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The Composition of Texas Coals and Lignites and The Use of Producer Gas in Texas

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INTRODUCTION

This Bulletin on The Composition of Texas Coals and Lignites and the Use of Producer Gas in Texas has been prepared for the purpose of supplying the numerous requests for information respecting the character of our fuels.

There has been no geological survey in Texas since 1892, and nearly all of the publications of that survey, 1888-1892, are now out of print, as are also the publications of the University Mineral Survey, 1901-1905. There have been three special publications on the subject of Texas Coals and Lignites. The first of these was a pamphlet entitled "Preliminary Report on the Utilization of Lignite," by E. T. Dumble, State Geologist, November 18, 1891. This was followed, in 1892, by his comprehensive "Report on the Brown Coal and Lignite of Texas," in which he discussed the character, formation, occurrence, and fuel uses of our lignites. Of this excellent report there are still some copies on hand for distribution, price, 20 cents for unbound and 25 cents for bound copies.

The Texas Geological Survey was discontinued in 1892, and there were no further publications until the establishment of the University Mineral Survey in 1901. This survey was discontinued in 1905.

In May, 1902, it issued Bulletin No. 3, entitled "Coal, Lignite and Asphalt Rocks," in which were given sections of coal and lignite seams and many detailed analyses. The edition of this Bulletin has long since been exhausted, and there is not a single copy that can be sent out. In the meantime there has been a considerable development of coal and lignite mining in Texas, the combined production having increased from 1,104,953 tons, valued at $1,907,024, in 1901, to 2,108,179 tons, valued at $3,771,089, in 1910. During this period the production of lignite alone has increased from 303,155 tons, valued at $251,288, to 979,232 tons, valued at $941,700. During the last few years there has been a marked increase in the use of lignite in gas-producers, the gas thus made going to gas engines for the generation of power. Lignite is also used in gas-producers for fuel to be employed in the burning of lime, etc.

In the chapter on "The Use of Lignite in Gas Producers," prepared by Mr. Drury McN. Phillips, at his own expense, this matter is discussed.

Considering the great extent of the lignite fields in Texas, probably in excess of 60,000 square miles, an area larger than the entire State of Georgia, and the fact that every variety of this fuel is to be found here, and further, that it affords the cheapest and best fuel in the State, with the possible exception of natural gas in certain favored localities, for many commercial purposes, it is well within reason to believe that this fuel will be our chief industrial reliance for power.

Since 1895 the production of lignite has increased from 124,343 tons, valued at $111,908, to 979,232 tons, valued at $941,700. During this period of 16 years the production of coal has increased about 200 per cent, while that of lignite has increased about 700 per cent.

The investigations on coal and lignite, begun by this Bureau, were planned to cover, as far as possible, two subjects, the detailed analyses and the gas-producing qualities, this latter to cover also the production of tar and ammoniacal liquor. The first part has now been completed, and work on the second part has begun. The analyses herewith submitted represent producing mines only, except when it is expressly stated to the contrary.

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Austin, Texas, July, 1911.

THE COMPOSITION OF TEXAS COALS AND LIGNITES

BY

WM. B. PHILLIPS AND S. H. WORRELL

AND

USE OF PRODUCER GAS IN TEXAS

BY

DRURY McN. PHILLIPS

CHAPTER I.

COAL.

In Bulletin No. 3 of the University Mineral Survey, May, 1902, there were given detailed analyses of the coals and lignites then mined in Texas. The samples were taken in person, at the mines, by an agent of the Survey and represented the freshly mined material. The complete exhaustion of the edition of that Bulletin and the constant requests for information respecting the composition of our coals and lignites has led to the preparation of this publication. It was planned to extend the inquiry to cover the gas-producing power of these fuels, the determination of the amount and quality of the gas to be obtained, the amount and quality of the tar, ammoniacal liquor, etc. But as this latter inquiry requires a great deal of time and the requests for information as to the composition of our coals and lignites have become so numerous and so pressing, it has been thought best to issue this Bulletin now, and to supplement it later by the results of further research.

It is not our purpose, at this time, to enter into a detailed description of the coal and lignite fields of Texas, or to discuss their geology. It will suffice to say that there are three well-recognized coal fields in Texas, two on the Rio Grande and one in north central Texas, west of Fort Worth.

The two on the Rio Grande are in Maverick County, with Eagle Pass as the chief town, and Webb County, with Laredo as the chief town. This field extends also into the counties of

Dimmit and Zavala. It is entered by the following railroads: Southern Pacific; International & Great Northern; Rio Grande & El Paso; Uvalde & Crystal Falls; Asherton & Gulf; and Texas Mexican.

The coal is probably of Tertiary age.

The North Central Coal Field lies in the counties of Brown, Coleman, Comanche, Erath, Eastland, Jack, McCulloch, Montague, Palo Pinto, Parker, San Saba, Shackelford, Stephens, Wise, and Young. It comes south of the Colorado river in McCulloch and San Saba counties. Its coal is of Carboniferous age.

The North Central Coal Field is entered by the following railroads: Texas & Pacific; Texas Central; Chicago, Rock Island & Gulf; Fort Worth & Denver; Fort Worth & Rio Grande (Frisco); Gulf, Colorado & Santa Fe; Wichita Falls & Southern; Mineral Wells & Northwestern; Stephenville, North & South Texas; Gulf, Texas & Western.

The total workable coal area may be taken at 8,200 square miles, with an additional area of 5,300 square miles, that may contain workable beds, as estimated by Mr. M. R. Campbell, of the United States Geological Survey. The original supply of coal in Texas is thought by Mr. Campbell to have been 8,000,000,000 tons. The total loss of coal, due to production and waste, certainly has not exceeded 15,000,000 tons, so that we have still 99 per cent of the original supply left. This supply is sufficient to provide for a mining loss of 10,000,000 tons a year for 800 years.

No extended mention is here made of the coal area in El Paso and Presidio counties, because no coal of commercial importance has been mined there for many years.

At one time, 1893-1895, it was hoped by the parties at interest that the San Carlos Coal Field, in Presidio county, 20 to 25 miles south of the Southern Pacific Railway, at Chispa, could be developed. A railroad was built to it, and a great deal of expensive work was done. But the enterprise has long since been abandoned, although there appears to be reason for thinking that the best coal there was not opened at all. It is possible that a coking coal of fair quality exists in that field, in addition to natural gas. (See this Bulletin, p. 34.)

The production of coal, as distinct from lignite, can not be given with accuracy prior to the year 1895. Up to that time, beginning with the year 1884, the total production of coal and lignite was 1,943,500 short tons, or an average for the eleven years of 176,681 tons a year. Beginning, however, with the year 1895 we have coal and lignite as separate items.

The following table gives the production and value of the coal and lignite from 1895 to 1910, inclusive. The statistics are those of the United States Geological Survey, except for 1909 and 1910. These were collected by the Bureau:

PRODUCTION AND VALUE OF COAL AND LIGNITE, 1895-1910—SHORT TONS.

Year.	Coal—Tons.	Value.	Lignite—tons.	Value.
1895	360,616	$ 801,230	124,343	$ 111,908
1896	376,076	747,872	167,939	148,379
1897	422,727	792,838	216,614	179,485
1898	490,315	968,871	196,419	170,892
1899	687,411	1,188,177	196,421	146,718
1900	715,461	1,350,607	252,912	231,307
1901	804,798	1,655,736	303,155	251,288
1902	696,005	1,326,155	205,907	151,090
1903	659,154	1,289,110	267,605	216,273
1904	774,315	1,652,992	421,629	330,644
1905	809,151	1,684,527	391,533	284,031
1906	839,985	1,779,890	472,888	399,011
1907	940,337	2,062,918	707,732	715,893
1908	1,047,407	2,580,991	847,970	838,490
1909	1,144,108	2,714,630	715,151	592,421
1910	1,128,947	2,829,389	979,232	941,700
Total	11,896,813	$25,425,933	6,467,450	$ 5,709,530

Since 1895 the production of coal has increased by more than 200 per cent. During the same period the production of lignite has increased by nearly 700 per cent. For each ton of coal mined in 1895 there are now mined more than three tons. For each ton of lignite mined in 1895 there are now mined nearly eight tons.

The average value of the coal in 1910 was $2.51 a ton, at the mines, while that of lignite was 96 cents.

In Texas there are no very large coal mines, the largest producer turning out about 600,000 tons a year. The smallest output in 1910 was something over 10,000 tons.

There is one coal washing establishment in Texas, that of the Olmos Coal Company, at Eagle Pass, Maverick county. The production of the Rio Grande Coal Field, comprising the counties of Maverick and Webb, in 1909, was 183,447 tons, valued at $536,001; in 1910 it was 215,328 tons, valued at $503,375.

The production of the North Central Coal Field, comprising the counties of Erath, Jack, Parker, Wise and Young, in 1909 was 960,661 tons, valued at $2,044,990; in 1910 it was 913,619 tons, valued at $2,326,014.

For the further development of the coal fields of Texas four railroads are possible. In the North Central Field the extension of the Chicago, Rock Island & Gulf from Graham to Stamford would give a western outlet for the coal along the Clear Fork of the Brazos. In the same field the extension of the Gulf, Texas & Western from Jacksboro to Seymour opens the undeveloped coal north of the Brazos river. The extension of the Wichita Falls & Southern from Newcastle to Brownwood, by way of Cisco, would afford another southern outlet for the coal in the counties of Young, Stephens, Eastland and Brown. In the Rio Grande Coal Field the extension of the Uvalde & Crystal Falls Railway to Laredo would open the undeveloped coal in the counties of Zavala and Dimmit.

The coal-producing counties are: Erath, Jack, Palo Pinto, Parker, Wise and Young, in the North Central Field (Carboniferous) and Maverick and Webb in the Rio Grande Field (Tertiary).

COMPOSITION OF TEXAS COALS.

In 1901-1902 an agent of the University Mineral Survey was sent to all of the coal mines for the purpose of securing fair samples of the coal as mined. These samples were placed in sealed cans and sent to the laboratory of the survey. Detailed analyses were made, with particular attention to the percentage of moisture in the coal as mined.

The samples came from the following properties:

No. 1518. Rio Grande Coal Co., Minera, Webb county.

No. 1519. Cannel Coal Co., Darwin, Webb county.

No. 1520. Maverick County Coal Co., Eagle Pass, Maverick county.

No. 1521. Rio Bravo Coal Co., Eagle Pass, Maverick county.

No. 1522. Wise County Coal Co., Bridgeport, Wise county.

Nos. 1523-1524. Bridgeport Coal Co., Bridgeport, Wise county.

Nos. 1525-1526-1527. Texas Coal & Fuel Co., Rock Creek, Parker county.

No.1528. Young Mine, Keeler, Palo Pinto county.

Nos. 1529-1530-1531-1532. Texas & Pacific Coal Co., Thurber, Erath county.

No. 1533. Strawn Coal Mining Co., Strawn, Palo Pinto county.

No. 1534. Smith-Lee Mine, Cisco, Eastland county.

The analyses of these coals, made by O. W. Palm and S. H. Worrell, were given in Bulletin No. 3, University Mineral Survey, May, 1902, as follows:

COMPOSITION OF TEXAS COALS—SAMPLED AT MINES BY UNIVERSITY MINERAL SURVEY, 1901-1902.

Analysis No.	Proximate Analysis. Natural Condition. Moisture.	Volatile and Combustible Matter.	Fixed Carbon.	Ash.	Sulphur.	Proximate Analysis. On Dry Basis. Volatile and Combustible Matter.	Fixed Carbon.	Ash.	Sulphur.	Ultimate Analysis. Natural Condition. Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ultimate Analysis. Dry Basis. Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Heat Value. British Thermal Units. Natural Condition. B.T.U.	Dry Basis. B.T.U.	Specific Gravity —Dry.	Weight per Cubic Foot—Pounds —Dry.	Analysis No.
1518	4.09	47.95	38.89	9.07	2.45	50.00	40.55	9.45	2.56	66.70	5.35	10.85	1.47	69.55	5.58	11.32	1.54	11,052	12,566	1.29	80.6	1518
1519	3.46	48.84	36.61	11.09	2.09	50.70	37.93	11.37	2.17	66.65	5.65	7.46	3.62	69.04	5.94	7.73	3.75	12,036	12,470	1.32	82.5	1519
1520	9.40	33.08	40.09	17.43	1.28	36.52	44.26	19.22	1.42	62.55	4.14	8.07	1.63	64.06	4.57	8.92	1.81	11,149	12,317	1.41	87.1	1520
1521	6.91	38.16	36.82	18.11	1.96	41.00	39.56	19.44	1.28	58.85	4.53	9.60	0.78	63.22	4.87	10.32	0.87	11,472	12,324	1.62	101.2	1521
1522	12.50	31.72	42.98	12.80	1.84	36.26	49.12	14.62	2.11	56.87	3.89	11.14	1.07	64.88	4.45	12.71	1.23	10,656	12,190	1.48	92.5	1522
1523	12.21	31.93	41.12	14.74	1.73	37.52	46.83	15.65	1.98	59.40	3.37	8.05	1.58	67.67	3.73	9,17	1.80	10,575	12,047	1.44	90.0	1523
1524	12.56	34.13	41.99	11.32	1.63	39.04	48.03	12.93	1.87	58.33	3.75	11.17	1.22	66.72	4.30	12.78	1.40	10,373	11,864	1.62	101.2	1524
1525	8.12	29.62	46.84	15.42	1.56	32.24	49.90	17.86	1.70	60.19	3.64	8.31	1.72	65.52	3.99	9.05	1.88	11,515	12,533	1.24	77.5	1525
1526	5.95	33.08	44.79	16.18	2.00	35.18	47.63	17.19	2.13	57.85	3.93	12.90	1.14	61.52	4.18	13.72	1.22	11,450	12,175	1.46	91.2	1526
1527	6.84	29.17	42.48	21.51	2.82	31.32	45.60	22.08	3.03	57.86	3.99	5.23	2.70	62.08	4.29	5.62	2.90	11,493	12,338	1.36	85.0	1527
1528	5.31	31.24	38.69	24.76	4.76	33.00	40.86	26.14	5.03	57.13	3.80	2.34	1.69	60.34	4.12	2.58	1.79	11,171	11,797	1.42	88.7	1528
1529	5.36	31.91	43.03	19.70	2.04	33.72	45.47	20.81	2.16	59.27	3.96	8.35	1.49	62.43	4.19	8.83	1.58	11,450	12,099	1.10	68.7	1529
1530	5.46	35.66	49.17	9.71	1.61	37.72	52.01	10.27	1.71	70.48	4.95	6.60	1.16	74.56	5.24	6.99	1,23	12,003	13,755	1.36	85.0	1530
1531	5.83	33.20	43.15	17.82	1.51	35.26	45.83	18.91	2.77	60.90	4.00	6.26	2.58	64.68	4.25	6.65	2.74	11,448	12,157	1.27	79.4	1531
1532	4.31	35.61	44.55	15.53	3.00	37.22	46.56	16.22	3.14	58.27	4.88	6.74	1.82	66.57	5.11	7.05	1.91	12,264	12,817	1.40	87.5	1532
1533	4.00	31.78	42.04	22.18	2.39	33.11	43.80	23.09	2.49	58.01	4.06	6.62	2.74	60.43	4.23	6.90	2.86	11,524	12,005	1.44	90.0	1533
1534	13.44	34.86	36.37	15.33	2.54	40.28	42.02	17.70	2.94	50.94	4.41	11.86	1.46	58.86	5.10	13.71	1.69	9,609	11,101	1.60	100.0	1534
Average	7.40	34.82	41.74	16.04	2.19	37.65	45.06	17.29	2.38	60.01	4.25	8.33	1.76	64.79	4.59	9.00	1.90	11,245	12,035	1.40	87.5	Ave.

The Tertiary Coals here represented are Nos. 1518, 1519, 1520 and 1521, the two former from Webb county, Laredo district, and the two latter from Maverick county, Eagle Pass district. The Webb county coals are higher in volatile and combustible matter and sulphur, and lower in ash and moisture than the Maverick county coals, the fixed carbon being about the same. The Tertiary coals from these counties show a considerable difference in the composition of the ash, as will appear further along. The Carboniferous coals, Nos. 1522 to 1534, inclusive, show a marked range in composition. On the average they contain more moisture, fixed carbon, ash and sulphur, with less volatile and combustible matter than the Tertiary coals.

From the composition of the ash of the Texas coals it may be concluded that while the coal was forming there were considerable variations in the character of the vegetation and in the character and amount of the sediments washed in. If we allow that the rate of accumulation of vegetable matter is 100 tons per acre per century and allow, also, for the differences in density and composition, it is likely that the rate of the formation of coal will not exceed one foot in 10,000 years. During such a period there would probably be many opportunities for climatic changes affecting the character of the vegetation, and for changes in the nature of the sediments mixed with the coal while it was forming.

In these coals, as mined, the following variations in composition were observed:

	From	To	Average
Moisture	3.46	13.44	7.40
Volatile and Combustible Matter	29.17	48.84	34.82
Fixed Carbon	36.37	49.17	41.74
Ash	9.07	24.76	16.04
Sulphur	1.28	4.76	2.19
Carbon	50.94	70.48	60.01
Hydrogen	3.37	5.65	4.25
Oxygen	2.34	12.90	8.33
Nitrogen	0.78	3.62	1.76
British Thermal Units	9,609	12,264	11,245

On dry basis these become:

	From	To	Average
Volatile and Combustible Matter	31.32	50.70	37.65
Fixed Carbon	37.93	52.01	45.06
Ash	9.45	26.14	17.29

	From	To	Average
Sulphur	1.28	5.03	2.38
Carbon	58.86	74.56	64.79
Hydrogen	3.73	5.94	4.59
Oxygen	2.58	13.72	9.00
Nitrogen	0.87	3.75	1.90
British Thermal Units	11,101	13,755	12,035

Without considering, for the present, the things that ultimately comprise coal and lignite, such as carbon, hydrogen, oxygen, nitrogen, etc., we may regard such fuel as made up, essentially, of five things, viz., moisture (ordinary water), volatile and combustible matter, fixed carbon, ash and sulphur. As to moisture, but little need be said. It is water which exists as such in the coal as it exists in a great many things in nature, in wood, in earth, in many rocks, etc. It is given off from coal at all ordinary temperatures, and is completely driven off at or a little above the boiling point of water, 212 degrees Fahrenheit. It is of no value in the coal, and, in fact, is an objection, for it detracts from the heating power. An amount of coal equivalent to the amount of water present must be used to evaporate the water before any appreciable heat is derived from the burning of the coal.

On the average, Texas coals, as mined, contain nearly 7½ pounds of water in each one hundred pounds, or nearly 150 pounds in a ton of 2000 pounds (short ton). If we allow that, on the average, it requires one pound of these coals to evaporate 10 pounds of water from and at 212 degrees Fahrenheit we would have to use 15 pounds of coal from every ton, or 450 pounds from each 30-ton car, to drive the moisture out. This amount of coal, 450 pounds per carload, is to be subtracted from the coal which is used for heating, as it is employed merely in driving the water out of the coal. We do not know what is the average amount of water in our coals as they are received and used. It is sometimes a question of the weather, whether the coal has been rained on or not while it was in transit, and whether the coal is stored under shelter or not, after being received. But the storing of coal brings up other questions which are not pertinent at this time. The loss of heating power in certain coals that are stored for some time enters in here, but this loss may be, in part, counterbalanced by the increased dryness of the coal. The danger of spontaneous combustion in stored coal has also to be considered.

In the purchase of coal on analysis it is customary to specify that the moisture shall not exceed such and such a percentage, the amount so allowed varying according to circumstances. In comparing one coal with another it is best to reduce the analyses to the same basis, and the most convenient one is the dry, or water-free, basis. For practical purposes it is necessary to consider the relative amounts of water which these coals would contain, *as received,* but on this subject we have very little data. It is seldom, or never, the case that coal as received contains the same amount of water as it did when it was mined. Unless it is exposed to wet weather, between the shipping and the delivery points, coal will lose water and decrease in weight. But this decrease in weight does not necessarily imply a loss in efficiency, looking at the matter from the standpoint of loss of moisture only. If, at the same time, there should be a loss of volatile and combustible matter, which could be used as a source of heat, the questions raised are of a different sort.

The next thing that coal contains is volatile and combustible matter which can be used as a source of heat. Water is volatile matter, but it can not be used for heating. The volatile matter that coal contains is also combustible matter, so we use the term "volatile and combustible."

As has been already remarked, Texas coals, as mined, contain from 29.17 to 48.84 per cent. of volatile and combustible matter, the average being 34.82 per cent. In other words, our coals contain a little more than one-third of their weight of volatile and combustible matter.

What is this substance?

To answer this question in detail would take us into highly technical discussions, with which this publication has but little to do. The expression "volatile and combustible matter" is taken to include those substances, simple or complex, which are given off from coal at temperatures a little above that of boiling water to full red heat, *with exclusion of air.* The air must be excluded or the solid matter of the coal will begin to burn. If we take a finely ground sample of coal and heat it at the temperature of boiling water, or a little above, it will lose weight, and this loss is water. If we take this same sample and heat it in a crucible with a closely-fitting cover up to full red heat (about 1000 degrees Fahrenheit) we get an additional loss of weight, and this loss is volatile and combustible matter. There will be left in the crucible fixed carbon and ash, which will be considered later. This volatile and combustible matter is not a simple substance, like water, but is composed of gases and smoke. The gases vary a good deal in composition, and so, also, does the smoke, although not to so great an extent.

The amount and nature, and, consequently, the value of this volatile and combustible matter, depends on a number of things, among them being the nature of the coal itself, the size of the coal treated, the rapidity in the increase of temperature, the final temperature, the temperature of the space into which the products evolved are carried, the mass of the coal, the time factor, etc. Most of the gases thus obtained are combustible, but at times and under certain conditions we have, also, water and carbonic acid, which are not combustible at all.

The term volatile and combustible matter does not, therefore, always mean that all of the material can be burned, and thus afford heat. At times there are certain gases evolved which can not be burned again, e. g., water and carbonic acid. If the coal be thoroughly dried and water is afterwards found as a part of the volatile and combustible matter it has doubtless been produced during the operation, and is not an essential part of the coal.

Disregarding the water and the carbonic acid (although, at times, they are important factors), the constituents of the volatile and combustible matter that claim our attention especially are the gases that can be burned and which, thus, are a source of heat. These are carbon monoxide, marsh gas (which composes 95 per cent of the best Texas natural gas), ethane, a group of gases known as "illuminants," and hydrogen. Oxygen and nitrogen are also present, the latter in considerable amounts if there is much air present.

It is perfectly true that "any statement as to the character of the gases or volatile products evolved from coal at specified temperatures has little value unless it is accompanied by a clear description of the conditions prevailing, and particularly of the points at which temperatures were taken and of the mass of coal which was heated.'"[1]

At the same time the term "volatile and combustible matter" is used by chemists and by practical coal men to designate those matters that are driven off from coal between the temperatures of boiling water, 212 degrees Fahrenheit, and full red heat. 1000 degrees Fahrenheit, without considering their composition. The more strictly scientific aspects of the case are, to some extent, subordinated to the necessity of having some term, in common use, for the substances in coal which are neither water, fixed carbon nor ash. We know that these substances vary a good deal in amount and nature, but there has not yet been found a more convenient or a more expressive nomenclature than the one here adopted.

We use it with the understanding that it includes some gases that are not combustible, but for the most part are so.

There is, as yet, but little information as to the amount and nature of the gases to be obtained from Texas coals under specified conditions. This is an investigation which this Bureau has planned, but which it has not yet been able to carry out. The plan outlined is to study these coals under conditions closely approximating those that maintain in the manufacture of ordinary illuminating and heating gas and producer-gas. It does not so much involve an inquiry into what these gases and other products would be under varying conditions as an inquiry into what they would be under specified conditions, approximating those in current practice. It would include the determination of the amount and nature of the gas, with respect to its illuminating and heating power, and the amount and nature of the tar, ammoniacal liquor and coke.

It is expected that this work will begin during the coming summer and be prosecuted vigorously, the results being given in another Bulletin. There is practically no information on these points, and that in spite of the fact that since 1895 we have produced nearly 12,000,000 tons of coal, valued at more than $25,000,000.

The third item to be considered is fixed carbon. This is the substance, less the ash, which is left after the moisture and the

[1]Horace K. Porter and F. K. Ovitz, in Bull. No. 1, Bureau of Mines, Department of the Interior, 1910, p. 55.

volatile and combustible matter have been removed from coal. It is the solid matter in coal, less the ash, and for our purposes may be considered as carbon. There is other carbon in coal, but this has gone off as gas and smoke, and what is left is not volatile.

In Texas coals, as mined, the fixed carbon varies from 36.37 to 49.17 per cent., the average being 41.74 per cent. In comparison with many other bituminous (soft) coals this amount is low, Alabama, Pennsylvania and Oklahoma coals carrying from 55 to 60 per cent. and New Mexico coal from 50 to 55 per cent. One reason why Texas coals do not make good coke is because the amount of fixed carbon is so low. The yield of coke from coal is very close to the amount of fixed carbon in the coal. When we connect this fact with the further fact that our coals carry almost twice as much ash and sulphur as good coking coal should carry, we may begin to understand why our coals are not used for making coke. Our coals carry about the same amount of volatile and combustible matter as do the coking coals of Alabama, Pennsylvania, Oklahoma and New Mexico, and there is, perhaps, not a marked difference in the nature of this matter, but those coals make good coke, while Texas coals do not, under ordinary bee-hive conditions. It is possible that a better coke could be made in by-product, or recovery, ovens, where the coking conditions are markedly different from those in bee-hive ovens, but we have no information on this subject with respect to Texas coals. Attempts to lower the amount of ash and sulphur by washing the coal, preparatory to coking, have not been successful here. There was a very considerable loss of coal, due to insufficient differences in specific gravity, without a counterbalancing improvement in the coke. The washing of coal is carried on in this State at one establishment, that of the Olmos Coal Company, at Eagle Pass, and three grades of washed coal are prepared, egg, nut and pea, but the coal is not used for coking.

So far as now known, there is no good coking coal in Texas, although it is reported that one of the seams in the San Carlos Coal Field, Presidio county, gives a fair coking coal. There are no developments in this field at present, nor has any work been done there since 1895. (See this Bulletin, p. 34.)

When the fixed carbon in coal is burned there is left ash, or the mineral constituents of the coal. In Texas coals, as mined, the ash varies from 9.07 to 24.76 per cent., the average being 16.04 per cent. In 1902 the University Mineral Survey made detailed analyses of the ash of Texas coals, and it has not been thought necessary to repeat this work. The following table gives the results of these analyses:

COMPOSITION OF THE ASH OF TEXAS COALS

Anal. No.	Silica.	Alumina.	Oxide of Iron.	Lime.	Magnesia.	Oxide of Manganese.	Sulphuric Acid.	Per-cent. of Ash in Coal as Mined.
1518 ------	42.08	24.79	23.03	4.69	none	1.75	4.57	9.07
1519 ------	44.48	35.62	14.74	2.56	trace	----------	3.52	11.09
1520 ------	65.34	30.04	3.38	0.91	0.36	0.80	0.80	17.43
1521 ------	62.72	24.56	9.84	0.64	0.70	----------	trace	18.11
1522 ------	34.16	24.76	13.56	16.08	----------	----------	12.19	12.80
1523 ------	34.32	14.62	22.94	14.85	1.42	1.16	10.97	14.74
1524 ------	34.46	14.10	13.26	22.08	1.43	trace	12.87	11.32
1525 ------	50.50	24.46	15.40	4.21	trace	trace	2.84	15.42
1526 ------	52.88	32.20	13.56	1.16	trace	----------	trace	16.18
1527 ------	47.20	17.88	28.02	1.35	1.47	----------	trace	21.51
1528 ------	32.50	32.40	20.64	6.68	trace	----------	6.64	24.76
1529 ------	52.06	41.12	4.00	1.08	1.50	----------	1.67	19.70
1530 ------	48.04	43.92	3.68	2.16	trace	----------	0.84	9.71
1531 ------	48.20	26.20	22.02	0.81	1.34	----------	0.96	17.82
1532 ------	49.12	25.71	24.37	trace	----------	----------	trace	15.53
1533 ------	54.34	13.10	28.02	1.56	2.25	----------	2.32	22.18
1534 ------	29.14	15.56	13.42	20.73	1.91	trace	15.00	15.33
Average --	45.97	25.94	16.11	5.97	0.73	0.22	4.42	16.04

The Tertiary coals, from the Rio Grande Field, are Nos. 1518, 1519, 1520, 1521, the first two being from Webb county, Laredo district, and the last two from Maverick county, Eagle Pass district. The ash of these coals shows a considerable difference in composition. The Webb county coals are low in silica and high in oxide of iron, with a medium content of alumina, lime and sulphuric acid. The Maverick county coals are high in silica and low in oxide of iron and sulphuric acid. As these coals are supposed to be of the same geological age and to have been formed under relatively the same conditions, we may infer that the vegetation from which they were made was of a different character, and that the in-wash of sediments varied a good deal.

