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The lignite coal of North Dakota

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THE LIGNITE COAL OF NORTH DAKOTA.

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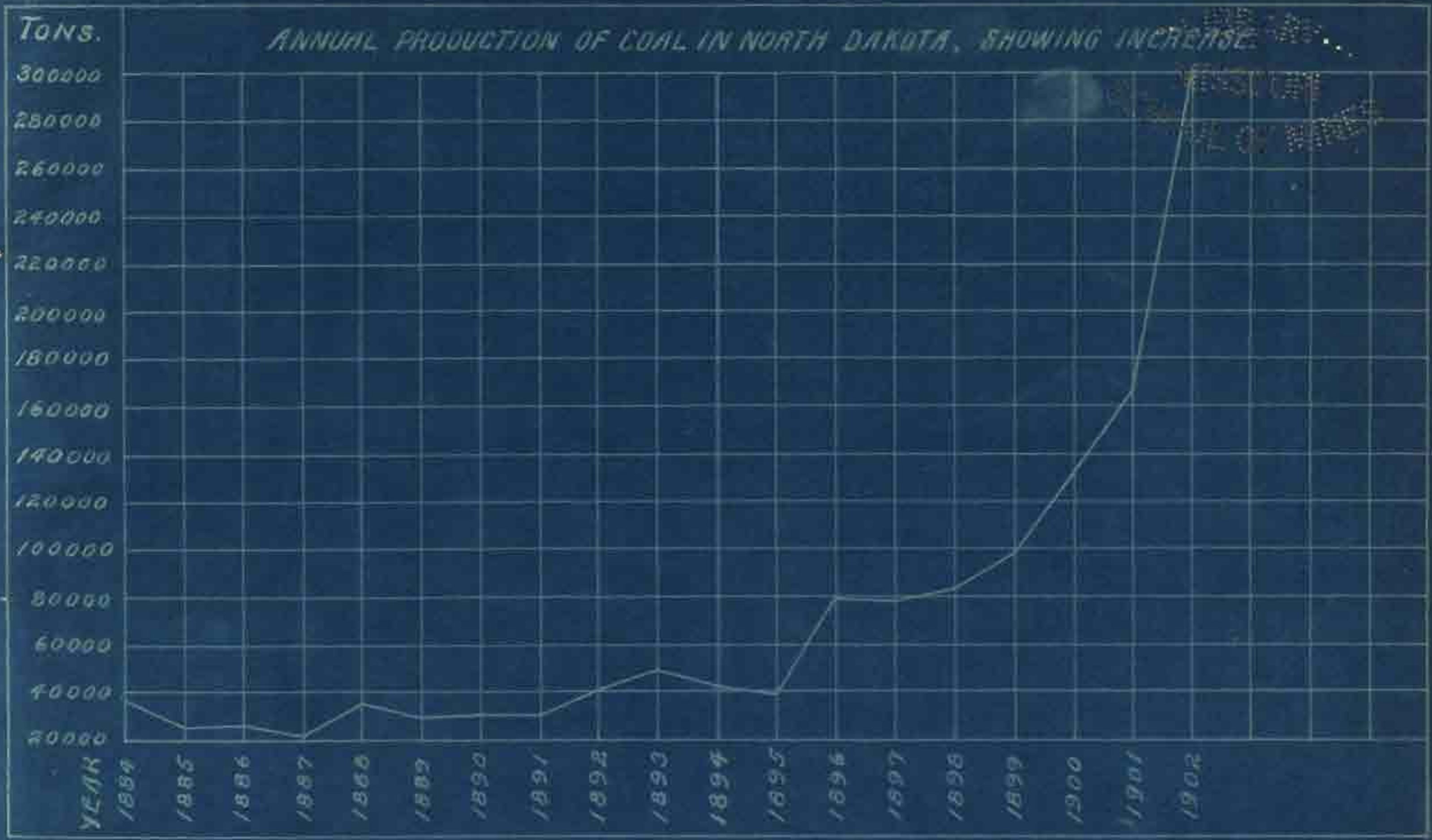
The importance of a supply of coal to any community can scarcely be overestimated. It is the great source of heat and light, furnishing not only comforts and conveniences, but it is also the life blood of industry and wealth.

