gas Light Co. supply one-half of the output to Thompsonville, which is 21½ miles away. The initial pressure is 35 pounds per square inch.

As an indication of the utility of gas it may be stated that there seems to be a strong tendency in the Rhine Valley (Germany) in the direction of abandoning the electric stations and taking to gas with long distance transmission. The latest example is Geisenheim-on-the-Rhine, which is co-operating with Johannesberg and Winkel to put up gasworks.[1]

The Illustriete Zeitung lately issued a "Gas Centenary Issue' which contained an article describing "the long distance main by which gas is conveyed from the coke ovens at Hamborn to the gasworks at Barmen, over 30 miles distant." The gas is pumped through this main at an initial pressure of two atmospheres, and the quantity dealt with is at present 1,061,000,000 cubic feet per annum, but the installation will suffice to meet all demands up to 3,500,000,000 cubic feet per annum.[2]

The above will doubtless be sufficient to show that there are no serious difficulties to surmount in the distribution of gas under high pressure over long distances. It may, however, occur in winter with low atmospheric temperatures, that some small portion of the constituents of the gas will condense and deposit, in which case it is an easy matter for the cities and town authorities to enrich it in a cheap manner.

Mr. Chas. E. Munroe, professor of chemistry of George Washington University, Washington, D.C., in concluding an interesting paper read at the Gas Centenary Celebration at Philadelphia a few weeks ago, made use of the following words: "I have long looked upon our present custom of transporting coal long distances to be converted into gas as uneconomic." To provide for emergencies, large stocks of coal must be accumulated in advance at the gasworks and as coal, particularly gas coal, begins to deteriorate as soon as it is removed from the mine, there is very considerable loss going on all the time from this cause.

"By producing the gas at the mine and shipping it in by pipe line the cost of haulage is saved. The wastage of coal by weathering is saved. Such coke as is not needed for industrial purposes can be converted in producer [illegible] which by means of internal combustion engines can be used in [illegible] lectricity for transmission, and the ash from the coal can be [illegible] mine for use as a filler in place of coal."

"It [illegible] at gas can, under these circumstances, be made and delivered [illegible] less cost than is the case at present, though it may be necessary after long travel to enrich it near the point of consumption. I foresee that should this plan of gas generation at the mine ever be realised there would grow up about the gas generating plant a large number of industries based upon the utilisation and further manufacture of the byproducts and that they would be greatly fostered, as would many of the industries, by very cheap gas, which could under these circumstances, be produced for use as a source of heat, power or light, and which could be so cheaply produced as to enter on the spot into competition with water power as a source of electric energy."[3]

In connection with the use of lignite gas, it is advisable not to count on domestic lighting as a great factor in its consumption, but rather to cater for heat and power. Lignite gas manufactured by means of up-to-

[1] Gas World, Sept. 30, 1912.
[2] Journal of Gas Lighting, Sept. 24, 1912.
[3] Progressive Age, Oct. 1, 1912.

date plant will answer for these purposes but it cannot be expected that the most efficient results can be obtained without ample experimentation.

If gas is made in this province from imported Virginia gas coal, costing, say, $8.50 per ton and producing 10,000 cubic feet, the cost for fuel alone will amount to about 85 cents per 1,000 cubic feet of gas, having a calorific value of about 600 British thermal units per cubic foot, that is, say 700,000 British thermal units for one dollar. Lignite at $1.50 will produce about 8,000 cubic feet of gas having a value of about 450 British thermal units per foot, that is 19 cents per 1,000 cubic feet for coal only, or 2,360,000 British thermal units per one dollar. This latter of course does not include cost of piping and pumping to cities. The value of by-products will be greater in the case of good gas coal than with lignite, and this must be allowed for.

As all the schemes presented herein are based on an assumed 10,000 H.P. plant, the lignite gas plant must necessarily also be on equivalent lines for the purpose of comparison. It is of course known that the principal towns of South Saskatchewan already possess electric power plants, but no town possesses a gas supply, and having regard to the many uses which gas can be put to, both domestic and industrial, it is apparent that a supply of lignite gas would not only be acceptable, but also the market for this commodity is immediately available without competition. Furthermore, it may seem redundant to both generate electricity and manufacture lignite gas at a central power plant located at a mine, but as will be shown later on these are financially possible provided that in the case of Moose Jaw, Regina and neighbouring villages, these plants are within reasonable distance so as to permit the scheme or schemes being run economically.

Although the lignite gas plant is for the purpose of comparison made equivalent to the electric combinations, it must be borne in mind that at present the demand for gas is practically an unknown quantity as far as the above cities and villages are concerned. But it is possible by analogy to estimate their probable requirements. In a city in the West, the number of consumers is about ten per cent. of the total population and the average annual gas consumption amounts at present to about 30,000 cubic feet per customer, or 3,000 cubic feet per annum per head of population. The growth of output of many gasworks as compared with the growth of population is such that the sale of gas in large cities grows almost twice as fast as the population. The same remark applies more or less accurately with regard to electric plants in this Province. The population resident within 50 miles south of Moose Jaw and Regina may be stated as follows:

Regina, say	40,000
Moose Jaw	30 000
Other towns, etc.	20,000
Total	90,000

By the time any gas supply could be made available, this figure will be increased to, say, 150 000. It is not to be anticipated that the number of consumers will be large during the first year or so, nor could it be arranged economically to insta the whole within one year but nevertheless on the ground of economical construction the gas plant would have to be designed to meet the probable maximum demand in, say, five years time. Three thousand cubic feet per head per annum for a population of 150,000 means the erection of gasworks having an annual capacity of 450,000,000 cubic feet, or a maximum daily output of, say, 2,500,000 cubic feet. This would be equivalent to an annual consumption of 56,000 tons of lignite and an output of about 20,000 tons of coke to be converted into 22,400 tons of briquettes.

DISTRIBUTION OF PRODUCER GAS.

There are not many instances to be found, so far as the present enquiries have extended, where the manufacture and distribution of producer gas on a large scale has been carried out.

Mond producer gas is supplied from Dudley Port, England, through 3 foot mains, under a pressure of 5 pounds per square inch. There are about 40 miles of distributing mains of various sizes.

There are no serious difficulties to surmount, and, undoubtedly, volume for volume, it is the cheapest artificial gas that can be made and distributed.

The table given below is taken from Technical Paper 9, United States Bureau of Mines, and gives the average results obtained by tests.

YIELD AND HEAT VALUE OF GAS per ton of fuel in an up draft pressure producer:

Character of fuel	Yield of gas per ton of fuel or fired	Heat value of gas per cubic foot	Heat value of gas per ton of fuel as fired
	Cubic feet	B.T.U.	B.T.U.
Coke or charcoal	170,000	140	23,800,000
Anthracite	140,000	135	19,000,000
Bituminous coal	120,000	152	18,200,000
Lignite	72,000	158	11,400,000
Peat	60,000	175	10,500,000

Lignite, when converted into producer gas and used in a gas engine will develop over two and a half times the power that it will generate when consumed in the soli[illegible] n for generating steam power.

The disadvantage of [illegible] e producer gas for distribution through a long length of main is its low heat value. Lignite producer gas on an average working condition will have a heat value of about 125 British thermal units, although under favourable conditions it will be higher. Lignite gas (dry distillation), will have about 450 British thermal units, coal gas (dry distillation) about 600 British thermal units and natural gas about 1,000 British thermal units. It will thus be seen that to obtain equal heating power the following quantities must be used:

Lignite producer gas	Lignite gas	Coal gas	Natural gas
1,000	280	210	125
	1,000	750	450
		1,000	600

A given quantity of natural gas is therefore equal to about eight times the same quantity of lignite producer gas, 2.24 times that of lignite gas and 1.66 times of coal gas.

As nearly four times as much lignite producer gas would be required to give the same power as lignite gas, it follows that the mains, fittings, etc., with producer gas would require mains having that many times the capacity that would be necessary for lignite gas.

But the producer gas can be manufactured very cheaply. If the cost is based on cost of coal alone, then if one ton of lignite costing $1.50 will produce 60,000 cubic feet of lignite producer gas having a calorific value of 125 British thermal units per cubic foot, then 5,000,000 British thermal units can be got at a cost of $1.00; lignite gas as before 2,360,000 British thermal units for $1.00; coal gas as before 700,000 British thermal units for $1.00. Natural gas at 40 cents per 1,000 cubic feet will be equal to 2,500,000 British thermal units for $1.00. The carrying capacity of the mains required for these gases under any given pressure will roughly be in inverse proportion to their heat values. There are, however, other factors which have to be considered in this connection, but it is unnecessary to discuss them here.

If lignite producer gas instead of lignite gas was manufactured, the long length of main from any central power plant at the mine to the points of consumption must be increased in size and therefore cost. This will be dealt with in the chapter on estimates.

UTILITY OF ELECTRICITY AND GAS.

There is no doubt that the uses to which electricity and gas can be put will multiply in a remarkable manner as fresh discoveries are made.

Electricity is used for power, light and in a less measure for heat. It is also used in connection with chemical, metallurgical and other industries.

Gas is used for power, light and heat and in connection with a great variety of works. The developments which have recently taken place with regard to surface-combustion appear to be fraught with great possibilities in the uses of gas for heating. The efficiencies and economies that are obtainable by Bonecourt's surface-combustion may revolutionise the methods of heating in vogue at present, and be the means of creating new industries in this province which today are out of the question owing to cost of fuel. The applications of Bonecourt's surface-combustion are numerous; its uses in connection with steam boilers have already been mentioned. Melting of metals, evaporation and concentration of liquids, cooking and heating, calcination of minerals, industrial uses such as annealing, galvanising, enamelling, brazing, etc., etc., are but few instances of its uses.

The pressure under which gas is usually supplied is only two or three ounces per square inch whereas if high pressure of one or two pounds per square inch is provided, the usefulness of gas is much increased, although the losses by leakage may be slightly greater. There does not appear to be any strong reason why this should not be done, apart from that of ancient custom and practice.

Sufficient has already been stated to show that the cost of producing electricity or gas depends largely on the proportion of the plant that is utilised continuously. In the case of a gas plant, however, the load factor will be higher because the storage of gas for any period by means of a gas holder is exceedingly cheap.

Although it is not in direct uniformity with the instruction of the Legislature, the introduction of a suggestion which will increase the load factor and therefore reduce the cost of producing electricity and at the same time confer additional benefits on the community may be opportunely referred to at the present stage of this report.

A vicinal railway laid on the side of public roads and operated by electricity, connecting the larger towns and cities, and also the cities with the lignite coal fields, would doubtless constitute not only cheap transporting facilities for fuel and agricultural produce, but also for conveying passengers as well.

Belgium affords the best example of what such railways are capable of doing for the community. About 30 years ago there were only 15 miles of vicinal railways in operation in that country, whereas in 1908 there were 2,586 miles and 1,300 miles either sanctioned or under construction. Farmers have siding where they want them, passengers and goods are taken on or put off at any point. These lines are important feeders to the ordinary railways, and the traffic may be appreciated when it is stated that in one year 4,000,000 tons of agricultural produce, merchandise and other goods are conveyed and 53,500,000 journeys made by passengers.

In an article which the writer wrote in 1910 he referred to a paper read by M. De Burlet, at the Paris Railway Congress in 1900, when he, in effect, stated that vicinal railways have, *inter alia* transformed insignificant or abandoned quarries into lucrative and important concerns, agriculture was raised from the slough of depression to the highest state of perfection, dormant villages became centres of human activity, new markets were found for all produce, the finances and commerce were revived, the value of land and other properties were enhanced, the low rates for workmen extended their sphere of employment, cheap facilities for travel and transport stimulated a new spirit, infused new energy, improved the economic conditions of the rural districts and produced an increasing national prosperity through Belgium.[1]

Even if M. De Burlet's expressions may be thought somewhat exuberant, the fact remains that Belgium has prospered to a remarkable degree.

These railways are financed by the state, the municipalities and private persons. The state holds 38 per cent. of the shares. As the great demand for such railways has taxed the financial resources of the parties concerned, arrangements were made so that the shares are paid up in ninety annual instalments, and by this means the shareholders became owners of the valuable undertakings without incurring any serious burden to handicap themselves.

Such a railway could take electricity at various points along the transmission lines, greatly increase the demand on the power house, and thereby reduce the cost of production and the selling price. On the other hand the public would be benefited by having cheaper power, cheaper fuel, cheaper transport, and the farmers would be able to ship their market and agricultural produce at all times to the advantage of themselves and the community.

[1] Public Roads and Vicinal Railways.—Practical Road Engineering, London, R. O. Wynne-Roberts.

The foregoing is a suggestion that may be found worthy of consideration, but nothing of course has been done to calculate the power that may be required. The suggestion is incidentally made to show the possibilities. Should a central gasworks be built then such a line would also be the means for distributing the by-products.

BRIQUETTES.

It will be observed by what has already been stated that in case of lignite gas manufacture, the coke as it is drawn out of the retort or oven is pulverulent and without further treatment is practically useless. There is no known process by which lignite by dry distillation can be made to produce hard coherent coke, and consequently some method must be adopted for its conversion into briquettes The method which was adopted by the Italians at Spezia in 1891 and by Professor Babcock at Hebron, as already referred to, has been adopted at a number of gasworks to dispose of breeze or fine coke with good results. Mr C. J. Bacon, Illinois Steel Company, South Chicago, recently conducted several tests to ascertain the best methods of utilising coke dust—the waste from coke ovens—and after many trials found coke with fifteen per cent. of Pocohantas coal briquetted with sulphite pitch as binder, gave good results in a gas producer, comparing favourably with anthracite pea coal as to gas analysis and power. He found sulphite pitch and dextine gave the best results as binders, although neither of these are waterproof, and therefore such briquettes when exposed to atmospheric influences would not weather well, but could be stored under cover without disintegrating.

In 1904 the United States Geological Survey made some tests in briquetting coke breeze.[1] The first one a mixture of 73 per cent. of crushed coke, 20 per cent. of West Virginia coal and 7 per cent. of pitch was made, and the briquettes were found to be hard and strong and easily handled while hot, but were somewhat dirty.