The coals of the Carboniferous formation also show considerable differences with respect to the composition of the ash, and this likewise would lead one to suppose that the character of the vegetation varied a good deal during the coal-forming period. In these coals the silica varies from 29.14 to 54.34 per cent.; the alumina from 13.10 to 32.40 per cent.; the oxide of iron from 3.68 to 28.02 per cent.; the lime from a trace to 22.08 per cent.; the magnesia from a trace to 2.25 per cent., and the sulphuric acid (combined not free) from a trace to 15.00 per cent.

It is impossible to observe these analyses without reaching the conclusion that the character of the coal-forming vegetation changed a good deal during Carboniferous times, from plants which secreted a comparatively small amount of silica to those secreting a large amount. This observation also holds true with respect to the oxide of iron, alumina, lime and sulphuric acid, for the composition of the ash of coal is closely related to that of the plants from which the coal was made. Of course, the washing in of sediments which became mechanically mixed with the decaying vegetation has also to be considered, but, aside from this, the ash of coal is largely the ash of the plants forming the coal. There are many interesting things found in the ash of coal, besides those already given, and in two Texas coals, both from Thurber, Erath county, copper was found in very small amounts. In a speculative way the occurrence of copper in the ash of these coals may be connected with the occurrence of copper in the Permian beds which lie to the west of the Carboniferous formation in Texas, and which are geologically above this formation.

For domestic purposes, where no great heat is required, more consideration is given to the quantity of ash in coal than to its fusibility. For boiler use, however, the fusibility (clinkering) of coal is a factor of great importance. Coal that clinkers badly, i. e., coal that has an easily fusible ash, is almost sure to give more or less trouble. It clings to the grate-bars, interferes with the draft and causes, at times, serious losses. Such clinkering troubles generally attend the use of coal whose ash is high in oxide of iron. On the contrary, coals whose ash is composed chiefly of silica and alumina, or silica, alumina and lime, do not clinker so readily. As a rule, red ash coals clinker much more easily than white or gray ash coals.

The design and construction of the grate and fire-box and the method of firing have also a good deal to do with clinkering.

We have thus far considered as briefly as possible four of the five things that comprise coal, moisture, volatile and combustible matter, fixed carbon and ash. In addition to these, and forming a part of the volatile and combustible matter is sulphur.

This may exist in coal as a sulphide (chiefly sulphide of iron, or pyrite), as a sulphate (chiefly as sulphate of lime, gypsum) and in certain obscure organic compounds whose nature is not clearly understood.

On burning coal a part of the sulphur is removed and a part remains, the proportions varying according to the nature of the coal, the method of combustion, etc. As a rule, the sulphur in organic combination is removed, going off in the volatile and combustible matter, the sulphur in the pyrite present is partly removed, while the sulphur in the sulphates is hardly affected. In Texas coals, as mined, the sulphur varies from 1.28 to 4.76 per cent., the average being 2.19 per cent. No investigations were made to determine the character of the sulphur-bearing compounds in Texas coals. Some of them, e. g., the coal from the old Young Mine, at Keeler, Palo Pinto county, from one of the seams at Thurber, Erath county, and from Rock Creek, Parker county, carry sulphur varying from 4.76 to 2.82, considerably above the average of the State at large.

Sulphur in coal, even up to 5 per cent., is not as injurious to boilers as is commonly supposed.

The five things in coal that have now been considered comprise what is known as the proximate composition and the analysis that determines them is called a "proximate analysis." When we go further and determine the elemental composition of coal, the analysis is called an "ultimate analysis." In this, as in the proximate analysis, we determine the moisture, ash and sulphur, but instead of the volatile and combustible matter and fixed carbon there is determined the amount of carbon, hydrogen, oxygen and nitrogen, as separate items.

This has also been done for Texas coals, as mined, and the results are given in the Table on p. 10. The carbon varies from 50.94 to 70.48 per cent., the average being 60.01 per cent. The average percentage of fixed carbon in these coals, as by proximate analysis, is 41.74, but the percentage of carbon is 60.01, which means that there is a loss of carbon in the volatile and combustible matter. The ultimate analysis recovers this.

The hydrogen varies from 3.37 to 5.65 per cent., the average being 4.25 per cent.

The oxygen varies from 2.34 to 12.90 per cent., the average being 8.32 per cent.

The nitrogen varies from 0.78 to 3.62 per cent., the average being 1.76 per cent.

A number of years ago the term "disposable hydrogen" was introduced in coal analyses, and it meant the hydrogen that remained after calculating all of the oxygen present as water, and deducting from the total hydrogen the hydrogen in this amount of water

The amount of this disposable hydrogen was supposed to have an important bearing on the value of the coal for gas-making. Be this as it may, we have calculated the percentages of disposable hydrogen in Texas coals on a dry basis. The results are as follows:

Analysis No.	Total Hydrogen.	Disposable Hydrogen.	
		Per Cent.	Per Cent. of Total.
1	4.17	2.66	63.79
53	5.09	3.60	70.72
2	4.40	3.27	74.32
3	5.65	4.42	78.23
4	4.83	3.23	66.87
5	5.08	3.39	66.73
6	4.14	2.97	71.74
31	4.92	3.64	74.00
32	4.63	3.41	73.65
33	4.40	3.43	77.95
42	4.04	2.33	57.67
43	3.73	2.29	61.39
50	4.00	2.66	66.50
51	4.13	2.30	55.69
52	4.20	2.48	59.00
8	5.72	4.23	73.95
7	4.85	3.71	76.49
9	5.15	4.15	80.58
10	5.35	4.03	75.33
37	3.77	2.56	67.90
11	4.67	3.27	70.02
Average	4.66	3.24	69.53

For the key to these numbers see page 27.
For a similar table for lignite see page 51.

In these coals the disposable hydrogen varies from 2.29 (Olmos mine-run), to 4.42 per cent. (Cannel Coal Company), the average being 3.24 per cent. Expressed as percentage of the total hydrogen, the range is from 55.69 (Olmos washed nut) to 80.58 per cent. (Strawn Coal Mining Company).

There is a remarkable difference between the coals and the lignites not only with respect to the amount of the disposable hydrogen, but also with respect to its percentage of the total hydrogen.

The much larger amount of oxygen which the lignites contain, in comparison with the coals, leaves a proportionately smaller amount of hydrogen for the hydrocarbons and free hydrogen.

Whether or no the amount of disposable hydrogen in coal may be taken as an index of its value for gas-making is a question yet to be decided with respect to our coals, under standard conditions. It is a part of the investigation planned and already begun.

The part that oxygen plays in coal has been the subject of much investigation. It is a highly technical matter, and need not concern us now. It may suffice to say that it affects the gas-making qualities of coal by influencing the amount of hydrogen available for the formation of the hydrocarbons and of free hydrogen. The larger the amount of oxygen present, if we allow that all of it has to combine with hydrogen as water, the less hydrogen will there be for the formation of useful compounds in the gas. It may be possible that the water thus formed is resolved into its constituent gases at higher temperatures, and in the presence of free carbon. We need not, however, go into such matters now.

The Table giving the disposable hydrogen in the coals should be compared with a similar Table for lignites on page 51.

The nitrogen in coal is an important constituent from the standpoint of the recovery of by-products. From it can be made ammonium sulphate, which is the starting point in the manufacture of many other ammonia compounds, anhydrous ammonia, etc.

The percentage of nitrogen in Texas coals, as mined, varies from 0.78, as in a Maverick county coal, to 3.62, as in a Webb county coal. The Tertiary coals show the highest and the lowest percentages of nitrogen. In the Carboniferous coals the range is from 1.07, as in a Wise county coal, to 2.74, as in a Palo Pinto county coal. The proportion of the total nitrogen in coal that is recoverable as ammonia varies within wide limits, and it is practically impossible to give a general average. The yield of sulphate of ammonia per ton of coal has varied from 7 pounds, as in the Jameson producer, to 70.6 pounds, as in the Mond producer, using coal with 1.50 per cent. of nitrogen. The nature of the coal and the method of treatment determine the yield of sulphate of ammonia, and there is such a diversity here that no general rule can be given. But under ordinary conditions of gas-making a yield of from 20 to 25 pounds of sulphate of ammonia per ton of coal is within the limits of current practice.

Some authorities[1] have stated that 14.50 per cent. of the total nitrogen may be given off as ammonia, 1.56 per cent. as cyanogen, 35.26 per cent. remaining as elementary nitrogen, and 48.68 per cent. being held in the coke.

It will doubtless be some years before there is much interest in the recovery of by-products from Texas coals. The coal treated in retorts for making gas does not cut much figure in the trade, inasmuch as oil and water gas and natural gas are the chief gaseous fuels at present. The recovery of by-products from producer-gas is not now commercially attractive, chiefly on account of the lack of a central plant to which the concentrated ammoniacal liquors could be sent for treatment. The total quantity of such liquors produced in the State is not known, but the distances separating the different establishments are such as to forbid the assembling of the liquor.

In 1908 the total value of all of the products from gas works and recovery ovens, using coal, in the United States was $64,660,040, which value was $8,912,964 less than for the year 1907. In 1907 the last returns available, the amount of coal carbonized in Texas in 7 establishments, was 28,282 tons, and the quantity of gas produced was 251,233,400 cubic feet. Of this quantity, 53,281,311 cubic feet were sold for illuminating purposes, the price per 1000 cubic feet being $1.66. There were sold for fuel purposes 167,885,909 cubic feet at $1.33 per thousand. The total quantity of coal gas sold was 221,167,220 cubic feet, at an average price of $1.41 per thousand. The quantity of gas unaccounted for was 30,066,180 cubic feet.

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[1]J. D. Pennock, Trans. Amer. Inst. Min. Engrs., Vol. XXI, p. 808.

In the same year, 1907, the quantity of oil and water gas produced in Texas, in 10 establishments, was 591,644,500 cubic feet. Of this quantity 191,529,803 cubic feet were sold for illuminating purposes, at $1.35 per thousand, and 335,849,977 cubic feet were sold for fuel purposes, at $1.27 per thousand. The total quantity of oil and water gas sold was 527,379,780 cubic feet, at $1.30 per thousand. The quantity of gas unaccounted for was 64,264,720 cubic feet. The total quantity of gas made in Texas in 1907 was thus 842,877,900 cubic feet, of which 251,233,400 cubic feet, or 29.81 per cent., were coal gas and 591,644,500 cubic feet, or 70.19 per cent., were oil and water gas. The total quantity of gas sold for illuminating purposes was 243,811,114 cubic feet, of which 52,281,311 cubic feet, or 21.03 per cent., were made from coal, and 191,529,803 cubic feet or 78.97 per cent., were oil and water gas. The total quantity of gas sold for fuel purposes was 503,735,886 cubic feet, of which 167,885,909 cubic feet, or 33.33 per cent., were made from coal, and 335,849,977 cubic feet or 66.67 per cent., were oil and water gas.

Of the total gas for illuminating purposes coal gas comprised 21.03 per cent., while it comprised 33.33 per cent. of the gas sold for fuel purposes.

These statistics are from returns made to the United States Geological Survey, and are entirely exclusive of natural gas.

In 1907 seven establishments in Texas produced 225,394 gallons of coal-tar, valued at $12,707, or 5.6 cents a gallon. The yield of tar per ton of coal was 7.97 gallons.

The production of gas-coke, in 1907, was 12,049 tons. No ammonia compounds were produced. The yield of coal-gas per ton of coal carbonized was 12,411 cubic feet.

There are no statistics available on the heating or illuminating power of this coal-gas, nor on the character or source of the coal carbonized. We do not know how much of the coal made into gas was Texas coal, nor what the prospects are, if any, for the use of these coals in this direction.

But if all of the coal thus used had come from Texas it would have formed a very small proportion of the total coal production, and in total value at the mines would not have exceeded $75,000.

The strong tendency, in gas-making, is towards oil and water gas, not towards coal-gas. With respect to gas-making, the best outlook for both coal and lignite is in the direction of producer-gas to be used direct as fuel, or in gas-engines for power. The investigations which have been begun by this Bureau along these lines are particularly pertinent at this time.

HEAT VALUE OF TEXAS COALS.

The heat value of fuels is expressed in British Thermal Units. (B. T. U.) This term signifies the amount of heat required to raise the temperature of one pound of water from 50 degrees to 51 degrees Fahrenheit. It is equivalent to the expression, "pound degree."

The term British Thermal Unit is employed in England and the United States. In Continental Europe the term calorie is used. If this word is spelled with a capital it signifies the amount of heat necessary to raise a kilogram of water (2.22 pounds) from 0 to 1 degree Centigrade. If it is spelled with a small letter it signifies the amount of heat necessary to raise the temperature of one gram of water from 0 to 1 degree Centigrade. The expressions large calorie and small calorie are also used.

The expression "pound calorie" is sometimes used, and it means the amount of heat necessary to raise the temperature of one pound of water from 0 to 1 degree Centigrade.

The large calorie is equal to 3.968 British Thermal Units, the small calorie to 1.802 B. T. U. The pound calorie is equal to 9/5 of a British Thermal Unit.

In this publication we use the British Thermal Unit, and not the calorie, as it is customary among engineers and practical operators to employ the British rather than the French system. The term British Thermal Unit is well understood, and has a definite meaning, whereas, if one uses the calorie he has to specify which calorie is to be taken, the large or the small one.

In Texas coals, as mined, the heat value varies from 9,609 B. T. U. as in coal from the old Smith-Lee Mine, Cisco, Eastland county, to 12,264, as in coal from Thurber, Erath county. The general average is 11,245.

All of the determinations were made with a Parr Standard Calorimeter, and represent the average of at least two separate estimations.

Many attempts have been made to secure a formula by which the heating power could be calculated from the analysis so as to avoid the labor and expense of actual determinations. Two of the best known of such formulas are the Goutal for proximate and the DuLong for ultimate analyses.

The Goutal formula is

$$P = \frac{14670C + AM}{100}, \text{ where}$$

P=heating power
C=fixed carbon
M=volatile and combustible matter.
A=a constant varying with the value of M. Thus
when M= 2 to 15 A=23400
when M=15 to 30 A=18000
when M=30 to 35 A=17100
when M=35 to 40 A=16200

The original Goutal formula did not extend the value of M beyond 40, so that in applying it to some of the Texas coals and lignites it was necessary to interpolate the values for A when M=40 to 45, 45 to 50, 50 to 55 and 55 to 60. The interpolated values are 15300, 14400, 13500 and 12600, respectively. For calculating the heat value from an ultimate analysis a modification of the DuLong formula was used, viz.:

$$P = 14600C + 62000(H - \frac{O}{8} + 4000S,$$

Where

P=heating power
C=percentage of carbon
H=Percentage of hydrogen
O=percentage of oxygen
S=percentage of sulphur.

We have calculated out the heating power of Texas coals, both from the proximate and the ultimate analysis, and give the results in the following Table, together with the heating power as actually determined, and the theoretical evaporation in pounds of water from and at 212 degrees Fahrenheit per pound of dry coal.

CALCULATED HEAT UNITS IN TEXAS COALS AND THEORETICAL EVAPORATION OF WATER PER POUND OF COAL—DRY BASIS.

Analysis No.	Heating Power, B. T. U.			Theoretical Evaporation in Pounds of Water from and at 212° F. per Pound of Coal. From Det'd B. T. U.
	Calculated.			
	From Proximate Analysis.	From Ultimate Analysis.	Determined.	
1	12,489	10,308	10,213	10.57
53	12,515	11,233	10,970	11.35
2	13,088	11,601	11,196	11.58
3	12,860	13,187	12,604	13.04
4	13,294	11,906	11,695	12.10
5	14,818	13,072	12,527	12.96
6	11,624	10,003	9,636	9.97
31	12,682	11,657	11,545	11.94
32	12,026	10,940	10,807	11.18
33	11,495	10,537	10,412	10.77
42	11,032	8,819	10,200	10.55
43	11,044	8,902	11,000	11.38
50	11,699	9,881	10,380	10.74
51	12,218	9,742	10,720	11.09
52	12,802	10,630	11,412	11.81
8	12,399	12,328	11,740	12.12
7	13,879	12,723	12,410	12.84
9	13,685	12,904	12,265	12.69
10	13,664	12,965	12,526	12.96
37	11,907	10,457	10,510	10.87
11	13,007	11,409	11,269	11.66
Average	12,582	11,200	11,240	11.63

On the average the calculated heat units from the proximate analysis, using Goutal's formula, are 10.67 per cent. higher than the heat units determined by calorimeter, while the heat units calculated from the ultimate analysis, using DuLong's formula, are practically the same as the results from the calorimeter.

SPECIFIC GRAVITY AND WEIGHT PER CUBIC FOOT

The specific gravity of Texas coals, as mined, varies from 1.02, as in a coal from Erath county, to 1.51, as in a coal from Maverick county. The Tertiary coals, from Maverick and Webb counties (Rio Grande Field) vary in specific gravity from 1.24 to 1.51, the average being 1.33. The variation in the Carboniferous coals is from 1.02 to 1.39, the average being 1.29.

On a dry basis the variation in the Tertiary coals is from 1.29 to 1.62, the average being 1.41, and in the Carboniferous coals from 1.10 to 1.62, the average being 1.39.

On a dry basis the weight per cubic foot in the Tertiary coals varies from 80.6 to 101.2 pounds, the average being 87.8

pounds. In the Carboniferous coals, dry basis, the variation is from 68.7 to 101.2 pounds, the average being 87.4 pounds.

The general average weight of all the coals, as mined, is 81.1 pounds per cubic foot and 87.5 pounds on a dry basis.

We have thus far considered the composition of Texas coals as represented by samples taken at the mines. These samples were secured in 1901-1902 and analyzed at that time. Beginning in the fall of 1910 and continuing into the spring of 1911, we solicited samples from the operating companies. The cans sent were provided with closely-fitting covers, but were not sealed. The moisture was determined at once upon receipt of the samples, so that there was very little, if any, loss of moisture from the samples. One or two of the larger samples came in closely-nailed boxes.

By making analyses of these company samples and comparing the results with those obtained from our own samples it was hoped that we would arrive at a fair statement of the composition of Texas coals. But few samples were taken at points of delivery and consumption, as we had not the means to do this.

Following is the description of the samples received:

No. 1. Belknap Coal Co., Newcastle, Young county.
No. 53. Belknap Coal Co., Newcastle, Young county.
No. 2. Bridgeport Coal Co., Bridgeport, Wise county.
No. 3. Cannel Coal Co., Laredo, Webb county.
No. 4. International Coal Mines Co., Eagle Pass, Maverick county.
No. 5. International Coal Mines Co. Eagle Pass, Maverick county. Special.
No. 6. Nos. 6, 31, 32, 33, 50, 51 and 52. Olmos Coal Co., Eagle Pass, Maverick county.
No. 31. Washed egg.
No. 32. Washed nut.
No. 33. Washed pea.
No. 50. Washed pea.
No. 51. Washed nut.
No. 52. Washed egg.
No. 42. Olmos washed nut. Sampled at McNeil, Texas.
No. 43. Olmos run-of-mines. Sampled at McNeil, Texas.
No. 8. Rio Grande Coal Co., Laredo, Webb county.

No. 7. Santo Mining & Developing Co., Weatherford, Parker county.

No. 9. Strawn Coal Mining Co., Strawn, Palo Pinto county.

No. 10. Texas & Pacific Coal Co., Thurber, Erath county.

No. 37. Stewart Creek Coal Co., Jermyn, Jack county.

No. 11. Wise County Coal Co., Bridgeport, Wise county.

Nos. 42 and 43 were Olmos coal, sampled at the works of the Austin White Lime Company, McNeil, Travis county, where producer gas was made for use in burning lime. Olmos run-of-mines, as represented by analysis No. 43, is no longer marketed, all of the product being washed. The analyses of these coals follow:

COMPOSITION OF TEXAS COALS—SAMPLES RECEIVED FROM THE COMPANIES, 1910-1911. ANALYSES BY S. H. WORRELL.

Analysis No.	As Received.										Dry Basis.									Analysis No.
	Proximate Analysis.					Ultimate Analysis.					Proximate Analysis.				Ultimate Analysis.					
	Moisture.	Volatile and Combustible Matter.	Fixed Carbon.	Ash.	Sulphur.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Heating Power B. T. U.	Volatile and Combustible Matter.	Fixed Carbon.	Ash.	Sulphur.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Heating Power B. T. U.	
1	11.00	34.22	37.99	16.79	3.77	51.84	3.71	11.00	1.89	9,090	38.45	42.68	11.87	4.24	58.25	4.17	12.35	2.12	10,213	1
53	7.00	37.56	40.18	15.26	1.99	56.93	4.74	11.29	2.79	10,203	40.38	43.20	16.42	2.13	61.21	5.09	12.15	3.00	10,970	53
2	9.40	34.65	42.53	13.42	3.09	61.49	3.99	8.47	2.54	10,144	38.30	46.94	14.76	3.41	65.42	4.40	9.21	2.80	11,196	2
3	2.30	52.78	37.10	7.82	2.20	69.41	5.53	9.06	2.94	12,315	54.00	37.97	8.03	2.25	71.04	5.65	10.03	3.00	12,604	3
4	4.85	38.30	46.30	10.55	2.04	64.22	4.83	12.34	1.40	11,128	40.25	48.65	11.10	2.14	67.38	4.83	13.08	1.47	11,695	4
5	8.20	35.99	53.00	2.81	1.66	70.62	4.67	10.53	1.51	11,500	39.20	57.73	3.07	1.80	74.74	5.08	13.67	1.64	12,527	5
6	6.50	31.51	37.37	24.62	1.87	51.84	3.88	8.91	2.38	9,010	33.70	39.96	26.34	2.00	55.44	4.14	9.56	2.52	9,636	6
31	5.40	35.05	42.09	16.56	1.23	60.66	4.66	9.84	1.65	10,921	38.00	44.49	17.55	1.30	64.12	4.92	10.41	1.74	11,545	31
32	5.30	35.58	38.35	20.77	1.61	56.83	4.39	8.39	1.71	10,235	37.58	40.49	21.93	1.70	60.01	4.63	9.93	1.80	10,807	32
33	5.70	33.48	36.93	23.89	1.70	53.94	4.15	7.50	3.12	9,819	35.50	39.16	25.34	1.80	57.20	4.40	7.96	3.30	10,412	33
42	4.20	36.55	32.35	26.95	1.71	48.33	3.88	13.31	2.62	9,772	38.15	33.76	28.09	0.74	50.44	4.04	13.96	2.73	10,200	42
43	3.64	28.82	37.20	30.34	0.54	49.37	3.60	11.35	1.16	10,600	29.90	38.60	31.50	0.56	51.23	3.73	11.78	1.20	11,000	43
50	4.90	33.10	37.28	24.72	1.55	53.34	3.81	10.43	1.25	9,871	34.80	39.19	26.01	1.62	56.08	4.00	10.98	1.31	10,380	50
51	5.20	34.53	40.94	19.23	1.48	53.78	3.92	14.27	2.12	10,163	36.42	43.07	20.51	1.56	56.72	4.13	14.95	2.13	10,720	51
52	5.30	37.11	41.69	15.90	1.14	58.79	3.98	13.26	1.63	10,808	39.18	44.02	16.80	1.20	62.08	4.20	14.00	1.72	11,412	52
8	2.80	49.05	37.04	11.11	2.04	64.22	5.56	11.84	2.43	11,412	50.45	38.10	11.45	2.09	66.06	5.72	12.18	2.50	11,740	8
7	3.50	38.12	49.21	9.17	2.03	68.42	4.69	8.96	3.23	11,976	39.50	50.99	9.51	2.10	70.91	4.85	9.29	3.34	12,410	7
9	2.90	38.46	48.13	10.51	3.08	67.97	5.01	7.90	2.63	10,910	39.60	49.56	10.84	3.17	70.00	5.15	8.14	2.70	12,265	9
10	2.70	40.82	48.73	7.75	1.93	69.85	5.21	10.45	2.11	12,188	41.95	50.08	7.97	1.98	71.78	5.35	10.75	2.17	12,526	10
37	10.24	34.28	35.02	20.46	1.66	54.11	3.39	8.86	1.28	9,434	38.18	39.01	22.81	1.84	60.28	3.77	9.88	1.42	10,510	37
11	9.20	33.96	43.02	13.82	1.82	57.94	4.24	10.33	2.65	10,233	37.40	47.37	15.23	2.00	63.80	4.67	11.40	2.90	11,269	11
Average	5.82	36.89	41.07	16.30	1.86	59.23	4.37	10.39	2.05	10,558	39.09	43.57	17.34	1.98	62.76	4.66	11.00	2.26	11,240	

PROXIMATE ANALYSES OF TEXAS COALS—ALPHABETICALLY ARRANGED—DRY BASIS.

	Volatile and Combustible.	Fixed Carbon.	Ash.	Sulphur.	Heating Power B. T. U.
1. Belknap Coal Co. Newcastle, Young County	38.45	42.68	11.87	4.24	10,213
53. Belknap Coal Co. Newcastle, Young County	40.38	43.20	16.42	2.13	10,970
2. Bridgeport Coal Co. Bridgeport, Wise County	38.30	46.94	14.76	3.41	11,196
3. Cannel Coal Co. Laredo, Webb County	54.00	37.97	8.03	2.25	12,604
4. International Coal Mines Co. Eagle Pass, Maverick County	40.25	48.65	11.10	2.14	11,695
5. International Coal Mines Co. Eagle Pass, Maverick County Special	39.20	57.73	3.07	1.80	12,527
6. Olmos Coal Co. Eagle Pass, Maverick County	33.70	39.96	26.34	2.00	9,636
31. Olmos Coal Co. Washed Egg	38.00	44.49	17.55	1.30	11,545
32. Olmos Coal Co. Washed Nut	37.58	40.49	21.93	1.70	10.807
33. Olmos Coal Co. Washed Pea	35.50	39.16	25.34	1.50	10,412
50. Olmos Coal Co. Washed Pea	34.80	39.19	26.01	1.62	10,380
51. Olmos Coal Co. Washed Nut	36.42	43.07	20.51	1.56	10,720
52. Olmos Coal Co. Washed Egg	39.18	44.02	16.80	1.20	11,412
42. Olmos Coal Co. Washed Nut	38.15	33.76	28.09	0.74	10,200
43. Olmos Coal Co. Mine-run	29.90	38.60	31.50	0.56	11,000
8. Rio Grande Coal Co. Laredo, Webb County	50.45	38.10	11.45	2.09	11,740
7. Santo Mining & Developing Co. Weatherford, Parker County	39.50	50.99	9.51	2.10	12,410
9. Strawn Coal Mining Co. Strawn, Palo Pinto County	39.60	49.56	10.84	3.17	12,265
10. Texas & Pacific Coal Co. Thurber, Erath County	41.95	50.08	7.97	1.98	12,526
37. Stewart Creek Coal Co. Jermyn, Jack County	38.18	39.01	22.81	1.84	10,510
11. Wise County Coal Co. Bridgeport, Wise County	37.40	47.37	15.23	2.00	11,269
Average	39.09	43.57	17.34	2.26	11,240

In this Table the Carboniferous Coals are Nos. 1, 53, 2, 7, 9, 10, 37 and 11. The Tertiary Coals are Nos. 3, 4, 5, 6, 31, 32, 33, 50, 51, 52, 42, 43, 8.

