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GEOLOGICAL SURVEY

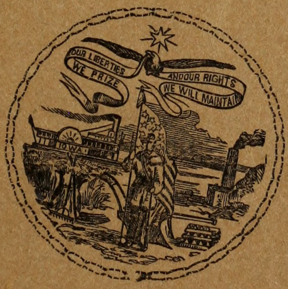
BULLETIN NO. 2.

A Preliminary Report on the Peat Resources of Iowa

AND

A Report on the Tests of Iowa Coals Made by the Government Coal-Testing Plant at the Louisiana Purchase Exposition, St. Louis, Mo., 1904

FRANK A. WILDER, PH. D., STATE GEOLOGIST.
T. E. SAVAGE, ASSISTANT STATE GEOLOGIST.



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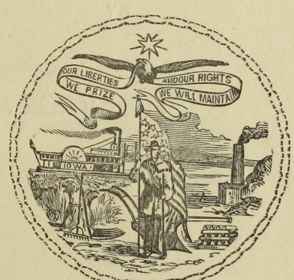

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A PRELIMINARY REPORT ON THE PEAT RESOURCES OF IOWA.

BY

T. E. SAVAGE.

INTRODUCTION.

For several years it has been known that considerable quantities of peat existed in the marshes of northern Iowa. As early as 1867 Dr. Charles A. White made some observations on these deposits and called attention to their importance.*

In the present series of Geological reports the presence of peat is noted in a few counties, but no attempt was made to determine the extent or the quality of such beds.

In recent years the increase in the cost of fuel and, especially, the improvement in the methods and the machinery by which peat is prepared and utilized, have so stimulated the development of the peat industry that such deposits promise to become important sources of heat, light and power.

For some time the Director of the Iowa Geological Survey has been planning a systematic study of the peat deposits of the state, but until recently this has been deferred owing to the pressure of other lines of work that seemed to be more imperative. However, the investigation was taken up during the summer of 1905, and the field work was assigned to Mr. L. H. Wood, under the supervision and with the assistance of the State Geologist.

A thorough examination of the individual marshes was undertaken to locate those that were productive, to learn the extent and the depth and the quality of the peat which they contain, and to collect samples from the several deposits from which analyses and tests could be made.

The marshes of the state proved to be richer in vegetable deposits than was anticipated. In view of the large quantity of peat that was located, and because of the growing importance of this industry, it was thought desirable to publish a general report on the peat resources of the state in the form of a bulletin, preliminary to the more complete report which will embody the results of the analyses and tests that are yet to be made.

The data relative to the distribution, location and description of the peat-bearing marshes are taken from notes made by Mr. Wood. Many of the facts relating to the manufacture of peat fuel, and cost of machinery were obtained from a paper by W. E. H. Carter in the Twelfth Report of the Ontario Bureau of Mines, and from Special Consular Reports, Volume XXVI, which treats of Briquettes as Fuel in Foreign Countries.

***White: 1st and 2nd Annual Reports of Progress, pp. 121-135. 1868. See also, Geol. of Iowa, Vol. 2, pp. 275-288. 1870.**

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COMPOSITION OF PEAT.

Peat represents the early stages in the carbonization of vegetable matter, just as coal is the product of a more advanced stage of this same process. It is composed of plant tissues that have undergone more or less decomposition and chemical alteration. It varies from a yellowish or brown, fibrous substance in which the leaves and tissues of the plants are quite perfectly preserved, through different stages of decay and maceration, to a dark colored, mucky material in which little of the original structure can be recognized.

There is always present in the peat a variable amount of mineral matter. This material may represent the ash or mineral constituents of the plants from which the peat was formed, or it may consist in large part of foreign matter derived from the silt borne by winds or from sediments carried by water.

In the natural state peat always contains a high percentage of moisture which is with difficulty removed by drying.

In Iowa marshes a large proportion of the vegetable matter is in a more or less fibrous condition. It is in part composed of the remains of aquatic species of mosses belonging to the genus Hypnum, but in most of the bogs the leaves and stems of rushes, sedges and other groups of water-loving plants have contributed the larger share.

The following analyses will show the composition of samples of Sphagnum moss, oak wood, New Jersey peat and Illinois coal. The table also shows the gradual increase in the percentage of carbon that takes place in the changing of the vegetable matter to peat, and in its further alteration to bituminous coal.

Comparative Table Of Analyses

Material	Carbon per cent.	Hydrogen per cent.	Oxygen per cent.	Nitrogen per cent.
*Sphagnum moss	49.88	6.54	42.42	1.16
*Oak wood	50.60	6.00	42.10	1.30
*New Jersey peat	58.00	6.36	31.85	1.14
†Illinois coal	65.48	5.09	15.04	1.39

The close similarity between the composition of Sphagnum moss and oak wood will appear from the table, and the decrease in the proportion of oxygen as that of the carbon content increases will also be observed. The best grades of peat contain 10 to 12 per cent more of carbon and 10 to 12 per cent less of oxygen than the vegetable matter from which it was formed.

CONDITIONS OF PEAT ACCUMULATION.

In order that vegetable matter may be preserved in the form of peat the material must accumulate under water where it will undergo imperfect decomposition without free access of air. When plants decay on the surface of the ground the tissues are soon broken down into the

*Ries: 21st Report of the State Geologist of New York, pp. 58 and 61, 1901.
†See this bulletin, p. 28.

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simple compounds out of which the vegetable structures were built, and the materials are returned to the air in the form of carbonic acid gas, water and ammonia. The humus of the soils and the leaf mould of the forests represent the products of incomplete oxidation or decay of organic matter on the surface of prairie and woodland.

Under water, where the supply of oxygen is limited, decomposition of vegetable matter is much less rapid and complete. In the water containing such matter there are also present soluble acids whose antiseptic properties serve further to hinder the process of plant decay. Under these circumstances small quantities of carbonic acid gas, marsh gas and nitrogen are slowly liberated, but there are left much of the hydrogen and the greater portion of the carbon. The further such decomposition proceeds the higher is the proportion of carbon that remains, as is shown in the foregoing table.

Conditions favorable for the accumulation of peat are usually present in swamps or marshes or around the margins of small lakes or ponds. In such places the vegetation is usually luxuriant, and as the successive generations of plants die their stems and leaves fall in the water and are there protected from complete decay.

MANNER OF ACCUMULATION OF IOWA PEAT BEDS.

When the glaciers melted from our state they left a comparatively level surface which was broken by numerous minor inequalities. Depressions of varying extent and depth dotted the prairies, and were especially abundant over a belt near the margin of the respective ice sheets known as the terminal moraine. Such basins became filled with water and formed lakes and marshes which are still conspicuous topographic features of northern Iowa. Such bodies of water are quite free from sediments, and furnish congenial conditions for the growth of a large variety of plants.

Marsh-loving forms soon established themselves around the shallow margins of these pools, and lowly algae flourished in the deeper water. Aquatic mosses spread widely over the surface in tangled mats and long, floating strands. As the growth of each year was completed the dying leaves and stems and filaments fell to the bottom and were embalmed together by the water of the bogs. As the seasons of the centuries came and went the water was constantly shallowed and the borders of the basins were constantly narrowed by the accumulation of plant remains. The grasses and sedges kept crowding each other further out from the shore, the amphibious rushes pushed out further still, while among and beyond these the water-loving mosses reached constantly toward the center. As the deposit deepened the alteration of the materials continued and the vegetable matter became more and more compacted into peat.

The rate of accumulation of these deposits depends largely upon the character of the vegetation which the marsh supported. Where the plants consisted chiefly of species of mosses the increase was made very slowly, but where the deposit is made up of the remains of coarser

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plants, the accumulation grew more rapidly. The stage of filling at present attained in the lakes of our state depends also upon the size of the lake and the original depth of the basin.

In north-central Iowa, lake filling by the accumulation of vegetable debris has been in progress ever since the retreat of the Wisconsin glacier. At the present time the history of many of the smaller lakes and marshes has been completely closed; areas of swamp soil being the only witnesses to the former existence of water, and the only indication of underlying deposits of peat.

In other lakes the filling is but partially completed, and they exist today as broad, shallow marshes overgrown with moss and rush and sedge, whose stems and leaves still contribute an annual increment to the vegetable accumulation on the bottom.

In the larger and deeper lakes, where wave action was stronger, there are no deposits of vegetable matter or but a discontinuous fringe which represents the initial deposit of a future bed of peat.

DISTRIBUTION OF PEAT MARSHES IN IOWA.

The peat deposits of Iowa occur in the north-central portion, over the area that was covered by the Wisconsin ice sheet. They are especially well developed in a belt eight to twelve miles in width around the margin of this area, among the ridges of the moraine. In such situations the water level of the lakes is held higher and more constant than over the level lands. The basins also are deeper, thus preventing a large proportion of mud being mixed with the vegetable material through the borings of crayfish. The gentle slopes that border the depressions were until recently covered with forests which protected the growing deposits from contamination by silt or sediments from wind or water. For these reasons the morainic basins generally contain deeper and purer deposits of vegetable matter than are found in the marshes over the prairies.

The greater number of good bogs occur among the hills of the Altamont moraine, on the eastern border of the Wisconsin drift plain. They cover areas of varying extent in the west half of Worth, Cerro Gordo and Franklin counties and the eastern portions of Wright, Hancock and Winnebago. Between this eastern belt and the west side of the Wisconsin drift area there are occasional marshes that contain considerable peat. The largest of these occur in the counties of Emmet, Palo Alto and Clay, while smaller areas are found in Dickinson, Kossuth, Green and Calhoun counties.

The quantity of peat in the Iowa marshes, distributed by counties, can be computed by multiplying the number of acres of peat-bearing marsh land in each county by the average depth of the peat in yards, on the assumption that one acre of peat, three feet in depth, would produce 1,000 tons of dried fuel.