Those states which contain deposits of anthracite or bituminous coal within their borders can almost be picked by their rank in industry and manufactures.

Owing to the great abundance of coal, both anthracite and bituminous, in the United States, no state need suffer for the lack of it, but to those states like North Dakota, situated in the great plains region and at great distances from such coal supplies, the price of these coals makes them almost luxuries. In the last few years however, the development of the lignite coal within the state of North Dakota has shown an abundance of fuel for many years to come, which, though at one time considered "A poor excuse for poor wood," now competes successfully with any coal from outside the state.

The average selling price of the coal per ton at the mines for the past twelve years is $1.20. In the fall the price usually advances and has reached $1.40 at times. A truer estimate of its value to the community would be to consider the cost of other fuel to the state, if lignite were absent. Measured by this standard the above figures would have to be multiplied by four or five.

It is the purpose of this paper to show the fuel value of this coal as determined by chemical analyses and calorific tests, and to treat somewhat of its geological formation and economical uses. Considerable in-



TONS.
ANNUAL PRODUCTION OF COAL IN NORTH DAKOTA, SHOWING INCREASE
300000
280000
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220000
200000
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120000
100000
80000
60000
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formation has been taken from reports of the State Geological Survey.

Analyses and tests were made on samples furnished by the Washburn Lignite Coal Company of Wilton, McLean County, North Dakota.

PRODUCTION.

The development of the Lignite Coal deposits of North Dakota in the last few years is well shown by the accompanying curve of production, indicating the output of each year from 1884 to 1902. As shown, from 1884 to 1895 the output remained nearly stationary. 1896, 1897, 1898 show the first marked increase in output, while in the four years from 1898 to 1902 the output increased nearly 400%. This increase was due to the greater recognition of the fuel value of the coal and the improvements and changes shown by experience to be necessary for the proper and economical burning of the fuel.

GEOLOGY.

North Dakota, classed as one of the great prairie states, presents but a limited number of marked topographical features. It may be divided into the Red River Valley on the east, the Pembina and Turtle Mountain Highlands on the north, the central rolling prairies and the Coteau du Missouri on the west, which includes the famous Bad Lands. As might be expected from the topographical features the geological formations represented are few. The old Archean and Paleozoic rocks have been found only by well borings. In the Red River Valley the granite lies about 385 feet below the surface, outcropping in South Dakota. The only formations appearing at the surface belong to the Mesozoic and Cenozoic eras. These formations were practically undisturbed by the elevation which changed the country from a sea bottom to an elevated plain, hence the beds lie in horizontal position. Erosion along stream lines has trenched the stratified rocks displaying sections of some diversity. Vertical sections several hundred feet high are exposed along the Missouri and its tributaries.

The Cretaceous Period embraces six stages; the Laramie, now generally included in the Cretaceous, though for some time considered intermediate between the Cretaceous and the Tertiary Periods, contains all the workable coal deposits. This classification places the lignite among the Cretaceous coals, of same age as the coal of the Rocky Mountain states, and the Laramie formation as the most important one, from an economical standpoint, in the state. The area embraced by the Laramie covers, with the possible exception of two counties, the entire western half of the state and is the most extensive geological formation exposed. On the eastern edge it thins out and is covered by glacial drift, while in the western part its thickness reaches 1500 feet or more. Workable beds of lignite probably do not exist in all parts of this region, but restricting the term "Lignite area" to that part which contains workable beds we have a very large area, fully equal to half the state of Ohio.

A study of the lignite coal confines one to the Laramie formation. Various sections taken throughout the state, show a series of clays, sands, sandstone, lignite, and thin bands of hematite, clay iron-stone, and shaly limestone. The lignite occurs in beds of from one inch to forty feet in thickness, the latter being the maximum so far found. Twenty to twenty-five foot seams are exposed near Sentinal Butte, and fifteen foot seams are not uncommonly exposed along the bluffs of the Little Missouri River. The lateral extent of the seams varies greatly, and except in a few instances can seams exposed at points four or five miles apart be correlated, usually running out inside of that distance and giving place to other seams a little below or above.

