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BUREAU OF ECONOMIC GEOLOGY AND TECHNOLOGY
WILLIAM B. PHILLIPS, Director

THE FUELS USED IN TEXAS

BY

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AND
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INTRODUCTION.

The two most important things in Texas, in so far as concerns its material progress, are an abundant supply of cheap fuel and good water. Without these it is not possible to attain comfortable living or commercial prosperity.

Our reason for offering this publication on The Fuels Used in Texas is based upon the fact that while we have very large supplies of good and cheap fuel, we are not utilizing them to the best advantage. Our production of coal, lignite, natural gas, city and producer gas and petroleum does not begin to keep pace with current demands nor to promise well for the future.

The workable coal area in the State is 8200 square miles, with a possible addition of 5300 square miles. The original supply of coal was about eight billion tons. The production, since 1895, has been thirteen million tons, so that we have barely scratched the surface, so to speak.

The workable lignite area is 50.000 square miles, with a possible addition of 10,000 square miles. The original supply of lignite was about thirty billion tons. The production, since 1895, has been eight million tons, an insignificant fraction of the total.

The total fuel area, coal and lignite, is 58,000 square miles, with a possible addition of 15,000 square miles. The total original supply of coal and lignite was about thirty-eight billion tons, the total loss. including production and waste, has been, we will allow, forty million tons, or a little over 1 per cent of the total supply. If we mined twenty million tons of coal and lignite a year, instead of two million tons, the supply of these fuels would last more than 1000 years, allowing that for each ton used there was a total loss of two tons. It is true that, as compared with some other coals, our coals are not of the best quality; the seams are thin and the content of ash and sulphur is relatively high. At the same time many of these coals have been used with excellent results.

A special feature of the coal industry in Texas is that by far the greater proportion of the product is used for railroad purposes, only a small proportion going into domestic use.

Quite aside, however, from the coal, we have in lignite a cheap and efficient fuel for all kinds of industrial employment, with the possible exception of railroad locomotives. Practically every known variety of lignite exists in Texas, and in very large amounts. The lignite industry has increased at a very rapid rate, and with the attention now being given to improved methods of firing, it is thought that a still larger increase may be expected, either in output or in efficiency, or both.

The time will come, if indeed it be not already come, when the establishment of large central power plants, using lignite as fuel, will present unusual attractions for investments of capital. The lignite will be converted into gas, either in producers or in retorts, and this gas will be sold for fuel purposes direct or converted into electrical energy and sold as such. From raw lignite there can be prepared a number of valuable products, in addition to the gas, as is set forth in Chapters X and XI.

If the lignite is distilled in retorts, one of the by-products is lignite residue, which makes an excellent material for high-grade briquettes, as is shown by Professor E. J. Babcock, Dean of the College of Mining Engineering, University of North Dakota, in Chapter IX.

The briquetting of lignite is not carried on in this State at all, but, in order to show what can be done, Professor Babcock kindly made for us a series of tests of these typical Texas lignites. The results were most encouraging, and our sincere acknowledgments are due to him for this timely assistance.

Through the courtesy of Mr. L. M. Davis, Minot, North Dakota, we are able to present a view of the lignite briquetting plant which he is now constructing there. This will be the only plant of the kind in the United States, and the results of its operation are awaited with a great deal of interest.

Our acknowledgment are also due to Mr. J. E. Stullken, Assistant Chemist to the Bureau, for much analytical work, and to Dr. W. Bredlick, who prepared Chapter X, assisted in the preparation of Chapter XI, and made the analyses of the coal tar given on pages 58-59.

We have also to thank Dr. Eugene A. Smith, Director of the Alabama Geological Survey, for analyses of Alabama coals.

We regret to say that a large number of analyses of Oklahoma coals, kindly sent to us by Dr. C. W. Shannon, Director of the Oklahoma Geological Survey, reached us too late for incorporation in this publication.

In connection with our work on the fuels of the State, the Legislature granted us a special appropriation, which will become available September 1, 1914. Plans are now being considered for the erection and operation of a modern steam-testing plant wherein a carload of fuel can be tried out at a time. It is hoped that particular attention can be given in this plant to lignite stokers and other appliances for increasing the efficiency of this and other fuels.

WM. B. PHILLIPS.
S. H. WORRELL.

Austin, Texas, December, 1913.

ORGANIZATION AND PUBLICATIONS OF THE BUREAU OF ECONOMIC GEOLOGY AND TECHNOLOGY.

The Bureau of Economic Geology and Technology was established by the Board of Regents of the University, September, 1909. As there has been no geological survey in Texas for many years nor any agency through which there could be conducted investigations of the mineral resources, etc., of the State, it was hoped that the Bureau would be able to supply this deficiency, as far as was possible with the means at its disposal.

The laboratory of the Bureau was opened in September, 1910, with Mr. S. H. Worrell in charge. Since that time the demand for information, especially in connection with the purchase of fuels by the State Purchasing Agent and the University, has required the addition of another chemist, and Mr. J. E. Stullken was appointed in January, 1913. In September, 1911, Dr. J. A. Udden became geologist for the Bureau, and his first work was the preparation of the Report on the Oil and Gas Fields of Clay and Wichita Counties, published by the University, September 8, 1912, as its Bulletin No. 246, Scientific Series No. 23.

Exclusive of this bulletin the following publications have been issued by the Bureau:

The Mineral Resources of Texas, Wm. B. Phillips. Issued by the State Department of Agriculture as its Bulletin No. 14, July-August, 1910.

The Composition of Texas Coals and Lignites and the Use of Producer Gas in Texas, Wm. B. Phillips, S. H. Worrell and Drury McN. Phillips. University of Texas Bulletin No. 189, July, 1911.

A Reconnaissance Report on the Geology of the Oil and Gas Fields of Wichita and Clay Counties, J. A. Udden, assisted by Drury McN. Phillips. University of Texas Bulletin No. 246, September, 1912.

A Map Showing the Location of Iron Ore Deposits in East Texas; Blast Furnaces; Lignite Mines in Operation; Lignite Outcrops; Producing Oil Fields, Etc., Wm. B. Phillips, September, 1912.

Eighteen Press Letters dealing with various features of mineral production in Texas.

A map showing the location of coal out-crops, coal mines, oil and gas fields, quarries of limestone and gypsum, deposits of copper ores, etc., in the area west and northwest of Fort Worth has been prepared, but has not yet been issued. Work on a geological map of the State is now in progress and we hope to have it ready for distribution by the close of the year 1914. There is no geological map of the State in existence and this attempt is the first that has been made to set forth the main geological formations throughout the State as a whole.

Field and chemical work for a special publication on the building materials mined and manufactured in the State is now in progress. This publication will include physical tests and chemical analyses of limestone, marble, granite, sandstone, serpentine, brick, hollow tile, etc.

All communications in regard to the work of the Bureau should be addressed to:

William B. Phillips, Director,
University Station, Austin, Texas.

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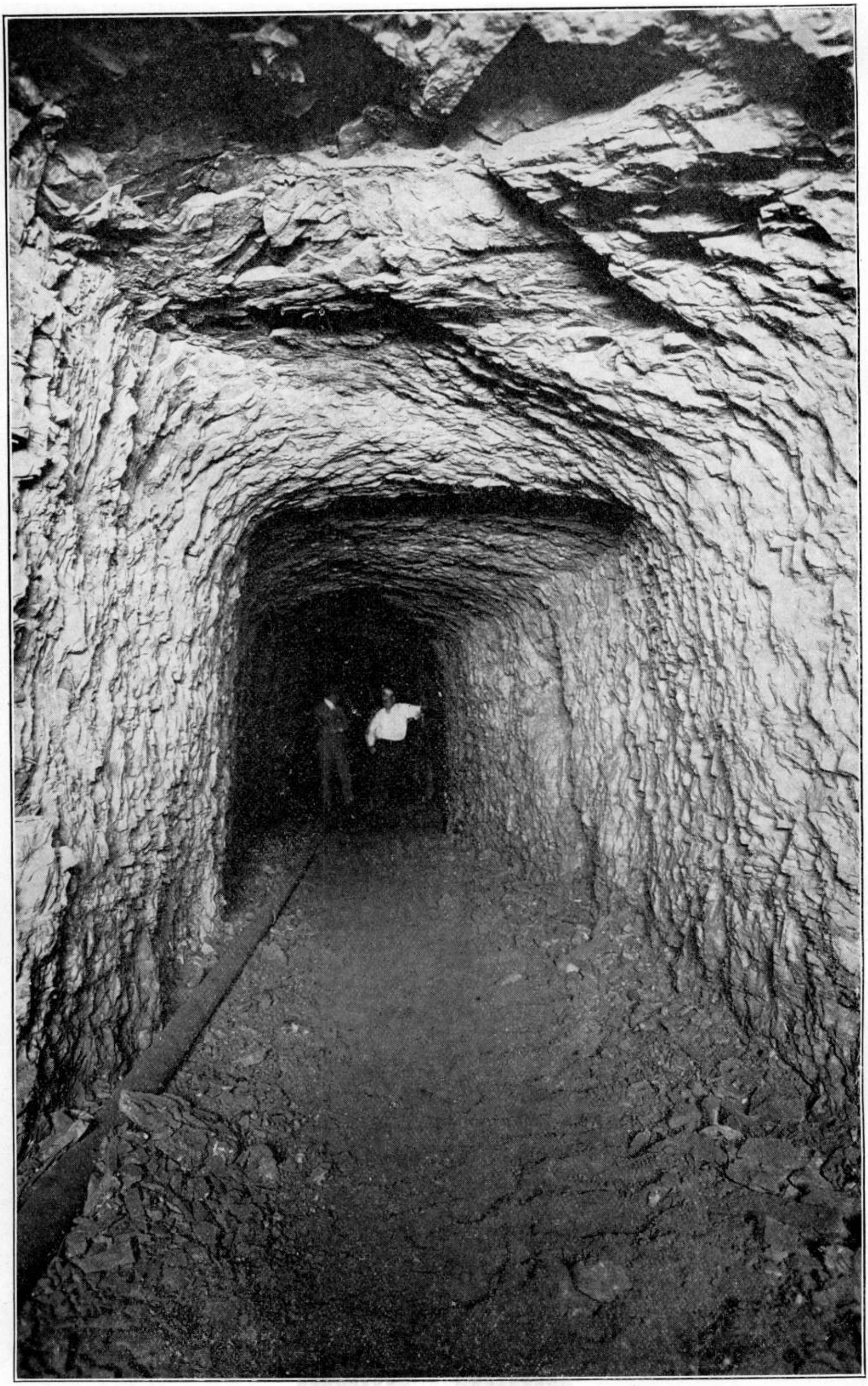


American Lignite Briquette Co., Big Lump, Milam County—Tunnel in 10-ft. of Lignite—2000 ft.

THE FUELS USED IN TEXAS

CHAPTER I.

BAGASSE (BEGASS, MEGASS) AND WOOD.

Bagasse is the name given to refuse sugar-cane after the juice has been extracted. It contains woody fiber, sugar juice and water. As a fuel under steam boilers it is used locally, but is of too low grade to be shipped to any considerable distances. We have no means of ascertaining how much of this material is used as fuel in Texas, but as the production of sugar-cane in the year 1912 was 400,000 tons there must be a good deal of bagasse made and used locally. We have not investigated this fuel but avail ourselves of a paper read before the Louisiana Sugar Chemists' Association, in 1892, by L. A. Becuel. We quote from this paper as follows:

"With tropical cane containing 12.5 per cent woody fiber, a juice containing 16.13 per cent solids, and 83.87 per cent water, bagasse of, say 66 and 72 per cent mill extraction, would have the following percentage composition:

	Woody fiber.	Combustible salts.	Water.
66 per cent bagasse	37	10	53
72 per cent bagasse	45	9	46

Assuming that the woody fiber contains 51 per cent carbon, the sugar and other combustible matters an average of 42.1 per cent and that 12,906 units of heat are generated for every pound of carbon consumed, the 66 per cent bagasse is capable of generating 297,834 heat units per 100 lbs. as against 345,200, or a difference of 47,366 units in favor of the 72 per cent bagasse.

"Assuming the temperature of the waste gases to be 450° F., that of the surrounding atmosphere and water in the bagasse at 86° F. and the quantity of air necessary for the combustion of one pound of carbon at 24 lbs., the lost heat will be as follows: In the waste gases, heating air from 86° to 450° F., and in vaporizing the moisture, etc., the 66 per cent bagasse will require 112,546 heat units, and the 72 per cent bagasse 116,150.

"Subtracting these quantities from the above, we find that the 66 per cent bagasse will produce 185,288 available heat units per 100 lbs., or nearly 24 per cent less than the 72 per cent bagasse, which gives 229,050 units. Accordingly, one ton of cane of 2,000 lbs. at 66 per cent mill extraction will produce 680 lbs. bagasse, equal to 1,259,958 available heat units, while the same cane at 72 per cent extraction will produce 560 lbs. bagasse, equal to 1,282,680 units.

"A similar calculation for the case of Louisiana cane containing 10 per cent woody fiber, and 16 per cent total solids in the juice, assuming 75 per cent mill extraction, shows that bagasse from one ton of cane contains 1,573,956 heat units, from which 561,465 have to be deducted.

"This would make such bagasse equivalent to nearly 92 lbs. coal per ton of cane ground. Under fairly good conditions, 1 lb. coal will evaporate 7½ lbs. water, while the best boiler plants evaporate 10 lbs. Therefore, the bagasse from 1 ton of cane at 75 per cent mill extraction should evaporate from 689 lbs. to 919 lbs. of water. The juice extracted from such cane would under these conditions contain 1,260 lbs. of water. If we assume that the water added during the process of manufacture is 10 per cent (by weight) of the juice made, the total water handled is 1,410 lbs. From the juice represented in this case, the commercial massecuite would be about 15 per cent of the weight of the original mill juice, or say 225 lbs. Said mill juice 1,500 lbs., plus 10 per cent equals 1,650 lbs. liquor handled; and 1,650 lbs. minus 225 lbs., equals 1,425 lbs., the quantity of water to be evaporated during the process of manufacture. To effect a 7½ lb. evaporation requires 190 lbs. of coal, and 142½ lbs. for a 10-lb. evaporation.

"To reduce 1,650 lbs. of juice to syrup of, say 27° Baume, requires the evaporation of 1,170 lbs. of water, leaving 480 lbs. of syrup. If this work be accomplished in the open air, it will require about 156 lbs. of coal at 7½ lbs. boiler evaporation, and 117 at 10 lbs. evaporation.

"With a double effect the fuel required would be from 59 to 78 lbs., and with a triple effect, from 36 to 52 lbs.

"To reduce the above 480 lbs. of syrup to the consistency of commercial massecuite means the further evaporation of 225 lbs. of water, requiring the expenditure of 34 lbs. of coal at 7½ lbs. boiler evaporation, and 25½ lbs. with a 10-lb. evaporation. Hence, to manufacture one ton of cane into sugar and molasses, it will take from 145 to 190 lbs. additional coal to do the work by the open evaporator process; from 85 to 112 lbs. with a double effect, and only 7½ lbs. evaporation in the boilers, while with 10 lbs. boiler evaporation the bagasse alone is capable of furnishing 8 per cent more heat than is actually required to do the work. With triple-effect evaporation, depending on the excellence of the boiler plant, the 1,425 lbs. of water to be evaporated from the juice will require between 62 and 86 lbs. of coal. These values show that from 6 to 30 lbs. of coal can be spared from the value of the bagasse to run engines, grind cane, etc.

"It accordingly appears that with the best boiler plants, those taking up all the available heat generated, by using this heat economically the bagasse can be made to supply all the fuel required by our sugar-houses."

FIREWOOD.

In Forest Service Circular No. 181, United States Department of Agriculture, issued September 23, 1910, the amount and value of the firewood used in 1908, in Texas, is given in considerable detail. The amount so stated is in cords of 128 cubic feet.

	Quantity—cords.	Value.
Used on the farms	2,518,360	$6,549,939
Cities and towns of from one to thirty thousand population	1,351,360	5,310,845
Cities of over 30,000 population	179,333	923,015
Mineral operations	55,933	176,507
Total	4,104,986	$12,960,306

This gives an average value per cord of $3.16.

In the total consumption of firewood, Texas ranks sixth among the States, the largest consumption being in the State of North Carolina. In the total value, Texas stands second; being exceeded only by Michigan. In average value per cord, Texas ranks thirty-fourth among the States. The highest price paid for wood was $8.99, in the District of Columbia, and the lowest value was in Georgia, $1.66 a cord.

In the year under consideration, namely, 1908, the quantity and value of the firewood used in the United States is stated as follows, in cords and dollars.

	Quantity—cords.	Value.
Used on the farms	69,961,066	$182,653,869
In towns and cities of from 1,000 to 30,000 population	12,611,033	50,549,855
In cities of over 30,000 population	1,613,594	11,106,526
In mineral operations	1,751,115	5,530,478
Total	85,936,806	$249,840,728

This gives an average value per cord for the entire country, of $2.91.

The heating power of well seasoned wood, expressed as British thermal units per pound, varies from 7,584 in willow, to 9,153 in some varieties of pine.

The following table partly compiled and partly made up from our own analyses, gives the British thermal units per pound of different varieties of wood:

Variety of Wood.	British thermal units per pound.
Ash	8,480
Birch	8,586
Cedar	9,507
Chestnut	8,338
Cottonwood	9,040
Cypress	9,429
Dogwood	8,806
Elm	8,510
Fir	9,063
Hickory	8,728
Maple	8,650
Mesquite	8,650
Mulberry	8,027
Post-oak	8,416
Oak, other from	8,316 to 8,440
Pine, bastard	8,759
Pine, long leaf yellow	9,118
Pine, spruce	8,962
Poplar	8,541
Sycamore	7,762
Willow	8,463

Relative Value of Wood and Coal, as Fuels.

Some authorities[1] state that one pound of good soft coal is equivalent to 2.50 pounds of air-dried wood. On this basis, a cord of

[1]Amer. Civil Eng. Pocketbook, 1911, p. 211.

pine wood, weighing on the average 2,600 pounds, is equivalent to 1,040 pounds of coal; a cord of hickory, with an average weight of 4,100 pounds, is equivalent to 1,640 pounds of coal; a cord of oak with an average weight of 3,550 pounds is equivalent to 1,420 pounds of coal; a cord of cedar, 2,500 pounds, is equivalent to 1,000 pounds of coal and a cord of mesquite, 3,000 pounds is equivalent to 1,200 pounds of coal.

These figures are of general value only, for a great deal depends on the boiler setting, grate installation, method and rate of firing, size of the wood, etc., in actual practice. As a rule, however, the proportion of 2.50 pounds of wood per pound of coal is reasonably accurate.

The relative cost of burning wood and coal depends upon a number of conditions, and each question has to be settled upon its own merits. If we allow that the cost of handling, firing and removal of ashes. is the same for the two fuels, coal at $5.00 a ton is equivalent to ordinary oak wood at $3.54 a cord, or pine at $2.60 a cord. With coal at $8.00 a ton, oak wood should be at $5.67 a cord, and pine at $3.20. In many of the towns and cities of the southwest, especially in Texas, these prices are current with respect to coal and oak wood; but inferior wood, such as cedar, cottonwood, willow, etc., is often sold at the same price as oak or mesquite.

As a rule, current practice in regard to the relative price of wood and coal, brings about a rough approximation to their respective values as determined by scientific investigation. When coal sells for $8.00 a ton, good oak wood sells for $5.50 to $6.00 a cord.

Weight of a Cord of Wood.

It is difficult to make a positive statement as to the weight of a cord of wood. Ordinarily, a cord contains 128 cubic feet. It is 4 feet high, 4 feet wide and 8 feet long. But in Michigan, a "cord" is 48 cubic feet and in California a "stack" (cord) contains 32 cubic feet. In Germany, the klafter, or cord, contains 108 cubic feet. But the ordinary cord lacks a great deal of containing 128 cubic feet of wood. The air space in a cord of wood may comprise as much as 25 per cent of the space, especially if the wood is crooked. If the wood is straight, accurately cut, evenly and well split and piled with care, the air space is reduced to a minimum but is never entirely removed. In his own practice, the writer has allowed as much as 160 cubic feet to be a cord, especially in dealing with crooked mesquite wood for quicksilver furnaces.

The amount of water in wood has a material bearing on the weight of a cord. If we allow that a cord of ordinary dry oak wood weighs 3,500 pounds and contains 25 per cent of water, the "wood" in the cord weighs 2,625 pounds and the water weighs 865 pounds. If a cord of pine wood weighs 2,500 pounds and contains 25 per cent of water, we have 1,875 pounds of "wood" and 625 pounds of water.

The weight of a cord of wood is not of much commercial importance, as the ordinary practice the country over is to purchase wood by the cord, irrespective of its weight or of its heating power.

When wood is shipped by rail it is not customary to weigh the car, but the shipment is made on a measurement basis, so many cords to the car. There is, of course, a considerable difference in the number of cords that can be placed in or on a car, and no general rule can be given. The number of cords in a car varies from 8 to 15, and, in exceptional cases, even more.

Kent[1] gives the weight of a cord, 128 cubic feet, of seasoned wood, in pounds, as follows:

Variety of Wood.	Pounds per cord.
Beech	3,250
Chestnut	2,350
Elm	2,350
Hemlock bark	2,200
Hickory	4,500
Maple, sugar	4,500
Oak, black and red	3,250
Pine, white or Norway	2,000

Poole[2] gives the weight of a cord of wood as follows, in pounds:

Variety of Wood.	Pounds per cord.
Ash, white	3,450
Beech, white	3,236
Butternut	2,534
Cedar, red	2,525
Chestnut	2,333
Dogwood	3,643
Hickory, shell-bark	4,469
Magnolia	2,704
Maple, hard	2,878

[1]Mech. Engrs. Pocketbook, 1908, p. 232.

[2]Calorific Power of Fuels, 1907, p. 87.

Variety of Wood.	Pounds per cord.
Maple, soft	2,668
Oak, black	3,254
Oak, chestnut	3,955
Oak, red	3,254
Oak, white	3,821
Pine, New Jersey	2,137
Pine, pitch	1,904
Pine, white	1,868
Pine, yellow	2,463
Poplar, Lombardy	1,774
Poplar, yellow	2,516
Sycamore	2,391
Walnut, black	3,044

Snow[3] gives the following figures as the weight of a cubic foot of seasoned wood, in pounds:

Variety of Wood.	Pounds per cu. ft.
Ash	39 to 40
Beech	42 to 45
Birch	35 to 37
Cedar	19 to 35
Chestnut	28 to 36
Cottonwood	23 to 24
Cypress	20
Dogwood	50
Elm	34 to 46
Fir	36
Hickory	44 to 56
Linden	28
Maple	26 to 43
Mesquite	47
Oak	40 to 59
Pine	22 to 43
Poplar	26 to 28
Spruce	21 to 36
Sycamore	30 to 35
Walnut, black	38
Willow	27

The weight of a cubic foot of lignum vitae varies from 71 to 83 pounds.

Amount of Ash or Mineral Matter in Wood.

The amount of ash in wood varies from 0.11 per cent as in some varieties of oak, to 8 per cent as in some varieties of fir. As a rule, the amount of ash in wood rarely exceeds 2 per cent of its weight, and consists of lime, magnesia, potash, soda, the oxides of iron, manganese and aluminum as bases, combined with carbonic acid, sulphuric acid, silicic acid, phosphoric acid and hydrochloric acid, to form carbonates, sulphates, silicates, phosphates and chlorides.

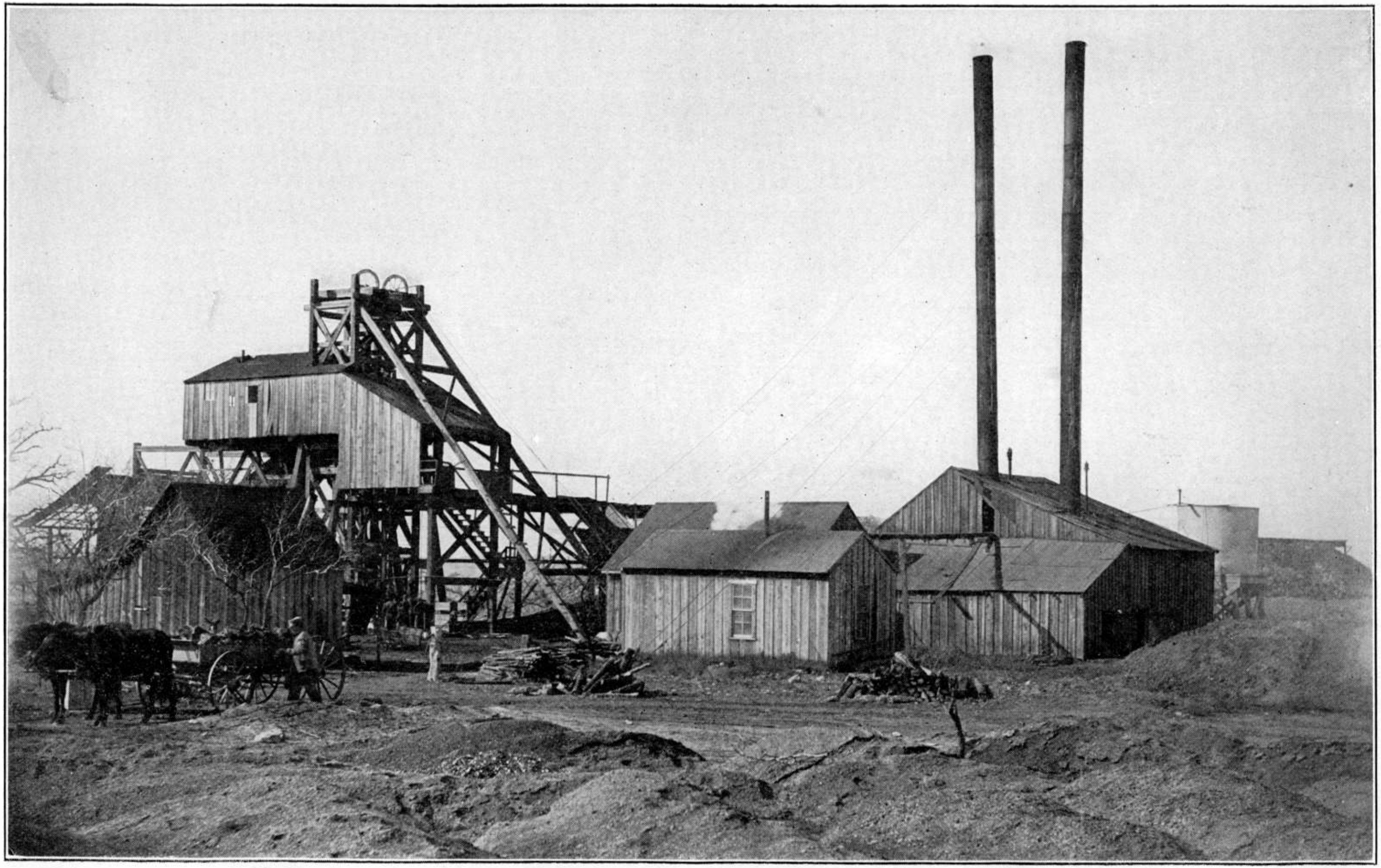
[3]Principal Species of Wood, 1910.

The ash of Scotch fir (pinus sylvestris), common in the British Islands and throughout northern Europe, may contain as much as 18 per cent of oxide of manganese, with 16 per cent of soda, and 5 per cent of phosphate of iron. The ash of some varieties of northern beech (fagus sylvatica) contains nearly 16 per cent of potash.

Amount of Water in Wood.

Ordinary, well seasoned wood may still contain 25 per cent to 30 per cent of water, and this water is not entirely removed up to 240° F. The proper age at which to cut wood for fuel varies from twenty years as in the case of alder to 120 years in the case of white beech.

As the population of the State increases and more and more demands are made on the supplies of firewood, we shall reach a time when we shall be obliged to look to some other source of fuel. In a great many parts of the State now there is no wood at all. The heavily wooded areas in East Texas will, of course, continue to supply a large amount of wood for many years, but we think that the cities and the larger towns will increase their consumption of coal and use less and less wood, as time goes along. It is likely that the practical efficiency of wood as a fuel is considerably below that of coal, but there are no investigations on this subject to which reference may be made.



Belknap Coal Co., mine No. 2, Newcastle, Young County.

CHAPTER II.

COAL.

COMPOSITION OF COALS MINED IN TEXAS.

Location and Extent of Coal Fields, Production, Etc.

In Bulletin No. 3, University Mineral Survey, May, 1902, there were given many detailed analyses of the coals and lignites then mined in Texas. The samples were taken in person by an agent of the Survey and represented the freshly mined material.

The edition of that bulletin was soon exhausted, and as the Survey was discontinued in 1905, nothing further was done until 1911. In this year there was prepared by the University Bureau of Economic Geology and Technology a bulletin on "The Composition of Texas Coals and Lignites and the Use of Producer Gas in Texas," and it was published by the University as its Bulletin No. 189. The edition of this bulletin has also been completely exhausted, so that it has become necessary to prepare another publication on the subject.

To the material which was published in 1911, we have added much new data dealing with the suitability of our coals and lignites for gas making and the recovery of valuable by-products. It is not our purpose to discuss the coal and lignite fields of Texas from a geological standpoint.

With respect to coal it is sufficient to say that there are three recognized coal fields in Texas, one in north central Texas, west of Fort Worth, and two on the Rio Grande. The North Central Coal Field lies in the counties of Brown, Coleman, Comanche, Erath, Eastland, Jack, McCulloch, 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 and sub-bituminous quality. It 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. It produces by far the greater proportion of the coal raised in Texas, one county alone, Erath, yielding more than 50 per cent of the entire output of the State.

The seams of coal are not thick, no single bench running to more than 24 inches. Nearly all of this coal is used for railroad purposes, the remainder going to stationary boilers. But little of it is used for domestic fires. The coal producing counties in the North Central Field are: Eastland, Erath, Palo Pinto, Wise and Young.

No coke is made from any of these coals, although some of them are capable of yielding a coke of fair strength, but high in ash and comparatively high in sulphur. No attempt has been made to wash these coals in a modern plant and it appears probable that the loss in coal would be excessive, as there is not much difference between the density of the coal and the non-coal.

There are two other producing coal fields in Texas, both of them fringing the Rio Grande; one in Webb county (Laredo) and one in Maverick county (Eagle Pass). The Webb county field extends also into Dimmit and Zavala counties, but there are no commercial operations in these counties. The coal is probably of Cretaceous age, although some lower Tertiary strata appear to be involved also. It is sub-bituminous in quality. The Rio Grande coal fields are entered by the following railroads: Southern Pacific; International & Great Northern; Rio Grande & El Paso; Uvalde & Crystal City; Asherton & Gulf; Texas Mexican. The total workable coal area in Texas 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.

According to the statistics collected by the United States Geological Survey for the year 1912 there were employed in the coal and lignite mines in Texas 5,127 men, who worked an average of 230 days. In 1910, there were 5,353 men who worked 226 days. In 1912 the coal mines employed 3,518 men for an average of 230 days and the lignite mines employed 1,609 men for 191 days. The average coal production per man was 340.5 tons, or 1.37 tons per working day. The average lignite production per man was 615.7 tons, or 3.22 tons per working day.

There is but little machine-mined coal produced in Texas, the amount in 1912 being 105,400 tons, or 4.8 per cent of the total. Shooting from the solid is not much practiced in Texas. While the mining methods reported account for less than one-half of the total production, the percentage of coal shot from the solid was but 25 per cent of the total, in 1911.

There is one coal washery in Texas, operated by the Olmos Coal Company, Eagle Pass, Maverick county. In 1912 this company washed 25,599 tons and recovered 20,639 tons of washed coal, with 4,960 tons of refuse.

The fatal accidents in 1912 were two, of which one occurred in the shaft and one on the surface. This is probably the lowest death rate in the entire country.

Separate statistics of the production of coal and lignite cannot 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 1912 inclusive. The statistics are those of the United States Geological Survey.

TABLE I.

Production and Value of Coal and Lignite, 1895-1912—Short Tons.

Year.	Coal.		Lignite.	
	Tons.	Value.	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	1,112,228	2,539,064	712,212	602,881
1910	1,010,944	2,397,858	881,232	763,107
1911	1,083,952	2,491,361	890,641	781,927
1912	1,197,907	2,774,956	990,705	880,788
Total	13,367,635	$28,795,998	8,041,940	$7,153,824

Since 1895 the production of coal has increased by three times. During the same period the production of lignite has increased by nearly eight times.

The average value of the coal in 1911 was $2.30 a ton, at the mines, while that of lignite was 88 cents, these figures for 1912 being $2.31 and 89 cents, respectively.

These average values per ton are to be accepted with some reservations. During the last year, for instance, mine-run lignite has sold as high as $1.40, while lignite slack has been in active demand at 60 cents.

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 Company, Thurber, Erath county.

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

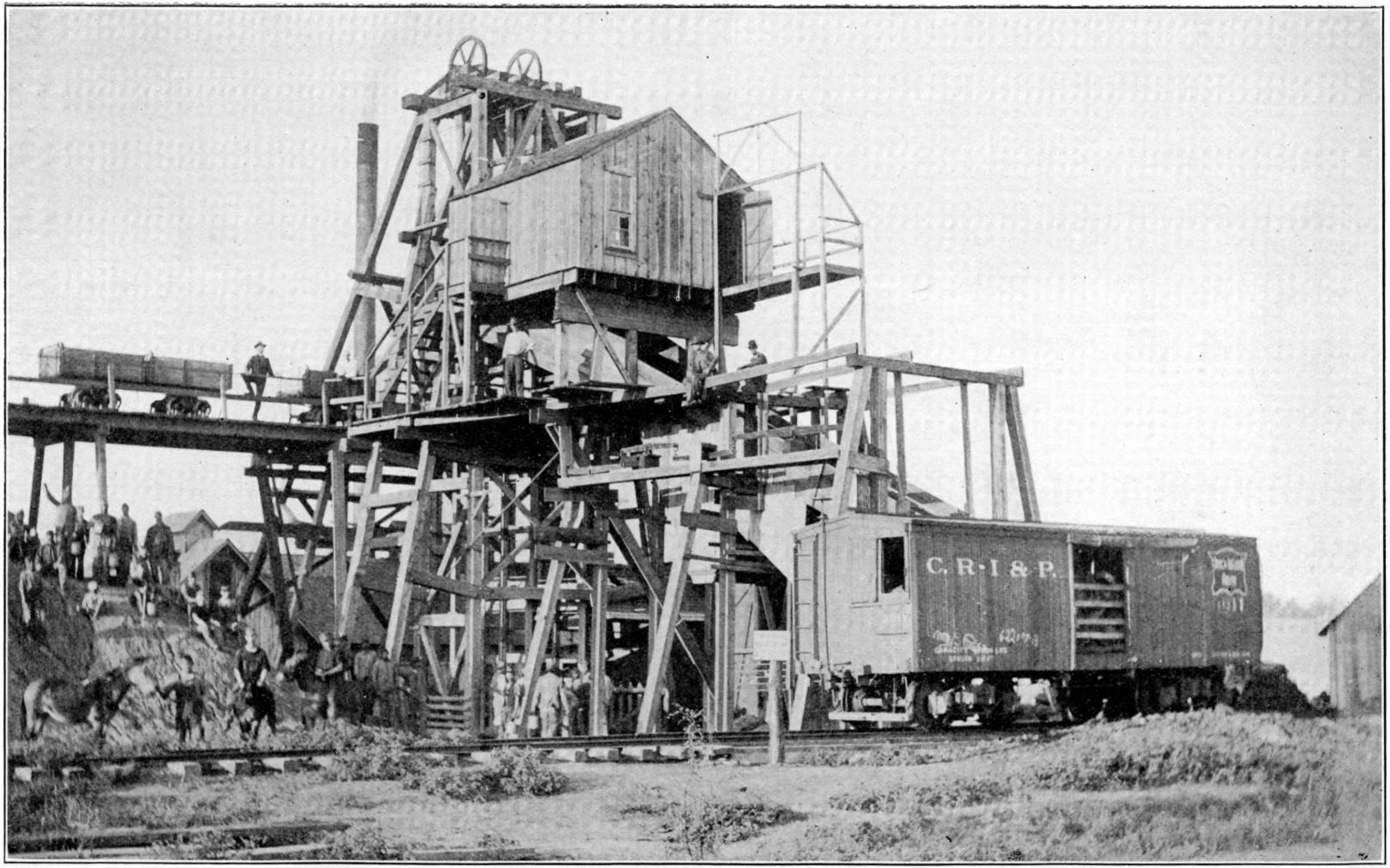
No. 1534. Smith-Lee Mine, Cisco, Eastland county.

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

TABLE II.

Composition of Texas Coals—Sampled at Mines by University Mineral Survey, 1901-1902.

Analysis No.	Proximate Analysis. Natural condition. Moisture.	Proximate Analysis. Natural condition. Volatile Combustible Matter.	Proximate Analysis. Natural condition. Fixed Carbon.	Proximate Analysis. Natural condition. Ash.	Proximate Analysis. Natural condition. Sulphur.	Proximate Analysis. Dry basis. Volatile Combustible Matter.	Proximate Analysis. Dry basis. Fixed Carbon.	Proximate Analysis. Dry basis. Ash.	Proximate Analysis. 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—Pounds—Dry.
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
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
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
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
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
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
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
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
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
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
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	11,707	1.42	88.7
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
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
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
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
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
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
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



Bridgeport Coal Co., shaft No. 2, Bridgeport, Wise County.

The Cretaceous 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 combustible matter and sulphur, and lower in ash and moisture than the Maverick county coals, the fixed carbon being about the same. The Cretaceous 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 combustible matter than the Cretaceous 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 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. per pound	9,609	12,264	11,245

On dry basis, these become:

	From	To	Average
Volatile combustible matter	31.32	50.70	37.65
Fixed carbon	37.93	52.01	45.06
Ash	9.45	26.14	17.29
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 per pound	11,101	13,755	12,035

Composition of the Ash of Texas Coals.

In Texas coals, as mined, the ash varied 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, made by O. H. Palm and S. H. Worrell:

Composition of the Ash of Texas Coals.

Analysis 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	5.68	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 Cretaceous 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 fusibile 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.

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 Cretaceous 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 Cretaceous 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 Cretaceous coals varies from 80.6 to 101.2 pounds, the average being 87.8 pounds. In the Carboniferous coals the variation is from 68.7 to 101.2 pounds, the average being 87.4 pounds.

The general average weight of all of the coals, is 81.10 pounds per cubic foot as mined, and 87.50 pounds on a dry basis.

A bushel of coal weighs from 76 to 80 pounds, according to legal enactment in the several States.

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., 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. 37. Stewart Creek Coal Co., Jermyn, Jack county.
No. 10. Texas & Pacific Coal Co., Thurber, Erath county.
No. 11. Wise County Coal Co., Bridgeport, Wise county.

Nos. 42 and 43, Olmos washed nut and mine-run, were taken at the works of the Austin White Lime Co., McNeil, where producer gas was made for burning lime. Olmos mine-run is no longer marketed.

The analyses of these coals were as follows:

TABLE III.

Composition of Texas Coals—Samples Received from the Companies, 1910-1911. Analyses by S. H. Worrell

Analysis No.	As Received.											Dry Basis.									
	Proximate analysis.					Ultimate analysis.						Proximate analysis.				Ultimate analysis.					
	Moisture.	Volatile Combustible Matter.	Fixed Carbon.	Ash.	Sulphur.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Heating Power B. t. u. per lb.		Volatile Combustible Matter.	Fixed Carbon.	Ash.	Sulphur.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Heating Power B. t. u. per lb.	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
42	4.20	36.55	32.35	26.95	1.71	48.38	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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	
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	

TABLE IV.

Proximate Analyses of Texas Coals—Alphabetically Arranged—Dry Basis.

Analysis No.		Volatile combustible matter	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. (Spl.) International Coal Mines Co.—	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	1.80	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
802	Santo Tomas Coal Co.—Laredo, Webb County	47.52	39.18	13.30	2.05	12,470
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	39.00	43.37	17.63	2.00	11,291

In this table the Carboniferous coals are Nos. 1, 2, 7, 9, 10, 11, 37 and 53. The Cretaceous coals are Nos. 3, 4, 5, 6, 8, 31, 32, 33, 42, 43, 50, 51 and 208.

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, per cent.	Personal samples, per cent.
Moisture	5.82	7.40
Volatile 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., per pound	10,558	11,245

On dry basis, these become:

	Company samples, per cent.	Personal samples, per cent.
Volatile combustible matter	39.00	37.65
Fixed carbon	43.37	45.06
Ash	17.63	17.29
Sulphur	2.00	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., per pound	11,291	12,035

There are no very considerable discrepancies between these analyses, and it may fully 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.