On this basis Worth county should yield in round numbers 6,000,000 tons of dry peat fuel; Winnebago county 8,000,000 tons; Hancock county 3;000,000 tons; Cerro Gordo county 10,000,000 tons; Wright

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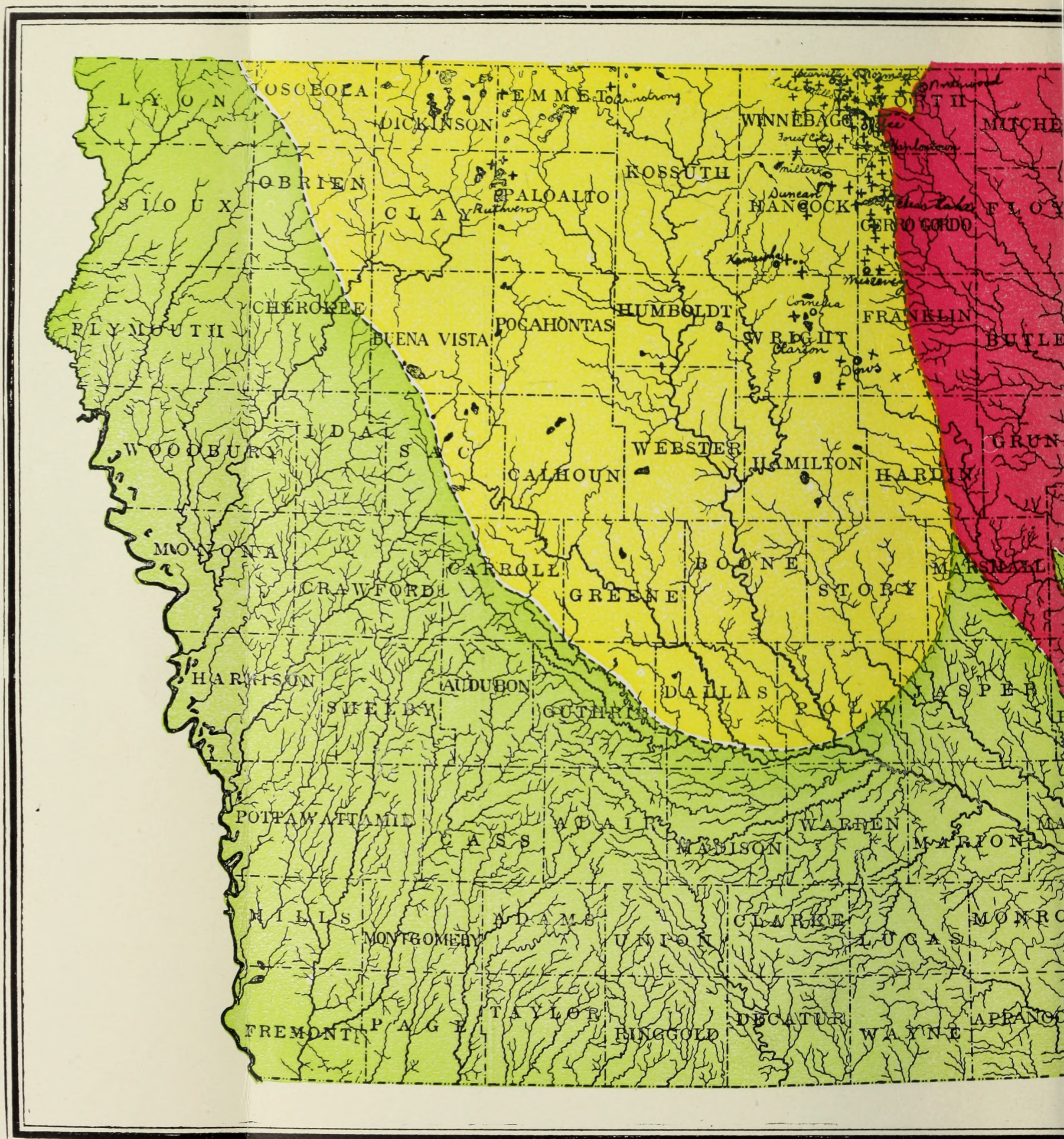

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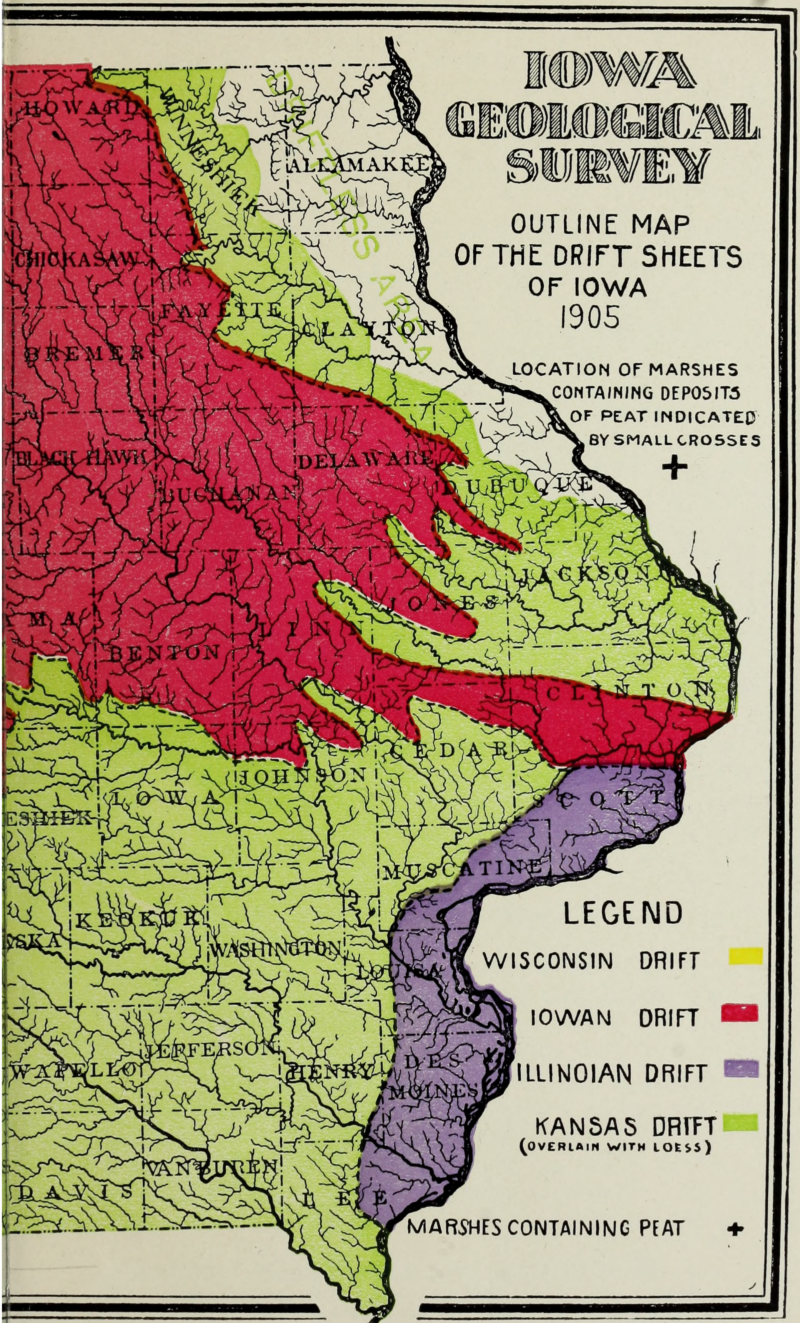

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county 1,000,000 tons; Franklin county 1,500,000 tons; Emmet county 2,000,000 tons and Clay and Palo Alto counties 4,000,000 tons.

If we would be very conservative and estimate the yield of peat per acre, three feet in depth, at only 600 tons* of dried fuel, we would still have about 22,000,000 tons of such fuel located in northern Iowa.

The distribution of the marshes, and their relation to the border of the Wisconsin drift sheet are shown on the accompanying map.

LOCATION AND DESCRIPTION OF INDIVIDUAL MARSHES.†

PEAT DEPOSITS IN WORTH COUNTY.

The peat-bearing marshes of Worth county occur in the townships of Fertile, Bristol, Silver Lake and Hartland.

Fertile township area.—About two miles west of Hanlontown, in the southern portion of Fertile township, is a large marsh known as Goose lake. It lies partially in sections 21, 22, 26, 27 and 28, and covers an area of from 600 to 800 acres. Two test borings at widely separated points showed a depth of 12 and 13 feet, respectively, of clean, fibrous, fairly dry vegetable matter.

Near the west side of this same township a marsh, 150 to 180 acres in extent, covers portions of sections 18, 19 and 30. A boring near the middle of section 19 showed a depth of 8 feet of peat.

In the northeast corner of Fertile township, and extending across section 7 of Danville, is a broad slough that embraces 160 to 200 acres, and contains a depth of 13 feet of clean, solid peaty material.

The above marshes and others of smaller extent, make Fertile township a rich center for peat. They could all be worked from Hanlontown, the nearest railroad station from which the most distant bog is about five miles.

Rice lake, in Bristol township, is bordered with vegetable deposits some of which are very deep. At the east end there is an area of 200 acres in which the deposit tested 12 feet in depth. An arm of this lake covering several hundred acres extends towards the southwest into Winnebago county.

Two and one-half miles east of Joice a marsh covering 50 acres tested 7 feet of solid peat, and another good deposit lies nearer to the town.

The larger marshes of Bristol township are convenient to the Lake Mills area, in Winnebago county.

Northwood area.—In Hartland township a narrow slough extends for three miles along a creek in sections 33, 34 and 36. This area embraces more than 200 acres and tested 9 feet in depth. Along Goose creek, in sections 13, 14 and 15, a marsh nearly as large as the last tested 3 to 10 feet of vegetable material. This deposit is somewhat scattered along the creek but might become valuable if worked

*Trans. Am. Inst. of Mining Engineers, Vol. XXXV. p. 101. 1905.

†A sufficient number of borings to determine the average depth of the vegetable material in the different marshes could not well be made. However, the figures given represent actual measurements taken, and it is believed that they will be a fairly reliable guide with regard to the relative thickness of the peat deposits in the several marshes.

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in connection with the very large area around Grass lake, a short distance north of the state line.

Norman area.—A large quantity of peat covers the bed and fringes the border of Bright lake, within one mile of the town of Norman. A small marsh in section 36 of this township also contains a good depth of peat. A boring in the marsh at the east end of Silver lake passed through 13 feet of vegetable debris.

PEAT IN WINNEBAGO COUNTY.

One and one-half miles southwest of Norman, a grass-grown slough, covering between 200 and 250 acres in section 14 of Norway township, tested 5 feet of dense, brown colored peat.

Scarville area.—A marsh about one mile southwest of Scarville covers nearly 200 acres in section 22 and 23 of Logan township, and contains peat 7 feet in depth. South of Harmon lake, in section 21, a small marsh covers 50 acres, and at the north end of the lake, in sections 20 and 21, is another nearly equal in size. Both of these contain a good depth of vegetable debris.

Two miles southeast of Scarville a swampy area lying north of the railroad includes portions of sections 20, 21, 27 and 28 in Norway township. This marsh is not uniform in depth, but borings in section 28 showed a depth of 6 to 15 feet of peaty matter.

Lake Mills area.—The thriving town of Lake Mills, in Center township, is fortunately located for the production of peat. Swamps aggregating 800 to 1,000 acres surround the town at a distance of from one to three miles, and two lines of railroad afford good facilities for distributing the product.

In section 34 and 35 of Norway township, a marsh covers 200 acres and tested 10 feet of peat. A bog of 100 acres, in section 1 of Center township, extends east into Worth county, and tested 13 feet of accumulated vegetable matter. Marshes in sections 3 and 4, about one mile west of town, aggregate nearly 300 acres and showed peat to a depth of 8 to 15 feet.