On cooling they became unusually tough and strong, and during combustion were solid and burned more like anthracite than bituminous. The next test was made of 92 per cent. of coke breeze and 8 per cent. of pitch. The resultant briquettes were clean, well formed and when struck had a metallic ring. They were very tough and strong and would bear much more handling than any of the briquettes made out of coal. They burned like ordinary coke, without any disintegration and with only a little flame. The crushing strength of these coke briquettes, even when porous, was much greater than the best of the coal briquettes.

Lignite coke does not contain moisture and the gas has been extracted, and under these circumstances the briquettes made of coke are not subjected to similar disintegrating forces as in the case of raw lignite.

The main difficulty in the manufacture of lignite coke briquettes as a commercial business is the cost of bituminous binders—coal tar, pitch and asphalt are expensive. In the case of Hebron process where pitch, flour and soft coal are used, the cost of pitch amounts to about 38 per cent. of the total cost of manufacture, excluding the value of the coke; the cost of flour absorbs about 20 per cent. and soft coal about 11 per cent. of the total cost. In other words, the total cost of these binders

[1] Fuel Tests at St. Louis United States Geological Survey, 1904. Professional paper No. 48.

represent about 69 per cent. of the cost of production, and this fact tends to make the business more or less non-remunerative, as the selling price must be less than that of imported briquettes. In the manufacture of lignite gas it will be necessary to convert the coke into briquettes so as to be able to dispose of it. If another satisfactory, and of course cheaper binder can be found, then there will be a greater margin between the cost of production and the wholesale selling price, and the profit will go to reduce the price of the lignite gas. No experiments have yet been made locally, but it may be possible that some cheap starchy composition may be found to effectively bind the coke, in which case the paraffin obtained from lignite tar may be useful to render the briquettes waterproof. Such a binder would probably enable the cost of manufacture to be reduced 50 per cent. This is a problem that needs solution, for the commercial success or failure of a briquetting plant depends largely upon the cost of the binder.

Sulphite-pitch, which is a by-product of wood-pulping process, appears to give some satisfaction, but the freightage on this commodity from the Eastern States or Quebec is heavy.

When proper tests are made locally it may be possible to utilise some gummy substance obtained from local product, such as from flax, straw, culled potatoes, defective wheat, etc., or asphaltic substance from the northern parts, molasses from Alberta, etc., and these may be made available as binder at a price much below imported pitch or asphalt.

The determining condition in connection with briquetted fuel is the acceptability of briquettes as a substitute for other forms of fuel on the local market. To create a demand they must excel the usual fuel supply in one or more respects, such as low in price on the heat basis, comparative smokelessness, size suitable for purpose intended, minimum of dirt in handling and minimum of clinker and ash.[1] Banff briquettes are sold in Regina at $9.00 per ton (2,000 pounds). These briquettes are made of the waste semi-anthracite, or superior bituminous coal, mixed with 9 to 15 per cent. of coal tar pitch and passed between rollers, having egg shape recesses and pressed into shape which is well known. Briquettes are made in a variety of shapes, such as that of the ordinary brick, biscuit shape, cylindrical, pillow shape and eggettes—each intended more or less for different uses. Experiments have been made by many persons to briquette raw lignite with indifferent success. A great variety of binders have been tried, but with raw lignite, as it contains so much moisture and volatile matter most of these briquettes break up when thrown on a fire.

Mr. Latta, of Minneapolis, however, has patented a binder which he mixed with dry pulverised lignite coal, and the mixture pressed into cylindrical moulds. Some of these briquettes were put on a fire in ordinary household grate and burned into ash without breaking up. A red hot briquette was withdrawn from the centre of the fire and plunged into cold water without causing any disintegration. If Latta's binder is not too expensive for a commercial undertaking and the briquettes are capable of giving similar results when used as ordinary fuel, it would enable the mine owners to produce a cheap fuel and at the same time give more regular employment to the men and better returns to the shareholders.

Assuming that the selling price of lignite coke briquettes in Moose Jaw and Regina would be $7.50 per ton (2,000 pounds), of which the mer-

[1] Progressive Age, May 1, 1912.

chant gets 50 cents per ton as profit, delivery costs $1.00, offloading 20 cents and the freight is $1.80 per ton from Estevan. The balance $4.00 would represent the price of briquettes at the works, as the cost of manufacturing them will be about $2.50, there is left $1.50 as the value of coke. If the works were located, say, near the Dirt Hills, the freight on briquettes will be less, and furthermore, if the price to be paid for raw lignite is less than $1.50 per ton, which is almost certain to be the case, then the selling price of lignite coke briquettes will be less.

Although no practical tests are known to have been made in partially gasifying lignite and then converting it into briquettes, experiments made in America would appear to point to such a possibility. Moreover, if peat can be converted into coke fuel by such means, as is done in Germany, Russia and Sweden on a commercial scale, it would be worth investigating into the practicability of such a process in connection with lignite, for water and portion of volatile matter would by this means be extracted and the residue would be more amenable to treatment.

BY-PRODUCT OF LIGNITE GAS MANUFACTURE.

Apart from coke briquettes, there are other by-products from the dry distillation of lignite, such as tar, sulphate of ammonia, etc.

Mr. Edwin T. Dumble, about the year 1891, sent specimens of air-dried lignite from Texas to Dr. Krey of the Riebeckschc Montan-Gesellschaft, having the following composition:

Moisture	12.15%
Volatile matter	37.11%
Fixed carbon	41.14%
Ash	6.50%
Sulphur	3.02%

Experiments were made by Dr. Krey and the lignite gave on distillation at the temperature for producing the maximum amount of tar:

Tar	5.56%
Coke	45.40%
Water	39.96%
Gas loss	9.08%

The tar was subjected to the usual tar analysis and yielded:

Raw oil, paraffin free	7
Raw oil, containing paraffin	70
Water	1
Coke	2
Loss of gaseous matter	20
	100

The yield of hard paraffin (melting at 52 centigrade) was eight per cent. of the tar.

The distillation of lignite tar is an industry in Germany. One firm, out of 11,000 tons (2,000 pounds) of tar produced 3,254 tons of paraffin and candles, 1,650 tons of light paraffin, 4,388 tons of dark paraffin oil, 1,600 tons of miscellaneous products.

Certain kinds of lignite in Germany by dry distillation yield tar which when treated produce paraffin and heating oil. There is a demand for these oils for Diesel engines.

With regard to the yield of sulphate of ammonia obtained from lignite, very little information has been obtained, but there is no doubt that some quantity will be produced. Sulphate of ammonia is a valuable fertiliser for which there is at present no local demand.

The ammonia is also manufactured into other products of considérable value.

TRANSMISSION OF POWER.

Electrical transmission of energy is well known to the public. The development of hydro electric power in Canada is one of the most potential factors which has contributed to and will further promote her industrial progress. Unfortunately, so far as the southern part of Saskatchewan is concerned, such power is not available, and attention must be paid to the development of energy by other means in the most efficient manner possible.

Whilst it is most desirable to transmit power from large central plants to such distances as may be found economically feasible, it is also advisable to have regard to the future connecting up of the different units so as to have a complete interchangeability of power between them, and thus render the whole less liable to interruptions. In other words the deficiencies of one unit should be capable of being balanced up by the surplusage of another. This is what has been done in North East Coast power system in England. In California 1,920 miles of transmission lines have been tied together, and the capacities of different stations owned by four separate companies are by this arrangement utilised to the full. In the Carolines the Southern Power Company have some 800 miles interconnected overhead circuits.

Mr. C. C. Cronk has dealt with the electrical details of the various schemes submitted, and as his report is appended hereto it will be unnecessary to go further into this matter here.

REQUIREMENTS OF SASKATCHEWAN IN RESPECT TO POWER.

Mr. Cronk, in his report, has dealt with the question of electrical power and its distribution. It is, however, manifest that the expansion of the electric supply in the principal cities is very great and the probabilities in respect to future requirements point to even greater expansion.

Hitherto it has been found that so soon as an electric installation has been fixed and running, it is insufficient for the growing needs of the community. With the advantage of cheaper electricity, there is every prospect of a more general and profuse consumption of current for power and light.

The annual increase in population is such as to make it practically impossible to predict the future. During the last two years it has been phenomenal and the indications are suggestive of a general and great annual increment for some time to come. With the advent of cheap power and fuel it will accentuate the difficulty of presaging the growth in the demand for power.

The present situation has been analysed and the results are fully set forth in Mr. Cronk's report, in which it is pointed out that in two years time Regina and Moose Jaw, for instance, will in all probability require 26,000,000 kilowatts per annum. This is about three times the present demand of these two cities.

The southern lignite fields have been more fully explored and lignite has been found in many places. It is therefore a question of which location will be the most advantageous for a central power plant. It must be evident that power *per se* can be generated equally as cheap at any coal mine, if similar facilities are available. The cost of the energy delivered, however, must depend on the capital expenditure involved in the construction of transmission lines interswitching stations and substations, together with the annual losses, fixed charges and cost of maintenance.

The magnitude of the expenditure, as well as the cost price of the energy delivered, will necessarily be in some proportion to the distance between the generating station and the points of consumption. These are points which are dealt with in Mr. Cronk's report.

It may be pointed out that although at present there are a number of small towns and villages along the probable routes of transmission lines—whether it will be for electricity or gas—the natural growth and especially the great influx of people into these parts will certainly add materially to the population and in time their requirements may be great.

Assuming that a power house was erected, say, in or near Estevan a transmission line of any form of power, heat and light laid from there to, say, Rouleau and then to Moose Jaw on the northwest and Regina on the northeast, measuring in all about 155 miles, would at present serve a population of about 90,000. The line could distribute power to the towns and villages *en route*, but this quantity will, for a time at any rate, be relatively small, yet the lines would in this respect be more or less similar to those at Winnipeg, Toronto, etc. It must be borne in mind that where electrical energy is generated by water power, it is usually cheap and the losses incurred in its transmission are counter balanced by the cheapness of the production. When such energy, however, is generated by means of solid or gaseous fuel there is a perennial expenditure in mining and hauling coal and its conversion at the plant. It then becomes a question whether it would not be more advantageous to locate the power plant in such a position so as to reduce the transmission losses and capital charges, in order to command the power market at the least possible cost and thereby render it possible to supply the energy at a lower price, with great advantage to the community generally.

If the power house is located on the lignite fields near the Dirt Hills, say 40 or 50 miles south of Moose Jaw, with direct transmission lines to Moose Jaw and Regina, the total length will be reduced to approximately 110 miles. In this case no expensive interswitching station with its inherent cost and losses will be necessary, the line will be cheaper and the transmission losses will be less.

Estevan, Weyburn, Rouleau, Moose Jaw and Regina already have their individual electric power stations and it is palpable that electricity delivered in bulk to such towns must be at such a rate as will render it profitable for the authorities to take it and let their power plant answer as auxiliary or standby installations.

A power house could be established in Estevan, or at one of the neighbouring mines, with lines to Weyburn, thence to Stoughton, Arcola, Carlyle, and perhaps Brandon.

The instalment of the first section of a 10,000 H.P. power plant is the smallest that can be provided with due regard to future demands, for it is clear that the annual increase has been and is much in excess of the growth in population, and it is quite probable that if it is known that cheap power is available, the first instalment will be too small by the time it is ready.

With regard to the northwest part of the province as there is a lack of information as to where an ample supply of lignite can be found within a reasonable distance of Saskatoon and Battleford, a discussion on the practicability of producing cheap power and distributing the same to these and other towns will have more or less an academic value. The nearest known location of lignite deposits is that mentioned at Brock, which is 100 miles from Saskatoon and 90 miles from Battleford. This renders the complete installation somewhat expensive and the cost of power delivered rather high. Estimates of this scheme are given in Mr. Cronk's report, and there will therefore be no further need to discuss it here. In this connection, however, it might be possible to provide cheaper electricity by means of a hydro-electric plant, but this is not a part of the present investigation.

The essential conditions to be complied with in connection with the location of any large power plant are:

(*a*) There must be an assured supply of lignite which can be delivered into the power house bunkers at the lowest possible price per ton.

(*b*) There must be a railway to transport the heavy machinery and materials to the site to dispose of any by-products and to afford the employees travelling facilities.

(*c*) There must be ample supply of good water available. As the water from Saskatchewan River is softer than ordinary ground water it would be useful in this connection.

Mr. Cronk's report will be found on page 106.

ESTIMATE OF COSTS.

Every effort has been made to collect the fullest possible data as to the cost of the different power schemes, but it must be stated that owing to the limited time available, after making investigations as to the needs of the province in respect to power and fuel, the disposition, area, extent, quantity and qualities of local lignites and their adaptability for the generation of power, the time for formulating power schemes and obtaining quotations for various items of machinery was rather inadequate.

It must be remembered that most of the above work was of the nature of pioneer developments, because in North America there has been comparatively little done in the utilisation of lignite as fuel for the generation of power on a large scale. Anthracite and bituminous coal or water power are so abundant in the vicinity of existing large industrial centres of North America and attention is only now being paid to the possibility of lignite as a potential power producer. The above remarks will also explain the hesitancy of some engineering firms to supply estimates, but when the power schemes are more fully developed no doubt they will be only too anxious to compete.

STEAM PLANT (Lignite fired).

Having regard to what has already been stated and to Mr. Cronk's report appended hereto, it will be unnecessary to dilate on the cost of steam and electrical plant to any extent.

Five units of 2,000 H.P. steam turbines, complete installation of boilers with coal and ash conveyors, etc., are included in the estimate.

The cost of installing the plant as well as to operate it has been prepared as carefully as circumstances would permit. A large steam plant fired with lignite has not been installed in this country, and therefore experience is somewhat lacking, but by analogy, it has been possible to calculate the cost. which is believed to be ample.

Two schemes are submitted, namely, one plant at Estevan mines and the other on the lignite fields south of Moose Jaw.

With regard to the transmission lines there is little to be stated, as they are of the usual type and of as economical design as is compatible with durability, stability and safety. The tentative routes are as shown on plan.

The initial cost of plant and cost of energy per kilowatt is given in Mr. Cronk's report.

GAS PRODUCERS AND ENGINE PLANT.

The cost of 5 units of gas producers and engines and generators are included in the tabulation continued in Mr. Cronk's rep o t.

As the subject of producers and engines have already been dealt with at some length it is unnecessary to dwell further on the same.