On comparing these analyses with the analyses made on personal samples we find as follows, the first figures representing Company samples and the latter figures personal samples, averages alone being given:

	Company samples.	Personal samples.
Moisture	5.82	7.40
Volatile and Combustible Matter	36.89	34.82
Fixed Carbon	41.07	41.74
Ash	16.30	16.04
Sulphur	1.86	2.19
Carbon	59.23	60.01
Hydrogen	4.37	4.25
Oxygen	10.39	8.33
Nitrogen	2.05	1.76
Heating power, B. T. U	10,558	11,245

On dry basis, these become:

Volatile and Combustible Matter	39.09	37.65
Fixed Carbon	45.57	45.06
Ash	17.34	17.29
Sulphur	1.98	2.38
Carbon	62.76	64.79
Hydrogen	4.66	4.59
Oxygen	11.00	9.00
Nitrogen	2.26	1.90
Heating power, B. T. U	11,240	12,035

There are no very considerable discrepancies between these analyses, and it may fairly be concluded that they represent the composition of Texas coals as they are mined. It must be remembered that they do not pretend to represent the composition or heating value of the coals as they are used in actual practice. This is a matter to be adjusted between the buyer and the seller. If the consumer is willing to continue the use of a system by which he buys so much coal at such and such a price, without regard to composition and its heating power, he is, of course, free to do so. At the same time he must remember that he is not getting from his money its full service. He may be handling twice as much ash as may be necessary. He may be getting many heat units less than he is entitled to, but so long as he does not buy coal under specifications, but simply on a tonnage basis, he will continue to get a good deal less from a dollar than it has in it.

These remarks apply not only to Texas coals, which represent a small proportion of the coal used here, but to all classes of coal brought in from Alabama, West Virginia, Pennsylvania, Kentucky, Arkansas, Oklahoma, Colorado and New Mexico.

Just how much coal is brought into Texas from outside points we do not know. There are no statistics on this subject, but the amount is certainly far in excess of local production.

It understands itself that these coals vary a good deal in composition and value, just as Texas coals do, but they are bought on a tonnage basis, and there are few, if any, specifications as to moisture, or ash, or sulphur, or heating power. A ton of coal is a ton of coal whether it has 160 pounds or 320 pounds of ash, and whether the heating power is 9,000 or 12,000 B. T. U. If we like this way of doing business, why, this is the way we like. In the meantime we are spending money for nothing.

OTHER ANALYSES OF TEXAS COALS.

There are not many sources of information on the composition of Texas coals. We have been able to find only a few, outside of Bulletin No. 3, University of Texas Mineral Survey, May, 1902.

In the First Annual Report of the Texas Geological Survey, 1889, page 215, there are given five analyses of coal from different parts of the Waldrip beds, McCulloch county (Carboniferous), and in Coleman county. These are as follows:

ANALYSES OF COAL FROM THE WALDRIP BEDS, COLEMAN COUNTY.

Locality.	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
Waldrip	8.25	38.27	47.27	6.20	3.25
*Waldrip	4.55	38.50	44.80	12.14	7.96
Bull Creek and Coleman County	4.05	40.40	46.75	8.80	2.87
Bull Creek	10.40	35.94	49.46	4.19	1.53
Silver Moon Mine	6.90	36.00	41.10	16.00	4.56

*Sample taken from the dump, not considered a fair sample.

In the Second Annual Report of the Texas Geological Survey, 1890, page 551, there are given six analyses of Texas coals, as follows:

ANALYSES OF TEXAS COALS.

Locality.	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
Bridgeport, Wise County	2.00	31.47	56.32	8.15	2.06
Sheuber Shaft, near Bowie, Montague County	2.30	34.48	61.28	0.60	1.14
Gilfoil Shaft, Young County	1.10	35.50	43.00	15.60	4.60
Thurber Shaft No. 1, Erath County	0.85	31.23	56.98	9.30	1.64
Thurber Shaft No. 2, Erath County	0.90	30.96	60.01	6.85	1.28
Thurber Shaft No. 3, Erath County	0.90	33.51	53.46	10.65	1.48
*San Tomas Coal, Webb County	2.59	51.05	39.01	7.35	1.50
*From 25 Miles N. W. of San Tomas, Webb County	2.35	42.67	37.59	16.55	0.86

No coal is now mined in Montague County.
*Brown Coal and Lignite, Dumble, 1892, p. 190.

The analysis of the coal from near Bowie, Montague county, is quite remarkable as showing only 0.60 per cent. of ash.

In a note appended to these analyses it is stated that the coal from the Gilfoil shaft, Young county, was taken from the dump, and was not a fair sample.

In the Fourth Annual Report of the Texas Geological Survey, 1893, pages 433-435, there are given eight analyses of coal from the southern part of Coleman county, near the Colorado river, and from the Silver Moon Mine, northeast of Santa Anna, Coleman county. These analyses are as follows:

ANALYSES OF COAL FROM COLEMAN COUNTY.

	Star & Crescent Co. near Rockwood. Average of 6 Analyses.	Silver Moon Mine N. E. of Santa Anna. Average of 2 Analyses.
Moisture	3.07	2.36
Volatile and Combustible Matter	33.05	38.55
Fixed Carbon	39.10	43.88
Ash	24.78	15.21
	100.00	100.00
Sulphur	3.10	5.91

One of the coals from the Star and Cresent property gave moisture, 4.71; volatile and combustile matter, 39.26; fixed carbon, 46.24; ash, 9.79, and sulphur, 2.22. This is the best analysis given. The analyses from the Silver Moon property represent a fair average of that coal, vicinity of Jim Ned Creek.

None of these coals is now worked, except perhaps, for purely local purposes.

Reference has been made in these pages to the coal in Presidio county and to the unsuccessful attempt that was made in 1893-1895, to develop it.

This coal is in the San Carlos district, from 20 to 25 miles south of Chispa, a station on the Southern Pacific Ry., 145 miles southeast of El Paso.

Without, at this time, expressing any opinion concerning the value of that field from a commercial standpoint, except that it appears to be worth further investigation, we give two analyses of the coal which are quoted in The Mineral Resources of the United States, United States Geological Survey, 1893, page 385. The analyses were sent to that survey by Mr. R. E. Russell, General Manager of The San Carlos Coal Company, a Pittsburg organization. There was said to be two benches in the seam separated by from 6 to 18 inches of slate. The lower bench was said to average from 30 to 40 inches and was softer than the upper bench, which was 32 inches, widening out, in places, to 6 feet or more.

Two analyses were given, but nothing is said as to which one represents the lower and which the upper bench.

ANALYSES OF COAL FROM THE SAN CARLOS FIELD, PRESIDIO COUNTY.

	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
No. 1	1.00	39.05	49.05	10.00	trace
No. 2	0.94	34.48	58.96	5.62	0.64

Mr. Russell said that coking tests of this coal had been made at Connellsville, Pennsylvania, and that 48-hour bee-hive coke gave carbon 93.7 per cent and ash 6.30 per cent.

A railroad test, made on coal that had been on the dump for five or six months, and that was practically crop coal, showed a haulage of 52.21 miles per ton of coal, passenger train with five or six coaches. The San Carlos Field would appear to merit a more careful examination than it has yet had, especially in view of the possibility of developing a good coking coal.

The undeveloped coal in Stephens county, in the vicinity of Crystal Falls and up the Brazos river from this place; west and southwest of Breckenridge, etc., has not been sufficiently opened for one to express a positive opinion concerning it.

On Coal Branch, a few miles west of Crystal Falls, Stephens county, there is an outcrop of coal with two benches, each 12 inches thick, which was sampled by Wm. B. Phillips, December 13th, 1906. The analysis was as follows:

ANALYSIS OF COAL FROM COAL BRANCH, STEPHENS COUNTY, UPPER BENCH.

Moisture	6.90
Volatile and Combustible Matter	38.07
Fixed Carbon	37.03
Ash	18.00
	100.00
Sulphur	6.49

This coal contained an excessive amount of sulphur and experiments were made to see what proportion of it could be eliminated. A large sample was put through a 3/8 inch screen and thoroughly mixed. A sample was treated in zinc chloride solutions of specific gravity 1.30, 1.35 and 1.40. The coal that floated in 1.30 was 29.50 per cent. of the total, and contained 11.34 per cent. of ash, with 4.10 per cent. of sulphur.

The coal that sank in the solution of 1.30 specific gravity, but floated in 1.35 was 29.50 per cent. of the total, and contained 19.24 per cent. of ash, with 5.36 per cent. of sulphur. The coal that sank in 1.35, but floated in 1.40, was 4.50 per cent. of the total, and contained 18.80 per cent. of ash, with 6.29 per cent. of sulphur.

The coal that sank in 1.40 was 36.50 per cent. of the total and contained 35.60 per cent. of ash, with 8.54 per cent. of sulphur. It is not likely that this coal could be improved by washing to such an extent as to warrant the expense to be incurred. The best of it contains over 4 per cent. of sulphur.

The bottom bench of this coal, separated from the upper bench by from 3 to 6 inches of bone and slate, shows a much better material.

ANALYSIS OF BOTTOM BENCH OF COAL, COAL BRANCH, STEPHENS COUNTY.

Moisture	3.15
Volatile and Combustible Matter	41.95
Fixed Carbon	43.60
Ash	11.30
	100.00
Sulphur	3.75

The composition of the entire seam of 24 inches at this place would be:

Moisture	5.02
Volatile and Combustible Matter	40.01
Fixed Carbon	40.46
Ash	14.51
	100.00
Sulphur	5.12

There has been, of late, an increase of interest in the Stephens county coals, and some work is now being done there, but no coal has been shipped, as there are no railroad facilities.

In the southern part of Brewster county, within 8 to 10 miles of the quicksilver area, there is a limited field of bituminous coal. This coal has been used under steam boilers with satisfactory results. We give three analyses of the coal from the Rough Run district.

	Cub Spring. Per cent.	Kimble Pits. Per cent.	Chisos Pen. Per cent.
Moisture	10.65	4.74	1.16
Volatile Matter	50.91	29.84	32.79
Fixed Carbon	19.52	49.84	44.53
Ash	18.92	15.58	21.52
	100.00	100.00	100.00
Sulphur	0.86	1.26	3.39
Heating Power, B. T. U.	8,432	11,887	11,958

This coal field is 90 miles from the Southern Pacific Railway, at Alpine, or Marathon. The coal can be used only for local purposes, but it could be used in producers for making gas for the quicksilver furnaces instead of wood. There are outcrops of this coal within two miles of furnaces now in operation. The Rattlesnake beds, 20 miles south of the Rough Run district, are probably a continuation of the more northern beds.

Chapter II.

LIGNITE.

The lignite fields of Texas probably extend over 60,00 square miles. The original supply of lignite may be taken to have been in excess of 30,000,000,000 tons and as it has scarcely been touched, the supply of this fuel need occasion no anxiety for the next thousand years or so. There is found in Texas every known variety of lignite, from a material carrying but a few per cent. of fixed carbon to nearly 45 per cent., and with from 30 per cent. of volatile and combustible matter to more than 76 per cent.

Physically the lignites range from what is but little more than carbonized wood to a material almost like bituminous coal.

In thickness, the beds run to 15 feet and more, and they are found from the surface to depths of 400 to 600 feet.

The counties in which workable beds of lignite occur are the following: Anderson, Angelina, Atascosa, Bastrop, Bowie, Brewster, Caldwell, Camp, Cass, Cherokee, Dimmit, Fayette, Freestone, Grimes, Harrison, Henderson, Hopkins, Houston, Jasper, Lee, Leon, Limestone, McMullen, Marion, Medina, Milam, Morris, Nacogdoches, Newton, Panola, Rains, Robertson, Rusk, Sabine, San Augustine, Shelby, Smith, Titus, Upshur, Van Zandt, Webb, Wood and Zavala.

In a general way, workable lignite is found in all that part of Texas lying east of the 97th meridian of west longtitude and north of the 31st degree of north latitude, but there are important areas outside of these boundaries.

In the year 1892 Mr. E. T. Dumble, State Geologist, issued a comprehensive and valuable report on Brown Coal and Lignite, and this still remains the chief source of information as to the geology and occurrence of lignite in Texas. In addition, many analyses are given and they are referred to in this Bulletin.

Mr. Dumble classed the brown coal (lignite) deposits as belonging to the Tertiary formation. They occur in the Gulf slope, from the Red river to the Rio Grande, in an area 650 miles in length and 200 miles in width. He says that the greater amount of the deposits are found in the Eocene series of the Tertiary and in the following divisions:

Fayette.

Yegua.

Timber Belt.

The lowest deposits are in the Timber Belt series, and this contains the heaviest and best beds. This series is epecially developed in the counties extending southwest from Bowie county, on the Red River, such as Cass, Marion, Harrison, Morris, Titus, Hopkins, Camp, Upshur, Wood, Rains, Van Zandt, Smith, Henderson, Anderson, Freestone, Limestone, Leon, Robertson, Milam, Lee, Bastrop and Caldwell.

The Yegua division, including the lower portion of the Fayette beds, are divided into three sections, viz.: East Texas, Brazos river and Rio Grande.

The Fayette division of the Tertiary, comprising the uppermost beds of the lignite-bearing Eocene, he divides into four sections, viz: East Texas, Brazos river, Colorado river and Rio Grande.

As this Bulletin is not intended for any discussions of the geology of Texas coals or lignites, it is sufficient merely to call attention to the matter in a general way, and to refer those who desire detailed information to Mr. Dumble's "Brown Coal and Lignite."

Inasmuch as the development of the lignite industry in this State has come about since the publication of that excellent report and to a great extent because of it, more recent and more detailed analyses of the lignites mined and in use were undertaken by the University Mineral Survey in 1901-1902. These were published in Bulletin No. 2 of that survey, 1902, but this has long been out of print.

At that time samples were taken, in person, at the mines and were placed in tight cans which were scaled. In this way the moisure in the lignites, as mined, was capable of accurate determination.

The mines visited and sampled were as follows:

No. 1535. Carr Mine, Lytle, Medina county.

No. 1536. Bertetti Mine, Lytle, Medina county.

No. 1537. Glenn-Belto Mine, Bishop, Bastrop county.

No. 1538. Worley Mine, Rockdale, Milam county.

No. 1539. Black Diamond Coal Co., Rockdale, Milam county.
No. 1540. Lignite Eggette Coal Co., Rockdale, Milam county.
No. 1541. J. J. Olsen & Sons, Rockdale, Milam county.
No. 1542. Big Lump Coal Co., Rockdale, Milam county.
No. 1543. Aransas Pass Lignite Co., Rockdale, Milam county.
No. 1544. Central Texas Mining, Manufacturing & Land Co., Calvert Bluff, Robertson county.
No. 1545. Houston County Coal Co., near Lovelady, Houston county.
No. 1546. Timpson Coal Co., Timpson, Shelby county.
No. 1547. North Texas Coal Co., Alba, Wood county.
No. 1548. North Texas Coal Co., Alba, Wood county.
No. 1549. Como Coal Co., Como, Hopkins county.

The production of lignite at that time and year by year since is given in the Table of Production of Coal and Lignite on page 7 of this Bulletin.

The analyses made on the samples taken in 1901-1902 are as follows:

COMPOSITION OF TEXAS LIGNITES, SAMPLED AT MINES BY UNIVERSITY MINERAL SURVEY, 1901-1902.
ANALYSES BY O. W. PALM AND S. H. WORRELL.

Analysis No.	Proximate Analysis. Natural Condition. Moisture.	Proximate Analysis. Natural Condition. Volatile and Combustible Matter.	Proximate Analysis. Natural Condition. Fixed Carbon.	Proximate Analysis. Natural Condition. Ash.	Proximate Analysis. Natural Condition. Sulphur.	Proximate Analysis. On Dry Basis. Volatile and Combustible Matter.	Proximate Analysis. On Dry Basis. Fixed Carbon.	Proximate Analysis. On Dry Basis. Ash.	Proximate Analysis. On Dry Basis. Sulphur.	Ultimate Analysis. Natural Condition. Carbon.	Ultimate Analysis. Natural Condition. Hydrogen.	Ultimate Analysis. Natural Condition. Oxygen.	Ultimate Analysis. Natural Condition. Nitrogen.	Ultimate Analysis. Dry Basis. Carbon.	Ultimate Analysis. Dry Basis. Hydrogen.	Ultimate Analysis. Dry Basis. Oxygen.	Ultimate Analysis. Dry Basis. Nitrogen.	Heat Value. British Thermal Units. Natural Condition.	Heat Value. British Thermal Units. Dry Basis.	Specific Gravity —Dry.	Weight per Cubic Foot —Dry.	Analysis No.
1535	35.30	36.33	28.85	7.52	0.93	56.15	32.24	11.61	1.45	41.36	3.07	10.76	1.04	63.93	4.75	16.64	1.62	7,903	12,215	1.28	80.0	1535
1536	34.29	40.31	18.50	6.90	1.20	61.36	28.17	10.47	1.84	41.01	3.25	13.82	0.73	61.03	4.85	20.57	1.09	7,536	11,470	1.42	88.7	1536
1537	35.40	36.88	21.22	6.50	0.94	56.94	32.86	10.20	1.47	42.24	3.13	10.67	1.00	65.40	4.85	16.52	1.56	7,859	12,166	1.30	81.2	1537
1538	32.79	37.09	22.91	7.21	1.18	55.20	34.10	10.70	1.76	41.01	3.25	13.82	0.73	61.03	4.85	20.57	1.09	7,763	11,551	1.32	82.5	1538
1539	34.72	34.26	22.73	8.29	1.04	54.02	34.82	11.16	1.60	41.93	3.12	11.03	0.85	64.24	4.79	16.90	1.31	7,697	11,792	1.20	75.0	1539
1540	32.27	44.30	15.26	8.17	2.31	65.41	22.54	12.05	3.42	38.56	2.85	14.85	0.96	56.94	4.22	21.94	1.43	7,383	10,901	1.37	85.6	1540
1541	33.63	46.78	7.45	12.14	0.99	70.49	11.24	18.27	1.50	38.78	2.70	10.89	0.86	58.44	4.07	16.42	1.30	7,359	11,088	1.37	85.6	1541
1542	31.52	44.49	17.48	6.51	0.93	64.98	25.57	9.45	1.36	41.15	3.36	14.68	0.86	60.10	4.91	22.91	1.27	8,046	11,750	1.39	86.9	1542
1543	29.07	28.96	24.47	17.60	3.29	40.84	34.49	24.67	4.65	38.65	2.73	7.32	1.40	54.51	3.86	10.33	1.98	7,439	10,489	1.44	90.0	1543
1544	29.86	51.00	10.00	9.14	0.91	72.72	14.26	13.02	1.30	43.17	3.29	12.78	0.83	61.56	4.70	18.23	1.19	7,929	11,305	1.39	86.8	1544
1545	36.16	33.16	19.93	10.75	0.40	51.95	31.26	16.70	0.64	34.93	3.17	13.69	0.89	54.73	4.98	21.46	1.40	7,518	10,994	1.35	84.4	1545
1546	31.96	39.53	23.05	5.46	1.46	58.10	33.89	8.05	2.16	43.85	3.32	13.05	0.85	64.45	4.89	19.19	1.26	8,053	11,837	1.46	91.2	1546
1547	35.00	45.21	11.60	7.59	0.47	70.21	18.02	11.77	0.73	40.06	2.91	12.01	1.41	62.12	4.52	18.66	2.20	7,567	11,751	1.16	72.5	1547
1548	34.23	41.74	19.85	4.87	0.56	63.47	70.19	6.34	0.86	42.27	2.87	14.83	1.05	64.27	4.37	22.55	1.61	7,691	11,694	1.33	88.1	1548
1549	33.87	45.88	3.41	16.84	0.68	69.39	5.16	25.45	1.04	34.05	2.30	11.15	1.09	51.50	3.49	16.87	1.65	6,474	9,790	1.18	78.7	1549
Average	33.37	40.39	17.24	9.00	1.12	60.61	25.88	13.51	1.68	40.13	3.03	12.29	1.18	60.23	4.55	18.45	1.47	7,614	11,427	1.33	88.1	Average

The **variations** in these analyses are as follows: Material as mined—

	From.	To.	Average.
Moisture	29.07	36.16	33.37
Volatile and Combustible Matter	28.96	51.00	40.39
Fixed Carbon	3.41	24.47	17.24
Ash	4.87	17.60	9.00
Sulphur	0.40	3.29	1.12
Carbon	34.93	43.85	40.13
Hydrogen	2.30	3.37	3.03
Oxygen	10.67	14.85	12.29
Nitrogen	0.85	1.41	1.18
Heating Power, B. T. U.	6,474	8,053	7,614

On dry basis these become:

Volatile and Combustible Matter	40.84	72.72	60.61
Fixed Carbon	5.16	34.82	25.88
Ash	6.34	25.45	13.51
Sulphur	0.64	4.65	1.68
Carbon	51.50	65.40	60.23
Hydrogen	3.49	5.13	4.55
Oxygen	10.33	22.91	18.45
Nitrogen	1.09	2.20	1.47
Heating Power, B. T. U.	9,790	12,215	11,427
Specific Gravity	1.16	1.44	1.33
Weight per cubic foot. Lbs.	72.5	90.0	83.1

COMPOSITION OF THE ASH OF TEXAS LIGNITES.

Analysis No.	Silica.	Alumina.	Oxide of Iron.	Lime.	Magnesia.	Oxide of Manganese.	Sulphuric Acid.	Analysis No.
1535	63.40	12.27	5.95	none	trace	1.00	13.71	1535
1536	40.46	16.92	8.32	15.60	1.22	----------	15.54	1536
1537	30.14	13.48	11.70	23.59	0.88	3.32	14.22	1537
1538	21.64	16.20	11.10	25.23	4.36	2.00	18.01	1538
1539	33.06	16.77	8.47	23.08	1.38	trace	17.10	1539
1540	27.44	28.87	24.85	7.00	trace	0.52	10.45	1540
1541	23.20	11.94	5.08	38.17	1.00	1.60	7.79	1541
1542	42.20	23.02	2.02	15.93	2.12	trace	12.81	1542
1543	47.04	23.18	18.32	6.64	trace	trace	4.58	1543
1544	40.60	34.26	2.02	12.08	trace	----------	9.52	1544
1545	59.00	20.11	3.69	10.58	0.48	0.48	5.47	1545
1546	25.64	19.08	12.92	18.68	1.76	----------	20.92	1546
1547	38.73	23.00	6.00	24.11	trace	trace	8.51	1547
1548	33.00	25.84	7.40	22.32	----------	----------	11.32	1548
1549	53.04	24.68	7.70	10.59	trace	trace	3.53	1549
Average	38.57	20.64	9.04	16.84	0.94	0.81	12.90	Average

In these lignites the following variations in the composition of the ash are to be noted.

	From.	To.	Average.
Per cent. of ash	4.87	17.60	9.00
Silica	21.64	63.40	38.57
Alumina	11.94	34.26	20.64
Oxide of Iron	2.02	24.85	9.04
Lime	0.00	38.17	16.84
Sulphuric Acid	3.53	20.92	12.90

With the lignites, as with the coals, there is a considerable variation in the composition of the ash, leading to the conclusion that the conditions, with respect to vegetation and the in-wash of sediments, varied within wide limits.

On comparing the composition of the ash of these lignites with that of the coals given on page 17 it is seen that the lignite ash carried considerably less silica, alumina, and oxide of iron than the coal ash, but considerably more lime and combined sulphuric acid.

What deductions may be made from these facts does not now appear except that it is probable that the vegetation forming the coal was different from that forming the lignite. and also that the in-wash of extraneous materials was different during the process of the formation of these beds.

Whether the coal and lignite beds have been formed "in situ" or by "drift," or by a combination of these two methods is an open question. It is likely that conditions varied a good deal not only in the coal period as a whole, but also locally, and, to some extent, while the same seam was being made.

It may be of interest to give a list of the principal fossil fauna and flora that have been found in different coal beds. and the list that follows is taken from James Tonge's *Coal*, 1907.

FAUNA.

Amphibia. All belonging to the Labyrinthodont order.

Fish. Many different kinds, both large and small, shark, etc. Many geologists hold to the opinion that what is known as "Cannel" coal is of marine origin, on account of the prevalence of the remains of fish, shells, etc.

Insects. Not very abundant. One specimen of Orthoptera has been found with a spread of wing of nearly two feet.

Myriopoda ("Thousand Legs"). Quite common.

Arachnida (Spiders). Both spiders and scorpions have been found.

Xiphosura (Crabs). Fairy well distributed.

Schizopoda (Shrimps).

Ostracoda (Oyster-like forms). Abundant but sometimes very small.

Brachiopoda.

Mollusca, both uni- and bi-valve.

Brachiopoda. Well represented in carboniferous limestone, but not plentiful in the coal measures themselves.

Vermes (Worms). Fairly plentiful, as borings, tracks, etc.

FLORA.

A great deal of work has been done in the study of the fossil flora of the coal measures and the coal beds themselves. Of late years the chief interest has centered around the study of fossil flora from the standpoint of stratigraphical succession. The results of such researches are to be compared with the work of the stratigraphical and structural geologist who looks at the problem from the standpoint of the sequence of rocks.

The flora of the coal measures is represented by Lycopods, moss-like plants, some of them growing to a height of 50 feet and more.

Calamites. Reed-like plants, akin to our "horse-tails." Very common in coal measures.

Coniferae. Cone-bearing trees and shrubs, pine, cedar, etc. They appear for the first time in the coal measures.

Cordiates.

Some of the Lycopods were more than fifty feet in height and represented the maximum devlopment of the club moss.

It is a notable fact that in many of the so-called "flaming" coals there are large quantities of the spores of this gigantic club moss. The bark of this club moss is, perhaps, the most common fosil plant in the coal measures, and is to be observed in a great many places.

In paleobotany there is still some confusion in nomenclature, for it is one of the younger sciences, dating back not more than 35 or 40 years.

During the period of its existence, 1888-1892, the Texas Geological Survey did much valuable work on the fossil remains found in the coal measures of this State, but since that time nothing has been done by the State itself, and but little by outside investigators.

There is an impression—quite erroneous—that such studies are too "scientific," that they do not touch upon matters of practical importance. On this point we will quote Mr. James Tonge, Westhoughton, England, a notable authority on coal, and the inventor of the Hydraulic Mining Cartridge, which has done more for the protection of human life and property in coal mines than almost any appliance that could be mentioned.

In his book on "*Coal*," 1907, page 83, he says:

"It is from the Palaeo-botanist that the mining student seeks information as to the mode of formation of the seams, information which can only be derived from a close and intimate knowledge of the botany of carboniferous plant remains."

The truth is that so-called "scientific" work and practical work must go hand-in-hand. There is no hard and fast line of separation between them. What is pure science today is the basis of great enterprises tomorrow, and the scientist in the laboratory is fore-runner to the manager of the factory.

The analyses that have so far been given and discussed represent samples of lignites that were secured from the mines by an agent of the University Mineral Survey in 1901-1902.