A filled lake basin extends from the south end of lake Greeley to the west end of Rice lake. A few wooded islands occur over this marsh but the greater portion of the area is covered with a deposit of peat which, near the east end, tested 13 feet in depth. A marsh that lies across section 26 of Center township, in a northeast-southwest direction, represents the northeastward extension of Walnut lake. Near the middle of this swamp a boring passed through a depth of 13 feet of peat. Southeast of Walnut lake a marsh extends for two miles, invading the northeast corner of Mount Valley township. In section 1 of the latter township, a marsh covering 40 acres showed a maximum depth of 10 feet of vegetable matter.

Another swamp, embracing nearly 80 acres, covers a portion of sections 2 and 3 of the latter township and of section 34 of Center. This area tested 9 feet of peat. All of the marshes of Center township and those in the northeast corner of Mount Valley belong naturally

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to the Lake Mills area. In the process of excavating the peat a waterway could, with little expense, be opened to the northward from the latter marshes above described through those between Walnut lake and Rice lake and on through the bogs connecting Rice lake with lake Greeley. Through such a channel the peat from several hundred acres of swamp land could be brought to Lake Mills by water and there prepared for shipment.

Forest City area.—About five and one-half miles northeast of Forest City, a marsh covers nearly 200 acres in sections 16 and 17 of Mount Valley township. A boring towards the north side of this marsh showed 10 feet of clean, solid vegetable material. Other marshes, together covering more than 100 acres, in sections 28 and 33 of this township, showed a depth of 13 feet of plant debris. This latter area consists of narrow bogs separated by north and south ridges of morainic material. The peat seems to be very pure and the bogs are fairly dry.

Near the south side of section 32, Forest township, a marsh covers more than 100 acres and contains a depth of 3 to 4 feet of vegetable matter. There are other scattered bogs of small extent in this portion of the county.

Among the hills in sections 24 and 25 of Mount Valley township there is an irregular basin over which marshes cover an aggregate of 100 acres, and show a depth of 6 to 15 feet of peaty matter. This latter area would be most successfully worked in connection with the Goose lake marsh in Worth county.

Thompson area.—A series of small swamps, separated by wooded ridges, occur in sections 1 and 12 of King township and sections 7, 8 and 17 of Newton. Together these cover more than 300 acres, and show a depth of 4 to 10 feet of peat which is dry, firm and very pure.

MARSHES IN HANCOCK COUNTY.

Many of the larger marshes of the county occur over level prairies and contain but shallow deposits of impure peat.

Kanawha area.—Two miles northeast of Kanawha a large marsh covers 160 acres, in sections 22 and 23 of Amsterdam township. Borings over this area showed 3 to 4 feet of vegetable matter, while a well towards the north edge of the marsh is reported to have passed through 8 feet of peat.

A short distance south of East Twin lake a cat-tail slough covers a portion of section 29 and crosses section 32 of Twin Lake township. Tests near the margin indicated a depth of 3 to 5 feet of peaty matter. Much of this swamp is very wet, but the water could be drawn off to the eastward through the west branch of Iowa river into which stream the area has already been partially drained.

Duncan area.—About one mile southeast of the town of Duncan a large marsh of 600 acres covers a portion of section 33 of Garfield township and of sections 4 and 9 of German. A ditch through this swamp drains the water to the southward. In the sides of this ditch good, clean peat is exposed to a depth of 3 to 6 feet. A small deposit

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of peat also occurs along the east side of Eagle lake.

Miller area.—An unusually good deposit of peat occurs in a narrow slough one and one-half miles southeast of the town of Miller. The bog covers 200 acres and tested 10 feet of clean vegetable matter.

A marsh is reported near the northeast corner of Concord township, and small bodies of peat also occur along the east branch of Iowa river between Miller and Hayfield Junction.

PEAT DEPOSITS IN CERRO GORDO COUNTY.

Practically all of the marshes of Cerro Gordo county lie in the west tier of townships. They are surrounded by low, morainic hills, 20 to 50 feet in height. They are generally well drained, and contain peat deposits that range from 3 to 15 feet in depth. The peat is uniformly clean and solid, and appears to be of excellent quality.

Clear Lake area.—The city of Clear Lake is situated in the midst of a rich deposit of peat. In section 26 of Clear Lake township an ice formed embankment[1] has cut off a southward extending arm from the main body of the lake. Over this area a marsh, covering more than 80 acres, occupies portions of sections 26 and 35. Tests in this bog showed 10 to 12 feet of black peat. A short distance further south a drained marsh, 250 acres in extent, covers the southern portion of section 35 of Clear Lake township and section 2 of Union. Borings over this area showed a depth of 5 to 6 feet of vegetable matter. Still further south a swamp covers 300 acres in sections 11, 12, 13 and 14 of Union township; and another marsh about equal in extent occupies a portion of section 24. The last two bogs are fairly dry and contain exceptionally pure deposits in which tests showed solid peat 12 feet in thickness. In the southwest ¼ of section 23 is a drained marsh, 60 to 80 acres in extent, that tested 7 feet of clean peat.

About one mile south of Clear Lake city, an ice formed wall separates another large marsh from Clear lake. From this ridge a bog extends nearly three miles towards the southeast, covering nearly 600 acres. Borings near the north end of this marsh indicated a depth of 3 feet of vegetable matter and it is probable that the thickness increases further south.

One and one-half miles north of Clear Lake a large marsh, 400 acres in extent, occupies a portion of sections 1 and 2 of Clear Lake township and of sections 34, 35 and 36 of Grant. This marsh is well drained, and contains a fine deposit of peat that tested 5 to 7 feet in depth. From the southwest ¼ of section 34 a narrow slough extends two and one-half miles towards the southwest, and contains a good depth of peat. In the west half of section 6, Clear Lake township, a marsh, connecting with bogs in Hancock county, covers nearly 80 acres, and showed a depth of 6 to 10 feet of peat. A smaller marsh in section 29 of Grant township contains a good deposit. A large swamp covering 400 acres, in sections 21, 22 and 27 of Grant township,

[1] For an explanation of the manner in which these embankments were formed see Iowa Geol. Survey, Vol. VII, p. 135.

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tested 7 to 9 feet of vegetable matter, and a smaller one of 160 acres, in section 15, showed 5 feet.

A marsh of 200 acres covers a portion of section 25, and contains an excellent deposit of plant remains, 12 feet in depth.

Near the northwest corner of Grant township a good bog is reported, and a few promising marshes are found further east in the township of Lincoln.

Meservey area.—About one mile northeast of Meservey, a drained marsh covers 60 to 80 acres in section 28, Grimes township. Borings over this area showed 8 to 9 feet of clean, solid peat.

A large marsh in sections 19 and 20 is tile drained, and tested 7 feet of pure vegetable debris. In section 3, a marsh of 60 acres showed 5 to 7 feet of peat. The peat deposits around Meservey are small, but in quality they rank among the best in the state.

PEAT AREAS IN WRIGHT COUNTY.

Clarion area.—About five miles north of Clarion a grassy marsh, lying partly in section 1 of Lake township and partly in section 6 of Grant, covers nearly 100 acres, and contains clean vegetable material to a depth of 9 feet.

Small bodies of peat, a few acres in extent and 3 to 6 feet in depth, occur between the above mentioned marsh and Little Wall lake. Other small marshes lie within a short distance north and east of Cornelia; while vegetable matter 2 to 3 feet in depth fringes a portion of the east side of Elm lake.

Dows area.—One mile west of Dows a number of disconnected swamp areas, aggregating nearly 100 acres, occupy portions of sections 27, 34 and 35 in Blaine township. Borings at different points over this area showed 4, 8 and 9 feet of clean, almost dry peat.

About five miles southwest of Dows a bog of 80 acres has been drained and, at one time, put under the plow. Tests over this marsh indicated 5 to 9 feet of vegetable matter.

Large marshes occur in the northeast $\frac{1}{4}$ of Wall Lake township, but the peat is shallow and carries quite a large percentage of earthy matter.

MARSHES OF FRANKLIN COUNTY.

About two miles northeast of Dows, and conveniently worked with that area, a swamp of 100 acres covers a portion of sections 20 and 28 of Morgan township. It contains peat of fair quality, ranging from 5 to 15 feet in depth.

Near the north side of Lee township a marsh known as the "Big Slough" covers several hundred acres. This area was not tested, but it is reported to contain a good deposit of peat.

PEAT DEPOSITS IN EMMET COUNTY.

Armstrong area.—In the southern portion of Iowa Lake town-

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ship a large marsh covers from 800 to 1,000 acres. The area lies about two miles north of Armstrong. It is well drained, and contains a depth of 7 to 9 feet of clean, solid peat.

MARSHES IN PALO ALTO AND CLAY COUNTIES.

An extensive area of marsh land lies about four miles north of Ruthven, embracing a portion of sections 19, 20, 29 and 30 of Lost Island township, in Palo Alto county, and of sections 25 and 26 of Lake township, in Clay. This marsh covers more than 1,500 acres. Tests over the south end indicated about 7 feet of vegetable debris.

At the outlet of Lost Island lake, in Clay county, there is a marsh of 200 to 300 acres that contains peat, but on account of the water the depth of the deposit could not be ascertained.

Small bodies of peat occur at the west end of Elbow lake and Virgin lake, in Palo Alto county, and a few small marshes are found both to the north and south of Ruthven.

GENERAL STATEMENT.

The greater number of the marshes mentioned above are almost dry. In some cases no water was reached at a depth of 9 or 10 feet. This dryness is partially due to artificial drainage and partly to prevailingly more arid conditions than formerly existed. Many of the areas support a heavy growth of sedges and slough grass and are utilized for wild meadow or pasturage, while a few have been put under the plow.

Although there is quite a wide range in the character of the peat found in these marshes, the most of it is somewhat fibrous, brown in color, and consists of very pure vegetable debris, with scarcely a trace of mud. It also showed very little evidence of oxidation due to the drying of the bogs and the resulting exposure to the air.

The fortunate distribution of the marshes with reference to towns is shown on the accompanying map. The railroad advantages of the respective points may be seen by referring to the map of the state published and distributed by the Iowa Railroad Commissioners.

Several million tons of peat are accessible from Clear Lake, Lake Mills, Dows, Hanlontown and Armstrong, while important quantities are convenient to the towns of Meservey, Scarville, Norman, Northwood, Forest City, Thompson, Duncan, Miller, Clarion and Ruthven. A railroad passes through each of these towns. Lake Mills, Forest City and Ruthven are supplied with two lines. Two branches also connect at Dows; while an electric line in addition to the railroad gives to Clear Lake practically all of the advantages of two lines of road.

USES OF PEAT.

The uses to which peat has been applied are many and varied. It has been used extensively as a fuel. It has been burned into coke

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and charcoal, and is being successfully converted into gas.

The undecayed upper portion of bogs furnishes "moss litter" which on account of its high powers of absorption for liquids and gases, finds a wide use as a deodorizer and disinfectant. When ground into fine meal peat is used for making antiseptic bandages, and for packing eggs, meat and fruit. Peat dust has been used as a substitute for charcoal in the manufacture of gunpowder, and, when mixed with India rubber and sulphur, it is used for insulating electric cables. Peat pulp is being used in place of straw and wood pulp in the manufacture of paper, card board and the coarser grades of paper board.