Records of two deep wells bored by the Northern Pacific Railway, one, at Medora, a point 1860 feet above sea-level, penetrated the Laramie clays 941 feet without passing through them and showed 17 lignite seams, varying in thickness from a few inches to 23 feet, the total aggregating over sixty feet, while the second well at Dickinson, 39 miles distant and at an elevation of 2400 feet above sea-level, in penetrating to the same depth above sea-level showed 16 seams giving an aggregate of 55 feet of coal. It is doubtful if these seams could be correlated with any degree of accuracy, the coal in general seeming to lie in lens shaped bodies.

The clays which occur with the lignite in the Laramie are of great economic importance, many of them being high grade fire, pottery, and ornamental brick clays. They vary in color and often sharply defined layers of orange, buff, brown, red, and white clays occur. These variously colored clays and the sandstones add materially to the beauty of the Bad Land scenery. Certain strata contain many beautiful examples of silicified wood, from small pieces to tree trunks twenty feet long, in all of which the wood fibre is beautifully brought out.

In many parts of the region the surface is covered with masses of so called "scoria", burned and vitrified clay, and slaggy masses of various colors, showing evidence of the great amount of coal which has burned at various times, probably intermittently. The combustion may be caused spontaneously or by prairie fires, and burning coal beds may be seen at a number of points at the present time. The "scoria" makes excellent railroad ballast, and no doubt would have considerable value for concrete work if the region were more populous.

PROSPECTING AND MINING.

Lignite is often exposed along the beds of streams by the cutting away of the bank and is easily recognized. Where it is much weathered it appears as a black clay and its true character must be determined by digging in to it. Where the surface is covered with vegetation, springs are the best evidence of the lignite beds, it being estimated that four fifths of the springs come out of the intersection of lignite seams and coulees. Owing no doubt to the moisture, grass remains greener later in the fall along surfaces immediately covering lignite.

The method of mining varies with the development of the field. In the heart of the lignite area there is scarcely a ranchman who does not have a coal mine in his back yard or sometimes in his cellar. From this coal is removed as needed, by pick, shovel, and bucket. In lignite mining proper, however, three systems are recognized and followed:-

1. The strip pit system,
2. Drifting in on the seam,
3. Through shafts, either inclined or vertical.

The strip pit system is the simplest, and requires the least equipment, and at the present time a large percentage of the output is mined by this method. Where the clay overlying a six foot vein does not have a thickness exceeding ten feet it is considered economical to strip it. The cost of stripping is about ten cents per cubic yard, and it is estimated that an acre of land bearing a seven foot coal seam will yield about 8000 tons by this method.

Many of the larger mines are drift mines, the entries being run in on the coal or starting a short distance above it, running down at an angle of 10° or 15° till the coal is encountered, and then following the seam. Underground the pillar and room method is used entirely. The size of pillars and rooms varies but little from the common practice in bituminous coal fields. No lignite seam thin enough to make the long wall method advisable has yet been developed except by stripping. Both single and double entry mines are found, the double entry being the more common. Water is usually present, the lignite lying between impervious clays forming a natural watercourse, and it is run to a sump at the lowest point in the mine and pumped out, either through the entry or vertically to the surface. The water is generally potableand free from salts which would make it unfit for most purposes. Where water is scarce, during part of the year, the water removed from a mine may be made to pay for the pumping by using it for irrigation.

Where the mine is fitted with more expensive equipment, shafts are sunk, sloping sometimes, if the mine is shallow, and vertical if the seams are deeper. The New Era Mine will have a vertical shaft over 300 feet deep when it reaches the lower ten foot seam.

The freedom of the lignite from pyrite nodules or other hard foreign substances makes it particularly fitted for the use of mining machinery, and modern machinery is in successful operation in at least three of the large mines. Other large mines are also being equipped with electric machinery. Electric drills and undercutting machines operate with about the same speed as in bituminous coal. The fact that labor is higher priced and more uncertain than in older regions makes the introduction of machinery more desirable.

Almost without exception it is found necessary to leave from six inches to one foot of the coal for a roof, and this must be deducted in estimating the available coal from a given seam.