GAS PRODUCERS AND ENGINES TOGETHER WITH GAS PRODUCERS AND STEAM BOILERS AND ENGINES.

In another part of this report reference was made to the economies which are obtainable by installing gas producers and engines to carry the constant load and install more producers and to utilise the waste heats, to generate steam power to take the variable and peak loads. The anticipated economies have to some extent been confirmed by the estimates.

ELECTRICITY AND LIGNITE GAS SUPPLY.

As the instructions of the legislature were to enquire into the practicability of producing power at coal centres and distributing it, there is no reason why two forms of power should not be supplied.

The practicability of producing power has been proven, and the cheapness of such power has been shown in figures, which, subject to revisions, compare very favourably with any other supply in Canada, when due regard is paid to the conditions of production.

The two powers, lectricity and gas, can be gene ted at the same centre, brought in by the same right of way, be managed by the same authority, be it government commission, inter-municipal commission or company, and by this means introduce many economies that would tend to reduce the cost of construction and operation.

REPORT AND ESTIMATES ON ELECTRIC TRANSMISSION SCHEMES.

November 21, 1912.

SIR,—

I beg leave to submit the following report on the question of electrical power transmission from the coal centres of the province. As no specific sites have yet been decided upon or any definite route laid out for the transmission lines, the figures given hereinafter must be considered as preliminary. They are, however, high enough to cover an average installation. The result obtained will give an indication of what may be expected, and when firm tenders are received they will probably reduce the capital expenditure to some extent.

ESTIMATION OF POWER REQUIRED.

As Moose Jaw and Regina offer the most promising fields for the sale of power in the Southern part of the province, it is desirable to ascertain the probable requirements of these two cities, where municipal power plants have been installed and worked for a sufficient time to enable analyses being made.

The population of Regina in 1906 was 6,200 and from that year to 1911 it increased to 30,200—the average annual compound increase was 37 per cent. Moose Jaw in the same period increased from 6,200 to, say, 17,000. This represents an annual compound increase of 22 per cent.

Tabulating the figures we get the following results:

Year	Regina	Moose Jaw	Total	Approximate Increase
1906............	6,200	6,250	12,450	
1907............	8,500	7,700	16,200	30%
1908............	11,600	9,400	21,000	30%
1909............	16,000	11,500	27,500	32%
1910............	21,900	14,000	35,900	30%
1911............	30,000	17,000	47,000	30%

The average rate of increase of the two cities combined was about 30 per cent.

Assuming that the future development of these cities will be the at same rate as above, then in five years' time the population will be:

1911 Regina and Moose Jaw	47,000
1912 " " " "	61,000
1913 " " " "	79,000
1914 " " " "	102,000
1915 " " " "	132,000
1916 " " " "	171,000
1917 " " " "	322,000

It is possible, however, that this growth may not take place but the indications are suggestive of expansion on a phenomenal scale.

In studying the question of power it may be stated that the following figures have been collected:

Year	Regina	Inc.	Moose Jaw	Inc.	Total	Annual Increase
1909	1,201,000 Kw.H	....	463,000 Kw.H	....	1,664,000 Kw.H	....
1910	1,568,000 Kw.H	30%	731,000 Kw.H	59%	2,299,000 Kw.H	38%
1911	2,459,000 Kw.H	57%	1,217,000 Kw.H	70%	3,706,000 Kw.H	61%

The increase in the consumption of power during the present year has been extraordinary, and as the demand increases far in excess of the growth in population the following table has been prepared to show the probable requirements of Regina and Moose Jaw:

Year	Regina	Inc.	Moose Jaw	Inc.	Total	Increase
1912	4,500,000 Kw.H	82%	2,500,000 Kw H	100%	7,000,000 Kw.H	88%
1913	7,000,000 Kw.H	55%	3,750,000 Kw.H	50%	10,750,000 Kw.H	53%
1914	10,900,000 Kw.H	55%	5,450,000 Kw.H	45%	16,350,000 Kw.H	52%
1915	17,000,000 Kw.H	55%	7,600,000 Kw.H	40%	24,600,000 Kw.H	50%
1916	25,500,000 Kw.H	50%	10,600,000 Kw.H	40%	36,100,000 Kw.H	47%
1917	37,000,000 Kw.H	45%	14,800,000 Kw.H	40%	51,800,000 Kw.H	43%

Up to the present time there has been no actual and heavy consumption of power for industrial purposes, but when cheap electricity is made available then the demand for power will be greatly expansive, and of an even more profitable character. Under these circumstances it would be safe to assume that in 1915, 26,000,000 kilowatt hours will be required, and each year afterwards there will be an annual but diminishing increase.

While the demand for electric power in general will depend upon the relative cost of electricity as compared with that of steam, gas or other form of energy, there are many factors which must be taken into consideration.

In a number of cases such as brick works, laundries, etc., the exhaust steam or heat is used in connection with the particular operation involved at the works, and it is not probable that manufacturers of this class will adopt electricity for power alone, as their production of steam and heat in addition to power obtained from outside sources will tend to increase rather than diminish; in wood working shops, mines, etc., waste material is used in the production of steam, and consequently such industries have been excluded from the estimated demand.

The capital cost of abandoning present plants and installing motors would also, in many cases, be considerable, and the ability of small users to bear this loss must also be a feature which should be considered where the market for power is being estimated. In considering the case of the municipal power plants of Moose Jaw, Regina, etc., this factor may be disregarded, as the present plants could be used as standbys in the event of interrupted service.

THE INFLUENCE OF THE LOAD AND DIVERSITY FACTOR ON THE COST OF GENERATION.

As the cost of production of energy is dependent upon the "load-factor," it is necessary therefore to explain what this term means. Assuming that 10,000 H.P. plant is installed and the average load during the year is only 33 per cent., the fixed charges and supervision will be the same, but the cost of coal and supplies and labour will be less than if the whole plant were utilised continuously, whereas if the load factor were, say, 100 per cent., practically the only extra cost would be that of additional labour, coal and other supplies.

The term "load factor" may thus be expressed as the ratio of the average to the maximum load.

At present in Regina the load factor of the municipal plant is about 30 per cent. and that in Moose Jaw about 17 per cent., exclusive of the street railway, which is operated by a private plant. A comparison of these two cities will show that the difference in the day load affects the cost of generation. Regina's cost of production is about 2.78 cents and Moose Jaw's cost is about 5.52 cents[1] per kilowatt hour. The more nearly the load factor approaches 100 per cent. the cheaper will become the unit cost of power. Although the coal consumption, which is the heaviest single item in the cost of running a power plant, will increase with the demand, the wages, capital charges, maintenance, etc., will remain practically the same.

The term "diversity factor" is also used in connection with the distribution of power.

It will doubtless be recognised that if a number of works of various kinds are established they will require power at different times and in varying quantities, but these are rarely taken simultaneously, so that the result will be that the average demands by a diversity of industries on a central power plant will not be equal to that of the combined requirements of all the users. It will be observed from this that these two factors have a great influence on the cost of generation.

The establishment of a central plant is conducive to the creation of a variety of large industries which will take power in bulk, and with a system covering a large territory, many varied industries are reached which combined tend to give a steady and uniform load throughout the entire day.

The following extract covering this question is taken from a lecture delivered by Dr. C. P. Steinmetz before the joint meeting of the Electrical Section of the Western Society of Engineers and the Chicago Section of the American Society of Electrical Engineers on October 28th, 1912.

"There is a marked tendency in generation towards the concentration of the supply of electrical energy for all uses for a large territory from one system. The large system has economical advantages over numerous small ones. One of its most conspicuous advantages is the possibility for utilisation of the diversity factor. The price of producing electrical energy depends to a large extent on the load factor. The station must be such as required by the maximum demand, but the income depends on the average demand. The load factors of most users of electrical energy are relatively poor. Even the factory operating continuously for eight hours creates a demand during only one-third of a twenty-four hour day. However, if a number of users of electrical energy are supplied from the same generating system a better average will result, owing to the diversity factor of the different loads. Therefore the more different uses there are for the energy the less will be the cost."[2]

As cheap power will form one of the best incentives to the establishment of industries, and as these will give rise to a much more steady demand than at present, it will be safe and conservative to assume that although the demand in Moose Jaw and Regina may not under existing

[1] Figures supplied for total cost 7.74 per kilowatt hour and an allowance on this of 3 per cent. for distribution charges has been made.
[2] Electrical World, November 2, 1912.

conditions come up to the estimated amount, a central plant affording a cheap supply will be able to dispose of at least 26,000,000 kilowatt hours in 1915.

TRANSMISSION.

The cost of electricity is also dependent upon the distance over which it is conveyed and upon the quantity transmitted. As it is only feasible to economically transmit electrical energy over long distances in large quantities, trunk lines of ample capacity for future demands must be erected at the outset, or provision made in the scheme to meet the increasing market. So it will follow that the cost of transmission will be in some proportion to the length of lines and the quantity of energy transmitted. These with the incidental losses which take place will, if regard is paid to the keeping of the cost of energy at a minimum, have the effect of limiting the range of supply, and eventually a point will be reached where it will be difficult to compete with the local supply.

Another item which must be given consideration is the question of reliability, and while in transmission over long distances this must be affected to some extent, the use of duplicate lines will usually obviate it. Authorities differ as to the best method of line construction and while the double circuit steel tower is advocated by some engineers, many prefer the duplication of the single circuit wooden pole, but on a separate right of way and of such distance apart as to insure of the safety on one of the power lines in case of damage to the other.

In the following estimate the carrying capacity of the power wire has been calculated so as to be ample to carry up to 20,000 H.P. While this item of cost might be lowered if a smaller sized wire were installed at the outset, the additional expenditure which must necessarily be incurred in a very few years in order to meet the increasing market would more than offset any saving in capital investment at the beginning.

The line pressure might be reduced to some extent, and by requiring the transformers to be equipped with taps for different voltages, this could be regulated as required, but for the purposes of estimation it has been deemed advisable to base the cost on that of the higher priced equipment, as it will cover all conditions which might arise in actual construction.

While only two classes of line supports have been considered in the following estimates, it may be well to consider the advantages of the different types now in use.

The upkeep of wooden poles is extremely small if they are properly treated by some preservative process and set in concrete. They will then last for an average period of twenty years. Wooden pole "A" frame power lines for a line pressure of 100,000 volts have been recently introduced in Colorado, the cross areas being constructed of steel. From actual tests this form of construction is about 4.5 times as strong as the single pole, and the limiting span appears to be in the region of 500 feet. With wooden poles, should an insulator break and the conductor fall on a cross arm, some time would probably elapse before the line is completely interrupted, whereas with steel towers the line would immediately become grounded.

Steel towers, while more expensive as a rule, require practically no attention if galvanised; otherwise they will require painting every three or four years to be kept in condition. For spans over 700 feet they are practically the only kind that are permissable.

Two classes of towers are generally in use: the stationary and flexible types. At the Winnipeg municipal hydro-electric plant both kinds are used; a flexible tower is placed between two of the heavier types with the object of lowering the initial expenditure.

Ferr-concrete poles have also been brought into use especially for city distribution lines, but very little has been done in adopting this type for high tension transmission systems. The principal objection to this type of pole so far has been the weight. The solid concrete pole is of about three times the weight of a wooden pole and a hollow concrete about twice the weight. Very often unsightly cracks appear after the pole has been in use for a short time.

The choice of the class of pole or tower will depend upon the relative cost, the weight of line and the length of span to be adopted.

DISTRIBUTION EN ROUTE.

In the distribution of power along the transmission lines there are several points which must be borne in mind, such as quantity of energy taken by each town and village, distance between adjacent towns, cost of substations, line losses and supervision.

In this report estimates have been prepared for the work entailed in tapping the lines for the supply of each town, with substations, etc., but when the scheme is gone into more fully it may be found that a central distributing station on the line may prove to be the more economical.

Again, it may be found that when each town has formed an estimate of its requirements a heavier transmission line with a lower line pressure but involving greater initial expense will be the most advantageous, and by this method no interswitching would be necessary.

There are two points which will require full consideration at the time the transmission lines are being finally designed; meanwhile the present scheme will include high tension (110,000 volts) transmission lines on steel towers, and substations at each point where power is required.

USES OF ELECTRICAL POWER.

The principal aim of any authority undertaking such a scheme as is herein described and estimated will no doubt be that of providing cheap power for industrial use. At present the only industry of importance is that of flour mills, which call for constant power, and therefore these will be valuable customers. There are other works which could with advantage be introduced, such as flax seed oil crushing, flax works, paint manufacturers, textile and other factories, large elevators, mining, briquetting, clay products, electro-chemical process, etc., and in connection with the manufacture of agricultural machinery, of which the whole is now imported. If mixed farming could be introduced then creameries, abattoirs, cold storage, tanneries, and other industries would follow. Moreover, cheap electrical power will be conducive to the construction of inter-urban railways, and could also be employed for pumping water and sewage.

The most common method in which electricity is employed by manufacturers in this province at the present time is in t[illegible] drive for mills, etc., and it may be well to point out that in factories where steam power has been transmitted by one system of shafting, belts, etc., motors may be installed on each floor of the building or even on each machine with but little loss in efficiency, and only such motors as are required to drive the machinery in use from time to time need be operated. In many cases, due to this the total energy consumption has been reduced from 25 per cent. to 50 per cent. below that which was required using a local steam plant.

To complete the information regarding the cost to the consumer the table following is given showing the cost of induction motor service per H.P. hour per annum. This was taken, with a few minor changes, from the annual report of the Hydro-Electric Power Commission of Ontario, and while applying to conditions in that province may be accepted as approximately accurate for Saskatchewan. By combine the cost of power to the municipalities with this and allowing for a city distribution charge in Moose Jaw and Regina of, say, 3 cents per kilowatt hour, the total charge to the consumer will be obtained.

ESTIMATED CAPITAL COST AND ANNUAL CHARGES OF MOTOR INSTALLATIONS. POLYPHASE—60 CYCLE—INDUCTION MOTORS.