As a fertilizer applied to sandy soils, peat adds warmth, increases the moisture, and promotes the solubility of the minerals of the soil.

For the people of Iowa the greatest interest will attach to the use of peat as a fuel and as a future source of producer-gas.

PEAT AS A FUEL.

Peat burns with a short, yellow flame and intense heat. It burns without scot, with little smoke, with no unhealthful gases, and leaves no clinker. It requires little draft, is easily ignited and, once lighted, will continue to burn until all the fuel is consumed. It is especially suited for culinary purposes because of its cleanliness, and on account of the fact that a peat fire quickly reaches a high temperature.

Peat is not only a valuable domestic fuel, but, in Europe, in the solid or gaseous form, it is widely used in metallurgical purposes, in steel and glass furnaces, for firing locomotive boilers and for generating electric power. Boilers using peat fuel are estimated to last three times as long as those fired with coal.

The heating power of unprepared peat compared with that ot other fuels is given in Thurston's Elements of Engineering as follows:

Table showing calorific power of peat and other fuels.

Fuel.	Calorific power.		Water vaporized at boiling point. Parts by one part.
	Relative.	Absolute B. T. U. per lb.	
Coal, anthracite	1.020	14,833	14.98
Coal, bituminous	1.017	14,796	14.95
Coal, lignite, dry	0.700	10,150	10.35
Peat, kiln dried	0.700	10,150	10.25
Peat, air dred	0.526	7,650	7.73
Wood, kiln dried	0.551	8,029	8.10
Wood, air dried	0.439	6,385	6.45

From the above table it will be seen that unprepared peat has a higher heating value than wood, but is inferior to coal. The American Society of Mechanical Engineers estimate 2.5 tons of pine wood to possess equivalent heating power to 1.8 tons of ordinary air-dried peat, and to 1 ton of anthracite coal. The German Chemical Testing Station of Berlin reports the fuel value of peat briquettes at 13,330 B. T. U. per pound.* The average is probably about 8000 to 11,000 B. T. U.

*Morrison: Address before the Nat'l Association of Engineers The calorific value of peat briquettes, like that of different coals, will vary within wide limits. See Trans. Am. Inst. of Mining Engineers, Vol. XXXV, p. 104, and Special Consular Reports, Vol. XXVI, p. 116.

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In the countries of Europe peat has been extensively used as a fuel for a very long time. Both Germany and Sweden produce 2,000,000 tons of peat each year, and Russia 4,000,000 tons. In Scotland and Ireland large quantities are annually consumed. The people of Holland prefer peat fuel in their brick yards and for domestic purposes. The large bogs of Russia are owned by the government, and permits for working them yield an annual revenue of $938,000. Germany is said to possess greater wealth in her peat bogs than in her coal fields. In Austria and Denmark peat has long been an important article of fuel, while, in recent years, large quantities of peat fuel are annually prepared in the province of Ontario, Canada.

In the United States the peat fuel industry has been largely neglected on account of the wide extent of her coal fields and the fortunate distribution of these deposits which has made an abundance of excellent fuel generally accessible at a moderate cost.

PREPARATION OF PEAT FOR FUEL.

There are three general methods of preparing peat, which result in the following forms of peat fuel:

(1) "cut peat"; (2) pressed or "machine peat"; and (3) peat briquettes.

CUT PEAT.

"Cut peat" is prepared in the simplest possible manner and forms the poorest grade of peat fuel. Blocks of crude material are cut out from the bog, dried in the air and burned without further treatment. One man can cut about one and one-fourth tons of dry peat per day. Six or eight weeks are required for drying and, when dried under the most favorable conditions, such peat will still contain as much as 30 per cent of water. The material is so loose and bulky that it is difficult to fire properly into a stove or furnace, and the large amount of water in the fuel makes it of low heating value.

On account of its cheapness "cut peat" is the staple fuel for a large number of the poorer people of Europe, but it would not prove a satisfactory fuel to persons accustomed to burning wood or coal.

MACHINE PEAT.

"Machine peat" is prepared by grinding the crude peat into a pulp while wet and then cutting or moulding or pressing the material into blocks. The blocks can be dried in the air in from six to eight weeks, or by artificial heat in a much shorter time. The grinding or maceration of the peat greatly facilitates the escape of moisture and causes "machine peat" to dry much more perfectly than "cut peat;" the blocks contracting to about two-thirds of their original volume. By the process of grinding a self-binding property is developed which causes the blocks to become dense and hard and practically waterproof. Dried "machine peat" can remain out doors without injury and be shipped long distances without crumbling.

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"Machine peat" is suitable not only for domestic use but for almost any purpose to which bituminous coal is applied. When air-dried, it contains 15 to 25 per cent of water,* while the water content of Iowa coal varies from 13 to 19 per cent. However, the more perfect combustion of the peat and the absence of soot in the flues tend to offset its disadvantage as a fuel on account of the larger amount of water it contains.

During 1903, the Swedish government conducted numerous fuel tests in locomotive engines which showed that, except for its bulkiness, "machine peat" could be fired in the engines with as good results as English coal, and with little more labor, and that when mixed with coal a fire superior in calorific value to either of the fuels alone was produced.†

All of the better classes of mills for making "machine peat" employ much the same principles. They consist of a hollow iron cylinder encasing a set of revolving cutters for thoroughly grinding, kneading and mixing the crude peat. Rollers set with screw ridges force the material past the cutters and out through the nozzle in a long cylindrical or rectangular rod, which is cut into blocks of desired size.

Cost of mills.—The Ackerman machine, used extensively in Sweden, requires an 18-horsepower engine and the help of 15 men. It can produce 20 to 25 tons of "machine peat" per day at a cost of $1.35 per ton, laborer's wages at $1.00 per day. The complete equipment of such a plant costs about $1,900.

The Anrys or Anrep machine, preferred in Russia, is built in two sizes, the larger producing 40 to 60 tons per day, with 38-horsepower engine and employing 28 men. This machine costs $1,900, exclusive of power plant. The smaller type produces 20 tons per day, with 19-horsepower engine and 13 men, and is sold for $830, without power plant. With these machines the working costs per ton of dried fuel are about 80 cents.

Another machine, coming into wide use in Sweden, is made in sizes ranging in capacity from 20 to 40 tons per day, and costing from $215 to $675, exclusive of power plant. German machines are quite similar to those employed in Sweden, and produce one and one-half to two tons of peat fuel per man per day. In Denmark a plant of 65 tons daily capacity is manufacturing "machine peat" at a cost of 60 cents per ton, with laborers' wages $1.33 per day.‡

The Atkinson-Norton machine, perfected and used by Prof. C. L. Norton, of the Massachusetts Institute of Technology, in making tests on peat, will produce 5 to 10 tons of "machine peat" per day with a 2-horsepower motor. The machine alone costs about $75. The entire cost of a plant equipped with a larger machine of this type, having a daily capacity of 20 tons, is estimated at $2,500.

On account of the greater bulkiness and somewhat lower heating

*Special Consular Reports, Vol. XXVI. p. 136. 1903.
†13th Report Ontario Bureau of Mines, p. 34, 1904.
‡Special Consular Reports, Vol. XXVI, p. 138. 1903.

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value of "machine peat" compared with good coal, it is not probable that this form of fuel will become widely used in the state. It seems certain, however, that a farmer having good peat deposits on his land or, better still to insure a wider demand for the fuel, a number of men could jointly install a small "machine peat" fuel plant, at a cost of a very few hundred dollars, and by operating such a plant during the autumn months they could supply a local demand for domestic fuel at a price very much below that at present paid for coal. While this form of peat is slightly inferior to good coal, yet it possesses a higher heating value than wood and, burned in peat stoves, would prove a satisfactory and very economical domestic fuel.

PEAT BRIQUETTES.

In the more approved peat briquetting plants the peat is dug, pulverized and spread by a mechanical excavator, and is dried in the air to a water content of 30 to 45 per cent. The air-dried peat is then passed through a disintegrator in which the fragments are beaten into small bits and the tissues thoroughly crushed in order to facilitate the further liberation of moisture. This broken peat is then conveyed to the dryer in which it is subjected to artificial heat until not more than 12 to 15 per cent of moisture remains. From the drying pan it is carried to the hopper and cooled, and thence conveyed to the briquetting press. Two general types of presses are in use; one consists of an open tube, and the other of a closed die resting on a solid base. The latter type has proved the most satisfactory. Pressure of 11 to 13 tons per square inch is applied, and the resulting briquettes are dense and solid, and have a heating efficiency equal to the best grades of Iowa coal.* Peat briquettes absorb moisture readily and hence must be kept dry.

In Holland the cost of production of peat briquettes is from $2.00 to $2.15 per ton. At Welland and Beaverton, Ontario, peat briquettes are being made for about $1.50 per ton, and are sold for $3.50 per ton at the works.† At the Beaverton plant "cut peat" was found to be a cheaper fuel for use under the boiler and dryer than good wood at $1.30 per cord.

The Beaverton is one of the oldest and most successful peat briquetting plants in America. Estimate of the cost of the complete equipment of a peat fuel plant, similar to the Beaverton, with a capacity of 3,000 tons of briquettes per year, running ten hours a day, or 6,000 to 7,000 tons when working continuously, is furnished as follows:‡

Briquette press, die or mould type	$ 2,500.00
Dryer	1,350.00
Breaker or disintegrator	400.00
Excavator, including motor	600.00
Generator, tram car, motor and tracks	1,200.00
Engine and boiler, 50-horsepower	2,000.00
Shafting, belts and conveyors	700.00
Buildings (brick)	1,500.00
Sundries	200.00
Total	$10,450.00

*For the calorific value of a number of Iowa coals see this Bulletin, pp 25-27; and also Iowa Geol. Surv., Vol. XIV, p. 37'.
†13th Report Ontario Bureau of Mines, p. 27, 1904
‡12th Report Ontario Bureau of Mines, p. 225, 1903.

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Some of the above items could probably be reduced, but the estimate may prove of value as a guide to the cost of a peat briquetting plant that has been proven successful by years of experience. The total cost of a plant with a capacity of 15 tons per day, or 30 tons working night and day shifts, is estimated at a little less than $28,000.

SPECIAL APPARATUS FOR BURNING PEAT.

In making comparative tests between peat and coal it is important that the peat should be burned in a stove adapted for this fuel. Peat briquettes are so similar to coal that they can be burned in stoves suitable for using the latter. However, a screen should be placed over the grate to prevent waste, and care exercised in the regulation of the draft. When peat is used under a boiler the grate bars should be reduced one-half, and both the grate and the fire wall behind it should be raised closer to the boiler, than for coal, on account of the short flame of burning peat.