One mine is said to have a sandstone layer 1' thick for a roof, but with this exception the roof is almost invariably a stiff clay, in one or two instances, strong enough to make a roof, but in nearly all cases it is necessary to leave some coal or use considerable timber.

The floor is usually a stiff clay. Excepting in the entries, very little timber is used. Timber is scarce, and it is considered more economical to leave part of the coal for a roof and do as little timbering as possible. Such a roof generally appears safe, but no doubt the state will soon take it upon its hands to have all mines examined by a competent mine inspector to insure safety to the workmen. The lignite mines are very free from dangerous gases, one accident, an explosion of firedamp, being the only one attributed to them. With the exception of two or three mines, no fans are employed for ventilating purposes. Usually an air shaft with a fire pot is considered sufficient, but in the larger mines where considerable powder is used, this method is inadequate. Powder is generally used in the mine, while dynamite is used with better effect in the open pit.

GENERAL PHYSICAL AND CHEMICAL PROPERTIES.

North Dakota lignite may be described as having an appearance intermediate between cannel and true lignite. The seams nearest the surface are more brownish in color, show the woody structure more, and are more friable than the seams at a greater depth. The sample used in our tests appeared dull black but it gave a brown "streak". The coal retains enough of its woody structure to make it tough and hard to reduce to a fine state.

A small amount of yellow powder is often seen in the upper part of the lignite seams; this is easily mistaken for sulphur, but it is a mixture of calcium sulphate and iron oxide. One of the marked characteristics of the coal is its tendency to check or crack, and to go to pieces on exposure to the air. Whether or not this slacking is accompanied by loss of fuel value is a disputed point. The general opinion of those burning lignite is that if the lignite in drying did not fall to pieces, becoming so fine that it is apt to go through the grates, or be blown out the stack, there would be great economy in burning it in that condition, and that in those devices where powdered or fine coal is used the dry lignite presents a material saving over the green. On the other hand the engineer at the State Insane Asylum, who has had extensive experience using lignite as a fuel says: "We find from our experience at this institution that the coal fresh from the mine gives us as good results as as the coal when dry. One pound of lignite coal, fresh mined, will evaporate as much water as a pound of lignite dried." The drying of the coal at the mines would mean a saving of 30% in freight charges, but no satisfactory method of drying has appeared. More experience in firing is necessary to obtain good results with the green coal.

When in the slacked state it adapts itself particularly well to mechanical stokers, while for ordinary stoves and grates the green lump coal is preferred. The coal has but slight tendency to clinker and the ash is generally grayish white and fine, resembling wood ashes. It ignites easily and burns freely with a rather yellow flame and with a comparatively small amount of smoke.

CHEMICAL ANALYSES AND CALORIFIC TESTS.

According to a report of the State Geological Survey, the percentage of moisture is high, the average of 26 samples fresh from the mines, showing 30% water, and this varies but little throughout the state. The average of 60 samples from different mines shows the following, in percentages of dry coal:-

Volatile matter............... 35.63,

Fixed Carbon.................. 51.21,

Ash........................... 8.50.

Sulphur in any form is commonly present in traces only.

The methods used by the writers for determining the moisture, volatile matter, fixed carbon, ash, and sulphur were those recommended by the committee of the American Sosiety of Chemists. The carbon and hydrogen were determined by the method in Benedict's "Elementary Organic Analysis," Nitrogen was determined as ammonia.

The Parr Standard calorimeter was used to determine the calorific value. In calculating the calorific value from the ultimate analysis the calorific values of hydrogen, carbon, and sulphur were taken as respectively, 34,460; 8,080; and 2,250 calories.

PROXIMATE ANALYSIS.

	% Moist coal.	% Dry coal.	% Combustible coal
Moisture	19.86		
Volatile matter	34.86	43.49	46.45
Fixed carbon	40.39	50.16	53.55
Ash	5.09	6.35	

ULTIMATE ANALYSIS ON DRY SAMPLE.

Carbon	65.56
Hydrogen	5.23
Sulphur	.91
Nitrogen	.87
Oxygen	21.08
Ash	6 .35

CALORIFIC VALUE DETERMINED.