In order to bring the matter down to date and present new and detailed analyses, the operating companies were asked to send in typical samples of the material they were mining and shipping. These samples were, for the most part. received in tin cans, with close-fitting covers. In those cases in which the moisture runs much below the normal the samples did not come in such cans, and, therefore, show a less amount of moisture than is usually found in our lignites.

As the analyses are given on the samples "as received," and on the dry, or waterfree basis, also they may readily be compared with each other.

The analyses of these "Company samples" are as follows:

ANALYSES OF TEXAS LIGNITES—COMPANY SAMPLES.
BY S. H. WORRELL, 1910-1911.

	As Received.									Dry Basis.								Heating Power.		
	Proximate Analysis.					Ultimate Analysis.				Proximate Analysis.				Ultimate Analysis				British Thermal Units.		
Analysis No.	Moisture.	Volatile and Combustible Matter.	Fixed Carbon.	Ash.	Sulphur.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Volatile and Combustible Matter.	Fixed Carbon.	Ash.	Sulphur.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	As Received.	Dry Basis.	Analysis No.
40	29.28	34.02	29.04	6.66	.57	39.61	3.08	19.71	1.09	48.10	41.05	10.85	.80	56.00	4.35	26.48	1.54	7,238	10,220	40
59	15.00	43.61	32.71	8.68	.94	49.47	3.58	20.95	1.38	51.30	38.48	10.22	1.10	58.20	4.21	24.65	1.62	8,789	10,340	59
12	29.94	39.03	21.09	9.94	.55	37.70	2.93	17.48	1.46	55.70	30.09	14.31	.78	53.80	4.18	24.95	2.08	6,291	8,979	12
57	7.30	45.62	36.65	10.43	.51	58.78	4.43	16.37	2.18	49.21	39.53	11.26	.45	63.40	4.78	17.76	2.35	10,411	11,230	57
13	29.96	41.68	22.24	6.12	.70	44.01	2.88	14.76	1.57	59.50	31.75	8.75	1.00	62.77	4.11	21.14	2.23	6,903	9,855	13
14	22.40	42.68	24.77	10.15	.55	45.34	3.85	16.00	1.71	55.00	31.91	13.09	1.33	58.42	4.96	20.00	2.20	8,156	10,510	14
16	24.36	33.89	25.64	16.11	.74	42.13	3.60	11.76	1.30	44.80	33.89	21.31	.97	55.69	4.75	15.57	1.71	7,068	9,344	16
41	36.64	28.33	27.02	8.01	.41	36.16	2.79	15.02	.97	44.70	42.63	12.67	.64	57.06	4.40	23.70	1.53	6,717	10,600	41
17	29.20	36.92	27.02	6.86	.58	43.29	3.37	15.49	1.21	52.14	38.22	9.64	.81	61.14	4.75	21.95	1.71	7,442	10,510	17
56	10.80	41.20	38.92	9.08	.61	48.80	2.81	25.99	1.91	46.18	43.63	10.20	.68	54.70	3.15	29.13	2.14	9,670	10,840	56
18	31.24	40.29	21.07	7.40	.73	39.73	3.23	16.30	1.37	58.60	30.64	10.76	1.05	57.77	4.70	23.74	1.98	6,727	9,782	18
36	27.20	40.90	27.09	4.81	.48	44.72	3.73	17.92	1.14	56.18	37.20	6.62	.65	61.42	5.12	24.63	1.56	7,682	10,540	36
20	25.58	39.37	25.30	9.75	.60	42.57	3.99	16.12	1.39	52.90	33.99	13.11	.80	57.20	5.36	21.67	1.86	7,532	10,120	20
21	37.26	31.85	24.81	6.08	.57	38.10	3.16	13.74	1.09	50.76	39.54	9.70	.90	60.72	5.03	21.92	1.73	6,416	10,226	21
22	27.50	35.20	27.30	10.00	.73	43.20	3.12	14.48	.73	48.54	37.65	13.81	1.00	59.58	4.29	19.99	1.33	7,040	9,709	22
23	31.12	33.95	22.66	12.27	.93	39.04	3.24	12.48	.93	49.28	32.90	17.82	1.34	56.67	4.70	18.14	1.33	6,688	9,709	23
55	12.60	44.75	33.90	8.75	.63	56.34	3.99	16.64	1.05	51.20	38.78	10.02	.72	64.20	4.56	19.30	1.20	9,774	11,182	55
44	12.62	37.91	36.21	13.26	.48	50.18	3.53	17.90	2.05	43.38	41.43	15.19	.54	57.42	4.03	20.48	2.34	9,525	10,900	44
28	30.20	33.23	28.84	7.73	.69	42.72	2.84	14.36	1.46	47.60	41.31	11.09	.98	61.20	4.06	20.58	2.09	6,920	10,030	28
25	30.34	34.14	30.66	4.86	.61	42.10	3.33	17.56	1.20	49.00	44.00	7.00	.87	60.47	4.78	25.20	1.70	6,797	9,957	25
26	25.64	35.55	30.28	8.53	.96	43.00	3.45	17.17	1.25	47.80	40.71	11.49	1.29	57.82	4.63	23.09	1.68	7,459	10,030	26
39	20.64	36.24	32.64	10.48	.70	46.70	3.54	15.95	1.99	45.66	41.12	13.22	.80	58.81	4.46	20.21	2.50	8,262	10,410	39
29	32.12	34.30	26.61	6.97	.82	40.16	2.60	15.57	1.76	50.52	39.20	10.28	1.20	59.16	3.82	22.96	2.58	6,690	9,855	29
Av'rage	25.17	37.59	28.45	8.79	.65	44.08	3.35	16.49	1.47	50.48	37.81	11.71	.90	58.85	4.48	22.20	1.86	7,661	10,212	Average

The key to these "Company samples" is as follows:

Analysis No.

40. Alba Lignite Co., Alba, Wood county.
59. Alba-Malakoff Lignite Co., Alba, Wood county.
12. American Lignite Briquette Co., Rockdale, Milam county.
57. American Lignite Briquette Co., Rockdale, Milam county.
13. Bear Grass Coal Co., Jewett, Leon county.
14. Bertetti Coal Co., Lytle, Medina county.
16. Carr Wood & Coal Co., Lytle, Medina county.
41. Como Lignite Co., Como, Hopkins county.
17. Consumers' Lignite Co., Alba and Hoyt, Wood county.
56. Consumers' Lignite Co., Alba and Hoyt, Wood county.
18. Cookville Coal & Lumber Co., Mt. Pleasant, Titus county.
36. Edgewood Coal & Fuel Co., Wills Point, Van Zandt county.
20. Houston County Coal & Manufacturing Co., Crockett, Houston county.
21. Independence Mining Co., Phelan, Bastrop county.
22. Lone Star Lignite Mining Co., Como, Hopkins county.
23. Melcher Coal & Clay Co., O'Quinn, Fayette county.
55. Rockdale Coal Co., Hicks, Lee county.
44. Rockdale Consolidated Coal Co., Rockdale, Milam county.
28. Rockdale Lignite Co., Rockdale, Milam county.
25. Rowlett & Wells, Rockdale, Milam county.
26. Southwestern Fuel & Manufacturing Co., Calvert, Robertson county.
39. Texas Coal Co., Rockdale, Milam county.
29. Vogel & Lorenz, Rockdale, Milam county.

Note.—The Alba-Malakoff Lignite Company is successor to the Alba Lignite Company. The Vogel Coal & Manufacturing Company is successor to Vogel & Lorenz.

Analysis No. 44, Rockdale Consolidated Coal Company, represents lignite sampled at the works of the Austin White Lime Company. McNeil, Travis county, January 13, 1911.

The lignite-producing counties are: Bastrop, Fayette, Hopkins, Houston, Leon, Medina, Milam, Rains, Robertson, Van Zandt and Wood.

The supplies of lignite in Texas are practically inexhaustible for the next thousand years even should we use ten times as much as we are now using.

A sample of lignite was received from the Como Coal Company, Como, Hopkins county, too late for the incorporation of the analysis in the body of this Bulletin and in the Tables. It had the following compositon:

PROXIMATE ANALYSIS. DRY BASIS.

	Per cent.
Volatile Matter	39.50
Fixed Carbon	49.38
Ash	11.12
	100.00
Sulphur	1.01
Heating Power, B. T. U.	11,680

ULTIMATE ANALYSIS. DRY BASIS.

	Per cent.
Carbon	62.59
Hydrogen	4.84
Oxygen	18.12
Nitrogen	2.32
Sulphur	1.01
Ash	11.12
	100.00

As received, the sample contained 34.0 per cent. of moisture.

The variations in these analyses are as follows::

SAMPLES AS RECEIVED.

	From.	To	Average.
Moisture	7.30	37.26	25.17
Volatile and Combustible matter	20.33	45.62	37.59
Fixed Carbon	21.09	38.92	28.45
Ash	4.81	16.11	8.79
Sulphur	0.41	0.96	0.65
Carbon	36.16	58.78	44.08

	From.	To.	Average.
Hydrogen	2.60	4.43	3.35
Oxygen	11.76	25.99	16.49
Nitrogen	0.73	21.8	1.47
Heating Power, B. T. U.	6,291	10,411	7,661

On a dry basis these become:

	From.	To.	Average.
Volatile and Combustible matter	43.38	59.50	50.48
Fixed Carbon	30.09	44.00	37.81
Ash	6.62	21.31	11.71
Sulphur	0.45	1.34	0.90
Carbon	53.80	64.20	58.85
Hydrogen	3.15	5.36	4.48
Oxygen	15.57	29.13	22.20
Nitrogen	1.20	2.58	1.86
Heating Power, B. T. U.	8,979	11,510	10,212

PROXIMATE ANALYSES OF TEXAS LIGNITES—ALPHABETICALLY ARRANGED—DRY BASIS. BY S. H. WORRELL.

Number and Description of Sample.	Volatile and Combustible.	Fixed Carbon.	Ash.	Sulphur.	Heating Power B. T. U.
40. Alba Lignite Co. Alba, Wood County	48.10	41.05	10.85	.80	10,220
59. Alba-Malakoff Lignite Co. Alba, Wood County	51.30	38.48	10.22	1.10	10,340
12. American Lignite Briquette Co. *Rockdale, Milam County*	*55.70*	*30.09*	*14.31*	*.78*	*8,979*
57. American Lignite Briquette Co. Rockdale, Milam County	49.21	39.53	11.26	.45	11,230
13. Bear Grass Coal Co. Jewett, Leon County	59.50	31.75	8.75	1.00	9,855
14. Bertetti Coal Co. Lytle, Medina County	55.00	31.91	13.09	1.33	10,510
16. Carr Wood & Coal Co. Lytle, Medina County	44.80	33.89	21.31	.97	9,344
41. Como Lignite Co. Como, Hopkins County	44.70	46.63	12.67	.64	10,600
17. Consumers Lignite Co. Alba and Hoyt, Wood County	52.14	38.22	9.64	.81	10,510
56. Consumers Lignite Co. *Alba and Hoyt, Wood County*	*46.18*	*43.63*	10.20	.68	10,840
18. Cookville Coal & Lumber Co. Mt. Pleasant, Titus County	58.60	30.64	10.76	1.05	9,782
36. Edgewood Coal & Fuel Co. Wills Point, Van Zandt County	56.18	37.20	6.62	.65	10,540
20. Houston County Coal & Mfg. Co. Crockett, Houston County	52.90	33.99	13.11	.80	10,120
21. Independence Mining Co. Phelan, Bastrop County	50.76	39.54	9.70	.90	10,226
22. Lone Star Lignite Mining Co. Como, Hopkins County	48.54	37.65	13.81	1.00	9,709
23. Melcher Coal & Clay Co. O'Quinn, Fayette County	49.28	32.90	17.82	1.34	9,709
55. Rockdale Coal Co. Hicks, Lee County	51.20	38.78	10.02	.72	11,182
44. Rockdale Consolidated Coal Co. Rockdale, Milam County	43.38	41.43	15.19	.54	10,900
28. Rockdale Lignite Co. *Rockdale, Milam County*	*47.60*	41.31	11.09	.98	10,080
25. Rowlett & Wells. Rockdale, Milam County	49.00	44.00	7.00	.87	9,757
26. S. W. Fuel & Mfg. Co. Calvert, Robertson County	47.80	40.71	11.49	1.29	10,030
39. Texas Coal Co. Rockdale, Milam County	45.66	41.12	13.22	.80	10,410
29. *Vogel & Lorenz.* Rockdale, Milam County	50.52	39.20	10.28	1.20	9,855
Average	50.48	37.81	11.71	.90	10,212

The heat units in perfectly dry lignite compare fairly well with the heat units in Texas coals as they are mined, but the heat units in lignite as received at points of consumption are much lower than in dry lignite and much lower than they are in coal.

But this is the very point not covered in this Bulletin. We have no means of knowing, except in a few cases, how much moisture lignites contain as they are used. In comparing one lignite with another or lignite with coal for practical purposes it is necessary to know how much moisture they contain, for upon this depends, to a great extent, their value as fuel. The following Table shows how great the differences in composition of lignites may be, according as they are considered with the moisture, they contain or on a dry basis.

Average composition of Texas lignites with moisture and without moisture:

	With 25 per cent. of moisture.	Dry.
Volatile and Combustible matter...........	37.59	50.48
Fixed Carbon	28.45	37.81
Ash	8.79	11.71
Sulphur	0.65	0.90
Heating Power, B. T. U..................	7,661	10,212

The percentages for any intermediate amount of water may readily be calculated from the "dry" analysis. In comparing one lignite wtih another it is necessary to know how much water they contain, and what the composition would be if reduced to a dry basis.

But since it is impracticable to dry lignite before it is used, and since it is customary to use it as soon as possible after it is mined, the amount of water it contains, *as it is used*, is a very important consideration.

A case has recently been reported to us in which the heating power of a certain lignite, as received at the works, was 6,410 B. T. U., the moisture being 31.45 per cent. Theoretically a pound of this lignite should evaporate 6.63 pounds of water from and at 212 degrees Fahrenheit. The returns reported an actual evaporative power per pound of lignite, of 3.25 pounds of water, or less than 50 per cent. of the theoretical evaporative power.

While a part of this loss may have been due to an uneconomical installation, yet it does not appear that this would account for all of it. In dealing with lignite we have to remember that we have a fuel which may contain a full third of its weight of water, and that, aside from this, the volatile and combustible matter, and, we suspect, the fixed carbon also, is different not only in amount, but in quality, from such substances in coal.

In producer practice and in ordinary steam installations these facts must be borne in mind, and both the producer and the firebox grates and air inlets designed accordingly. There is a marked difference in lignites, and a producer, for instance, designed and built for a certain lignite, and which gives good results from it is not necessarily suited for all lignites. Nor is it merely a question of design and construction. The actual handling of the plant is, perhaps, of even greater importance. So far as we are aware, there is no successful traveling grate used in lignite firing. There are traveling grates that are used with a mixture of soft coal and lignite, but none operating successfully on lignite alone. Hand-firing, with a boiler similar in type to the Dutch, or Dutch-oven, boiler has given, we understand, the best results from lignite. It is hoped that the experiments to be carried on this winter in the new power-house at the University will give accurate data on some of these questions.

DISPOSABLE HYDROGEN IN TEXAS LIGNITES—DRY BASIS.

Analysis No.	Total Hydrogen.	Disposable Hydrogen.	
		Per Cent.	Per Cent. of Total.
40	4.35	1.10	25.29
59	4.21	1.19	28.26
12	4.18	1.12	26.79
57	4.78	2.59	54.19
13	4.11	1.52	36.98
14	4.96	2.50	50.40
16	4.75	2.84	59.79
41	4.40	2.94	33.18
17	4.75	2.06	43.37
56	3.15	none	none
18	4.70	1.79	38.08
36	5.12	2.10	41.01
20	5.36	2.70	50.26
21	5.08	2.34	46.12
22	4.29	1.84	42.89
23	4.70	2.47	52.55
55	4.56	2.20	48.24
44	4.03	1.52	37.71
28	4.06	1.73	42.61
25	4.78	1.69	35.35
26	4.63	1.79	38.66
39	4.46	1.98	42.39
29	3.82	1.00	26.18
Average	4.48	1.87	41.74

The first thing to attract attention in this Table, as compared with the Table giving the disposable hydrogen in Texas coals, page 20, is that while the total hydrogen in the lignites is very nearly the same as in the coals (4.48 and 4.66), the percentage of disposable hydrogen in the lignites is much less than in the coals (1.87 and 3.24). The amount of disposable hydrogen, expressed as percentage of the total hydrogen, is also much less in the lignites than in the coals (41.74 and 69.53).

In more than half of the lignites the disposable hydrogen was less than one per cent., while in the coals there was not a single case in which it fell below 2.29 per cent From the standpoint of the disposable hydrogen expressed as percentage of the total hydrogen there were only five cases out of twenty-three in which it rose above 50 per cent. in the lignites, while in the coals there was not a single case in which it fell below 54 per cent.

From the standpoint of the gas-maker, whether illuminating or fuel gas, retort or producer, these facts are of considerable moment, for they indicate radical differences in these fuels with respect to the composition and value of the gas to be obtained from them under standard conditions.

There is very little data to be obtained with referenec to the use of lignite for making gas in retorts, its principal use, in gas-making, being in the producer. If the plans that have been made for the further study of our coals and lignites can be carried out, we shall have more to say on this subject later. In the meantime there will be found in the chapter on "The Use of Producer Gas in Texas" a compact statement of the progress that has been made in Texas within the last few years, together with some observations on the tendency of the industry. This chapter has been prepared especially for this Bulletin by Mr. Drury McN. Phillips, who has visited nearly every plant in Texas that is making producer-gas, after having had considerable practical experience in producer work, and the application of machinery to such problems.

In order to arrange in one convenient form the different analyses that have been made on Texas lignites, we quote those given in Mr. E. T. Dumble's report on Brown Coal and Lignite, 1892. The proximate analyses and key are given first, and then the ultimate analyses.

The examinations made at the coal testing plant of the United States Geological Survey will also be found in Chapter III.

PROXIMATE ANALYSES OF TEXAS LIGNITES, COMPILED FROM E. T. DUMBLE'S "BROWN COAL AND LIGNITE, 1892."

Analysis.	Moisture.	Volatile and Combustible.	Fixed Carbon.	Ash.	Sulphur.
A.	8.35	41.28	42.73	6.40	1.24
B.	12.40	36.37	37.77	13.60	not det'd
C.	13.28	59.86	18.52	8.32	not det'd
D.[1]	11.11	57.06	26.46	4.50	.87
E.[1]	10.60	36.12	38.16	15.12	3.51
F.	15.80	39.42	39.78	4.99	not det'd
G.[2]	7.17	40.55	34.27	17.19	2.24
H.[2]	20.29	32.67	26.58	17.50	3.11
I.[3]	12.43	38.37	38.90	8.50	1.34
J.[1]	6.25	54.05	33.47	6.27	.69
K.[1]	16.56	45.10	32.89	5.49	not det'd
L.[3]	8.41	38.41	28.65	23.38	.74
M	16.50	36.07	37.17	8.60	1.66
N.	10.35	39.03	43.25	6.87	.50
O.	12.00	42.00	32.00	13.00	not det'd
P.	13.25	40.62	36.47	8.40	1.26
Q.[3]	15.89	42.24	34.46	6.85	1.06
R.[1]	6.50	46.64	28.02	17.72	2.22
S.	20.80	52.08	22.67	3.97	.48
T.[1]	10.17	39.52	36.60	12.80	.95
U.[3]	16.45	40.24	35.89	8.95	1.17
V.[4]	13.51	45.36	32.44	8.15	.88
W.[1]	13.10	37.24	41.22	6.07	2.36
X.[3]	10.11	37.37	24.39	27.59	1.15
Y.	18.26	43.51	29.53	8.70	2.46
Z.[4]	9.67	59.59	39.90	10.08	.76

1. Average of two analyses. 2. Average of four analyses. 3. Average of five analyses. 4. Average of three analyses.

Key to analyses of lignites compiled from "Brown Coal and Lignite, Dumble," 1892:

A. Anderson county. From an outcrop on Caddo Creek, about seventeen miles northeast of Palestine: thickness, about two feet.

B. Angelina county.

C. Atascosa county, near Somerset: thickness, 5 feet 3 inches to 5 feet 6 inches.

D. Bowie county, near New Boston: thickness, 12 feet. One of the analyses shows 1.45 per cent. of ash, with 76.41 per cent. of volatile and combustible matter and 10.62 per cent. of fixed carbon.

E. Caldwell county. Burdett Wells.

F. Cass county. Stone Bluff.

G. Cherokee County. Bean's Creek, six miles south of Alto; near Jacksonville; McBee's school house.

H. Fayette county. Manton Bluff: thickness, up to 15 feet. On O'Quinn creek the lignite is of excellent quality and has a thickness up to 8 feet.

I. Harrison county. Robertson's Ferry and Rocky Ford, Sabine river; McCathern Creek: thickness, 2 to 6 feet.

J. Henderson county. C. M. Walters headright: thickness, up to 6 feet.

K. Hopkins county, near Sulphur Springs: thickness, up to 16 feet.

L. Houston county. Hyde's Bluff and Westmoreland Bluff, Trinity river; J. Bethel headright; Wallace headright, near Calthorp: thickness, 4 to 6 feet.

M. Lee county. Blue Branch: thickness, 6 feet.

N. Leon county, near Jewett: thickness, up to 9 feet.

O. Limestone county. Head's Prairie.

P. Medina county. Lytle: thickness, 5 feet.

Q. Milam county. Rockdale: thickness, 4 to 6 feet.

R. Morris county. Pruit place: thickness, less than 2 feet.

S. Panola county. Mineral Springs Ridge, near Beckville: thickness, 4 1-2 feet.

T. Rains county. Emory, and seven miles east.

U. Robertson county. Little Brazos; Calvert Bluff: thickness, 3 to 7 feet.

V. Rusk county. Iron Mountain; Graham's Lake, 12 miles west of Henderson: thickness, 3 to 6 feet.

W. San Augustine county. Sabine and Angelina rivers: thickness, 6 to 15 feet.

X. Smith county. Southwest of Tyler, 8 ½ miles; south of Tyler, 6 miles; southeast of Tyler, 12 miles; west of Lindale, 3 miles: thickness, 3 feet and upwards.

Y. Shelby county. South of Timpson, 7 miles: thickness, 4 to 5 feet.

Z. Wood county. Alba and Mineola: thickness, 8 feet.

ULTIMATE ANALYSIS OF TEXAS BROWN COALS—FROM: "BROWN COAL AND LIGNITE," DUMBLE, 1892.

County.	Moisture.	Carbon.	Hydrogen.	Ozygen and Nitrogen.	Ash.	Sulphur.
Anderson	----------	53.06	4.06	24.12	17.74	1.02
Bowie	10.67	59.84	3.10	26.97	9.10	1.00
Cherokee	----------	66.67	3.81	22.08	5.83	1.64
Gregg	12.00	60.79	4.96	23.68	9.27	.88
Harrison	13.35	66.32	3.95	21.56	8.97	2.20
Houston	----------	63.09	3.64	22.56	9.68	1.03
Lee	16.50	62.48	3.21	20.80	11.56	1.95
Leon	----------	63.60	4.08	24.02	7.79	.55
Medina	13.25	60.92	2.57	25.34	9.70	1.47
Milam	----------	60.93	4.12	22.27	11.36	1.32
Milam	17.75	62.50	5.45	20.84	7.54	.97
Milam	18.25	64.50	5.37	20.76	8.56	.81
Morris	8.55	59.87	4.70	24.35	8.66	2.42
Rains	----------	57.04	4.01	24.48	13.35	1.11
Rains	----------	59.32	2.80	20.27	16.63	.98
Robertson	----------	58.16	4.46	13.11	12.77	1.50
Robertson	16.40	65.14	5.29	19.28	9.21	1.15
Rusk	16.63	58.93	4.20	22.14	10.09	4.64
San Augustine	----------	61.12	3.32	24.53	7.75	3.39
Smith	9.83	57.40	3.60	23.31	14.74	.95
Webb (outcrop)	----------	59.28	3.29	16.98	17.56	.89
Wood	10.85	56.33	4.29	24.13	14.39	.84
Average	13.67	60.98	4.01	22.16	11.01	1.48

The calculated heat units of some of the Texas lignites were also given by Mr. Dumble as follows:

	British Thermal Units. Dry.
From Medina county	11,320
From Milam county	11,169
From Milam county	11,278
From Robertson county	11,320

In order to compare the heat units in lignite as actually determined with those obtained by calculation, we have prepared a Table based on our recent analyses. The Goutal formula. (p. 25), was used for the calculations based on proximate analyses and the DuLong formula for those based on ultimate analyses. The results are as follows:

Analysis No.	Heating Power, B. T. U. Dry. Calculated. From Proximate Analysis.	Heating Power, B. T. U. Dry. Calculated. From Ultimate Analysis.	Heating Power, B. T. U. Dry. Determined.	Theoretical Evaporation in Pounds of Water from and at 212° F. per Pound of Lignite. Dry.
40	12,948	8,852	10,220	10.58
59	12,570	9,081	10,340	10.71
12	11,933	8,542	8,979	9.29
57	11,885	10,853	11,230	11.62
13	12,154	10,115	9,855	10.19
14	12,106	10,107	10,510	10.87
16	11,805	9,910	9,344	9.67
41	13,098	9,247	10,600	10.97
17	12,644	10,204	10,510	10.87
56	13,049	------	10,840	11.21
18	11,877	9,548	9,782	10.12
36	12,535	10,282	10,540	10.90
20	12,127	10,026	10,120	10.47
21	12,644	10,330	10,226	10.58
22	12,410	9,841	9,709	10.04
23	11,922	9,832	9,709	10.04
55	12,661	10,734	11,182	11.57
44	12,426	9,315	10,900	11.28
28	12,914	9,897	10,030	10.38
25	13,510	9,872	9,757	10.09
26	12,856	9,570	10,030	10.38
39	12,601	9,814	10,410	10.77
29	12,570	9,274	9,855	10.19
Average	12,489	9,784	10,212	10.56

An examination of this Table shows that the Goutal formula applied to the calculation of heat units from the proximate analysis of lignites gives on the average, results that are 22.30 per cent. higher than the heat units obtained by actual determination. It is, therefore, unreliable and can not be used with a reasonable degree of accuracy.

The modified DuLong formula, applied to ultimate analyses of lignites gives, on the average, results that are 4.10 per cent. lower than the determined heat units, and may be used for approximate results.

Applied to proximate analyses of coal, the Goutal formula gives results which, on the average, are 10.67 per cent. too high, and the modified DuLong formula applied to ultimate analyses gives results which, on the average, are almost the same as those obtained in the calorimeter. In this connection the Table on p. 26 may be consulted.

In the Table giving the calculated heat units in Texas lignites we have included a calculation of the theoretical evaporation in pounds of water from and at 212 degrees Fahrenheit per pound of lignite, dry basis. The results vary from 9.29 to 11.62 pounds of water per pound of lignite, the general average being 10.56, dry basis. In actual practice the efficiency of lignite as a fuel under steam boilers varies according to circumstances, and no rule of general application can be given.

It is stated that one of the railroads in Texas will soon begin a series of tests with lignite as fuel for locomotives. If this work is undertaken, the results will be of great interest and value.

It is likely that tests will be made during the coming winter at the new power house of the University with reference to stationary boilers.

Chapter III.

THE USE OF PRODUCER GAS IN TEXAS.

BY

DRURY MCNEILL PHILLIPS.