Capacity H.P.	Capital cost per H.P. installed	Interest 5 %	Depreciation and Repairs	Oil, Care Operation	Total per H.P. per annum
5	$39 00	$1 95	$2 35	$4 00	$8 30
10	36 00	1 80	2 15	3 00	6 95
15	30 00	1 50	1 80	2 50	5 80
25	25 00	1 25	1 50	2 00	4 75
35	22 00	1 10	1 30	1 75	4 15
50	20 00	1 00	1 20	1 50	3 70
75	19 00	95	1 15	1 25	3 35
100	17 00	85	1 00	1 00	2 85
150	15 00	75	90	80	2 55
200	14 00	70	85	70	2 25

For the kilowatt hour basis, it must be remembered that the motor is rated on its output and the charge for electricity is made on the input. Taking, for example, a machine shop operating 54 hours per week and 31 per cent. of full time, the average annual load factor for the plant would be approximately 10 per cent. An average efficiency for motors from 5 to 50 H.P. may be taken at 85 per cent. Assuming the power required was 23 H.P., this would be equal in electrical units, input to 22 kilowatts. The load factor of 10 per cent is due to both intermittent and varying load, but it introduces no error to assume, for the purpose of this calculation, that the plant is worked at full load for very short hours. The whole percentage is, therefore, taken off the hours per year which gives 876 hours. 876 times 22 kilowatts equals 19,300 kilowatt hours per year. Assuming the city were supplied with power at 1.2 cents per kilowatt hour and the city distribution charge were 3 cents this would make the total charge to the consumer 1.5 cents per kilowatt hour.

19,300 Kw.H. at 1.5 cents equals	$289.50
Capital and operating charges on a 25 H.P. motor equals 25 times $4.75...... ..	113.75
Total annual cost...	$408.25

Electric cook stoves and household utensils have also been improved upon, and this furnishes many smaller cities an excellent method of reducing the unit cost of energy by bringing up the average load of the plant. In comparing the cost of electric and gas cooking, with which most of us are more or less familar, it has been stated by an eminent engineer that electricity at a price not exceeding 4.5 cents per kilowatt hour is cheaper than coal gas at 75 cents per thousand cubic feet.

Only recently the Hydro-Electric Commission of Ontario has in outline a scheme to distribute power throughout the farming districts of that part of the province through or near which their system is extended, in order that the benefits of electrical energy may be enjoyed by the farmer. This may also be said to be the case in the United States, when only a few months ago a bill was introduced before the Congress to establish a bureau to investigate and report on all matters pertaining to methods for furnishing power on farms, and the employment of electricity and so forth in propelling farm vehicles and in operating all kinds of agricultural implements.

SIZES, TYPES AND COST OF CENTRAL PLANT.

In this report four types of central plant are dealt with: the steam boiler and turbine, gas producer and engines, the combination of steam turbine and gas engine, and lignite gas engines, all directly connected to alternators.

In considering the steam turbine plant it has been assumed that a boiler and furnace (of the dutch oven or semi-producer type, properly designed) will show an evaporation of about 5 pounds of water and, from the results of the test made at the municipal plants of Estevan and Weyburn, this is a reasonable result to expect. From a number of tests made on steam turbines the average steam requirements run from 16 to 20 pounds per kilowatt hour, including extra pumps, banking fires, etc., the average coal requirement has been taken at six pounds per kilowatt hour.

With the producer and gas engine plant the consumption based on the guarantees of several firms manufacturing this class of equipment, and also on the results from other places using similar coal, making allowance for all purposes, will run approximately to 4 pounds per kilowatt hour.

With regard to the governing of gas engines this should correspond to steam engine practice, say 3 per cent. from no load to full load and the variation in annular velocity per cycle or revolution should not be greater than a displacement from true uniform rotation of $2\frac{1}{2}$ electrical degrees, or in case of a 60 cycle 150 R.P.M. generator of approximately .01 of a mechanical degree. In the estimates on producer plant no allowance has been made in the cost of operation of the central station for the possible recovery and sale of the by-products such as tar and sulphate of ammonia, as no data was available on the results obtained from the use of this grade of coal.

SUMMARISED ESTIMATED COST OF DIFFERENT TYPES OF CENTRAL STATION EQUIPMENT.

Steam turbine.		
Turbines and electrical equipment	$337,500.00	
Boilers complete	225,000.00	
Power house and foundations	100,000.00	
Water supply and reservoir	25,000.00	
Employees' houses, teams, etc.	15,000.00	
Engineering and contingencies	70,000.00	
		$772,500.00
Producer gas.		
Producers	$150,000.00	
Gas engines	450,000.00	
Alternators and electrical equipment	160,000.00	
Buildings and foundations	102,000.00	
Water supply and reservoir	25,000.00	
Employees' houses, etc.	15,000.00	
Engineering, etc.	90,000.00	
		$992,000.00
Producer and steam.		
Turbines and electrical equipment	$202,500.00	
Boilers complete	97,500.00	
Producers	135,000.00	
Gas engines and electrical equipment	244,000.00	
Building and foundations	90,000.00	
Water supply and reservoir	25,000.00	
Employees' houses, etc.	15,000.00	
Engineering, etc.	60,000.00	
		$889,000.00
*Gas engines supplied with gas from separate plant.		
Gas engines	$400,000.00	
Electrical equipment	160,000.00	
Building and foundations	78,000.00	
Water supply and reservoir	20,000.00	
Employees' houses, etc.	15,000.00	
Engineering, etc.	70,000.00	
		$743,000.00

* For estimates on Gas Plant see general report.

LOCATION OF PLANT.

Three schemes have been outlined for the distribution of power as shown on the accompanying maps; under the first, the energy as distributed from the Estevan fields to Moose Jaw and Regina; in the second, as distributed from two centres, the Estevan fields and the Dirt Hills; and in the third, as distributed from the Brock fields to Saskatoon and Battleford. By adopting schemes similar to those outlined in schemes two and three, separate plants could eventually be interconnected.

To show the advisability of such interconnection many cases could be cited, for instance, that of the Utah Light and Railway Company, where six systems were in this way brought together.[1]

[1] "Electrical World," August 3, 1912.

Such interconnections between contiguous systems offer decided and important eng'neering advantage.

(1) It improves the constancy of electrical pressure.

(2) It enables the system to draw power from two or more independent power plants.

(3) It permits reduction in operating expenses by rendering repairs easier owing to greater facilities for shutting down for work or inspection.

(4) It assures better service by reducing to a minimum the probability of total interruptions at any time from line troubles or otherwise.

(5) The investment and consequently the cost of power can be reduced by combination, because less capacity in generating equipment to serve as spare plant for emergencies need be installed.

The present tendency in the generation of electrical energy is to concentrate in larger system units. The districts, which are being served, are gradually increasing in size and while the larger cities have the advantage in that they have, as a nucleus, their own large demand, ultimately village and small city generating plants must be replaced by the substations of the large systems.

Modern types of machinery will thus depose the old, and as engines, boilers, etc., are constantly being improved in efficiency, the cost of generation will be continually lowered.

TRANSMISSION LINES.

As no survey has been made of the route to be followed, it has been assumed that the transmission lines under the first plan will be 162 miles in length, with an initial maximum line pressure of 110,000 volts, stopped down at the interswitching station to 45,000 volts for distribution. In the second plan 84 miles in length, with a maximum line pressure of about 45,000 volts. While changes in these lines may be found advantageous in actual design, the results based on these figures will doubtless suffice for the present. Two sets of figures have been worked out for the power lines; the first, for a double circuit steel tower construction with two circuits installed at $4,600.00 per mile; and the second, for a lower tension (45,000 volts line pressure) single circuit wooden pole line at $2,400.00 per mile.

On account of the longer life the use of steel construction throughout is to be advised, and also as the first cost between single and double circuit steel towers only varies from 10 to 15 per cent., the former have not been considered in the estimate.

the question of the first cost is to be considered between these last two types it would seem more advisable to construct a double circuit tower line and run thereon at first a single circuit of such capacity, as will carry the immediate needs; then follow this as the market extends, with a future line upon the other side, of the same, or of a greater capacity, than the first, after which the original line could be replaced with a second heavy capacity line.

SUMMARISED ESTIMATED COST OF TRANSMISSION LINES.

Assuming for an average right of way of 66 feet double circuit steel towers, two circuits installed.

Right of way........	$400.00
Steel towers erected........................	1,700.00

Insulator and clamps	$500.00	
Power wire erected	1,100.00	
Ground wires erected	250.00	
Telephone wires erected	250.00	
Engineering and incidentals	400.00	
Total per mile		$4,600.00

Wooden pole line single circuit.

Right of way	$ 400.00	
Poles erected	450.00	
Cross arms and braces	175.00	
Power wire erected	550.00	
Insulators and pins	225.00	
Ground wire and plates	150.00	
Telephone wires erected	250.00	
Engineering and incidentals	200.00	
Total per mile		$2,400.00

SUMMARISED ESTIMATED COST OF INTERSWITCHING AND RECEIVING STATIONS.

Interswitching and transforming station, 7,500 kilowatts.

6 transformers with circuit breakers, lightning arresters, switchboards, cables, etc. installed	$100,000.00	
Building	20,000.00	
Engineering and incidentals	12,000.00	
		$1,132,000.00

Regina receiving station, 4,200 kilowatts.

3 transformers complete with all electrical equipment installed	$29,700.00	
Building	12,000.00	
Engineering, etc.	4,200.00	
		$45,900.00

Moose Jaw receiving station 3,600 kilowatts.

3 transformers complete with all electrical equipment installed	$26,200.00	
Building	10,000.00	
Engineering, etc.	3,600.00	
		$39,800.00

ESTIMATED CENTRAL STATION ANNUAL CHARGES, PLAN NO. 1.

Steam Turbine.

Coal, 87,750 tons at $1.50	$131,625.00	
Labour and management	31,700.00	
Maintenance and supplies	30,000.00	
Interest, depreciation and taxes, 10%	77,250.00	
Total per year		$270,575.00

Producer Gas.		
Coal, 58,500 tons	$87,750.00	
Labour and management	35,300.00	
Maintenance and supplies	40,000.00	
Interest, depreciation and taxes	99,200.00	
Total per year		$262,250.00
Producer and Steam.		
Coal, 58,500 tons	$87,750.00	
Labour and management	35,300.00	
Maintenance and supplies	35,000.00	
Interest, depreciation and taxes	88,900.00	
Total per year		$246,950.00
Gas Engines.		
Gas, at 48 cents per M. cubic feet	$494,400.00	
Labour and management	27,200.00	
Maintenance and supplies	30,000.00	
Interest, depreciation and taxes	74,300.00	
Total per year		$625,900.00

ESTIMATED INTERSWITCHING AND LINE ANNUAL CHARGES, PLAN NO. 1

Investment.		
110 miles power line at $4.200.00	$462,000.00	
Station	132,000.00	
Right of way	44,000.00	
		$638,000.00
Maintenance and supplies	$12,000.00	
Operation.		
Station	5,000.00	
Patrol	6,000.00	
Interest, depreciation and taxes.		
Line and station	59,400.00	
Right of way	3,080.00	
		$85,480.00

PLAN NO. 1, ESTIMATED ANNUAL CHARGES RECEIVING STATIONS.

REGINA.

Investment.		
22 miles power line at $2,200	$44,000.00	
Station complete	45,900.00	
Right of way	8,800.00	
		$98,700.00

Maintenance and supplies	$3,500.00	
Operation.		
Line	1,000.00	
Station	3 000.00	
Interest, depreciation and taxes.		
Line and station	8,990.00	
Right of way	610.00	
Total		$17,100.00

MOOSE JAW.

Investment.		
30 Miles power line	$60,000.00	
Station	39,800.00	
Right of way	12,000.00	
Total		$111,800.00

Maintenance and supplies	$4,000.00	
Operation.		
Line	1,000.00	
Station	3,000.00	
Interest, depreciation and taxes.		
Line and station	9,980.00	
Right of way	840.00	
Total		$18,820.00

SUMMARY OF ESTEVAN LINE—PLAN NO. 1.

Capital Expenditure.

Steam Turbine.		
Cost of power plant	$772,500.00	
H. I. Double transmission line and inter-switching station	638,000.00	
Regina substation and low tension distributing line	98,700.00	
Moose Jaw substation and low tension distributing line	111,800.00	
Total		$1,621,000.00

Annual Charge.

Steam Turbine.		
At power house	$270,575.00	
Interswitching	85,480.00	
Regina substation	17,100.00	
Moose Jaw substation	18,820.00	
Total		$391,975.00

Dividing the annual charge by 26,000,000 kilowatts gives 1.51 cents per Kw.H.

SUMMARY OF ESTEVAN LINE—PLAN NO. 2.

Capital Expenditure.

Producer Gas.		
At Power house	$992,000.00	
Lines, substation, etc., same as above	848,500.00	
Total		$1,840,500.00

Annual Charge.

Producer Gas.		
At power house	$262,250.00	
Other charges as above	121,400.00	
Total		$383,650.00

Dividing as above 1.47 cents per Kw.H.

SUMMARY OF ESTEVAN LINE—PLAN NO. 1.

Capital Expenditure.

Producer and Steam.		
Power plant	$889,000.00	
Line, substation, etc., same as above	848,500.00	
Total		$1,737,500.00

Annual Charge.

Producer and Steam.		
At power house	$246,950.00	
Other charges as above	121,400.00	
Total		$368,350.00

Dividing as above, 1.417 cents per Kw.H.

Capital Expenditure.

Gas Engines.		
Power plant	$743,000.00	
Lines, substation, etc., same as above	848,500.00	
Total		$1,591,500.00

Annual Charge.

Gas Engines.		
At power house	$625,900.00	
Other charges as above	121,400.00	
Total		$747,300.00

Dividing as before, 2.874 cents per Kw.H.

SUMMARY OF ROULEAU LINE—PLAN NO. 2.

Following the methods outlined under Plan 1, the following is a summary of the cost of power delivered to Moose Jaw and Regina.

Capital Expenditure.

Steam Turbines		
Cost of power plant	$772,500.00	
Transmission line	201,600.00	
Regina substation	45,900.00	
Moose Jaw substation	39,800.00	
Total		$1,059,800.00

Annual Charge.

Steam Turbines.		
*At power house	$ 262,000.00	
Regina substation and line	25 500.00	
Moose Jaw substation and line	20 200.00	
Total		$307,700.00

Dividing by 26,000,000 kilowatts gives 1.18 cents per Kw.H.