French calories	2856
Pound calories	6297
British Thermal units	11334

CALORIFIC VALUE CALCULATED FROM ULTIMATE ANALYSIS.

French calories	2818
Pound calories	6213
British thermal units	11183

ULTIMATE ANALYSIS CORRECTED TO SAMPLE AS RECEIVED.

Carbon	52.53
HYdrogen	6.40
Sulphur	.73
Nitrogen	.70
Oxygen	34.55
Ash	5.09

CALORIFIC VALUE DETERMINED.

French calories.................. 2285.

Pound calories .... 5038.

British thermal units........... 9068.

CALORIFIC VALUE CALCULATED FROM ULTIMATE ANALYSIS.

French calories.................... 2207.

Pound calories..................... 4978.

British thermal units.............. 8760.

The above analyses and tests are the average of not less than four determinations.

METHODS OF BURNING.

For steam plants the most satisfactory method of burning now in use is by using mechanical stokers and forced draft.

At the Fargo-Edison Electric Plant, at Fargo,North Dakota, lignite varying in size from dust to pieces of half a pound weight is burned in this manner, successfully competing with Eastern coal. The cost of firing is reduced and the fires are exceedingly uniform. Natural draft alone is used successfully in many places, but it requires the construction of much higher chimneys,and larger boilers and grates are an advantage but not essential. On account of the large percentage of volatile gases of high fuel value, devices are used in a number of plants to aid in their combustion. The most common device is a fire brick arch built over the front of the fire-box. This becomes very hot and secures the combustion of the gases,although it interferes with hand firing to some extent and shuts off a small part of the boiler from the direct action of the fire. The advantage of this arch has not been fully demonstrated. Undoubtedly pulverized lignite could be burned to decided advantage by introducing it in an air blast similar to the method of burning crude petroleum,thus utilizing the high calorific value ofits gases as well as its fixed carbon. So far, however, there seems to be no record of its use in this way, the pulverizing machinery necessary being a drawback.

BRIQUETTING.

When the problem of briquetting lignite is successfully solved an excellent,clean,and high grade fuel will be available. Experiments in this line extending in a number of cases over periods of two or three years have not yet been able to produce an economical and satisfactory briquette of lignite. The recent negative results obtained by the U.S. Fuel Testing Plant in briquetting North Dakota lignite,equipped as it is with English and American power briquetting machines and a large number of binding materials, did not encourage the writers to attempt or expect much in this way of hand briquetting in the laboratory. The only experiments made were with an inorganic binder, natural cement being used. At least 8% of cement was required and with this amount the briquettes seemed quite firm, but they were broken in removing from the moulds. The use of an inorganic binder is not desirable as it lessens the fuel value and increases the ash.

It appears that some organic binder, such as tar, pitch, or resin must be used. When the coal is used in a gas producer a yellow sticky tar is extracted from the gas before it is used in the gas engine,and it may be possible to utilize this tar in making briquettes from the fine coal.

BOILER AND EVAPORATION TESTS.

Without question practical evaporative tests carried on under boilers of standard pattern are more satisfactory than either chemical or calorific test s. A large number of such tests have been carried on throughout the state. Comparing the water evaporation per pound of coal the average results show that the lignite appears to be worth 78 percent of the Iowa coal and 70 per cent of the Missouri product.

LOCOMOTIVE TESTS.

Tests of lignite coal as a fuel for locomotives hauling heavy loads were made by the Northern Pacific Railroad Company, and showed conclusively that the lignite can be successfully used and at a great saving of cost over Eastern coal. The engine was especially constructed for burning lignite, having a larger and wider fire-boxand a brick arch to assist in burning the gases. Burned in this way , the coal gave little smoke. The test trip covered a distance of 106 miles. The average speed was 20 miles an hour. The number of cars was 43 loads. Eighteen and one quarter tons of lignite were consumed, at a cost of $1.00 a ton, as against eight tons of eastern coal, at$4.03 a ton, showing a saving, in favor of lignite, of $13.99, or 43.4 per cent. Onthe return trip, with a heavier train, the saving was $20.08, or45.3 per cent.

GAS MAKING.