During the last few years there has been a marked increase in the use of lignite for making gas in gas-producers. The gas thus made is used for power, e. g. in gas engines of special design, or for fuel, e. g. for burning lime, etc. So far as known, this gas is not used in Texas for burning brick, sewer-pipe, tiling, etc., although it would certainly be well adapted for such purposes.

The use of lignite for making gas is confined to the above mentioned purposes. No illuminating gas is made from this material, although an excellent light could be supplied by use of some of the well known types of incandescent mantles, such as the Welsbach, etc.

There have been installed in this State 56 producers for making gas. Of this number there are now 47 in active operation, representing 12,270 engine horse-power. Of the 36 establishments that have been recorded 6 are now out of commission, 3 make fuel gas for burning lime, 1 uses coal from New Mexico, 1 coal from Colorado, 1 now uses natural gas and 1 uses a mixture of semi-anthracite from Arkansas and Texas lignite. This leaves 23 establishments that use Texas lignite exclusively. The consumption of lignite at these plants is about 180 tons per 24 hours, and the total gas engine horse-power is 12,270.

Most of the installations are of comparatively small size, for out of the total 11,490 engine horse-power in operation 7,700 (=67 per cent.) are represented by two plants. This leaves only 3,790 horse-power to be divided among 21 plants.

The three cement plants, at Eagle Ford, Harry and San Antonio, represent at present 8,300 horse-power, and, upon the addition of the 600 horse-power at San Antonio, they will represent 8,900 horse-power.

But the success that has been reached in the smaller plants indicates the adaptability of the producer and gas engine to requirements varying from 50 to 250 horse power, quite as well as to the larger uses.

The producer plants in Texas are scattered over a wide area, from Kingsville to Gainesville and from San Angelo to Huntsville. In visiting the 26 establishments that were upon the itinerary there was necessary a total travel of more than 2,500 miles, and if all of the plants had been visited, the trip would have involved nearly 4,000 miles. This circumstance has an important bearing on the utilization of the by-products, such as tar and ammoniacal liquor, for it means that they would have to be transported over considerable distances to some central plant for treatment. This is out of the question now, so that the utilization of the tar and ammoniacal liquor is possible only at the large plants. No attempt is made to make use of these by-products, save that a little of the tar is used as fuel and a little for "creosoting" telephone and electric light poles, etc.

The cost of the lignite, delivered, varies from 90 cents to $3.65 a ton, according to distance from the mines, amount involved in the contract, etc. The average value of the lignite mined in the State in 1910, at the mines, was 96 cents, the production having been 979,232 tons, the largest in the history of the industry. The word of prophecy uttered by Mr. E. T. Dumble, State Geologist, in 1891, in his pamphlet, "The Utilization of Lignite," and repeated, in 1892, in his "Brown Coal and Lignite," is now being fulfilled, and there appears to be no reason to doubt that there will be a further and larger development of this source of power.

The supplies of lignite of all kinds is certainly beyond all question. In the United States there are about 123,700 square miles of lignite territory distributed as follows:

Alabama	6,000
Arkansas	5,900
Louisiana	8,800
Montana	7,000
North Dakota	31,000
South Dakota	4,000
Tennessee	1,000
Texas	60,000
	123,700

The lignite area in Texas comprises nearly one-half of the entire known area in the United States and is nearly as large as the entire State of Missouri. Practically all varieties of lignite are found here, and there is offered a wide choice to the designers of producer plants, even inclusive of material that carries 75 per cent. of volatile and combustible matter. There is no intention, in this paper, to prepare a dissertation on gas-producers or to enter into the details of the design and construction of producer-gas plants. We wish merely to give the chief results of personal observation at 26 plants that were visited and information derived by correspondence with ten other plants.

It may not be amiss to say that the writer has served his time in the shops of the Allis-Chalmers Company, Chicago, and West Allis, and was afterwards in the gas department of an establishment in Texas that used 60 tons of lignite a day in gas-producers. He endeavors to look at the matter from a practical standpoint, and has visited by far the larger number of producer plants in Texas for the purpose of acquainting himself with what is now being done here.

It is beyond question that a very active interest is now being shown in the use of producer-gas made from lignite, and as experience is gained both in the handling of the various types of producers, and, more especially, in the design and construction of engines for using large volumes of a gas of low heating power, the use of lignite will be extended.

The total producer horse-power, operating on lignite in Texas, is now (about) 13,000, while the total engine horse-power is 12,270. In such use of lignite Texas exceeds all of the other States combined, as it exceeds, in lignite area, all of the other States.

In certain favored localities within reach of the natural gas fields of Clay and Wichita Counties, Texas, and of the Caddo fields in Louisiana, lignite faces a serious competitor. This competition, however, is not manifested throughout the State at large, and even in north Texas, where natural gas is available, some of the larger establishments prefer lignite. The question of competition from natural gas, excellent as this fuel is, is more academic than practical. So far as is known, only one large establishment is to change from producer-gas to natural gas, while its near-by neighbors will continue to use lignite.

It is a question of relative economy into which many diverse factors enter, and we do not discuss them here.

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

We do not mean to say that good results are not obtained by the use of a producer not specially designed for the engine or by the use of an engine not specially designed for the producer.

As a matter of fact, good results are obtained in establishments where the producer is designed and built without particular reference to the type of engine to be used, as also where the engine is supposed to handle the gas from almost any kind of standard producer.

But we believe that better results, more uniform and more economical, can be secured by designing the producer for the engine and the engine for the producer. Producer and engine must be regarded as a compact and symmetrical unit to do a certain thing at all times to the best advantage.

Furthermore, a producer and engine designed to operate on a certain kind of fuel can not be expected to give as good results on some other kind of fuel. Within certain limits, to be determined when the plant is designed, the results should not vary excessively, but they will vary, through no fault of producer or engine, if the character of the fuel is materially changed. There is a wide variation in the composition of lignite, and this variation gives rise to differences in the amount and nature of the gas, the tar and ammoniacal liquor.

An engine designed to operate on a rich gas will certainly not work to its rated capacity on a poor gas. It is not fed on material that it can utilize. It can not do its work, any more than a strong man, accustomed to strong food, can do his work on milk toast. If the heat units are not in the gas, the engine certainly can not get them out, and if the heat units are not in his gas, the lime-burner certainly can not burn his charge. It is not a question of tuyeres, or gas-ports or air valves; it is a question of heat units in the gas.

In Bulletin No. 416, United States Geological Survey, 1909, "Recent Development of the Producer-Gas Power Plant in the United States," by Robert H. Fernald, there is given a list of 16 installations in Texas. These were as follows, by localities:

Blooming Grove, Corpus Christi, (near) Dallas, Garwood, Gatesville, Leonard, Mart, Mineola, Rockport, Royse, Smithville, Stephenville, Taylor, Teague and Yorktown. With the exception of the plants at Royse and Taylor, which used anthracite, all of these used lignite. To Mr. Fernald's list we have added 20 more, so that there are now 36 gas-producer plants in the State, with 5 out of commission. The total producer horse-power, as given by Mr. Fernald, was 8,001, and the total engine power was 7,616. We have increased these to (about) 13,000 and 12,270, respectively.

To those who wish to inform themselves as to the progress of producer-gas practice in the United States and to acquire concise and accurate knowledge of the possibilities in this direction we would commend Mr. Fernald's paper.

It may be of interest to give here a list of the producer plants mentioned by Mr. Fernald, and we have prepared a Table to set forth the main facts. This table gives the number of producers in each State, the total producer horse-power, the total engine horse-power and the fuel used, together with the number of producer plants, the producer horse-power and the engine horse-power expressed as percentages of the respective totals.

In this table under the term "bituminous coal" is included also sub-bituminous coal, under the term "anthracite" is included semi-anthracite, and under the term "lignite" is included brown coal.

TABLE SHOWING PRODUCER-GAS PLANTS IN THE UNITED STATES—ARRANGED FROM FERNALD, 1909.

State.	No. of Producer Plants.	Total Producer-horse-power.	Total Engine Horse-power.	Fuel.	Percentage of Total No.	Percentage of Producer horse-power.	Percentage of Engine horse-power.
Alabama	3	260	60	Bituminous Coal and Anthracite	.62	.21	.09
Alaska	1	250	250	Anthracite	.21	.20	.40
Arkansas	1	75	100	Anthracite	.21	.06	.16
Arizona	5	4,422	422	Bituminous Coal and Anthracite	1.05	3.58	.68
California	2	560	420	Wood and Anthracite	.42	.45	.68
Colorado	8	1,405	1,090	Lignite and Anthracite	1.68	1.13	1.76
Connecticut	16	7,430	1,251	Bituminous Coal and Anthracite	3.36	6.01	2.02
Delaware	1	200	not given	Anthracite	.21	.16	----------
Dist. of Columbia	3	875	683	Anthracite	.62	.70	1.10
Florida	8	3,000	1,543	Bituminous Coal and Anthracite	1.68	2.43	2.49
Idaho	2	400	400	Anthracite	.42	.32	.64
Illinois	29	3,087	2,688	Bituminous Coal and Anthracite	6.09	2.50	4.35
Indiana	17	9,847	3,138	Bituminous Coal and Anthracite	3.57	7.96	5.08
Iowa	8	902	398	Anthracite	1.68	.73	.64
Kansas	13	1,330	1,383	Bituminous Coal and Anthracite	2.73	1.07	2.24
Kentucky	2	70	70	Anthracite	.42	.05	.11
Louisiana	3	810	310	Bituminous Coal and Anthracite	.62	.65	.50
Maine	2	765	65	Anthracite	.42	.61	.10
Maryland	10	1,220	585	Anthracite	2.10	.98	.94
Massachusetts	25	7,385	3,324	Bituminous Coal, Coke and Anthracite	5.25	5.98	5.38
Michigan	16	2,631	2,556	Anthracite	3.36	2.13	4.14
Minnesota	16	1,871	1,769	Anthracite	3.36	1.43	2.86
Missouri	17	13,147	3,566	Bituminous Coal and Anthracite	3.57	10.64	5.77
Montana	1	60	60	Anthracite	.21	.04	.09
Nebraska	18	1,291	1,144	Anthracite	3.78	1.04	1.85
Nevada	1	200	150	Anthracite	.21	.16	.24
New Hampshire	2	1,000	635	Anthracite	.42	.81	1.02
New Jersey	37	6,657	2,480	Bituminous Coal and Anthracite	7.77	5.39	2.91
New Mexico	3	260	260	Anthracite	.62	.21	.42
New York	37	7,964	4,540	Bituminous Coal and Anthracite	7.77	6.45	7.35
North Carolina	4	2,180	1,680	Bituminous Coal and Anthracite	.84	1.76	2.72
North Dakota	8	497	478	Anthracite	1.68	.40	.77
Ohio	19	1,855	1,670	Bituminous Coal and Anthracite	3.99	1.50	2.70
Oklahoma	6	695	695	Bituminous Coal, Lignite, Anthracite	1.22	.56	.92
Oregon	2	200	200	Anthracite	.42	.16	.32
Pennsylvania	42	4,299	1,845	Bituminous Coal and Anthracite	8.82	3.48	2.98
Porto Rico	3	60	not given	Anthracite	.62	.04	----------

Rhode Island	4	2,375	625	Bituminous Coal and Anthracite	.84	1.92	1.01
South Dakota	18	2,336	2,029	Anthracite	3.78	1.88	3.28
Tennessee	2	150	100	Anthracite	.42	.12	.16
Texas	16	8,001	7,616	Lignite, Bituminous Coal and Anthracite	3.36	6.48	12.33
Utah	2	275	193	Anthracite	.42	.22	.31
Vermont	1	80	not given	Anthracite	.21	.06	----------
Virginia	13	1,110	498	Bituminous Coal and Anthracite	2.73	.90	.70
Washington	7	810	810	Lignite and Anthracite	1.47	.65	1.31
Wisconsin	26	9,306	7,741	Bituminous Coal and Anthracite	5.46	7.54	12.54
Wyoming	1	65	65	Lignite	.21	.06	.10
Total	481	123,268	61,585				

An examination of this Table shows that there were in the United States, at that time, 1908-1909, 481 producer plants, of which Texas had 16, or 3.36 per cent., ranking twelfth. Of producer horse-power there were 123,268, of which Texas had 8,001, or 6.48 per cent., ranking fourth. Of engine horse-power there were 61,585, of which Texas had 7,616, or 12.33 per cent., ranking second. This is in respect of all kinds of fuel, bituminous coal, anthracite and lignite.

But when we consider the use of lignite alone, for there is very little bituminous coal or anthracite used in producers in Texas, the situation is radically changed. According to the data in Mr. Fernald's paper, there were in the United States 9,275 producer horse-power from lignite, viz: 625 in Colorado, 50 in Oklahoma, 7,985 in Texas, 550 in Washington and 65 in Wyoming. Of th 9,275 lignite producer horse-power Texas had 7,985, or 86.10 per cent. of the total. There were 8,570 engine horse-power derived from producers operated on lignite distributed as follows: Colorado 380, Oklahoma 50, Texas 7,525, Washington 550, Wyoming 65. Of the 8,570 engine horse-power derived from lignite, Texas was credited with 7,525, or 87.8 per cent. of the total. Texas has not only the largest output of lignite, more than double that of any other State, and the largest lignite area, twice that of any other State, it also utilizes its lignite for making gas to the extent of 87.8 per cent. of the total engine power thus derived in the entire country.

North Dakota has 31,000 square miles of lignite area, being next to Texas in this respect, and mines about 400,000 tons of lignite a year, but at the time of the preparation of Mr. Fernald's report there was not a single lignite gas-producer in that State.

It may, therefore, be said with entire accuracy that Texas leads the country in area, production and utilization of lignite.

In Bulletin No. 261, 1905, United States Geological Survey, there are given the results of testing two Texas lignites in the coal testing plant at St. Louis. These tests were under the care of Mr. Robert H. Fernald. The producer was a No. 7 Wood, 250 horse-power. The engine was a three-cylinder vertical Westinghouse gas engine, rated at 225 brake horse-power. It was belted to a six-pole 175-kilowatt Westinghouse direct-current generator.

Without going into all of the details of the work conducted there we will give the chief results as set forth in the above-mentioned Bulletin.

The first test was made on lignite from the Houston County Coal & Manufacturing Company, Crockett, Houston County. The analysis of the lignite used was as follows:

		Per cent.
Moisture		33.50
Volatile matter		32.34
Fixed carbon		23.80
Ash		10.36
Sulphur		0.63
Heating Power, B. T. U.		7,267
Duration of test,	hours	21.67
Total coal consumed in producer	pounds	12,800
Moisture in coal	per cent.	33.50
Dry coal consumed in producer	pounds	8,510
Refuse from dry coal	per cent.	15.85
Total refuse from coal	pounds	1,327
Total combustible consumed in producer	pounds	7,183

LIGNITE CONSUMED, POUNDS PER HOUR.

Lignite consumed in producer	590
Dry lignite consumed in producer	393
Combustible consumed in producer	332
Equivalent lignite used by producer plant	660
Equivalent dry lignite used by producer plant	439.5
Equivalent combustible used by producer plant	371.3

BRITISH THERMAL UNITS.

Per pound of lignite as fired	7,267
Per pound of dry lignite	10,928
Per pound of combustible	12,945
Per cubic foot of standard gas	169.7
From standard gas per pound dry lignite burned in producer	7,260
From standard gas per hour per brake horse-power	12,230

GAS PRODUCED, CUBIC FEET (reduced to standard).

Total	363,654
Per hour	16,800
Per pound lignite consumed in producer	28.4
Per pound dry lignite consumed in producer	42.7
Per pound combustible consumed in producer	50.6

Per pound equivalent lignite used by producer plant	25.5
Per pound equivalent dry coal used by producer plant	38.2
Per pound equivalent combustible used by producer plant	45.3

HORSE-POWER DEVELOPED.

Average electrical horse-power available for outside purposes	187
Average electrical horse-power developed at switch-board	198
Average brake horse-power[1] available for outside purposes	220
Average brake horse-power developed at engine	233

[1]Based on an assumed efficiency of 85 per cent. for generator and belt.

LIGNITE CONSUMED IN PRODUCER, POUNDS PER HORSE-POWER HOUR.

	Coal as Fired.	Dry Coal.	Combustible.
Per electrical horse-power available for outside purposes	3.16	2.10	1.78
Per electrical horse-power developed at switch-board	2.98	1.99	1.68
Per brake horse-power[1] available for outside purposes	2.68	1.79	1.51
Per brake horse-power[1] developed at engine	2.54	1.69	1.43
Equivalent pounds used by producer plant per electrical horse-power available for outside purposes	3.53	2.35	1.99
Equivalent pounds used by producer plant per electrical horse-power developed at switch-board	3.34	2.22	1.88
Equivalent pounds used by producer plant per brake horse-power available for outside purposes	3.00	2.20	1.69
Equivalent pounds used by producer plant per brake horse-power developed at engine	2.83	1.99	1.60

[1]Based on an assumed efficiency of 85 per cent. for generator and belt.

AVERAGE COMPOSITION OF PRODUCER-GAS BY VOLUME.

	Per cent.
Carbon dioxide	11.10
Carbon monoxide	14.43
Hydrogen	10.54
Methane	7.48
Nitrogen	56.22
Oxygen	0.22

"The gas from this lignite was not so rich as that from the North Dakota lignite that was tested, but it was higher in heat units than is the gas obtained from ordinary soft coal. The lignite was more difficult to handle in the producer than bituminous coal, but by frequent poking and by supplying the right amount of air to the producer the bed was kept in good condition, and at the end of the thirty-hour test it was possible to break up the clinkers in the bed, requiring the removal of only a few ashes before beginning a new test. This lignite yielded a large amount of tar of the same kind as the North Dakota lignite, yellow and sticky. As a producer fuel it is better than many grades of bituminous coal."

Another test was made on lignite from the mines of the Consumers' Lignite Company, at Hoyt, Wood County, Texas.

This lignite had the following composition:

	Per cent.
Moisture	33.71
Volatile matter	29.25
Fixed carbon	29.76
Ash	7.28
Sulphur	0.53
Heating power B. T. U.	7,348

Duration of test	hours	19.33
Total lignite consumed in producer	pounds	9,050
Moisture in lignite	per cent.	33.71
Dry lignite consumed in producer	pounds	5,999
Refuse from dry lignite	per cent.	10.98
Total refuse from lignite	pounds	658.7
Total combustible consumed in producer	pounds	5,340.3

LIGNITE CONSUMED, POUNDS PER HOUR

Lignite consumed in producer	468
Dry lignite consumed in producer	310.3
Combustible consumed in producer	276.2
Equivalent lignite used by producer plant	519.5
Equivalent dry lignite used by producer plant	344.4
Equivalent combustible used by producer plant	306.6

BRITISH THERMAL UNITS.

Per pound of lignite as fired	7,348
Per pound of dry lignite	11,086
Per pound of combustible	12,450
Per cubic foot of standard gas	156.2
From standard gas per pound dry lignite burned in producer	8,060
From standard gas per hour per brake horse-power	10,570

GAS PRODUCED, CUBIC FEET (reduced to standard).

Total	309,140
Per hour	16,009
Per pound lignite consumed in producer	34.2
Per pound dry lignite consumed in producer	51.6
Per pound combustible consumed in producer	57.9
Per pound equivalent lignite used by producer plant	30.8
Per pound equivalent dry lignite used by producer plant	46.4
Per pound equivalent combustible used by producer plant	52.2

HORSE-POWER DEVELOPED.

Average electrical horse-power available for outside purposes	189.6
Average electrical horse-power developed at switch-board	201.2
Average brake horse-power[1] available for outside purposes	223
Average brake horse-power[1] developed at engine	236.5

[1]Based on an assumed efficiency of 85 per cent. for generator and belt.

LIGNITE CONSUMED, POUNDS PER HORSE-POWER HOUR.

	Coal as Fired.	Dry Coal.	Combustible.
Per electrical horse-power available for outside purposes	2.47	1.64	1.46
Per electrical horse-power developed at switch-board	2.33	1.54	1.37
Per brake horse-power available for outside purposes	2.10	1.39	1.24
Per brake horse-power developed at engine	1.98	1.31	1.17
Equivalent pounds used by producer plant per electrical horse-power available for outside purposes	2.74	1.82	1.62
Equivalent pounds used by producer plant per electrical horse-power developed at switch-board	2.58	1.71	1.52
Equivalent pounds used by producer plant per brake horse-power[1] available for outside purposes	2.33	1.55	1.38
Equivalent pounds used by producer plant per brake horse-power[1] developed at engine	2.20	1.46	1.30

[1]Based on an assumed efficiency of 85 per cent, for generator and belt.

COMPOSITION OF PRODUCER-GAS BY VOLUME.

Carbon dioxide	9.60
Carbon monoxide	18.22
Hydrogen	9.63
Methane	4.81
Nitrogen	57.53
Oxygen	0.20

This lignite "gave highly satisfactory results in the producer, yielding a rich, uniform gas and a large amount of yellow tar. It is an excellent fuel for producers."

The term "combustible" is used to designate dry coal minus refuse; that is, the actual amount of combustible matter consumed for the gas made. The term "equivalent coal" refers to the coal actually used in the producer plus the coal equivalent of the steam used in operating the producer. It represents the gross fuel consumption of the entire plant.

In Bulletin No. 332, United States Geological Survey, 1908, there are given two producer-gas tests made on Texas lignite at the fuel testing plant, St. Louis. These are as follows:

LIGNITE FROM J. J. OLSEN & SONS, MILAM COUNTY.

	Per cent.
Moisture	32.20
Volatile matter	30.11
Fixed carbon	7,870
Ash	8.87
Sulphur	0.88
Heating power, B. T. U., car sample	7,870

Size as used: over one inch, 61 per cent.; ½ inch to 1 inch, 18 per cent.; ¼ inch to ½ inch, 8 per cent.; under ¼ inch, 13 per cent. Duration of test, 50 hours. Average electrical horsepower, 200.1. Average heating power, B. T. U., per cubic foot of gas, 171.8. Total coal fired, 25,000 pounds.

ANALYSIS OF GAS BY VOLUME.

	Per cent.
Carbon dioxide	10.3
Carbon monoxide	19.8
Hydrogen	14.8
Methane	2.4
Nitrogen	51.3
Oxygen	0.7
Ethylene	0.7

	Lignite as Fired.	Dry Lignite.	Combustible.
Lignite consumed in producer per horse-power hour, pounds.			
Per electrical horse-power:			
Commercially available	2.70	1.83	1.59
Developed at switch-board	2.55	1.73	1.50
Per brake horse-power:			
Commercially available	2.29	1.55	1.35
Developed at engine	2.17	1.47	1.28
Equivalent used by producer plant, pounds.			
Per electrical horse-power:			
Commercially available	2.90	1.97	1.71
Developed at switch-board	2.75	1.86	1.62
Per brake horse-power:			
Commercially available	2.47	1.67	1.46
Developed at engine	2.33	1.58	1.38

LIGNITE FROM HOYT, WOOD COUNTY.

(probably from mines of Consumers' Lignite Company, W. B. P.):

	Per cent.
Moisture	34.08
Volatile matter	33.15
Fixed carbon	25.32
Ash	7.45
Sulphur	0.49
Heating power, B. T. U., car sample	7,497

Size as used: Over 1 inch, 68 per cent.; ½ inch to 1 inch, 16 per cent.; ¼ inch to ½ inch, 7 per cent.; under ¼ inch, 9 per cent. Duration of test, 50 hours. Average electrical horse-power, 193.4. Average heating power, B. T. U., per cubic foot of gas, 156.1. Total coal fired, 24,500 pounds.

Analysis of gas by volume:	Per cent.
Carbon dioxide	10.3
Carbon monoxide	20.0
Hydrogen	15.4
Methane	2.5
Nitrogen	51.8

	Lignite as Fired.	Dry Lignite.	Combustible.
Lignite consumed in producer per horse-power hour, pounds.			
Per electrical horse-power:			
Commercially available	2.66	1.75	1.55
Developed at switch-board	2.54	1.67	1.48
Per brake horse-power:			
Commercially available	2.26	1.49	1.32
Developed at engine	2.16	1.42	1.26
Equivalent used by producer plant, pounds.			
Per electrical horse-power:			
Commercially available	2.87	1.89	1.67
Developed at switch-board	2.74	1.81	1.60
Per brake horse-power:			
Commercially available	2.43	1.61	1.42
Developed at engine	2.33	1.54	1.36

The Westinghouse Machine Company, Pittsburg, Pa., in its Circular W. M. 503, September, 1909, gives the results of testing lignite from the mines of the Consumers' Lignite Company, Hoyt, Wood County, Texas. The analysis of the lignite used was as follows:

	Per cent.
Moisture	23.83
Volatile matter	38.32
Fixed carbon	29.22
Ash	8.63
Heating power, B. T. U.	8,007

The engine was operated 72 hours. The total lignite fired was 16,970 pounds. The average load was 128 brake horse-power and the gross lignite per brake horse-power was 1.85 pounds. The gas was delivered through a line of 8-inch pipe over 650 feet long, with no correction for leaking or for gas consumed by three pilot lights burning continuously in the producer-house, laboratory and engine room.

In another case, given by this Company, the same lignite being used, the following statement is made:

Duration of test .... 46.5 hours
Total lignite fired .... 12,693 pounds
Heat value per pound .... 8,007 B. T. U.
Total heat in-put=12,693,x8,007 .... 101,632,857 B. T. U.
Total gas made (corrected to 62 degrees Fahrenheit
and 30 inches barometer) .... 612,361 cubic feet
or 49.03 cubic feet per pound of lignite fired.
Total heat value of gas per cubic foot .... 128.3 B. T. U.
Effective heat value of gas per cubic foot .... 117.1 B. T. U.

Total output ....78,565,816 B. T. U.
Effective output ....71,707,463 B. T. U.

$$\text{Total efficiency} = \frac{78{,}565{,}816}{101{,}632{,}857} = \text{.................77.3 per cent.}$$

$$\text{Effective efficiency} = \frac{71{,}717{,}463}{101{,}632{,}857} = \text{..............70.5 per cent.}$$

The composition of the gas in this latter test was as follows:

	Per cent.
Carbon dioxide	12.4
Oxygen	0.9
Carbon monoxide	13.3
Marsh gas	3.6
Hydrogen	14.7
Nitrogen	55.1

The Smith Gas Power Co., Lexington, Ohio, in its circular of recent date, gives the results of operating on Texas lignite at two establishments. In the one case the original plant was on steam power, using 80 horse-power, the cost for fuel and supplies being $10.00, and for labor $5.00 per 24 hours, total, $15.00. This plant changed to producer-gas. The cost of the lignite was $2.22 a ton, the average load on the engine was 80 horse-power, and the cost of fuel and supplies was $5.50, and for labor $5.00 per 24 hours, total $11.50, as against $15.00 for steam. In the other case steam was also used, before the change to producer-gas was made, with an average load of 30 K. W. The plant is now operated on producer-gas made from lignite. The cost of the lignite is $1.20 a ton; the load is the same, and there is a saving of two tons of fuel per night.

The producer-gas plants that have been established in Texas are as follows, by towns and counties:

Those visited personally are marked with a *.

Town.	County.
Altair*	Colorado
Amarillo	Potter
Blooming Grove*	Navarro
Brownwood	Brown

Calallen*	Nueces
Canadian	Hemphill
Corpus Christi*	Nueces
Dallas*	Dallas
Dittlinger*	Comal
Eagle Ford*	Dallas
Gainesville*	Cooke
Garwood*	Colorado
Gatesville*	Coryell
Glen Flora	Wharton
Harry*	Dallas
Houston*	Harris
Huntsville	Walker
Kingsville*	Nueces
Leonard*	Fannin
Longview	Gregg
McNeil*	Travis
Mart	McLennan
Mineola*	Wood
Pittsburg*	Camp
Rockport*	Aransas
Round Rock*	Williamson
Royse*	Rockwall
San Angelo	Tom Green
(near) San Antonio*	Bexar
Smithville*	Bastrop
Stephenville*	Erath
Taylor*	Williamson
Teague*	Freestone
Terrell*	Kaufman
Weatherford	Parker
Yorktown	DeWitt

The plants at these places vary in capacity within wide limits, from one in which there is a 30 K. W. engine, with a producer using 1500 pounds of lignite a day, to one in which there are engines aggregating 4400 horse-power and using 60 tons of lignite per 24 hours.