Other Analyses of Texas Coals.

Brewster County.

In the southern part of Brewster county, within 8 to 10 miles of the quicksilver area, there is a limited field of sub-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 combustible 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. per pound	8,432	11,887	11,95

This coal field is 90 miles south of 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. The Rattlesnake beds, 20 miles south of the Rough Run district, are probably a continuation of the northern beds.

Burnet County.

In Bulletin No. 55, United States Geological Survey, 1889, page 87, there is given an analysis of coal from Burnet county, exact locality not given. The analysis was made by J. Edward Whitfield, and was as follows:

	Per cent.
Moisture	3.72
Volatile combustible matter	42.27
Fixed carbon	39.41
Ash	14.60
Sulphur and B. t. u. not given.	100.00

Coleman County.

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, northwest of Santa Anna. 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 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 Crescent property gave moisture, 4.71; volatile combustible 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.

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 in percentages:

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 in percentages:

LOCALITY	Mois-ture	Vola-tile matter	Fixed carbon	Ash	Sul-phur
Bridgeport, Wise County	2.00	31.47	56.32	8.15	2.06
Thurber Shaft, near Bowie, Montague County[1]	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
Santo Tomas Coal, Webb County	2.59	51.05	39.01	7.35	1.50
From 25 miles N. W. of Santo Tomas, Webb County[2]	2.35	42.67	37.59	16.55	0.86

[1]No coal is now mined in Montague County.
[2]Brown Coal and Lignite, Dumble, 1892, p. 190.

The analyses 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.

Jack County.

An analysis of coal from Lost Valley, Jack county, has been given to us, with no name signed. This analysis was as follows:

	As received, per cent.	Dry, per cent.
Moisture	10.28	....
Volatile combustible matter	25.49	28.11
Fixed carbon	55.10	60.77
Ash	9.13	11.12
	100.00	100.00

Maverick County.

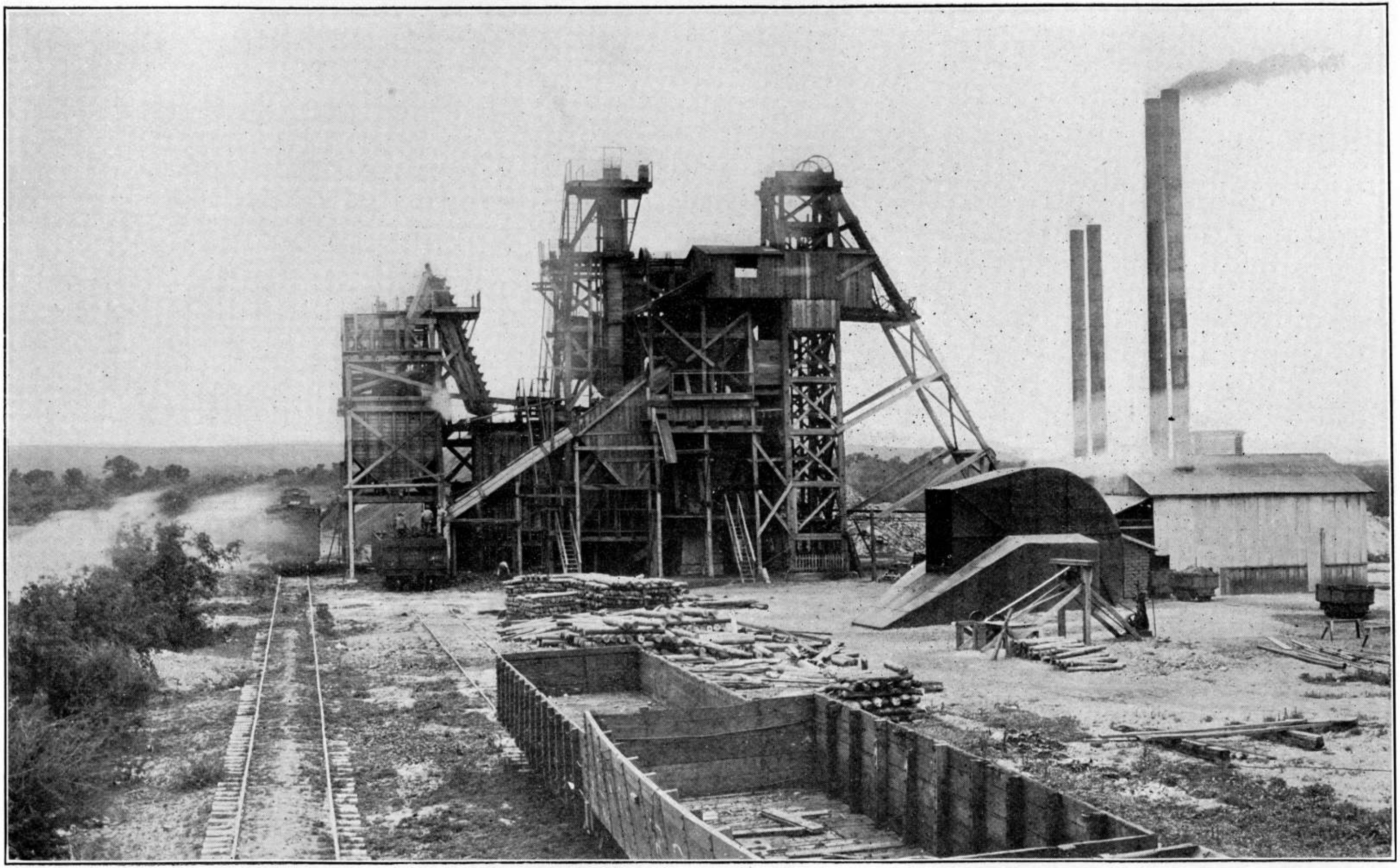
In Bulletin No. 164, United States Geological Survey, 1900, page 66, there is given an analysis of coal from near Eagle Pass, Maverick county, as follows:

	As received, per cent.	Dry, per cent.
Moisture	3.67	....
Volatile combustible matter	39.42	40.92
Fixed carbon	41.70	43.29
Ash	15.21	15.79
	100.00	100.00
Sulphur	0.81	....

The following analyses represent an average of the coal from the Dolch Mine, near Eagle Pass, Maverick county, and were made by the Bureau of Mines, Washington:

	Mch. 7, 1911, per cent.	Sept. 14, 1911, per cent.
Moisture	1.60	2.80
Volatile combustible matter	32.40	32.80
Fixed carbon	58.95	55.55
Ash	7.05	8.85
	100.00	100.00
Sulphur	1.70	0.80
B. t. u. per pound	14,020	13,165

We received from the Olmos Coal Company, Eagle Pass, in April, 1913, four samples of coal, one of lump and three of washed coal. These samples gave the following analyses:



Olmos Coal Co., Eagle Pass, Maverick County. Washer Plant.

Analyses of Coal from Olmos Coal Company, Eagle Pass, Maverick County.

	Washed pea.		Washed nut.		Washed egg.		Lump.	
	As rec'd, per cent.	Dry, per cent.	As rec'd, per cent.	Dry. per cent.	As rec'd, per cent.	Dry, per cent.	As rec'd, per cent.	Dry, per cent.
Moisture	11.11	....	7.98	....	8.68	....	8.83	....
Volatile combustible matter	28.53	32.10	30.00	32.60	30.94	33.88	32.68	35.84
Fixed carbon	42.26	47.54	40.06	43.54	42.94	47.02	44.89	49.24
Ash	18.10	20.36	21.96	23.86	17.44	19.10	13.60	14.92
Sulphur	1.06	1.19	0.94	1.02	0.90	1.02	0.90	0.99
British thermal units	9,698	10,910	9,681	10,520	10,361	11,455	10,941	12,001

Mr. C. S. Plant, Superintendent, Fuel Service, Sunset-Central lines, has kindly furnished us with the following analyses of coal from the Olmos Coal Company, Eagle Pass:

	Choice lump, per cent.	Ordinary lump and slack, per cent.	Washed egg, per cent.
Moisture	7.48	6.43	6.43
Volatile combustible matter	32.18	32.43	29.33
Fixed carbon	45.67	42.88	40.73
Ash	14.67	18.26	23.51
	100.00	100.00	100.00
B. t. u. per pound	11,530	11,240	10,146

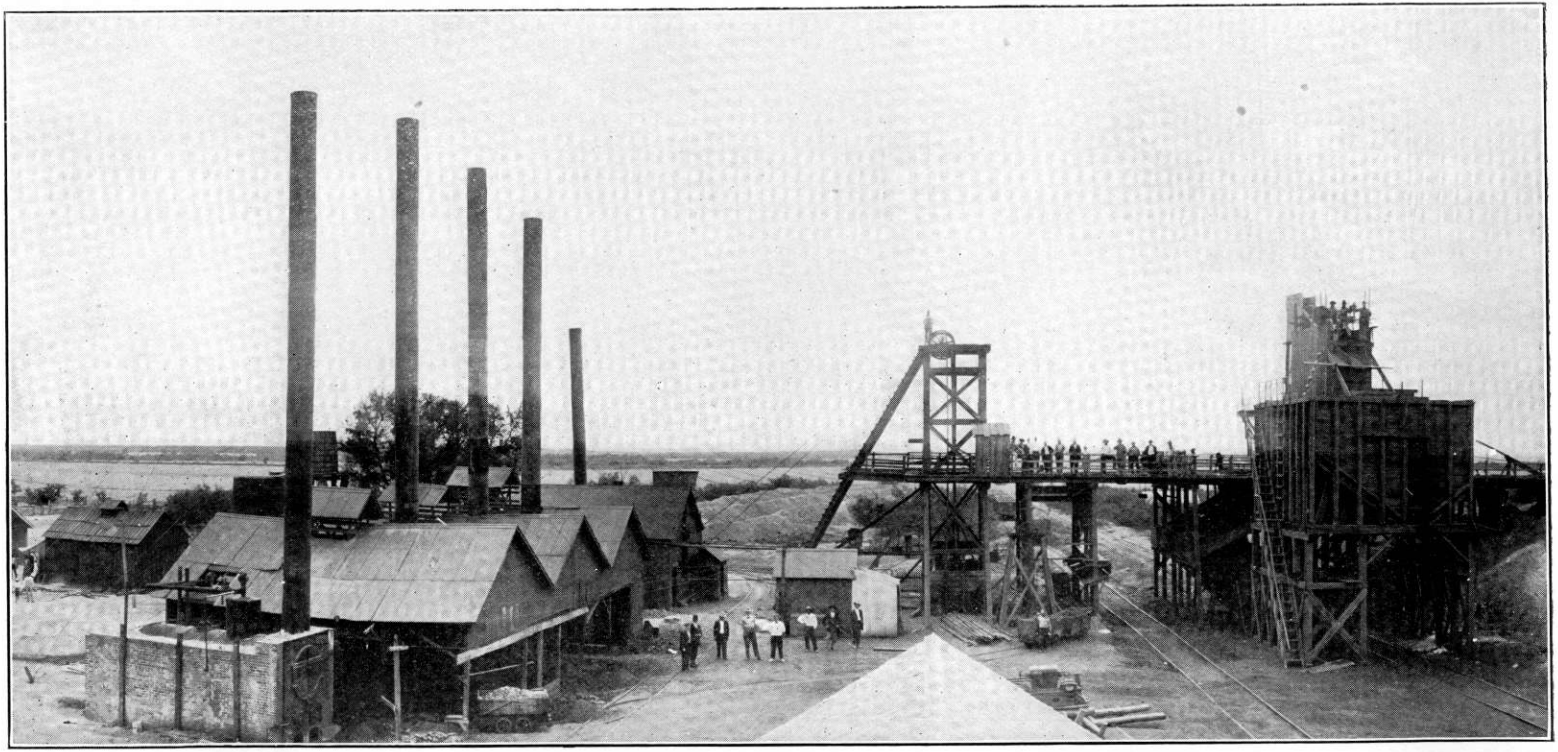
During the months of September and October, 1911, the International Coal Mines Company, Eagle Pass, Maverick county, sold 800 tons of coal to the Federal Government for use at Fort Sam Houston, San Antonio. The analyses were made by the Bureau of Mines, Washington, and were as follows:

	400 tons, Sept., 1911,		400 tons, Oct., 1911.	
	As rec'd, per cent.	Dry, per cent.	As rec'd, per cent.	Dry, per cent.
Moisture	2.80	....	1.50	....
Volatile combustible matter	32.80	33.74	33.40	33.91
Fixed carbon	55.55	57.15	58.95	59.85
Ash	8.85	9.11	6.15	6.24
	100.00	100.00	100.00	100.00
Sulphur	0.80	0.82	1.70	1.73
British thermal units per pound	13,163	13,544	14,020	14,213

Palo Pinto County.

We have received from the Strawn Coal Mining Company, Strawn, Palo Pinto county, an analysis of coal made for them by The Detroit Testing Laboratory, Detroit, Michigan, December 14, 1912. It was as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	1.06	....
Volatile combustible matter	39.28	39.70
Fixed carbon	50.12	50.65
Ash	9.54	9.65
	100.00	100.00
Sulphur	2.88	2.91
British thermal units per pound	13,421	13,563



International Coal Mines Co., Eagle Pass, Maverick County.

Since December 10, 1912, we have examined five samples of coal from Strawn, Palo Pinto county, for Mr. J. R. Elliott, State Purchasing Agent. This coal was sampled from the bins and the boiler room of the State Epileptic Colony, Abilene, November 27, 1912; January 4 and 15, February 11 and March 20, 1913.

The average of the analyses was as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	2.08	....
Volatile combustible matter	33.22	33.89
Fixed carbon	45.08	46.02
Ash	19.62	20.09
	100.00	100.00
Sulphur	3.96	4.05
British thermal units per pound	11,258	11,506

Presidio County.

This coal is in the San Carlos district, from 20 to 25 miles south of Chispa, a station on the Southern Pacific Railway, 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 were 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.

In Bulletin No. 164, United States Geological Survey, 1900, page 87, there are given five analyses of the San Carlos coal and one of coke, by Dr. Peter Fireman. These analyses were as follows:

Analyses of San Carlos Coal, Presidio County.

No. 4 MINE	Upper part of seam	Above binder	Below binder	Above clay, lower seam	Coal shaft
Moisture	1.09	1.17	1.19	1.68	0.97
Volatile combustible matter	36.61	39.93	39.73	60.37	40.95
Fixed carbon	35.29	35.39	40.30	24.89	43.77
Ash	24.01	23.51	18.78	13.06	14.31
	100.00	100.00	100.00	100.00	100.00

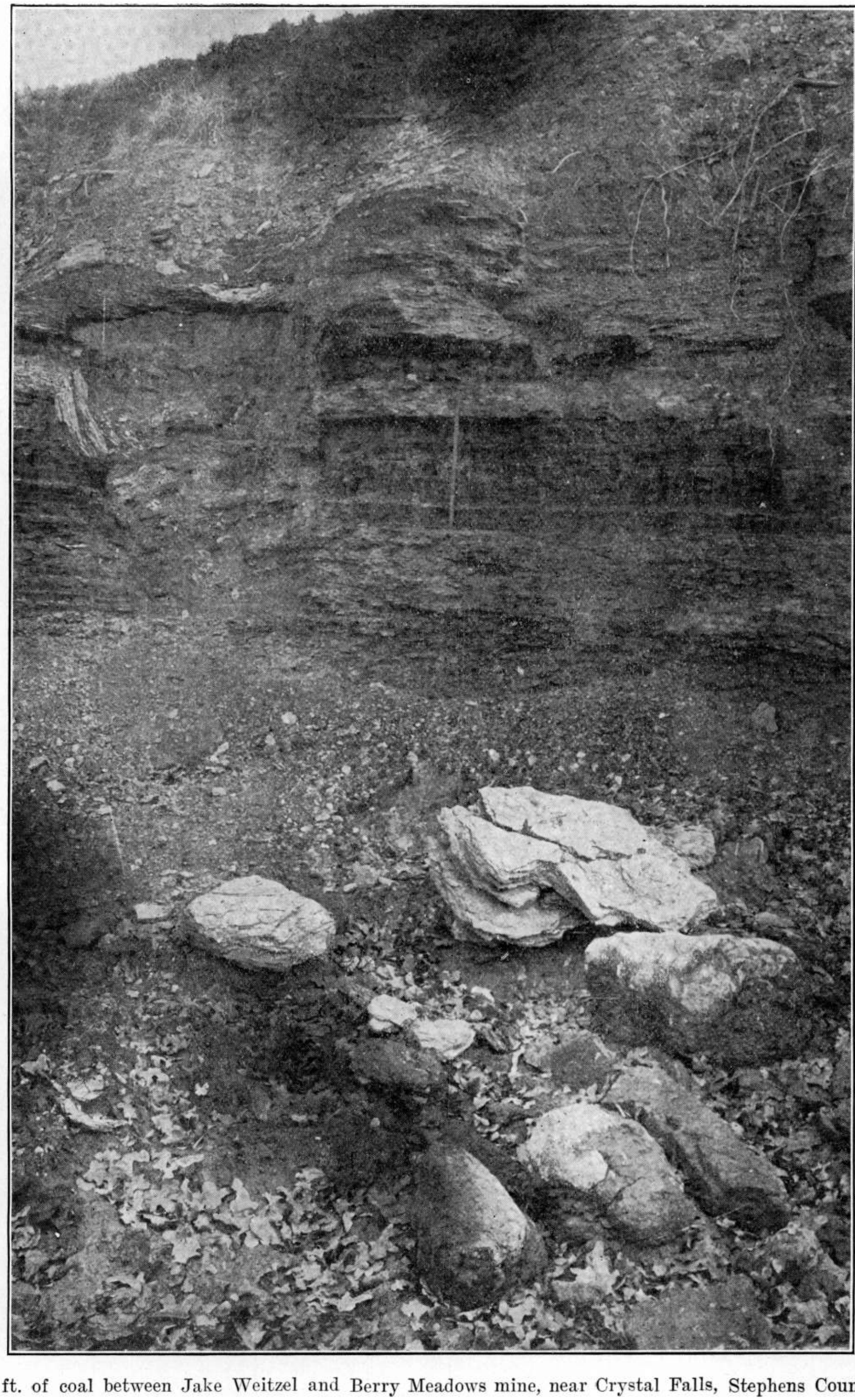
Sulphur and B. t. u. not given.

The analysis of the coke was:

	Per cent.
Moisture	1.24
Volatile combustible matter	4.96
Fixed carbon	66.93
Ash	26.87
	100.00

The coke was described as coherent, hard and lustrous.

During the summer of 1913, Dr. J. A. Udden, geologist for this Bureau, visited the field and brought back samples of the coal from two localities. The analyses are as follows:



2 ft. of coal between Jake Weitzel and Berry Meadows mine, near Crystal Falls, Stephens County.

Analyses of Coal from the San Carlos Coal Field, Presidio County, Texas. Samples collected by J. A. Udden, in July, 1913.

	Upper vein, 300 yards S. E. of old Ingle tunnel		Upper vein, near S. W. corner Sec. 67	
	As rec'd	Dry	As rec'd.	Dry
Moisture	4.60	....	4.90	....
Volatile combustible matter	39.20	41.13	32.80	34.49
Fixed carbon	50.10	52.47	43.04	45.26
Ash	6.10	6.40	19.26	20.25
	100.00	100.00	100.00	100.00
Sulphur	0.62	0.64	0.85	0.88
British thermal units per pound	12,157	12,757	9,663	10,161

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.

Stephens County.

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 13, 1906. The analysis was as follows:

Analysis of Coal from Coal Branch, Stephens County, Upper Bench.

	Per cent.
Moisture	6.90
Volatile 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 ⅜-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.

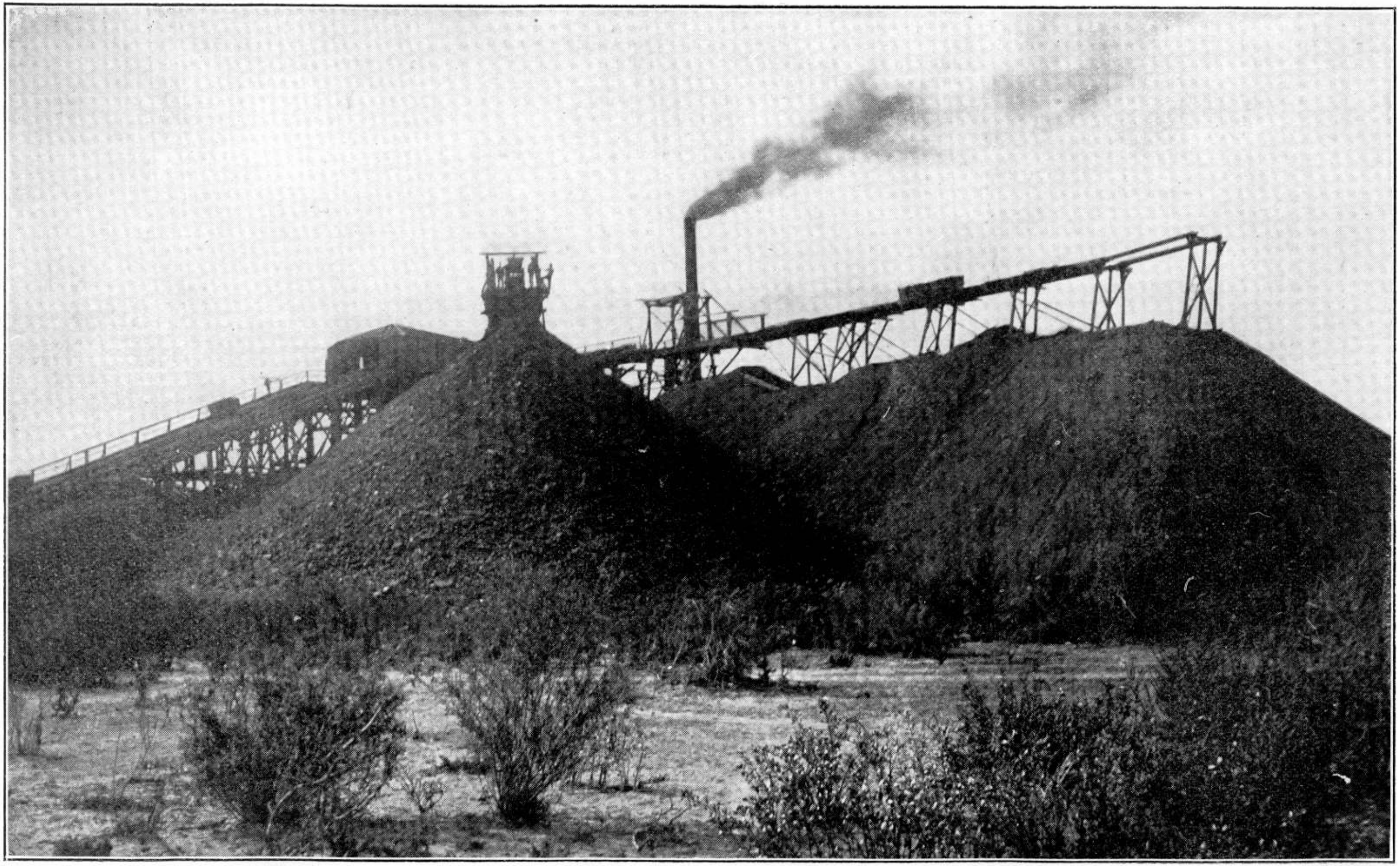
The bottom bench of this coal, separated from the upper bench by from 3 to 6 inches of bone and slate, shows a much better material.

Analysis of Bottom Bench of Coal, Coal Branch, Stephens County.

	Per cent.
Moisture	3.15
Volatile 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:

	Per cent.
Moisture	5.02
Volatile combustible matter	40.01
Fixed carbon	40.46
Ash	14.51
	100.00
Sulphur	5.12



Cannel Coal Co., Darwin (near Laredo), Webb County, San José Mine.

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.

Webb County.

We have received from the Cannel Coal Company, Laredo, Webb county, a copy of an analysis of their coal made by the Technologic Branch of the United States Geological Survey, Pittsburg, Pennsylvania, February 21, 1910. The sample represented a lot of 1,000 pounds taken at the mines by an agent of the Survey and was not freed of the impurities which are ordinarily removed when the coal is shipped on regular orders. The analysis is as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	3.97	....
Volatile combustible matter	43.63	45.43
Fixed carbon	36.15	37.65
Ash	16.25	16.92
	100.00	100.00
Sulphur	4.18	4.35
British thermal units per pound	11,588	12,067

An analysis of coal from the Laredo district, Webb county, has been given to us by Mr. Otto Stolley, Austin. It was made by Dr. J. R. Bailey, University of Texas, as follows:

	Llave coal.	
	As rec'd, per cent.	Dry, per cent.
Moisture	3.00	....
Volatile combustible matter	48.87	50.34
Fixed carbon	39.52	40.71
Ash	8.61	8.95
	100.00	100.00
Sulphur	3.52	3.63
British thermal units per pound	13,107	13,509

In Bulletin No. 164, United States Geological Survey, 1900, page 64, there are given two analyses, by Dr. Peter Fireman, of samples of coal from the Rio Grande Coal & Irrigation Company, near Laredo, Webb county. They are as follows:

	Upper bench.		Lower bench.	
	As rec'd, per cent.	Dry, per cent.	As rec'd, per cent.	Dry, per cent.
Moisture	2.26	....	2.63	....
Volatile combustible matter	48.64	49.77	45.67	46.91
Fixed carbon	36.15	36.99	39.96	41.04
Ash	12.95	13.24	11.74	12.05
	100.00	100.00	100.00	100.00
Sulphur, not given.				
British thermal units, not given.				

A sample of 25 pounds of coal received from the Santo Tomas Coal Company, Laredo, Webb county, June 17, 1912, gave the following analysis:

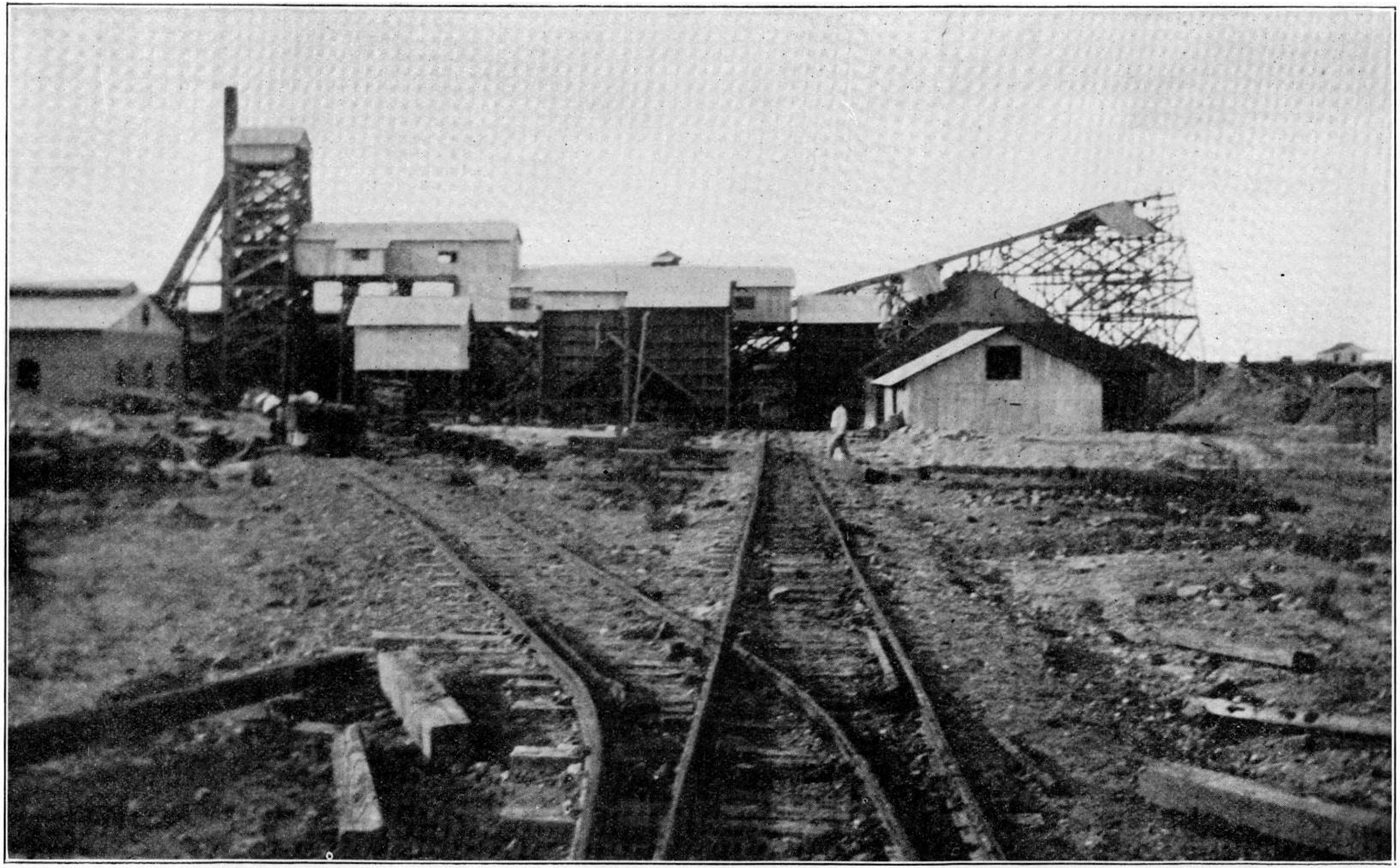
	As rec'd, per cent.	Dry, per cent.
Moisture	4.00	....
Volatile combustible matter	45.50	47.32
Fixed carbon	37.67	39.18
Ash	12.83	13.30
	100.00	100.00
Sulphur	1.97	2.05
British thermal units per pound	12,000	12,470

On October 12, 1912, we examined two samples of Santo Tomas Coal, Laredo, Webb county, for the University of Texas Power-house. The analyses were as follows:

	Special.		Carloads.	
	As rec'd, per cent.	Dry, per cent.	As rec'd, per cent.	Dry, per cent.
Moisture	2.60	....	2.50	....
Volatile combustible matter	46.49	47.70	45.27	46.40
Fixed carbon	38.98	40.00	29.27	30.00
Ash	11.93	12.30	22.96	23.60
	100.00	100.00	100.00	100.00
Sulphur	2.34	2.40	2.44	2.50
British thermal units per pound	12,339	12,660	10,917	11,190

Another analysis of Santo Tomas Coal is given in Table IV under No. 802.

From the best information to hand, derived from our own analyses and such as we have been able to procure, we think that the following statements of the average composition of Texas coals and the range of composition are reasonably correct.



Santo Tomas Coal Co., Minera (near Laredo), Webb County.

Average Composition of Texas Sub-bituminous Coals.

	As mined, per cent.	Dry, per cent.
Moisture	6.61	....
Volatile combustible matter	35.60	38.12
Fixed carbon	41.40	44.33
Ash	16.39	17.55
	100.00	100.00
Sulphur	2.12	2.28
British thermal units per pound	10,901	11,672
Carbon	59.62	63.84
Hydrogen	4.31	4.61
Oxygen	9.36	10.02
Nitrogen	1.90	2.03

These figures do not correspond exactly with the averages given on pages 15 and 21, but the discrepancies are due to taking a larger number of analyses than appear on those pages.

Taking the same number of analyses as are represented in the preceding statement, more than 60 in all, we find that the range of composition of these coals is as follows [natural condition]:

	From, per cent.	To, per cent.
Moisture	2.30	13.44
Volatile combustible matter	28.82	49.05
Fixed carbon	32.35	53.00
Ash	2.81	30.34
Sulphur	0.54	4.76
British thermal units per pound	9,010	12,315
Carbon	48.33	70.62
Hydrogen	3.37	5.65
Oxygen	2.34	14.27
Nitrogen	0.78	3.62

CHAPTER III.

COMPOSITION OF COALS BROUGHT INTO TEXAS.

We have attempted to secure analyses of coals brought into Texas from other States, but we have not been as successful as we could wish. We had not the means for sending a man to various cities and towns to secure samples in person, so that we have been compelled to accept samples that were sent in by coal companies or their agents. We have no means of ascertaining whether or not these samples correctly represent the coals as received and used and we distinctly disclaim all responsibility in the matter, except as to the analyses. The services of this Bureau have been and are still at the disposal of citizens of this State who wish to know the quality of the fuels they are using and we hope that the publication of this bulletin will be a means for calling attention to this important matter. It is likely that the value of the coals brought into this State, for railroad, industrial and domestic purposes, is not less than $10,000,000 annually.

Alabama Coals.

We have received a sample of coal marked "Alabama Lump." It was dry when received and had the following composition:

	Per cent.
Volatile combustible matter	38.50
Fixed carbon	56.00
Ash	5.50
	100.00
Sulphur	1.70
British thermal units, per pound	14,200

We have received from Jung & Sons Co., New Orleans, La., three samples of Alabama coal, which is marketed in Texas. The composition of these samples was as follows, in percentage:

	1. Per cent.	2. Per cent.	3. Per cent.
Moisture, as received	1.40	1.70	1.60
On Dry Basis—			
Volatile combustible matter	35.92	38.07	31.89
Fixed carbon	57.85	54.77	66.08
Ash	6.23	7.16	2.03
	100.00	100.00	100.00
Sulphur	0.85	1.71	1.08
British thermal units, per pound	13,989	13,944	15,126

1. Alecto Red Ash, Cahaba Field, Bibb county, Alabama.
2. Oak Hill Mine, White Ash Coal, Walker county, Alabama.
3. Bear's Creek, No. 3 Lump, Etowah county, Alabama.

We received from the Consumers Fuel and Ice Company, Austin, a sample of Alabama blacksmith coal, from Yolande. The composition of this sample was as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	4.00	....
Volatile combustible matter	24.29	25.30
Fixed carbon	63.96	66.63
Ash	7.75	8.07
	100.00	100.00
Sulphur	0.86	0.90
British thermal units, per pound	13,499	14,061

The following analyses have been kindly furnished by Dr. Eugene A Smith, Director of the Geological Survey of Alabama, the analyses having been made by Mr. R. S. Hodges in the laboratory of that survey:

Analyses.	Moisture, per cent.	Volatile combustible matter, per cent.	Fixed Carbon, per cent.	Ash, per cent.	Sulphur, per cent.	B. t. u., per pound calculated.
1	1.62	35.53	52.13	10.72	2.23	13,077
2	1.60	35.35	49.45	15.60	2.99	12,718
3	1.37	29.57	58.78	10.28	1.08	13,651
4	1.89	28.32	61.52	8.27	1.08	13,802
5	1.00	31.02	59.46	8.52	1.26	12,999
6	0.97	32.00	58.38	8.65	1.37	Not det'd
7	0.73	28.58	65.05	5.64	1.38	Not det'd
8	0.80	29.80	64.46	4.94	1.32	14,783
9	1.83	35.00	56.65	6.52	0.65	Not det'd
10	1.02	26.13	63.42	9.43	0.99	*13,973
11	1.74	34.61	58.38	5.27	0.61	13,890
12	0.84	29.26	63.69	6.21	1.55	*14,495
13	1.39	32.66	52.47	13.48	0.53	Not det'd
14	1.54	32.48	54.83	11.15	0.59	*13,297
15	0.78	26.17	56.92	16.13	0.75	12,821
16	0.91	27.50	54.77	16.82	0.98	Not det'd
17	2.31	33.79	53.23	10.67	1.40	Not det'd
18	2.49	32.78	52.46	12.27	1.46	*12,515
19	1.11	37.74	56.85	4.30	0.44	14,688
20	0.98	36.75	57.04	5.23	0.51	14,365
21	1.39	36.48	55.24	6.89	0.36	13,946
22	1.35	36.57	54.08	8.00	0.39	13,623

*Determined by Bureau of Mines, Washington.

1. Deer Creek Coal Co., Tidewater.
2. Same.
3. Central Iron and Coal Co., Kellerman.
4. Same.
5. Alabama Consolidated Coal and Iron Co., Searles.
6. Tennessee Coal, Iron and Railway Co., No. 5 Pratt.
7. Tennessee Coal, Iron and Railway Co., No. 3 Pratt.
8. Tennessee Coal, Iron and Railway Co., No. 5 Pratt.
9. Tennessee Coal, Iron and Railway Co., No. 5 Blocton.
10. Tennessee Coal, Iron and Railway Co., No. 4 Johns.
11. Tennessee Coal, Iron and Railway Co., No. 7 Blocton.
12. Tennessee Coal, Iron and Railway Co., No. 3 Pratt.
13. Galloway Coal Co., Garnsey.
14. Same.
15. Alabama Consolidated Coal and Iron Co., Mary Lee.
16. Same.
17. Galloway Coal Co., No. 6 Carbon Hill.
18. Same.
19. Wadsworth Red Ash Coal Co., Falliston.
20. Same.
21. Conners Wyman Steel Co., Falliston.
22. Same.

The analyses sent to us by Dr. Smith included also the ultimate composition of these coals, but it does not appear necessary to give these determinations here, as our purpose is merely to show what is the proximate composition of well known Alabama coals.

Arkansas Coals.

We have received from the Dow Coal Co., McAlester, Oklahoma, a sample of coal marked "Hartford, Arkansas, semi-anthracite." The composition of this sample was as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	1.20	....
Volatile combustible matter	16.74	16.94
Fixed carbon	77.32	78.26
Ash	4.74	4.80
	100.00	100.00
Sulphur	0.88	0.89
British terminal units, per pound	14,474	14,650

A sample of Arkansas semi-anthracite sold for domestic use in Austin at $10 a ton had the following composition:

	As rec'd, per cent.	Dry, per cent.
Moisture	1.14	....
Volatile combustible matter	11.54	11.67
Fixed carbon	73.22	74.06
Ash	14.10	14.27
	100.00	100.00
Sulphur	2.16	2.19
British thermal units, per pound	12,624	12,770

A sample of Arkansas semi-anthracite taken in Austin, August 20, 1913, showed the following composition:

	As rec'd, per cent.	Dry, per cent.
Moisture	1.26	....
Volatile combustible matter	18.54	18.78
Fixed carbon	63.20	64.10
Ash	17.00	17.21
	100.00	100.00
Sulphur	1.28	1.30
British thermal units, per pound	12,390	12,548

NOTE.—As 50 per cent of this coal passed a ⅛-inch screen, it might be classed as slack.

We have received from the McAlester Fuel Co., McAlester, Oklahoma, a sample of Arkansas semi-anthracite marked "Bernice Slack." The composition of this sample was as follows:

	As rec'd, per cent.
Moisture	1.30
Volatile combustible matter	13.60
Fixed carbon	70.49
Ash	14.61
	100.00
Sulphur	2.25
British thermal units per pound	12,619

Colorado Coals.

Two samples of Colorado coal from Trinidad were obtained from the Consumers Fuel and Ice Co., Austin. The composition of these samples was as follows:

	I. As rec'd, per cent.	II. As rec'd, per cent.
Moisture	3.80	3.80
Volatile combustible matter	37.48	34.43
Fixed carbon	52.78	49.83
Ash	5.94	11.94
	100.00	100.00
Sulphur	0.88	0.84
British thermal units, per pound	13,271	11,995

The Colorado coals as used by the railroads in Texas carry about 3 per cent of moisture, from 30 to 35 per cent volatile combustible matter, from 50 to 55 per cent of fixed carbon, and from 8 to 12 per cent of ash.

Illinois Coals.

A little Illinois coal comes into Texas and we have received from Jung & Sons Co., New Orleans, a sample of Blue Ridge coal, Saline county, which had the following composition:

	As rec'd, per cent.	Dry, per cent.
Moisture	2.60	....
Volatile combustible matter	34.88	35.81
Fixed carbon	55.42	56.90
Ash	7.10	7.29
	100.00	100.00
Sulphur	2.23	2.29
British thermal units, per pound	13,150	13,501

Kentucky Coals.

Some Kentucky coal is marketed in Texas, but we are unable to give any analyses.

New Mexico Coals.