In the report of the State Geological Survey of North Dakota for 1901 is found the statement. "Lignite coal is not adapted for the manufacture of gas and coke nor for smelting purposes." While lignite will probably never be used for smelting or coke making, recent gas-producer tests made by the U. S.Fuel Testing Plant show that North Dakota lignite is an excellent coal for the production of gas. Quoting from the preliminary report of the test, "This brown lignite would be an ideal gas producer fuel, but for its tendency to clinker. It yielded a rich gas and not so very much tar. This tar was yellow and sticky, and not at all like that from bituminous coal. The bed had to be carried deeper than for soft coal, and had to be poked frequently to prevent the formation of clinkers. After thirty hours continuous run, the bed was in good condition and the test could have been continued or a new run begun without renewing the producer bed. During the test the engine carried only two-thirds of its normal load, but there seems to be no doubt that it could have carried full load throughout the entire run." The next test was on the Texas lignite, and quoting further, "The Texas No.1. was a brown lignite, strongly resembling that previously tested from North Dakota. The gas from it was not so rich as that from the North Dakota lignite, but it was higher in heat units than is the gas obtained from the ordinary soft coal. ----------- This lignite yielded a large amount of tar of the same kind as the lignite previously tested. As a producer of fuel it is better than many grades of bituminous coal."

E. W. Parker, director of the Fuel Testing Plant, writes in the Engineering Magazine, "Special attention is called to the comparatively high calorific value of the gas obtained from Texas No.1., and North Dakota No.2., both of which are brown lignites. The average heating value of the former, as expressed in B. T. U.,was 169.7 per cubic foot, and that of the latter was 188.5. The best gas obtained from bituminous coals was made from Indiana No.2.,which averaged 159.3 B. T. U. per cubic foot, and Indian Territory No.1., 159.2 B. T. U. On account of the large percentage of water and ash in the lignites, the amount as mined required to produce a certain quantity of gas naturally exceeds the amount of bituminous coal required to produce the same quantity. For instance, one pound of Texas No.1 yielded only 28.4 cubic feet of gas; Texas No.2 34.2 cubic feet; North Dakota No.2, 25.2 cubic feet; Colorado No.1, (lignite),42.1, and Wyoming No.2, (lignite)37.0,cubic feet, wheras one

West VIRginia coal yielded 70.1 cubic feet, another West Virginia coal 79.6 cubic feet, while the yield of other bituminous coals ranged from 44.5 to 63.2 cubic feet.

"But the economic results as shown by the horse power developed at the switch board, and as calculated as available for effective use, are the striking features. In this we find that for each horse power per hour developed at the switch board there were used of these lignites the following:- Colorado #1, 2.14 pounds; North Dakota #2, 3.8 pounds; Texas #1, 3.34 pounds; Texas #2, 2.58 pounds; Wyoming #2, 2.28 pounds. For effective horse power per hour, or that available for purposes outside of that used at the plant, the required would be:- Of Coloorado #1, 2.3 pounds; of North Dakota #2, 4.07 pounds; of Texas #1, 3.53 pounds; of Texas #2, 2.74 pounds and of Wyoming #2, 2.49 pounds.

How thes compare with bituminous coal used under boiler is shown by the fact that the best West Virginia coal required 3.39 pounds per electrical horse power per hour at the switch board, and of seventy-six tests under boilers, only five (all from West Virginia) required less than 3.5 pounds; and only twenty-six (fourteen from West Virginia) required less than four pounds of fuel. From this it appears that lignite coals, converted into gas and used in a gas engine, will do equally as good service as the average bitumtnous coals used under boilers."

The average composition, of the gas of North Dakota lignite by volume was:

Carbon dioxide	8.69%,
Oxygen	.23%,
Carbon monoxide	20.99%,
Hydrogen	14.33%,
Methone	4.85%,
Nitrogen	51.02%.

RELATION OF LIGNITE TO VARIOUS INDUSTRIES AND IRRIGATION.