The plants at Royse and Taylor used anthracite when in operation. The plant at Pittsburg uses a mixture of Arkansas semi-anthracite and Texas lignite. The plant at Amarillo uses Colorado bituminous coal, and that at Canadian uses bituminous coal from New Mexico. The plants at McNeil, Round Rock and Dittlinger, which are fuel gas plants for burning lime, used Texas coal and lignite. There were 26 plants in operation on producer-gas at the time of the preparation of this report, June, 1911, but impending changes may alter this number. Of these there were 23 that used lignite exclusively, the estimated consumption being 180 tons per 24 hours. The aggregate gas engine horse-power at these 23 plants was 11,490. The total primary horse-power in Texas, used in establishments, etc., in the last census year was 319,371.

The producers in use are made by the following firms:

Bethlehem Steel Company, South Bethlehem, Penn.

Fairbanks-Morse & Co., Chicago, Illinois.

Elbert Harvey (Industrial Gas Company), New York.

Herrick (Industrial Gas Company), New York.

Irvin, J. H. McDonough, The Murray Company, Dallas, Texas.

Power & Mining Machinery Company, Cudahy, Wisconsin. (Loomis-Pettibone Producer.)

Smith Gas Power Company, Lexington, Ohio.

The Westinghouse Machine Company, East Pittsburg, Penn.

R. D. Wood & Company, Philadelphia, Penn.

The gas engines that have been and are in use are made by the following firms:

Alberger, Alberger Gas Engine Company, Buffalo, N. Y.

Allis-Chalmers Company, West Allis, Wisconsin.

Bethlehem Steel Company, South Bethlehem, Penn.

Buckeye, The Buckeye Engine Co., Salem, Ohio.

Fairbanks-Morse & Co., Chicago, Illinois.

Foos. The Foos Gas Engine Company, Springfield, Ohio.

Muenzel. Minneapolis Steel & Machinery Co., Minneapolis, Minn.

Nash. The National Meter Co., 1223 Wabash ave., Chicago, Ill.

Rathbun-Jones, The Rathbun-Jones Engineering Company, Toledo, Ohio.

Snow. Snow Steam Pump Works, Buffalo, N. Y.

Weber. The Weber Gas and Gasoline Engine Co., Kansas City, Missouri.

The Westinghouse Machine Company, East Pittsburg, Penn.

It may be worthy of note that of the nine producer and twelve engine manufacturers, there are but three that make both producer and engine, viz: The Bethlehem Steel Company, The Fairbanks-Morse Company and The Westinghouse Machine Company. The Bethlehem producers and engines are replacing Loomis-

Pettibone producers and Snow engines in the only plant at which any of these types of equipment are in use This plant is the largest in the State, and, when completed, will be of about 4,400 horse-power. The Fairbanks-Morse equipment is used now at eight plants, aggregating 1,050 horse-power. There are in operation three Westinghouse installations of a total of 740 horse-power, which is being increased to 1,180. The Smith leads in the number of installations, there being now in operation ten plants of a total of 1,615 horse-power, which will be raised to eleven plants, with a total of 2,815 when producer operation is resumed at Dallas, and the plant at San Antonio doubled. R. D. Wood & Co. have six installations, only four of which were in operation, with a total of 1,125 horse-power. The single Harvey plant is of 3,300 horse-power, but here producers are to be replaced by natural gas shortly. Other makes are represented by single installations.

With regard to engines, the Bethlehem, replacing the Snow, will lead with 4,400 horse-power at a single plant, followed by Allis-Chalmers with 3,900 horse-power at two plants, Rathbun-Jones, with 1,235 at six plants to be increased to 1,835 at seven plants, and Fairbanks-Morse with 1,050 horse-power at eight plants. Following are: Westinghouse with 680 horse-power at three plants, now being increased to 1,060; Buckeye with 600 horse-power at one, now operating at 720 horse-power on natural gas and shortly to resume producer operation; Foos, with 325 horse-power at two plants, and Alberger with 250 horse-power at a single plant. The other makes are small and in single installations. In number of plants, Fairbanks-Morse leads with eight, Rathbun-Jones has six, Westinghouse three, Allis-Chalmers and Foos two each and all others a single plant.

The producer made by the Bethlehem Steel Company is used at the following establishment: Texas Portland Cement Company, Harry (near) Dallas (being installed).

The Fairbanks-Morse is used by: G. M. Jackson, Garwood; G. C. Gifford Plantation, Glen Flora; Huntsville Electric Light & Power Company, Huntsville; Bayliss Earle, Mart; Rockport Ice & Light Company, Rockport; Smithville Light & Power Co., Smithville; Stephenville Light & Water Works, Stephenville; Teague Electric Light & Power Co., Teague.

The Harvey producer is used by the Southwestern States Portland Cement Company, Eagle Ford, (near) Dallas. The Herrick producer has been used by the Dittlinger Lime Co., Dittlinger. The Irvin producer is used at the shops of the Texas Midland Railway, Terrell.

The Loomis-Pettibone producer is used by the Texas Portland Cement Company, Harry, (near) Dallas.

The Smith producer is used by: The Home Light & Water Co., Blooming Grove; Brownwood Water Works, Brownwood; The People's Light Co., Corpus Christi; The Stanard-Tilton Milling Co., Dallas; Gainesville Electric Co., Gainesville; Gatesville Power & Light Co., Gatesville; Kingsville Power Co., Kingsville; Mineola Light & Ice Co., Mineola; San Angelo Street Car Co., San Angelo; San Antonio Portland Cement Co., San Antonio, and The Yorktown Light & Ice Co., Yorktown.

The Westinghouse producer is used by: The Arkansas & Texas Consolidated Ice & Coal Co., Pittsburg; The Canadian Water, Light & Power Co., Canadian; Amarillo Water, Light & Power Co., Amarillo, and by plants at Weatherford and Longview, not now in operation.

The R. D. Wood producer is used by: J. J. Richolson, Altair; Nueces River Irrigation Co., Calallen; The People's Light Co., Corpus Christi; Houston Cotton-meal Mill, Houston; Austin White Lime Co., McNeil; Round Rock White Lime Co., Round Rock.

The Alberger gas engine is used by the San Angelo Street Car Co., San Angelo.

The Allis-Chalmers gas engine is used by: San Antonio Portland Cement Co., San Antonio, and Southwestern States Portland Cement Co., Eagle Ford, (near) Dallas.

The Bethlehem Steel Company's gas engine is used by: The Texas Portland Cement Company, Harry, (near) Dallas.

The Buckeye gas engine is used by: The Stanard-Tilton Milling Co., Dallas.

The Fairbanks-Morse & Co.'s gas engine is used where the Fairbanks-Morse producer is installed and reference is made to the list of producers.

The Foos gas engine is used by: J. J. Richolson, Altair, and by the Nueces River Irrigation Co., Calallen.

The Muenzel gas engine is used by: The Gatesville Power & Light Co., Gatesville.

The Nash gas engine is used by: The Gainesville Electric Co., Gainesville.

The Rathbun-Jones gas engine is used by: The Home Light & Water Co., Blooming Grove; The People's Light Co., Corpus Christi; Houston Cotton-meal Mill, Houston; Kingsville Power Co., Kingsville; Mineola Light & Ice Co., Mineola; Yorktown Light & Ice Co., Yorktown.

The Snow gas engine is used by: The Texas Portland Cement Co., Harry, (near) Dallas.

The Weber gas engine is used by: The Texas Midland Railway in the shops at Terrell.

The Westinghouse gas engine is used where this type of producer is used and reference is made to the list of producers.

TABLE OF PRODUCER PLANTS IN TEXAS.

The plants visited personally are marked *.

The plants no longer in operation are marked †.

Those using lignite exclusively are marked L

The plant at Amarillo uses Colorado bituminous coal, and is being doubled. Canadian uses New Mexico bituminous coal. Pittsburg uses a mixture of Arkansas semi-anthracite and Texas lignite. Dallas uses natural gas now, but is shortly to return to producers on lignite. At Harry, Bethlehem producers and engines are replacing Loomis-Pettibone producers and Snow engines. At San Antonio, Smith producers and Rathbun-Jones engine will increase the capacity to 1200 horse-power.

TABLE OF PRODUCER PLANTS IN TEXAS.

Locality.	Producers.		Gas Engines.		
	Number.	Kind.	Horse-power.	Kind.	Number.
L. Altair*	1	R. D. Wood & Co.	100	Foos	1
Amarillo	1	Westinghouse	380	Westinghouse	1
L. Blooming Grove*	1	Smith	60	Rathbun-Jones	1
L. Brownwood	1	Smith	100		1
L. Calallen*	1	R. D. Wood & Co.	225	Foos	1
Canadian	2	Westinghouse	200	Westinghouse	2
L. Corpus Christi*	3	2 Wood, 1 Smith	425	Rathbun-Jones	2
Dallas*	3	Smith	600	Buckeye	1
†Dittlinger*	4	Herrick		Fuel gas for burning lime	
L. Eagle Ford*	6	Harvey	3,300	Allis-Chalmers	3
L. Gainesville*	1	Smith	150	Nash	1
L. Garwood*	1	Fairbanks-Morse	200	Fairbanks-Morse	1
L. Gatesville*	1	Smith	80	Muenzel	1
L. Glen Flora	1	Fairbanks-Morse	200	Fairbanks-Morse	1
L. Harry*	3	Bethlehem, Loomis-Pettibone	4,400	Bethlehem, Snow	4
L. Houston*	2	R. D. Wood & Co.	500	Rathbun-Jones	1
L. Huntsville	1	Fairbanks-Morse	100	Fairbanks-Morse	1
L. Kingsville*	1	Smith	100	Rathbun-Jones	1
†Leonard*	1	Fairbanks-Morse	50	Fairbanks-Morse	1
†Longview	1	Westinghouse	?	Westinghouse	1
McNeil*	2	R. D. Wood & Co.		Fuel gas for burning lime	
L. Mart	1	Fairbanks-Morse	100	Fairbanks-Morse	1
L. Mineola*	1	Smith	90	Rathbun-Jones	1
Pittsburg*	1	Westinghouse	100	Westinghouse	1
L. Rockport*	1	Fairbanks-Morse	50	Fairbanks-Morse	1
Round Rock*	1	R. D. Wood & Co.		Fuel gas for burning lime	
†Royse*	1	Fairbanks-Morse	75	Fairbanks-Morse	1
L. San Angelo	1	Smith	250	Alberger	2
L. San Antonio*	3	Smith	600	Allis-Chalmers	1
L. Smithville*	1	Fairbanks-Morse	150	Fairbanks-Morse	1
L. Stephenville*	1	Fairbanks-Morse	100	Fairbanks-Morse	1
†Taylor*	1	Fairbanks-Morse	25	Fairbanks-Morse	1
L. Teague*	2	Fairbanks-Morse	150	Fairbanks-Morse	2
L. Terrell*	1	Irvin	100	Weber	1
†Weatherford	1	Westinghouse	?	Westinghouse	1
L. Yorktown	1	Smith	60	Rathbun-Jones	1
Total installed	57		13,020		42
Total operating	47		12,270		37

Following is a brief description of the different plants visited. At some of these places it was not possible to secure more information that is here given.[1]

ALTAIR *.

An irrigation pumping plant on the Colorado river, Colorado county, operated by J. J. Richolson. One R. D. Wood & Co.'s suction up-draft producer and fittings. The engine is a two-cylinder vertical Foos driving a single-phase high-lift centrifugal pump, through a 12-rope connection. The plant was designed and erected by the Southern Gas & Gasoline Engine Company, Houston, but was not in operation. No one in authority could be seen, but the service is said to be satisfactory, when pumping is required.

AMARILLO.

Amarillo Water, Light and Power Company.

One Westinghouse producer rated at 440 horse-power at sea level, one Westinghouse 18″x26″ gas engine rated at 380 horse-power at sea level, direct connected to a Westinghouse 250 k. v. a. 2,300 volt generator. This equipment is now being duplicated.

The fuel is screened pea bituminous coal from Colorado, and costs $4.00 a ton. The following operating data is quoted from a letter from the Company:

"May, 1911.

"Total coal, pounds, 192,487; hours of actual operation, 682; kilowatts generated, 88,250; average pounds of coal per kilowatt hour, 2.19; average run per day, 22 hours."

This letter further states that the average load is 130 k. w., and that the gas will average 125 B. T. U. per cubic foot. The production of tar is a barrel in three months, this coming from the scrubbers and being full of lamp black. The water from the scrubbers goes to the sewer.

Producers were installed here to replace steam, and entire satisfaction is expressed with the operation, as is shown by plans which contemplate a plant of 1,000 k. v. a.

[1]The places visited personally are marked with a *.

BLOOMING GROVE.*

The Home Light & Water Company.

Equipment: One 60 horse-power Smith suction down-draft producer; one Rathbun-Jones two-cylinder vertical gas engine of 60 horse-power. The engine is direct connected to a line shaft from which are driven an Allis-Chalmers generator, an Ingersoll-Rand two-cylinder air compressor for "blowing" a well from a depth of 200 feet, and a Fairbanks-Morse geared two-cylinder pump for lifting water from a surface tank 100 feet to a stand-pipe. The generator is an alternator of 17 k. w. at 2,200 volts, and operates about 12 hours a day, from noon until midnight, at an average load of 35 per cent The compressor requires about 25 horse-power, and operates about seven hours. The pump requires about 12 horse-power and operates about four hours. The average fuel consumption is about 1,600 pounds per 12 hours. The lignite used is from the mines of the Consumers' Lignite Company, Hoyt and Alba, Wood County, and costs $2.10 a ton, delivered.

The producer is of an old type, similar to the one noticed at Mineola, i. e., the fire-containing shell rests directly upon the foundation, the ashes being drawn by hand with long-handled shovels. Less tar was noticed here than at any plant visited, with the exception of the plant at Pittsburg, where the Westinghouse Tarless Producer is used. The jacket water is further heated in an exhaust heater and goes to the saturator at a temperature of about 140 degrees Fahrenheit, which can be increased to 170 degrees Fahrenheit.

This producer, in addition to the gasoline engine-driven blower for starting, is further equipped with a hand blower so arranged as to be connected with the producer only when the main air inlet through the saturator is closed. It is used regularly to force gas to the engine for starting. The use of this hand blower does not seem to be required, as it was not observed elsewhere.

The plant has been in operation about three years, during which time the repair account has been very small. The pipes in the exhaust water heater are eaten up in 18 months.

BROWNWOOD.

Brownwood Water Works.

There is a 100 horse-power Smith producer here operating on lignite. We were unable to secure further information by correspondence.

CALALLEN.*

An irrigation pumping plant, operated by the Nueces River Irrigation Company, a co-operative farming enterprise.

One No. 6 Wood suction up-draft producer and standard fittings. The engine is a three-cylinder vertical Foos, with rope drive to a 16-inch Worthington involute pump. This plant was not in operation at the time of visiting, but information was secured from the general manager and the operating engineer.

The lignite used is from the mines of the Bear Grass Coal Company, Jewett, Leon county. The cost, on the producer floor, is $3.65 a ton.

The engine is rated at 225 horse-power at 225 r. p. m. The guarantee calls for one brake horse-power from two and one-half pounds of lignite, as fired, and for the delivery of 6,500 gallons of water per minute on a lift of 83 feet.

The plant was put in operation the first of January, 1911, but has not been run steadily for more than twelve hours at a time. There is no information as to consumption of lignite or details of operation. The producer is of the new Wood type, with the upper third of the producer walls and the top water-jacketed. From the jacket a pipe conveys water to the saturator for mixing water-vapor with air. The temperature of this air is kept at about 140 degrees Fahrenheit for normal operations. By increasing the temperature to 170 degrees Fahrenheit the tendency towards "clinkering" is arrested at an early stage.

All of the water for engine and producer auxiliaries is taken from the main lift pipe through a two-inch line. The scrubber-water and tar are pumped back into the irrigation canal. It was at first intended to allow the waste water, tar, etc., to flow by gravity back into the river, but as the in-take for the Corpus Christi Water Works was but two miles below, the waste, etc., was taken back into the irrigation canal. It is not known how much ammonia the waste water carries, but at any rate it would probably not be sufficient to benefit vegetation under the conditions there.

This plant was designed and installed by the Southern Gas & Gasoline Engine Company, Houston.

CANADIAN.

Canadian Water, Light & Power Company.

The equipment here consists of two producers of 100 horse-power each and two gas engines of 100 horse-power each, of Westinghouse make. The fuel is bituminous coal from New Mexico. This plant was not visited, and no further information could be secured by correspondence.

CORPUS CHRISTI.*

The People's Light Company.

The original plant here consisted of one Smith suction producer of 125 horse-power capacity, and one Rathbun-Jones three-cylinder vertical gas engine. The engine was direct connected to a Westinghouse two-phase generator at 2,300 volts. This equipment was afterwards increased by a No. 6 Wood suction producer, rated at 300 horse-power, and a Rathbun-Jones engine similar to the one in use, but rated at 300 horse-power. It was found that the producer would not supply sufficient gas for rated capacity, so a larger Wood, No. 7, was installed a few months ago by the manufacturer. Since that time there has been no trouble, the two Wood producers carrying the entire load, while the Smith producer is held in reserve.

The large engine carries the entire lighting and power load from 6 a. m. to midnight, the small engine being then used. Both generators deliver two-phase current at 2,300 volts, but no attempt is made to synchronize. The lighting current is transformed to 110 volts, with some power current at 220 volts, and the street car current is run through a rotary to 550 volts, direct current.

The exhaust from the large engine is led through a heater for supplying water-vapor to the saturator, which is arranged to serve both producers. The maximum temperature of the blast is 150 degrees Fahrenheit, which is not as high as has been found best at other plants where a similar arrangement is in use. It is questionable whether the exhaust from a 300 horse-power engine will furnish enough water-vapor for two producers of this size, particularly when the heater is at least 25 feet from the engine. When the large engine is shut down, six hours out of every twenty-four, the blast is not heated at all, as the small engine exhausts direct into the air. It is during this time that clinkering is most apt to occur.

On full load the larger producer is charged with 200 pounds of lignite every hour, the smaller one with a like amount every two hours, both being cleaned every morning. In general, the suction is proportioned to the size of the producers and the fuel consumed in each. Clinker troubles are frequent and serious, masses of such size and consistency as to require sledging on the end of a one-inch poker being of common occurrence. The repair bill for broken pokers is sometimes as much as $15.00 in a month. This trouble has not been observed elsewhere in so serious a form, and it seems likely that means for obviating it would more than repay the expense. Among other things, both the temperature and the wetness of the blast might be increased when a clinker is observed to be forming. All cooling, scrubbing and jacket water is drawn direct from the bay (salt water) by small motor-driven centrifugal pumps, and all waste water and tar runs into the bay. Several hundred pounds of tar are produced daily, but no accurate measurements have been taken, and there is no attempt made to utilize this product.

Salt water makes no appreciable difference in producer operations, although heavy encrustations were observed at one or two points where a slight leak had developed in the out-let piping from the engine-jackets. It seems natural to suppose that in time such encrustation would be a source of trouble. It is understood that the original water-jacketed exhaust valves did give trouble on this account; at any rate, they have been replaced by air-cooled valves. Various lignites have been tried here, such as Calvert, Crockett and Rockdale. The price of the Calvert lignite, delivered at the works, is $2.65 a ton, of the Crockett lignite $2.67 and of the Rockdale lignite $2.47.

The operating labor consists of three firemen, two ash-men and two engineers. The firemen and ash-men are Mexicans, at $1.50 a day.

Owing to the recent installation of the larger producer, no definite method of operation has been developed, nor are there any definite figures as to the consumption of fuel per kilowatt hour. Before the new producer was installed and while the one then in use was being forced beyond its point of economy, the fuel consumption was more than five pounds per kilowatt hour. Of late, however, this has been reduced to a little over three pounds, and there is a probability of an additional reduction, especially, if the combustible matter remaining in the ash is lessened by more frequent poking of the fuel bed and by drawing ashes oftener. Additional poke-holes and ash-doors have been made in the sides of the two Wood producers, but as these were not observed elsewhere in similar installations their usefulness may be questioned.

DALLAS.*

Stanard-Tilton Milling Company.

Equipment: Three 200 horse-power Smith suction down-draft producers. One Buckeye twin tandem two-cylinder, double-acting horizontal gas engine, direct connected to a 500 kilowatt Westinghouse alternator, furnishing power for a flour mill.

This plant is now operating on natural gas supplied by the Lone Star Gas Company, Fort Worth, from its wells in Clay county, 110 miles northwest of Dallas. As installed, the engine would develop, on producer-gas, only 600 horse-power. On natural gas it develops 720 horse-power. The consumption of natural gas is about 250,000 cubic feet for 8,000 kilowatt hours. Larger cylinders have been ordered and the engine is to be operated again on producer-gas, as the Company is enthusiastic over this form of power. No details of operation are available for publication at this time, beyond the statement that there was no trouble from the producers.

The heat units in the natural gas supplied to north Texas establishments, under the best conditions, may be taken at 980. The gas consists almost entirely of methane.

DITTLINGER.*

Dittlinger Lime Company.

At this plant there are four Herrick up-draft producers for making fuel gas to be used in burning lime. The kilns are now being fitted to use oil, but the producers will not be dismantled. These producers have been operated for about three years, and the change to oil is said to be on account of economy.

The fuel used was coal from the mines of the Olmos Coal Company and the International Coal Mines Company, Eagle Pass, Maverick county, the consumption being ten tons a day for 300 barrels of lime. Parallel operations on coal and oil showed that about 90 barrels of lime were obtained from the use of producer-gas and 120 barrels from oil.

The producers are set very close to the kilns, and there are two for each kiln. This arrangement is more like that of a reverberatory furnace than a producer plant such as was operated at McNeil and Round Rock for burning lime. However this may be, the fact remains that this plant is changing to oil, and the other lime plants have not had success in using producer-gas.

EAGLE FORD.*

Southwestern States Portland Cement Company.

Equipment: Six Harvey up-draft pressure producers and three 750 kilowatt Allis-Chalmers horizontal two-cylinder tandem double-acting gas engines. These engines have, on the main shaft, Allis-Chalmers generators of 2,300 volts supplying power for the establisment.

The original installation consisted of two Allis-Chalmers engines, to which a third was recently added.

It is understood that the demand for power has increased so much that it would become necessary to add two producers or to go on natural gas, with some corresponding changes in the engines.

After full consideration the Company has decided to use natural gas, without, however, dismantling the producer plant. The natural gas is supplied by the Lone Star Gas Comapny, which has pipe lines into Fort Worth, Dallas, etc., from Clay and Wichita counties.

The writer worked in the gas department of this Company several months, and what is here given concerning the operations is with permission.

Fuel. The fuel used was lignite from the mines of the Consumers' Lignite Company, Hoyt and Alba, Wood county, and Grand Saline, Van Zandt county. It cost $1.62 a ton, delivered.

A sample of this lignite taken from the producer-floor gave the following analysis:

	Per cent.
Moisture	10.80
Volatile matter	42.76
Fixed carbon	40.38
Ash	6.06
	100.00
Sulphur	0.63

An ultimate analysis of this sample gave the following results:

Dry Basis.	Per cent.
Carbon	54.70
Hydrogen	3.15
Oxygen	29.13
Nitrogen	2.14
Ash	10.20
Sulphur	0.68
	100.00
Heating Power, B. T. U., Dry	10,840

The lignite represented by the above analysis is much drier than it usually is. The following analysis represents material with about as much moisture as it generally contains.

	Per cent.
Moisture	29.20
Volatile matter	40.38
Fixed carbon	21.83
Ash	8.61
	100.00
Sulphur	0.63

It is likely that this analysis more truly represents the lignite, *as charged,* than the one first given. The heat units in the lignite, as charged, are, on the average, 7,500 B. T. U. For convenience of reference we have prepared two Tables of producer operations involving the use of 233,920 pounds of lignite, and the production of 66,740 kilowatt hours of energy, equivalent to 89,411 horse-power hours.

These Tables represent two distinct, but not consecutive periods of 24 hours each, and these periods were divided into 11 and 13-hour sub-periods. For the 11-hour periods the readings are hourly, while for the 13-hour periods only the totals are given.

TABLE I.

PRODUCER OPERATIONS—TEXAS LIGNITE.

Time.	Producer Number.												Gas press. in main. Inches.	St. press. average lbs.	Total fuel lbs.	Hours		Pounds of fuel per	
	1		2		3		4		5		6								
	Fuel lbs.	St. press. lbs.	Fuel lbs.	St. press. lbs.	Fuel lbs.	St. press. lbs.	Fuel lbs.	St. press. lbs.	Fuel lbs.	St. press. lbs.	Fuel lbs.	St. press. lbs.				Kilo-watt.	Horse-power.	K.W. hour.	H. P. hour.
8 a. m. ---	950	24	760	30	190	27	950	29	950	29	1,140	29	5.5	28	4,940	1,250	1,675	3.9	2.9
9 a. m. ---	760	25	1,140	31	1,710	29	570	30	380	30	570	30	6.0	29	5,130	1,240	1,649	4.1	3.1
10 a. m. --	570	27	570	31	1,140	27	1,140	27	760	30	570	30	6.5	29	4,750	1,170	1,567	4.1	3.1
11 a. m. --	1,140	36	1,140	39	760	35	1,520	36	190	39	570	42	7.0	38	5,320	1,440	1,929	3.7	2.8
12 m. ------	570	34	760	39	1,140	36	950	34	1,140	43	1,520	40	6.0	37	6,080	1,500	2,010	4.0	3.0
1 p. m. ---	760	35	570	40	950	37	1,330	35	1,140	44	1,520	41	5.5	38	6,270	1,620	2,170	3.9	2.9
2 p. m. ---	1,140	35	950	41	1,140	37	570	35	1,330	39	760	42	6.5	38	5,890	1,560	2,090	3.8	2.8
3 p. m. ---	950	45	950	40	1,330	36	1,140	34	1,140	38	570	40	4.5	37	6,080	1,610	2,157	3.8	2.8
4 p. m. ---	570	32	760	38	760	36	950	40	1,520	34	950	39	5.0	37	3,190	1,710	2,291	1.9	1.4
5 p. m. ---	1,140	34	950	40	570	36	380	36	190	36	950	50	5.0	36	4,510	1,460	1,956	3.1	2.2
6 p. m. ---	950	35	1,330	41	760	37	380	44	none	37	1,330	43	7.5	39	4,750	1,750	2,345	2.7	2.0
11 hrs. av. and total	9,500	32	9,690	37	10,450	34	9,880	35	9,120	38	10,450	38	6.0	36	59,090	16,330	21,882	3.5	2.7
13 hrs. Total ---	6,080	------	11,020	------	11,590	------	8,740	------	10,070	------	--------	------	--------	--------	57,190	15,300	20,502	3.7	2.8
24 hrs. Total ---	15,580	------	19,380	------	21,470	------	21,470	------	17,860	------	20,520	------	--------	--------	116,280	31,630	42,384	3.7	2.8

TABLE II.

PRODUCER OPERATIONS—TEXAS LIGNITE.