Capital Expenditure.

Producer Gas.		
Cost of power plant	$992,000.00	
Line, substation, etc	287,300.00	
Total		$1,279,300.00

Annual Charge

Producer Gas.		
*At power house	$247 300.00	
Other charges	45,700.00	
Total		$293,000.00

Giving 1.13 cents per Kw.H.

Capital Expenditure.

Producer and steam.		
Cost of power plant	$889,000.00	
Line, substation, etc	246,500.00	
Total		$1,135,500.00

Annual Charges.

*At power plant	$229,000.00	
Other charges	45,700.00	
Total		$274,700.00

Giving 1.06 cents per Kw.H.

* As the average losses in transformation and line are less and consequently the coal item is less, the cost of generation at the power plant is reduced to these figures.

SUMMARY OF RATES TO TOWNS ALONG THE RIGHT OF WAY.

The following are the approximate prices at which power could be delivered to the various towns along the right of way:

	Plan 1.		Plan 2
Weyburn	.5 cents per kilowatt hour	*	
Estevan	6 " " " "	*	
Rouleau	10 " " " "		10 cents
Drinkwater	15 " " " "		22 cents
Yellow Grass	11 " " " "	*	
Milestone	16 " " " "	*	

* Supplied by plant 3 or interconnecting line.

ESTEVAN LOCAL SCHEME UNDER PLAN 3.

It will have been observed that a long transmission line for the neighbourhood of Estevan to Regina and Moose Jaw causes the price per kilowatt of electricity to be higher than, say, if supplied for the Dirt Hills. There is, however, the question of supplying electrical power to the Estevan, Weyburn and Arcola districts, but a separate and independent power station or these districts will involve a considerable outlay, without the prospects of commensurate returns. But it is quite possible for one of the larger mining companies to install the necessary power plant to use the energy in the day time for mining and other purposes, and at night for transmission. In such an installation the colliery company could use the waste slack. Assuming that such a proposition was taken up, then the probable consumption of electricity will be as follows:

Estevan	120,000	kilowatt horse power per hour
Weyburn	150,000	" " " " "
Arcola	30,000	" " " " "
Stoughton	15,000	" " " " "
Carlyle	15,000	" " " " "
Total	330,000	

The cost of wooden pole transmission will be about $440,000 and with substations at Estevan, Weyburn, Stoughton, Arcola and Carlyle of 300 300, 100, 100 and 100 kilowatt capac ty will make a g and tota expenditure for l ne construction of approximately $480,000.' 0

SASKATOON AND BATTLEFORD.
PLAN 4.

Requirements of Saskatchewan in Respect to Power.
North-West Part.

The towns in the part of the province having a population of 300 and over (according to the census of June, 1911) are Saskatoon, 18,100; North Battleford, 2,100; Battleford, 1,330; Biggar, 320; Kindersley, 460; Langham, 390; Lloydminster, 660; Macklin, 330; Radisson, 300; Rosetown, 350; Scott, 420; Wilkie, 540. The nearest known local coal supply is at Brock, about 100 miles southwest of Saskatoon and 90 miles from Battleford.

This will entail a transmission line to Biggar, 55 miles and then to Battleford, 60 miles in the north west, and Saskatoon 60 miles to the East, making a total length of 175 miles. The communities which would economically be served by such lines would be Saskatoon, Battleford and Biggar having a total population of about 22,000 and a line might be extended to Langham, Rosetown, Scott and Wilkie adding another 2,000. These towns have of course grown since the data of the census taking and the total number of inhabitants may now be about 40,000.

The growth and power consumption on the same ratio as that of Moose Jaw and Regina the results will be as follows:

	Saskatoon	Battleford and North Battleford
1912	24,000	4,400
1913	31,000	5,700
1914	42,300	7,400
1915	65,000	9,600

Power Consumption.

	Saskatoon	Battleford and North Battleford
1912	1,700,000 kilowatt hours	250,000 kilowatt hours
1913	2,550,000 " "	380,000 " "
1914	3,800,000 " "	570,000 " "
1915	5,700,000 " "	860,000 " "

Following the methods as before laid out the cost of energy to these three cities would be approximately 2.6 cents per kilowatt hour. This as may be seen, does not compare with the cheap power offered by a hydro-electric scheme and until coal is found in sufficient quantities nearer these sources of supply it would not seem advisable to go into this in further detail.

APPROXIMATE RATE PER HORSE POWER.

The question will doubtless be asked, what will be the cost per H.P.?

It will be understood that if 26,000,000 kilowatts are consumed and the load factor is 40 per cent, the cheapest flat rate per kilowatt delivered in bulk to Moose Jaw and Regina from Estevan will be 1.44 cents for all purposes. But the ob ect of a central plant as has been already pointed out is to induce the establishment of industries, for which purpose the rate must be cheaper. Therefore to obtain the result the cost of electricity must be made differential in character and those purposes, for which electricity is used during comparatively few hours a day must be charged more whilst those which take current during the day time should be supplied at a lower rate.

In the absence of statistics as to the quantity of electricity used for various purposes the following table has been prepared:

Consumption equal to percentage of whole output.	Purpose for which electricity is used.
30	Domestic lighting.
20	Town lighting.
25	Small power up to 50 H.P.
15	Power 50 to 200 H.P.
10	Power 200 H.P. upwards.

It is computed that the rate for the above purposes based on the flat rate of 1.41 will be as follows:

Domestic lighting . . .	1.70 cents
Town lighting	1.70 cents
Small motors	1.70 cents
50 to 200 H.P. motors	0.90 cents
200 H.P. motors and upwards	0.65 cents

Basing prices on the above for 300 working days per year, the following are approximate rates which would apply:

Motors up to 50 H.P. could be sold energy at $91.00 per H.P. per annum.
Motors up to 200 H.P. could be sold energy at $49.00 per H.P. per annum.
Motors up to 500 H.P. could be sold energy at $36.00 per H.P. per annum.

Adapting the same method of basing the differential rating on the Dirt Hill scheme with a flat rate 1.06 cents per kilowatt hour. Then

Domestic lighting charge will be. .	1.30 cents
Town lighting. . . .	1.30 cents
Small motors.	1.30 cents
50 to 200 H.P. motors . .	0.70 cents
200 H.P. motor and upwards	0.50 cents

Basing the rates as before, the following approximate schedule would apply:

Motors up to 50 H.P.	$70.00 per H.P. per annum.
Motors up to 200 H.P.	$38.00 per H.P. per annum.
Motors up to 500 H.P.	$27.00 per H.P. per annum.

The foregoing estimated costs do not include distribution within the cities, as the electricity will in these schemes be delivered in bulk at a substation outside the city limits.

If the total consumption and load factor are less than 26,000,000 kilowatts per annum and 40 per cent. respectively the foregoing estimate will require revising.

SUMMARY.

Summarising the foregoing statistics the following results are obtained:

1. The present cost of electric current at the switchboard is, in Regina 2.78 cents per kilowatt hour and in Moose Jaw 5.52 cents per kilowatt hour.

2. The estimated cost of electric current supplied from Estevan will be:

Steam turbine plant	1.51 cents per Kw. H.
Producer gas	1.47 cents per Kw. H.
Combined steam and producer plant . . .	1.41 cents per Kw. H.
And from Dirt Hills	
Steam turbine plant	1.18 cents per Kw. H.
Producer gas	1.13 cents per Kw. H.
Combined steam and producer plant	1.06 cents per Kw. H.

3. The Saskatoon-Battleford scheme will afford a supply of electricity at a cost of about 2.6 cents per kilowatt hour delivered at substations outside these cities.

4. The cost of electricity delivered at towns between Estevan and Rouleau are given in the report.

5. The foregoing data may have to be revised when the schemes are being finally developed.

6. It is assumed that the power scheme will be undertaken by a commission and that no profit is made, otherwise the rate must be increased to provide for profit.

7. Having regard to what has been previously stated, it will almost be unnecessary to add that it is practicable to generate power at the collieries and that a cheaper electrical power will result.

LIGNITE GAS PLANT ESTIMATE.

Preliminary estimates have been prepared for a complete lignite gas plant capable of supplying 800,000,000 cubic feet per annum or a maximum of 5 million cubic feet per day. These works will consist of vertical retorts, coal and coke handling machinery, usual type of condensers, scrubbers and washers, station meter and gas holder. The coal will be delivered into elevators and stored in bunkers with arrangements for utilising the waste heat for drying coal. The coke will be converted into briquettes and stored in bins. If the gas is to be purified, then purifiers will be required and this is tentatively included.

As, of course, no plans have been prepared and the works must be adapted to suit local lignite instead of ordinary gas coal, there are many points which will require full consideration when the scheme is designed, meantime the estimates which are believed to be ample must necessarily be considered as preliminary and provisional.

As under ordinary pressure the gas mains would be excessive in size and cost, it will be necessary to compress the gas to say 100 pounds per square inch at the works and allow the pressure to drop to say 10 pounds at the precincts of Regina and Moose Jaw. It is to be understood that in this scheme as in all others, the city authorities will take the gas in bulk and distribute the same throughout the town.

The cost of such a gas works is estimated as follows:

Works at $450 per 1,000 cubic feet per day..	$2,250,000
Holder at $120 per 1,000 cubic feet capacity..	300,000
Cottages, etc.	50,000
Coal and coke handling plant, say	100,000
	$2,700,000
10 per cent. contingencies, etc.	270,000
	$2,970,000
	Say $3,000,000

The cost of briquetting plant capable of dealing with 45,000 tons of lignite coke per annum is placed at say $100,000.

To compress the gas to 100 pounds per square inch it will be necessary to install two engines and compressors costing:

2, 300 Horse Power gas engines	$24,000
2 Compressors	10,000
Buildings, etc.	2,000
	$36,000
10 per cent. contingencies, etc.	3,600
	$39,600 say $40,000

If the gas works are located at or near Estevan it will be necessary to lay 12 inches steel main for say 115 miles to Rouleau and 10 inch main to Moose Jaw and Regina, about 32 and 24 miles respectively, the cost of which will amount to:

Approximately	$2,305,000	
Allowing 10 per cent. contingencies	230,000	
	$2,535,000	
		Say $2,500,000

The annual working expenses will amount to:

100,000 tons lignite at $1.50	$150,000	
Manufacturing, etc., 800,000,000 cubic feet at 20 cents per thousand	160,000	
Capital charges at 6 per cent.	180,000	
	$490,000	
Cost of briquetting coke	100,000	
	$590,000	
Less sale of 45,000 tons briquettes at $4.00 per ton	180,000	
		$410,000

No deduction is made for sale of tar and sulphate of ammonia.

The cost of compressing the gas will roughly be about $40,000 per annum; this includes labour, fuel, repairs, maintenance, interest and depreciation.

The annual cost of gas main will be 6 per cent on capital of $2,500,000	$150 000	
Patrol, repairs, etc., say	10,000	
		$160,000

The loss on this line under 100 pounds pressure will be at least 6 per cent., so 800,000,000 cubic feet pumped into the main of the works will be reduced to about 750,000,000 at the towns.

The total cost will therefore be:

Operating works	$410,000	
Compression	40,000	
Pipe line	160,000	
		$610,000

Dividing this by 750,000,000 cubic feet per annum will give the cost of this gas delivered at the terminals at 81 cents per 1,000 cubic feet.

If the gas was compressed to 200 pounds per square inch at the works, the cost of the compressors and working the same will have to be increased, the pipe line cost would be considerably less, but the loss by leakage would be more, and the net result is that the cost of the gas delivered at the terminal will be practically the same as above.

It will doubtless be recognised that the cost of about 170 miles of gas mains must be in some proportion to their aggregate length, and if a location can be found to reduce the same, the gas can be delivered at a cheaper rate.

Let it be assumed that the gas works would be located in the Dirt Hills, the cost of manufacturing process and compression would be the same, but the mains would be shorter and the leakage somewhat less.

The mains in such a case would be 10 inch diameter to Briercrest and 8 inch from there to Moose Jaw and Regina, and these would cost about $670,000, the annual charge on which would be:

6 per cent. on $670,000	$40,200	
Patrol, etc..	9,800	
		$50,000

The loss may be assumed to be the same as from Estevan, although this is an excessive estimate, so the total cost will be:

Operating works.	$410,000	
Compression..	40,000	
Pipe line..	50,000	
		$500,000

Or 66 cents per 1,000 cubic feet delivered.

The above figures are given for the purpose of comparing the cost of power on similar basis as electricity, namely, 10,000 H.P. plant.

It has, however, already been pointed out that the immediate demands for gas supply will not exceed 450,000,000 cubic feet per annum, which will mean the erection of a lignite gas plant capable of supplying a maximum of 2,500,000 cubic feet per day. The estimated cost of such a plant will now be given.

The cost of installing the works at the Dirt Hills will be about $1,750,000 and the cost of operation:

50,000 tons of lignite at $1.50....	$75,000	
Manufacturing cost.....	80,000	
Capital charge at 6 per cent......	105,000	
	$260,000	
Cost of briquetting.....	50 000	
		$310,000
Less sale of briquettes at $4 per ton...... ..		90,000
		$220,000

The annual cost of compressing the gas to 100 pounds pressure will in this case amount to about $25,000.

The pipe lines will cost about $520,000.

So the annual charge at 6 per cent. will be....	$31,200	
Patrol, repairs, etc...	9,800	
		$41,000

The works will produce 450,000,000 cubic feet per annum but as the loss by leakage on the lines will be about 30,000,000, there will be about 420,000,000 cubic feet delivered at the outskirts of the towns.

The total annual cost will approximately be:

Operating works......	$220,000	
Compression works....	25,000	
Pipe line......	41,000	
		$286,000

Dividing this by 420,000 gives the cost of gas at about 68 cents per 1,000 cubic feet delivered.

If the pressure was increased to 200 pounds the cost of gas would be a little less.

If the works are erected at Estevan, the pipe line would have to be increased in the dimensions and cost, but in other respects the estimate of initial cost would remain the same.

Without overloading this part of the report with figures, it may be stated that the annual cost for an Estevan gas works scheme would be as follows:

Operating works	$220,000	
Compression	25,000	
Pipe line	114,000	
		$359,000

Assuming for the purpose of comparison that the loss on this line would be the same as from the Dirt Hills, then $359,000 divided by 420,000 will give about 80 cents as the cost of gas delivered at terminal stations.