Special stoves have been designed for burning "machine peat" which possess a heating efficiency of 90 per cent. The upper part consists of a chamber into which the fuel is stored and from which it is fed to the fire automatically through a trap door at the bottom. The fire box is V-shaped, with perforated sides. Through these holes the air enters in such a way that the draft is never choked and there is no loss from unconsumed fuel. The ashes accumulate in the trough of the fire box, by shaking which they are dropped to the pan below. Tests with such stoves in midwinter showed that a continuous fire could be kept for 96 hours on 46 pounds of "machine peat," by firing seven times at intervals of twelve to fifteen hours; an even and suitable temperature being maintained in the rooms during the time.*

PEAT AS A SOURCE OF PRODUCER GAS.

Prof. C. L. Norton of the Massachusetts Institute of Technology, says that gas can be produced from New England peat in about the same amounts and of much the same kind as that obtained from bituminous coal. He suggests that it is as a source of producer-gas that we must look for the greatest development of the peat fuel industry. A test of "machine peat" from a bog near Taunton, Mass., gave 4 cubic feet of gas with a calorific power of 654 B. T. U. per cubic foot, from each pound of peat.[1]

The advantages of using peat as a gaseous fuel pertain equally to the burning of coal gas.[2] The use of solid peat fuel involves a loss of 25 to 30 per cent of heat, which heat loss may be reduced as low as 15 per cent by first converting the peat into gas and then burning the gas.

In the iron and steel industry peat gas is preferred above coal gas on account of its greater freedom from sulphur and phosphorus. It is also coming into extensive use as a fuel for steam boilers.

*12th Report Ontario Bureau of Mines, p. 227, 1903.
[1]Norton: Report No. XV. on Bog Fuel. Insurance Engineering Exp't Station p. 10 1904
[2]See this bulletin, pp. 37 and 38

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It has been found that, for industrial purposes, by locating the power plant at the bog, peat can be converted into gas and the gas used as a fuel more economically than solid peat, for the reason that "cut peat"—the cheapest kind of peat fuel—can be successfully converted into gas without any previous treatment. The peat gas can be conveyed through pipes to the place of consumption, or it may be converted into electrical energy and transmitted in that form to more distant points. In such plants the cost of fuel has been estimated at only one-ninth of a cent per horsepower per hour.[1]

Tests on the fuel value of peat gas made by the Merrifield generator from "cut peat" fuel showed an average of about 135 B. T. U. per cubic foot of gas.

Cost of gas plants.—With regard to plants for the production of peat gas the following estimate* is made: one ton of compressed peat analyzing approximately: moisture 15 per cent, ash 7 per cent, fixed carbon 21 per cent, and volatile matter 57 per cent, will yield not less than 100,000 cubic feet of fixed gas, carrying not less than 150 B. T. U. per cubic foot. Peat carrying up to 30 per cent of water may be used, but the yield of gas will be reduced about 1,000 cubic feet for every additional 1 per cent of moisture. Complete apparatus and material for equipping such a plant, producing not less than 20,000 cubic feet of gas per hour, will cost about $5,000.

THE PEAT INDUSTRY IN IOWA.

Little has been done towards utilizing the peat deposits in our state. Small quantities of "cut peat" have been burned at Lake Mills, Ruthven, Meservey and a few other points.

At Dows, Iowa, the Iowa Fuel and Brick Company has been preparing peat fuel in a small way for the past two years. In 1904 several tons of "cut peat" were taken from the bog, while during the past year they have been doing pioneer work in the manufacture of "machine peat" fuel. The process they follow consists in mixing and pressing the crude peat in a brick machine and drying the bricks in the air. The dried blocks are quite dense and do not crumble when handled. About 75 tons of peat fuel have been prepared in this way during the past summer.

Mr. Henry Lemke, of Dows, the secretary of the company, estimates the cost of preparation of peat bricks in the present condition of the plant at $2.50 per ton, but he feels confident that the expense can be reduced to $1.50 per ton, or less. He states that there is a good demand, at $3.00 per ton, for all the peat bricks they can produce; that people who once use them for fuel always come back for more.

CONCLUDING REMARKS.

It is not expected that the peat fuel industry will immediately be developed in Iowa on a large scale. It will require time for the people

[1]Special Consular Reports, Vol. XXVI, p. 140, 1903.
*12th Report Ontario Bureau of Mines, p. 231, 1903.

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to become assured that peat fuel, even at the cheaper cost of production, can be more profitably burned than coal. It is possible, too, that peat may only become popular as a fuel in that portion of the state remote from coal supplies and where deposits of peat are abundant.

Doubtless the vegetable matter in the various marshes will differ very materially with regard to its suitability for successful manufacture into a good grade of peat fuel. It would be wise to have thorough tests and analyses made of any deposit before attempting to exploit it commercially. Peat samples for tests and analyses should be sent to the State Geologist, Dr. Frank A. Wilder, at Iowa City, Iowa, who will see that proper tests are made and the results of the same reported. Prof. C. L. Norton of the Institute of Technology, Boston, Mass., will also test keg samples of peat, sent by freight prepaid to the above address, and report on the quality of the peat, and to what extent it is adapted for being worked in the common types of "machine peat" mills.

Until the use of peat fuel becomes pretty well established, it is probable that small peat manufacturing plants located at a number of favorable points will prove more successful, in Iowa, than those of large capacity and very expensive equipment.

There seems no reasonable doubt that the time will come when prepared peat fuel will become an important article of manufacture in the state; and that the hitherto neglected peat deposits of northern Iowa will prove a source of domestic fuel but little inferior to, and even less expensive than, the fuel supply in what we have been accustomed to consider the more favored portions of our state. Neither is it impossible that cities like Clear Lake, Lake Mills, Armstrong and Dows, convenient to large peat-bearing marshes, may yet the most economically obtain their supply of heat, light and power from plants that convert peat fuel into producer-gas.

NOTE—Inasmuch as large sums of money have been practically wasted in recent years through the formation of companies to utilize peat beds, it would be wise for intending operators to confer with those in Canada, who have a thorough knowledge of the practical manipulation of peat, before investing in a stock company to exploit untried patent processes or new appliances. This office will be glad to render all possible assistance with regard to determining adaptability of deposits for fuel purposes, methods of working peat, cost of machinery, etc.

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REPORT ON THE TESTS OF IOWA COALS MADE BY THE GOVERNMENT COAL-TESTING PLANT AT THE LOUISIANA PURCHASE EXPOSITION, ST. LOUIS, MO., 1904.

BY

T. E. SAVAGE.

PRELIMINARY STATEMENT.

An act of congress making appropriations for the fiscal year 1905, which was approved February 18, 1904, contained an item which provided for the analyzing and testing of the coals and lignites of the United States in order to determine their fuel values and the most economic method for their utilization. These tests were to be conducted at the Louisiana Purchase Exposition, St. Louis, Mo., under the supervision of the Director of the United States Geological Survey. One of the provisions of this law was that all coal offered for testing purposes should be furnished to the testing plant at St. Louis free of cost to the Government.

The coal-testing plant was equipped with standard apparatus, and with the most approved and accurately calibrated instruments for making steaming tests, washing tests, coking tests, briquetting tests and producer-gas tests, besides chemical analyses and calorimetric determinations.

The above act for the first time made it possible for coal from all of the coal fields of our country to be brought to a single well equipped plant and be put through an elaborate and expensive series of tests; and that, too, under absolutely uniform conditions and by the same corps of trained experts whose position guaranteed the greatest accuracy of work and a true and impartial statement of results. From such a series of tests the adaptability of the coal from any mine or coal field for a particular purpose can be determined, and the coal intelligently used in the way in which its highest efficiency may be secured. The comparative fuel value of the coal of different states can also be ascertained as never before.

A preliminary report on the work done by this coal-testing plant during 1904 has been recently published by the United States Geological Survey, as Bulletin No. 261. The descriptions of the several tests and the tables of results which appear on the following pages were taken from that report.

SECURING THE SAMPLES.

The Director of the Iowa Geological Survey recognized at once the value such a series of tests would be to the coal operators of the

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state as well as to every user of coal. He early made arrangements to co-operate with the United States Survey, and to have a number of samples of Iowa coal tested at the Government plant. He selected and secured the donation of five car loads of coal from as many important mines in Iowa, and through the generosity of the railroad companies he was able to deliver four of these lots of coal to the testing plant at St. Louis without any charges for transportation. The freight on the fifth car was paid by the Iowa Survey.

Below is given a list of the Iowa operators who donated a car load of coal for testing purposes, the grade of coal provided by each, and the number and location of the mine from which the sample was taken.

Name of sample.	Operator.	Mine.	Location.	Grade of coal.	Name of bed
Iowa 1	Anchor Coal Co., Ottumwa, Ia.	No. 2	Laddsdale, Ia.	Over ¼ inch screen.	Middle bed.
Iowa 2	Mammoth Vein Coal Co., Hamilton, Ia.	No. 5	Liberty Twp., Marion Co., Ia.	Run of mine.	Big vein.
Iowa 3	Gibson Coal Mining Co., Des Moines, Ia.	No. 4	Near Altoona, Polk Co., Ia.	Over ⅓ inch screen.	Third vein.
Iowa 4	Centerville Block Coal Co., Centerville, Ia.	No. 3	Centerville, Appanoose Co., Ia.	Over 1⅜ inch screen.	Lower bed.
Iowa 5	Inland Fuel Co., Chariton, Ia.	No. 1	Chariton, Lucas Co., Ia.	Run of mine.	Lower bed.

COLLECTING THE SAMPLES.

The writer accompanied the representative of the United States Geological Survey in supervising the loading of the car lots of coal that were sent to St. Louis from Iowa, and in securing the samples from the mines for chemical analysis. Care was taken in each case to obtain coal for testing purposes that represented as near as possible the actual output of the mine.

From each of the mines from which a car of coal was shipped to be tested, two samples were taken for chemical analysis. These samples were obtained from points in the mine quite widely separated. They were cut from the full section of the working faces of the seam mined at the time the car was loaded, and were immediately sent to the St. Louis laboratory by mail in air-tight cans. The two coal samples that were collected at the mine for chemical analysis are referred to in the tables which follow as "mine sample A" and "mine sample B" respectively.

As each car load of coal, sent to the plant for testing, was unloaded at St. Louis, a third sample was taken for chemical analysis which

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represented the coal actually contained in the car to be tested. This sample is designated in the following tables as the "laboratory car sample."

As the coal was distributed to the testing divisions samples were taken at frequent intervals, quartered down, and analyzed. In this way at least six separate samples from each car of coal were obtained at the plant, and two at the mine.

CHEMICAL ANALYSES AND CALORIMETER DETERMINATIONS OF THE IOWA COALS TESTED.

Proximate analyses were made on each sample of coal taken and an ultimate analysis was made on each car sample. Calorimeter determinations were made on one mine sample and also on each car sample. It is safe to say that such a series of coal analyses has never before been obtained.