New Mexico coals are sold in El Paso and other cities and towns of west and northwest Texas. We give three analyses of these coals from samples taken in El Paso in September, 1913. These are as follows, as received:

	1. Per cent.	2. Per cent.	3. Per cent.
Moisture	4.35	1.50	1.12
Volatile combustible matter	3.15	36.96	35.48
Fixed carbon	79.70	46.54	50.20
Ash	12.80	15.00	13.20
	100.00	100.00	100.00
Sulphur	0.82	0.68	0.68
British thermal units, per pound	12,546	12,468	12,546

1. Anthracite from Cerrillos Coal Co., Albuquerque. Mines at Madrid. Sells in El Paso for $6.50 a ton.

2. Bituminous coal from Raton, Swastika Fuel Co., Raton. Sells in El Paso at $3.50 a ton, wholesale.

3. Dawson coal, sells in El Paso at $3.50 a ton, wholesale.

We have received from S. C. Awbrey & Co., El Paso, under date of September 18, a letter in which they state that the fixed carbon in Cerrillos coal is about 85 per cent, and the ash about 6 per cent. They have kindly sent us an analysis of a sample representing a carload which was shipped to Mexico City. This analysis is as follows:

	Per cent.
Moisture	2.92
Volatile combustible matter	4.35
Fixed carbon	85.09
Ash	6.84
Sulphur	0.79

They also inform us that the bituminous coal from the Raton district carries moisture from 0.85 to 1.70 per cent; volatile combustible matter from 36 to 41 per cent; fixed carbon from 51 to 53 per cent; and ash from 6 to 10 per cent.

Oklahoma Coals.

A great deal of coal from Oklahoma is brought into Texas, for railroad, industrial, and domestic purposes; but no statistics on the subject are now available. We have received from a number of operating companies samples of the coal shipped to Texas, and we herewith present the analyses which have been made on the same, as received:

Analysis.	Moisture, per cent.	Volatile combustible matter, per cent.	Fixed carbon, per cent.	Ash, per cent.	Sulphur, per cent.	B. t. u., per pound.
1.........	3.60	32.58	59.77	4.05	0.80	13,296
2.........	1.80	37.20	54.64	6.36	1.94	14,495
3.........	2.00	35.44	56.68	5.88	1.68	13,746
4.........	3.80	29.96	61.14	5.10	1.06	13,794
5.........	2.60	36.72	56.30	4.38	0.67	13,586
6.........	0.24	38.90	52.44	8.32	2.81	13,403
7.........	0.10	37.20	59.00	3.70	1.37	13,871
8.........	4.66	31.64	59.40	4.30	0.85	13,404
9.........	5.20	32.80	59.16	2.84	1.34	12,976
10.........	2.90	37.90	48.50	10.70	3.23	12,702
11.........	2.80	37.34	49.26	10.60	4.12	12,312
12.........	1.20	40.00	51.60	7.20	2.75	13,092
13.........	1.26	33.59	59.03	6.12	1.10	13,927
14.........	6.40	32.10	59.29	2.21	1.29	12,983
15.........	4.80	34.88	55.37	4.95	3.79	12,567
16.........	2.60	32.34	60.58	4.48	0.83	13,586
17.........	6.00	31.62	58.90	3.48	1.17	13,039
18.........	3.00	33.85	59.46	3.69	0.56	13,833
19.........	4.60	34.03	54.68	6.69	1.29	12,963
20.........	3.80	33.47	57.05	5.68	1.67	12,957
21.........	3.60	34.03	55.04	7.33	1.99	12,846
22.........	4.80	38.37	49.79	7.04	3.55	12,538
23.........	5.20	34.41	52.71	7.68	3.00	11,968
24.........	4.80	31.51	45.89	18.80	2.73	10,831
25.........	3.20	36.69	52.37	7.74	3.43	12,603
26.........	3.20	31.17	62.24	3.39	0.61	13,805
27.........	3.70	30.76	50.91	14.63	2.22	11,027
28.........	3.60	27.41	46.72	22.27	2.60	10,448
29.........	3.26	42.12	47.55	7.07	3.20	Not det'd
Average..	3.40	35.17	54.98	7.09	1.98	12,503

1. From the receivers of the Bolen-Darnall Coal Co., McAlester; May 30, 1913.

2. Degnan-McConnell mines, Wilburton; July 18, 1913.

3. Dow Coal Co., Adamson; May 30, 1913.

4. Dow Coal Co., Savannah; June 16, 1913.

5. Dow Coal Co., Pocahontas; May 30, 1913.

6. Hailey-Ola Coal Co., Haileyville; July 19, 1913; No. 1 mine.

7. Hailey-Ola Coal Co., Haileyville; July 19, 1913; No. 2 mine.

8. Hailey-Ola Coal Co., Haileyville; July 19, 1913; No. 6 mine.

9. Henryetta Coal and Mining Co., Henryetta; June 28, 1913.

10. McAlester-Edwards Co., Pittsburg; July 18, 1913; mine-run from No. 1 mine.

11. McAlester-Edwards Co., Pittsburg; July 18, 1913; mine-run from No. 2 mine.

12. McAlester-Edwards Co., Pittsburg; July 18, 1913; washed nut.

13. McAlester Fuel Co., McAlester; August 15, 1913; Buck No. 6.

14. McAlester Fuel Co., McAlester; June 28, 1913; Pleasant Valley Coal Co. Coalton, No. 1 mine.

15. McAlester Fuel Co., McAlester; June 28, 1913; Pleasant Valley Coal Co. Coalton, No. 2 mine.

16. McAlester Fuel Co., McAlester; June 26, 1913; Great Western Coal and Coke Co., Wilburton, Mine No. 3.

17. Oklahoma Coal Co., Dewar, May 30, 1913.

18. Osage Coal & Mining Co., McAlester; June 25, 1913; No. 5 mine, McAlester vein.

19. Southern Fuel Co., McAlester, June 21; Brewer-McAlester domestic lump.

20. Southern Fuel Co., McAlester, June 21; Brewer-McAlester chestnut.

21. Southern Fuel Co., McAlester, June 21; Brewer-McAlester slack.

22. Southern Fuel Co,. McAlester, June 21; Caney Creek domestic lump, Coalgate.

23. Southern Fuel Co., McAlester, June 21; Caney Creek chestnut.

24. Southern Fuel Co., McAlester, June 21; Caney Creek slack.

25. Southern Fuel Co., McAlester, June 21; Chamber's lump coal.

26. Southern Fuel Co., McAlester, June 21; Hartshorne lump coal.

27. Southern Fuel Co., Dallas, September 4, 1911; screened pea from Brewer Coal & Mining Co.

28. Southern Fuel Co., Dallas, Texas, September 4, 1911; slack; from Brewer Coal & Mining Co.

29. Southern Fuel Co., Dallas, Texas, September 19, 1911; Midway McAlester coal.

We have also examined a sample of so-called McAlester slack, sampled at Austin, Texas, April 27, 1911. The analysis was as follows:

	As rec'd,
Moisture	3.70
Volatile combustible matter	27.09
Fixed carbon	44.93
Ash	24.28
	100.00
Sulphur	2.97
British thermal units, per pound	10,366

The following analyses represent samples of Oklahoma lump coal submitted to us for analysis:

	30. Per cent.	31. Per cent.	32. Per cent.
Moisture	2.00	1.12	1.00
Volatile combustible matter	35.78	37.12	37.00
Fixed carbon	58.33	58.61	57.70
Ash	3.89	3.05	4.30
	100.00	100.00	100.00
Sulphur	0.49	0.80	0.78
British thermal units, per pound	13,725	14,059	14,788

30. Buck McAlester lump.
31. Krebs McAlester lump.
32. Osage McAlester lump.

But coal that is termed "Oklahoma domestic lump," may depart very widely from the above composition, as the following analysis of a sample taken from a private residence in Austin, March 16, 1913, will show: This coal was bought for Oklahoma domestic lump and the price was $8.50 a ton. The analysis was as follows, as received:

	Per cent.
Moisture	1.84
Volatile combustible matter	34.60
Fixed carbon	46.20
Ash	17.26
	100.00
Sulphur	0.91
British thermal units, per pound	11,845

This coal contained 20 per cent of material that passed a ½-inch screen.

During the season of 1912-1913, between the dates November 20, 1912, and April 2, 1913, we made 41 analyses of samples of washed McAlester Chestnut coal delivered at the University Power-house, Austin, Texas. The analyses represent more than a thousand tons of coal and the average composition of this coal was as follows:

	As rec'd, per cent.
Moisture	1.86
Volatile combustible matter	34.88
Fixed carbon	56.36
Ash	6.90
	100.00
Sulphur	1.02
British thermal units, per pound	13,556

It is to be noted with respect to these analyses that the moisture in the coal as received is probably considerably higher than the results above given, for the samples were not delivered promptly to the laboratory and lost a good deal of water between the time of sampling and the time of delivery to the laboratory. In these analyses the following variations were noted:

Washed McAlester Chestnut.

	From, Per cent.	To, Per cent.
Moisture	....	4.00
Volatile combustible matter	24.56	45.96
Fixed carbon	46.04	66.24
Ash	3.00	16.20
Sulphur	0.29	2.48
British thermal units, per pound	11,705	15,305

It is also to be noted that the sample carrying 16.20 per cent of ash was, in all probability, not washed McAlester chestnut. Just what this coal was we are unable to say, but we do not believe that it was washed chestnut.

The following analyses of Oklahoma coal were made in our laboratory for the State Purchasing Agent, Austin, by J. E. Stullken, assistant chemist:

McAlester Lump

Samples from State Lunatic Asylum, Austin, Texas, November 30, 1912 to April 7, 1913. Average of 7 analyses, as received at laboratory:

	Per cent.
Moisture	4.08
Volatile combustible matter	35.94
Fixed carbon	53.49
Ash	6.49
	100.00
Sulphur	1.59
British thermal units, per pound	13,042

Samples from Deaf, Dumb and Blind Institute for Colored Youth, Austin, January 30 to April 18, 1913. Average of 6 analyses, as received at laboratory.

	Per cent.
Moisture	3.85
Volatile combustible matter	33.10
Fixed carbon	52.37
Ash	10.68
	100.00
Sulphur	1.97
British thermal units, per pound	12,314

Samples from Confederate Home, Austin, January 17 to March 24, 1913. Average of three analyses, as received at laboratory.

	Per cent.
Moisture	3.97
Volatile combustible matter	35.73
Fixed carbon	53.14
Ash	7.16
	100.00
Sulphur	1.94
British thermal units, per pound	12,582

The average of two samples of McAlester Mine Run, from the North Texas Hospital for the Insane, Terrell, January 3 and February 5, 1913, gave as received at laboratory:

	Per cent.
Moisture	3.25
Volatile combustible matter	30.00
Fixed carbon	52.20
Ash	14.55
	100.00
Sulphur	1.41
British thermal units, per pound	11,486

The average of four samples of McAlester Mine Run from the Southwestern Insane Asylum, San Antonio, January 7 to April 13, 1913, as received at the laboratory, was as follows:

	Per cent.
Moisture	2.96
Volatile combustible matter	34.40
Fixed carbon	49.04
Ash	13.60
	100.00
Sulphur	1.61
British thermal units, per pound	11,507

The average of fourteen samples of Dewar coal, Oklahoma, examined for the State Purchasing Agent during 1912-1913, gave the following, as received at the laboratory:

	Per cent.
Moisture	3.90
Volatile combustible matter	35.37
Fixed carbon	53.01
Ash	7.72
	100.00
Sulphur	1.95
British thermal units, per pound	12,690

CHAPTER IV.

DRY DISTILLATION OF TEXAS COALS.

We have investigated the coals mined in Texas with reference to their gas-producing and coking qualities, not at all for the purpose of saying the last word on the subject, but to ascertain whether any of them was suitable for gas-making.

There is not much coal used in Texas for gas-making, the total amount being less than 30,000 tons a year. None of this coal, however, is Texas coal, Oklahoma and Alabama supplying the demand. Of the two establishments that used Texas coal in producers, one has closed its producer plant and the other is now using oil-fired kilns.

By far the greater amount of city gas used in Texas is made by the Lowe system (water gas), or by a combination of water-gas and oil-gas.

The inquiry that was set on foot did not involve illuminating gas at all, but was restricted to fuel gas. The candle-power of the gas made from each coal was determined in an American Bunsen photometer, with single or double standard candles and an Argand burner. By use of a Welsbach mantle, candle-powers from 30 to 40 were observed. The equipment of the experimental gas plant consisted of a steel retort holding two pounds of coal, broken to $\frac{1}{4}$-$\frac{1}{2}$ inch and dried; pipe-condensers for water, ammoniacal liquor and tar, and galvanized iron boxes for holding the caustic lime for absorption of carbonic acid. The gas, after passing through a Wright meter, was conducted into a capacious tank, counterbalanced and water-sealed. The temperature within the retort was taken with an electric pyrometer (Chatelier, thermocouple). The wires were carried into the retort through a silica tube, tightly packed with asbestos. The temperature observed was that of the retort immediately above the coal; not the temperature of the coal itself; and was kept as near 600° F. as possible. Porter and Ovitz have shown[1] that the temperature of an electric furnace may be from 167° to 248° F. above that of the highest temperature

[1]Bur. Mines, Washington, Bull. 1, 1910, pp. 29-30.

reached by the coal, the difference being less as the temperature of the furnace rises.

From the containing holder the gas was piped to a Junkers Continuous Gas Calorimeter and to the photometer. The heat units in the gas were also calculated from the analysis, both sets of figures being given. For calculating the heat units the following factors were used: illuminants, 1,700; carbon monoxide, 315; hydrogen, 264; methane, 853; for 60° F. initial temperature and 328° F. final temperature. In many cases there was a substantial agreement between the observed and the calculated heat units.

Table V.

Results of Distillation Tests on Texas Coals. Analyses by S. H. Worrell.

Analysis No.	Yield of gas cubic feet per net ton.	Gas—Dry.									Coal—Dry.								
		Composition.					Specific Gravity.	Candle Power.	B. t. u. per cu. ft.		Proximate Analysis.				Ultimate Analyses.				B. t. u.
		Illuminants.	Carbon Monoxide.	Hydrogen.	Methane.	Nitrogen.			Obs.	Calc.	Volatile Combust. Matter.	Fixed Carbon.	Ash.	Sulphur.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Per Pound.
246........	7,480	2.2	14.8	49.3	27.6	6.1	.410	1.0	562	559	38.45	42.48	11.87	4.24	58.25	4.17	12.35	2.12	10,213
247........	5,966	2.6	5.1	54.4	29.7	8.2	.355	4.5	590	573	38.30	46.94	14.76	3.41	65.42	4.40	9.21	2.80	11,196
248........	7,320	5.5	2.1	42.0	43.9	6.5	.385	1.6	687	630	54.00	37.97	8.03	2.25	71.04	5.65	10.03	3.00	12,604
249........	6,935	2.4	12.0	42.0	35.9	7.7	.441	12.4	700	622	40.25	48.65	11.10	2.14	67.38	4.83	13.08	1.47	11,695
250........	6,601	1.6	12.0	44.4	37.2	4.8	.427	9.6	637	622	39.20	57.73	3.07	1.80	74.74	5.08	13.67	1.64	12,527
251........	6,926	1.5	1.9	54.0	29.1	13.5	.355	4.0	591	533	33.70	39.96	26.34	2.00	55.44	4.14	9.56	2.52	9,636
747........	5,967	1.0	12.2	44.7	30.8	10.1	.446	6.5	530	516	35.50	39.16	25.34	1.80	57.20	4.40	7.96	3.30	10,412
699........	7,113	2.2	13.4	50.2	27.4	6.0	.410	10.0	540	527	38.00	44.44	17.51	1.30	64.12	4.92	10.41	1.74	11,545
700........	5,787	2.0	9.4	41.6	27.4	16.8	.490	2.5	475	483	37.58	40.49	21.05	1.70	60.01	4.63	9.93	1.80	10,807
340........	6,600	5.4	11.8	40.3	39.0	3.5	.428	6.5	724	702	50.45	38.10	11.45	3.09	66.06	5.72	12.18	2.50	11,740
257........	7,780	1.8	5.2	42.2	41.2	8.2	.421	8.1	641	638	39.50	50.99	9.51	2.10	70.91	4.85	9.29	3.34	12,410
753........	6,110	0.4	20.8	46.4	24.2	7.6	.437	1.5	474	471	38.18	39.01	22.81	1.84	60.28	3.77	9.88	1.42	10,510
802........	7,147	5.4	6.6	43.6	36.2	8.2	.424	15.4	702	667	47.52	39.18	13.30	2.05	......	......	......	......	12,470
341........	8,112	3.0	4.5	50.8	34.2	7.5	.378	7.0	632	615	39.60	49.56	10.84	3.17	70.00	5.15	8.14	2.70	12,265
396........	5,752	3.8	7.5	52.1	33.5	3.1	.330	4.2	598	606	41.95	50.08	7.97	1.98	71.78	5.35	10.75	2.17	12,526
698........	7,058	1.0	14.2	49.7	24.4	9.7	.424	5.3	462	474	37.40	47.37	15.23	2.00	63.80	4.67	11.40	2.90	11,269
Average.	6,790	2.6	8.3	46.7	32.6	7.9	.410	7.1	596	577	40.59	44.50	14.38	2.30	61.02	4.48	9.86	2.21	11,489

Explanation of Table V.

246. Belknap Coal Company, Newcastle, Young county.
247. Bridgeport Coal Company, Bridgeport, Wise county.
248. Cannel Coal Company, Darwin, Webb county.
249. International Coal Mines Co., Eagle Pass, Maverick county.
250. International Coal Mines Co. "Special."
251. Olmos Coal Co., Eagle Pass, Maverick county.
744. Olmos Coal Co., washed pea.
699. Olmos Coal Co., washed egg.
700. Olmos Coal Co., washed nut.
340. Rio Grande Coal Co., Laredo, Webb county.
257. Santo Mining & Developing Co., Weatherford, Parker county.
753. Stewart Creek Coal Co., Jermyn, Jack county.
802. Santo Tomas Coal Co., Laredo, Webb county.
341. Strawn Coal Mining Co., Strawn, Palo Pinto county.
396. Texas & Pacific Coal Co., Thurber, Erath county.
698. Wise County Coal Co., Bridgeport, Wise county.

Note.—Numbers 257 and 753 represent coals that are not now mined.

In order to compare these results with those reached in the distillation of well known coals used in Texas for gas-making, an Oklahoma coal was selected.

McAlester pea coal gave 6,130 cubic feet of gas per net ton, with the following composition:

	Per cent.
Illuminants	1.60
Carbon monoxide	7.60
Hydrogen	43.00
Methane	45.00
Nitrogen (by diff.)	2.80

The specific gravity of the gas was 0.400, the observed heating power, per cubic foot, was 708, and the calculated heating power was 686. The candle-power was 7.0. The composition of the coal from which this gas was made was as follows:

	Dry, per cent.
Volatile combustible matter	36.87
Fixed carbon	58.81
Ash	4.32
	100.00
Sulphur	1.40
British thermal units, per pound	13,090

There was left in the retort 75 per cent of good coke.

In the operations, as conducted, it was not possible to deprive the coals entirely of their volatile combustible matter, and the amounts left in the residues from the retort varied from 1.91 per cent, as in the case of a Carboniferous coal from Palo Pinto county, No. 341, to 8.75 per cent, as in the case of a Cretaceous coal from Maverick county, No. 340.

Table VI gives the results of the analyses of the several residues, the percentage yield and the character of the residue, i. e., whether it was coke of fair quality or not.

TABLE VI.

Composition and Character of Residue Left in Retort after Distilling the Coals Represented in Table V.

No.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	British thermal units, per pound.	Residue.	
						Yield, per cent.	Character.
246 } 778 }	3.18	75.30	21.52	4.72	11,523	62.50	Did not coke.
247 } 739 }	5.16	71.8	23.0	3.34	11,084	62.50	Did not coke.
248 } 733 }	3.51	78.31	18.18	2.01	12,050	81.25	Coke fair.
249 } 734 }	8.75	73.80	17.45	0.73	11,530	62.40	Coke fair.
250 } 735 }	6.15	90.19	3.66	0.91	13,082	65.00	Coked feebly.
251 } 740 }	2.93	73.12	23.95	0.71	10,848	68.7	Did not coke.
699 } 764 }	2.22	69.38	28.40	0.64	10,327	68.0	Did not coke.
700 } 765 }	2.81	70.87	26.32	0.85	10,679	65.0	Did not coke.
340 } 737 }	8.11	73.63	18.26	1.35	11,664	62.5	Coke fair.

No.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	British thermal units, per pound.	Residue.	
						Yield, per cent.	Character.
257 } 736 }	2.52	85.16	12.32	1.76	12,414	68.8	Coke fair.
753 } 769 }	7.54	63.38	29.08	3.17	11,248	68.0	Did not coke.
341 } 742 }	1.91	81.06	17.03	2.95	11,914	68.7	Coke good.
396 } 738 }	2.47	83.41	14.12	1.38	12,090	75.0	Coke good.
698 } 741 }	2.47	79.44	18.09	2.23	12,083	68.0	Did not coke.
Average......	4.26	76.35	19.39	1.91	11,610	6.76	....

A study of Tables V and VI gives some very interesting results:

First. The highest yield of gas was not from a coal containing the largest amount of volatile combustible matter. The highest gas yield, 7,780 cubic feet per ton, was from a coal from Parker county, containing 39.50 per cent of this matter, whereas a coal from Webb county of 54 per cent (the highest percentage observed) gave 7,320 cubic feet of gas per ton. Each per cent of volatile combustible matter in the one coal gave 1.97 cubic feet of gas and in the other coal 1.36 cubic feet.

Second. The lowest yield of gas, 5,752 cubic feet, per ton, was not from a coal containing the lowest amount of volatile combustible matter. This particular coal, from Erath county, contained 41.95 per cent of this matter, whereas a coal from Maverick county of 33.70 per cent (the lowest percentage observed) gave 6,926 cubic feet of gas per net ton.

Third. The coal giving the highest heat value in the gas, viz., 724 B. t. u. per cubic foot, was from the Rio Grande Coal Co., Webb county, and the coal giving the lowest heat value in the gas, viz., 462 B. t. u. per cubic foot, was from Wise county, the yield of gas being, respectively, 6,600 and 7,058 cubic feet per net ton.

Fourth. The Carboniferous coals, Nos. 246, 247, 257, 753, 341, 396 and 698, contain, on the average, 39.05 per cent of volatile combustible matter and yield, on the average, 6,894 cubic feet of gas per net ton, with 566 B. t. u. per cubic foot.

The Cretaceous coals, Nos. 248, 249, 250, 251, 744, 699, 700, 341, and 802, contain, on the average, 41.8 per cent of volatile combustible matter and yield, on the average, 6,711 cubic feet of gas per net ton, with 621 B. t. u. per cubic foot.

Fifth. Of the seven Carboniferous coals, two (Strawn coal, Palo Pinto county, and Texas & Pacific coal, Erath county), gave a good coke; one, from Parker county, gave a fair coke, and four showed no coking qualities. Of the seven Cretaceous coals examined for coking qualities, three gave a fair coke, one coked feebly and three showed no coking qualities. The three Cretaceous coals giving a fair coke were from the Cannel Coal Co., and the Rio Grande Coal Co., Webb county; and the International Coal Mines Co., Maverick county.

Sixth. Three of the coals examined gave a fairly good candle-power gas. These were a coal from the Cannel Coal Company, Laredo district, Webb county, with 16 c. p.; a coal from the Santo Tomas Coal Company, Laredo district, with 15.4 c. p.; and a coal from the International Coal Mines Company, Eagle Pass, Maverick county, with 12.4 c. p. A coal from the Olmos Coal Company, Eagle Pass, gave 10.00 c. p.

These coals are all Cretaceous and gave a fairly good coke, with ash ranging from 13 to 18 per cent and sulphur from 2 to 2.25 per cent.

Seventh. The highest heat value, 12,604, expressed as British thermal units (B. t. u.) per pound, on dry basis, was observed in a coal from the Cannel Coal Co., Laredo, Webb county. Coal from the International Coal Mines Co., Eagle Pass, Maverick county; from the Texas & Pacific Coal Co., Thurber, Erath county; from the Santo Tomas Coal Co., Laredo; and from the Strawn Coal Mining Co., Strawn, Palo Pinto county, also contained more than 12,000 B. t. u.

On the average, the Carboniferous coals contain 11,484 B. t. u. per pound; and the Cretaceous coals, 11,493, on dry basis.

Eighth. On the average, the Carboniferous coals contain 13.28 per cent of ash, and the Cretaceous coals, 15.24 per cent.

Ninth. From these investigations it would appear that we have in this State coals that are well adapted to the manufacture of both illuminating and fuel gas and that from some of them a good metallurgical coke can be made, suitable for copper, silver and lead smelting. It may not be possible to meet the severe requirements for coke used in iron smelting, where the specifications as to strength, ash and sulphur are more rigid.

We have not investigated any of these coals with reference to the yield and quality of the tar and ammoniacal liquor. As some of them are high in nitrogen, it is likely that they would yield a liquor rich enough in ammonia compounds to render the manufacture of sulphate of ammonia attractive. But this method of utilizing by-products can be profitably applied only in comparatively large establishments, using from 10,000 tons of coal a year to 20,000 and upwards.

The coal that yielded a 16 candle-power gas contained 3 per cent of nitrogen and yielded 7,320 cubic feet of gas per net ton. From a ton of such coal it would be possible to obtain at least 25 pounds of sulphate of ammonia, worth 75 cents. A gas plant using 10,000 tons a year could produce $7,600 worth of this material, and 732,000,000 cubic feet of gas of more than 600 B. t. u. per cubic foot. In heat units this gas would compare very favorably with the natural gas now used in Texas, as also with the best oil or water gas.

CHAPTER V.

GAS.

The fuel gas used in Texas may be classed under two general headings, namely:

1. Manufactured

a. City gas.
b. Producer gas.

2. Natural.

1. Manufactured Gas: a. City gas:

During the year 1912, according to statistics gathered by the United States Geological Survey, the total quantity of fuel gas (city gas) sold in Texas was 787,898,000 cubic feet, of which 70,-652,000 cubic feet, or about 9 per cent, was coal gas, and 717,-246,000 cubic feet, or 91 per cent, were oil and water gas. The price per 1,000 cubic feet for the oil and water gas was $1.21, and for the coal gas $1.42.

The statistics since 1902 are incomplete, with respect to coal gas, as they were not obtained for the years 1906, 1909, 1910 and 1911. For the other seven years, inclusive of 1912, the total quantity of coal gas sold for fuel was 713,101,000 cubic feet, of an average value of $1.36 per 1,000 cubic feet. The following Table, No. VIA, gives the production and distribution of coal gas and by-products from coal since 1902, with the exception of the years just noted.

Table VIA.

Production and Distribution of Coal Gas and By-Products from Coal in Texas—1902-1912. Arranged from Statistics of the United States Geological Survey.

Year.	No. of establishments.	Coal, carbonized, short tons.	Coke.		Tar.		Total quantity gas produced in M. cubic feet.	Gas sold for illuminants.		Fuel gas sold.		Fuel gas.	Total value of all gas sold.
			Yield, short tons.	Value per short ton.	Yield, gallons.	Value per gal. Cents.		Quantity in M. cubic feet.	Value per M. cubic feet.	Quantity in M. cubic feet.	Value per M. cubic feet.	Per cent of total.	
1902..........	9	15,257	9,162	$5.30	218,943	9.5	142;415	79,547	$1.82	47,942	$1.44	33.6	$ 214,479
1903..........	8	15,653	8,755	5.72	.154,629	8.6	139,400	75,515	1.75	56,095	1.31	40.2	205,949
1904..........	9	16,560	10,114	6.02	185,364	7.5	149,975	60,512	1.76	78,677	1.34	52.5	211,962
1905..........	10	19,188	11,984	4.55	236,341	6.4	177,287	60,402	1.75	106,515	1.38	60.1	253,566
1907..........	7	28,282	12,049	4.68	225,394	5.6	251,233	53,281	1.66	167,886	1.33	66.8	312,792
1908..........	8	30,461	8,733	4.55	101,580	5.7	284,650	53,717	1.83	185,534	1.29	65.2	239,251
1912..........	4	9,581	/2,548	4.88	88,680	5.3	90,220	3,697	1.30	70,652	1.42	78.3	105,038
Total and average...	....	134,982	63,345	$5.10	1,210,931	6.9	1,235,181	386,671	$1.69	713,101	$1.36	56.7	$1,543,037

The total amount of coal carbonized was 134,982 tons, from which there were produced 63,345 tons of coke, of an average value of $5.10 a ton; 1,210,931 gallons of tar, of an average value of 6.9 cents a gallon; 1,235,181,000 cubic feet of gas, of which 386,671,000 cubic feet, or 43.3 per cent, were sold for illuminating purposes, at $1.69 per 1,000 cubic feet, and 713,101,000 cubic feet, or 56.7 per cent, were sold for fuel purposes, at $1.36 per 1,000 cubic feet. The yield of gas for all purposes was 9,150 cubic feet per ton of coal and the total value of all gas sold was $1,543,037. The maximum amount of coal carbonized during any one year was 30,461 tons, in 1908. During this year there were sold 185,534,000 cubic feet for fuel purposes. In 1912, the amount of coal carbonized was 9.581 tons, and there were sold 70,652,000 cubic feet for fuel. No attempt is made in this State to utilize the ammoniacal liquor. Some of the tar is distilled for roofing and paving purposes, but this industry is not extensive.

An analysis of the tar produced by an establishment using McAlester District nut coal, from Oklahoma, has been made in our laboratory.

Analysis of Coal Tar from Oklahoma Coal.

Specific gravity.. 1.252

	Per cent.
Water	4.00
Free carbon	25.32
Ash in free carbon	0.40
Coke yield	38.08
Ash in coke	0.22

The distillation gave:

	Per cent.	Specific gravity.
Ammonia water	4.10	....
Light oil	2.97	0.981
Intermediate oil	6.24	0.990
Heavy oil	11.84	1.090
Anthracene oil	5.51	....
Pitch	68.39	....
Loss	0.95	....
Total	100.00	

The distillation of the light oil gave:

	Per cent.
Water	9.23
To 284 deg. F. (raw benzol I)	31.80
To 348 deg. F. (raw benzol II)	2.57
To 383 deg. F. (carbol oil)	17.90
Residue	37.90
Loss	0.60
Total	100.00

The distillation of the intermediate oil gave:

	Per cent.
To 284 deg. F	0.60
To 348 deg. F	0.58
To 383 deg. F	12.15
To 428 deg. F	56.60
Residue	28.10
Loss	2.07
Total	100.00

The distillation of the heavy oil gave:

	Per cent.
To 383 deg. F	0.48
To 428 deg. F	33.22
To 518 deg. F	48.21
Residue	18.00
Loss	0.09
Total	100.00

From 1,000 gallons of this tar there could be recovered:

Commercial benzine, gallons	8
Solvent naptha, gallons	3
Heavy naptha, gallons	42
Wood preserving oils, including creasols, gallons	170
Napthalene, pounds	739
Pure phenol, pounds	32
Medicinal cresol, pounds	43
Technical cresol, pounds	15
Pitch, melting point 106 deg. F., pounds	7,100

During the last few months we have made a number of analyses of coal gas supplied to a Texas city of about 35,000 inhabitants. This gas is, for the most part, coal gas, but a little oil and water gas is mixed in. The average composition of this gas was as follows (23 analyses):

	Per cent.
Carbonic acid	5.5
Illuminants	7.4
Oxygen	0.9
Hydrogen	45.8
Carbon monoxide	9.6
Methane	19.8
Nitrogen (by diff.)	11.0
Total	100.0

During this period the average candle-power was 15 and the average British thermal units per cubic feet were 546, by Junkers Calorimeter. In this city the quantity of fuel gas sold in 1912 was about 68,000,000 cubic feet, at the following prices per 1,000 cubic feet:

	Amount.
Less than 10,000 cubic feet, $1.50 .... less 20 per cent	$1 20
From 10,000 to 20,000 cubic feet .... net	1 00
20,000 cubic feet and more .... net	0 90

On these terms, the cost of 100,000 cubic feet would be:

	Amount.
First 10,000 cubic feet	$13 00
Second 10,000 cubic feet	10 00
Remaining 80,000 cubic feet	72 00
Total	$95 00

This gives an average cost of 95 cents per 1,000 cubic feet. The maximum production of fuel gas in any one establishment during 1912 was 340,000,000 cubic feet, and the selling price was $1.00 per 1,000 cubic feet.

The United States Geological Survey has also collected statistics of the production and distribution of oil and water gas, in Texas, for the years 1905, 1907, 1908, and 1912. No statistics are available prior to the year 1905. The following Table, No. VIB, has been prepared from these statistics, and sets forth the number of establishments, the yield and value of the tar, the total quantity of gas produced, the distribution of the gas, whether sold for illuminating or fuel purposes, the quantity of fuel gas expressed as percentage of the total, and the total value of all gas sold. The returns in regard to the tar in 1908 are included with those from Florida, Louisiana and Mississippi and in 1912, with those from Alabama in addition.

NOTE.—The gas coke made from Oklahoma coal at a plant in Texas contains volatile combustible matter 3.32, fixed carbon 76.76, ash 16.52 and moisture 3.40. The sulphur was 1.28 and the B. t. u. per pound 11,322.

Table VIB.

Production and Distribution of Oil and Water Gas and By-Products in Texas—1905-1912. Arranged from Statistics of the United States Geological Survey.

Year.	No. of establishments.	Tar.		Total quantity of gas produced in M. cubic feet.	Illuminating gas sold.		Fuel gas sold.		Fuel gas, per cent of total.	Total value of all gas sold.
		Yield in gallons.	Value per gallon. Cents.		Quantity in M. cubic feet.	Value per M. cubic feet.	Quantity in M. cubic feet.	Value of M. cubic feet.		
1905	7	23,900	5.0	231,992	93,511	$1.51	196,960	$1.40	61.2	$418,754
1907	10	102,781	2.7	591,644	191,529	1.35	335,849	1.27	56.8	686,106
1908	11	*558,714	2.7	671,360	286,206	1.27	306,458	1.27	45.7	754,732
1912	16	†668,702	2.5	1,149,840	303,559	1.19	717,246	1.21	62.4	1,231,923
Total and average	....	....	....	2,734,836	874,805	$1.28	1,556,513	$1.27	56.9	$3,091,515

*Includes also Florida, Louisiana and Mississippi.
†Includes also Alabama, Florida, Louisiana and Mississippi.

A study of this table shows that:

1. There were produced, during the years mentioned, 2,734,-836,000 cubic feet of oil and water gas, as against 803,390,000 cubic feet of coal gas during the same period. The production of oil and water gas was more than three times as large as that of coal gas.

2. The quantity of illuminating gas sold was 874,805,000 cubic feet, at an average price of $1.28, as against 171,097,000 cubic feet of coal gas at an average price of $1,73 per 1,000 cubic feet.

3. The quantity of fuel gas sold was 1,556,313,000 cubic feet, at an average price of $1.27, as against 530,587,000 cubic feet of coal gas at an average price of $1.34.

4. The fuel gas expressed as percentage of the total ranged from 45.7 to 62.4, with a general average of 56.9, which is almost exactly the general average for the fuel gas made from coal, expressed as percentage of the total.

We have made a number of analyses of the oil and water gas supplied to a Texas city of about 35,000 inhabitants, the same as mentioned under coal gas, and have found the average composition to be as follows:

	Per cent.
Carbonic acid	2.3
Illuminants	10.1
Oxygen	0.9
Hydrogen	36.3
Carbon monoxide	28.0
Methane	6.8
Nitrogen (by diff.)	15.6
Total	100.0
British thermal units, per cubic foot	573

For comparing the composition of oil and water gas with that of coal gas, made in the same city and by the same company, we state the two together:

	Coal gas.	Oil and water gas.
Carbonic acid	5.5	2.3
Illuminants	7.4	10.1
Oxygen	0.9	0.9
Hydrogen	45.8	36.3
Carbon monoxide	9.6	28.0
Methane	19.8	6.8
Nitrogen (by diff.)	11.0	15.6
Total	100.0	100.0
British thermal units, per cubic foot	546	573

In the coal gas (with a small admixture of oil and water gas) the carbonic acid was 2.4 as much as in the oil and water gas; the oxygen was the same; the hydrogen was 1.26 as much, and the methane was 2.9 as much. In the oil and water gas, however, the illuminants were 1.39 as much as in the coal gas, and the carbon monoxide was 3 times as much. The British thermal units in the two gases were practically the same. These analyses are representative of those made over a period of three years.

In each case the British thermal units were made in a Junkers Continuous Gas Calorimeter of the latest design, and were not calculated from the analysis. Particular attention is called to this because of the variation in the British thermal units obtained by calculation, according to the factors used. Thus, if we take the following analysis, viz.:

	Per cent.
Illuminants	7.4
Hydrogen	45.8
Carbon monoxide	9.6
Methane	19.8

and calculate the heat units by the factors 1580 for illuminants, 324 for hydrogen, 324 for carbon monoxide and 1010 for methane (the factors used in some producer gas plants), we have B. t. u. 458, as against 546 by actual determination. If, for an initial temperature of 60 degrees F. and a final temperature of 328 degrees F., we take the factors 1700 for illuminants, 264 for hydrogen, 315 for carbon monoxide, and 853 for methane, we have B. t. u. 446. Again, if we take the factors 2000 for illuminants, 326 for hydrogen, 324 for carbon monoxide, and 1010 for methane, we have B. t. u. 528, as againset 546 by determination. In case the heat units have to be determined by calculation, when the sample of gas is not sufficient for the calorimeter, we use the following factors:

	Factors.
Illuminants	2,000
Hydrogen	326
Carbon monoxide	324
Methane	1,010

For securing considerable quantities of gas, we use a steel cylinder capable of holding 50 cubic feet under a pressure of 30 pounds.

The consumption of fuel gas in Texas for the year 1912 was about as follows:

	Cubic feet.
Manufactured gas (city gas)	787,898,000
Natural gas	7,470,373,000
Producer gas (made mostly from lignite)	3,250,000,000
Total	11,508,271,000

The figures for producer gas are approximate, but it is thought that the total consumption of fuel gas of all kinds during the year 1912 was between eleven and twelve billion cubic feet. The consumption during the year 1913 will probably be considerably larger.

Owing to the increasing cost of gas oil and, to some extent also, to local conditions, there is a tendency towards the manufacture of coal gas. One establishment which used a combination of the Lowe system and oil and which sold, in 1912, 68,519,000 cubic feet of fuel gas, has erected retorts for coal gas, using Oklahoma coal.

In most, if not all, of the cities and towns using manufactured gas, the illuminating and fuel gas are conveyed through the same pipes.

No statistics have been gathered as to the cost of manufacturing city gas in Texas, but it is likely that an average of 45 cents per thousand cubic feet is not far from the truth.

Manufactured gas is largely used for domestic purposes, whereas natural gas is largely used for industrial purposes. The heat units in the best natural gas are a good deal higher than in the best manufactured gas, but, as a general rule, there are only from 150 to 200 more B. t. u. per cubic foot in the natural gas used in Texas than in the manufactured gas. Many gas engines of comparatively small horse-power are operated on manufactured gas, but some of the gas engines operated on natural gas and lignite producer gas are of 1,000 horse-power.

The use of the candle-power as a standard for gas is of but little value in this part of the country and under the conditions that are likely to maintain. There is no longer any considerable illumination from gas direct, for the extensive introduction of the Welsbach and other 'mantles' has done away with the old-fashioned gas burners. The encroachments of electric lighting have also been a serious factor in the gas industry, especially since the introduction of the metallic filament. Acetylene, blau-gas, etc., have also added to the competition.

A striking illustration of the advantages to be derived from the use of an incandescent 'mantle' is shown by the fact that gas distilled from lignite can be made to yield an illumination equivalent to 40 candle power, although the gas itself has a very low candle power.

It is much to be desired that the "British thermal unit per cubic foot" should replace the "candle-power," as a standard for gas. When the British thermal unit per cubic foot is given, a statement should be made whether the figures are from direct determination in some accepted calorimeter or from calculation, the factors used being given in the latter case.

As the greater quantity of gas made or produced in Texas is used for fuel purposes, the change of the standard from candle-power to British thermal units per cubic foot would entail no hardships in the trade, upon producer or consumer.

Manufactured Gas:—b. Producer Gas.

Producer gas in Texas is made almost entirely from lignite, and the following pages give the chief points of interest in connection with this business. It will be seen that during the year 1912 there were used about 65,000 tons of lignite for this purpose, no attempt being made to save the by-products such as tar, ammoniacal liquor, etc.

The Use of Raw Lignite in Gas Producers.

In Bulletin No. 189, University of Texas, issued in 1911 and entitled "The Composition of Texas Coals and Lignites and the Use of Producer Gas in Texas," there was a special chapter on this subject, prepared by Drury McN. Phillips, who was in the producer-gas department of the Southwestern States Portland Cement Company, at Eagle Ford, near Dallas.

At that time there were in the State fifty-six producers for making gas and forty-seven in active operation, representing 12,270 horse-power. There were twenty-three establishments using Texas lignite exclusively, with a total consumption of about 180 tons per twenty-four hours and a total engine horse-power of 11,490.

Most of the installations were and are still of comparatively small size, as the three cement plants (at Eagle Ford, Harry and near San Antonio) represent 9,000 engine horse-power out of the total of 11,490. Since Bulletin No. 189 was issued, one large cement plant has changed from lignite producer gas to natural gas.