The foregoing estimates are necessarily approximate, as without plans, details and specifications, it is obviously impossible to prepare estimates which are close, but it is firmly believed that the figures given can be improved upon when it is decided to carry the investigation a step further. At present the above statistics will afford a guide as to the probable expenditure that will be necessary to manufacture gas and deliver the same at the cities' precincts. Even allowing for the difference in the heat value of the gas as compared with ordinary coal gas it will be seen that by concentrating the work at one centre, artificial gas can be manufactured and supplied at a rate that is below that obtaining in most Canadian cities.

LIGNITE COKE OVEN GAS.

The great development of the recovery coke ovens in America and Europe has been the means of furnishing cheap gas to neighbouring towns and districts. In this case, it is the supply of metallurgic coke that constitutes the principal commodity sought for, whilst the sale of gas, tar and sulphate of ammonia bring in additional income.

In the case of lignite, however, coke will not be a saleable article until it is briquetted and this introduces a new item of working expenses. Nevertheless it is quite possible that even with this disability, gas can be manufactured more cheaply, but of a slightly lower grade than lignite gas.

As no experience has been gained in the carbonisation of lignite in coke ovens, it is not at present possible to obtain data as to cost, but by adopting figures relating to ordinary coal in this respect, the following rough estimations are obtainable.

To make 800,000,000 cubic feet per annum or 5,000,000 cubic feet per day as before, the capital expenditure would be about $1,000,000 for ovens and equipment $100,000 for briquetting plant and $40,000 for compression station making a total of $1,140,000.

Assuming the gas making plant will be located at Estevan, the pipeline will cost as before $2,500,000, and if at the Dirt Hills, as before, $670,000.

The operating cost will be:

100,000 tons lignite $1.50		$150,000	
Labour, steam s[illegible] etc.	$1.00 per ton	100,000	
Maintenance		25,000	
Interest at 6 per cent..........		60,000	
		$335,000	
Cost of briquetting ...		100,000	
		$435,000	
Sale of briquettes.....		180,000	
		$255,000	
Cost of compression.......		40,000	
			$295,000

The annual cost of Estevan pipe line will be $160,000, this added to above makes a grand annual total of $455,000 and the gas delivered in bulk will cost about 61 cents. The annual cost of Dirt Hills pipe line will be $50,000 so the grand total in that case will be $345,000 and the gas will cost, say, 46 cents delivered in bulk to cities.

With the second but smaller gas scheme the gas delivered tar bulk will cost about 50 cents from Dirt Hills.

The foregoing as already explained are rough indications of the probable cost, when experiments are made it will be possible to arrive at a closer estimate.

PRODUCER GAS INSTALLATION.

As already mentioned producer gas has an average heat value of about 125 B.T.U. per cubic foot. For the information of the general reader of this report it may be stated that B.T.U. is an abbreviation of the words "British Thermal Units," which is the quantity of heat required to raise the temperature of one pound of water at the temperature of its maximum density one degree Fahrenheit.

Producer gas can be used for most purposes to which coal gas is applicable, but a larger volume must be consumed to secure the same heating power.

The cost of a producer gas plant will be as follows:

10,000 H.P. Producers at $15 ...	$150,000	
Gas holder	300,000	
Buildings, etc., say........	75,000	
Pipes on works and other equipment, say.....	100,000	
	$625,000	
10 per cent. contingencies, etc...	65,000	
	$690,000	
		Say $700,000

Although the gas produced per ton of lignite by this means averages in the American tests about 72,000 cubic feet, and in the Montreal tests about 80,000 for the present purpose it is based at 60,000.

The operating expenses, etc., may be estimated as below:

10,000,000 cubic feet per day plant.

35,000 tons lignite at $1.50	$52,500	
Labour	22,500	
Management and incidentals	10,000	
Repairs	30,000	
Maintenance	50,000	
Interest at 6 per cent	42,000	
Depreciation on producers	15,000	
		$222,000

Compressing plant will cost about $90,000 and the working expenses, etc., about $50,000 per annum.

The mains say from Dirt Hills will cost approximately $1,250,000 and the annual charge thereon about $78,000.

The leakage will be assumed at the same percentage as before, namely 6 per cent., so out of the annual make of about 2,000,000,000 cubic feet 160,000,000 will be lost, making an available volume for distribution at the terminal of 1,840,000,000 cubic feet.

On the above basis the annual expenditure will be:

Operating works	$222,000	
Compressing station	50,000	
Pipe line	78,000	
		$350,000

Dividing this total by 1,840,000, the cost of the gas delivered at the terminals will be about 19 cents per 1000 cubic feet.

If this plant is erected at Estevan then the pipes must be larger and their cost is estimated at about $4,000,000 and the annual charge about $250,000. In other respects the cost will be identical with the preceding estimate, so on these approximate calculations the annual expenditure will be:

Operating works	$222,000	
Compressing station	50,000	
Pipe line	250,000	
		$522,000

This will be equal to a little less than 30 cents per 1,000 cubic feet. There is scarcely any doubt that the foregoing figures will exceed the final estimates which will be prepared, when the schemes are further gone into, and therefore it is to be clearly understood that in the absence of fuller data these calculations must be regarded as provisional.

If the Government decide to continue the investigations there will be time to revise all these calculations and the public will have estimates based on firm quotations, which hitherto, owing to limited time and details have not been available.

Apart from the Mond gas scheme at Dudley Port, England, no information has been received of the distribution of producer gas on a large scale. But there are some instances where poor coke oven gas has been utilised by laying more or less extensive system of pipe lines.

It is hoped that this report will satisfy your requirements and that information contained herein will indicate the potentialities of lignite in the development of power and that it will be conducive to its greater and more efficient use in this direction.

Having now submitted the information collated, it may be desirous to express my conclusions in a few concise paragraphs.

CONCLUSIONS.

1. The large quantities of workable lignite deposits in the Province of Saskatchewan can be utilised at the coal centres for the production of power and its distribution in parts of the province.

2. The generation of electrical power at such coal centres is both a practicable and commercial possibility, and its distribution at a low rate per kilowatt is feasible, if the larger municipal authorities wil co-operate by taking currents in bulk. It was the co-operation of the municipal authorities at the initial stage of the development that made the North East Coast Power System in England the huge success it is.

3. The manufacture of lignite gas at a gas works located on the coal fields is also a practicable and commercial possibility. The quality of this gas will not be equal to coal gas, but it can be supplied at a much lower price per 1,000 cubic feet if the larger municipal authorities will co-operate in taking the same in bulk. This gas will be useful for power and heating purposes and if it is required to be of a higher illuminating value, it can be easily enriched by the authorities at small expense.

4. The demand for power at the larger centres at present amounts to about 5,000 horse power, but it is advisable to make provision for an immediate instalment of at least 10,000 horse power plant, with arrangements for extension each year.

5. The present load factor at Regina is about 30 per cent. and Moose Jaw about 17 per cent., exclusive of street railway, but having regard to the probable effect of the introduction of cheap power, it is very possible that the load factor will be greater, especially if diversified industries are established. For the purpose of calculating the cost of plant and operating expenses a 40 per cent. load factor has been assumed. If after further consideration this is found to be too high, the estimates can be modified accordingly.

6. It is not possible by means of imported fuel consumed at individual power stations to produce as cheap electricity or gas supply as can be done in bulk at the coal centres and delivered same to the points of consumption.

7. With regard to the question of supplying power to the North West portion of the province, it may be desirable to ascertain the possibility of a hydro-electric scheme and compare the same with power obtainable from lignite This subject is not included in the instructions and therefore is not considered in this report.

8. It is desirable that further investigations should be made to ascertain the most satisfactory method of using lignite for generating power and manufacturing gas.

Mr. Wynne-Roberts in his report makes the following recommendations:

1. That further and more extended investigations be made with the view to promoting the use of lignite as fuel and thereby the development of the mining industry in Saskatchewan.

2. That an experimental plant be installed to study the behaviour of local lignites in gas producers and their individual capacity for producing power.

3. That an experimental plant be installed to ascertain the best method of producing lignite gas by dry distillation.

4. That experiments be made to find out the most satisfactory method of consuming lignite for domestic purposes.

5. That complete analysis be made of lignites found in this province.

6. That the lignite fields be explored to ascertain their areal extent, positions and values.

7. That well sinkers be asked to report the stratas through which they sink any wells over 30 feet deep, and especially to report finds of coal so as to enable the geological details being recorded for future reference.

8. That in view of the enormous use made of lignite in Germany and Austria investigations be made in those countries to ascertain to what extent the methods there adopted can be applied here.

9. That to encourage more efficient methods of consuming lignite and stimulate a healthy rivalry among operating engineers and therefore to obtain the most economical results, testing of power plants similar to those made by Mr. R. N. Blackburn, Wh. Sch., at Estevan and Weyburn be continued where suitable facilities are afforded. This will doubtless constitute a powerful incentive to the development of the use of lignite.

10. That investigations and experiments be made to discover if possible a process by which satisfactory briquettes can be made of raw lignite and lignite coke.

11. That the railway companies be asked to give preferential rates for local lignite as is done in T[illegible]

12. That government inst[illegible]se lignite where found economical.

13. That experiments be [illegible] connection with the burning of clay products with a view to encouraging the introduction of industries for the manufacture of clay products which now have to be imported from great distances for buildings, etc.

ACKNOWLEDGMENTS.

In the course of the investigation covered by this report it was found necessary to seek for information in many quarters, both in America, Europe and elsewhere; to one and all my thanks are due for the assistance rendered.

I have also to acknowledge the services rendered in this connection by Mr. C. C. Cronk, Electrical Engineer, Mr. R. N. Blackburn, Wh. Sch., the Provincial Chief Boiler Inspector, and to Mr. L. W. Wynne-Roberts, B. Sc., (Eng.) (London.)

And in conclusion I have to tender my thanks to you for the confidence you reposed in me in this direction, in which I trust I have acquitted myself to your satisfaction.

Respectfully submitted,

(Signed) R. O. WYNNE-ROBERTS,

Member of the Institution of Civil Engineers.

HEAT BALANCE DIAGRAM – WEYBURN.

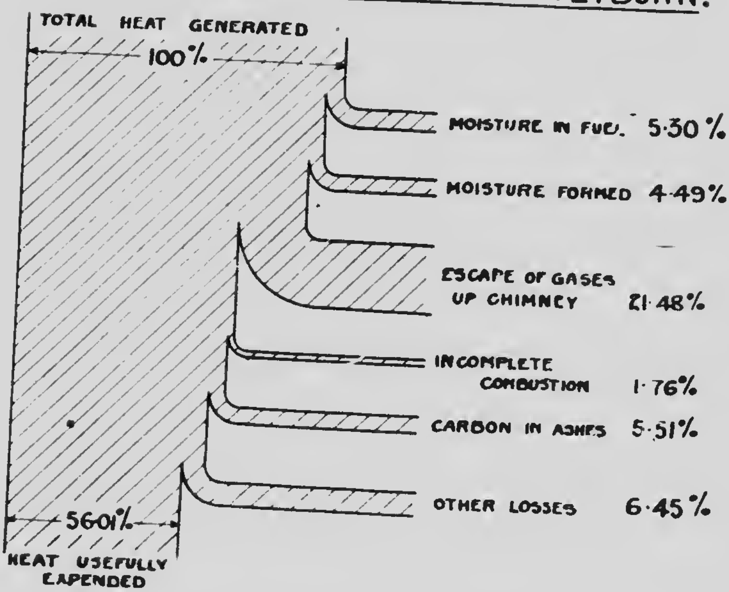


PLATE. I.

HEAT BALANCE DIAGRAM
OF A FIRST CLASS STEAM PLANT.

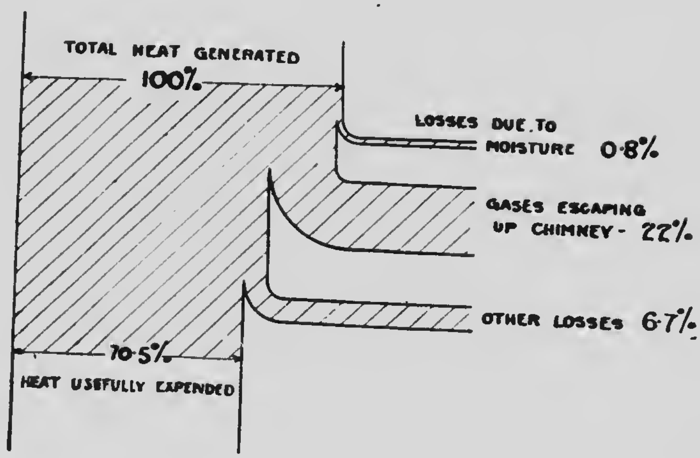


PLATE. 2.