METHODS OF ANALYSIS

"The methods employed in the coal analyses were essentially those recommended by the committee of the American Chemical Society. The moisture was determined by drying the weighed sample for one hour in an air bath at 105° C. The calorific value was determined in the Mahler bomb calorimeter. The actual value of the result in the calorimeter was corrected for the sulphuric acid formed in the bomb.

In calculating the calorific value from the ultimate analyses the calorific value of hydrogen, carbon, and sulphur was taken as, respectively, 34,460, 8,080 and 2,250 calories."

The results of the analyses of the "mine" and "laboratory car" samples, and of the calorimeter determinations appear in the accompanying tables.

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CHEMICAL ANALYSES OF IOWA COALS TESTED.

Analyses of mine and laboratory car samples of coal.

	Iowa No. 1.		
	Mine sample B.	Mine sample A.	Laboratory car sample.
Loss of moisture on air drying	7.90	8.00	3.20
Analysis of air-dried sample.			
Prox. Moisture	3.74	4.43	5.21
Prox. Volatile matter	41.96	40.52	31.76
Prox. Fixed carbon	42.89	41.65	46.51
Ash	11.41	13.40	16.52
Sulphur	5.12	5.42	5.20
Ultimate. Hydrogen	....	....	4.61
Ultimate. Carbon	....	....	61.80
Ultimate. Nitrogen	....	....	0.97
Ultimate. Oxygen	....	....	10.90
Calorific value determined:			
Calories	6,843	....	6,329
British thermal units	12,317	....	11,392
Calorific value calculated from ultimate analysis:			
Calories	....	....	6,230
British thermal units	....	....	11,214
Analysis corrected to sample as received			
Prox. Moisture	11.35	12.07	8.24
Prox. Volatile matter	38.65	37.28	30.74
Prox. Fixed carbon	39.49	38.32	45.02
Ash	10.51	12.33	16.00
Sulphur	4.72	4.99	5.03
Ultimate. Hydrogen	....	....	4.81
Ultimate. Carbon	....	....	59.82
Ultimate. Nitrogen	....	....	0.94
Ultimate. Oxygen	....	....	13.40
Calorific value determined:			
Calories	6,303	....	6,126
British thermal units	11,345	....	11,027
Calorific value calculated from ultimate analysis:			
Calories	....	....	6,031
British thermal units	....	....	10,856

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Analyses of mine and laboratory car samples of coal—Continued.

	Iowa No. 2.			Iowa No. 3.		
	Mine sample B.	Mine sample A.	Laboratory car sample.	Mine sample B.	Mine sample A.	Laboratory car sample.
Loss of moisture on air drying..	9.30	9.50	10.40	9.60	11.00	9.80
Analysis of air-dried sample.						
Prox. Moisture	7.00	6.63	4.25	5.33	5.51	4.52
Prox. Volatile matter	40.65	40.82	37.02	41.82	42.04	40.96
Prox. Fixed Carbon	39.52	42.40	41.74	40.69	3 55	38.99
Prox./Ultimate. Ash	12.83	10.15	16.99	12.16	13.90	15.53
Ultimate. Sulphur	5.49	5.74	5.20	6.52	7.59	6.83
Ultimate. Hydrogen	....	....	4.84	....	....	4.93
Ultimate. Carbon	....	....	60.36	....	....	60.62
Ultimate. Nitrogen	....	....	1.46	....	....	0.93
Ultimate. Oxygen	....	....	11.15	....	....	11.16
Calorific value determined:						
Calories	6,302	....	6,212	6,539	....	6,309
British thermal units	11,344	....	11,182	11,770	....	11,856
Calorific value calculated from ultimate analysis:						
Calories	....	....	6,183	....	....	6,271
British thermal units	....	....	11,129	....	....	11,288
Analysis corrected to sample as received.						
Prox. Moisture	15.65	15.50	14.21	14.42	15.90	13.88
Prox. Volatile matter	36.87	36.94	33.17	37.81	37.42	36.94
Prox. Fixed carbon	35.84	38.37	37.40	36.78	34.41	35.17
Prox./Ultimate. Ash	11.64	9.19	15 22	10.99	12.37	14.01
Ultimate. Sulphur	5.10	5.19	4.66	5.89	6.76	6.15
Ultimate. Hydrogen	....	....	5.50	....	....	5.52
Ultimate. Carbon	....	....	45.08	....	....	54.68
Ultimate. Nitrogen	....	....	1.31	....	....	0.84
Ultimate. Oxygen	....	....	19.23	....	....	18.80
Calorific value determined:						
Calories	5,716	....	5,566	5,911	....	5,691
British thermal units	10,239	....	10,019	10,640	....	10,244
Calorific value calculated from ultimate analysis:						
Calories	....	....	5,540	....	....	5,656
British thermal units	....	....	9,972	....	....	10,181

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Analyses of mine and laboratory car samples of coal—Continued.

	Iowa No. 4.			Iowa No. 5.		
	Mine sample B.	Mine sample A.	Labora-tory car sample.	Mine sample B.	Mine sample A.	Labora-tory car sample.
Loss of moisture on air drying..	9.40	8.60	4.50	9.40	7.10	6.80
Analysis of air-dried sample.						
Prox. Moisture	8.53	8.25	10.03	10.25	12.37	9.22
Prox. Volatile matter	39.12	38.23	37.27	35.10	36.98	32.71
Prox. Fixed carbon	44.55	41.40	41.22	46.12	42.95	44.52
Prox. / Ultimate. Ash	7.80	12.12	11.48	8.53	7.70	13.55
Ultimate. Sulphur	4.42	5.21	4.46	2.64	3.34	3.42
Ultimate. Hydrogen	....	....	5.31	....	....	5.35
Ultimate. Carbon	....	....	61.25	....	....	59.89
Ultimate. Nitrogen	....	....	0.94	....	....	1.22
Ultimate. Oxygen	....	....	16.56	....	....	16.57
Calorific value determined :						
Calories	6,703	....	6,237	6,442	....	6,105
British thermal units	12,065	....	11,227	11,596	....	10,989
Calorific value calculated from ultimate analysis :						
Calories	....	....	6,165	....	....	6,045
British thermal units	....	....	11,097	....	....	10,881
Analysis corrected to sample as received.						
Prox. Moisture	17.13	16.14	14.08	18.69	18.59	15.39
Prox. Volatile matter	35.44	34.94	35.59	31.80	34.36	30.49
Prox. Fixed carbon	40.36	37.81	39.37	41.78	39.90	41.49
Prox. / Ultimate. Ash	7.07	11.08	10.96	7.73	7.15	12.63
Ultimate. Sulphur	4.00	4.76	4.26	2.39	3.10	3.19
Ultimate. Hydrogen	....	....	5.57	....	....	5.74
Ultimate. Carbon	....	....	58.49	....	....	55.81
Ultimate. Nitrogen	....	....	0.90	....	....	1.14
Ultimate. Oxygen	....	....	19.82	....	....	21.49
Calorific value determined :						
Calories	6,073	....	5,957	5,836	....	5,690
British thermal units	10,931	....	10,723	10,505	....	10,242
Calorific value calculated from ultimate analysis :						
Calories	....	....	5,888	....	....	5,634
British thermal units	....	....	10,598	....	....	10,141

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For purposes of comparison with the Iowa coals there are given below the analyses of two samples of Illinois coal and two samples from Missouri.

Analyses of mine and laboratory car samples of coal—Continued.

	Illinois No. 3.			Illinois No. 6.		
	Mine sample A.	Mine sam B.	Laboratory car sample.	Mine sample A.	Mine sample B.	Laboratory car sample.
Loss of moisture on air drying,	1 50	1.80	2.70	5.60	4.00	
Analysis of air-dried sample.						
Prox. Moisture	6.00	5.63	5 98	9.84	10.35	5.13
Prox. Volatile matter	32.16	34.93	30.29	36.86	35.35	32.68
Prox. Fixed carbon	54.49	51.78	52.16	44.96	42 94	47.46
Prox. / Ultimate. Ash	7.26	7.67	11.59	8.34	11.36	14.73
Ultimate. Sulphur	1.00	2.08	1.77	3.82	3.95	4.45
Ultimate. Hydrogen	....	....	4.92	....	....	4.88
Ultimate. Carbon	....	....	67.30	....	....	60.51
Ultimate. Nitrogen	....	....	1.43	....	....	1.23
Ultimate. Oxygen	....	....	12.99	....	....	14.20
Calorific value determined:						
Calories	6,986	....	6,724	6,483	....	6,199
British thermal units	12,565	....	12,103	11,669	....	11,158
Calorific value calculated from ultimate analysis:						
Calories	....	....	6,615	....	....	6,059
British thermal units	....	....	11,907	....	....	10,906
Analysis corrected to sample as received.						
Prox. Moisture	7.50	7.34	8.50	14.89	13.94	14.43
Prox. Volatile matter	31.68	34.29	29.47	34.80	33 93	29.48
Prox. Fixed carbon	53.67	50.84	50.75	42.44	41.22	42.81
Prox. / Ultimate. Ash	7.15	7.53	11.28	7.87	10.91	13.28
Ultimate. Sulphur	0.99	2 04	1.72	3.61	3.79	4.01
Ultimate. Hydrogen	....	....	5.09	....	....	5.49
Ultimate. Carbon	....	....	65.48	....	....	54.59
Ultimate. Nitrogen	....	....	1.39	....	....	1.11
Ultimate. Oxygen	....	....	15.04	....	....	21.52
Calorific value determined:						
Calories	6,881	....	6,542	6,120	....	5,591
British thermal units	12,386	....	11,776	11,016	....	10,064
Calorific value calculated from ultimate analysis:						
Calories	....	....	6,436	....	....	5,465
British thermal units	....	....	11,585	....	....	9,837

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Analyses of mine and laboratory car samples of coal—Continued.