It does not seem to be necessary at this time to repeat the statistics gathered in 1911, so we shall merely give the items of chief interest and then discuss, briefly, the condition of the industry at the close of the year 1912. As the lignite area in Texas represents about one-half of the total known area in the United States, and as the production here is twice as great as from any other State, so the use of lignite in Texas for making producer-gas is largely in excess of such use in all of the other States combined. Texas leads the entire country in area, production and utilization of lignite.

In Bulletin No. 261, 1905, United States Geological Survey, there are given the results of using Texas lignites in gas producers at the fuel testing plant, St. Louis. These tests were under the care of Mr. Robert H. Fernald, now professor of mechanical engineering in the University of Pennsylvania. As we gave the results obtained in our Bulletin No. 189, above referred to, it is not necessary to repeat them here in detail and we shall merely quote the chief points of interest:

Lignite from the Houston County Coal and Manufacturing Company, Crockett, Houston county, gave 28.4 cubic feet of gas per pound of raw lignite consumed, in a No. 7 Wood producer, and this gas showed 169.7 B. t. u. per cubic foot. The average composition of the gas was:

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

Per brake horse-power developed at the engine there were consumed 2.54 pounds of lignite, on an assumed efficiency of 85 per cent for generator and belt.

Lignite from the Consumers Lignite Company, Hoyt, Wood county, gave 34.2 cubic feet of gas per pound of lignite and this gas showed 156.2 B. t. u. per cubic foot. The average composition of the gas was:

	Per cent.
Carbonic acid	9.60
Carbon monoxide	18.22
Hydrogen	9.63
Methane	4.81
Nitrogen	57.53
Oxygen	0.20

Per brake horse-power developed at the engine, there were consumed 1.98 pounds of lignite, on an assumed efficiency of 85 per cent for generator and belt.

In Bulletin No. 332, United States Geological Survey, 1908, there are given the results of producer gas tests on lignite from J. J. Olsen & Sons, Rockdale, Milam county. The yield of gas is not given, but the B. t. u. per cubic foot were 171.8. The composition of the gas was:

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

Per brake horse-power developed at the engine, there were consumed 2.17 pounds of lignite.

The Westinghouse Machine Company, Pittsburg, Pennsylvania, in its circular W. M. 503, September, 1909, gives the results of testing lignite from the Consumers Lignite Company, Hoyt, Wood county, as follows:

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 leakage or for gas consumed by three pilot lights burning continuously in the producer house, laboratory and engine room.

Another test made by this company on the same lignite showed a gas yield of 49.03 cubic feet of gas per pound of lignite fired, the gas giving 128.3 B. t. u. per cubic feet, total, and 117.1 B. t. u. effective. The composition of the gas was:

	Per cent.
Carbonic acid	12.4
Carbon monoxide	13.3
Hydrogen	14.7
Methane	3.6
Nitrogen	55.1

The Smith Gas Power Company, Lexington, Ohio, is authority for the statement that a certain plant using Texas lignite for an 80-horse-power installation saved $3.50 a day as compared with steam.

An irrigation pumping plant on the Nueces river, Nueces county, used lignite from the Bear Grass Coal Company, Jewett, Leon county, under a guarantee that one brake horse-power should be given by 2.50 pounds of lignite, the engine being rated at 225 horse-power.

A large cotton seed meal company in Houston used lignite from the Houston County Coal and Manufacturing Company, Crockett, Houston county. The specifications called for a gas of 140 B. t. u. per cubic foot and the engine was to deliver one brake horse-power for each 10,000 effective heat units. In this establishment the consumption of lignite was said to be 1.75 pounds per brake horse-power.

In a report made by Drury McN. Phillips and by permission of the Southwestern States Portland Cement Company, Eagle Ford, near Dallas, very complete returns were available in regard to operations there. Six Harvey producers were in use and two sets of figures were secured. In the first case, the total lignite charged was 116,280 pounds in twenty-four hours, or 4,845 pounds per hour; the lignite coming from the Consumers Lignite Company, Hoyt, Wood county, and costing $1.62 a ton, delivered. The total number of kilowatt hours was 16,330 (=21,882 horse-power hours) and the consumption of lignite was, on the average, 3.6

pounds per k. w. hour (=2.7 pounds per h. p. hour). The cost of the fuel was 2.18 mills per horse-power hour.

In the second case, the total lignite charged was 117,640 pounds in twenty-four hours, or 4,902 pounds per hour. The total number of kilowatt hours was 16,010 (=21,453 horse-power hours) and the consumption of lignite was 3.2 pounds per kilowatt hour (=2.4 pounds per horse-power hour).

Taking this test as a whole there were used 233,920 pounds (=116.96 tons) of lignite, with a production of 66,740 kilowatt hours (=89,411 horse-power hours), 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, delivered, this represented a raw fuel cost of 2.83 mills per kilowatt hour (=2.11 mills per horse-power hour).

The B. t. u. per cubic foot, during the first run, varied from 106.3 to 139.9, the average being 119.8 During the second run, the B. t. u. per cubic foot varied from 116.0 to 138.0, the average being 127.1.

The average composition of the gas, during the two runs, was as follows:

	First run, per cent.	Second run, per cent.
Carbonic acid	10.8	10.3
Carbon monoxide	14.3	12.6
Hydrogen	8.1	8.7
Methane	3.5	4.8
Oxygen	0.6	0.5
Nitrogen	61.9	62.4
Ethylene	0.8	0.4

The heat units were determined by calculation, the factors used being for:

Carbon monoxide	324
Hydrogen	324
Methane	1010
Ethylene	1580

At this establishment the equipment consisted of six Harvey up-draft pressure producers and three 750 k. w. Allis-Chalmers horizontal two-cylinder tandem double-acting gas engines. On the main shaft there were Allis-Chalmers generators of 2,300 volts.

So far as could be ascertained, the consumption of lignite in

1911, for making producer gas, was about 180 tons a day. Several plants ran intermittently so that it is not likely that the total consumption of lignite during the year, for this purpose, exceeded 50,000 tons. If we allow that a ton of lignite yields 50,000 cubic feet of gas in a producer, we would have 2,500,000,000 cubic feet of gas from the 50,000 tons. If we allow, further, that this gas carried, on the average, 125 B. t. u. per cubic foot, we would have a total output of 312,500,000,000 B. t. u. for the year. This amount of heat would exaporate 32,000,000 pounds of water from and at 212 degrees F.

During the year 1912, so far as could be ascertained, the consumption of lignite in gas producers was about 65,000 tons, a gain of 15,000 tons, or 30 per cent over the returns for the year 1911. The delivery prices varied from 75 cents to $3.32 a ton according to quality and distance hauled.

One large consumer reports the use of 32,898 tons of lignite at $1.50 a ton, the yield of gas being 69,000 cubic feet per ton. Another reports the use of 7,600 tons at $1.60 a ton, and a calorimeter card, typical of the practice there, shows a gas of very uniform heat value, from 135 to 165 B. t. u. per cubic foot.

Lignite screenings, costing from 75 cents to $1.00 a ton, are also used in gas producers with satisfactory results.

There is practically no recovery of by-products in producer gas practice in Texas. At some of the plants the tar is burned under auxiliary steam boilers and at others a little tar is used for "creosoting" telephone poles, etc. No tar is distilled, nor is there any attempt to utilize the ammoniacal liquor.

It is not the custom here to meter the gas, so that there are but few reliable statistics as to the yield of gas per ton of lignite. One consumer, already referred to, reports the use of 32,898 tons of lignite during the year 1912, and says that the yield was 69,000 cubic feet per ton. This may be in excess of the average yield, but we have no means of ascertaining whether it is or not. For purposes of calculation, we would prefer to take 50,000 cubic feet of 125 B. t. u. gas per ton of lignite, and be on the safe side.

During the last year there has been considerable interest in the establishment of a central power plant located at or near some of the lignite mines and the matter has been looked into carefully.

The plans contemplated the erection of a modern producer gas plant, with recovery of by-products, such as tar and ammonia, and the wiring of electric power to cities, towns, cotton gins, irrigation installations, etc. From some of the lignites available, it would be possible to recover from 75 to 100 pounds of sulphate of ammonia per ton of lignite and this is worth from 2½ to 3 cents a pound, with a steady market all the year round.

If we allow that the 65,000 tons of lignite used in gas producers in Texas in 1912 could have yielded 50 pounds of sulphate of ammonia per ton (a very reasonable assumption) the total value of this salt, at 2½ cents a pound, would be $81,250.

Owing to the scattered locations of the producer plants it is impossible to recover the sulphate of ammonia from all of them, so we can confine the matter more closely.

The plant that used 32,898 tons of lignite could have recovered sulphate of ammonia to the value of $39,122.

The plant that used 7,600 tons could have recovered sulphate of ammonia to the value of $9,500, so that these two plants could have recovered $48,622 worth of this valuable material, all of which was lost.

A central power plant, using 200 tons of lignite a day, could produce, in one year, sulphate of ammonia to the value of $136,875, to say nothing of the value of the tar and the products obtainable from it by distillation. Furthermore, these estimates do not include the value of the electric current to be secured from generators operated by gas engines.

The value of this current would depend almost entirely upon the location of the plant with reference to power consumption, not with reference to population except as this may imply the consumption of electric power. Thus, in north and north central Texas, within 100 miles of large deposits of lignite, the population of twenty cities and towns is about 350,000; but we do not know what are the power requirements in this area, inclusive, not only of the cities and towns, but also of smaller rural establishments. Electric power is already supplied to the larger cities and towns, so that any new supply would have to compete with a business which is active and progressive. It is not as though one was going into new territory, unoccupied by electric plants, but he would have to invade a territory fairly well supplied at present. This could be done successfully only by providing cheaper power or more uniform and dependable power. With the recovery of valuable by-products from the central power plant, both of these requirements could be met, but without such recovery the investment does not appear to be attractive.

In 1909, the Consumers Lignite Company, Dallas, Texas, sent several carloads of Hoyt lignite to the Westinghouse Machine Company, East Pittsburg, Pa., for testing in gas producers. The following is the complete report, made by Mr. H. E. Longwell, consulting engineer:

"October 23, 1909.

We beg to report that the several carloads of Hoyt lignite, received from your company, have been carefully tried out in our testing plant at East Pittsburg to determine the question of the suitability of this fuel for use in gas producers, and the results have been highly satisfactory.

The gas was free from tar, and averaged 128.3 B. t. u. total, and 117.1 B. t. u. effective, per cubic foot, at 30 inches barometric pressure, and a temperature of 62 degrees F.

We have experienced no trouble with clinkering, and the labor required to operate the producer and keep the fires in good condition is noticeably less than with a coking coal. In fact, the operator must be cautioned *not* to poke the fire too much, as we have found that too zealous poking is not only unnecessary, but is absolutely deterimental in operating the producer with this fuel. As compared with Pocahontas, or any other high-grade bituminous coal, the value of your lignite for use in a gas engine and producer plant is practically in direct ratio to the British thermal units in a pound of the respective fuels.

This has been determined by comparative tests with Pocahontas coal made under the same conditions as the tests made with your lignite. Summaries of the tests are given below:

	Fuel.	
	Hoyt lignite.	Pocahontas coal.
Duration of test	46½ hours	72 hours
Total coal used	12,693 lbs.	10,699 lbs.
Average load of engine	151.5 brake h. p.	149.2 brake h. p.
Gross coal per brake-horse-power hour	1.8 lbs.	0.996 lbs.
B. t. u. per pound of coal	8,007	13,983
B. t. u. per brake-horse-power hour	14,412	13,927

In this case there is a variation of 3½ per cent in the number of British thermal units supplied per brake horse-power, but we should consider that this difference is well within the limit of agreement that we would expect between two tests made with the same kind of fuel.

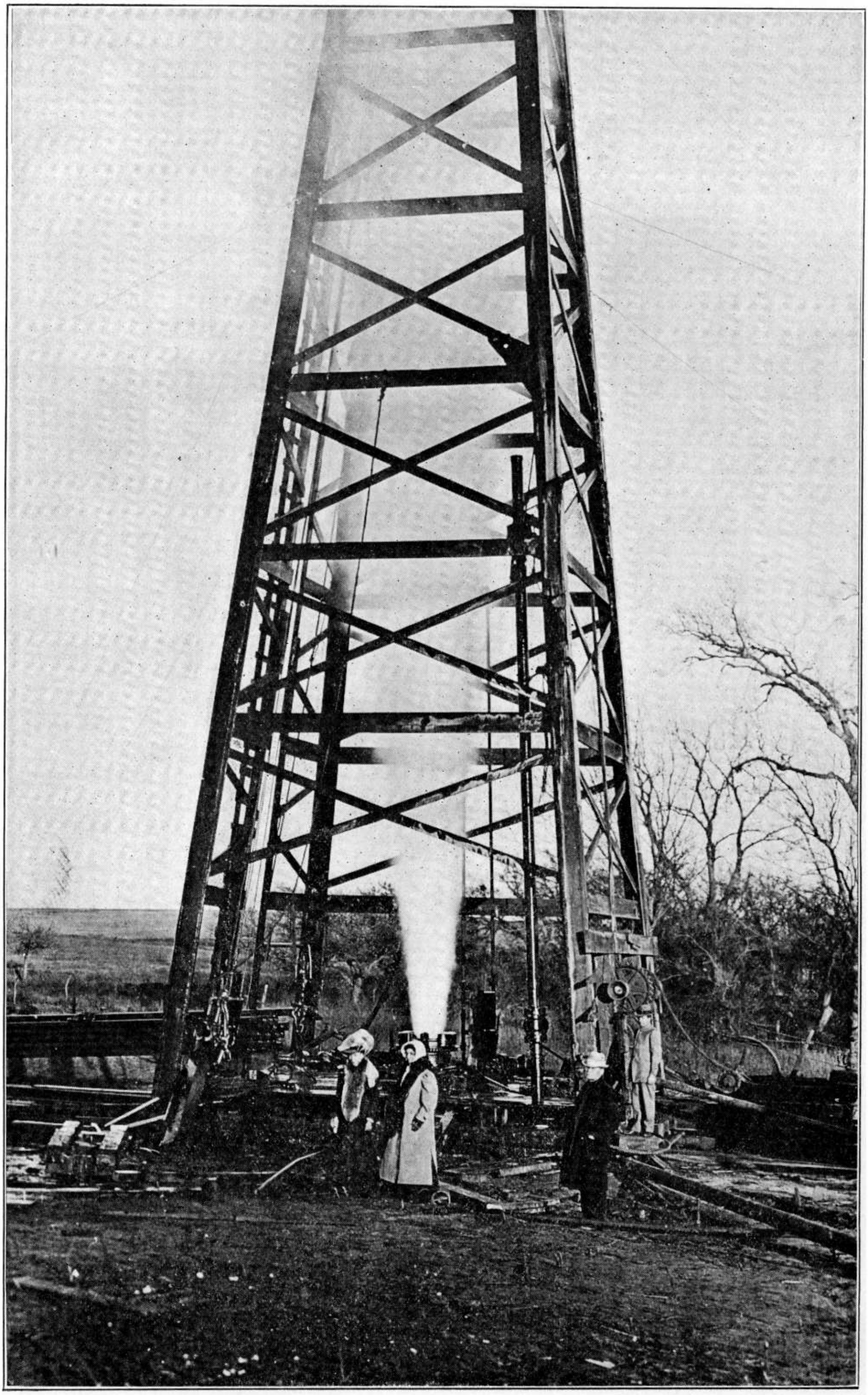
Two other tests at approximately 125 horse-power show very much closer agreement:

	Fuel.	
	Hoyt lignite.	Pocahontas coal.
Duration of test	72 hours	48 hours
Total coal used	16,970 lbs.	6,403 lbs.
Average load of engine	128 brake h. p.	126.3 brake h. p.
Gross coal per brake-horse-power hour	1.85 lbs.	1.06 lbs.
B. t. u. per pound of coal	8,007	13,983
B. t. u. per brake-horse-power hour	14,812	14,821

From the foregoing tests it will be readily seen that with a suitably designed producer, the brake horse-power developed by the engine is only a matter of the number of British thermal units in the fuel supplied hourly to the producer, and it is immaterial whether this number of British thermal units is contained in a given quantity of Pocahontas coal averaging 14,000 B. t. u. per pound, or in a proportionately greater quantity of Hoyt lignite averaging only about 8,000 B. t. u. per pound.

We were somewhat fearful that the extra weight of lignite required to develop a given power might necessitate a proportionately larger producer than would be required for coal of a higher heat value. This we found not to be the case. As a large portion of the weight of the lignite consists of moisture and combustible matter that is already in a volatile state, the additional quantity of fuel charged hourly does not mean that the producer is really being worked with any greater intensity.

For your information we give below the comparative proximate



The Miller Gas Well, Petrolia, Clay County—Lone Star Gas Co.

analyses of the Hoyt lignite, and Pocahontas coal tested, also comparative analyses of the gas from the two kinds of fuel:

Coal Analyses

	Hoyt lignite, per cent.	Pocahontas coal, per cent.
Moisture	23.83	1.39
Volatile matter	38.32	16.01
Fixed carbon	29.22	74.28
Ash	8.63	8.32
	100.00	100.00
B. t. u. per pound, by calorimeter	8,007	13,983

Gas Analyses

	Hoyt lignite, per cent.	Pocahontas coal. per cent.
Carbon dioxide	12.4	7.9
Oxygen	0.9	0.5
Carbon monoxide	13.3	18.1
Methane (marsh gas)	3.6	2.6
Hydrogen	14.7	12.6
Nitrogen	55.1	58.3
	100.0	100.0
Total heat value per cubic foot	128.3 B. t. u.	126.9 B. t. u.
Effective heat value per cubic foot	117.1 B. t. u.	117.8 B. t. u.

It is proper to add that the lignite as tested at our East Pittsburg plant had lost considerable of its moisture in transit, and in storage. With freshly mined lignite we should expect the B. t. u. value per pound to be less than in the samples tested, by reason of the probably higher moisture content, and as a consequence we should expect the fuel consumption per brake horsepower per hour to be proportionately higher than shown on our tests with the partially dry fuel.

However, this does not affect the main point of interest, i. e., that in a suitable type of producer this lignite can be utilized not only conveniently, but as efficiently in proportion to its actual thermal value as any fuel whatsoever."

As to the advantage of using producer gas, Mr. William Morey, Jr., has stated the matter in an excellent manner. He says[1]:

"The combined efficiency attainable in the best steam engines and boilers, operating under the most favorable conditions, is about

[1]The Americana, Vol. IX, Article—Gas Producer.

12 per cent of the intrinsic heat energy of the fuel used. On the other hand, the modern gas engine, even in small powers, will give an efficiency much higher, but if it be supplied with illuminating gas for fuel, a large amount of the economy due to the higher efficiency is lost in the cost of the gas. Heat energy in the form of coal gas at a dollar per thousand feet, costs thirteen times as much as an equivalent amount of energy in the form of coal at three dollars per ton; therefore, in order to utilize a gas engine to its full advantage, the gas used must be produced as economically as possible. This is exactly the function of the gas producer, and by its use a good gas engine with a theoretical thermal efficiency of 75 or 80 per cent, or a practical thermal efficiency of 25 or 30 per cent, will readily convert into actual work, or available power, 25 per cent of the heat energy of the gas delivered to it. The gas producer of such a plant will transfer to the gas abount 80 per cent of the intrinsic energy of the coal, so that a gas-producer engine operating on an inferior grade of coal will show an efficiency of 20 per cent, as against the 12 per cent of a steam engine and boiler plant using the best steaming coal."

2. *Natural Gas.*

We first quote from "The Production of Natural Gas in 1912" advance chapter from the mineral resources of the United States calendar year 1912, United States Geological Survey, prepared by B. Hill under the supervision of David T. Day.

"The year 1912 was the best in the history of the natural-gas industry of Texas and the Clay county field was the greatest source of gas supply, the Lone Star Gas Company being the principal producer. This company does not distribute gas to consumers direct, but supplies its gas to the North Texas Gas Company, the Fort Worth Gas Company, the Dallas Gas Company, and the County Gas Company, which supply consumers. The following named places were supplied with gas from the Clay county gas field in 1912: Alvord, Arlington, Bellevue, Bowie, Bridgeport, Byers, Dallas, Dalworth, Decatur, Denton, Eagle Ford, Fort Worth, Grand Prairie, Henrietta, Irving, Petrolia, Rhome, Sunset, Wichita Falls.[1]

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[1]Additional towns supplied, October, 1913; Gainesville, Whitesboro, Sherman and Denison.

We are informed by the Lone Star Gas Co., Fort Worth, Texas, under

During 1912 a total of 13 wells were drilled in Clay county, of which eight were gas producers, the number of gas wells at the close of the year being 29. Although stray gas sands are occasionally struck at 1,250 to 1,500 feet, the best wells in this field range from 1,550 to 1,750 feet. The pressure varies from 600 to 742 pounds, the highest original rock pressure of wells in this field. The average pressure on January 1, 1912, was 659 pounds and on December 31, 1912, it was 626 pounds. One well in this field not in use during 1912 never fell below 730 pounds, and for five months stood at 740 pounds. A test of gas from a number of wells in the field made by S. H. Worrell, chemist for the Bureau of Economic Geology and Technology, University of Texas, shows 700 British thermal units per cubic foot.

Second in importance to the Clay county gas field is the gas field in Webb county (Reiser field) from whose wells gas is being supplied to consumers in the town of Laredo by the Border Gas Company, which receives its supply from the Producers Oil Company. Another gas field of importance is found in Shackleford county, (Moran field), from whose wells gas is being supplied to consumers in the town of Moran by the Pioneer Natural Gas Company and to the town of Albany by the Albany Natural Gas Company, both of these companies receiving their supply of gas from The Texas Company operating in this field.

Other fields in which developments were in progress in 1912 are as follows: In Angelina county a well was drilled to a depth of 312 feet, with a showing of oil and gas; work was discontinued and the well not finished. On Holloway Mountain, northwest part of Brown county, a gas well was drilled to a depth of 306 feet,

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date of October 29, 1913, that their pipe line mileage, in main and branch lines, is as follows, in round numbers:

2 inch line	17
3 inch line	5
4 inch line	43
6 inch line	42
8 inch line	14
10 inch line	40
12 inch line	50
16 inch line	155
	366

In addition to main and branch lines, there were between 15 and 20 miles of gathering lines, from 2 inches to 10 inches, in the field.

which furnished more than enough gas to operate an engine; another well drilled in this locality to a depth of 310 feet also furnished gas to run an engine. Two gas wells were drilled in Wichita county, gas being used for field purposes. In Gonzales county a gas well was completed at 468 feet, with 150 pounds pressure, product to be used in field work. There has been completed in Limestone county (Mexia field) three good, dry gas wells, having an estimated combined capacity of 40,000,000 cubic feet. In prospecting for oil in Maverick county, considerable gas was found in one well at depths of 725, 975, and 1,041 feet; in a second well only one gas stratum, at 941 feet, was discovered, this well not being drilled deeper. The first well at a depth of 725 feet has about 50 pounds pressure, and gas has been used from it for drilling. Two wells were drilling in McCulloch county at the close of 1912; four wells completed in this county in 1912 were abandoned. In Falls county an experimental well was drilled to a depth of 760 feet, with considerable showing of oil and gas; at a depth of about 160 feet it caved and shut out prospective findings. Coleman county was a field of activity in 1912, but up to the close of the year only two gas wells had been completed, the product of which was used for fuel in the field.

Considerable gas produced in the oil fields of Navarro and Harris counties is consumed for field purposes. Consumers in Corsicana are supplied with gas from Navarro county wells.

In Atascosa county several artesian wells have been drilled, which produce a small quantity of gas with the water. From a few of these wells, gas is being used by the owners of the wells for illuminating and heat.

The total quantity of gas produced from wells in Texas in 1912 amounted to 7,470,373,000 cubic feet, valued at $1,405,077, an average price of 18.81 cents per 1000 cubic feet as compared with 5,503,393,000 cubic feet, valued at $1,014,945, an average price of 18.44 cents per 1000 cubic feet, in 1911. This is a gain in value of $390,132. The greater portion of the value for 1912 was received for gas supplied for domestic purposes, which aggregated $906,412, or nearly double the value of the gas consumed for manufacturing and power purposes, which was $498,665. Some gas is used in Texas for brick manufacture. For power purposes it is utilized in operating gas engines and boilers at waterworks, ice plants, cotton gins, and also largely in field work.

The total number of gas wells in this State was 87 at the close of 1912, of which 24 were drilled in 1912. The number of dry holes drilled was 23, and the number of gas wells abandoned was six.

In the year 1908, there were 24 producers having natural gas wells, with 1,225 domestic, and 18 industrial consumers. In the years 1908, 1909, 1910, the amount of natural gas consumed and the value were combined with the returns from Alabama and Louisiana.

In the following table is given a record of the natural gas industry in Texas from 1909 to 1912, inclusive:

Record of Natural Gas Industry in Texas, 1909-1912.

Year.	Number of producers.	Number of consumers.		Total value of gas produced.	Wells.		
					Drilled.		Productive Dec. 31.
		Domestic.	Industrial.		Gas.	Dry.	
1909	17	2,322	52	$ 127,008	7	6	38
1910	19	14,719	133	447,275	22	5	52
1911	29	22,972	303	1,014,945	19	14	69
1912	41	27,226	329	1,405,077	24	23	87

The acreage controlled by natural gas companies in Texas, is shown by the following statement, taken from the volumes of the Mineral Resources of the United States, issued by the United States Geological Survey.

Acreage Controlled by Natural Gas Companies in Texas.

Year.	Fee.	Leased.	Gas rights.	Total.
1908	155	31,455	....	31,610
1909	1,845	19,653	131,597	153,095
1910	7,394	395,335	54,685	457,414
1911	3,740	153,379	361,739	518,858
1912	7,660	153,919	6,369	167,948

In any account of natural gas in Texas mention is to be made of the promising field at Crowther, northeast part of McMullen county, where the Boston and Texas Corporation has found excellent gas under good pressure. Our analysis No. 239 in Table VII gives the composition of this gas. It had high heating value, 947 B. t. u. per cubic foot.

We have made no analysis of the gas from the Mexia fields, Limestone county, but in a pamphlet issued by the Mexia Commercial Club it is stated that the heat units were 1,060 B. t. u. per cubic foot, on the authority of H. C. Morris, of the Dallas Gas Company.

Under date of November 3, we are informed by the Mexia Commercial Club that they now have 17 producers in that field, ranging in volume from two to fifteen million cubic feet per 24 hours, making approximately 150,000,000 cubic feet production per day. The pressure of the wells is uniformly 275 pounds to the square inch, and the depth varies from 650 to 725 feet.

The composition of natural gas from Texas is given in Table VII.

TABLE VII.

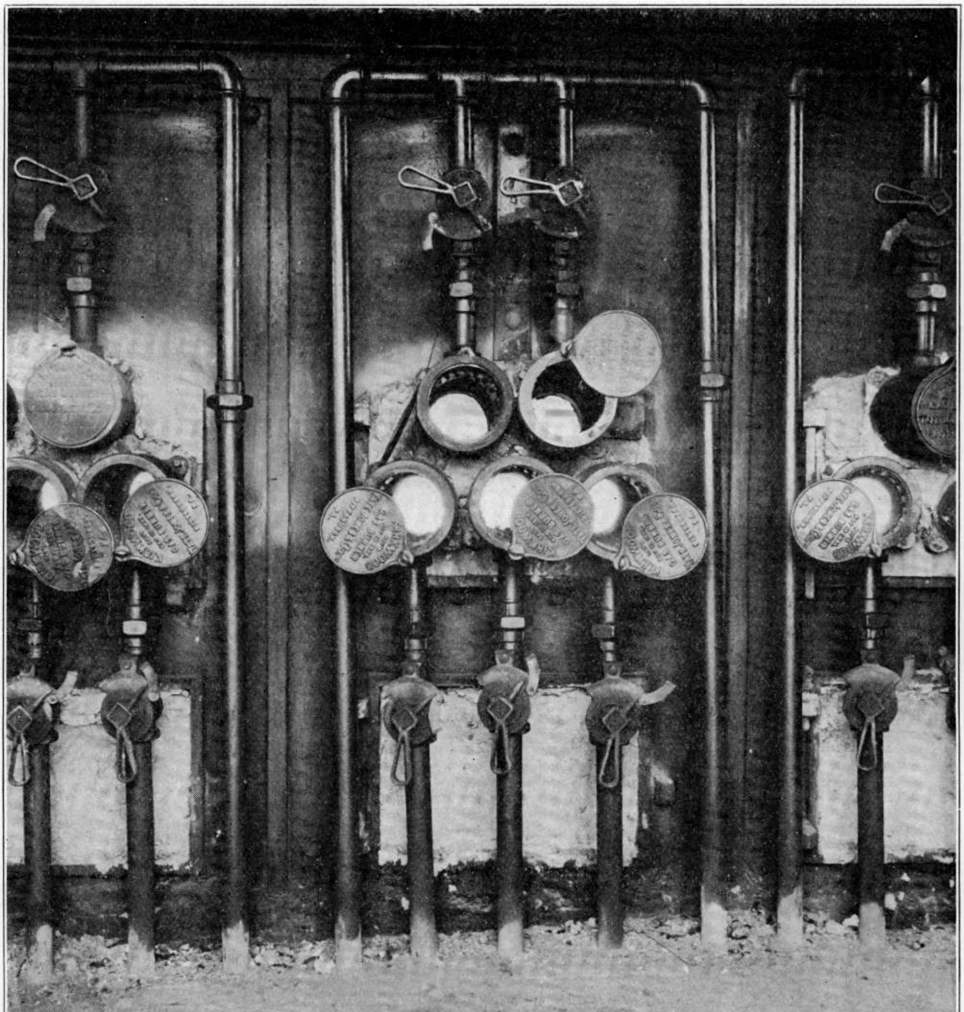
Composition of Texas Natural Gas—Analyses by S. H. Worrell.

Analysis No.	Carbon Dioxide.	Illuminants.	Oxygen.	Carbon Monoxide.	Hydrogen.	Methane.	Nitrogen (by diff.)	B. t. u. per cubic foot.	Specific Gravity.
362–367	......	......	......	......	......	......	......	700	......
144	None	None	2.2	None	None	50.3	47.5	503	......
243	None	None	None	None	None	56.0	44.0	649	......
502	None	None	None	None	None	85.4	14.6	862.5*	......
828	None	None	0.2	None	None	90.4	9.6	913	......
239	0.4	None	0.2	None	22.8	74.0	2.6	947*	0.458
166	None	None	1.4	1.2	None	34.8	62.6	300.5*	0.826
197	5.2	None	2.6	None	25.8	48.3	20.1	463*	......
696	None	None	None	None	None	80.8	19.2	835.5	......
852	None	None	None	None	None	92.0	8.0	929	0.588
311	None	None	Trace	None	None	85.2	14.8	726*	0.614
624	......	......	......	......	......	......	......	948	......
174	None	None	0.6	0.4	None	66.3	32.7	564*	......
Other Analyses.									
A	None	0.80	0.70	Trace	None	67.93	31.37	715*	......
B	0.20	0.30	0.40	......	0.80	47.2	38.6	474*	......
C	None	0.30	0.20	0.30	1.0	55.9	36.8	561*	......

Explanation of Table VII

Analyses Nos. 362-367, inclusive, represent heating power as examined in the gas from Petrolia, Clay county, for the Lone Star

*Determined by calculation from the analysis, using the following factors: Illuminants, 1,700; carbon monoxide, 315; hydrogen, 264; methane, 853; for 0 deg. F. initial and 328 deg. F. final temperature. In analysis B there was reported 12.5 per cent. and in analysis C 5.50 per cent. ethane, which is not included in the calculation of thermal units.



Kirkwood Burners for Natural Gas. Wichita Falls Light & Water Co., Wichita Falls, Wichita County.

Gas Company, Fort Worth; the average of all tests being given.

No. 443, gas from Petrolia, Clay county; taken from the main in Fort Worth, and received by us in steel tank, January 9, 1913.

Analysis No. 243, gas from Petrolia, Clay county, from service pipes in Dallas, May 20, 1912.

Analysis No. 502, from a well nine miles west of Gonzales, Gonzales county.

Analysis No. 822, from a locality 14 miles west of Crockett, Houston county.

Analysis No. 239, from Crowther, McMullen county, Boston & Texas Corporation.

Analysis No. 166, depth of 712 feet, Fleming & Davidson well, Maverick county.

Analysis No. 197, gas bubbling up through Red River, at mouth of Cash Creek, Red River county.

Analysis No. 696, sample taken from gas line, 16 miles from the wells at Moran, Shackelford county. Lone Star Gas Company, Fort Worth.

Analysis No. 852, sample taken from a spring, 1 mile east of Trinity, Trinity county, Texas.

Analyses Nos. 311, 624, and 174, gas supplied to Laredo from Reiser, Webb county, by the Border Gas Company.

A. Gas from Petrolia, Clay county. Analysis by W. M. Russell, late city gas inspector, Fort Worth.

In our Bulletin No. 246, Oil and Gas Fields of Wichita and Clay Counties, page 283, this analysis is erroneously given. The figures for hydrogen should be those for methane, as Mr. Russell reported no hydrogen. We used the analysis that was sent to us, not, however, by Mr. Russell, and regret the error.

B. Gas from Petrolia, Clay county. Analysis by United Gas and Improvement Company, Philadelphia, September, 1909.

C. Same, November, 1910.

D. Gas from Caddo, Louisiana. Analysis by F. C. Phillips, Pittsburg, Pa. This gas is supplied to Texarkana, Marshall, Atlanta and Pittsburg.

In all of these analyses the B. t. u. marked * have been calculated by the factors given above. It is fair to say that other factors are used and that they give higher results than those we employed. We believe that the lower results will approach nearer commercial requirements than the higher ones. The B. t. u. not marked, were determined in the Junkers Continuous Calorimeter in our own laboratory.

According to statistics gathered by the United States Geological Survey, the total quantity of natural gas produced in the United States in 1912 was 562,203,452 M cubic feet, with an average value of 15.04 cents per M cubic feet. West Virginia led with a production of 239,088,068 M cubic feet. Texas ranked ninth in production and total value. In the quantity of natural gas consumed, Pennsylvania easily leads all of the other states, for, in 1912, it used 173,656,003,000 cubic feet, valued at $26,486,302, or 15.25 cents per thousand. In Pennsylvania the greatest consumption was for industrial purposes and the average value of the gas was 11.45 cents per M cubic feet. For domestic purposes, the average value per M cubic feet was 24.53 cents. A great deal of gas from West Virginia is piped to and consumed in Pennsylvania.

According to Poole,[1] the variation in, and the average composition of, 21 samples of natural gas from different localities in the United States, is as follows:

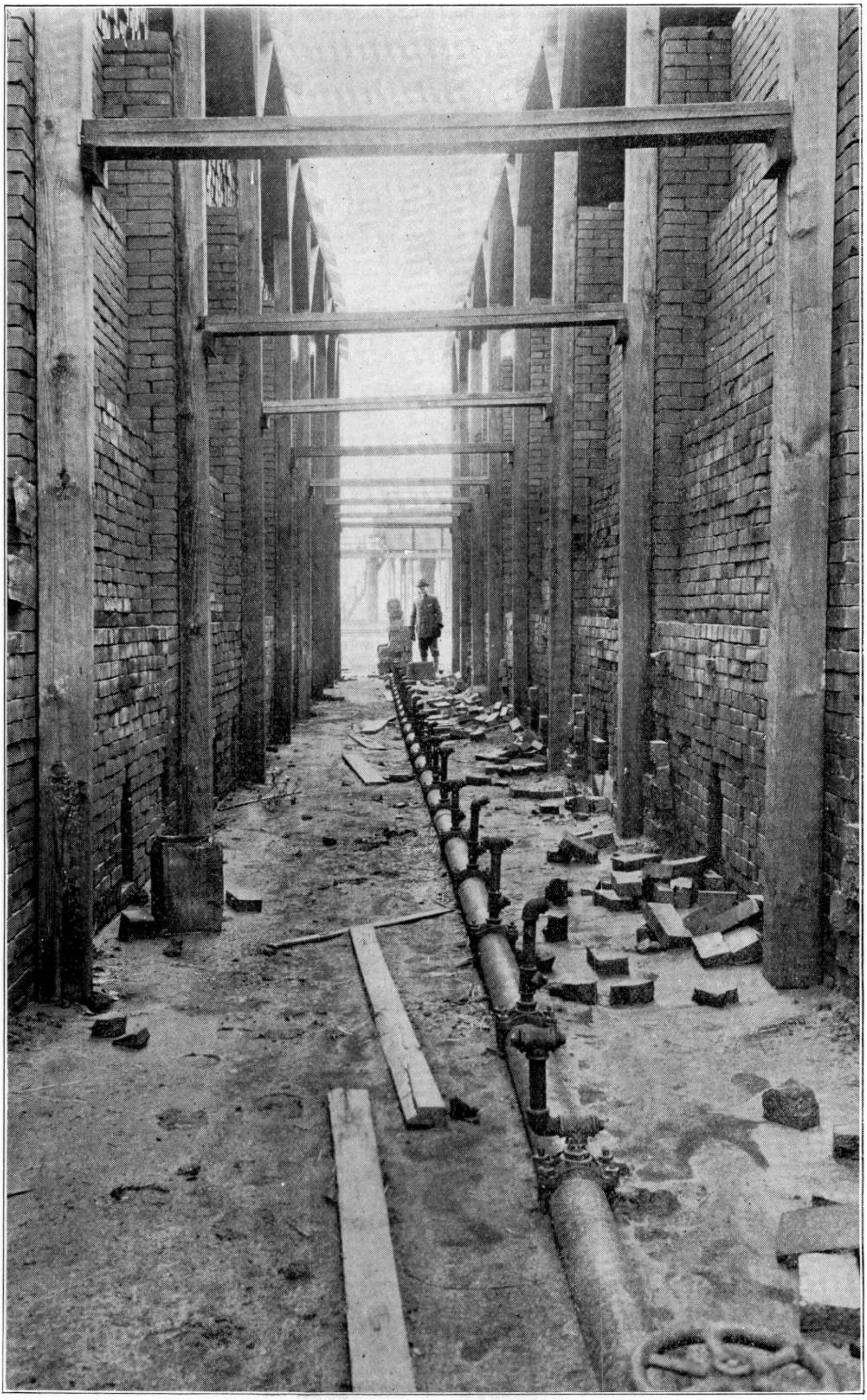
	From.	To.	Average.
Carbon dioxide	Trace	10.11	1.51
Illuminants	Trace	39.64	8.48
Oxygen	0.12	2.10	0.69
Carbon monoxide	Trace	1.00	0.48
Hydrogen	1.20	24.56	6.84
Methane	14.93	96.50	79.66
Nitrogen	2.96	27.84	4.83
Ethylene	0.15	18.12	2.77
Hydrogen sulphide	0.15	0.21	0.18
British thermal units per cubic foot	592	1,170	975

Of the 21 analyses given, eight contain hydrogen sulphide, in amounts varying from 0.15 to 0.18 per cent.

No gasoline is made from natural gas in Texas. This industry came into prominence in 1911 when there were produced in the United States 7,426,839 gallons valued at $531,704, or an average of 7.16 cents per gallon.

In this year the natural gas used for the manufacture of gasoline was 2,475,697,263 cubic feet, valued at $176,961; the yield of gasoline, per thousand cubic feet of gas, ranging from 2.68 to 3.56 gallons. Some kinds of natural gas yield from 8 to 10 gallons of gasoline per thousand cubic feet.

[1]The Calorific Power of Fuels, 2nd Ed., 1907.



Natural Gas Line at Plant of Northwestern Brick Co., Wichita Falls, Wichita County.

In 1912, the production of gasoline from natural gas rose to 12,081,179 gallons, valued at $1,157,476, or an average of 9.6 cents per gallon. The quantity of natural gas used was 4,687,796,329 cubic feet. As also in 1911, West Virginia was the largest producer of gasoline from natural gas, the other states, in order of rank, being, Pennsylvania, Ohio, Oklahoma, and California. The returns from Illinois, Colorado, New York and Kentucky were combined.

It might be possible to establish this industry in Texas, using natural gas or lignite gas, but the cost of such investigations has prevented us from working in this direction.

Natural gas at 9 cents per thousand cubic feet competes with lignite producer gas. There are two large establishments in the same immediate vicinity engaged in the same line of industry, and using about the same amount of power. One of them has natural gas, and the other lignite producer gas. The natural gas consumer formerly used lignite producer gas and changed to natural gas without, however, dismantling the producer plant.