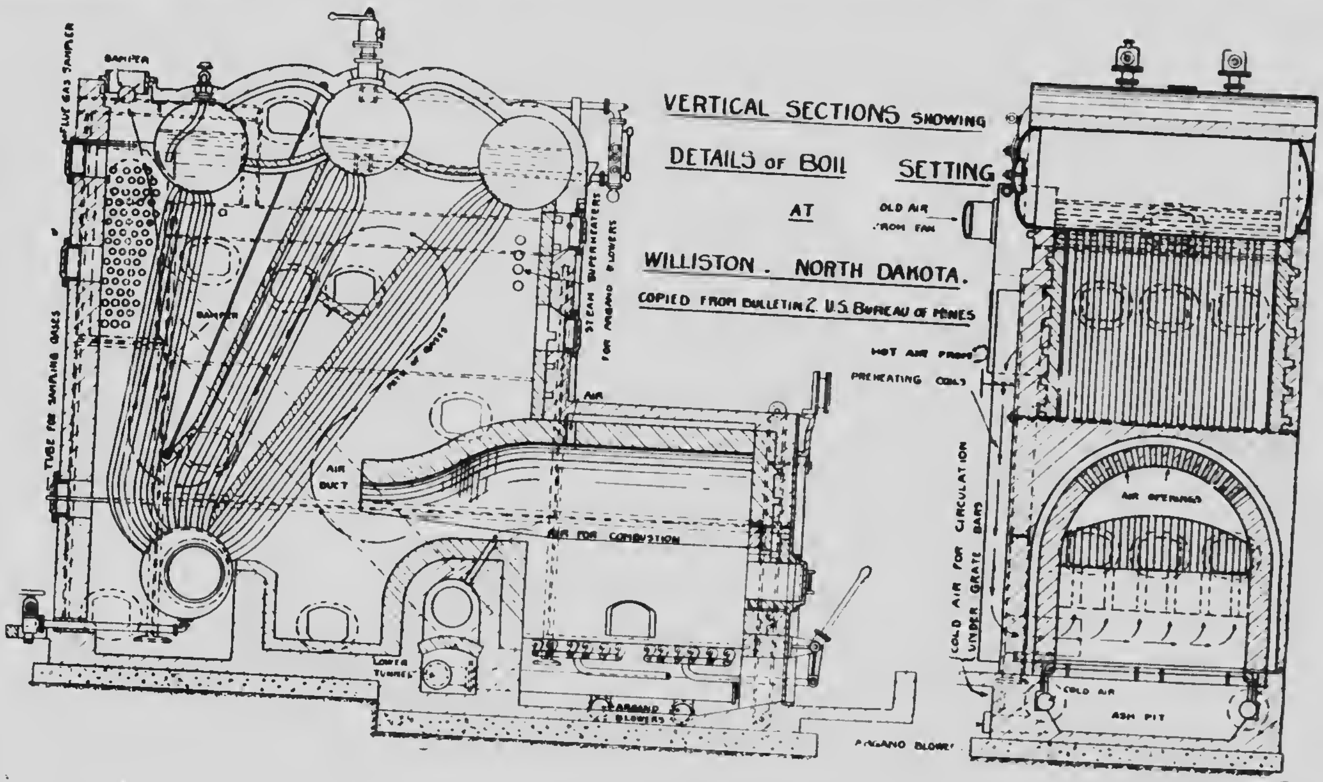

VERTICAL SECTIONS SHOWING
DETAILS OF BOIL SETTING
AT
WILLISTON . NORTH DAKOTA.
COPIED FROM BULLETIN 2. U.S. BUREAU OF MINES
FLUE GAS SAMPLER
DAMPER
TUBE FOR SAMPLING GASES
STEAM SUPERHEATERS
FOR ARGAND BLOWERS
AIR
AIR DUCT
AIR FOR COMBUSTION
LOWER TUNNEL
ARGAND BLOWERS
OLD AIR FROM FAN
HOT AIR FROM PREHEATING COILS
COLD AIR FOR CIRCULATION UNDER GRATE BARS
AIR OPENINGS
COLD AIR
ASH PIT
ARGAND BLOWER

PLATE. 3.

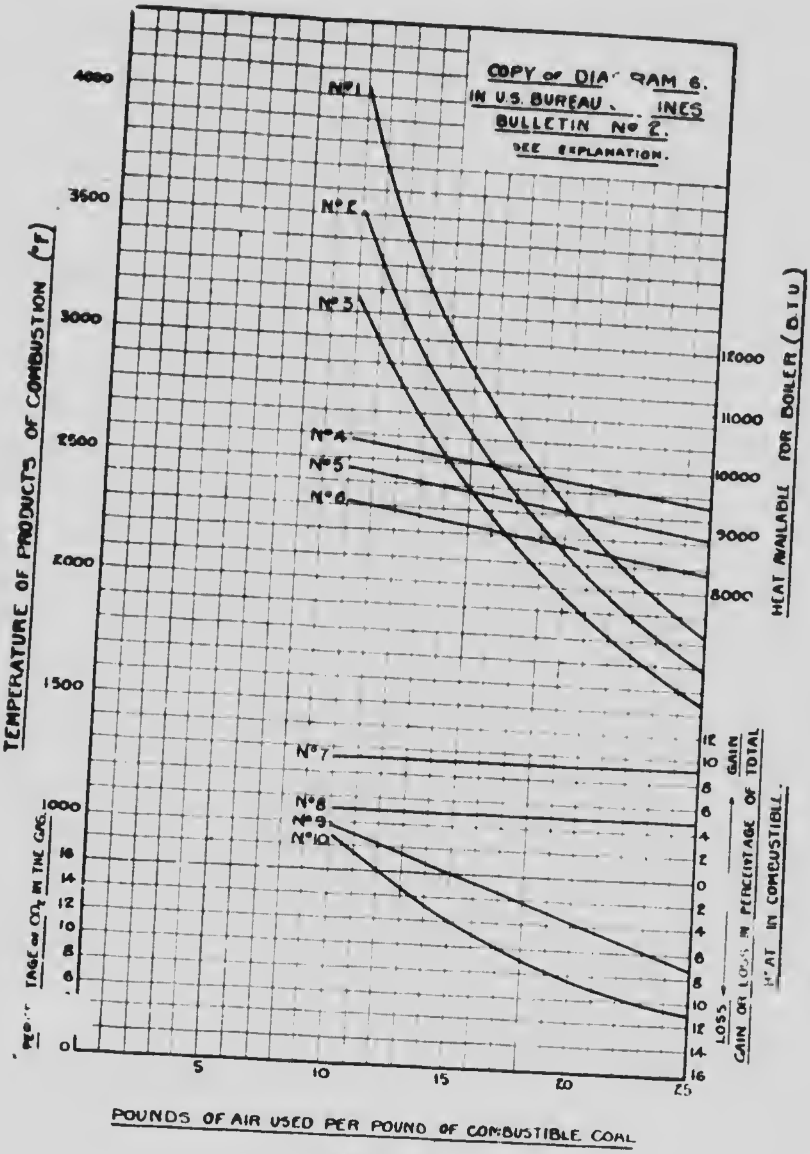


PLATE. 4.

The first three curves on diagram (Plate 4) copied from U. S. Bureau of Mines, Bulletin 2, are intended to show the relation of the temperature of the products of combustion to the weight of air used to burn one pound of combustible

Curve 1 is for lignite, chemically dry

Curve 2 is for lignite, containing 20 per cent moisture.

Curve 3 is for lignite containing 44 per cent moisture.

The next three curves are to show the heat available for boiler in burning one pound of combustible of lignite.

Curve 4 with moisture previously driven off

Curve 5 with moisture reduced to twenty per cent.

Curve 6 with 44 per cent moisture

Curve 7 shows gain of condition of curve 4 over condition of curve 6

Curve 8 shows gain of condition of curve 5 over condition of curve 6

Curve 9 shows gain or loss when less or more than 15 pounds of air is used to burn one pound of combustible.

Curve 10 shows percentage of CO_2 in the flue gases under varying air supply.

HEAT BALANCE DIAGRAM FOR N.DAKOTA LIGNITE.

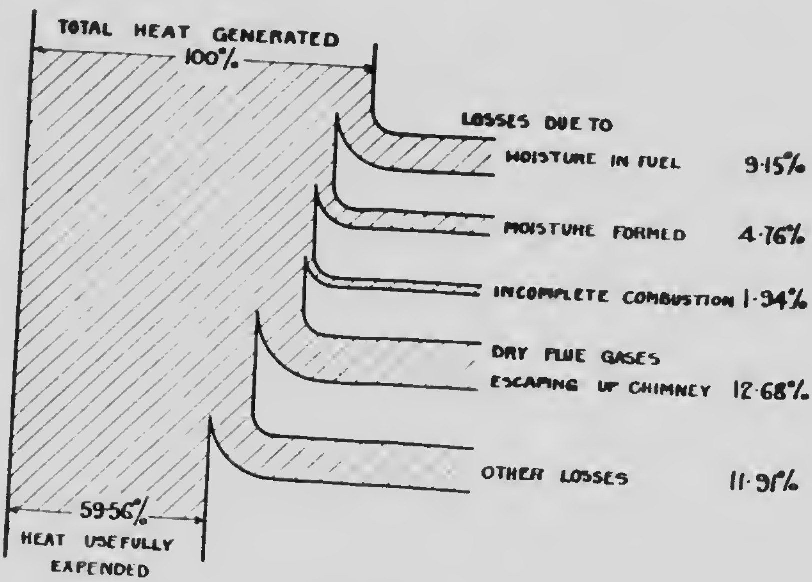
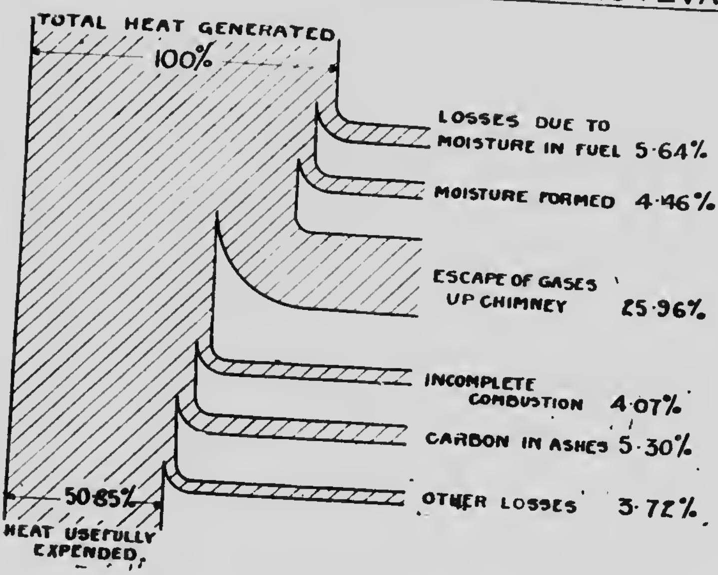


PLATE. 4A.

HEAT BALANCE DIAGRAM — ESTEVAN.



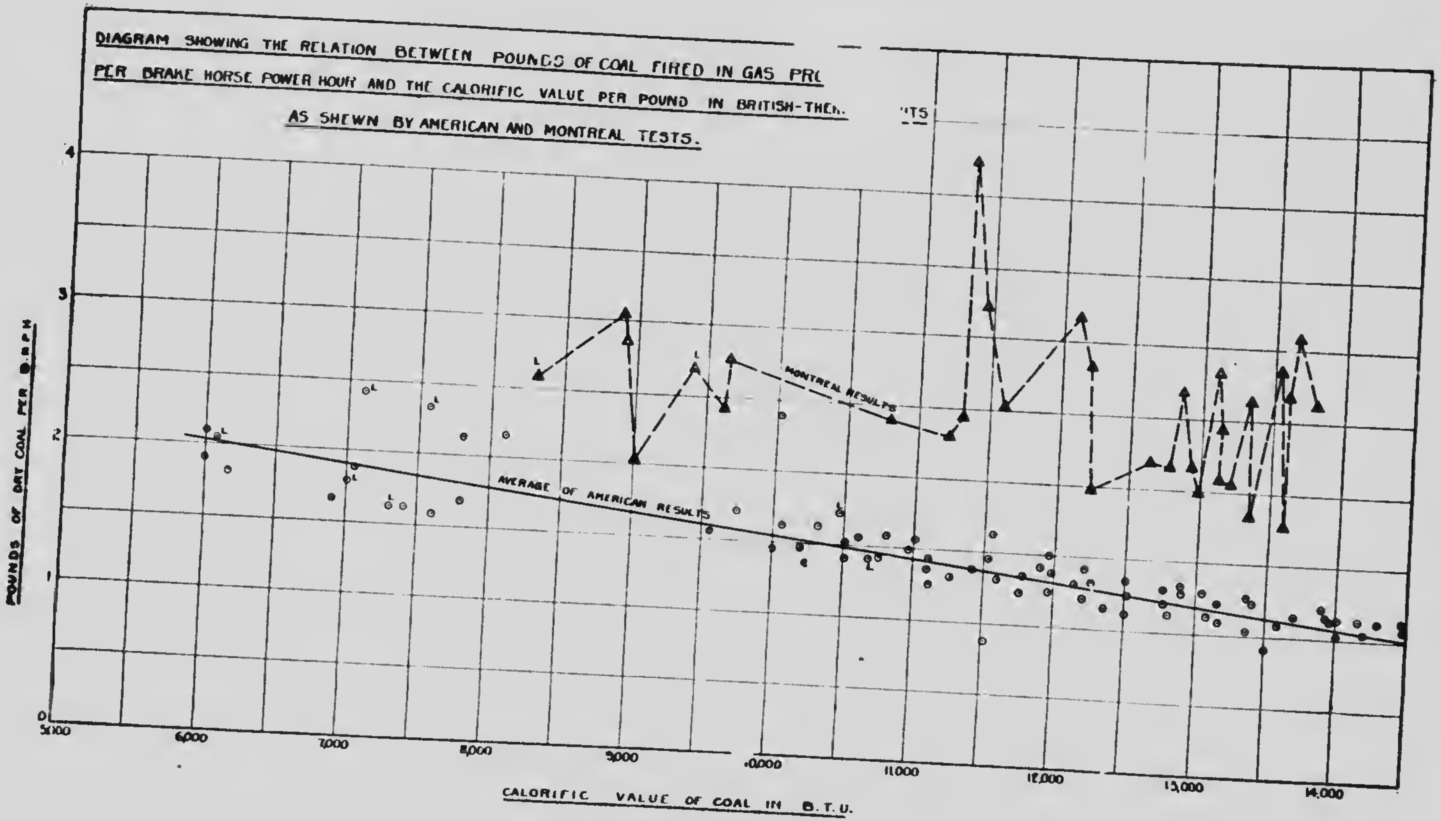
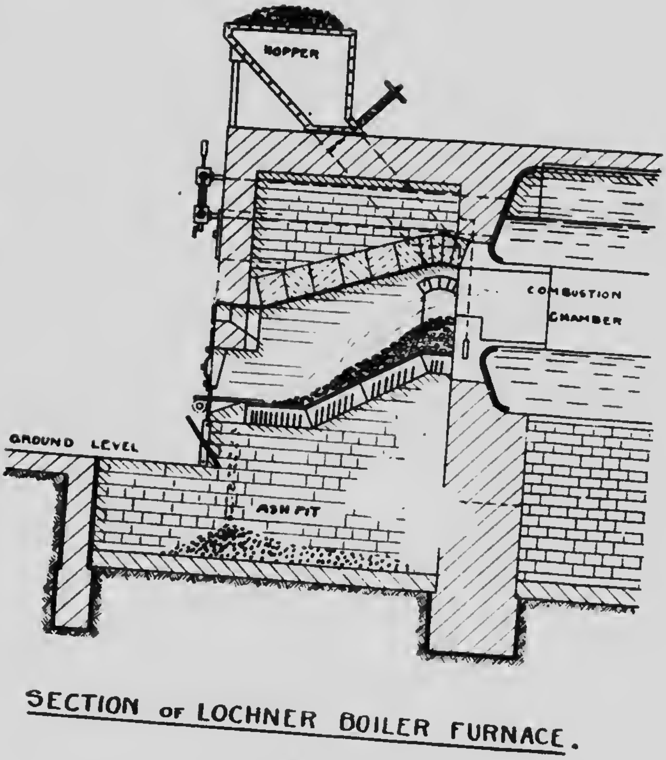


DIAGRAM SHOWING THE RELATION BETWEEN POUNDS OF COAL FIRED IN GAS PR
PER BRAKE HORSE POWER HOUR AND THE CALORIFIC VALUE PER POUND IN BRITISH-THE
AS SHEWN BY AMERICAN AND MONTREAL TESTS.
MONTREAL RESULTS
AVERAGE OF AMERICAN RESULTS
POUNDS OF DRY COAL PER B.H.P.H
0
1
2
3
4
5000
6000
7000
8000
9000
10,000
11,000
12,000
13,000
14,000
CALORIFIC VALUE OF COAL IN B.T.U.