	Missouri No. 2.			Missouri No. 4.		
	Mine sample A.	Mine sample B.	Laboratory car sample.	Mine sample A.	Mine sample B.	Laboratory car sam
Loss of moisture on air drying.	6.20	5.00	2.60	7.40	6.00	7.70
Analysis of air-dried sample.						
Prox.: Moisture	9.10	8.31	9.14	6.42	4.86	5.39
Volatile matter	41.07	38.47	34.53	40.73	43.74	44.91
Fixed Carbon	41.53	42.00	39.02	45.39	44.86	44.47
Prox. and Ultimate: Ash	8.30	11.22	17.31	7.46	6.54	5.23
Ultimate: Sulphur	4.04	4.03	5.30	5.46	5.32	5.55
Hydrogen	....	....	4.96	....	....	5.77
Carbon	....	....	56.25	....	....	72.45
Nitrogen	....	....	0.99	....	....	0.75
Oxygen	....	....	15.19	....	....	10.25
Calorific value determined:						
Calories	6,625	....	5,806	6,962	....	7,516
British thermal units	11,925	....	10,451	12,532	....	13,529
Calorific value calculated from ultimate analysis:						
Calories	....	....	5,719	....	....	7,526
British thermal units	....	....	10,294	....	....	13,547
Analysis corrected to sample as received.						
Prox.: Moisture	14.74	12.90	11.50	13.34	10.57	12.67
Volatile matter	38.53	36.54	33.63	37.72	41.11	41.45
Fixed Carbon	38.95	39.90	38.01	42.03	42.17	41.05
Prox. and Ultimate: Ash	7.78	10.66	16.86	6.91	6.15	4.83
Ultimate: Sulphur	3.79	3.83	5.16	5.06	5.00	5.12
Hydrogen	....	....	5.12	....	....	6.18
Carbon	....	....	54.79	....	....	66.87
Nitrogen	....	....	0.96	....	....	0.69
Oxygen	....	....	17.11	....	....	16.31
Calorific value determined:						
Calories	6,214	....	5,655	6,447	....	6,937
British thermal units	11,185	....	10,179	11,605	....	12,487
Calorific value calculated from ultimate analysis.						
Calories	....	....	5,570	....	....	6,946
British thermal units	....	....	10,026	....	....	12,503

A careful comparison of the above tables shows that the average per cent of sulphur contained in the Iowa coal samples is 4.67, and the same figures represent the per cent of sulphur in the coals of Missouri. The average amount of ash present in the Missouri samples is a little less than that in the Iowa coal samples. The six samples of Illinois coal contained on the average a slightly smaller per cent of sulphur than the coals of Missouri and a somewhat larger percentage of ash. It would seem that for domestic purposes the coal of these three states should rank about equal in value.

It will be noticed, also, that the calorific value of the Iowa coals compares very favorably with the coals of Missouri and Illinois, yielding on the average 6,144 calories and 11,066 British thermal units.

WASHING TESTS.

The washing apparatus at the World's Fair coal-testing plant consisted of a New Century jig and a modified Stewart jig. The former

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is designed for washing finely pulverized material, while the latter will successfully wash coal composed of pieces up to one and one-half inches in diameter. The modified Stewart jig gave good satisfaction, and seems very well adapted to most kinds of coal.

Charges of Iowa coal for coking tests were first washed, and the results of this process appear in the following analyses:

Iowa No 1.—Lump and fine coal from mine No. 2, Anchor Coal Company, Laddsdale, Iowa.

About five tons of this coal were washed for a coking test, but the coal was not tried in a raw condition, and consequently the coking test affords no clue to the improvement made by washing. The change is shown by the chemical analyses.

Analyses showing effect of washing Iowa No. 1 *coal.*

	Car sample.	Washed coal for coking.
Ash	16.0	10.25
Sulphur	5.03	4.61

Iowa No. 2. —Run-of-mine coal from mine No. 6, Mammoth Vein Coal Company, Hamilton, Iowa.

About 5½ tons of coal were washed for a coking test. The reduction of impurities effected by washing was not great, as shown by the following analyses:

Analyses showing effect of washing Iowa No. 2 *coal.*

	Car sample.	Washed coal for coking.
Ash	15.22	10.28
Sulphur	4.66	3.93

Iowa No. 3.—Lump coal from mine No. 4, Gibson Coal Mining Company, Altoona, Iowa.

About 4½ tons of this coal were washed for a coking test. The improvement in the quality of the coal effected by washing is shown in the following analyses:

Analyses showing effect of washing Iowa No. 3 *coal.*

	Car sample.	Washed coal for coking.
Ash	14.01	8.03
Sulphur	6.15	4.55

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Iowa No. 4.—Lump coal from mine No. 3, Centerville Block Coal Company, Centerville, Iowa.

A charge consisting of about 4½ tons of this coal was washed for coking purposes. The results were not so satisfactory as those obtained on other samples from this state. The analyses are given below:

Analyses showing effect of washing Iowa No. 4 coal.

	Car cample.	Washed coal for coking.
Ash	10.96	7.14
Sulphur	4.26	3.59

Iowa No. 5.—Run-of-mine coal from mine No. 1, Inland Fuel Company, Chariton, Iowa.

A charge consisting of nearly 5 tons of this coal was washed for a coking test, but the coal did not coke, although the washing was fairly successful in reducing the impurities, as shown by the following analyses:

Analyses showing effect of washing Iowa No. 5 coal.

	Car sample.	Washed coal for coking.
Ash	12.63	7.93
Sulphur	3.19	2.28

The improvement of the Iowa coal by washing was most marked in samples No. 3 and No. 5. In the former the ash was reduced 6.98 per cent, and the amount of sulphur was lowered 1.60 per cent. In some samples the improvement by washing was slight.

The removal of impurities from coal by means of washing is accomplished by the sorting action of water upon particles fairly uniform in size, but differing in their specific gravity. In some states there is a growing practice on the part of the operators to wash their coal, especially that which is to be burned into coke. The cost of washing does not exceed 6 or 7 cents per ton.

It is possible that some of the Iowa coal would be sufficiently improved by washing to make that process profitable. For most purposes it would be very desirable to reduce the sulphur content of the coal as low as possible. The efficiency of washing in accomplishing this result depends largely upon the form in which the sulphur of the coal exists, and whether this undesirable constituent is disseminated through the coal in a finely divided condition.

In Iowa coal the sulphur commonly occurs either in the form of gypsum (hydrous calcium sulphate) or as pyrite or marcasite (iron disulphide). The specific gravity of coal is variable, but is somewhat less than 1.5. That of gypsum is about 2.31, while that of iron disulphide

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is about 4.95. It will be seen that as pyrite and marcasite have a density so much greater than that of coal they can be much more readily separated from it by washing than can gypsum whose specific gravity is more nearly equal to that of coal itself. In any event the tests show that the benefits from washing would differ greatly at different mines.

COKING TESTS.

The coking tests at the Government testing plant were made in ordinary bee-hive ovens of standard shape and size, 12 feet in diameter and 7 feet high. Before being charged into the oven the coal was passed through rolls which reduced it to particles one and one-half inches in diameter or less, and then washed as above stated.

The general results of these tests are given below:

Iowa No. 1.—Lump and fine coal from mine No 2, Anchor Coal Company, Laddsdale, Iowa.

In this test, as in all those on Iowa coals, the charge was of washed coal. The charge weighed 9,500 pounds, and after burning 46 hours yielded 4,828 pounds of coke and 572 pounds of breeze and ash. The coke was brittle, with cracks lengthwise and crosswise through it. It was also high in sulphur and ash.

Iowa No. 2.—Run-of-mine coal from mine No. 5, Mammoth Vein Coal Company, Hamilton, Iowa.

The charge in this test consisted of 10,000 pounds of washed coal, which was burned for 64 hours. The coke (3,866 pounds with 1,153 pounds of breeze and ash) was all in small pieces sintered together and with no bond.

Iowa No. 3.—Lump coal from mine No. 4, Gibson Coal Mining Company, Altoona, Iowa.

The charge in this test consisted of 8,000 pounds of washed coal, which was burned for 43 hours. It yielded 3,336 pounds of fine-fingered, brittle coke that was high in sulphur and ash, and 585 pounds of breeze and ash.

Iowa No. 4.—Lump coal from mine No. 3, Centerville Block Coal Company, Centerville, Iowa.

The coke produced in this test was of the same general character as that obtained from Iowa No. 3, except that it was not quite so high in either sulphur or ash. The charge consisted of 8,000 pounds of washed coal, which was burned for 40 hours, producing 3,722 pounds of coke and 426 pounds of breeze and ash.

Iowa No. 4.—Run-of-mine coal from mine No. 1, Inland Fuel Company, Chariton, Iowa.

The result of this test, made on 9,000 pounds of washed coal and burned 66 hours, was a mixture of unburned coal, charred coke, and ash.

All of the Iowa coals tested are too high in sulphur to produce blast-furnace coke, and as the sulphur occurs largely as gypsum it can not be removed by washing. The ash is also high in relation to the fixed carbon.

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Table showing results of coking tests.

Sample.	Coal. Chemical composition: Moisture.	Volatile matter.	Fixed carbon.	Ash.	Suphur.	Amount charged in oven.	Coking time.	Coke. Amount produced.	Breeze and ash.	Chemical composition: Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur	Phosphorus.	Specific gravity.	Per cent. produced.	Remarks.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Pounds.*	*Hours.*	*Lbs.*	*Lbs.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*			
Iowa No. 1.	12.84	35.91	41.00	10.25	4.61	9,500	46	4,823	572	10.53	1.65	70.39	17.45	3.89	.051	1.87	60.7	Very brittle.
Iowa No. 2.	12.85	35.44	35.43	10.28	3.93	10,000	64	3,866	1,153	......	......	......	......	......	......	....	38.7	Sintered.
Iowa No. 3.	16.83	39.27	35.87	8.03	4.55	8,000	48	3,336	585	5.73	1.87	75.49	16.91	4.57	.0183	1.88	41.7	Fine fingered.
Iowa No. 4.	17.80	37.59	37.39	7.14	3.59	8,000	40	3,722	426	13.05	2.32	73.10	11.53	2.97	.0123	1.82	46.5	Do.
Iowa No. 5.	19.25	31.07	41.75	7.93	2.28	9,000	66	......	......	......	.....	.....	.....	....	......	....	....	Charred coke and ash.

The accompanying table presents a comparison of the chemical composition of the washed coal and of the coke burned from the same in each of the above tests.

This table shows that from an average charge of 8,900 pounds of coal only 3,150 pounds of coke was produced. This represents a yield for the coal of less than 36 per cent of coke, and more than 6 per cent of ash and breeze or fine coke. This coke, too, was of a rather inferior quality. The better grades of West Virginia coal yielded 70 per cent of coke and only 2 to 4 per cent of breeze and ash. The average yield of coal in coke throughout the United States is about 60 per cent.

Since the tests reported above were made coals quite like the Iowa product, which failed in the earlier tests, have been coked with a fair degree of success. Other tests will be made and there is still ground for hope that commercial coke may be made from Iowa coal.

BRIQUETTING TESTS.

"One ton of lump coal from mine No. 3 of the Centerville Block Coal Company, Centerville, Iowa, was briquetted with 7 per cent of pitch as a binder. The briquettes were well pressed, of a grayish color, but on cooling crumbled decidedly. They weighed 6.73 pounds each. As they did not contain an excess of pitch, 7 tons more of this coal were briquetted with 8 per cent of pitch, in order to have a sufficient quantity for a steam test. The resultant briquettes were bluish-black in color, but they were not quite hard enough, although fairly strong, and would stand considerable hard treatment in

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transportation. In burning they held together until consumed. They weighed, on an average, 6.77 pounds each. The eggettes made from this same mixture were stronger than the briquettes, had a polished surface, but were very brown in color. In the cook stove they burned very satisfactorily, crumbling but little."

Steam tests were made on these briquettes under the boilers of the Government testing plant, which showed that every 3.8 pounds of the briquettes would furnish one horsepower of energy for one hour. The briquetting test is especially interesting to the coal operators of Iowa inasmuch as it indicates that the fine waste material, that is usually lost at the mines, can be successfully briquetted and placed on the market as a good quality of fuel. It also demonstrates that about 8 per cent of the pitch or tar is necessary to furnish the desirable bond to the briquettes.