Manufacturing industries are in their infancy in North Dakota, but the abundance of this cheap fuel tends to their rapid growth and already great advances have been made in a number of lines. Practically every flouring mill west of the Red River Valley uses lignite to great advantage and each year sees an increasing number erected. Where a few years ago stock raising alone was considered, it is now carried on in connection with dairying, and creameries are multiplying rapidly. The large quantities of straw annually burned suggests the possibility of paper board mills and other industries which, with the aid of cheap fuel, can utilize this product. To lignite is due in a large measure the fact that even the smaller cities and towns enjoy electric lights and waterworks. Of the manufacturing industries connected with the lignite, that of brick making, is perhaps the most advanced. Great deposits of valuable clays are directly associated with the lignite In a number of mines the clay used in making the bricks comes from the same mine as the coal used in burning them. Fire clays which stand the highest tests are made into brick and shipped to Milwaukee on the east and Butte, Montana on the west. The Dickinson Fire and Pressed Brick Company produce a most excellent fire brick using lignite mined on their own ground to burn it. The kilns are modern, permanently built for intense and uniform burning. The lignite burned under a blast system gives most satisfactory results. For common brick a blast is not neccessary. It is estimated that 1000 pounds of coal will burn 1000 bricks.

Pottery and other clays are also found in abundance, but so far have not been developed, though they deserve the careful consideration of capitalists.

North Dakota is pre-emiently an agricultural state, and in the connection of lignite coal with the irrigation of the semi-arid portions of the western part of the state, we find the greatest interest at the present time. The success of the irrigation projects now being carried on by the U. S. Government for the reclamation of arid lands depends, in North Dakota, to a great extent if not entirely, upon the lignite coal of that area. The principal points to consider are the water supply and the means of getting the neccessary head to distribute the water over large tracts of land. Much of the land that is level enough to irrigate is in the form of broad terraces which border the streams. These terraces often contain as much as 1000 acres having a slight slope and excellent soil. Back of these are still other large tracts suitable for irrigation if the water can be elevated 75 or 100 feet. The Missouri and its tributaries furnish the water, but, as the gradient of the Missouri is but 2.7' per mile, and, as at least 1' per mile is neccessary in an irrigation ditch, to draw water from the upper river would require canals many miles in length.

Topographical considerations and also the fact that the required irrigation will be rather intermittant—— the average rainfall being 16" per year, which if properly distributed throughout the season would be sufficient to mature a crop—— excludes this method in most cases. It is not economical to construct dams to raise the water to such an elevation. A method of much wider application consists in pumping water from the streams up to the flats. Where fuel is cheap this method is practical, as has been proved in California where oil and wood are used. In North Dakota we have the lignite.

The computations here given which indicate the amount of lignite that will be required to raise water to the level of the various flats in western North Dakota were made by Chas. S. Magowan, Professor of Municipal and Sanitary Engineering at the State University of Iowa. Centrifugal pumps only are discussed. The evaporative power of lignite was taken as 4.1 pounds of water per pound of coal.

As shown previously, used in a gas-producer and gas engine, a much better efficiency would be expected.

Diameter of discharge opening		6"	8"	10"	15"	18"	24"
The capacity in gallons per minute		1050	2000	3000	7000	10000	15000
H. P. delivered to	20' Lift	11.8	22	32	70	100	130
shaft to give eco-	40' "	23.6	44	84	140	200	260
nomical discharge	60' "	35.4	66	96	210	300	390
at elevation named	80' "	47.2	88	128	280	400	520
Efficiency of pump in %		45	46	47	51	52	58
Unit of lignite in	20' Lift	1.2	2.2	3.2	7	10	13
tons to furnish	40' "	2.4	4.4	6.4	14	20	26
power to operate	60' "	3.6	6.6	9.6	21	30	39
pump 24 hours.	80' "	4.8	8.8	12.8	28	40	52

Mr wilson, "Manual of Irrigation Engineering" makes the general statement that 1000 gallons per minute will irrigate in the course of a season about 100 acres.

Not only are the engineers in the Reclamation service making a study of the lignite as applied to irrigation, but more recently the Department of Agriculture has taken up the subject of motive power for farm purposes. Experts have been appointed to make tests on the new gas producer gas engines to determine how cheaply power may be produced from lignite coal for farm purposes in the lignite coal fields of North Dakota.