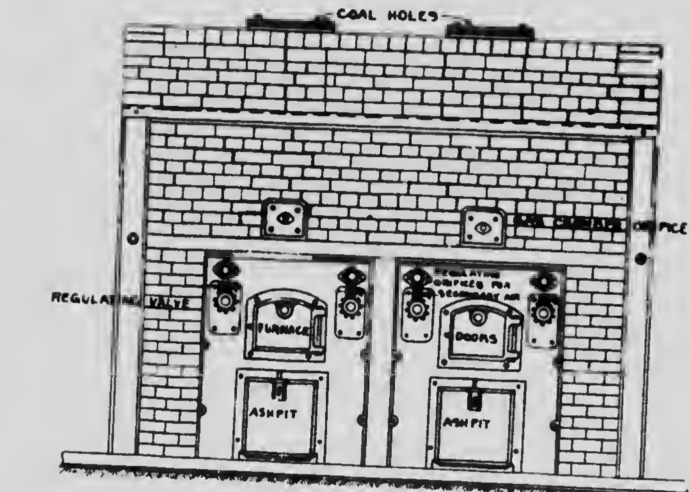
PLATE. S.



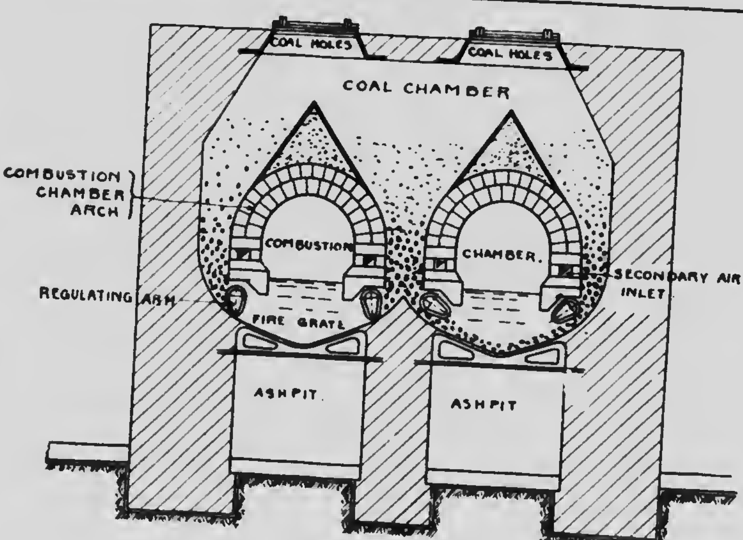
SECTION OF LOCHNER BOILER FURNACE.

PLATE. 6.

MULDENROST BOILER FURNACE FOR LIGNITE.

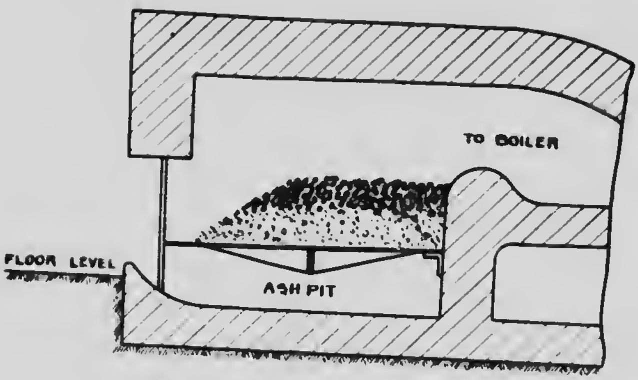


ELEVATION



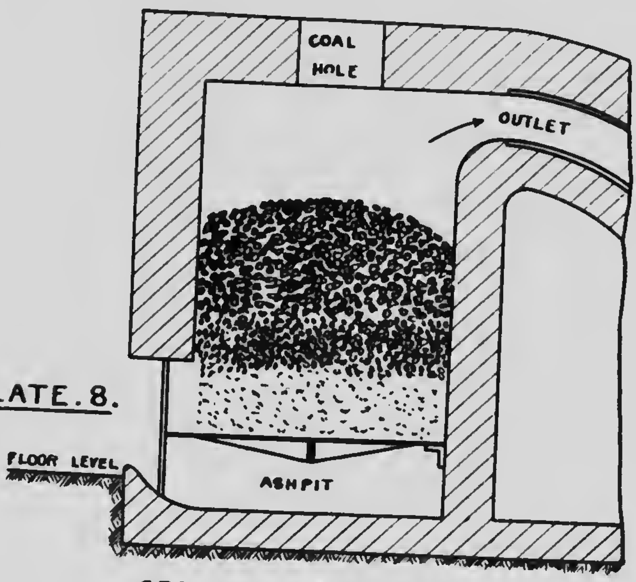
CROSS SECTION.

PLATE. 7.

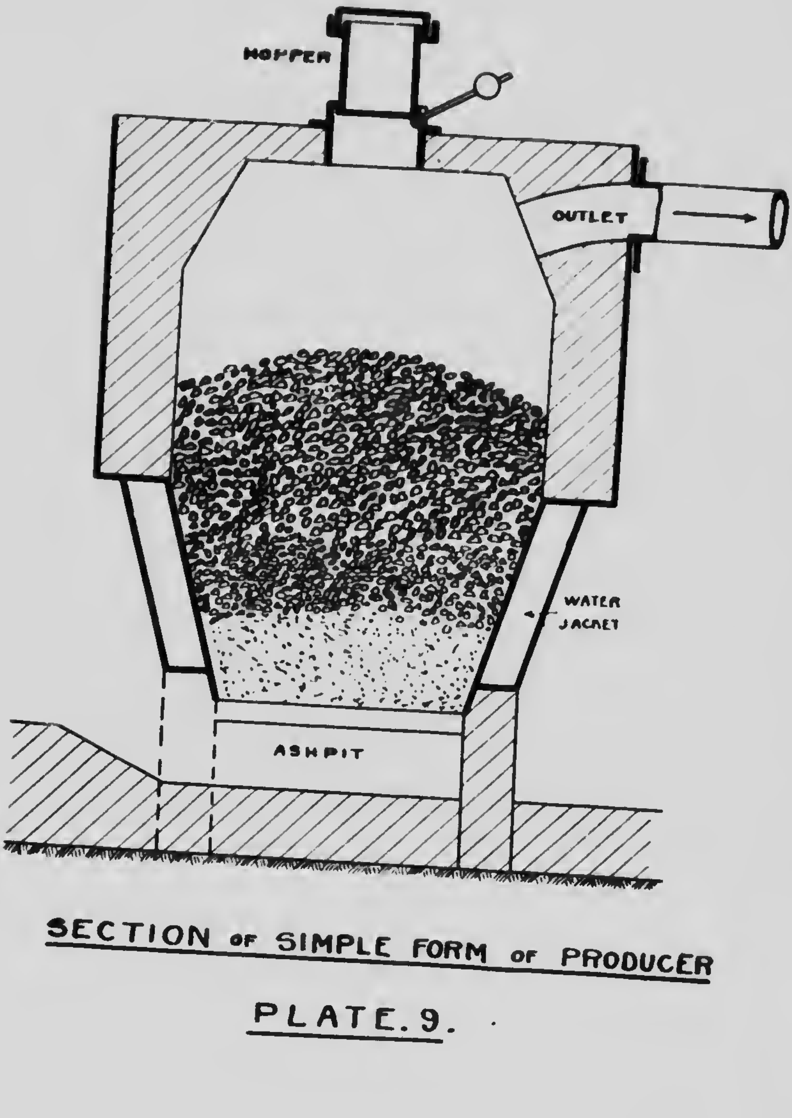


SECTION OF ORDINARY FURNACE

PLATE. 8.



SECTION OF PRODUCER FURNACE



SECTION OF SIMPLE FORM OF PRODUCER

PLATE. 9.

HISLOPS PRODUCER FOR FIRING BOILERS.

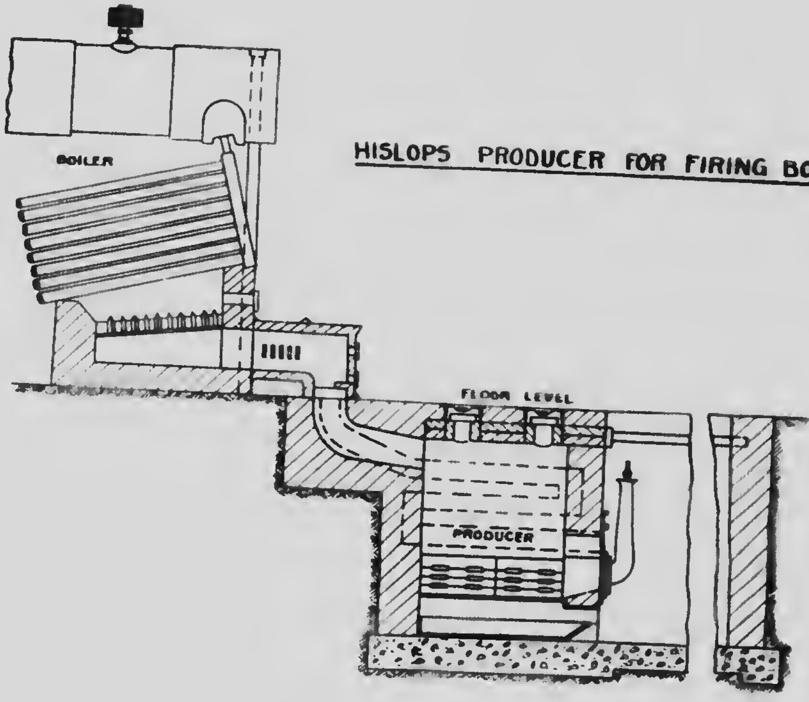
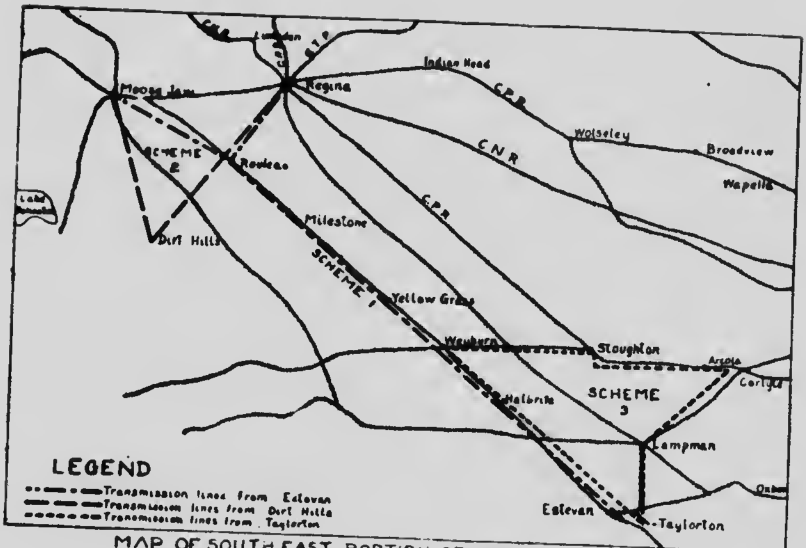
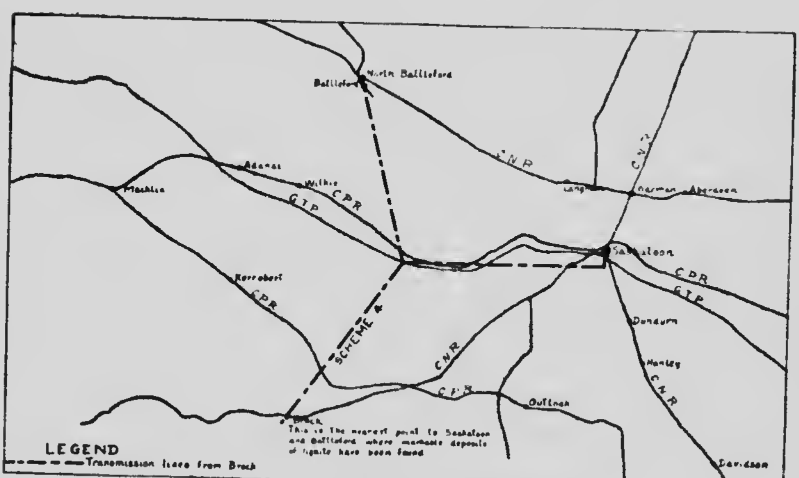


PLATE. 10.



MAP OF SOUTH EAST PORTION OF SASKATCHEWAN
SHOWING
PROPOSED LINES FOR DISTRIBUTION OF POWER



MAP OF NORTH WEST PORTION OF SASKATCHEWAN
SHOWING
PROPOSED LINES FOR DISTRIBUTION OF POWER

MAP SHOW
COAL FORMA
OF
SASKATCHE

SHOWING
ORMATIONS
OF
TCHEWAN