The prices at which natural gas is sold are as follows:

In Dallas—net, minimum bill per month:

	Cents per 1,000 cubic feet.
First 10,000 cubic feet	45
Next 5,000 cubic feet	40
Next 15,000 cubic feet	35
Next 70,000 cubic feet	30
Next 900,000 cubic feet	20
All over 1,000,000 cubic feet	14

Boiler rates on term contract guaranteed minimum bill $60.00 a month:

First 250 M cubic feet, 20 cents per M cubic feet. All in excess of 250 M cubic feet, per month, 10 cents per M cubic feet. Boiler rates on yearly contract, guaranteed minimum bill $1,200 per annum—9 cents per M cubic feet.

In Wichita Falls natural gas is offered at 7 and even 6 cents per M. cubic foot, the piping distance from the wells in Clay county being from 15 to 20 miles.

In Marshall, which derives its natural gas from the Caddo fields, Louisiana, the following prices maintain, the piping distance being 25 to 30 miles:

Domestic rate, 25 cents per M. cubic feet, less 10 per cent if bills are paid on or before the tenth of the month following the purchase.

School and church rate, and for steam heating plants, 25 cents per M. cubic feet, net.

Factory rate, 15 cents, less than 250 M cubic feet.

Factory rate, 13½ cents, 250 M. to 500 M. cubic feet.

Factory rate, 12½ cents, 500 M. to 1,000 M. cubic feet.

Factory rate, 11 cents, 1,000 M. to 1,500 M. cubic feet.

Factory rate, 10 cents, 1,500 M. cubic feet and over.

For 30 days' consumption.

The gross sales in Marshall, for the fiscal year ending July 1, 1913, were 186,000,000 cubic feet for domestic and 426,000,000 cubic feet for industrial purposes.

In Fort Worth the prices are: Low pressure steam rate, heating only:

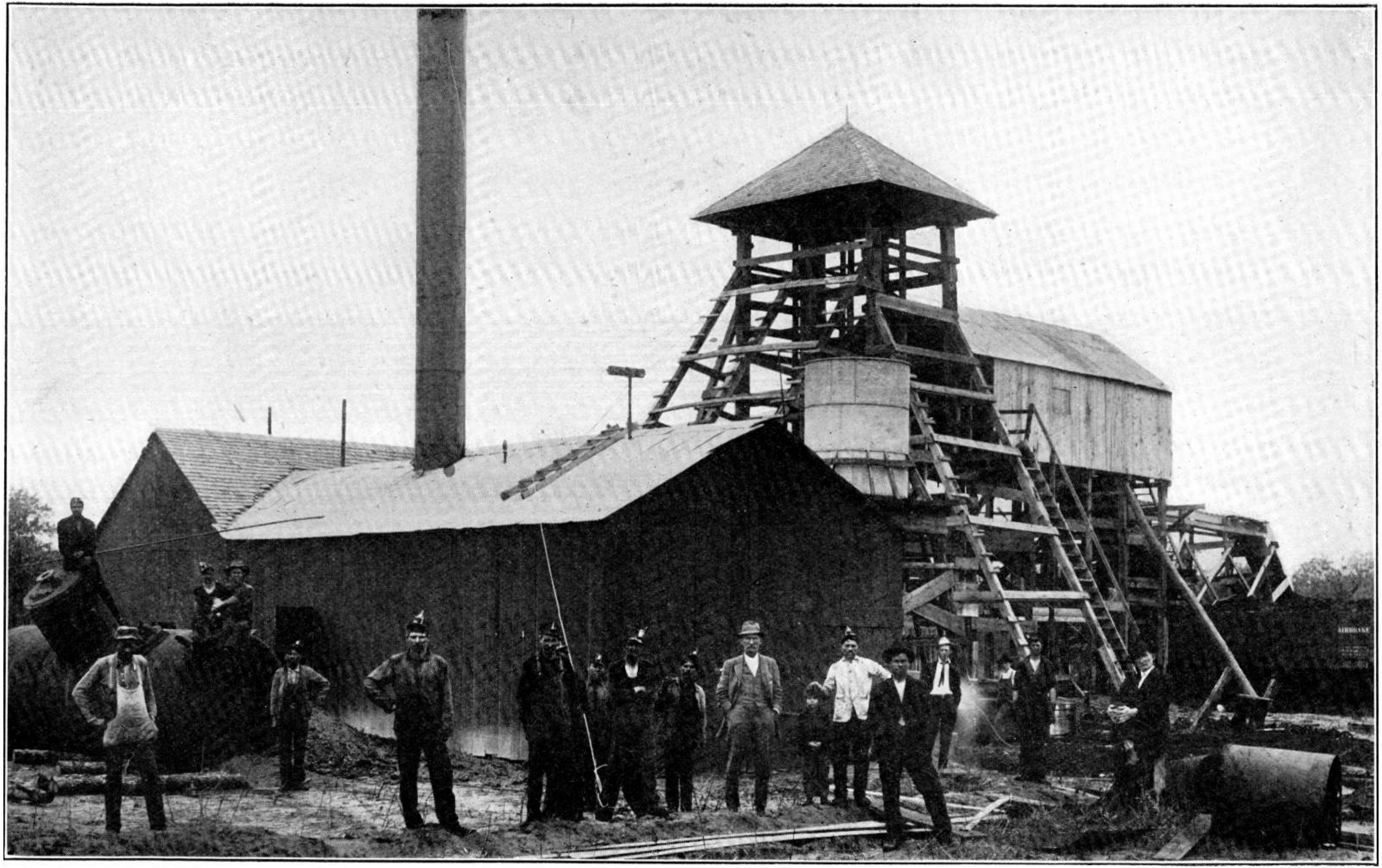
	Per 1,000 cu. ft.
First 250 thousand	25 cents, net.
All over 250 thousand	10 cents, net.
Industrial rate	9 cents, net.

In Texarkana, which uses natural gas from the Caddo fields, Louisiana, the net rates are 24 cents for domestic and 10 cents for industrial purposes per M. cubic feet. In 1912 there were sold in Texarkana 1,360,000,000 cubic feet, of which about 65 per cent was for industrial purposes.

Waco will soon have natural gas from the Mexia fields, Limestone county, and the price will probably be 50 cents per M. cubic foot for domestic purposes. The price of industrial gas will depend upon the amount consumed. The distance is about 45 miles.

Brownwood is to have natural gas from the Bangs field, Brown county, a distance of about 10 miles. The domestic rate will be 50 cents per M. cubic foot, but 15 cents for the use of the municipality.

Port Arthur now has natural gas from the Caddo field, Louisiana, utilizing an oil pipe line.



Como Lignite Mining Co., Como, Hopkins County.

CHAPTER VI.

LIGNITE.

Location and Extent of Fields—Composition.

In the United States there are about 127,200 square miles of lignite territory distributed as follows:

Alabama	6,000
Arkansas	5,900
Kentucky	500
Louisiana	8,800
Mississippi	3,000
Montana	7,000
North Dakota	31,000
South Dakota	4,000
Tennessee	1,000
Texas	60,000
Total	127,200

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.

The lignite fields of Texas probably extend over 60,000 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 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 800 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 Zavalla.

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

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 especially 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, is 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, 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 sealed. In this may the moisture 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— of this Bulletin.

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

TABLE VIII.

Composition of Texas Lignite, Sampled at Mines by University Mineral Survey, 1901-1902.

Analyses by O. H. Palm and S. H. Worrell.

Analysis No.	Proximate Analysis.									Ultimate Analysis.								Heat Value. British thermal units per pound.		Specific gravity	Weight per cubic foot—Dry.
	Natural condition.					Dry basis.				Natural condition.				Dry basis.							
	Moisture.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Natural condition.	Dry basis.		
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
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	1.00	7,536	11,470	1.42	88.7
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	81.8
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
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
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
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
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
1543	29.07	28.96	24.47	7.60	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
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
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
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	2.16	64.45	4.89	19.19	1.26	8,053	11,837	1:46	91.2
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
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	83.1
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	73.7
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	83.1

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

	From.	To.	Average.
Moisture	29.07	36.16	33.37
Volatile 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., per pound	6,474	8,053	7,614
On dry basis these become:			
Volatile 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., per pound	9,790	12,215	11,427
Specific gravity	1.16	1.44	1.33
Weight per cubic foot, pounds	72.5	90.0	83.1

TABLE IX.

Composition of the Ash of Texas Lignites.

Analysis No.	Silica.	Alumina.	Oxide of iron.	Lime.	Magnesia.	Oxide of Manganese.	Sulphuric acid.
1535	63.40	12.27	5.95	None	Trace	1.00	13.71
1536	40.46	16.92	8.32	15.60	1.22	....	15.54
1537	30.14	13.48	11.70	23.59	0.88	3.32	14.22
1538	21.64	16.20	11.10	25.23	4.36	2.00	18.01
1539	33.06	16.77	8.47	23.08	1.38	Trace	17.10
1540	27.44	28.87	24.85	7.00	Trace	0.52	10.45
1541	23.20	11.94	5.08	38.17	1.00	1.60	7.79
1542	42.20	23.02	2.02	15.93	2.12	Trace	12.81
1543	47.04	23.18	18.32	6.64	Trace	Trace	4.58
1544	40.60	34.26	2.02	12.08	Trace	....	9.52
1545	59.00	20.11	3.69	10.58	0.48	0.48	5.47
1546	25.64	19.08	12.92	18.68	1.76	....	20.92
1547	38.73	23.00	6.00	24.11	Trace	Trace	8.51
1548	33.00	25.84	7.40	22.32	....	....	11.32
1549	53.04	24.68	7.70	10.59	Trace	Trace	3.58
Average	38.57	20.64	9.04	16.84	0.94	0.81	12.90

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 16 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.

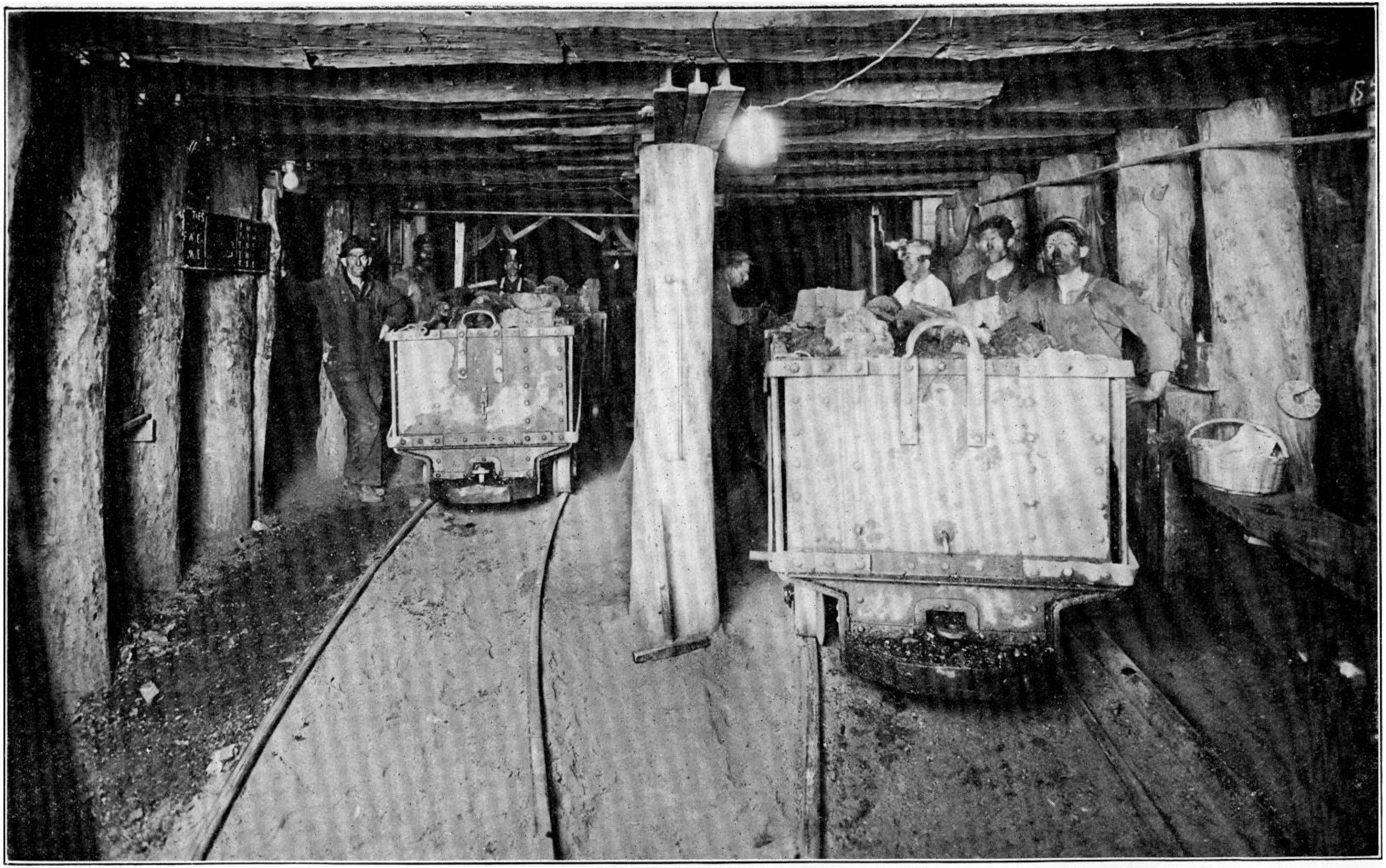
Whether the coal and lignite beds have been formed "in situ" or by "drift," or by a combination of these two methods is an open question. It is likely that conditions varied a good deal not only in the coal period as a whole, but also locally, and, to some extent, while the same seam was being made.

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:



Underground Electric Haulage, American Lignite Briquette Co., Big Lump, Milam County.

TABLE X.

Analyses of Texas Lignites—Company Samples. By S. H. Worrell, 1910-1911.

Analysis No.	As Received.									Dry Basis.								Heating Power.	
	Proximate Analysis.					Ultimate Analysis.				Proximate Analysis.				Ultimate Analysis.				British thermal units, per pound.	
	Moisture.	Volatile Combustible Matter.	Fixed Carbon.	Ash.	Sulphur.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Volatile Combustible Matter.	Fixed Carbon.	Ash.	Sulphur.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	As Received.	Dry Basis.
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
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
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
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	11,130
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
Average	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

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., Big Lump, Milam county.
57. American Lignite Briquette Co., Big Lump, 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., Hoyt, Wood county.
56. Consumers' Lignite Co., 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.[1]
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 variations in these analyses are as follows:

[1]Now Southwestern Fuel Company. Main office in Waco.

Samples as Received.

	From.	To.	Average.
Moisture	7.30	37.26	25.17
Volatile 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
Hydrogen	2.60	4.43	3.35
Oxygen	11.76	25.99	16.49
Nitrogen	0.73	2.18	1.47
Heating power, B. t. u., per pound	6,291	10,411	7,661
On a dry basis these become:			
Volatile 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. per pound	8,979	11,510	10,212

TABLE XI.

Proximate Analyses of Texas Lignites—Alphabetically Arranged—Dry Basis. By S. H. Worrell.

Number and description of sample.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Heating power, B. t. u., per lb.
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. Big Lump, Milam County	55.70	30.09	14.31	.78	8,979
57. American Lignite Briquette Co. Big Lump, 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. Hoyt, Wood County	52.14	38.22	9.64	.81	10,510
56. Consumers Lignite Co. 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

Number and description of samples.	Volatile combustible matter.	Fixed carbon.	Ash.	Sulphur.	Heating power, B. t. u., per lb.
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	10,030
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 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 with 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 combustile 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 fire-box 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. There are traveling grates that are used with a mixture of soft coal and lignite, and one operating successfully on lignite alone. Hand-firing, with a boiler similar in type to the half-Dutch oven has given, we understand, the best results from lignite.

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 was used for the calculation 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 cannot 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 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,

Tipple and Boiler-house, American Lignite Briquette Co., Big Lump, Milam County.

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.

Analyses of lignite made in the laboratory of the Bureau but not included in Table X, page 91.

Atascosa county, near Poteet, as received:

Analysis No.—	936	599	600
Moisture	24.00	25.00	34.82
Volatile combustible matter	36.07	18.20	19.73
Fixed carbon	32.97	43.80	34.62
Ash	6.96	13.00	10.83
	100.00	100.00	100.00
Sulphur	0.62	1.23	1.26
B. t. u., per pound	9,002	8,105	7,860

936. From Jos. A. Burger, San Antonio, 30 to 40 feet under cover; thickness of vein 4 to 5 feet.

599. From Poteet Sand & Coal Company, San Antonio.

600. The same.

Bastrop county: As received:

Analysis No.—	192	175
Moisture	24.50	10.00
Volatile combustible matter	38.02	47.00
Fixed carbon	30.54	24.09
Ash	6.94	18.91
	100.00	100.00
Sulphur	0.64	1.80
B. t. u., per pound	8,779	8,114

192. Independence Mining Company, Phelan.

175. Outcrop near Clepton Switch, 6 miles south of Elgin.

Bowie county: Sample from R. W. Rodgers, Texarkana. Analysis No. 38, as received:

	Per cent.
Moisture	13.68
Volatile combustible matter	48.59
Fixed carbon	26.27
Ash	11.46
	100.00
Sulphur	0.48
B. t. u., per pound	10,370

Brown county: Sample from D. F. Johnson, Brownwood. Analysis No. 695, as received. A typical form of lignite showing carbonized woody fiber, jet black in color:

	Per cent.
Moisture	18.04
Volatile combustible matter	44.91
Fixed carbon	35.82
Ash	1.23
	100.00
Sulphur	1.77
B. t. u., per pound	10,794

Fayette county: From mines of The Lower Strata Lignite Mining Company, Ledbetter; formerly known as The Big Four Mines, as received, percentages:

Analysis No.—	61	62	157	181	237
Moisture	19.82	27.80	33.50	39.00	38.50
Volatile combustible matter	36.45	38.31	33.45	35.69	34.77
Fixed carbon	28.23	13.08	18.23	21.05	19.99
Ash	15.50	20.21	14.82	4.28	8.74
	100.00	100.00	100.00	100.00	100.00
Sulphur	n. d.	n. d.	1.47	n. d.	n. d.

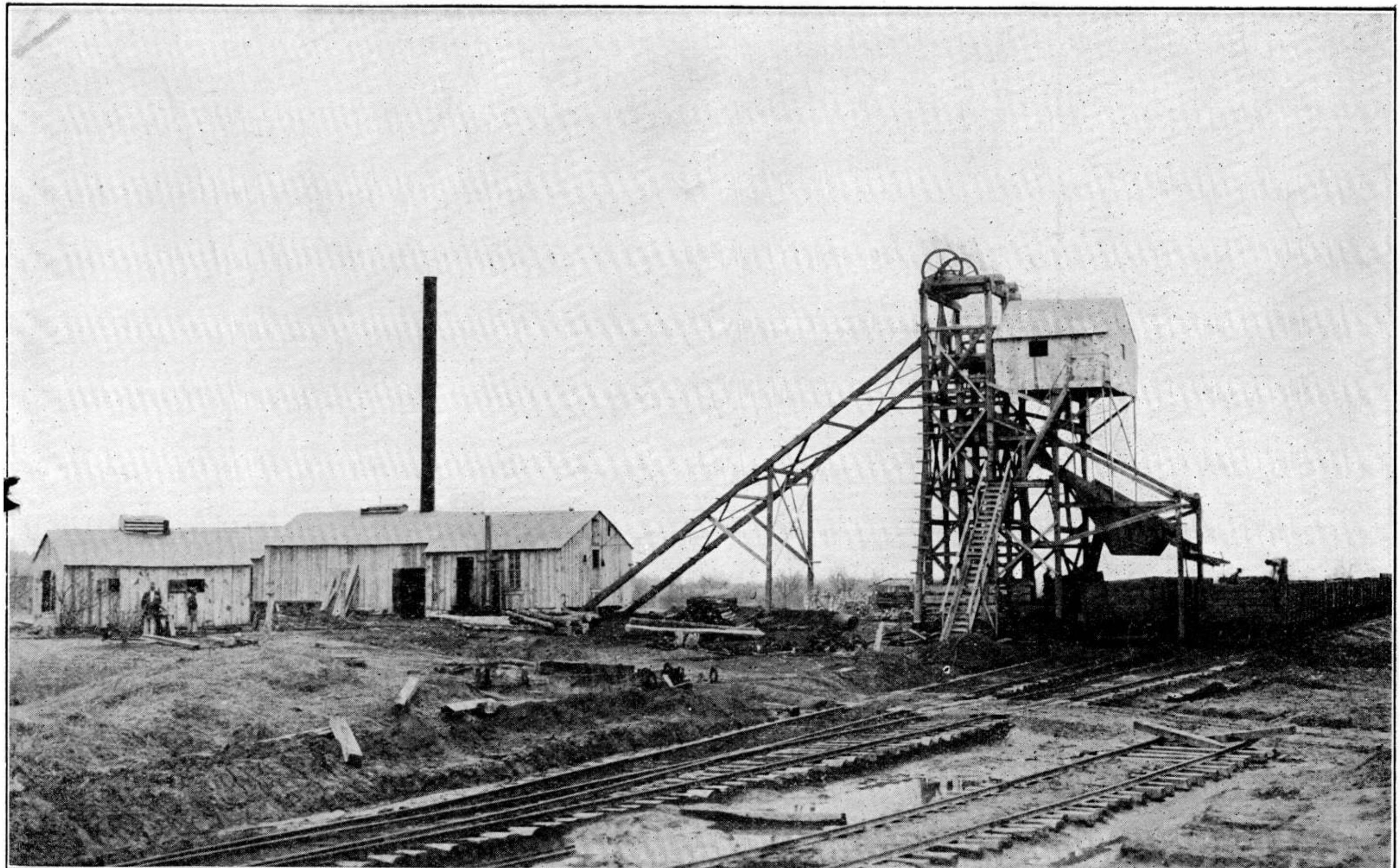
Nos. 61 and 237 are said to represent the 8-foot seam, 55 feet below the surface.

Nos. 62, 157 and 181 are said to represent the 7-foot seam, 95 feet below the surface.

Henderson county: Sample from W. Reid, Dallas Lignite Company, Dallas, of 12-foot vein, two and one-half miles from Stockard. Analysis No. 216.

	Per cent.
Moisture	25.00
Volatile combustible matter	36.81
Fixed carbon	29.89
Ash	8.30
	100.00
Sulphur	0.70
B. t. u., per pound	7,950

Assuming the same amount of moisture, Ledoux & Company, 99 John St., New York, gave analysis of lignite from the Dallas Lignite Company's mine at Tredlow, one and one-fourth miles east of Malakoff, as follows:



Alba-Malakoff Lignite Co., Mine No. 2, Malakoff, Henderson County.

	Per cent.
Moisture	25.00
Volatile combustible matter	34.47
Fixed carbon	33.25
Ash	7.28
	100.00

On the same basis, an analysis of this lignite, made by the Babcock & Wilcox Company, New York, gave:

	Per cent.
Moisture	25.00
Volatile combustible matter	33.59
Fixed carbon	33.39
Ash	8.02
	100.00

The vein at this locality is said to show 10 feet 6 inches of clean lignite without a parting.

A sample of lignite screenings received from the Malakoff mines of the Alba-Malakoff Lignite Company, May 15, 1913, had the following composition:

Analysis No. 751	Per cent.
Moisture	24.14
Volatile combustible matter	39.49
Fixed carbon	19.83
Ash	16.54
	100.00
Sulphur	1.08
B. t. u., per pound	7,578

Houston county: A sample of lignite screenings from the Houston County Coal & Manufacturing Company, Wooters, sent in by the Huntsville Light & Power Company, Huntsville, had the following composition:

Analysis No. 648,	Per cent.
Moisture	30.95
Volatile combustible matter	32.84
Fixed carbon	27.64
Ash	8.57
	100.00
Sulphur	1.43
B. t. u., per pound	7,855

Leon county: Bear Grass Coal Company, Jewett: as received:

Analysis No.—	551, Per cent.	307, Per cent.	933, Per cent.
Moisture	28.20	27.00	26.50
Volatile combustible matter	34.77	37.91	28.90
Fixed carbon	24.72	27.80	28.81
Ash	12.31	7.21	15.73
	100.00	100.00	100.00
Sulphur	1.02	0.44	1.11
B. t. u., per pound	7,805	7,308	6,528

Note.—Analysis No. 933 represents screenings through straight bars with $\frac{3}{8}$-inch openings at bottom. About 20 per cent of the mine run passes the screen. Newby.

Mr. A. Bement, Chicago, made an analysis of Bear Grass lignite, March 11, 1909. In the samples as received, the moisture was 16.47 per cent, the ash was 11.24 per cent, and the B. t. u. per pound were 9,362.

Houston County Coal & Manufacturing Company, Evansville, Leon county:

Analysis No.—	342, Per cent.	927, Per cent.	928, Per cent.
Moisture	25.80	24.60	34.80
Volatile combustible matter	33.39	32.60	29.28
Fixed carbon	31.91	32.70	30.25
Ash	8.90	10.10	5.67
	100.00	100.00	100.00
Sulphur	1.04	0.62	0.55
B. t. u., per pound	8,146	7,760	7,619

Medina county: In a communication from the Carr Coal Company, San Antonio, May 26, 1913, it is stated that the following analysis more nearly represents the average of their Lytle lignite:

	Per cent.
Moisture	24.50
Volatile combustible matter	35.00
Fixed carbon	30.00
Ash	10.50
	100.00

Milam county: Two samples representing the lignite mined at Big Lump by the American Lignite Briquette Company. Analysis No. 420 represents the deep vein and was sent to us by the

Company, January 4, 1913. Analysis No. 833 represents a sample taken from the boiler room at Big Lump by Mr. E. L. Porch, Jr., July 11, 1913.

Analysis No.—	420, Per cent.	833, Per cent.
Moisture	24.20	32.00
Volatile combustible matter	36.28	29.77
Fixed carbon	30.62	29.20
Ash	8.90	9.03
	100.00	100.00
Sulphur	1.14	1.24
B. t. u., per pound	7,684	7,842

Lignite from the Texas Coal Company, Rockdale, sampled in University power house, May 9, 1913:

Analysis No.—	745, Per cent.
Moisture	29.60
Volatile combustible matter	31.50
Fixed carbon	30.24
Ash	8.66
	100.00
Sulphur	1.00
B. t. u., per pound	7,593

Robertson county: From near Bremond, July 5, 1913:

Analysis No.—	823, Per cent.
Moisture	31.00
Volatile combustible matter	34.02
Fixed carbon	27.88
Ash	7.10
	100.00
Sulphur	0.65
B. t. u., per pound	8,500

We have recently received some samples of lignite from near Wootan, Robertson county. The analyses of the samples and the descriptions are as follows:

Analyses Nos.	Samples as received:				
	953	954	955	956	957
Moisture	29.40	29.40	35.60	31.40	30.60
Volatile combustible matter	32.12	29.51	32.24	29.36	30.19
Fixed carbon	33.89	32.01	27.46	31.25	34.07
Ash	4.59	9.08	4.70	7.99	5.14
	100.00	100.00	100.00	100.00	100.00
Sulphur	0.73	0.91	0.88	0.88	0.86
B. t. u., per pound	8,110	7,438	8,219	8,386	8,938

953. On farm of Strumensky Son, 2½ miles northeast of Wootan, Robertson county, Texas. Thickness of seam, 6½ feet, in well 72 feet deep.

954. One and a quarter miles south southwest of farm of Strumensky Son, near Wootan, Robertson county. Thickness of seam, 6½ feet, in well 73 feet deep.

955. One-half mile north northwest of locality given in No. 954. Thickness of seam, 6 feet, in well 53 feet deep.

956. One-fourth of mile from locality given in No. 953. Thickness of seam, 8½ feet, in well 33½ feet deep.

957. From mines of Southwestern Fuel Company, Calvert, Robertson county. New mine. Sample taken 700 feet from shaft, north. Thickness of seam, 6½ feet. Depth below surface, 60 feet.

Smith county: In a communication from Mr. T. M. Coupland, Troup, December 9, 1912, we were given an analysis of a sample of lignite said to be from a depth of 800 to 900 feet, near Whitehouse, made by N. C. Hamner, Dallas. It was as follows:

	Per cent.
Moisture	14.45
Volatile combustible matter	38.82
Fixed carbon	35.18
Ash	11.55
	100.00
Sulphur	0.93

Upshur county:

Analysis No.—	54, Per cent.	148, Per cent.
Moisture	11.40	25.20
Volatile combustible matter	42.80	37.50
Fixed carbon	33.76	26.09
Ash	12.04	11.21
	100.00	100.00
Sulphur	0.88	1.20
B. t. u., per pound	....	7,650

No. 54. Sample from R. B. Nelson, Gilmer.
No. 148. Sample from R. E. Ezekiel, Kelsey, top of vein.

Walker county: From 10 to 15 miles north of Huntsville and south of Trinity river. Analysis by P. S. Tilson, Houston, of a sample from G. A. Wynne, Huntsville, February 8, 1909:

	Per cent.
Moisture	13.73
Volatile combustible matter	45.95
Fixed carbon	37.22
Ash	3.10
	100.00

Wood county: A sample of lignite screenings received from the Alba-Malakoff Lignite Company, Alba, Wood county, May 10, 1913, had the following composition, as received. Analysis No. 744.

	Per cent.
Moisture	25.80
Volatile combustible matter	36.55
Fixed carbon	24.67
Ash	12.98
	100.00
Sulphur	0.61
B. t. u., per pound	8,095

Consumers Lignite Company, Hoyt.

PERCENTAGES.

Analysis No.—	282	592	593	701	913	914	915	916
Moisture	24.10	33.46	33.14	32.79	25.85	27.51	26.54	24.95
Volatile combustible matter	36.48	31.51	30.81	29.51	35.58	33.42	30.85	32.21
Fixed carbon	31.92	27.44	27.39	28.94	31.30	28.12	32.71	32.06
Ash	7.50	7.59	8.66	8.76	7.27	10.95	9.90	10.78
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sulphur	1.00	0.61	0.65	0.85	0.54	0.62	0.68	0.70
B. t. u., per pound	7,882	8,257	7,038	7,437	7,974	7,739	7,728	7,785

Note.—Analyses Nos. 282 and 913 are of lump; 593, 915 and 916 are dust; 914 is nut; 592 and 701 are screenings.

An analysis of this lignite made by Crossley Bros., Manchester, England (probably in 1909), gave the following results, in percentages:

	Per cent.
Moisture	24.50
Volatile combustible matter	31.30
Fixed carbon	38.00
Ash	6.20
	100.00
Nitrogen, dry	0.98

CHAPTER VII.

Other Analyses of Texas Lignites.

In Bulletin No. 22, Bureau of Mines, Washington, 1913, there are given some analyses of Texas lignites made by the United States Geological Survey, and in the laboratory of that Bureau. A description of the samples and the analyses is as follows:

Houston county: Crockett, 11 miles south of Wooters Station, Room 17, north entry 3,890 feet from foot of shaft, 5 foot cut:

	Per cent.
Moisture	32.58
Volatile combustible matter	37.02
Fixed carbon	19.56
Ash	10.84
Sulphur	0.56
Same, main entry, 600 feet from shaft, 5.66 feet cut:	
Moisture	33.50
Volatile combustible matter	39.50
Fixed carbon	16.25
Ash	10.75
Sulphur	0.56
B. t. u., per pound	7,142
Same, over ½-inch bar screen:	
Moisture	34.70
Volatile combustible matter	33.23
Fixed carbon	21.87
Ash	11.20
Sulphur	0.79
B. t. u., per pound	7,056

Medina county: Lytle, Carr No. 3 mine, 350 feet, northeast entry No. 6, 51½ inches cut:

	Per cent.
Moisture	31.67
Volatile combustible matter	24.81
Fixed carbon	26.49
Ash	17.03
Sulphur	3.55
Same, 600 feet northwest; room at middle of northwest entry No. 5; 49¾ inches cut:	
Moisture	32.92
Volatile combustible matter	27.42
Fixed carbon	27.08
Ash	12.58
Sulphur	1.46
B. t. u., per pound	6,840

Milam county: Near Rockdale, Olsen mine, 400 feet east of shaft, 77 inch cut:

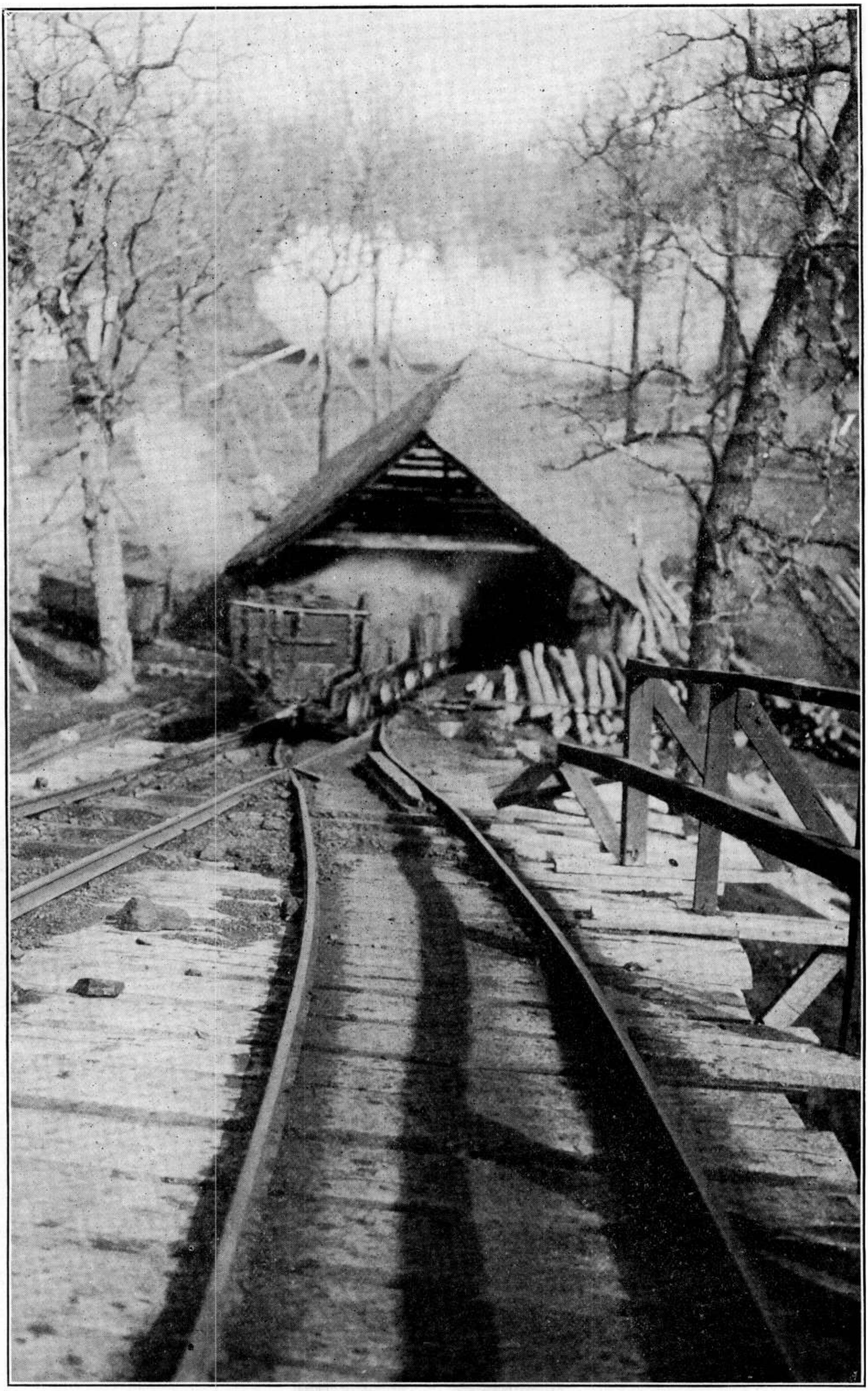
	Per cent.
Moisture	36.01
Volatile combustible matter	27.95
Fixed carbon	28.66
Ash	7.38
Sulphur	0.77
B. t. u., per pound	7,132
Same, 500 feet east of shaft, 79-inch cut:	
Moisture	35.56
Volatile combustible matter	28.91
Fixed carbon	27.49
Ash	8.04
Sulphur	0.75
B. t. u., per pound	.....
Same, lump, over ¾-inch screen:	
Moisture	31.06
Volatile combustible matter	27.67
Fixed carbon	33.39
Ash	7.88
Sulphur	0.99
B. t. u., per pound	7,870

Big Lump mine, 720 feet north of opening, entry No. 6, 7 foot cut, "big vein":

	Per cent.
Moisture	35.86
Volatile combustible matter	26.50
Fixed carbon	29.72
Ash	7.92
Sulphur	0.87
Same, 1,020 feet northwest entry No. 8; 82-inch cut:	
Moisture	35.30
Volatile combustible matter	26.22
Fixed carbon	29.58
Ash	8.90
Sulphur	0.76
B. t. u., per pound	6,898

Robertson county: Calvert, Calvert mine, room 4 of entry 1 south, 250 feet south of opening, upper 81¼ inch bed, 77-inch cut:

	Per cent.
Moisture	34.32
Volatile combustible matter	35.94
Fixed carbon	30.93
Ash	8.80
Sulphur	0.95
B. t. u., per pound	7,214
Same; room 8, off east entry north, 550 feet northeast of opening; 83½-inch bed, 78¼-inch cut:	
Moisture	33.50
Volatile combustible matter	26.06
Fixed carbon	30.38
Ash	10.06
Sulphur	0.97



Coming up the slope with a trip of loaded cars. Consumers Lignite Co., Hoyt, Wood County.

Wood county: Hoyt, No. 1 mine, south entry, 2,500 feet from mouth, 8¼ foot cut:

	Per cent.
Moisture	28.86
Volatile combustible matter	35.96
Fixed carbon	27.26
Ash	7.92
Sulphur	0.50
B. t. u., per pound	7,996
Same, No. 3 Mine, foot of air-shaft; 94-inch cut:	
Moisture	31.34
Volatile combustible matter	41.18
Fixed carbon	18.98
Ash	8.50
Sulphur	0.57
Same, run-of-mine:	
Moisture	33.71
Volatile combustible matter	29.25
Fixed carbon	29.76
Ash	7.28
Sulphur	0.53
B. t. u., per pound	7,348
Same, screened:	
Moisture	33.98
Volatile combustible matter	31.01
Fixed carbon	27.33
Ash	7.68
Sulphur	0.56
Same, 1,100 feet southeast of slope; 6½-foot cut:	
Moisture	36.80
Volatile combustible matter	28.86
Fixed carbon	28.09
Ash	6.25
Sulphur	0.53
B. t. u., per pound	7,101
Same, 400 feet northeast of slope; 8½-foot cut:	
Moisture	34.87
Volatile combustible matter	29.80
Fixed carbon	27.69
Ash	7.64
Sulphur	0.50
Same, run-of-mine:	
Moisture	33.85
Volatile combustible matter	27.50
Fixed carbon	31.35
Ash	7.30
Sulphur	0.51
B. t. u., per pound	7,497

TABLE XIII.

Proximate Analyses of Texas Lignites, Compiled from E. T. Dumble's "Brown Coal and Lignite, 1892."

Analysis.	Moisture.	Volatile Combustible Matter.	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	57.05	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	39.59	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 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, 4½ 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, 8½ 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.

TABLE XIV.

Ultimate Analysis of Texas Brown Coals—From "Brown Coal and Lignite," Dumble, 1892.

County.	Moisture.	Carbon.	Hydrogen.	Oxygen 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, per pound. Dry.
From Medina county	11,320
From Milam county	11,169
From Milam county	11,278
From Robertson county	11,320

In the Second Annual Report, Texas Geological Survey, 1890, page 55, there are given some additional analyses of Texas lignites but they do not materially affect the results given above.

In a report on general mine conditions at Mines 5 and 6, Hoyt, made for the Consumers Lignite Company, May 8, 1913, by W. S. Hamnett, representative at Dallas for the Pittsburg Testing Laboratory, the following analyses were given:

Analyses Nos.—	Percentages as received.						
	1.	2.	3.	4.	5.	6.	7.
Moisture	27.03	26.00	28.45	27.27	28.28	27.67	27.48
Volatile combustible matter	33.41	32.41	33.15	34.44	31.61	32.02	32.24
Fixed carbon	30.25	29.63	30.56	28.69	27.16	31.06	33.01
Ash	9.31	11.96	7.84	9.60	12.95	9.25	7.27
Sulphur	0.79	0.85	0.73	0.79	0.83	0.71	0.69
B. t. u., per pound	7,813	7,538	7,706	7,809	7,246	7,710	8,004

1. Taken from the head of the main north entry, Mine No. 6.
2. Taken from Room No. 1, eighth cross from fourth east entry, Mine No. 6.
3. Taken from Room No. 10, fourth west entry, Mine No. 6.
4. Taken from Room No. 19, eighth east entry, Mine No. 6.
5. Taken from Room No. 4, second cross off sixth east entry, Mine No. 6.
6. Taken from the heading of third east entry, Mine No. 5.
7. Taken from Room No. 3, second east entry, Mine No. 5.