Time.	Producer Number.												Gas press. in main. Inches.	St. press. average lbs.	Total fuel lbs.	Hours		Pounds of fuel per	
	1		2		3		4		5		6								
	Fuel lbs.	St. press. lbs.	Fuel lbs.	St. press. lbs.	Fuel lbs.	St. press. lbs.	Fuel lbs.	St. press. lbs.	Fuel lbs.	St. press. lbs.	Fuel lbs.	St. press. lbs.				Kilowatt.	Horsepower.	K.W. hour.	H.P. hour.
8 a. m.	1,520	20	760	25	570	23	380	27	760	22	760	27	6.5	24	4,750	1,350	1,809	3.5	2.6
9 a. m.	570	20	760	26	570	20	1,140	25	950	27	950	25	5.5	24	4,940	1,370	1,835	3.6	2.7
10 a. m.	380	21	190	26	1,710	20	760	25	380	21	570	26	5.0	23	3,990	1,400	1,876	2.9	2.2
11 a. m.	380	22	950	28	1,520	25	950	25	1,330	24	570	30	5.5	26	5,600	1,470	1,969	3.8	2.8
12 m.	760	31	760	39	950	33	1,330	38	950	30	570	36	4.5	36	5,320	1,440	1,929	3.7	2.8
1 p. m.	950	34	1,520	39	1,520	33	1,140	39	950	30	760	39	5.5	36	6,840	1,600	2,144	4.3	3.2
2 p. m.	760	25	760	31	1,330	25	1,900	32	950	25	950	31	5.5	28	5,750	1,790	2,398	3.2	2.4
3 p. m.	190	23	380	29	950	24	570	30	570	23	380	29	6.0	26	3,040	1,280	1,715	2.4	1.8
4 p. m.	380	23	380	29	570	24	190	29	190	23	330	29	6.0	26	2,090	1,550	2,077	1.3	1.0
5 p. m.	1,140	24	760	30	1,140	25	190	30	760	23	760	30	5.5	27	4,750	1,550	2,077	3.1	2.2
6 p. m.	1,140	23	760	30	190	25	760	29	570	23	570	29	6.0	27	3,990	1,210	1,621	3.3	2.5
11 hrs. av. and total	8,170	24	8,380	30	11,020	25	9,310	30	8,350	25	7,220	30	5.6	27	51,060	16,010	21,453	3.2	2.4
13 hrs. Total	11,020	------	8,290	------	10,590	------	11,780	------	11,410	------	13,490	------	--------	--------	66,580	19,100	25,594	3.5	2.6
24 hrs. Total	19,190	------	17,670	------	22,610	------	21,090	------	19,760	------	20,710	------	--------	--------	117,640	35,110	47,047	3.3	2.5

The six Harvey producers were used. In Table I the total lignite charged was 116,280 pounds, i. e., 59,090 pounds in 11 hours and 57,190 pounds in 13 hours. The rate of charging was 5,190 pounds per hour for the 11-hour period and 4,399 pounds an hour for the 13-hour period. The rate of charging over the entire period of 24 hours was 4,845 pounds an hour.

During the 11-hour period, when observations were taken hourly, the amount of lignite charged was 59,090 pounds, the average steam pressure (blower) was 36 pounds, the average gas pressure in the main was 6 inches, the total number of kilowatt hours was 16,330 (=21,882 horse-power hours), and there was used 3.6 pounds of lignite per kilowatt hour (=2.7 pounds per horse-power hour). It will be observed that there was a considerable variation in the number of pounds of fuel per kilowatt hour, from 1.9 to 4.1, but the general average was 3.6 pounds, worth 2.91 mills. Taking the cost of the lignite, delivered, as $1.62 a ton, the cost of the fuel per horse power hour was 2.18 mills. This, of course, is raw fuel cost, and does not include the cost of converting the lignite into gas.

In Table II the total lignite charged was 117,640 pounds, i. e., 51,060 pounds in 11 hours and 66,580 pounds in 13 hours. The rate of charging was 4,642 pounds per hour for the 11-hour period and 5,122 pounds an hour for the 13-hour period. The rate of charging for the entire period of 24 hours was 4,902 pounds an hour. During the 11-hour period the total amount of lignite charged was 51,060 pounds, the average steam pressure (blower) was 27 pounds, the average gas pressure in the main was 5.6 inches, the total number of kilowatt hours was 16,010 (=21,453 horse-power hours), and there was used 3.2 pounds of lignite per kilowatt hour (=2.4 pounds per horse-power hour).

In this sub-period of 11 hours there was a somewhat greater range in the number of pounds of lignite per kilowatt hour than in Table I, i. e., from 1.3 to 4.3, but the general average was lower, 3.2 as against 3.6.

During the entire period covered by these tables, 48 hours, there were used 233,920 pounds (=116.96 tons) of lignite, with a production of 66,740 kilowatt hours (=89,411 horse-power hours) of energy, or a general average of 3.5 pounds of lignite per kilowatt hour (=2.6 pounds per horse-power hour). With lignite at $1.62 a ton, delivered, this represents a raw fuel cost of 2.83 mills per kilowatt hour (=2.11 mills per horse-power hour).

TABLE III.

PRODUCER OPERATIONS—TO ACCOMPANY TABLE I—COMPOSITION OF GAS, ETC.

Time of sampling.	Gas pressure inches of water.	Load when sampled. Kilowatts.	Kilowatts produced in preceding hour.	Lignite charged in preceding hour. Pounds.	Pounds of lignite		Analysis of Gas.							Heat. Power B. T. U. per cubic foot.
					Per K. W. hour.	Per H. P. hour.	Carbon dioxide.	Carbon monoxide.	Methane.	Ethylene.	Hydrogen.	Oxygen.	Nitrogen.	
8 a. m.	5.5	1,300	1,250	4,940	3.9	2.9	8.4	14.8	.4	2.3	8.9	1.8	63.4	106.3
9 a. m.	6.0	1,150	1,240	5,130	4.1	3.1	11.2	16.4	3.2	.8	10.4	.4	57.6	131.8
10 a. m.	6.5	1,600	1,170	4,750	4.1	3.1	11.1	16.8	3.2	.7	8.8	.6	58.8	126.3
11 a. m.	7.0	1,350	1,440	5,320	3.7	2.8	11.1	15.3	2.9	.6	7.6	.4	62.1	113.9
12 m.	6.0	1,550	1,500	6,080	4.0	3.0	11.2	15.0	3.3	.5	10.2	.9	58.9	122.9
1 p. m.	5.5	1,500	1,620	6,270	3.9	2.9	11.4	13.8	3.0	.5	6.3	.5	64.5	108.3
2 p. m.	6.5	1,550	1,560	5,890	3.8	2.8	11.0	13.3	3.3	.8	6.3	.6	64.7	109.5
3 p. m.	4.5	1,700	1,610	6,080	3.8	2.8	11.4	14.4	3.3	.6	8.0	.4	61.9	115.4
4 p. m.	5.0	1,650	1,710	3,190	1.9	1.4	11.3	14.0	3.7	.7	7.7	.2	62.4	118.4
5 p. m.	5.0	1,750	1,460	4,510	3.1	2.2	10.8	12.0	5.7	.5	7.9	.7	62.4	129.9
6 p. m.	7.5	1,600	1,750	4,750	2.7	2.0	10.3	11.7	6.5	.8	7.3	.5	62.9	139.9
Average	5.91	1,518	1,483	5,174	3.5	2.0	10.8	14.3	3.5	.8	8.1	.6	61.9	119.3

TABLE IV.

PRODUCER OPERATIONS—TO ACCOMPANY TABLE II—COMPOSITION OF GAS, ETC.

Time of sampling.	Gas pressure inches of water.	Load when sampled. Kilowatts.	Kilowatts produced in preceding hour.	Lignite charged in preceding hour. Pounds.	Pounds of lignite		Analysis of Gas.							Heat. Power B. T. U. per cubic foot.
					Per K. W. hour.	Per H. P. hour.	Carbon dioxide.	Carbon monoxide.	Methane.	Ethylene.	Hydrogen.	Oxygen.	Nitrogen.	
8 a. m.	6.5	1,300	1,350	4,750	3.5	2.6	10.7	13.6	3.4	.7	8.2	.2	63.2	116.0
9 a. m.	5.5	1,400	1,370	4,940	3.6	2.7	9.6	13.8	4.2	.2	8.4	.4	63.4	117.5
10 a. m.	5.0	1,350	1,400	3,990	2.9	2.2	10.6	14.6	4.4	.5	7.7	.5	62.7	124.6
11 a. m.	5.5	1,500	1,470	5,600	3.8	2.8	8.2	14.7	3.4	.1	11.8	1.0	60.8	121.8
12 m.	4.5	1,550	1,440	5,320	3.7	2.8	11.8	11.4	4.6	.4	11.4	----------	60.4	125.6
1 p. m.	5.5	1,650	1,600	6,840	4.3	3.2	10.8	12.7	4.9	.5	9.4	.6	61.1	130.0
2 p. m.	5.5	1,700	1,790	5,750	3.2	2.4	10.2	11.6	6.1	.4	6.1	.9	64.7	125.3
3 p. m.	6.0	1,250	1,280	3,040	2.4	1.8	10.2	8.2	7.6	.6	3.6	.6	69.2	131.0
4 p. m.	6.0	1,500	1,550	2,090	1.3	1.0	10.1	9.3	7.5	.3	6.3	.9	65.6	131.0
5 p. m.	5.5	1,600	1,550	4,750	3.1	2.2	11.0	11.7	5.3	.8	10.5	.8	59.9	138.0
6 p. m.	6.0	1,300	1,210	3,990	3.3	2.5	10.6	17.6	2.8	.6	12.8	----------	55.6	137.2
Average	5.6	1,464	1,456	4,642	3.2	2.4	10.3	12.6	4.8	.4	8.7	.50	62.4	127.1

From Table I it will be seen that the consumption of lignite was 116,280 pounds, and from Table III that the average heat units in the gas during this period were 119.8. The heat units in the gas were determined by calculation from the analysis, and were not determined in a calorimeter. The factors used in this calculation were as follows:

Carbon monoxide	324.
Methane	1010.
Ethylene	1580.
Hydrogen	324.

These factors differ somewhat from those commonly accepted for these substances, but were used at this establishment.

The variations in composition were as follows:

	From.	To.	Average.
Carbon dioxide	8.4	11.4	10.8
Carbon monoxide	11.7	16.8	14.3
Methane	0.4	6.5	3.5
Ethylene	0.5	2.3	0.8
Hydrogen	6.3	10.4	8.1
Oxygen	0.2	1.8	0.6
Nitrogen	57.6	64.7	61.9
Heat units	103.3	139.9	119.9

During the period represented by Table II the consumption of lignite was 117,640 pounds, and the average heat units in the gas were 127.1. The variations in composition were as follows:

	From.	To.	Average.
Carbon dioxide	8.2	11.8	10.3
Carbon monoxide	8.2	17.6	12.6
Methane	2.8	7.6	4.8
Ethylene	0.1	0.8	0.4
Hydrogen	3.6	12.8	8.7
Oxygen	0.0	1.0	0.5
Nitrogen	55.6	69.2	62.4
Heat units	116.0	138.0	127.1

There is not a well marked difference between these gases and the fact that the average heat units are so close together would indicate that the gas, throughout the two periods, was of fairly uniform quality.

The amount of lignite charged per hour varied, for the entire six producers, from 2,090 pounds to 6,840 pounds, the amount so charged depending on the power requirements.

There is no practical difference in the heat units during the morning, from 8 to 12, and the afternoon, from 1 to 6 (120.6 and 125.7). The lowest heat units observed, 103.3, were at 1 p. m., when during the preceding hour, i. e., from 12 to 1, there had been charged 6,270 pounds of lignite. The highest heat units observed, 139.9, were at 6 p. m., when during the preceding hour, i. e., from 5 to 6, there had been charged 4,750 pounds of lignite. There was one time, 4 p. m., when the heat units were 131.0, with a charge of 2,090 pounds of lignite during the preceding hour.

The producers, being of the pressure type, require to be blown with live steam at a pressure proportionate to the load. In this plant the steam is furnished by two horizontal fire tube boilers, crude oil fired, which also furnish steam at about 140 pounds for two air compressors; two oil pumps for furnishing crude oil at about 90 pounds pressure to the kilns; a city water pump; a battery of underwriters fire pumps; an exciter for use in starting and when it becomes necessary to shut off the producers; and the necessary boiler feed pumps. It would be impossible, from the data at hand, to apportion the fuel costs to the various departments using steam, although it is undoubtedly true that the six producers use more steam than the remainder of the equipment combined. The pressure on the producers has been observed to vary from a minimum of 19 pounds to a maximum of 46 pounds, a general average probably being close to 36 pounds. It is stated that as much as 55 pounds has been carried, although at danger of blowing the various water seals in the line. About 60 barrels of crude oil are used under the boilers in twenty-four hours, and it is to avoid a large part of this expense that the change to natural gas is being made.

The amount of tar made is considerable, and the quality seems good. No definite figures are obtainable as to the quantity of this tar, but it is understood that at various times measurements have been made. Attempts have been made to utilize this product under the boilers, but without any noticeable success, and at present it is hauled away with the ash, at times being used to surface roads. The arrangement of storage tanks is such that it could readily be stored and barreled at a small cost. The waste water from coolers and scrubbers is allowed to flow away in open ditches, after first passing a trap designed to catch such tar as is suspended in it. At times the supply of water for these purposes is rather scanty, a further factor in the change to natural gas.

The producers are arranged in three sets of two each, and there are but three coolers, three washers and two dry scrubbers, in which excelsior is used, being changed every two months. Fires are cleaned regularly every other day on normal operation, although cases have been observed when all six were cleaned the same day. The system observed is to clean one producer of each set every day. This, however, means that the set—that is, the two producers—are not operating at all satisfactorily while cleaning is going on. In general it has been shown to be best to lighten the load about four hours in the morning, and even then, back-firing, due to high hydrogen in the gas, is more frequent than at other times. The shifts change at 6 a. m. and the two ash men immediately start cleaning. The rule, when operating at full load, is one man to a producer, and while cleaning it is customary for four men to work on top of the producer that is being cleaned, leaving to the other two the firing of the remaining producers. It is in the necessity of poking these producers through the top that the great loss of gas occurs, and it is not to be questioned that this loss is appreciable. On a still day it is almost impossible to remain long immediately over the producer, and the men are allowed breathing spells at the edge of the charging floor. The fuel is handled from the cars to overhead storage bins of about 300 tons capacity by a clam shell coal crane, and from the bins by four spouts to the charging floor between the two sets of producers. From the floor it is shoveled into the hoppers, as before stated, by one man to a producer per shift. These men are Italians and negroes. They receive 20 cents an hour. In general, it may be said that though not clearly shown in the Tables given, the charging is heavier and more variable in the morning, while cleaning, and that beginning about noon, it becomes more regular and not so frequent. The fuel consumption has been observed to be less in a 13-hour run than in an 11-hour run, though the power output is greater. This, of course, is due to the "settling" of the producers and the greater steadiness of operation. Similarly the gas is more apt to vary within wide ranges in the morning, to average low, and to carry more hydrogen, while in the afternoon and night it is of more uniform quality, higher in heating power and lower in hydrogen. Consequently, the fuel consumption per kilowatt hour during the night was generally lower than during the day, although this was not invariably the rule.

GAINESVILLE.*

Gainesville Electric Company.

Equipment: One 150 horse-power Smith suction down-draft producer. One Nash three-cylinder vertical gas engine rated at 150 horse-power, but developing 135 horse-power. The engine is direct connected to a General Electric direct current generator at 250 volts, 400 amperes, 250 r. p. m.

This unit operates 24 hours a day for about two weeks and is then out half a day, Sunday. It is not of sufficient capacity to handle the night load, and is helped, for about four hours, by the steam plant.

The engines operated by steam are: One Atlas cycloidal four-valve tandem compound; one Ball slide-valve and one Harrisburg four-valve. These engines are belted to five General Electric generators. The Ball engine is most frequently used and is belted to two D. C. generators, each of 360 amperes capacity, at 125 volts.

Fires are kept banked under two boilers all the time, Arkansas slack coal being used, with a supply of oil for sudden demands. The consumption of coal, under the boilers, averages over 30 pounds per kilowatt hour, which seems abnormally high.

The original plant here, as at many of the places visited, was steam. Increasing demands caused the installation of the producer-plant to use lignite two years ago. The producer-plant was at first used merely as an auxiliary to the steam plant, but it soon showed such economy in fuel that the steam plant is now the auxiliary.

The lignite used is from the mines of the Consumers' Lignite Company, at Hoyt, Wood county, and costs $1.95 at the plant.

On normal operations less than five pounds of lignite are used per kilowatt hour.

The operating force consists of three men per 24 hours, two of these being on duty from noon until midnight and one from midnight until noon. These men were all employed in the old steam plant and had had no previous experience with producers.

The producer is charged every three hours, and the fire is rodded down at a like interval. The grate is equipped with the air-shaker now supplied with this producer, and is given two or three "licks" every hour. An individual motor drives the elevator for the ashes, and these are drawn at irregular intervals. Some large masses of clinker were noticed and the combustible matter left in the ashes was greater in amount than was observed at some other plants. The temperature of the blast was 140 degrees Fahrenheit, and the hot water was obtained both from an exhaust heater and the economizer. An increase of temperature of the blast to 160 degrees Fahrenheit can be readily attained. The scrubber is run by an individual motor. No attempt is made to save the tar or ammoniacal liquor.

A small gasoline engine drives the blower and compressor, and the compressor may also be driven from the engine shaft.

The lignite is screened before going to the producer, with a considerable loss in fine stuff.

Garwood.*

Mr. G. M. Jackson operates a pumping plant for irrigation purposes at this place. The equipment consists of one Fairbanks-Morse 200 horse-power suction producer and a Fairbanks-Morse four-cylinder vertical 200 horse-power gas engine at 250 r. p. m. This engine drives an 18-inch American centrifugal pump through a 12-rope connection. The pump carries a guarantee of 9,600 gallons a minute on a 42-foot lift. The auxiliary equipment for starting the producer, engine and pump is also of Fairbanks-Morse installation.

The initial plant here consisted of a 175 horse-power Corliss engine, operating from wood-fired boilers. Later, however, the wood was replaced by oil, and later still the steam equipment was changed to producer-gas. The fuel cost with oil-fired boilers was $60.00 a day, while with producer-gas it rarely exceeds $12.00 a day, and the service is better. The cost of the steam installation, which was second-hand, was $9,500, while the producer plant represents an investment of $22,000.

Operation is continuous four months in the year, and at a net saving of daily expenses of $30.00, the total saving during the season would be about $3,600.00. The lignite used is from the Burnet Fuel Company, Milano, Milam county, and costs $2.06 a ton at the works. The consumption of fuel is five tons in twenty-four hours. The producer is charged every two hours, the ash being shaken down just before charging. As usual with this type of producer, the air for gasification receives its moisture from water in the ash-pit. This practice is apt to cause trouble from clinkering, but no serious annoyances of this kind have been observed here. The ash appeared to contain more combustible matter than should be allowed, but this might be prevented by admitting more steam with the air.

Cooling, scrubbing and jacket water is obtained from a well by a belt-driven pump, the waste water and tar being pumped into the river.

The tar is in a very finely divided condition, and there is no difficulty in forcing it through the waste-pipe. While no attempt has been made to save this tar, it is understood that offers for it are under consideration. No detailed information as to the actual consumption of fuel per brake horse-power was obtainable, but from the above figures an over-all result would be about four pounds of lignite per brake horse-power on the basis of water delivered.

GATESVILLE.*

Gatesville Power & Light Company.

Equipment: One Smith suction down-draft producer, rated at 75 horse-power; one Muenzel single cylinder single-acting horizontal gas engine, rated at 80 horse-power. The engine is belted to a General Electric alternator of 75 kilowatts at 2,300 volts, three-phase, sixty cycle. This voltage is transformed to 100 for lights and fans and to 220 for motors.

The fuel is lignite from the mines of the Bear Grass Coal

Company, Jewett, Leon county, and costs $2.27 a ton at the plant.

The engine runs from 4 a. m. until midnight on about 2,000 pounds of fuel, with an average load, for the entire period, of 25 kilowatts, although this rises to 60 kilowatts for a few hours when a roller-mill uses the current. The night load is rarely more than 30 kilowatts, but the engine has successfully carried for some time a 30 per cent. excess over this figure. The original plant here was steam-power, and was operated several years. The engine was of 110 horse-power, but was never run on full load. The producer-gas plant was put in about twenty months ago, and has already shown a marked saving over the steam plant. The consumption of lignite under the boilers was more than twice the present consumption. The President of the operating company stated that the difference in the cost of the two plants would be written off in a little less than six years, under present conditions. Sliding rates for power and light are in effect, the prices ranging from 5 cents to 15 cents per kilowatt hour. Three men do all the work at the plant and on the lines.

The producer is charged every six hours and ashes are drawn by hand once in 24 hours. At the time of the visit, June 1st, a large pile of clinker was noticeable, some of the pieces being of considerable size. The ash also contained some combustible matter. No attempt is made to save the tar or ammoniacal liquor. As is the case generally with this type of producer—the Smith—the tar is not only small in amount, but is very finely comminuted and of a yellow color.

There is a water heater in the exhaust line, but only a part of the jacket water is passed through it, as the passage of the entire quantity would so far reduce the temperature as to render it almost useless in the saturator. With the engine on half load the temperature of the water was 113 degrees Fahrenheit, the top of the producer being half open and the ash-pit overflowing a little.

The scrubber is driven from the main shaft through a belt. The coal elevator, blower and compressor are driven by a gasoline engine.

On starting up about twenty minutes are required to get gas to the engine.

GLEN FLORA.

G. C. Gifford Plantation.

One Fairbanks-Morse suction up-draft producer of 200 horse-power and standard fittings.

One Fairbanks-Morse vertical four-cylinder gas engine of 200 horse-power with rope drive to pump for irrigation purposes. The fuel is lignite from Calvert and Milano, and costs $2.00 a ton at the plant. The consumption is given at 2.87 pounds per horse-power hour, or about seven tons per 24 hours on full load. The plant operates continuously during the rice irrigation season, but is idle the rest of the year.

No attempt is made to utilize tar or ammoniacal liquor, and entire satisfaction is expressed with the plant, particularly on account of low operating expense. It is further stated, however, that when such a plant is operated only three or four months, the interest on the investment offsets the low operating expense.

HARRY.*

The Texas Portland Cement Company.

This is the largest lignite gas plant in the State, but no details of operation can be published at this time.

The original equipment consisted of Loomis-Pettibone producers and Snow engines. This is now being replaced by producers and engines made by the Bethlehem Steel Company, South Bethlehem, Penn. It is hoped that some details of operation can be given later.

The company is well pleased with producer-gas made from lignite, and is of the opinion that this is not only the cheapest fuel in Texas, but that producer-gas is fully as reliable as steam. The former plant was operated on lignite from the mines of the Consumers' Lignite Company, Hoyt and Alba, Wood county. It showed a consumption of three and one-half pounds of lignite per kilowatt hour and the new plant is expected to lower this.

HOUSTON.*

The Houston Cotton-meal Mill, Sixth Ave. and Rutland St.

Equipment: Two No. 7 R. D. Wood & Co.'s suction up-draft producers. One Rathbun-Jones four-cylinder vertical gas engine of 500 horse-power belted direct to lay shaft and to main line shaft with metal-to-metal friction clutches.

This plant has been in operation for two years, but runs only 3,720 hours each year. The engine runs under load eleven and a half hours a day, with a light load for half an hour at noon, but is idle at night except under unusual conditions.

The normal day load varies from 450 to 500 horse-power, with an overload capacity, for a short time, of 550 horse-power. The service here is such as to make a momentary "peak" of frequent occurrence, as when a fresh charge of cotton-seed cake is fed to the grinders.

A fuel consumption of 10,000 pounds of lignite per 24 hours is reported, but the charging is confined to the 12 hours of actual service. The producers are charged at staggered intervals of 25 minutes, this practice giving a more uniform gas, as there is no receiver or regulating tank on the line. The ashes are drawn almost continuously, this giving a slower and more even settling of the fire, and also preventing, to a considerable extent, pitting and channeling.

To this method the Company attributes the unusually clean ash which comes from the producers.

The producers are of the water-jacketed type, the temperature of the blast, under normal conditions, being kept at 140 degrees Fahrenheit, but this may readily be increased to 170 degrees.

A noticeable feature of this installation is the use of Korting's Positive Steam Blowers for starting the producer, instead of the engine-driven air-blower generally employed. These positive blowers are available only when live steam is obtainable. In this case it is piped from boilers in another part of the mill. In addition to the use of these blowers in starting the producer they are always in readiness for any other emergency.

During the first year of operation the tar was returned to the combustion zone of the producer, but this practice has been discontinued and the tar is now sent to special filter beds. The tar is not utilized, but it is understood that steps are being taken in this direction. The filter beds to which the tar is now sent were made necessary by the presence, in the cooler and scrubber-water, of sufficient ammoniacal compounds to render its discharge into the bayou objectionable. The entire waste water, including the tarry matter, is first forced upward through broken coke which removes the tar, the remaining water being sprayed over six filter beds Before the installation of the coke-columns and the filter beds it is stated that the waste water contained 9.6 grains of free and albuminoid ammonia per gallon, whereas now it contains not more than 0.02 grains per gallon. The yield of tar is stated to be about 500 pounds a day. The lignite used now is from the mines of the Houston County Coal & Manufacturing Company, Crockett, Houston county. It is screened through a three-fourths-inch screen and over a three-eighths-inch screen.

Analyses, by P. S. Tilson, Houston, of the Crockett lignite, as received, are as follows:

	1 Per cent.	2 Per cent.	3 Per cent.
Moisture	31.45	12.88	28.16
Volatile and Combust. Matter	30.80	47.57	43.60
Fixed Carbon	25.60	29.40	21.02
Ash	12.75	10.15	6.64
Sulphur	trace	trace	0.58
Heating Power, B. T. U.	6,410	.....	7,326

No. 1 is lignite screenings, through 3-4-inch and over 3-8-inch screen, charged into the producers. No. 2 is lignite used under boilers in another part of the plant. This shows an evaporation of 3.25 pounds of water, from and at 212 degrees Fahrenheit, per pound of fuel, which is equivalent to 10.6 pounds per boiler horse-power.

Analyses of other lignites received at this plant have been made by Mr. Tilson as follows:

	4 Per ct.	5 Per ct.	6 Per ct.	7 Per ct.
Moisture	23.11	27.20	19.42	33.83
Volatile & Combust. Matter	39.84	41.28	43.12	38.83
Fixed Carbon	29.39	25.99	29.46	21.90
Ash	6.78	4.89	7.08	4.84
Sulphur	0.88	0.64	0.92	0.60
Heating Power, B. T. U.	8,336	8,114	7,695	6,158

No. 4 is lignite from the Bear Grass Coal Company, Jewett, Leon county.

No. 5 is lignite from the Bastrop Coal Company, Bastrop county.

No. 6 is lignite from the Southwestern Fuel & Manufacturing Company, Calvert, Robertson county.

No. 7 is lignite from the Consumers' Lignite Company, Hoyt and Alba, Wood county.

In these analyses the heating power was determined by lead-button assay.

The specifications call for a gas of 140 B. T. U. per cubic foot, and the engine is to deliver a brake horse-power for each 10,000 effective heat units.

No analyses of the gas were obtainable, although it is understood that some were made when the plant was installed and tested.

The consumption of lignite is stated to be 1.75 pounds per brake horse-power.

HUNTSVILLE.

Huntsville Electric Light & Power Company.

Equipment: One Fairbanks-Morse producer of 100 horse-power; one Fairbanks-Morse gas engine of 100 horse-power, belted to generator. The service is 24 hours, driving generator and ice machine of 12 tons capacity.

The fuel is lignite screenings from the mines of the Houston County Coal & Manufacturing Company at Wooter's Spur, Houston county, and the consumption is 9,645 pounds per 24 hours. The cost of the fuel at the plant is 90 cents a ton.