STEAM TESTS.

Steam tests were made on each of the five samples of Iowa coal, and also on the briquettes of the Centerville coal above described. The method of conducting these tests and of reporting the results was in accordance with the standard approved by the American Society of Mechanical Engineers. The tests were made with Hein water-tube boilers and Allis Corliss engine, generating electrical energy through a Bullock 240-volt generator.

Some of the most important results of the tests of the Iowa, Illinois and Missouri coal samples appear in the following table.

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Results of coal tests under boiler.

Name of sample.	Coal: size, and condition.	Chemical composition. Fixed carbon.	Volatile matter.	Moisture.	Ash.	Sulphur (separately determined).	Duration of trial.	Total coal consumed.	Horsepower developed by boiler.	Dry coal burned per square foot of grate surface per hour.	Equivalent evaporation from and at 212° F. per pound of dry coal.	Dry coal per indicated horsepower hour.	Dry coal per electrical horsepower hour.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Hours.*	*Lbs.*		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Iowa No. 1	Nut, dull	39.89	33.08	8.69	18.34	6.39	10.02	10,331	197.7	23.23	7.24	3.91	4.82
Iowa No. 2	Nut, very dirty	33.73	35.35	14.88	16.04	4.73	9.92	10,986	192.7	23.28	7.05	4.01	4.95
Iowa No. 3	Nut, dull	35.77	36.14	12.44	15.65	6.07	10.03	10,668	189.3	22.96	7.02	4.03	4.97
Iowa No. 4	Mine run, dull	37.28	34.09	13.48	15.15	5.04	10.00	9,885	167.3	20.02	7.11	3.98	4.91
....do	Large briquettes	37.85	36.50	13.24	12.41	3.90	10.03	9,900	184.5	21.11	7.43	3.80	4.70
Iowa No. 5	Nut, medium bright	33.83	31.76	16.01	13.40	3.09	9.98	11,200	204.7	23.23	7.50	3.77	4.66
Illinois No. 1	Nut, dull	38.21	36.91	9.69	15.19	4.40	9.93	11,124	211.4	24.90	7.21	3.92	4.85
Illinois No. 2	Slack, dull, washed	41.72	37.77	10.45	10.06	3.36	9.97	10,096	210.2	22.36	8.00	3.54	4.38
Illinois No. 3	Nut, dull	48.75	31.19	8.51	11.55	1.50	10.13	9,537	200.6	21.23	8.04	3.52	4.34
Illinois No. 4	Lump, dull	41.59	33.48	13.47	11.46	1.28	10.07	9,367	172.0	19.84	7.37	3.83	4.73
....do	Nut, dull	43.63	32.44	12.58	11.35	1.36	10.02	10,750	197.8	23.13	7.27	3.89	4.80
Illinois No. 6	....do	39.62	32.31	13.19	14.88	3.48	9.92	10,343	194.3	22.34	7.40	3.82	4.72
Missouri No. 1	Mine run, dull	40.64	34.88	7.28	17.20	4.37	10.00	9,737	207.4	22.30	7.92	3.57	4.41
Missouri No. 2	Nut, dull	37.33	32.88	13.09	16.70	4.92	9.98	11,650	208.2	25.00	7.08	3.99	4.93
Missouri No. 3	Nut, dull	29.98	26.18	18.63	25.21	3.85	9.95	10,828	149.5	21.85	5.82	4.86	6.00
Missouri No. 4	Nut, dull	42.11	40.10	12.24	5.55	4.98	9.98	9,515	214.1	20.64	8.83	3.20	3.96

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From this table it appears that when burned under the boilers at St. Louis the Iowa coals, on the average, yielded energy sufficient to maintain a horsepower for one hour for each 3.9 pounds of fuel consumed. It will be seen that the average of the four samples of Missouri coal also required 3.9 pounds to furnish one horsepower of energy for one hour—practically the same quantity as the Iowa coal. For the six samples of the Illinois coal, the average weight of coal burned per horsepower hour was a little more than 3.7 pounds. Of the Pennsylvania and West Virginia coals there were required about 3 to 3.1 pounds to yield one horsepower hour of energy.

PRODUCER-GAS TESTS.

Among the notable and important facts brought out by the Government coal tests at St. Louis, none have a greater economic bearing than those connected with the tests of producer-gas. It was demonstrated that bituminous coal, such as is produced in Iowa, can readily be converted into gas and that when this gas is burned in a gas engine it yields from two to two and one-half times as much energy as could be obtained from burning the same coal under a boiler. The same statement is true of the lignites of North Dakota, Indian Territory and Texas.

The tests were made using a Taylor (R. D. Wood & Co.) producer, and a Westinghouse triple-cylinder, vertical gas engine of 235 brake horsepower, operating a Westinghouse 240-volt generator.

The results of the producer-gas tests on all of the Iowa coal samples are not at present available, but those on the Mammoth Vein sample, from Hamilton, Iowa, appears in the following table with those of representative samples from other states. This table embodies a comparative summary of some of the results of the coal tests in the generation of power (1) by the boiler and steam engine, and (2) in the producer and gas engine.

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Comparative summary of the leading results of the coal tests made under the boiler and in the gas producer.

Name of sample.	Duration of trial.		Total dry coal consumed per hour.*		Dry coal burned per square foot of grate surface per hour.†		Water evaporated from and at 212° F. per lb. of dry coal	British thermal units per pound of dry coal used.		Electrical horse-power delivered to switchboard.		Total dry coal per electrical horsepower per hour.‡		Ratio of dry c per elec-t'ic'l horse-power per hour in steam plant to that in gas-producer plant.
	Steam plant.	Gas-producer plant.	Steam plant.	Gas-producer plant.	Steam plant.	Gas-producer plant.	Steam plant.	Steam plant.	Gas-producer plant.	Steam plant.	Gas-producer plant.	Steam plant.	Gas-producer plant.	
	Hours.	*Hours.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*					*Lbs.*	*Lbs.*	
Alabama No 2	10.02	43.00	874	328.7	21.54	7.78	8.55	12,555	13,365	213.7	200.6	*4.08*	*1.64*	2.49
Colorado No 1	9.97	30.00	722	341.7	17.80	7.56	7.21	12,577	12,245	149.1	200.2	*4.84*	*1.71*	2.83
Illinois No. 3	10.13	30.00	861	356.7	21.23	8.41	8.04	12,857	13,041	198.1	199.6	*4.34*	*§1.79*	2.42
Illinois No. 4	10.02	30.00	938	348.5	23.13	7.96	7.27	12,459	12,834	195.4	198.4	*4.80*	*§1.76*	2.73
Indiana No. 1	9.93	29.67	908	384.3	22.39	9.08	8.45	13,377	13,037	220.0	199.9	*4.13*	*§1.93*	2.14
Indiana No. 2	10.18	7.00	832	312.0	20.51	7.13	8.02	12,452	12,953	191.0	201.0	*4.35*	*§1.55*	2.81
Indian Territory No. 1.	9.75	31.00	778	374.0	19.17	8.95	8.64	12,834	13,455	192.3	204.0	*4.04*	*1.83*	2.21
Indian Territory No. 4.	10.22	22.67	853	284.6	21.04	6.59	7.53	12,027	11,392	184.0	199.5	*4.64*	*1.43*	3.24
Iowa No. 2	9.92	13.33	945	340.7	23.28	7.87	7.05	11,497	10,489	190.9	197.5	*4.95*	*1.73*	2.86
Kansas No. 5	9.90	13.00	837	323.6	20.62	7.65	8.88	13,144	13,421	212.8	200,2	*3.93*	*1.62*	2.43
Kentucky No. 3	10.07	30.00	882	381.2	21.75	8.92	8.27	13,036	13,226	208.9	200.5	*4.22*	*§1.91*	2.21
Missouri No. 2	9.98	4.33	1,014	339.6	25.00	7.96	7.08	11,500	11,882	205.6	198.6	*4.93*	*§1.71*	2.88
West Virginia No. 1	9.98	24.00	768	315.6	18.94	7.36	8.95	14,198	14,306	196.7	200.4	*3.90*	*1.57*	2.48
West Virginia No. 4	10.00	9.00	770	258.2	18.98	5.96	9.65	14,002	14,202	212.5	199.7	*3.62*	*1.29*	2.80
West Virginia No. 7	10.18	22.67	736	290.2	18.15	6.68	9.85	14,305	14,720	207.5	199.1	*3.55*	*1.46*	2.43
West Virginia No. 8	9.98	21.00	760	355.1	18.72	8.32	9.62	14,436	14,558	209.0	199.9	*3.63*	*1.78*	2.04
West Virginia No. 9	10.00	24.00	721	278.5	17.78	6.36	10.09	14,616	14,548	208.2	199.3	*3.46*	*1.40*	2.47
West Virginia No. 12	10.13	30.00	719	300.5	17.68	6.92	9.90	15,170	14,825	203.6	199.8	*3.53*	*§1.50*	2.35
Wyoming No. 2	9.95	30.00	1,075	416.5	26.51	9.50	5.92	10,897	10,656	182.0	201.2	*5.90*	*2.07*	2.85
Average														2.57

*Coal actually consumed in producer only.
†This is fuel-bed surface in producer and not strictly grate surface.
‡In gas-producer plant this includes the coal consumed in the producer and the coal equivalent of the steam used in operating the producer.
§Gas-producer hopper leaked during these tests.

The two columns in italics are directly comparable, and the figures are worthy of the most thoughtful consideration. The Iowa coal sample was found to yield 2.86 times as much energy when converted into gas and the gas burned in a gas engine as when the coal was fired directly under the boiler. For the nineteen samples named in the table the amount of coal consumed per horsepower per hour by the boiler plant was on the average 2.57 times that used in the gas producer plant.

The above results have great economic significance. Probably more than three-fourths of the coal mined in Iowa is used for the generation of power. This would make 4,880,740 tons of coal consumed in power production out of the total of 6,507,655 tons mined in Iowa during 1904. Disregarding the difference in cost of installation and operation of machinery, and with the very conservative estimate of 50 per cent gain in efficiency of coal by means of the gas producer and gas engine above that of the boiler and steam engine, the saving by the former method would be equal to 2,440,370 tons of coal. This at $1.60 per ton, which was the average price at the mines of Iowa coal in 1904, would be equivalent to an annual saving to the people of the state of $3,904,592.

For 18 samples of coal from 12 different states the average composition of the gas by per cent of volume was as follows: carbon dioxide 10.08, oxygen 22, carbon monoxide 15.45, hydrogen 9.59, marsh gas 5.50 and nitrogen 59.13.

In conclusion it should be said that the Government has provided for continuing the coal-testing work that was begun at St. Louis last year, and arrangements are being made by the Iowa Geological Survey to have tests made on a number of other samples of Iowa coal.

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