CHAPTER VIII.

Raw Lignite as a Fuel Under Stationary Boilers.

There are four principal methods of utilizing lignite (brown coal) in Europe, where the industry has long been established on a very large scale. These are as follows:

1. Raw coal, as a fuel under stationary boilers, etc.
2. Raw coal, as a fuel in gas producers.
3. Briquetting (1) the raw coal, or (2), the dry coal.
4. Dry distillation and recovery of by-products.

The use of powdered lignite as a fuel under boilers has been recommended and some establishments have done a considerable amount of work in this direction. A little lignite is also used for domestic fires. In Texas, a small amount of dust lignite is used in the manufacture of hollow brick tile for building purposes, as the lignite on burning out imparts a certain porosity to the product.

Of the four principal methods given above the first two are used in Texas. There is but little lignite used in Texas for household purposes or for use under locomotive boilers. We may now consider the various methods for utilizing lignite in the order given.

(1) *Raw Lignite as a Fuel under Stationary Boilers, etc.*

Irrespective of its use in gas producers, which will be considered later, and its use in household fires, the chief value of lignite is as fuel for generating steam, whether under stationary or in locomotive boilers. Under stationary boilers it may be used direct or in the form of pulverized fuel.

Of the 13,776,992 tons of lignite used in the United States between the years 1895 and 1912, inclusive, it is likely that 95 per cent, or more than 13,000,000 tons were used for making steam. For this purpose, the lignite is neither air-dried nor artificially dried, but is used, as mined, with such loss of its original moisture as may be due to air-drying between the mine and the consuming plant. Just what the loss of moisture may be, due to this cause, is not known with accuracy, for it is seldom the case that the moisture in the lignite as shipped and as received is determined. There are several factors that influence this matter, e. g., the amount of moisture originally present; the size of the lignite; the depth of the lignite bed in the car; the character of the car, whether a "gondola" or a box car; the atmospheric moisture and temperature; the length of time elapsing between shipment and receipt; the method of temporary storage, etc.

As a rule, lignite is not carried in stock, it is used as rapidly as possible after mining; but it has not infrequently happened that shipments have been delayed for 15 to 30 days in transit, even when the distance did not exceed 100 miles.

As soon as it is exposed to the air, lignite begins to lose moisture, and this may continue, in a hot and comparatively dry climate, until 50 per cent of the original moisture has been removed. During this drying the lignite breaks up into smaller and smaller pieces and more or less "fines" result. If the lignite is stored for considerable periods, spontaneous combustion may set in and the writer has been informed of a fire that began in this way, in a pile of Texas lignite. Spontaneous combustion may arise from the presence of excess of "fines," or dust, or finely divided pyrite (sulphide of iron) but does not seem to be much influenced by high volatile matter in the lignite. It is due to the oxidation of constituents in the lignite itself and when the heat generated by this oxidation is not lost through radiation or convection as rapidly as it is formed, the heating of the lignite may become so marked as to cause it to catch fire.

So far as now known there have been no systematic tests on our lignites to determine just what loss there may be on weathering; but in certain Illinois coals, which, however, do not correspond to lignites, a calorific loss of from 1 to 3 per cent, in a year, has been reported. In certain Wyoming coals, there was a loss of 2.50 per cent in the first three months and of 5.30 per cent in 2¾ years.[1]

It is probable that, up to a certain point, varying largely with the nature of the lignite itself, the loss of moisture increases the value of the lignite for fuel purposes, but just where this point may be is a matter to be settled for each case separately. On a

[1]Comp. Bull. 38, Univ. Ill. Eng. Expt. Sta. 1909. Chemical Engineer, Vol. 12, July, 1910, and Tech. Paper No. 16, Bur. Mines, Washington, 1912.

carload of coal weighing 30 tons, and moved, we will say, 100 miles, in Texas, the freight is 60 cents a ton.

With an average content of moisture of 31 per cent, there would be 9.30 tons of water in this car, on which freight has to be paid. The freight on 30 tons of lignite at 60 cents a ton is $18, of which $5.58 is paid on the water. This water is of no value in the lignite except as a sort of binder. When it is removed, the lignite breaks up; and the question is, whether the more solid lignite plus the water can be more economically used than the finer lignite minus the water. Up to a certain point it is probable that there would be a decided economy in removing a large proportion of this water, especially if this could be done on drying floors, or in revolving cylinders, heated by the waste heat from the boilers.

"The harmful effect of excessive moisture in lignite on steam boiler operation, is due to the fact that a large part of the heat held by the moisture is below the temperature of the water in the boiler, and hence is not available for making steam. This can be illustrated by a specific example.

"Suppose a boiler operates under a pressure corresponding to a steam temperature of 350 degrees Fahrenheit (about 135 pounds), absolute), that the temperature of the products of combustion is 2,000 degrees Fahrenheit and that the temperature of the atmosphere is 70 degrees Fahrenheit. Under these conditions, one pound of moisture in the products of combustion contains heat units below the temperature of the water in the boiler (and hence not available for absorption by the boiler) as follows: below the boiling point (212—70) 142 B. t. u.; latent heat of steam, 965 B. t. u.; superheating steam to 350 degrees Fahrenheit (350—212) x 0.48=66 B. t. u., making a total of 1,173 B. t. u.

"The heat units in this pound of moisture above the temperature of the water in the boiler (and hence available for absorption) are (2000—350) x 0.48=792 B. t. u. These figures show that the larger part of the heat in the moisture is not available for making steam. In fact, the moisture in lignite and the moisture formed by burning the hydrogen of lignite are equivalent to a small boiler placed in the furnace and making steam equal in weight to the moisture passing out of the furnace, thus absorbing that amount of heat before the main boiler gets a chance to absorb it."[1]

A temperature of 150 to 175 degrees F. would suffice for drying the lignite without seriously endangering the heat units through loss of volatile combustible matter, for there does not seem to be an appreciable loss of such matter under 220 degrees F.

If the moisture could be reduced to 20 per cent there would be a gain in heat units of 1,548, or 20 per cent; and if the moisture could be reduced to 15 per cent, the gain in heat units would be 1,939, or 26.30 per cent. Whether this gain in heat units would be more than counterbalanced by the cost of drying and the loss of fine lignite through the grate, is a question still to be settled. No general rule can now be stated, for lignites vary a good deal with respect to the proportion of "fines" resulting from drying. They do not all behave alike nor do they exhibit the same rapidity of drying under similar conditions. The more friable lignites, of comparatively loose texture, dry more rapidly than those of a more clay-like texture, although there may be no remarkable differences in chemical composition. The differences in friability among the lignites is especially noticeable on grinding, whether in a machine or by hand in a mortar. Some of them go to powder within a short while, while others are more or less spongy or smeary and go to powder only after long grinding.

The larger proportion of "fines" in the dried lignite, and the influence of these "fines" on the combustion and on the clinkering, has also to be considered. While the boiler setting, the character of the firebox, the position and arrangement of the fire arches and the combustion chamber, the rate of firing, the size of the fuel, the thickness of the fuel bed, the amount of air supplied and the rate and pressure at which it is supplied, are of great importance in all steaming operations on solid fuel, yet they are of particular moment when we consider lignite.

It is much to be regretted that in the State where there are the largest deposits of lignite and where the consumption of this fuel is greater by far than elsewhere in the country, there should have been so little systematic study of the economic use of such fuel.

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[1]D. T. Randall and Henry Kreisinger, Bull. No. 2, Bur. Mines, Washington, 1910.

Here and there, in Texas, there have been attempts to solve some of the more pressing problems in this connection, but there is no fuel testing station in the State where such investigations may be conducted by trained observers. Most of the information we have on the subject is derived from North Dakota, where the lignite area is only about one-half of that in Texas, where the production of this fuel is not half of the Texas production, and where the demand for cheap and effective fuel is certainly no greater than in Texas.

So far back as 1894 boiler tests on North Dakota lignite were made at Jamestown, North Dakota, under the care of Mr. Thomas Pettigrew, Chief Engineer for the Hospital for the Insane.[1]

Under natural draft, the water evaporated per pound of lignite actually consumed was 4.20 pounds, and 4.46 pounds per pound of combustible. The ash in the lignite was 5.93 per cent. The boiler was 6 feet in diameter and 16 feet long, with thirty 4½-inch flues. The grate surface was 4 feet 5 inches by 5 feet, or 22.8 square feet. The lignite burned per square foot of grate surface per hour was 18.72 pounds. The total amount of water evaporated at the temperature of the feed water (74 degrees F.) was 14,157 pounds. In comparison with Youghiogheny (Pennsylvania) bituminous coal, the water evaporation per pound of combustible was 4.46 : 7.10 pounds. The cost of the bituminous coal was $6.80, and of the lignite $2.80 a ton.

From another test of North Dakota lignite (same authority as above), with natural draft, made by the Missouri Valley Milling Company, Mandan, North Dakota, the following report was rendered:

Boiler Tests on North Dakota Lignite, at Mandan, N. D.

Duration of test	11 hours
Kind of furnace	Smith-White
Grate surface	30 sq. ft.
Width of air space in grate	¼ inch
Water heating surface	1,549 sq. ft.
Ratio of water heating surface to grate area	51 to 1
Average steam pressure, pounds per square inch	104
Average temperature of feed water entering boiler	175 deg. F.
Total lignite fed to furnace	12,221 pounds
Moisture in lignite	23 per cent.
Lignite consumed per sq. ft. of grate surface, per hour	37 pounds
Total cost of lignite	$9.77

[1]F. A. Wilder, U. S. G. S., Water Supply and Irrigation Paper, No. 117, 1905.

Cost of lignite delivered at mill, per ton	$1.60
Total weight of water fed to boiler	56,350 pounds
Water evaporated per hour, from and at 212 deg. F	5,554 pounds
Horse-power developed	163
Cost of fuel for evaporating 1,000 pounds of water	17.34 cents
Average horse-power of engine	190
Cost of fuel per H.-P. hour	0.47 cent

The capacity of the mill was 450 barrels of flour per day and the cost of the fuel was 4.46 cents per barrel.

From a test made on North Dakota lignite at the Fargo-Edison Electric Light Plant, Fargo, N. D., in 1901, the following report was rendered:

Boiler Tests on North Dakota Lignite, at Fargo, N. D.

Natural Draft—	
Duration of test	12 hours
Boilers used—Two 16 x 6 ft. tubular, one 220-h.-p. Heine water tube	
Total heating surface	4,823 sq. ft.
Total grate surface	88 sq. ft.
Average steam pressure, pounds per square inch	83
Average temperature of feed water, deg. F	140
Total weight of lignite fired	26,400 pounds
Cost of lignite per net ton at boilers	$2.60
Total cost of lignite	$34.32
Total weight of water apparently evaporated	97,500 pounds
Water evaporated per pound of lignite, from average pressure and temperature	3.70 pounds
Equivalent water evaporated from and at 212 deg. F	4.10 pounds
Lignite burned per square foot of grate surface, per hour	25 pounds
Cost of lignite to evaporate 1,000 pounds of water	35.2 cents
Moisture in lignite	30 per cent.
Ash in lignite	3.50 per cent.

Another natural draft test was made on North Dakota lignite at the North Dakota Agricultural College, in 1902. The report was as follows:

Duration of test	8.5 hours
Boilers used—Common fire tubular, with 62 flues 3 inches in diameter and 16 ft. long; diameter of shell, 60 inches.	
Total heating surface	962 sq. ft.
Total grate surface	24 sq. ft.
Total weight of lignite burned	3,907 pounds
Water apparently evaporated per pound of lignite burned	3.16 pounds
Equivalent water evaporated from and at 212 deg. F	3.38 pounds
Lignite burned per sq. ft. of grate surface, per hour	18.38 pounds
Moisture in lignite	36 per cent.
Ash in lignite	9.03 per cent.

Under forced draft, a test of North Dakota lignite was made at the University of North Dakota, in 1904. The boilers were fire tubular, with a diameter of shell of 54 inches. Each boiler contained 48 flues 16 feet long and 3½ inches in diameter, and had 841.76 square feet of heating surface. Fire brick arches were used in the furnace. The test lasted twelve and one-half hours. Per pound of fuel there were evaporated 4.30 pounds of water. After four days' air drying, the moisture in the lignite was 10 per cent and the ash 7.82 per cent.

Mr. Wilder remarks that with boiler and grate conditions about like those used in the test at the Asylum for the Insane, three Iowa coals, tested at Des Moines, gave a water evaporation, from and at 212 degrees F. of 5.44, 5.21 and 6.52 pounds per pound of fuel used, and that four standard Missouri coals gave 6.84, 6.27, 6.23 and 5.86 pounds, respectively. In comparing these coals with lignite, he allows for the lignite an evaporation of 4.20 pounds of water per pound of fuel and considers this conservative. Other instances of the fuel value of North Dakota lignite are given by Mr. Wilder as follows:

The 500-barrel milling plant of the Russell-Miller Milling Company, Jamestown: A single boiler 72 inches by 16 feet, with seventy-two 4-inch flues, a shaking grate, 36 square feet, with $\frac{1}{2}$-inch air spaces, forced draft. The engine was a Corliss compound condensing rated at 165 horse power. The full power was maintained for twelve hours with 7,600 pounds of fuel, or one horse power from 3.73 pounds of the fuel per hour. The cost of the lignite at the mill was $2.45 a ton.

The Kenmare Roller Mill, Kenmare: Boiler 66 inches by 16 feet, with a grate of $\frac{3}{8}$-inch spaces. There were used 161 pounds of lignite slack per hour, for 40 horse power, under 65 pounds steam pressure. The Minot Electric Light Company, Minot, had two boilers 54 inches by 16 feet, and maintained 50 horse power for ten hours with two tons of raw lignite. Natural draft was used and the engineer did the firing.

Automatic stokers and forced draft have given good results, but these have also been secured with natural draft and ordinary hand-firing.

One of the most complete tests of lignite as fuel under stationary boilers was conducted by D. T. Randall and Henry Kreisinger,[1] at Williston, North Dakota.

The boiler was one of six Stirling water-tube boilers installed for the Williston irrigation project of the United States Reclamation Service. It had three steam drums, one mud drum and three nests of tubes. The furnace was of the type which has been termed "semi-gas producer," with a deep-set grate and a narrowing of the space between the bridge-wall and the end of the prolonged fire-

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[1]Bull. No. 2, Bur. of Mines, Washington, 1910.

brick arch. The grate was 21 inches below the lower edge of the charging door. The air for combustion was pre-heated to 200 to 300 degrees F. and blown into the furnace under a water pressure of ½-inch to 1-inch. The grate was of the rocking-grate type, and had two rows of bars. Cold air was blown through a 2-inch pipe which supported each grate bar, with the hope that the formation of clinkers would be lessened or prevented.

Inasmuch as considerable care was taken throughout this investigation, it has been thought best to speak of it at some length.

The principal dimensions of the furnace, boiler and grate were as follows:

Principal Dimensions of Furnace, Boiler and Grate Used in Tests of North Dakota Lignite, Williston, 1908.

Furnace:—		Firing door:—	
Width in front	6.6 ft.	Lower edge, above grate	21 in.
Width back of bridge wall	7.5 ft.	Height	14.75 in.
Length	8.0 ft.	Width	19.75 in.
Height	7.0 ft.	Chimney:—	
Roof of furnace:—		Height above grate	155 ft.
Length (straight portion)	8.5 ft.	Diameter	54 in.
" at sides	15.8 ft.	Boiler:—	
" in middle	15.3 ft.	Builder's rating, H.-P	258
Height in rear, above bridge wall	23 in.	Water-heating surface	2,587 sq. ft.
Number of openings[1]	16	Diam. of steam drums	42 in.
Size of openings	2x4.5 in.	Length of steam drums	10.33 ft.
Width of partitions	2 in.	Diam. of mud drums	42 in.
Bridge wall:—		Length of mud drums	8.33 ft.
Width at base	5 ft.	Number of tubes	209
Width on top	3 ft.	Diam. of tubes	3.25
Height	40 in.	Grate:—	
Number of openings[2]	6	Width	6.6 ft.
Size of openings	5x2.5 in.	Length	8.0 ft.
Side door:—		Width of grate bars	7.4 in.
Lower edge above grate	7.5 in.	Width of rib	0.44 in.
Height	17 in.	Width of air space	0.44 in.
Width	19 in.	Depth of air space	1.75 in.

[1]Note.—Openings in roof of furnace were 6.5 ft. from front of furnace
[2]Note.—Openings in bridge wall were 9 inches from front of bridge wall.

The average composition of the lignite used was as follows:

	Per cent.
Moisture	42.61
Volatile combustible matter	24.09
Fixed carbon	26.27
Ash	7.03
	100.00
Sulphur	1.04
Carbon	42.06
Hydrogen	3.04
Oxygen	14.80
Nitrogen	0.75
B. t. u., per pound	7,129

The total weight of fuel used, with moisture as above, was 431,326 pounds=215.66 net tons. The average amount of carbon left in the ash was 22.13 per cent, which, in the heat balance, represents an average loss of 1.93 per cent, due to incomplete combustion of the carbon. The equivalent amount of water evaporated from and at 212 degrees F. per pound of fuel, as fired, was on the average, 3.50 pounds, with an average developed horse power of 238.8. The over-all efficiency of the boiler and furnace was, on the average, 53.88 per cent, calculated from the chemical analysis of the coal and ash.

There was considerable trouble from clinkering and the removal of the clinkers was rendered difficult both by the deep setting of the grate and the inability to use tools through the side opening.

The chief conclusions reached by Messrs. Randall and Kreisinger, from the tests at Williston, are thus stated:

"The combination of boiler and furnace setting described gives good results with North Dakota lignite. Steam can be made with a fuel efficiency of 55 to 58 per cent of the heat in the coal, and no difficulty is experienced in obtaining the full capacity of the boiler.

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

"Little, if any, advantage is gained by crushing the lignite by hand instead of in a power crusher.

"To reduce the moisture in the lignite by weathering seems to improve the economy, but these tests are not sufficient in number to determine definitely the condition of the fuel and the time required for weathering to insure the best results.

"The steam blower for the ash pit is inefficient, and there is no gain in supplying superheated steam to it. A considerable saving in steam and equally good results could probably be obtained by substituting for the steam blower a fan such as is commonly used for forced draft."

In tests at the Fort Worth Waterworks, Fort Worth, Texas, for the fuel contract of 1908-1909, lignite from the mines of the Bear Grass Coal Company, Jewett, Leon county, Texas, gave the following results:

Hours run, 66; pounds of lignite used, 102,448; gallons of water pumped, 8,877,050; gallons of water pumped per pound of coal, 95. The delivery cost of the lignite was $2.22 a ton, i. e., $1.50 at the mines and 72 cents freight. The cost of the fuel, per million gallons of water pumped, was $11.68.

This test was made in comparison with bituminous coal from Oklahoma, Arkansas and Texas. The cost of fuel, per million gallons of water pumped, was:

Name of company and kind of fuel.	Cost.
Southern Fuel Company (Oklahoma coal)	$ 9.74
Bear Grass (Texas lignite, mine run)	11.68
R. J. Clark (Oklahoma coal)	11.68
Dow Coal Company (Oklahoma coal)	12.86
Interstate Coal Co. (Arkansas coal)	14.16
Jenny Lind Coal Co. (Arkansas coal)	14.47
Rock Creek Coal Co., Texas	21.59

The results of some tests made at the Dallas Waterworks, Dallas, Texas, showed the following evaporation per pound of Oklahoma coal, with water temperature of 140 degrees F., 7.23, 7.30, 7.87, 6.42, 7.20, 5.32, and 4.91; an average of 6.61. Four Texas lignites were tested at the same time with the following results:

Location.	Water temperature.	
	140 deg. F.	212 deg. F.
Como, Hopkins county	3.565	4.05
Alba, Wood county	4.054	4.60
Hoyt, Wood county	3.981	4.51
Bear Grass, Leon county	6.667	7.308

Several years ago some fuel tests were made by Cypress Bros., Caldwell, Texas, with a 60 horse power shell boiler, each test being for eighty-four hours. Bituminous coal was charged off at $5.50 a ton, black jack (oak) wood at $5.50 a cord, fuel oil at 80 cents a barrel of 42 gallons, and Rockdale, Milam county, Texas, lignite at $1.75 a ton. The results showed that to produce one horsepower the relative costs were as follows:

Kind of fuel.	Cents.
For bituminous coal	1.33
For wood	0.90
For fuel oil	0.80
For lignite	0.70

In other words, it cost nearly twice as much per horse power to use bituminous coal as it cost to use lignite, one and a third times as much for wood as for lignite, and a little more for fuel oil than for lignite.

In a test conducted by J. P. Greenwood, M. E., Dallas, at the plant of the Columbia Manufacturing Company, Dallas, Texas, in May, 1912, with Hoyt screened lump lignite (Consumers Lignite Company) it was ascertained that the average evaporation per pound of lignite per hour was 4.44 pounds of water.

The equipment consisted of a battery of two O'Brien horizontal return tubular boilers, in brick settings, with a 4-inch air chamber wall vented to the outside. Each boiler was 72 inches in diameter and 22 feet long, with twenty-six 6-inch tubes. There was a furnace of 84 square feet of surface, common to the two boilers. The stack was 4 feet in diameter and 100 feet high, set on a twin up-take over the two boilers. In the up-take there was a bank of 2-inch pipes for increasing the temperature of the feed water. The grates were of special make, known as "Velvet," and were built for using lignite. They were 4 inches wide by 6 feet long, the width of the furnace being 14 feet. Each linear foot of grate surface had twenty-five round holes, $\frac{3}{8}$-inch in diameter. The draft doors of the furnace were bricked up solid and in the center of each furnace there was an Argand steam blower, the steam entering at the center of a ring through eighteen holes, 1-32-inch in diameter.

As already stated, the fuel used was lump lignite from the mines of the Consumers Lignite Company, Hoyt, Wood county, Texas, screened over a $\frac{3}{4}$-inch screen and it showed 8,030 B. t. u. per pound.

There were six furnace doors, one fireman using each door alternately every few minutes. The average length of time the doors were open each hour was 24 per cent.

The fire was kept on the hill-and-valley system, on account of the large lumps of lignite, and Mr. Greenwood observes, in his report, that the lignite should have been broken into smaller lumps.

There was a $\frac{3}{4}$-inch steam pipe for each blower and the valves were kept wide open during the test. On account of the design of the blower equipment, almost no ash fell through the grates.

The light ash went over the bridge wall and was deposited in the combustion chamber. The clinkers, amounting to 4.50 per cent, were taken out through the furnace doors.

The heating surface of the two boilers was 2,354 square feet. While the builder's rating on the boilers was 294 horse power, there was actually developed 410 horse power. The combined efficiency of the furnace and boiler was 54 per cent. (Compare the efficiency of 53.88 per cent obtained by Messrs. Randall and Kreisinger on North Dakota lignite, with Stirling water tube boilers.)

The duration of the test was ten hours. During this time the following averages were obtained:

	Average.
Steam pressure	105 pounds
Air temperature	80 deg. F.
Up-take temperature	563 deg. F.
Feed-water temperature	192 deg. F.
Pounds of fuel per square foot of grate surface, per hour	36
Boiler, horse-power	410
Pounds of water evaporated per pound of fuel	4.44

The total amount of fuel used was 30,302 pounds and the total amount of water evaporated was 133,301 pounds. On a fuel basis, the cost of evaporating 1000 pounds of water was 16.9 cents, allowing that the coal cost $1.50 a ton, delivered. This represents a cost of $1.50 for evaporating 8,880 pounds of water. (Compare the cost of 17.34 cents for evaporating 1000 pounds of water with North Dakota lignite.)

In a private communication from the Consumers Lignite Company, July 3, 1912, it is stated that evaporative tests on nut and slack lignite, through a ¾-inch screen, showed 4.07 pounds of water per pound of lignite. The opinion is expressed, in that communication, that with an experienced fireman and under good conditions, the Hoyt lignite will show an evaporation of 5.50 pounds of water per pound of fuel. The average for Oklahoma coal appears to be 6.61 pounds.

In a test made at San Antonio, Texas, in 1910, by Charles V. Gambs, chief engineer of the Lone Star Brewing Company, on lignite supplied by the American Lignite Briquette Company, from its mines at Big Lump, Milam county, Texas, it was reported that the evaporation of water from and at 212 degrees F. per pound of the fuel was 5.50 pounds. Following are the items of this test:

Boiler Tests on Texas Lignite at San Antonio, Texas.

	Description.
Kind of lignite used	Big Lump lump
Duration of trial, hours	24
Kind of boilers used	Heine water tube
Number of boilers used	3
Average steam pressure per gauge, pounds	100
Average temperature of feed water, degrees F	150
Average atmospheric temperature, degrees F	68
Total lignite consumed in 24 hours, pounds	64,944
Total water evaporated in 24 hours, pounds	324,720
Draft	Natural
Total water evaporated from and at 212 deg. F., pounds	358,490
Evaporation from and at 212 deg. F., per pound of fuel, in pounds	5.50
Horse-power developed, per hour	432.9
Temperature of escaping gases, deg. F	524.5

In tests made at the Temple Waterworks, Temple, Texas, in 1909, by Pat Bracken, superintendent, on five different kinds of Texas lignites, the results were as follows, each test being run for twenty-four hours:

Mine.	Lignite used, pounds.	Water pumped, gallons.	Cost, per 1,000 gallons.
Calvert	6,600 at $1.58	758,000	$0.0068
Bastrop	6,200 at 1.38	756,000	0.0056
Milano Coal Co	7,100 at 1.30	712,000	0.0064
Burnet Fuel Co	6,400 at 1.30	756,000	0.0055
Standard Lignite Co	7,600 at 1.30	900,000	0.0054

The fuel cost of pumping a million gallons of water, from this test, varied from $5.40 to $6.80. The number of gallons of water pumped, per pound of coal, varied from 100.30 to 121.90, with an average of 114.70.

Report by J. P. Greenwood, Dallas, Texas, December 6, 1911.

Central Texas Cotton Oil Company, Temple, Texas.

Duration of test, 10 hours.

Grate surface, 108 square feet.

Heating surface, 4,647 square feet.

Super-heating surface, not given.

Steam gauge, 120 pounds.

Draft, 0.5 inch.

Temperature of external air, 66.8 degrees Fahrenheit.

Temperature of fire room, 66.8 degrees Fahrenheit.

Temperature of steam, 349.6 degrees Fahrenheit.

Temperature of uptake, 463.5 degrees Fahrenheit.

Temperature of feed water, 198.3 degrees Fahrenheit.

Fuel.

Lignite consumed, 24,872 pounds.
Ash, 8 per cent.

Water.

Actually evaporated, 104,706 pounds.
Evaporated per pound of lignite, 4.20 pounds.
Evaporated per pound of combustible, not given.

Rate of Combustion.

Lignite per square foot of grate surface per hour, average 23.5 pounds.

Commercial Horse Power.

($34\frac{1}{2}$ pounds water at 212 Fahrenheit) h. p., 320.7, average.
Rated H. P., 3 boilers, each 150.
Maximum h. p. developed, 341.5.
Minimum h. p. developed, 295.4.

Boilers.

Three, each 72 inches by 18 feet. Set in one steel casing with independent furnaces of the half-Dutch oven type. The steel breechings were side draft type and extended into a nipple on a 100-foot steel stack, 66 inches in diameter.

The fuel was Rockdale lignite, no analysis given.

Grate Surface.

Each boiler had 36 square feet, or 108 for the three. Grates were of herring bone type, with $\frac{3}{8}$-inch air spaces.

The longitudinal space was $\frac{3}{4}$-inch.

The fuel average per hour was 2,487.2 pounds.

Water average per hour was 10,470.6 pounds.

The average evaporation per pound of fuel per hour was 4.2 pounds of water from and at 212 degrees Fahrenheit.

The average amount of carbonic acid for the 10 hours was 5.76 per cent.

Boiler Efficiency.	Per cent.
No. 1	75
No. 2	71
No. 3	70

After cleaning fires the highest evaporation was reached, 5.33

pounds when burning 19.5 pounds of fuel per square foot of grate surface.

The boiler feed pumps, 2, were 6 inches by 4 inches by 6 inches.

The heaters were of open type LXL Casey-Hedges and raised the temperature of the water to 198 degrees Fahrenheit.

Fuel, pounds.	Water, gallons.	Evaporation pounds.	Per square foot of grate.
2491	10,521	4.22	23.1
2372	10,521	4.43	22.0
2531	11,147	4.40	23.4
2516	10,521	4.18	23.3
3006	9,643	3.20	27.8 (cleaning fires)
2977	10,521	3.05	27.5 (cleaning fires)
2103	11,147	5.33	19.5
2645	10,521	3.97	24.5
2139	10,521	4.91	19.8
2092	9,643	4.60	19.4

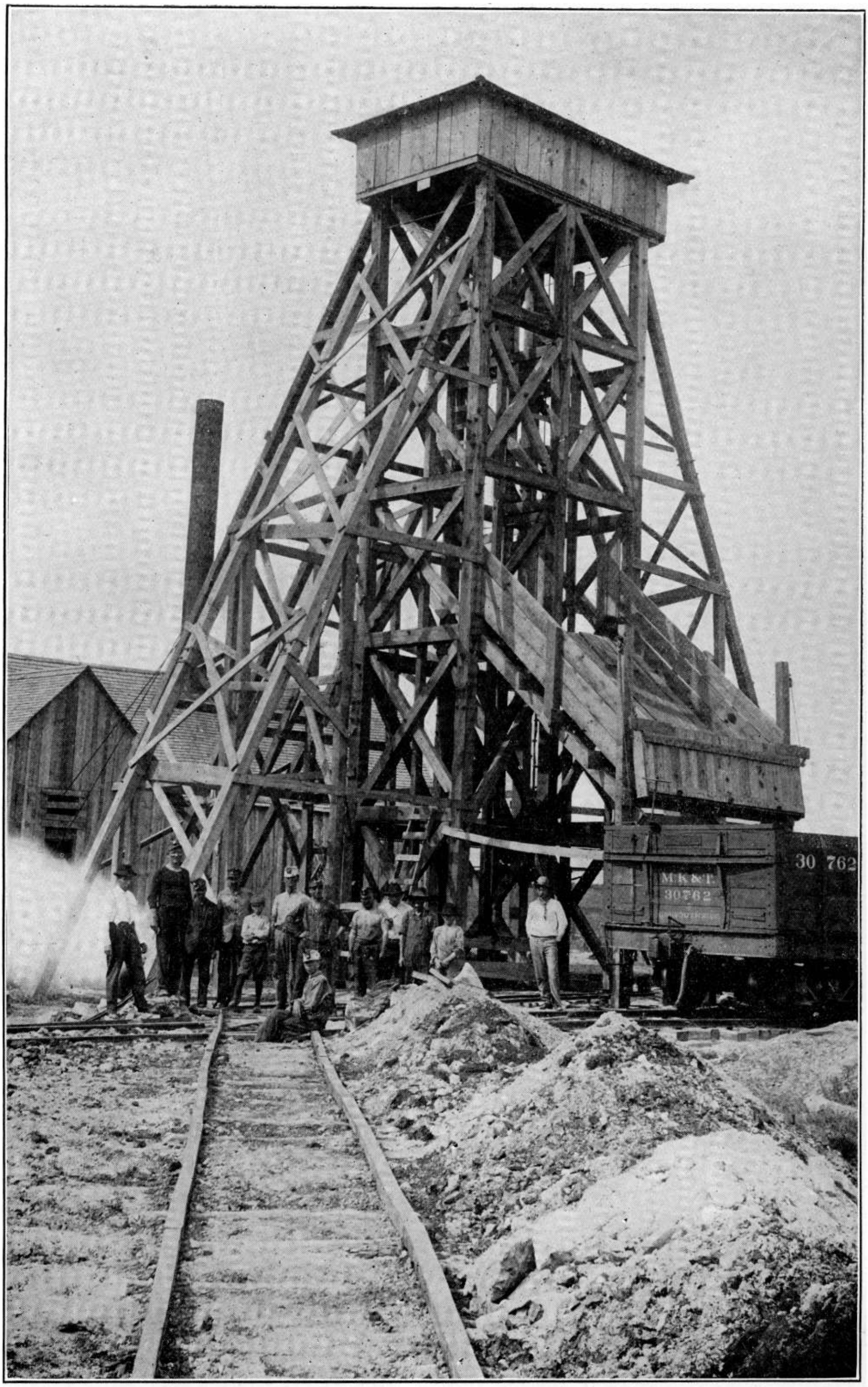
In July, 1913, with the permission of the American Lignite Briquette Company, Mr. E. L. Porch, Jr., made some observations for this Bureau at the Big Lump mines, near Rockdale, Milam county. His report is as follows:

"Description of the Power Plant"

"The boiler plant consists of two Casey-Hedges return tubular boilers (half-Dutch type setting). Both boilers are contained in the same setting and use a common 60-foot stack, the height above the grates being about 75 feet. The boilers are 18 feet long, 6 feet in diameter, and contain 86 3½-inch tubes, giving a heating surface of 1,420 square feet, for the tubes plus 170 square feet for the bottom of the boilers; or a total heating surface of 1,590 square feet for each boiler.

Each grate is 6 feet deep and 5½ feet wide, giving each boiler a grate surface of 33 square feet. The grate bars are the ordinary cast iron bars with V-shaped openings.

The steam pressure carried is 100 pounds, although it varied at times from 80 to 105 pounds. Each boiler is rated at 150 h. p., total 300 h. p. Run-of-mine lignite is used in the boilers, the pieces of lignite too large to fire being broken by hand on the boiler room floor. Some of this lignite used is quite wet, as it comes from the mines, also the boiler room (including the lignite) is sprinkled occasionally to lay the dust, this wet lignite being fired directly into the boilers. The boilers are fired approximately every



McKay Lignite Mining Co., Como, Hopkins County.

fifteen minutes, the bed on the grates being carried from 6 to 14 inches deep.

The water for the boilers is pumped from the mines before the day shift goes to work, there being no night shift. The exhaust steam from the compressor, the generator engine and the hoisting engine, goes through a (jet) condenser, no water being used in the condenser, however; and the very small part of the steam that condenses runs from the condenser through the feed water heater and is pumped up to the supply tank. The machines to which steam is supplied consists of:

One Ridgway engine (rated at 160 h. p.) driving a 100-k. w. (364 amperes, 250 volts) D. C. Thompson-Ryan Generator. The normal load on the generator was 75 amperes and the highest noted during the test was 330 amperes. This great variation of the load was caused by the starting and stopping of the electric locomotives that are used for the underground haulage, since they only operate a part of the time. An Ingersoll-Rand air compressor of about 35 h. p., a hoisting engine of about 60 h. p., and a saw-mill engine of about 15 h. p., total, about 270 h. p.

The results of the test do not show the boilers to be very rapid evaporators, but on Tuesday the plant was operating below its normal working capacity and on Friday conditions were still worse. For this reason Tuesday's and Friday's results were kept separate. Some smoke was noted during the test (as mentioned elsewhere), but the majority of the time the stack gave off no smoke. This seemed to be due to the type of setting, which gives an unusually large area of combustion, and possibly also to regularity in firing. The beds were not raked very often (3 to 4 times a day only) on account of the large amount of unburned lignite that would fall through the grate into the ash-pit.

Friday's Test

Duration of test—10:40 a. m.–4:05 p. m	5 hrs., 25 mins.
Lignite burned	6,834 lbs.
Lignite burned per sq. ft. of grate surface, per hour	19.1 lbs.
Water evaporated	19,199 lbs.
Water evaporated per hour	3,546 lbs.
Water evaporated per hour, per boiler	1,772 lbs.
Water evaporated per hour per pound of lignite, equals .336 gal., equals .336 x 8.355, equals	2.81 lbs.
Ashes drawn for the time specified, 1,200 lbs., equals, per boiler	600 lbs.

A very small amount of smoke was noted at 12:33 p. m., 1:30 p. m., 1:45 p. m., 2:00 p. m., 3:15 p. m. and 3:30 p. m.

An unusual amount of smoke for these boilers was noticed at 2:25 p. m., 2:45 p. m. and 3:00 p. m.

Tuesday's Test

Duration of test—9:40 a. m.–5:00 p. m.	7 hrs., 20 mins.
Lignite burned	9,146 lbs.
Lignite burned per sq. ft. of grate surface, per hour	18.9 lbs.
Water evaporated	31,941 lbs.
Water evaporated per hour	4,352 lbs.
Water evaporated per hour, per boiler	2,176 lbs.
Water evaporated per pound of lignite, 0.418 gal., equals .418 x 8.355, equals	3.5 lbs.
Ashes drawn for the time specified, 1,492 lbs., equals, per boiler	746 lbs.

A very small amount of smoke was noted at 2:12, 2:25, 2:48, 4:07 and 4:27 p. m., which may have been due to a too vigorous raking of the fires, or to the boiler room having been sprinkled at about 2:00 p. m. The amount of ashes obtained in these tests is not exactly correct, because the mine pumps are run every morning from 3:00 a. m. to 7:00 a. m., and the amount of ash made during this time had to be estimated and deducted from the total amount drawn.

Under date of June 17, 1913, Mr. A. C. Köhler, Superintendent of the American Lignite Briquette Company, Big Lump, Milam county, wrote us as follows:

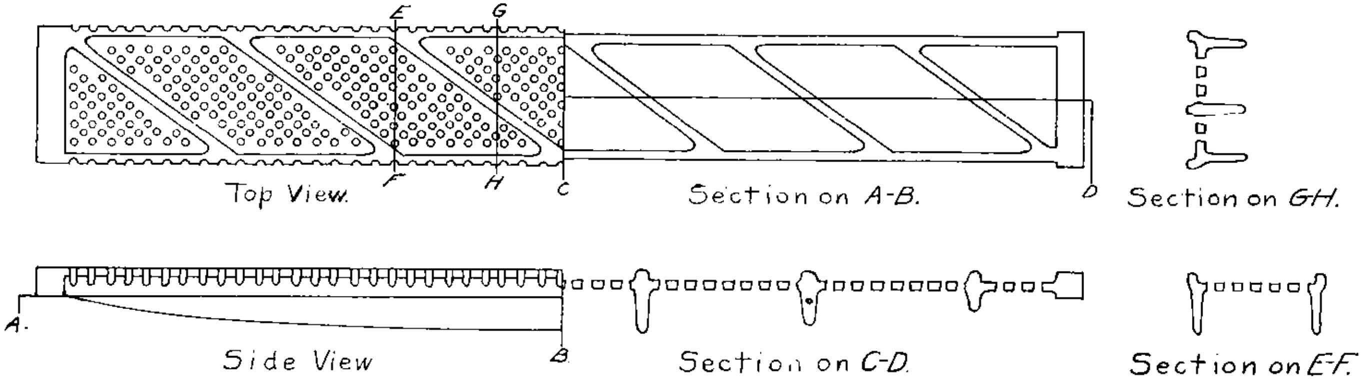
"We have two 150 h. p. boilers of the half-Dutch oven type, made by the Casey-Hedges Company, Chattanooga, Tennessee, at our Big Lump No. 5 mine, that have been in continuous operation for the past three years. While we have kept no exact costs on the operation of these boilers for any great length of time, we have made comparisons with the other types of boilers used here under the identical conditions and find that we can operate the semi-Dutch oven type far more economically, making a saving in fuel alone from 40 to 50 per cent. The first cost on the installation of these boilers was high as compared to the old style, but we feel that we have saved the difference several times over, in the fuel consumption.

As to the absence of smoke: the combustion is so thorough that they may be said to be smokeless. When properly fired, there is only a thin film of smoke and condensed vapor from the stack and this only for the moment when the fresh fuel is being fired. Altogether, this style of boiler and setting is the most satisfactory we have seen yet, especially when lignite is the fuel used."

Under date of June 10, 1913, Mr. M. F. Smith, Manager of the Georgetown Oil Mills, Georgetown, Texas, writes us as follows:

"We have been using the half-Dutch oven type of boiler, with steel setting, for about three years and we like it very much. We believe it to be more economical where a low grade of fuel, such as lignite, is used. With this type of oven, the fuel is completely burned and there is almost no smoke, unless a forced draft is used."