The tar is mixed with lignite screenings and is burned under the boilers. No use is made of the ammoniacal liquor. Leaky valves and stopping-up of pipes, due to poor tar extraction, has given some trouble at this plant.

The original installation here was steam, but there is a considerable saving in fuel and labor since the introduction of the producer plant.

This establishment was not visited personally, the above data having been supplied by the Company.

KINGSVILLE.*

The Kingsville Power Company.

Equipment: One 100 horse-power Smith suction producer and one 100 horse-power Rathbun-Jones three-cylinder vertical gas engine. The producer is said to be of insufficient capacity to operate the engine at full load. The engine is belted to a Western Electric Company's alternator for supplying lighting current at night, being idle during the day.

No records were obtainable concerning fuel consumption or power delivered, but from 1,800 to 2,000 pounds of lignite are used every night, the fuel coming from the mines of the Consumers' Lignite Company, Hoyt, Wood County. The exhaust from the engine is lead through a water-heater for supplying water-vapor to the saturator. The temperature of the blast varies from 140 degrees to 170 degrees Fahrenheit.

The ash-pit of this producer is generally kept full of water to within a few inches of the grate to "settle the ashes." No coal is charged during the day, but the producer is filled when the engine is shut down in the morning and the ashes thoroughly drawn and new coal charged when the blower is started in the evening.

From the time of starting the blower twenty minutes are generally sufficient for securing good gas at the engine.

In order to obtain additional power for use in a new cottonseed oil mill there has recently been installed a 350 horse-power De La Vergne twin oil engine for using crude oil. The guarantee of this engine is a brake horse-power from 0.6 pound of oil. This engine has not been operated on full load, but tests have shown an efficiency a little higher than the guarantee.

No attempt is made to recover the tar or ammoniacal liquor, nor is the tar burned under boilers in the ice plant belonging to the same Company.

LEONARD.*

Leonard Ice & Light Company.

This plant has not been in operation for a year or more. The equipment consistsed of a 65 horse-power Fairbanks-Morse suction up-draft producer and a Fairbanks-Morse single cylinder horizontal gas engine rated at 50 horse-power. The plant was in operation, but not continuously, for about two years.

The fuel used was screened-lump lignite from the mines of the Consumers' Lignite Company, Hoyt and Alba, Wood County, and cost $1.34 a ton, delivered.

The Company changed hands and the producer power plant was turned over to the manufacturer. Since that time it has been dismantled and removed. The plant is now operated by steam, lignite being used under the boilers.

LONGVIEW.

A Westinghouse producer and engine plant was installed here, to operate on lignite, but for some reason or other it was removed and no records concerning it are available.

MCNEIL.*

Austin White Lime Company.

At this place there are two No. 10½ R. D. Wood & Company's producers, used for making fuel gas for burning lime. They have been working on washed nut coal from the Olmos Coal Company, Eagle Pass, Maverick county. Samples of this coal taken in person gave the following analysis:

OLMOS WASHED NUT COAL.

	Per cent.
Moisture	4.20
Volatile and Combustible Matter	36.55
Fixed Carbon	32.35
Ash	26.90
Sulphur	0.71
Heating Power, B. T. U.	9,772

Under the boilers this plant was using lignite (hand-fired) from the mines of the Rockdale Consolidated Coal Company, Rockdale, Milam County. It was sampled in person and had the following composition:

LIGNITE FROM ROCKDALE CONSOLIDATED COAL COMPANY.

	Per cent.
Moisture	12.62
Volatile and Combustible Matter	38.11
Fixed Carbon	36.21
Ash	13.06
Sulphur	0.48
Heating Power, B. T. U.	9,525

The gas is passed directly into the kilns, through ordinary gas-ports, where it is mixed with air for combustion. No attempt is made to separate tar or ammoniacal compounds.

For many years this establishment used wood for burning the white lime for which it has long been famous. On entering upon the manufacture of hydrated lime, the producers were installed and have been in fairly continuous operation for a year or more.

As is also the case with the Round Rock White Lime Company, a few miles away, there has not been much success at McNeil in using producer-gas for burning lime. The chief difficulty has been in controlling the quality of the gas.

MART.

Home Light & Power Company.

Operator, Bayliss Earle, Waco.

This plant is not in operation, and was not visited, but Mr. Earle gave the following details:

The equipment consists of one 100 horse-power Fairbanks-Morse suction up-draft producer and one two-cylinder vertical gas engine of the same make, rated at 100 horse-power.

During the cotton-ginning season this plant operates steadily at full load, with a fuel consumption of about 4,400 pounds of lignite from the mines of the Southwestern Fuel & Manufacturing Company, Calvert, Robertson county.

It rarely operates except during the ginning season, but is held in reserve as an auxiliary to a steam-driven generator which is a part of an ice-plant. The gas engine was the original installation, but the addition of the ice-plant made steam necessary, and it was not found economical to continue the gas-unit in continuous operation.

The lignite which is used in the producer and under the boilers costs $1.55 a ton, delivered. About a barrel of tar a day is produced when the gas-unit is in operation, and is used for tarring the butts and the cross-arms of poles used by the Company.

No attempt is made to save the ammoniacal liquor.

MINEOLA.*

Mineola Light & Ice Company.

Equipment: One Smith suction down-draft producer of 100 horse-power, one Rathbun-Jones three-cylinder vertical gas engine rated to develop 90 brake horse-power on 80 cubic feet of gas of 135 B. T. U. per cubic foot, at 700 feet elevation. The engine drives a line shaft for two generators.

The gas unit operates about 13 hours every night during the winter months and about 11 hours during the summer months. The winter load is greater than the summer load, and the consumption of fuel is correspondingly higher. Lignite screenings are used, 2,000 pounds a day in winter and 1,400 pounds in summer.

Two boilers, of 80 and 50 horse-power, are used for the ice machines and for driving a 25 kilowatt Curtis horizontal turbine for the day load. These boilers are rarely operated at rated capacity, the average load seldom being over 110 horse-power. The fuel used under the boilers is the same as is used in the producer, lignite screenings, yet the consumption is about four times as great.

In the original plant here, which was operated about seven years, there was an Ideal automatic engine. The producer-plant has been in operation three years, and has shown a net saving of $500 a year. It represents an investment of about $13,000.

The lignite screenings, used in the producer, come from the mines of the Consumers' Lignite Company, Hoyt and Alba, Wood County. This fuel costs 90 cents a ton, delivered. Screened lump, which may be used, would cost $1.40, delivered. The producer is of an old type, the fire-containing body resting directly upon the foundation and the ashes falling into a pit from which they are drawn with long-handled shovels. The three charging holes in the top of the producer are absent and the fuel is fed directly inside the ring at the top, instead of outside of it, as is the case with the newer type of this producer. Hot water is supplied from an exhaust heater situated on the side of the engine away from the producer.

For the most part, the tar is thrown away, although a little has been used to dip some poles and cross-arms. No attempt is made to save the ammoniacal liquor.

The producer is charged four times during its run, and the ashes are drawn every morning after the engine is shut down. The ashes were free of combustible matter, and no large clinkers were seen.

PITTSBURG.*

The Arkansas & Texas Consolidated Ice & Coal Company.

Equipment: One Westinghouse double-zone suction producer (tarless), rated at 100 horse-power, and a Westinghouse three-cylinder vertical gas engine, rated at 75 horse-power. The engine is belted to a General Electric generator of 75 K. W. for power and lighting.

The unit operates continuously for 24 hours a day, although at full load not more than four hours. At times a small overload is carried.

The fuel used is a mixture of Arkansas semi-anthracite pea and Texas lump lignite, in varying proportions, although for the most part the mixture is composed of three parts of anthracite and one part of lignite. The lignite is from the mines of the Como Lignite Mining Company, Como, Hopkins County. The semi-anthracite pea coal is delivered at $5.00 a ton, and the screened lump lignite at $1.10. The lignite is also used under two 125 horse-power boilers for the ice plant and the evaporation, per pound of lignite, is three pounds of water from and at 212 degrees Fahrenheit. The boilers are seldom operated at rated capacity.

The anthracite and lignite are charged separately, the anthracite being used, for the most part, during the day, while the lignite carries the peak load at night. It was stated that the lignite gave a more uniform gas, but required more attention than the anthracite. The use of anthracite seems to be required by the necessity of operating the plant steadily, as no time is allowed for attending to the "drop" in the producer when lignite alone is used. The chief trouble in the use of the lignite was said to be due to its high content of moisture. A successful test made by the Westinghouse Company, at Pittsburg, Penn., was on lignite that carried about 23 per cent. of moisture, but ordinarily the lignite used carries over 30 per cent.

When the plant was first installed freshly mined lignite was used, but it "hung" in the producer. Air-dried lignite was then used, but it was found to cause trouble in choking. The present mixture of semi-anthracite and screened lump lignite has enabled the operators to avoid these troubles.

A brake horse-power is obtained from 1.10 pounds of the mixture.

The following analysis of the gas was given as typical:

	Per cent.
Carbon dioxide	9.0
Carbon monoxide	16.8
Hydrogen	13.2
Methane	4.1
Oyxgen	0.7
Nitrogen	56.2
	100.0

This analysis represents the gas from the ordinary mixture of three parts of anthracite and one part of lignite. The average B. T. U., or heating power, is 120. When running on all lignite the average B. T. U. is not over 106, but "snap" samples have shown as high as 150. The producer is guaranteed to deliver 75 per cent. of the available heat units in the fuel which is not to contain less than 8,000 B. T. U. per pound. The gas is to carry 120 B. T. U. per cubic foot and the engine is to deliver one brake horse-power for each 10,000 available heat units.

Operating conditions here vary with the proportion of lignite in the mixture. In general, the pressure of the blast is greater on the lower zone of the producer than on the upper zone. During the day and when the proportion of anthracite is as 3 to 1, the upper inlet valve is about one-fourth open, and the lower valve about three-fourths open. When the lignite predominates, at night, the top of the producer is generally cracked open.

The producer is charged every hour, poked every eight hours, and the ashes are drawn twice a day. The ashes were free of combustible matter, and no clinkers were observed. The producer is of the tarless type, and no tar is made. No attempt is made to utilize the ammoniacal liquors.

The consumption of water in the cooler and scrubber is about 10,000 gallons per 24 hours, the cooler being fitted with auxiliary spray pipes. One man fires the producer and the two boilers on a 12-hour shift.

At the end of the ice-making season it is likely that the plant will be operated on anthracite alone, until the next season.

The original installation here comprised an Ideal high-speed steam engine, belted to an old 133 cycle generator. The fuel consumption was about 38 pounds of lignite per kilowatt hour.

Since the installation of the producer power plant there has been effected a saving in fuel alone of $350.00 a month. But this may not represent the net gain, as the expense of oil and repairs is likely to be larger now than it was then.

ROCKPORT.*

Rockport Ice & Light Company.

Equipment: One 50 horse-power Fairbanks-Morse suction up-draft producer and a 50 horse-power Fairbanks-Morse gas engine, single cylinder, horizontal. The engine is belted to a Fairbanks-Morse generator, rebuilt by John B. Connelly, San Antonio. The engine operates not more than 10 hours a day on a fuel consumption of about 1,500 pounds. The generator has not hitherto been loaded to more than three-fourths of the rated capacity. The entire current is used for domestic and street lighting, and the load is fairly steady.

While operating, the producer is charged every one and a half hours with about 200 pounds of lignite and immediately before charging the fire is poked down and the ashes drawn. The ash-pit is cleaned once a day. The cooling and scrubbing water is drawn from one of six wells drilled for the ice plant, and all waste products are discharged into the bay.

No attempts are made to save any by-products. No records are available in regard to the consumption of lignite per brake horse-power.

ROUND ROCK.*

Round Rock White Lime Company.

At this place a No. 10½ Wood pressure up-draft producer was installed in the fall of 1910 for providing gas for burning lime, but it has not been in operation for two months. It is stated that the gas showed excessive variations in composition. At times it blazed and smoked at the top of the kilns; at other times it could hardly be lighted. It is understood that changes are to be made whereby better results can be secured.

Three different fuels have been tried here, coal from the Cannel Coal Company, Laredo, Webb county; coal from the Olmoso Coal Company, Eagle Pass, Maverick county, and lignite from the Texas Coal Company, Rockdale, Milam county.

The delivery price of the Olmos Coal was $3.80 and of the lignite $1.30. The operating force consisted of two men on each of three shifts and half time of one man for firing a steam boiler for running a hoisting engine. This is the second producer plant installed for burning lime that has not operated successfully. The experience at the plant of the Austin White Lime Company at McNeil, a few miles from Round Rock, is similar to that at Round Rock.

Just where the trouble is we are not prepared to say, but it is likely that most of it is in the method of handling the producer. This type of producer is well known and is successfully used elsewhere on similar work. Whatever may be the explanation, the fact remains that neither at McNeil nor at Round Rock has there been much success in burning lime with producer gas. At both these plants complaint is made that the gas shows undue variations in composition, and that it has been impossible to keep it within the limits of efficiency.

ROYSE.*

The Royse Milling & Light Company.

The equipment here consisted of a Fairbanks-Morse suction up-draft producer of 75 horse-power and a 75 horse-power gas engine of the same make. The producer used a mixture of Pennsylvania anthracite and Texas lignite. The plant was operated for about four years, during which time the power was used for milling and for lighting. About a year ago it was dismantled and is now for sale. It is said that a serious shortage of water has caused the suspension of operations by this Company, the steam plant which replaced the producer plant not having been in operation for ten months, nor has any ice been made in that time.

San Angelo.

San Angelo Street Car Company.

Equipment: One Smith suction down-draft producer of 250 horse-power; two Alberger gas engines of 125 horse-power each. The engines are direct connected to generators.

The fuel used is lignite from Rockdale, Milam county, and costs $2.32 a ton, delivered. The consumption of fuel per 18 hours is 4,000 pounds.

The yield of tar is 12 gallons per ton of lignite, and the tar is sold for 10 cents a gallon for creosoting.

Producer gas is cheaper than steam, but is not as reliable.

This plant was not visited personally, and the above information was supplied by the Company.

San Antonio.*

The San Antonio Portland Cement Company.

Works about five miles north of the city.

Equipment: Three 90-inch Smith down-draft producers, of 200 horse-power each, and one Allis-Chalmers 600 horse-power horizontal two-cylinder double-acting tandem gas engine. The engine is direct connected to an Allis-Chalmers generator for supplying power for the cement mill and operates continuously. The fuel is lignite.

No data is available concerning the fuel consumption per kilowatt hour, although the amount used is said to be nine tons per 24 hours.

The supply of water being somewhat limited, at times, the scrubber and cooler water is filtered, cooled and used over again, as is also the engine water.

No attempt is made to utilize the tar or ammoniacal liquor.

Two men per shift of 12 hours are required on the producers, only one of whom can be classed as a skilled laborer. The producer capacity of this plant is soon to be increased by the installation of enough Smith producers to bring the capacity up to 1,200 horse-power. This, of course, will call for additional engine capacity, and it is understood that the Rathbun-Jones engines will be installed.

SMITHVILLE.*

Smithville Light & Power Company

Equipment: One 150 horse-power Fairbanks-Morse suction up-draft producer and one 150 horse-power Fairbanks-Morse three-cylinder vertical gas engine. The engine is belted to a line-shaft which is connected, through a belt, with the generator. The fuel is lignite from the mines of the Independence Mining Company, Phelan, Bastrop county.

The engine operates practically all the time, for it performs three classes of service. The pumps for supplying the town of Smithville with water are in constant use. During the day the power necessary for operating an aerial tram system for conveying sand and gravel from the bed of the Colorado River is taken from the main line shaft through a rope drive. At night the lighting load approaches the rated capacity of the engine. The fuel used is approximately 4,000 pounds per 24 hours, the producer being charged about every three hours on day load and about every two hours at night.

There was trouble, at first, in discharging the tar through the waste-pipe, but this was corrected by piping the hot water from the engine jacket to the scrubber. No attempt is made to save the tar or ammoniacal liquor.

Two features of this plant deserve special mention. First, the use of cotton-seed hulls in the dry scrubber. These are changed every three months, and their use has been found to be satisfactory. So far as known, this is the only plant in the State making such use of cotton-seed hulls. The other is the riveting together of the grate bars in the producer in sets of three, so as to prevent warping. Here, as elsewhere with this type of producer, the only source of moisture for the blast is the water in the ash-pit. No data is available concerning the consumption of fuel per brake horse-power or per kilowatt hour.

STEPHENVILLE.*

Stephenville Light & Water Works.

Equipment: One Fairbanks-Morse suction up-draft producer of 100 horse-power and one Fairbanks-Morse two-cylinder vertical gas engine of 100 horse-power. The engine is belted to a 75 kilowatt Fairbanks-Morse alternator at 1,150 volts for light and power. It is also belted to a line shaft for driving a double battery of cotton gins.

This plant was not in operation at the time of visiting, June 2nd, as the engine cylinders had been re-bored and the new pistons were not yet in place.

The plant was installed about three and one-half years ago to supplement steam. The steam plant was operated with oil as fuel and the engine was a Skinner automatic, belted to a Fairbanks-Morse generator. The producer plant operates steadily 24 hours a day and seven days in the week on a fuel consumption of 6,000 to 7,000 pounds of lignite a day. The lignite comes from the mines of the Consumers' Lignite Company, Hoyt, Wood county, and costs $2.25 a ton, delivered.

On full load the consumption of lignite is about three pounds per brake horse-power. About a barrel of tar is made every 24 hours, but no attempt is made to save this or the ammoniacal liquor.

The engine exhausts into an underground muffler, with no water heater anywhere on the line. The only moisture available for the blast is from the ash-pit. The ashes seemed to be free of combustible matter, and no large clinkers were observed.

Two men on each shift and two shifts a day is the practice here. The producer is charged every hour, rodded down and the ashes drawn on a regular plan. Thus, rod on the half hour, charge on the hour and draw ashes immediately after charging.

An individual induction motor has been installed to drive the scrubber, as the engine is about 60 feet from the producer.

Coke is used in the dry scrubber, and is changed every ninety days. The sudden variations of load, due to the double battery of gins, are well cared for. The gins are not run at night, so the effect of slowing the engine is not noticed in the lights.

TAYLOR.*

T. W. Marse Company.

Equipment: One 25 horse-power Fairbanks-Morse anthracite producer and one 25 horse-power horizontal single cylinder gas engine of the same make. The plant was used for a coffee roasting and grinding establishment and for lighting. The plant was operated for a year and was then replaced by current from a central power station run by steam.

TEAGUE.*

Teague Electric Light & Power Company.

Equipment: One 50 horse-power Fairbanks-Morse suction updraft producer and one 50 horse-power engine of same make, horizontal, single cylinder. This engine is belted to a 30 k. v. a. Fairbanks-Morse alternator.

There is also one 100 horse-power Fairbanks-Morse suction updraft producer and one 100 horse-power two-cylinder vertical gas engine of same make. This engine is belted to a 75 k. v. a. Fairbanks-Morse alternator.

The small engine operates from 9 a. m. to 6 p. m. on about three-fourths load, the larger engine from 6 p. m. to 12 p. m., on about 80 per cent. of full load. The small engine comes on again at 12 p. m. and runs until 6 a. m. on half load. The entire plant is idle from 6 a. m. until 9 a. m. The larger unit requires about 1,500 pounds of fuel for six hours and the smaller about 3,000 pounds for 15 hours.

The lignite used is from the mines of the Houston County Coal & Manufacturing Company, at Evansville, and costs $1.80 a ton, delivered.

The small plant was installed in April, 1908, at a cost of about $7,200.00. The addition was installed in December, 1909, at a cost of about $13,000.

The scrubber water and tar are led through a barrel flush with the surface. The tar flows over the top of this barrel into open ditches. The water is conveyed from the bottom of this barrel to a second barrel, and thence is pumped to a cooling tower and returned to circulation. The engine jacket-water is similarly cooled, in a separate tower, and used again. The only use made of the tar is for treating the butts and cross-arms of poles. From 20 to 25 gallons of tar are produced daily. Each of the tar extractors is driven by an independent motor and the same blower serves both producers.

The producers are charged every two to three hours and the clinker is broken out from the bottom every hour. The ashes were free of combustible matter and no large clinkers were observed.

TERRELL.*

Shops of Texas Midland Railway.

An Irvin producer of 100 horse power capacity was installed here, but was not in operation at the time of visiting. The engine is a Weber three-cylinder vertical, direct connected to the generator. It is said that this plant has not been run longer than 15 days, all told.

The producer is of the suction up-draft type, with revolving body, and was made by The Murray Company, Dallas. Both top and bottom are stationary, with water-seal. The fuel (lignite) was charged continuously and automatically, the ashes being drawn at irregular intervals. The amount of tar produced was excessive and the tar extractor was unable to handle it. A standard Smith extractor has been ordered and experiments will be continued. The tar was of good quality and was used for starting fires in the locomotives, etc.

The longest recorded run at this plant was about 10 hours, during which time the engine operated at approximately full load with about 2,500 pounds of lignite from the mines of the Consumers' Lignite Company, Hoyt and Alba, Wood county.

Attempts have been made to clean the scrubber water and return it to circulation, but these will not be made when operations are resumed. The jacket-water is tower-cooled, and used again. The blast obtained its heat and moisture from a saturator supplied from an exhaust water heater. In this saturator the hot water was run down a section of spiral conveyor.

The producer body is revolved by a small motor operating through double worm gears once in 40 minutes. As the feed is by adjustable ratchet from one of these worm shafts, the amount of fuel charged may be regulated at will.

This producer was built in the shops of The Murray Company, Dallas, by Mr. Irvin, Mr. J. H. McDonough and Mr. E. H. R. Green. It is to be tested thoroughly before others are built. It is said that the results, so far, were very satisfactory.

WEATHERFORD.

A Westinghouse producer and gas engine plant was installed here some time ago, but is not now in operation, and no records are available.

YORKTOWN.

Yorktown Light & Ice Company.

Equipment: One Smith suction down-draft producer of 60 horse-power and a Rathbun-Jones 60 horse-power vertical gas engine. The fuel used is lignite.

This plant was not visited and we were unable to secure further information by correspondence.

SUMMARY.

In conclusion it might be well to give a brief summary of the features which apply to the producer gas field as a whole. Certain of these have already been touched upon; others have not heretofore been mentioned.

The fact that but three manufacurers handle both producer and engine has been spoken of, as also the advantage of regarding producer and engine as a unit, to be designed and operated as such. The seemingly analogous case of steam boilers and engines does not apply here at all. Steam is steam, whether generated in the fire-tube or water-tube, horizontal or vertical, coal-fired or oil-fired boilers, and the sole requisite made by a steam engine is that its working medium be under pressure and dry. Steam engine performance is commonly guaranteed in terms of so many pounds of dry steam at a rated pressure to generate a brake horse-power. The production of the steam is a separate process, involving entirely separate economies, and the relation between furnace, boiler and engine is by no means close, this being particularly the case between furnace and engine. The fuel bears a direct relation to the boiler economy, but between it and the prime mover one must consider the steam. It would seem that in the steam plant represented by a compound Corliss engine, followed by a low pressure condensing turbine, the maximum efficiency in steam prime movers had been reached, and that future improvements must come in the furnace and boilers. It is for these reasons that the relation between fuel and engine are not so close as is the case with gas producer and engine.

In the gas plant, engine performance is generally based on effective heat units delivered to the engine, a common guarantee being a brake horse-power for each 10,000 effective heat units. By "effective" heat units we mean only those that are actually used in the cylinder during the combustion of the charge. A certain amount of heat is evolved when the gas is burned, and owing to the presence of hydrogen, water is formed, which is evaporated to steam. This steam is lost in the exhaust, and hence is not available in doing work. The effective heat units equal the total minus the loss by steam in the exhaust. As these effective heat units are to be supplied by the combustion of the various substances that comprise the gas, it follows that they vary directly with the composition of the gas, and as the gas varies more with the composition of the fuel than with any other one factor, it follows that the relation between engine and fuel is much closer than is the case with steam. A case very much at instance can be noted at Dallas, where an engine developing 600 horse-power on producer-gas of rather a low heating power developed 720 on natural gas of a very much higher heating power.

A much better analogue than the steam engine and boiler will be found in the gasoline engine and carburetor. The great advantage of the internal combustion motor lies in its ability to discard the boiler, and deal direct with its fuel, and it seems to the writer that one of the greatest advantages of the producer-gas power plant should lie in its treatment as a single compact unit. This must not be taken as a criticism of those plants where producer and engine are not made by a single manufacturer, but as an expression of individual opinion.

Many of the plants have shown excellent economy and operation, and no criticism is intended.

A further fact worthy of mention is the apparent lack of interest shown by the manufacturers after installation and acceptance by the purchaser. The operator is frequently left to work out his troubles alone, and the almost invariable experience has been "trouble the first six months, but as soon as I learned to run my plant I got along fine. The manufacturers seemed not to care." Some makers are a gratifying exception to this general rule, but it is the belief of the writer that if the makers took a more intimate interest in the operation of their equipment, there would be more general satisfaction, particularly during the first year.

The province of the producer-gas power plant is by no means unlimited. It has its uses, and for these particular uses it is undoubtedly the most efficient type of prime mover—water excepted, of course—yet developed. Where water for boiler purposes is scarce, and even where water is plentiful, but the size of the plant does not warrant condensers, the producer is peculiarly adapted, more especially if the distance from good steaming coal is great. The widespread area of lignite in Texas, its cheapness and the question of water, all combine to make the producer-gas power plant well worthy of close consideration.

Austin, Texas,
June, 1911.

ADDITIONAL ANALYSES OF LIGNITES.

A sample of lignite received from Mr. R. B. Nelson, Gilmer, Upshur county, had the following composition:

	Per cent.
Moisture	11.40
Volatile matter	43.36
Fixed carbon	34.20
Ash	11.04
	100.00
Sulphur	0.89

A sample of lignite received from Mr. R. W. Rodgers, Texarkana, Bowie county, had the following composition:

Proximate Analysis—	Per cent.
Moisture	13.68
Volatile matter	48.61
Fixed carbon	26.25
Ash	11.46
	100.00
Sulphur	0.47
Ultimate Analysis—	
Carbon	47.05
Hydrogen	3.91
Oxygen	21.90
Nitrogen	1.53
Sulphur	0.89
Ash	11.04
Heating power, British Thermal Units	10,362

TAR FROM TEXAS LIGNITES.

In his "Brown Coal and Lignite," 1892, Mr. E. T. Dumble, former State Geologist, gives (pp. 218-221) the results of some researches made on tar from Texas lignites by Dr. Krey, Riebecksche Montan-Gesellschaft, Webau, Germany. The lignite, from which the tar tested by Dr. Krey was obtained, came from the Angelina river, San Augustine county. It had the following composition:

	Per cent.
Moisture	12.15
Volatile matter	37.14
Fixed carbon	41.14
Ash	6.50
Sulphur	3.02

This lignite yielded 5.56 per cent. of tar, the composition of which was as follows:

	Per cent.
Raw oil, paraffin—free	7
Raw oil, containing paraffin	70
Water	1
Coke	2
Loss as gaseous matter	20
	100

The yield of hard paraffin (melting at 125.6° F.) was 8 per cent. by weight of the tar, which was equal to the yield from German tar. "The paraffin, being the only valuable product, however, the brown coal tested could not be considered a tar coal, and would not yield sufficient returns for lucrative manufacture."

Lignites from other parts of the State gave the following yield in tar:

Counties—	Per cent.
Bowie	9
Lee	8
Leon	6
Medina	6
Milam	7 to 8
Robertson	5 to 6.5
Rusk	8
San Augustine	8.5
Smith	8
Wood	7 to 8

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