Mr. C. C. Roberts, Manager of the Ladonia Cotton Oil Company, Ladonia, Texas, writes us as follows, under date of June 10, 1913:



THE VELVET GRATE BAR for Burning Lignite Coal

"Answering yours of the 7th instant, with reference to our experience with the Casey-Hedges Company half-Dutch oven type of boiler and their steel casing for same, beg to advise that we have had but little experience with same, using lignite as a fuel; however, the six or eight weeks that we used lignite, we found same to be very economical as against slack coal, and that our furnace gave entire satisfaction from point of combustion, no smoke being visible from stack only while furnace doors were open.

The reason we don't use lignite altogether is because our boiler capacity is rather limited, and when it becomes necessary to clean our fires, any low grade fuel gives us trouble, as we only have one unit and a limited amount of capacity.

We are well pleased with the boiler job the Casey-Hedges people gave us, as we have reduced our fuel cost almost 40 per cent since its installation, and find that we can use any grade of fuel to much better advantage than formerly."

Much other testimony could be adduced to show that, under proper conditions, lignite gives entire satisfaction as a fuel under stationary boilers and that it can be and is burned with almost no smoke. It may appear somewhat strange that there should remain in the minds of some people any doubt as to the advantage of this fuel, when we consider that Texas alone consumes a million tons a year and that the business is steadily growing.

The necessity of adapting the grate to the fuel led Mr. D. C. Earnest, Dallas, Texas, to take out patents on what is known as the "Velvet" grate. In a letter of August 31, 1913, Mr. Earnest, who is president of the Consumers Lignite Company, writes as follows:

"To show how the lignite business has developed, as far as this company is concerned, I will say that eight years ago it was the custom to load strictly mine-run. Among some operators there was a custom of forking the coal in the mines, but the miners got so expert with the forks that very little, if any, dust failed to get into the pit-cars. With the idea of producing a better grade of coal, we almost immediately installed screens, thinking that we could dispose of the screenings at some price. But we discovered that we could not even give this coal away, and the expense of merely throwing it away was, at times, from $250 to $300 a month.

Since that time, the Velvet grates, in connection with the steam blowers, have enabled us to sell the screenings, or coal which comes through the $\frac{3}{4}$-inch screen, at from 50 to 60 cents a ton, f. o. b. mines. We have one customer, a brick manufacturer, who will take all the dust we can produce."

In response to our request, Mr. Earnest kindly sent the following description of his "Velvet" grate bar, which is illustrated.

"The 'Velvet' grate bar is especially adapted for burning lignite or any low grade fuel, either lump, mine-run, or slack.

The principal object of the grate is to secure a thorough distribution of air to the fuel on the grate, and the retention thereon, after raking the fire, of sufficient incandescent fuel to ignite a fresh supply of fuel.

The "Velvet" grate bar, in its general outline, is like the ordinary grate bar commonly used in boiler furnaces, being approximately rectangular in cross-section, and wider at top than bottom. It is provided on its top face with marginal ribs and transverse ribs or partitions, forming a plurality of individual fuel pockets adapted to retain fine fuel, and on its bottom face with recesses forming air pockets corresponding to the fuel pockets. These fuel pockets are about one-half to five-eighths of an inch deep. The fuel pockets are connected with the air pockets by ventilating holes, tapering, and largest at their lower ends, being about three-eighths of an inch in diameter at the top and fifty per cent larger at the bottom.

The tapering form of the ventilating holes tends to cause a discharge of the air in jets into the fuel.

In ordinary grates, especially where a forced or induced draft is used, there is a tendency of the air to rush through the weakest places in the fire. In the "Velvet" grate the individual air pockets underneath tend to prevent the air rushing past some of the ventilating holes and overcharging others. These air pockets form separate sources of supply to the separate groups of ventilating holes and cause an even distribution of the air to the fuel pockets in the top of the bar throughout the grate surface.

A steam blower is used with these grates; the blower may be put through the ash-pit wall, or through ash-pit door.

"Velvet" grates have been installed at more than 160 steam plants in Texas. Below are the names of a few:

Greenville Electric Light Plant, Greenville.
City Light and Water Plant, Terrell.
Grand Saline Salt Company, Grand Saline.
Tyler Cotton Oil Company, Tyler.
Tyler Electric Company, Tyler.
Smith County Compress Company, Tyler.
Houston Packing Company, Houston.
Fidelity Cotton Oil and Fertilizer Company, Houston.
Magnolia Petroleum Company, Corsicana.
Brazos Valley Cotton Mills, West.
Giddings Manufacturing Company, Giddings.
Union Iron Works, Houston.
Quanah Cotton Oil Company, Quanah.
Texas Power and Light Company, Palestine.
Henderson Cotton Oil & Ginning Company, Henderson.
Farmers and Ginners Cotton Oil Company, Sulphur Springs.
Fraser Brick Company, Ginger.
Bonham Ice Company, Bonham.
Planters Cotton Oil Company, Bonham.
Bonham Cotton Compress Company, Bonham.

Many fuel consumers have the erroneous idea that more boiler capacity is necessary when lignite coal is used as fuel. This is unquestionably untrue when "Velvet" grates are installed. These grates are installed on a guarantee of satisfaction, and when handled according to instructions, increased efficiency will be shown.

"Velvet" grates are covered by Patents Nos. 962805 and 972965, dated June 28, 1910, and October 18, 1910. Patent is owned, and installations are made, by D. C. Earnest, Dallas, Texas.

Reference has been made to the boiler setting for lignite manufactured and installed by the Casey-Hedges Company, Chattanooga, Tennessee. What is known as the half-Dutch oven steel setting has proved to be very satisfactory on Texas lignites and full particulars can be secured from that company. We can present here only a partial list of the installations in Texas, compiled to May 23, 1913.

Name of Company	Location.	Boilers.	
		Number.	Size, Inches—Feet
American Lignite Briquette Co	Big Lump	2	72 x 18
Central Texas Cotton Oil Co	Temple	3	72 x 18
Brownwood Ice & Fuel Co	Brownwood	2	72 x 18
Bruceville Cotton Oil Co	Bruceville	1	78 x 18
Carthage Ice & Electric Co	Carthage	2	72 x 18
G. F. Fitzhugh	Beaumont	3	72 x 18
Georgetown Oil Mill	Georgetown	1	78 x 20
Ladonia Cotton Oil Co	Ladonia	1	84 x 14
Lampasas Light & Water Co	Lampasas	1	60 x 16
Midlothian Oil & Gin Co	Midlothian	2	84 x 18
Paris Oil & Cotton Co	Paris	3	72 x 18

Total number of installations, 21. Of the standard casing installations, this company had, in Texas, 61 up to May 23, 1913.

Other large establishments are now concerned over the question of using lignite on stokers and the possibilities in this direction would appear to warrant all of the attention now being given to it.

In November, 1913, Mr. Jas. C. Kennedy, Brenham, Texas, read a paper on "Lignite Stokers" before the Southwestern Ice Manufacturers' Association, at Marlin. Mr. Kennedy has kindly placed this paper at our disposal, and we make the following extracts from it, as bearing particularly upon this subject.

Mr. Kennedy says:

"In handling the subject of lignite stokers, I cannot draw from my own experience, but must rely entirely upon facts and figures which I have obtained by correspondence with parties who have experimented with stokers or are using stokers for burning lignite. Just here, I will say that there have been and are yet a great many experimenters, but the users are very scarce.

"To get to a specific application of the stoker to lignite-burning, I will take the case of a stoker which was installed in our plant. The president of our company tells me that this stoker was the best money-maker that he had ever had offered him—on paper—and before it started to operate. The construction was the usual pattern of chain-grate stoker. The grate was built to cover the width of the furnace and was a unit without divisions longitudinally; but was arranged with rails and wheels so as to allow of removing it for inspection or repairs. A Dutch-oven construction extended from about 18 inches back of the front water by 5 feet 6 inches on the horizontal out in front of the boilers. The roof of the Dutch oven was lined with fire-tile and had an incline out and downward of about 15 degrees, from the horizontal. The top was one foot from the grate at the front end and two feet four and one-half inches at the back end.

"The top of the Dutch oven was called by the manufacturers the "ignition arch." Its business (according to the literature) was to get white hot and ignite the fresh lignite soon after it entered the furnace. The operation *was to be* this: The fire was to be started, as on any other grate, and allowed to heat up the surfaces, and especially the "ignition arch," at which time the stoker was set in operation and would take care of itself as long as you fed it coal. The burning fire on that part of the grate and of the arch under the tubes would radiate sufficient heat to maintain the arch at a white heat, and the arch would ignite the incoming lignite. The operation *was* this: The fire was started in the usual way; everything was heated up nicely, also the arch; then the stoker was placed in operation; but right here fiction stopped and actual events began to happen. When the fresh lignite was struck by the heat from the ignition arch, the large amount of moisture the fuel contained arose in a volume of steam and cooled the arch, and ignition was delayed until the fuel reached the furnace proper. It was also discovered that the fuel burned out before it reached the point where it was supposed to be ashes. This stoker was an absolute failure. * * *

"In my endeavor to obtain information, I wrote to various concerns which are reported to have burned lignite with mechanical stokers successfully. Here is an extract from a letter:

" 'We have burned a little lignite on both of these grates with very good results, as compared with hand-firing. However, these grates were not installed at this plant for the purpose of burning lignite. They are strictly semi-anthracite.' Another paragraph reads: 'In burning lignite, a great deal depends on the arch. On this, if you go into it, you will probably have to do some experimenting with different constructions of arches.' I understand that this installation gave a great amount of trouble when it was first put in. Here is an extract from another letter from a man who had made a study of Texas lignites: 'We tried out lignite on a chain-grate stoker under a 200 h. p. B. & W. boiler, but found that it did not burn successfully because of the moisture in the fuel. The fire died out before the end of the grate was reached and, of course, the ignition was too slow.'"

"Here is one from Colorado: 'We have six B. & W. boilers, four of them 300 h. p., two 400 h. p. equipped with chain-grate stokers. Have had them in operation about three years. Our total expense for repairs on grates, gear, engine belts and brick-work, has been about $100 per year. We burn lignite altogether, except when there is labor trouble. We are saving from 20 per cent to 25 per cent of coal over good hand-firing. I am sending you analysis of the coal we burn, also some other information.' Following are the analysis and evaporation:

Kind of coal, Cruches mine run.	Per cent.
Volatile matter	33.23
Fixed carbon	35.25
Ash	7.79
Moisture	23.73
Calorific value; British thermal units	11,600

Water eqaporation from and at 212 deg. per lb., natural coal	5 lbs.
Water eqaporalion from and at 212 deg. per lb., dry coal	6.55 lbs.
Efficiency of boiler and furnace	56.9 per cent.
Draft suction uptake	0.57 inches of water.
Draft suction over fire	0.24 inches of water.
Capacity of boiler	400 H. P.
Load developed	480 H. P.
Over rating	20 per cent.

"'This was from an eight-hour test run before stokere were put in, stack temperature 600 to 700 degrees F.

"'Another test run after stokers were installed, same coal used:

Water evaporated from and at 212° per pound, natural coal, pounds	6.14
Water evaporated from and at 212° per pound, dry coal, pounds	8.05
Efficiency of boiler and furnace, per cent	69.7
Draft suction uptake, inches of water	0.498
Draft suction over fire, inches of water	0.232
Capacity of boiler, 400 h. p.	
Horse-power developed, 502.	
Over rating, 28 per cent. Average C O 10 to 12.	
Stack temperatures between 500 and 600.	

"'Both tests were run for eight hours, and in the case of the stoker we were not familiar at the time with the best method of firing. I believe the chain grate is the only stoker for lignite.'

"Here are two analyses of the lignite we are burning at Brenham, Texas:

	1. At the mine. Per cent.	2. Taken from in front of boilers as it was being fired. Per cent.
Moisture	20.82	13.74
Volatile combustible matter	43.31	38.10
Fixed carbon	29.87	38.30
Ash	6.00	9.86
Calorific value on wet basis, B. t. u.	....	10,070
Calorific value on dry basis, B. t. u.	....	11,670

Note.—Analysis No. 2 is more reliable as we had it made by a reputable, unbiased chemist; I am not so sure about No. 1.

"It has been impossible for us, on account of making alterations in our plant, to get exactly our evaporation factor, but, in the tests run last year, we had tests which ran as high as 5 pounds of wated to a pound of lignite as fired; our average being 4.5 pounds. Comparing the Colorado lignite and the lignite which we are using, it seems as if we would be better fixed to use a stoker than they are.

"The manufacturers of the type of stoker used with Colorado lignite claim to have more than sixty stokers burning lignite, in Colorado.

"What I have learned about stokers for lignite, as we find it in Texas, forces me to the conclusion that they are still in the process of development and, while I hear very often of what has been accomplished at this or that place, it has been impossible for me to secure authentic results of test.

"There are variables connected with lignite which make efficient stoking difficult.

"As set forth in another place, there is the moisture, the most variable of them all. If it leaves the mine in fair, dry weather, its moisture content will be lower when it reaches you; and, if the weather is damp or it is raining, you have more moisture. And good operation or, rather, good ignition and combustion by the stoker, requires some stability of moisture.

"The same mines have been known to produce lignite of variable chemical composition. I think this is true of all mines, although our lignite runs very uniformly.

"The requisites for successful mechanical stoking are the elimination of most of the moisture; the breaking up of the lumps to uniform sizes so as to obtain, as far as possible, the same grading; some mechanical means for avoiding surface coking; and the construction of ignition arch applicable to the particular fuel to be used. I have been informed that one of the large companies in this State is about to carry on some extensive experiments with a lignite stoker. We will all be glad, I am sure, to see success crown their efforts, as the fuel situation in this State is becoming a serious one.

"In conclusion, I wish to tell you that recently we are developing about 15 per cent over capacity with a boiler which formerly never exceeded 75 per cent of its capacity. The source of this increase consists of three elements: CO_2 Recorder; Rocking Grates and African muscle. The latter is a little hard to keep moving, but is the only stoker we have been able to rely on."

With respect to stokers using lignite: We have been furnished with the results of a test made on lignite from the mines of the Southwestern Fuel Company, Calvert, Robertson county, at Fort Worth, December 23, 1912. The stoker used was the Green Chain Grate, and the water evaporated per pound of lignite, under actual conditions, was 5.02 pounds, the horse-power developed having been 524, with a boiler efficiency of 73.4 per cent.

The details of this test are as follows:

Boiler Test at Fort Worth.

BOILER.

Duration of test, 6 hours.
Plant, Swift & Company, No. 9.
Type, B. & W. Water Tube.
Diameter of shell, 42 inches.
Length of shell, 20 feet 4 inches.
Number of tubes, 224.
Diameter of tubes, 4 inches.
Heating surface, 4544 square feet.

FURNACE.

Type, Horizontal L Type GECO.
Depth, 11 feet.
Width, 8 feet.

Grate area, 88 sq. ft.
Kind of grate, Green Chain Grate.
Percentage of space, 15.
Ratio of heating to grate surface, 51.7:1.

COAL.

Kind of coal, Mine-run lignite.
Bought from Southwestern Fuel Co., general offices at Calvert, Robertson county.
Broken to egg size for firing.
Weight of coal as fired, 19,200 pounds.
Percentage of moisture in coal, 30.17.
Weight of dry coal consumed, 13,407 pounds.
Weight of ashes, 1441 pounds.
Weight of combustible consumed, 11,966 pounds.
Percentage of ashes to dry coal, 89.3.
Calorific value of fuel, dry, 10,669 B. t. u.

COAL PER HOUR.

Coal consumed, actual conditions, per hour, 3,200 pounds.
Dry coal consumed per hour, 2,235 pounds.
Combustible per hour, 1,995 pounds.
Dry coal, per sq. ft. grate surface, per hour, 25.4 pounds.
Dry coal, per sq. ft. heating surface, per hour, 49 pounds.

ANALYSIS OF COAL.	Per cent.
Fixed carbon	24.03
Volatile matter	38.32
Moisture	30.17
Ash	7.48

ANALYSIS OF ASH.

Moisture	0.28
Volatile combustible matter	16.01

WATER.

Total water evaporated, pounds	96,363
Equivalent water evap. from and at 212° F., pounds	108,408
Water evap. per hour, pounds	16,061

Equivalent water evap. per hour from and at 212° F., pounds 18,068
Factor of evaporation................................ 1.125
Water evap. per sq. ft. heating surface, pounds........... 3.53
Water evap. per pound coal, actual conditions, pounds.... 5.02
Water evap. per pound coal, from and at 212° F., pounds. 5.64
Water evap. per pound combustible, actual conditions, pounds 8.05
Quality of steam, per cent, dry.........................99.3

PRESSURES.

Steam pressure, pounds...................................146
Draft at uptake in inches water........................0.77
Draft entering economizer over fire.....................0.24

TEMPERATURES.

Feed water, 136° F.
Escaping gases from boiler, 503° F.
Boiler room, 51° F.

HORSE POWER.

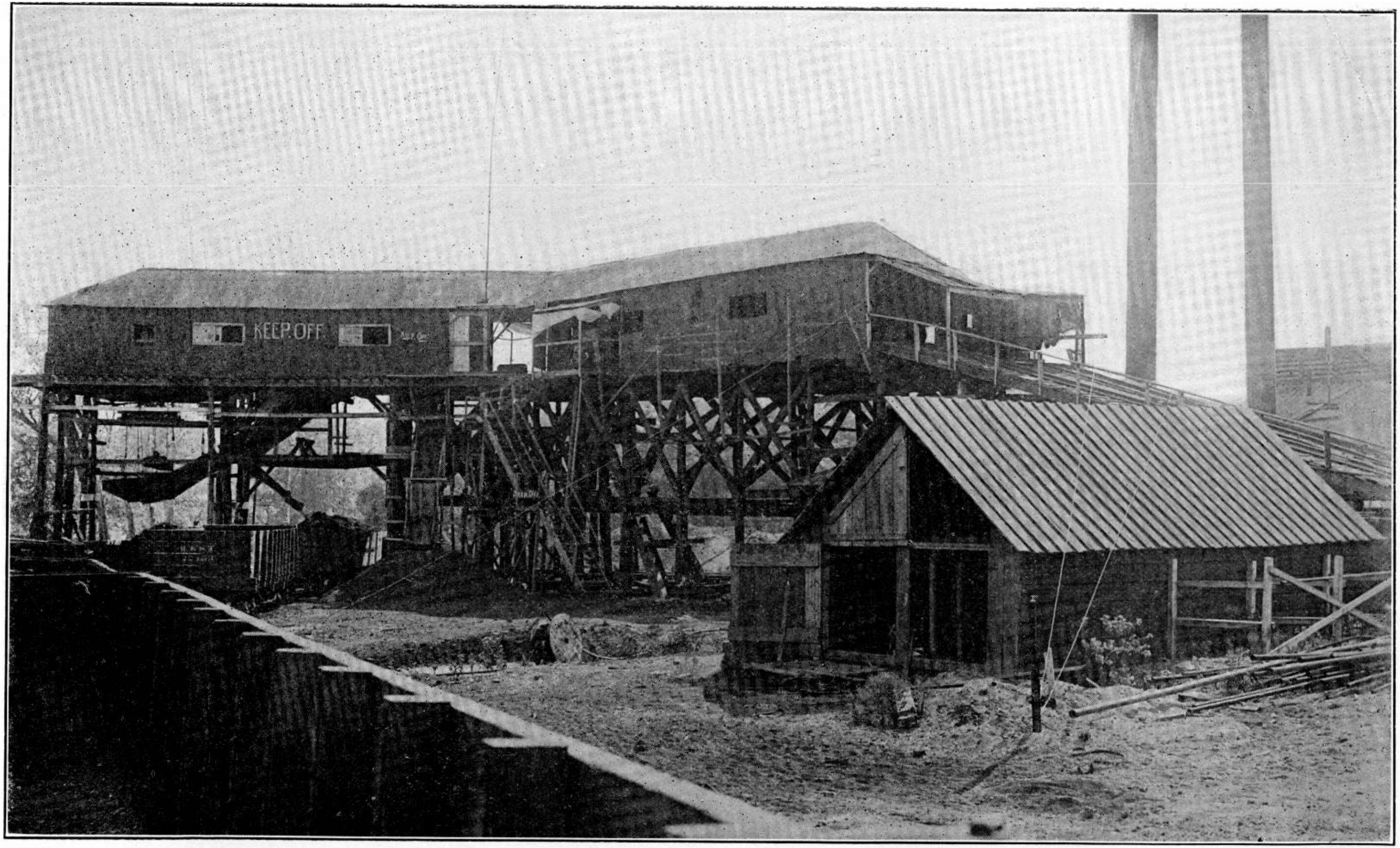
Rated horse-power of boiler...............................454
Horse-power developed from and at 212° F. (1 h. p. equiv. 34.5 pounds water)......................................524
Percentage above rated h. p.............................15.4

ECONOMIC RESULTS.

Water evap. per pound coal, actual conditions, pounds.......5.02
Equiv. evap. from and at 212° per pound coal, pounds......5.64
Equiv. evap. from and at 212° per pound dry coal, pounds..8.08
Equiv. evap. from and at 212° per pound comb., pounds.....9.06

EFFICIENCY.

Efficiency of boiler (heat absorbed by boiler per pound of combustile, divided by heat value 1 pound comb.), per cent....74.8
Efficiency of boiler (heat absorbed by boiler per pound dry coal fired, divided by the heat value of 1 pound dry coal), per cent 73.4



Consumers Lignite Co., Hoyt, Wood County.

A large tonnage of lignite is now fired by hand and while this method unquestionably gives good satisfaction when proper care is bestowed on it, yet for large establishments, the use of an automatic stoker seems to be necessary. There are no insuperable obstacles to be overcome. The main points to consider are that in lignite we have a fuel that parts with its volatile combustible matter more quickly than ordinary bituminous coal does, and that the fixed carbon is not of a coking nature. This means that a large quantity of air must be supplied within a short time after the fuel begins to part with its volatile combustible matter, and supplied at the requisite points. The smoke must be prevented from forming, for it is difficult to handle it after it is once formed. The fixed carbon will take care of itself, if prevented from falling through the interstices of the grate; it is the volatile combustible matter that has to be cared for.

It does not appear that there are greater variations in the composition of lignites than in coals with which they are to compete, so that a stoker installation successful with one lignite should be capable of burning any other lignite, under comparable conditions. The preparation of lignite, according to size, has a direct bearing on the use of automatic stokers. In this connection we quote a letter received from the Consumers Lignite Company, Dallas, with reference to the practice at their mines at Hoyt, Wood county. "The cleaning of lignite slack, or its separation into nut and dust, was first suggested by the practice of the Fraser Brick Company, of Dallas, at its plant at Ginger, Rains county, of mixing a certain amount of lignite dust with the raw material for making fire tile. Their practice was to put the standard slack—all material through a ¾-inch bar screen—through a Williams crusher, set for ¼-inch. The possibility of making a separation of material of this size at the mines led to experiments at the mines of the Consumers Lignite Company, Hoyt, Wood county, Texas, in the summer of 1912, under the care of Mr. A. M. Hodges, assistant manager, and Mr. Drury McN. Phillips, mining engineer.

The original equipment provided for a two-size separation, graded as "lump" and "slack," the lump being all material over a ¾-inch bar screen 12 feet long and 5 feet wide set at an angle of about 35 degrees, and the slack being all material through this screen. These two grades of coal are delivered by gravity to gondola freight cars on two parallel tracks under the tipple, which is for slope hoisting. The amount of slack in mine-run coal varied from 18 to 23 per cent for the last year. Alterations in the existing installation were, of necessity, very limited and it was decided to provide a bin for the dust instead of loading it direct into the cars.

Preliminary experiments on a small scale showed that approximately 25 per cent of the slack was of suitable size and could be obtained through a properly slotted screen. This experimental screen was of ordinary corrugated iron, supported two inches above the floor of the slack pan, and extending two inches beyond the lower edge, across which was fitted a nozzle connected to the suction end of a gin fan. These experiments were so successful that a larger installation was planned, initial operation of which has shown a satisfactory extraction.

The screen at present used for making the separation into "nut" and "dust" is of No. 16 gauge galvanized sheet steel, in which have been cut slots $\frac{1}{4}$-inch wide by 4 inches long. The screen is 12 feet long and 5 feet, 9 inches wide, with a pitch of 35 degrees. The slots are arranged in parallel staggered rows $1\frac{1}{4}$ inches apart, with 2 inches of metal between slots in the same row. Thus there are 24 slots in a row and 50 rows, a total of 1,200 slots with an area of 1 square inch each, making the area of openings about 15 per cent of the total area.

Galvanized angle irons of $1\frac{1}{2}$ inch are riveted along each side of the screen and through these angle irons are drilled six equally spaced $\frac{7}{8}$-inch holes, corresponding to similar holes drilled in the sides of the slack pan $3\frac{1}{2}$ inches above the floor. Through these holes and flush with the lower surface of the screen are passed $\frac{3}{4}$-inch stud bolts, secured by jamb nuts at each end. The lower edge of this screen extends 3 inches beyond the lower edge of the slack pan proper, thus affording ample clearance for the larger particles that slide on the screen without interfering with the finer material that passes through the slots and slides on the pan. Extending across this lower edge of the slack pan proper is a nozzle so designed as to give a uniform suction across its entire width and this nozzle is connected with an 11-inch sheet iron pipe running to the suction side of a 45-inch A. B. C. high speed fan. The distance from the mouth of the nozzle to the fan inlet is 17 feet, with a rise of 4 inches. The fan is belt-driven from a 30 horse-power Lansing engine, with a maximum speed of 1,800 r. p. m., but the necessary speed rarely exceeds 1,500 r. p. m. The distance from the fan outlet to the bin is 48 feet, with a rise of 7 feet, and the delivery pipe has a diameter of 11 inches. The bin is constructed to discharge into gondola cars through four spouts and has a capacity of 50 tons of dust.

The following analyses, made in the laboratory of the Bureau of Economic Geology, University of Texas, show the composition of the various sizes, the samples having been taken simultaneously at three different points. The lump and nut were taken from railroad cars being loaded at their respective shutes and the dust was collected at the mouth of the nozzle. The sample marked "dry dust" was taken from the bin and represents material after its passage through the fan and exposure to the air for several hours.

Analyses of Lignites from Consumers Lignite Co., Hoyt, Wood County, Texas.

	Per cent., as received.			
	Lump.	Nut.	Dust.	Dry Dust.
Moisture	25.85	27.51	26.54	24.95
Volatile combustible matter	35.58	33.42	30.85	32.21
Fixed carbon	31.30	28.12	32.71	32.06
Ash	7.27	10.95	9.90	10.78
	100.00	100.00	100.00	100.00
Sulphur	0.54	0.62	0.68	0.70
British thermal units per pound	7,974	7,739	7,728	7,785

	Per cent. on dry basis.			
	Lump.	Nut.	Dust.	Dry dust.
Volatile combustible matter	47.99	46.10	42.00	42.92
Fixed carbon	42.21	38.80	44.52	42.72
Ash	9.80	15.10	13.48	14.36
	100.00	100.00	100.00	100.00
Sulphur	0.73	0.85	0.92	0.95
British thermal units per pound	10,754	10,676	10,520	10,598

CHAPTER IX.

THE BRIQUETTING OF TEXAS LIGNITE.

Report of Professor E. J. Babcock, University of North Dakota, Grand Forks.

We do not propose to enter upon this subject in detail, for it would require a book to itself. All that is necessary at this time is to give the results which have been recently obtained from the briquetting of typical samples of Texas lignite in the Mining Experimental Sub-station of the University of North Dakota. We shall not discuss the briquetting of raw lignite, for we are of the opinion that this offers few, if any, commercial advantges over ordinary lignite.

Lignite briquettes should be made of carbonized material or material that has had most of the volatile combustible matter removed, whether in closed retorts or in bee-hive or recovery ovens.

We are aware of the experiments that have been made on the briquetting of raw lignite, but we do not consider the results obtained as of sufficient importance to warrant further discussion at this time. Furthermore, it is not necessary to discuss the briquetting of other lignites, for the heart of the matter lies in the results actually obtained from Texas lignites.

During the summer of 1912, we sent to the Mining Sub-station of the University of North Dakota, three separate shipments of 1,000 pounds each of the following lignites, contributed by the companies concerned:

Bear Grass Coal Company, Jewett, Leon county.

Consumers Lignite Company, Hoyt, Wood county.

Houston County Coal and Manufacturing Company, Evansville, Leon county.

We also shipped three barrels of Texas asphaltum (petroleum residue), contributed by The Texas Company, Houston, to be used as a binder for the briquettes.

The composition of the three lignites shipped was determined at the School of Mines of the University of North Dakota, as follows:

Bear Grass Coal Company, Jewett, Leon County.

	As rec'd, per cent.	Dry, per cent.
Moisture	9.30	....
Volatile combustible matter	42.40	46.35
Fixed carbon	39.51	43.18
Ash	8.79	10.47
	100.00	100.00
Sulphur	not det'd	not det'd
British thermal units per pound	10,263	11,315

Consumers Lignite Company, Hoyt, Wood County.

	As rec'd, per cent.	Dry, per cent.
Moisture	10.68	....
Volatile combustible matter	40.87	45.24
Fixed carbon	41.03	45.41
Ash	7.42	9.35
	100.00	100.00
Sulphur	not detr'd	not detr'd
British thermal units per pound	9,923	11,098

Houston County Coal and Manufacturing Company, Evansville, Leon County.

	As rec'd, per cent.	Dry, per cent.
Moisture	13.46	....
Volatile combustible matter	38.00	43.12
Fixed carbon	40.87	46.37
Ash	7.67	10.51
	100.00	100.00
Sulphur	not det'd	not det'd
British thermal units per pound	9,642	11,142

While these coals were in transit from Texas to North Dakota, they lost a large part of their original moisture.

The briquetting tests were under the immediate supervision of Professor E. J. Babcock, Dean of the College of Mining Engineering, University of North Dakota, whose excellent work on the North Dakota lignites needs no commendation here.

In abridging his thorough report we have omitted no essential facts bearing on this investigation.

Experimental Methods, Equipment, etc.

Report of Professor E. J. Babcock.

He says, under date of July 9, 1913:

"The tests given in this report were carried on both at the School of Mines and the Mining Experimental Sub-station of the University of North Dakota. The analyses and tests of the raw coal, the tests of the coal for the yield and quality of gas and carbonized residue, and the analyses of gas, residue and briquettes were all made at the experimental laboratories of the School of Mines at the University.

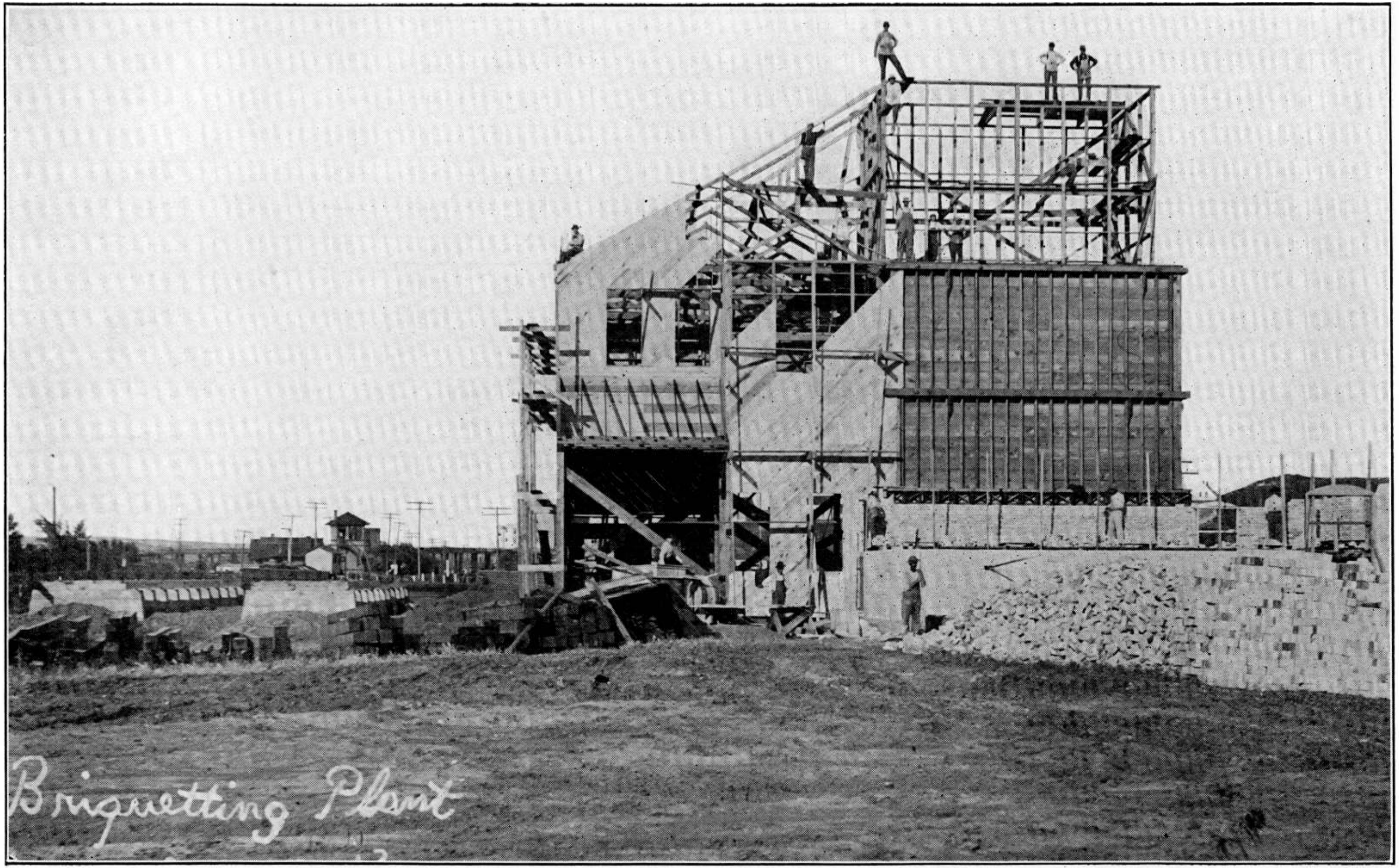
The carbonization of the residue for the production of briquettes and the manufacture of the briquettes from the various samples of coal and the various binding mixtures, was carried on at the Mining Experimental Sub-station under my supervision.

All of these tests were very thoroughly and carefully made with the purpose of approaching, as nearly as possible, conditions which could be secured in a commercial plant. The most serious difficulty in these tests was the lack of sufficient quantity of the different kinds of coal. For this reason, the gas tests were all made in our smaller plant at the School of Mines, but this has proven very satisfactory.

The small experimental gas plant in which this coal was tested for gas is very complete and of sufficient size to give accurate and reliable results and it approximates very closely the methods which might be actually used in the manufacture of gas from lignite on a commercial scale.

The retort is so arranged that pyrometer readings can be taken constantly during the carbonization, thus showing the yield at varying temperatures. The retort is connected by a riser to the hydraulic main. This hydraulic main is then connected with a secondary tar extractor of special design. From the extractor the gas passes to the condenser which removes water, any remaining tar and other solids or liquids. Beyond this is the scrubber provided with sprayer, coke trays, etc. From the scrubber, the gas passes to the purifier, having compartments for either lime or oxide of iron. An exit pipe leads from the purifier to the gas holder which is very carefully constructed and calibrated, and is provided with an accurately graduated scale reading the gas contents at any height to the one-hundredth of a cubic foot.

The holder is so constructed that the gas can be obtained under any pressure desired, and so compensated as to give a uniform pressure with any quantity of gas. It is also provided with thermometers, pressure gauges, etc. From this holder the gas is piped



Lignite Briquetting Plant under construction, Minot, North Dakota.

directly to the gas testing laboratory, where the chemical analyses and the calorific tests are made. The gas determinations were all corrected to normal temperature and barometric pressure.

Standard U. G. I. gas testing apparatus and government methods and a carefully standardized Sargent gas calorimeter were used. The gas and coke determinations were made in this experimental plant. (A more complete description of this plant may be found on page 30, bulletin entitled "Investigations of Lignite Coal Relative to the Production of Gas and Briquets," by E. J. Babcock, University of North Dakota, 1911.)

The carbonization of the lignite for briquettes was carried on at the Mining Experimental Sub-station and in our standard full size gas retort. The experimental gas plant at the Mining Sub-station consists of a bench of one retort, hydraulic main, condenser, exhauster, two scrubbers, purifier, meter, all of the full size used in commercial plants, and one gas holder, together with pressure gauges, pyrometers, temperature recording apparatus, etc.

The gas bench contains a standard retort 9 feet long, capable of carbonizing about 400 pounds of coal in four hours. This plant is complete and contains standard full size apparatus of the latest type. The temperature apparatus is very complete and conveniently arranged so that the temperature of the retort can be taken at any time by means of a high temperature pyrometer and the temperature and pressure of the gas can be taken in any part of the plant by means of a central temperature recording device and a central differential pressure gauge.

The Texas lignite carbonized in this plant was used for the production of briquettes. No determination of gas was made in the carbonization in the large plant as there was not sufficient quantity of the coal. Furthermore, the coal was not completely carbonized, as it was thought that with this particular lignite, and under your climatic conditions, it would not be necessary or desirable to attempt to drive off all of the volatile matter, so as to produce a briquette which could be used as a substitute for anthracite coal.

For this reason the Texas lignite used in making briquettes was only partially carbonized and in each case a different proportion of gas was extracted, leaving each residue entirely different in its proportion of fixed carbon and volatile matter. This method was pursued purposely because of the small quantity of coal available and the large number of tests desired. It was thought that by adopting this method, a large amount of data could be secured with the limited supply of coal. No analyses are given of the residues used in the briquettes. The relative amount of carbonization and some idea of the character of the residue in each case can be obtained by referring to the chemical analyses of the briquettes.

If complete carbonization is desired, the composition of the residue can be seen by referring to the gas and residue tests. Briquettes made from residue from which the gas has been nearly all extracted, will, of course, have a somewhat higher heat value and will give a denser and somewhat stronger and better product. But it was thought that in many cases in the Texas district it would not be desirable to extract all of the gas.

After the lignite was carbonized, it was removed from the retort and quenched by spraying with water. It was then conveyed to the grinding room where it passed through the pulverizer which reduced it to a size ranging from dust to fine shot. It was the intention to have about 75 per cent of it pass a 10-mesh, but retained on a 20 or 30-mesh screen. In running these small samples it was, however, impossible to put the samples through our larger crushers, elevators and mixers, since a considerable part of the samples would be lost.

For this reason it was necessary to grind these samples of lignite in a disc pulverizer and as the Texas lignite itself produces a good deal of fine material in crushing, and because of this type of grinder, the proportion of over fine material was too large, as will be seen by reference to the screening tests given in another part of this report. An excess of fine or coarse material will, in either case, lower the quality of the briquettes, especially with reference to strength and abrasive qualities.

After the residue was ground it was conveyed to a steam-jacketed mixer in which it was heated to the proper temperature and the binding material mixed with it. The binding material consisted of varying proportions of pitch and low grade flour, or ground screenings. The proportion of each is given in the description of the various briquette runs in another part of this report.

The proper proportions of water and steam were then introduced and the mixture thoroughly made, at a temperature of 170 to 180 degrees Fahrenheit. After the mixture was completed, it was cooled to the proper briquetting temperature and then passed through a rotary briquette press, making briquettes weighing from 2 to 2¼ ounces. This press has a capacity of about twenty tons per ten hours. The briquettes were then conveyed on a cooling belt to the storage bin and then were sacked ready for testing.

As has already been stated, we were unable to run these samples of coal completely through our large briquetting plant. It was necessary to use a small grinder and mixer, as already described. Had there been sufficient quantity of the Texas lignite (a carload) to have run through our complete plant, considerably better briquettes could, no doubt, have been produced, although the small sample lots which we made are very good, taking everything into consideration.

The experimental briquetting plant at the Mining Sub-station is a continuous one with a capacity of about twenty tons per ten hours. In this plant, as normally operated, the carbonized residue goes first to a disintegrator which breaks all lumps of residue to a quarter inch and finer. This is then conveyed to a set of rolls which reduce it to the proper size for briquetting. It is then elevated to a bin from which it passes through an automatic feeder which gives the correct proportion of residue to binding material.

At this point, an automatic feed delivers also the proper amount of ground screenings, or low grade flour, between 1 and 2 per cent generally being used. This mixture of ground residue is then delivered to a preheater and conveyer which conveys and mixes the dry material and at the same time brings it to about 100 degrees Fahrenheit and delivers it, at this temperature, into the mixer. At this point, the binding pitch is introduced through a rotary meter, giving the exact amount of pitch binder desired. The pitch used is generally what is known as 145 degrees melting point.

This pitch is melted in a steam heated tank from which it flows by gravity to the meter. It is then sprayed and blended with steam in the mixer. This mixer is steam-jacketed and so designed that it thoroughly mixes the binding material and the lignite residue, at the same time moving it forward and delivering it at exactly the proper speed for the briquetting press. On its way to the briquetting press, it is carefully tempered by a special device which cools the mixture to the proper temperature and which can be regulated to meet the changes in atmospheric temperature. The mixture then passes through the press and the briquettes are delivered to a cooling belt which conveys them to briquette storage bins.

This plant is complete and no hand work is done from the time the residue is delivered to the crusher. All of the machinery is very carefully timed so that every part operates at the proper speed and delivers exactly the right proportion of material. Considerable care and skill is required in the operation of the plant to keep the adjustment exactly right, but the plant has been so carefully worked out that it operates very uniformly and with comparatively little attention.

INVESTIGATIONS ON THE SEPARATE LIGNITES.

Bear Grass Coal Company, Jewett, Leon County.

The analysis of this lignite has already been given. The lignite, as received, yielded 11,450 cubic feet of unpurified gas per ton, the temperature of the retort ranging from 1,472 to 2,057 degrees Fahrenheit (800-1,125° C.). The composition of this gas was:

	Per cent.
Carbonic acid	14.1
Carbon monoxide	17.90
Illuminants	1.70
Oxygen	0.30
Hydrogen	44.60
Methane	16.60
Nitrogen	4.80
	100.00

British thermal units per cubic foot, 334.8.

The yield of residue was 52.34 per cent of the lignite as received and it had the following composition, dry:

	Per cent.
Volatile combustible matter	4.11
Fixed carbon	77.25
Ash	18.64
	100.00

British thermal units per pound, 12,820.

The yields of tar and ammoniacal liquor were not determined.

Briquette Tests.

A series of briquetting tests was made under varying conditions. The gas was not all driven off from the residue which was briquetted and on this account an entirely new series was obtained. The carbonization was carried on in a larger gas oven, only a portion of the gas being removed. The residue was crushed to the following sizes:

	Per cent.
Coarser than 10-mesh	0.38
Between 10 and 30-mesh	34.72
Between 30 and 50-mesh	20.66
Between 50 and 100-mesh	12.11
Finer than 100-mesh	32.13

By reference to this it will be seen that a large amount of the residue was crushed finer than 100 mesh. This was unintentional, as we aim to have very little as fine as 100 mesh. This residue seemed to crush to a fine powder much more readily than our North Dakota lignites and was ground finer than we intended. As a result, the briquettes are not as strong as they would be if there were not in them so much very fine material. It will, however, be difficult to get a large proportion of the right size without considerable fine dust from this residue, as the Texas lignite does not seem to give as hard a residue as that obtained from the North Dakota lignite.

Briquettes: This coal was used for the production of briquettes under a variety of modifications, some made of raw coal and some with the lignite residue, and each lot was made with varying proportion of binding materials. The purpose of this series of tests was to secure a wider range of briquette products so that a comparison of composition, heat value and general quality could be made, taking into account differences in cost of production, etc. The following series of briquettes was made from this coal:

Laboratory No. 2,887 A. These briquettes were made from slightly carbonized lignite residue. The carbonization was made in the regular standard size gas retort. The following mixture was used:

6 per cent. coal tar pitch, about 145 degrees melting point.

2 per cent. ground screenings, or low grade flour.

5 per cent. bituminous coal.
87 per cent. slightly carbonized lignite residue.

The composition of these briquettes is as follows:

Chemical Analysis Briquettes.

	As rec'd, per cent.	Dry, per cent.
Moisture	5.14	....
Volatile combustible matter	34.81	36.60
Fixed carbon	43.42	45.65
Ash	16.63	17.75
	100.00	100.00
British thermal units per pound	11,110	11,616

These briquettes have fairly good physical properties, although not as good as the other samples made from carbonized residue, probably for the reason that the residue from which these briquettes were made was only slightly carbonized. As has already been explained as in the case of the other briquettes, these briquettes are not as strong as those made from the harder North Dakota lignite residue, due largely to the fine powder obtained in crushing the carbonized residue. This can probably be considerably reduced in the operation of a plant by careful adjustment of the grinding machinery; but in this test the quantity was too small to admit of experimental changes in the grinding.

These briquettes, however, are quite satisfactory. They are nearly jet-black in color and have a very good surface. They are sufficiently strong to handle without great breakage and stand in the air without tendency to slack. Although but slightly carbonized, they hold their form well and burn well in the furnace.

These briquettes burn with a little more flame than those which are more fully carbonized, but after the combustion is well under way, the flame becomes very small and there is but little smoke. They burn quite freely, between the more fully carbonized and the raw lignite briquettes, but since a portion of the lighter gas has been taken out, they hold together well while burning. These briquettes are good for steaming coal under boilers and are excellent for furnaces, fire places and ranges; and while they are better than the raw lignite briquettes for use in self-feeding anthracite stoves, they are not as desirable for this purpose as the briquettes made from the completely carbonized residue. These briquettes, however, would probably give very good satisfaction.

Laboratory No. 2,887 B. These briquettes were made from raw lignite which had been dried, but from which the gas had not been removed. The following mixture was used:

11 per cent coal tar pitch, about 145 degrees melting point.
3 per cent ground screenings, or low grade flour.
5 per cent bituminous coal.
81 per cent raw lignite, dry.

Chemical Ananlysis Briquettes.

	As rec'd, per cent.	Dry, per cent.
Moisture	5.26	....
Volatile combustible matter	36.86	38.80
Fixed carbon	46.98	49.45
Ash	10.90	11.75
	100.00	100.00
British thermal units per pound	11,040	11,653

These briquettes are strong enough to stand a limited amount of handling but are not nearly as strong as they would be if they were made from carbonized lignite and therefore the breakage will be considerably greater. The color is nearly black. The shrinkage is comparatively small.

These briquettes stand very satisfactorily in the air, but as is usual with raw lignite briquettes, they crack considerably in the fire. due to the rapid production and escape of gas. However, they do not disintegrate and they stand up quite well in burning. As with all raw lignite briquettes, there is a considerable volume of flame, especially noticeable on fresh firing, and at this period there is also considerable smoke, due to the coal tar pitch used, but after the fire has gotten well started, the flame and the smoke are both largely reduced.

These briquettes burn very freely and too rapidly to be used as a substitute for anthracite. Furthermore, they contain too much gas to be used with entire satisfaction in self-feeding anthracite stoves. They can, however, be used in furnaces, ranges and under boilers, but will not hold the fire as well as briquettes made from carbonized lignite residue and will not stand handling as well. They have, however, a very good heating value.

Consumers Lignite Company, Hoyt, Wood County.

The analysis of this lignite has already been given. The lignite as received, yielded 9,970 cubic feet of unpurified gas per ton. The temperature of the retort ranged from 1,472 to 2,012 degrees Fahrenheit. (800-1,100° C.) The composition of this gas was:

	Per cent.
Carbonic acid	20.30
Carbon monoxide	15.30
Illuminants	1.30
Oxygen	0.40
Hydrogen	31.94
Methane	24.07
Nitrogen	6.69
British thermal units per cubic foot	335

The yield of residue was 54.69 per cent of the lignite as received, and it had the following composition, dry:

	Per cent.
Volatile combustible matter	11.37
Fixed carbon	73.53
Ash	15.10
British thermal units per pound	13,360

The yields of tar and ammoniacal liquor were not determined.

Briquette Tests: A series of briquetting tests was made under varying conditions, on material from which all of the gas had not been removed. The carbonization was carried on in a larger gas oven at the briquetting plant. The residue was crushed to the following sizes:

	Per cent.
Coarser than 10-mesh	1.48
Between 10 and 30-mesh	44.63
Between 30 and 50-mesh	16.52
Between 50 and 100-mesh	11.04
Finer than 100-mesh	26.34

As in the case of the preceding tests, the large amount of the residue was crushed finer than 100 mesh. This was unintentional, for the purpose was to have very little material as fine as 100 mesh. This residue seemed to crush to a fine powder much more readily than our North Dakota lignite, and the briquettes are not as strong as they would be if made from coarser material.

Laboratory No. 2,885 A. These briquettes were made from partially carbonized lignite residue, with the following mixture:

6 per cent coal tar pitch, about 145 degrees melting point.
2 per cent ground screenings, or low grade flour.
5 per cent bituminous coal.
87 per cent partly carbonized lignite residue.

The composition of these briquettes was as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	2.50	....
Volatile combustible matter	22.44	23.00
Fixed carbon	58.53	60.00
Ash	16.53	17.00
	100.00	100.00
British thermal units per pound	11,640	11,938

These briquettes have fairly good physical qualities, and will probably give satisfaction. Their color is nearly jet black. They have a reasonably good surface and are fairly dense. They are sufficiently strong to handle without an excessive amount of breakage. They stand in the air without any tendency to slack. They burn with a small amount of flame which is noticeable mostly at the beginning of the fire, but after combustion is well started, they burn with but little flame and smoke. They burn freely and hold together well while burning. They can be used in an anthracite self-feeding stove and in furnaces, fire places, or ranges. They can also be used for steam purposes, although with a little more volatile matter they would give a longer flame. For general fuel purposes, these briquettes would give very satisfactory results.

Laboratory No. 2,885 B. These briquettes were made from partly carbonized lignite residue. The carbonization was made in a standard gas retort. The briquettes were made with the following mixture:

10 per cent coal tar pitch, about 145 degrees melting point.
2 per cent ground screenings, or low grade flour.
5 per cent bituminous coal.
83 per cent partly carbonized lignite residue.

The composition of these briquettes was as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	2.48	....
Volatile combustible matter	32.64	33.45
Fixed carbon	51.81	53.10
Ash	13.07	13.45
	100.00	100.00
British thermal units per pound	12,627	12,920

These briquettes have fairly good physical properties, and would probably give satisfaction, and the same remarks made under 2,885 A are applicable here. They seem to be somewhat stronger than briquettes No. 2885 A and would doubtless stand handling some what better.

Laboratory No. 2,885 C. These briquettes were made from raw lignite, from which most of the water was removed, but without the removal of the gas. The following mixture was used:

10 per cent coal tar pitch, about 145 degrees melting point.
2 per cent ground screenings, or low grade flour.
5 per cent bituminous coal.
83 per cent raw lignite, dry.

The composition of these briquettes was as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	5.62	....
Volatile combustible matter	43.65	46.10
Fixed carbon	41.28	43.60
Ash	9.45	10.30
	100.00	100.00
British thermal units per pound	12,070	12,788

These briquettes are probably strong enough to stand handling to a limited degree, but they are not nearly as strong nor as satisfactory as the briquettes made from the carbonized lignite. The waste in breakage where there is much handling would be considerable. These briquettes stand very satisfactorily in the air, but in the fire they crack considerably, due to the rapid production and escape of gas. They do not, however, disintegrate, but will stand much poking while burning. There is a large volume of flame, especially noticeable on fresh firing, and in this respect they are very similar to dry lignite. There is also a considerable amount of smoke at this period; due to the coal tar pitch used, but after the fire is well started the flame is somewhat reduced, and the smoke largely disappears. These briquettes burn very freely, and too rapidly to be satisfactory as a substitute for anthracite; and they also contain too much gas to be used in a self-feeding anthracite stove. They could, however, be used in furnaces, ranges, and under boilers, but they do not hold the fire as well as the briquettes made from the carbonized lignite residue. They could not be considered very satisfactory for general commercial use.

Laboratory No. 2,885 D. These briquettes were made from raw lignite, from which most of the water had been removed, but without the removal of the gas, and in this respect they were similar to briquettes 2,885 C. The following mixture was used:

15 per cent Texas petroleum residue.
1 per cent ground screening, or low grade flour.
5 per cent bituminous coal.
79 per cent raw lignite, dry.

Their composition was as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	5.63	....
Volatile combustible matter	40.80	43.10
Fixed carbon	44.59	47.10
Ash	8.98	9.80
	100.00	100.00
British thermal units per pound	11,990	12,705

These briquettes are very good physically. They are quite dense, and as soon as they are dry from the press, they stand handling very well, and I think that the breakage in any reasonable handling would be comparatively small. The color is almost coal black. The surface is very smooth and satisfactory and they stand exposure to the air without any signs of change. They crack in the fire considerably, but do not disintegrate, although they do not stand much poking while burning.

It will be noticed that we reduced the percentage of flour and an additional amount of asphalt was used, and it is probable that 15 per cent of the asphalt could be used without making the briquettes too costly. There is a large volume of flame, especially noticeable on fresh firing, but not much smoke. These briquettes, with 15 per cent petroleum residue are much better than the briquettes made from raw lignite with either 10 or 12 per cent of coal tar pitch. The Texas petroleum residue seems to be an excellent binding material. It evidently requires a little longer to gain its strength than coal tar pitch does, and it is not quite as hard. It seems to be much more elastic, and therefore the briquettes will probably stand handling fully as well as the briquettes mades of coal tar pitch. It also has the advantage of giving much less black smoke. These briquettes burn very freely, and probably too rapidly to be used as a substitute for anthracite, and they also contain too much gas to be used to good advantage in a self-feeding anthracite stove. They could, however, be used for the same purposes as briquettes No. 2,885 C.

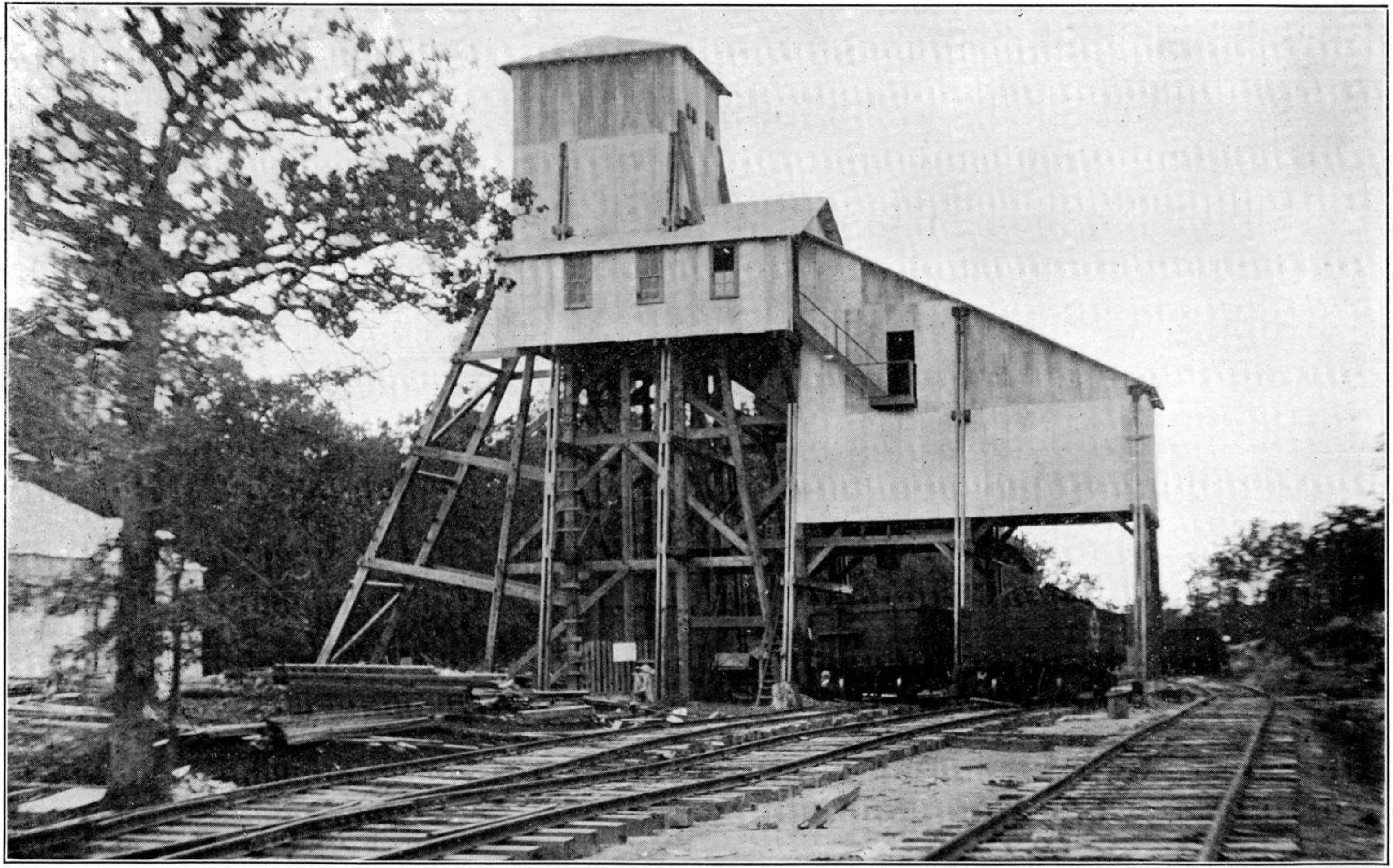
Laboratory No. 2,885 E. These briquettes were made from raw lignite from which most of the water had been removed, but without the removal of the gas. The following mixture was used:

12 per cent coal tar pitch, about 145 degrees melting point.
3 per cent ground screenings, or low grade flour.
5 per cent bituminous coal.
80 per cent raw lignite, dry.

Their composition was as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	4.17	....
Volatile combustible matter	41.28	43.00
Fixed carbon	45.89	47.80
Ash	8.66	9.20
	100.00	100.00
British thermal units per pound	11,180	11,666

These briquettes are very similar to No. 2,885 C. They seem to be a little stronger and will probably stand handling, to a limited degree, a little better, but they are not as satisfactory as No. 2,885 D, made with 15 per cent of Texas petroleum residue. The color is a brownish black. These briquettes are considerably smaller than those made from carbonized residue. The shrinkage is greater on drying than in the briquettes made from carbonized residue, and also greater than in the raw lignite briquettes in which 15 per cent of petroleum residue was used. They stand very satisfactorily in the air, but in the fire they crack considerably. They will not



Houston County Coal & Manufacturing Co. Tipple at Evansville, Leon County. Limit stand much poking while burning. There is a large volume of flame and considerable smoke.

It will be noticed that in this mixture a large per cent of pitch and flour renders the binder rather expensive, especially when applied to raw lignite. These raw lignite briquettes cannot be considered commercially satisfactory.

Houston County Coal and Manufacturing Company, Evansville, Leon County.

The analysis of the lignite has already been given. The lignite as received yielded 10,250 cubic feet of unpurified gas per ton, the temperature of the retort ranging from 1,742 to 2,012 degrees Fahrenheit. (950-1,100° C.). The composition of this gas was:

	Per cent.
Carbonic acid	14.90
Carbon monoxide	17.60
Illuminants	1.60
Oxygen	0.60
Hydrogen	41.25
Methane	15.87
Nitrogen	8.18
British thermal units per cubic foot	335.20

The yield of residue was 49.3 per cent of the lignite as received, and it had the following composition, dry:

	Per cent.
Volatile combustible matter	4.79
Fixed carbon	77.04
Ash	18.17
	100.00
British thermal units per pound	12,327

The yield of tar and ammonia was not determined.

A series of briquetting tests was made on material from which not all of the gas had been removed. The residue was crushed to the following sizes:

	Per cent.
Coarser than 10-mesh	0.24
Between 10 and 30-mesh	22.46
Between 30 and 50-mesh	13.93
Between 50 and 100-mesh	15.57
Finer than 100-mesh	47.80

The same remarks in regard to sizing apply here as in the other cases.

Laboratory No. 2,886 A. These briquettes were made from partly carbonized lignite residue, the carbonization having been made in the regular standard size gas retort. The following mixture was used:

8 per cent coal tar pitch, about 145 degrees melting point.
2 per cent ground screenings, or low grade flour.
5 per cent bituminous coal.
85 per cent partly carbonized lignite residue.

The composition of the briquettes was as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	7.00	....
Volatile combustible matter	18.00	19.26
Fixed carbon	57.46	61.48
Ash	17.54	19.26
	100.00	100.00
British thermal units per pound	11,190	12,032

These briquettes have good physical properties and would give good satisfaction. Their color is nearly jet black, they have good surface and are quite dense. They are sufficiently strong to handle without great breakage. They stand in the air without any tendency to slack, and in the furnace they burn well and hold their form satisfactorily. They burn with a small amount of flame when the fire is first started, but after combustion is well under way, the flame is very slight and there is but little smoke. They burn freely and hold together well. They can be used in anthracite self-feeding stoves, in furnaces, fire places, ranges, etc. For general fuel purposes, these briquettes will give very satisfactory results.

Laboratory No. 2,886 B. These briquettes were made from raw lignite which had been dried, but from which the gas had not been removed. The following mixture was used:

12 per cent coal tar pitch, about 145 degrees melting point.
2 per cent ground screenings, or low grade flour.
5 per cent bituminous coal.
81 per cent raw lignite, dry.

Their composition was as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	11.38	....
Volatile combustible matter	29.81	33.20
Fixed carbon	48.48	54.00
Ash	10.33	12.80
	100.00	100.00
British thermal units per pound	10,490	11,837

Laboratory No. 886 C. These briquettes were made from raw lignite which had been dried, but from which the gas had not been removed. The following mixture was used:

10 per cent coal tar pitch, about 145 degrees melting point.
4 per cent ground screenings, or low grade flour.
5 per cent bituminous coal.
81 per cent raw lignite, dry.

Their composition was as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	7.61	....
Volatile combustible matter	31.32	33.70
Fixed carbon	51.67	55.60
Ash	9.40	10.70
	100.00	100.00
British thermal units per pound	10,900	11,797

Nos. 2,886 B and 2,886 C are both made from raw lignite. The difference being that the per cent of pitch in B is 2 per cent higher than in C, while the per cent of flour in C is 2 per cent higher than in B. I consider the B the more desirable briquette. These briquettes are so nearly of the same character and composition that the following statements apply to both alike:

They are probably strong enough to stand handling to a limited degree, but they are not as strong as the briquettes made from carbonized lignite residue. They are, however, both very good for raw lignite briquettes. The waste in breakage where there is much handling would be higher than in the briquettes made from carbonized lignite. The color is almost black, and there is comparatively little shrinkage. They stand well in the air, but in the fire they tend to crack considerably, without, however, disintegrating. There is a large volume of flame and considerable smoke, but after the fire is well started the smoke is not as noticeable. These briquettes may be considered very good considering the fact that they are produced directly from raw lignite, but it is very doubtful if raw lignite briquettes will prove to be generally satisfactory for commercial use.

Laboratory No. 2,888. Briquettes made from partly carbonized North Dakota lignite. The carbonization was carried on in a modified bee-hive oven; and Texas petroleum residue was used as a binder instead of coal tar pitch. The following mixture was used:

6 per cent Texas petroleum residue.
2 per cent ground screenings, or low grade flour.
5 per cent bituminous coal.
87 per cent partly carbonized North Dakota Lignite.

The composition of these briquettes was as follows:

	As rec'd, per cent.	Dry, per cent.
Moisture	7.50	....
Volatile combustible matter	15.35	16.50
Fixed carbon	61.30	65.90
Ash	15.85	17.60
	100.00	100.00
British thermal units per pound	12,140	12,984

In this sample the ash is unusually high because of the fact that some of the residue was reduced to ash in the burning and quenching. Under ordinary conditions, the ash would be considerably lower. These briquettes have excellent physical qualities. They are very strong and hard and stand exposure to the air without any tendency to slack. They are almost jet black in color, have an excellent surface, and are very dense. They stand handling remarkably well and there is very little breakage. In the fire they stand well and hold their form satisfactorily, although they do not seem to be quite as hard as the briquettes made with coal tar pitch. They burn with a small flame and but little smoke. They would make an excellent substitute for anthracite in self-feeding stoves, and would also be an excellent material in furnaces, fire places, ranges, etc. For general fuel purposes these briquettes would give excellent satisfaction. This test was run for the purpose of determining the value of Texas petroleum residue as a substitute binder for coal tar pitch, and the sample which we made this test with has proven very satisfactory for this purpose. The briquettes are not quite as hard as those made from the coal tar pitch, which we have described and used in other tests in this report; but they are very tough and elastic, and I think would stand handling fully as well as briquettes made with the same precentage of harder but more brittle coal tar pitch, and would give less breakage.

This Texas petroleum residue works very satisfactorily and produces an excellent briquette. It has an advantage in the fact that it produces much less black smoke than coal tar pitch does.

Conclusions.

The results obtained in these tests would indicate that the methods which we have worked out and which are applicable to North Dakota lignites, can also be used with a fair degree of success on your Texas lignites. The special characteristics of the Texas lignites require slight modification in the commercial application of this process, but no material changes in principles or methods.

On account of the climatic conditions and the cost of fuels, it is probable that the type of briquette should be slightly different from that which would be considered most desirable commercially in North Dakota. The main difference would probably be in the degree to which the carbonization should take place, and possibly in the use of crude petroleum residue, if it can be obtained in sufficient quantity and at sufficiently low price, as a substitute for coal tar pitch.

By reference to the earlier part of this report, it will be seen that the samples of air-dried Texas lignite will produce, per ton, from 9,000 to 11,000 cubic feet of gas of about 335 B. t. u., unpurified. Although the heat value is somewhat low, the yield is very good. It is probable that if this coal were completely dried before carbonizing and the carbonizing were done at a somewhat lower temperature, the gas would be of higher heating value but of correspondingly smaller yield. Moreover, if the gas were purified, as with ordinary city gas, its B. t. u. would be considerably raised.

In commercial practice it would probably be more economical to dry the coal in a rotary drier before carbonizing it, as this would increase the rapidity of carbonizing and the quality of the product. By so doing, it is probable that a yield of 8,500 to 9,000 cubic feet of gas could be counted on in a commercial plant.

This gas is valuable for heat and power purposes and if used with a 'mantle' is excellent for lighting. Considering the ease with which it can be produced and the low cost of the original lignite and the value of the resulting residue, such lignite gas should, in many localities, have a good commercial value. If produced as a by-product in connection with the briquetting of lignite, it could be sold unpurified at a very low price, especially if used for heat and power gas. A very few cents saving on the by-product gas would net a considerable revenue per ton of briquettes.

In addition to this, if desired, some saving in ammonia and lignite tar could be effected. The yields of these two substances were not determined on these tests of Texas lignite, but it is not probable that they would vary greatly from the results obtained with North Dakota lignite (see "Investigations of Lignite Coal Relative to the Production of Gas and Briquets," by E. J. Babcock). This lignite tar should have considerable commercial value.

The residue produced after the gas has been extracted is of high fuel value. It is probable that in commercial practice about 50 per cent of this carbonized residue could be obtained per ton of raw air-dried lignite with most of the gas removed. When the binding material is deducted, it will be seen that it will require about a ton and three-quarters of raw coal for a ton of finished briquettes. These briquettes, however, would be of high fuel value and if carbonized to that extent should be an excellent substitute for anthracite coal. Such briquettes would have many advantages over the raw lignite. They would be much higher in heating value, they would not disintegrate when exposed to the air or on burning, would be uniform in size and convenient to handle and would be of high economic value.

The results of these tests lead me to believe that in consideration of the climatic conditions in your region, the cost of other fuel and the special characteristics of the raw lignite, it would not be desirable, in many cases, to make a completely carbonized residue briquette, but rather an intermediate quality in which the lignite would be partially carbonized by a cheap and simple process and thus produce a briquette which could be marketed at a much lower price than a completely carbonized residue briquette could be sold for, unless a fair price could be obtained for the gas.

Such a briquette from partly carbonized residue, would prove an excellent steaming fuel and also good for most household purposes. It would be of good heating value, much above the raw lignite and would be sufficiently strong for ordinary handling. These conclusions are borne out, I think, by examination of the accompanying briquettes made from the partially carbonized residue, the tests of which are given in this report.

By such a partial carbonizing process, the moisture and lighter volatile gases would be driven off easily and with little cost and the residue yield would be, of course, correspondingly larger. If these briquettes were made with the proper proportion of binder they would undoubtedly give a satisfactory product for the uses mentioned.

On the other hand, these tests would indicate that it would not be desirable to attempt to produce, for commercial purposes, raw or uncarbonized briquettes. Raw lignite briquettes will not stand the weather or handling very satisfactorily, as will be seen by reference to the samples which accompany this report. They crack and crumble quite readily in the furnace, due to the rapid production and escape of a large quantity of gas which is present in the raw lignite. Furthermore, these briquettes have not as high heat value. Raw lignite briquettes would cost nearly as much to produce as the partially carbonized residue briquettes and would be very much inferior in quality. Therefore, I would not advise any attempt at the manufacture of raw or uncarbonized lignite briquettes.

I believe, however, that by the partial carbonization of the Texas lignite and the use of the proper proportion of "Texas Petroleum Residue," if it can be secured at low enough price and in large quantities, a satisfactory commercial product can be successfully produced in localities or under conditions where there is not demand for all of the gas which would be produced by complete carbonization. If, however, there is a good market for this byproduct gas, the more completely carbonized residue briquettes should be produced at a commercial advantage."

This concludes the report of Professor Babcock.

The investigations made by Professor Babcock are the first attempts to bring this matter into the sphere of commercial possibilities. He takes what seems to us to be the only rational view of the situation when he says that it is doubtful if raw lignite can be made into acceptable briquettes. It is not necessary to quote the results of experiments that were made in St. Louis and elsewhere, by the United States Geological Survey, for they do not lead us in the right direction. These experiments looked to the manufacture of briquettes from raw lignite and it seems to us to be quite useelss to hope for a profitable exploitation of this field.

We are decidedly of the opinion that the best, if not the sole, outlook is in the direction of briquettes made from carbonized lignite, whether this carbonization is partial or complete, with recovery of gas, tar and ammoniacal liquor. The development of this industry will, we think, depend on the utilization of all of the products derivable from lignite, viz.: the solid residue, the gas, the tar (and products of its distillation) and ammonia compounds to be obtained from the ammoniacal liquor.

In order to throw some light on this subject, we built in our own laboratory an experimental gas plant for distilling lignite in a closed retort and determining the yield and quality of the products obtained. This investigation was an elaboration of our work on samples of all of the coals and lignites mined in Texas, and was confined to one particular lignite because it was impracticable to conduct so detailed an experiment on more than one sample. This special work occupied us for nearly four months and had we extended it to embrace all other lignites produced in the State, it would have been three years before the work could have been finished.

In this special investigation we were greatly aided by Dr. W. Bredlick, a Bohemian chemist of wide experience in such matters, and our grateful acknowledgments are due him, as also to Mr. J. E. Stullken, assistant chemist to the Bureau. The detailed results of this special work are set forth in Chapter XI.

CHAPTER X.

UTILIZATION OF BROWN COAL AND LIGNITE IN EUROPE.

BY W. BREDLICK.

The utilization of the brown coals and lignites of Europe, by briquetting and by destructive distillation and recovery of the by-products, has reached a high stage of development. This industry may be compared, for the purpose of illustration, to the highly developed petroleum industry in the United States. A barrel of crude oil is worth about $1.00, on the average, but may be made to yield considerably more than this by distillation and refining. The brown coals and lignites of Europe have been enhanced in value by briquetting or made to yield by-products of greater value than the original substance by the process of destructive distillation.

The comparison may be carried still further. Crude petroleum from one district may differ widely from that of another district, even from different wells in the same district, yet these different petroleums can all be refined by similar processes and made to yield products of higher value. In like manner, the brown coals and lignites of Europe, of which there are many varieties and grades, either are or can be utilized, within certain limits, for the manufacture of more concentrated fuels, and for their yield of by-products.

In view of the fact that many of these European fuels, which are thus treated, are not only similar to but some nearly identical with and others even inferior to, the Texas lignites, a description of the industry as developed in Europe is of special interest, because the utilization of Texas lignites will naturally follow similar lines of development. Other chapters of this bulletin give the results obtained in the laboratory of the Bureau by the dry distillation of Texas lignite.

It may be said of lignite that it is a somewhat inferior fuel; that is, its heating power is lower than that of coals in ordinary use. This is due primarily to the fact that lignite contains a much larger percentage of water than ordinary coal, and, also, that it nearly always contains more oxygen and sometimes more ash.

The beneficiation of lignite may be accomplished by mechanical and chemical treatment in three ways.

The first, a purely mechanical treatment, consists in drying the fuel. By driving off the moisture, usually from 25 to 30 per cent, the percentage of the other constituents is raised and the heating power increased. The elimination of the moisture results in partial disintegration of the fuel with the result that it cannot bear transportation or handling. The dried material must consequently be compressed into briquettes either with or without a binder.

The second method is the dry or destructive distillation, a purely chemical treatment. In this process, which is, in principle at least, identical with that used for the manufacture of coke for metallurgical purposes, the lignite is heated with the exclusion of air. The products resulting are as follows:

First. A residue composed of the fixed carbon and mineral contained in the lignite.

Second. The volatile by-products, consisting of gas, tar, and ammoniacal vapors.

The residue is not a coke in the ordinary use of the word, being disintegrated into small pieces instead of agglomerated into masses.

The gas resembles coal gas made in the same manner; the ammonia is, of course, the same. The tar is quite different, as will be shown later.

The oldest distillation plant in Europe is still in operation in Saxon-Thuringen, in Germany.

The third method of treating lignite is that of extraction with solvents. This is a new industry which began to flourish only during the past year. It has found practical application with the bituminous lignites (pyropissit) of the Saxon-Thuringen district. This particular lignite contains a soluble substance which can be removed without the usual decomposition by heat. This has been known since the beginning of pyropissit distillation, but that it can be commercially accomplished on a large scale is a modern achievement. From this lignite the soluble portion is removed by tar oils of low boiling point, made from brown coal. A part of this extract is purified by the Bayens and similar methods. It is used as a substitute for Carnauba wax and is mixed with ceresin. It is black-brown in color and has a conchoidal fracture. It is used for making phonograph plates, for the manufacture of shoe-polish, for sizing paper, etc. Its extraction can be carried on profitably only from lignite containing a certain amount of this waxy substance. However, all kinds of lignite (called brown coal in central Europe) are treated either chemically or mechanically or both, for the purpose of concentrating the heating power or for the recovery of by-products.

As regards their properties for the purpose of treatment, the lignites of central Europe may be classed according to their use into the following groups:

I. Lignites used as fuel without any preparation.
II. Lignites that are briquetted.
III. Lignites that are distilled.

To the first group belongs the young lignite, really a fossil wood, then the common brown coal, and the lignite anthracite. The moisture content of these lignites varies from 10 per cent to 30 per cent. They are all low in ash. This group is represented in all gradations by the Bohemian lignites of the northwest brown coal basin. They are used exclusively under boilers, for generating gas, for all kinds of smelting and for household purposes. Those rich in gas are used for the manufacture of illuminating gas. The only treatment these lignites receive is screening to size them into lump, nut and gravel coal. In Bohemia, some of these lignites are briquetted with the addition of a binder and a small quantity is distilled to obtain lignite coke. The industry is local, however.

To the second group belong the briquette coals. Their moisture content is between 40 per cent and 60 per cent. Since these lignites are not compact and oftimes are slimy from excessive moisture, they are not suitable for fuel in the crude state, except when burned on a special form of step grate or when dried before firing. They are used in briquetting factories for local consumption, usually in factories in the immediate vicinity of the lignite mines. They are found in immense layers, sometimes 120 feet thick at a depth of only 6 to 10 feet below the surface of the earth, consequently they are mined chiefly by open-cut workings. To prepare them for briquetting, when very moist, the larger pieces of wood are removed and then the remainder is disintegrated and sifted to separate out the ashy lignite powder. The homogeneous lignite is then dried in vertical or horizontal cylinders, until it contains only 13 to 15 per cent moisture. Under a pressure of 9 to 11 tons, this dried substance is pressed into briquettes of various forms. The lignites of Germany can be pressed into briquettes that are weather and water proof without the addition of any binding material like tar pitch, or petroleum pitch. These briquettes do not suffer any loss by deterioration on exposure to the air. This is due partly to the nature of the lignite used and partly to climatic conditions. They are used extensively for domestic purposes, not only in heating stoves but also in cook stoves. For boiler heating and gas production, smaller briquettes are made that find a ready sale in central, south, and west Germany.

This lignite, as mined, has a heat value of 3,600 to 4,500 B. t. u. The briquettes made from it will run from 8,300 to 9,700 B. t. u. The cost of mining by open cut workings is on the average 30 cents per ton. This is the cost of the raw material required, since no binder is necessary. The profit in briquetting this lignite consists in raising its heat value from 3,600-4,500 B. t. u. per pound to 8,300-9,700 B. t. u. per pound. To express the relation in cost per ton of briquettes, the following figures are given:

1.92 tons lignite required for 1 ton briquettes, at 40 cents per ton for the raw material	$0.770
1 ton for power	0.435
Labor, depreciation, maintenance, interest on the investment.	0.750
General management	0.125
	$2.080

The selling price per ton in Germany is on the average $2.50, making a profit of 42 cents per ton on the briquettes. A plant with a capital of $110,000 can manufacture 36,000 tons of briquettes per year, clearing a profit of $15,000, or nearly 13½ per cent. Since 5 per cent interest is included in the above calculation under the item of "Labor, depreciation, maintenance, interest on investment," the briquette factory nets a profit of 18½ per cent, on the average.

Other lignites, like those of Bohemia, need a binder, often as high as 8 to 12 per cent being necessary. In general, the older the lignite the more binding material is necessary. West Bohemian lignites are made into briquettes in only three factories. The binder used is pitch. The production in Bohemia is very small in comparison with the output in Germany.

Besides briquetting with a press, there is another method in use in some localities for working lignites. In ordinary briquetting, the heating value is raised 80 to 90 per cent, or more, and the lignite is also fitted for handling and transportation. In the method about to be described, the heat value is raised only 15 to 20 per cent, and the territory of sale is limited to small distances from the point of production. The lignite is spread on a floor. Woody pieces are removed and it is then moistened. The soft mass is then thoroughly mixed by tramping on it. This mass is then placed on a flat surface to the depth of seven inches. It is smoothed, moistened again and is allowed to dry in the open air. It is then tamped down with a wooden tamper and cut into cubical blocks. These blocks are laid in rows under drying sheds. This work is generally done by hand, but can be done by a machine similar to that used in a tile factory. This method of preparing lignite is in use in Hessia, Saxony Province, in the Thuringen States, and in the Kingdom of Saxony. The total production of these hand briquettes in Germany reached its maximum in 1901 with an output of 740,000 tons but was reduced to 583,000 tons in 1906.

The third group of lignites includes those that are utilized through dry distillation, a chemical process in which decomposition is effected by heat. To this group belongs the earthy brown coal with high bitumen content called pyropissit. Bituminous shales are also treated in this way. The brown coal, pyropissit, is worked on a large scale at present only in Saxony-Thuringen, of Germany. It consists of pyropissit and fuel coal. Between these two exists the real distillation coal, called Schwell coal. According to its composition, pyropissit belongs to the wax coal, the fuel coal to the humus coal. In origin, pyropissit must belong to the vegetable waxes and rosins of the Tertiary age. This explains why these substances so strongly resist decay and dissolution and therefore were preserved under conditions under which other parts of plants were completely destroyed. The distillation coal in the damp condition in which it occurs in the mines forms a plastic mass, at times greasy and fatty to the touch. When dry it is of a light color and resembles an earthy brown coal that is soaked more or less with a wax-like bitumen. The deposit, which is mined by open cut, is not homogeneous, but consists of layers of lignites rich in bitumen, pyropissit, and fuel coal.

The other material mentioned for destructive distillation is bituminous shale. It belongs to the sapropel coals and is formed by the addition of clay sediment to the decaying bog. This shale occurs at Messel, near Darmstadt, Germany. The bituminous shale of Scotland resembles that near Darmstadt. The German shale distillation works are not open to the public and the literature on the subject, so far as German practice is concerned, is meager.

The distillation of brown coal and bituminous shale is similar in the sense that in each case a bituminous substance is treated. As has been stated, in the brown coal that contains pyropissit, usually there occurs also the fuel-lignite. It is quite difficult to distinguish between them in a moist condition. Both form a more or less plastic brown mass which, in the case of pyropissit, turns on drying to a yellow or white color, according to its purity. Distilling-lignite, when dry, shows an earthy fracture and feeble gloss. Its specific gravity is 1.0 or less, while that of fuel-coal is 1.2 to 1.4. Distilling-lignite melts at 302 to 392 degrees Fahrenheit (150-200 degrees C.), while fire-lignite never melts but burns with a strong sooty flame and faint odor which changes, on being blown out, to the odor of burnt shellac. Pure distilling-lignite is free from vegetable remains. It consists only of amorphous resinous particles that saponify when treated with an alkali.

The composition of pyropissit, distilling-lignite, and fuel-lignite respectively was ascertained by Brückner as early as 1852.[1]

Through successive extraction with oils and alcohol and afterwards by distillation of the extracts, a whole series of wax or rosin products was obtained. Special names and formulae were given to the isolated bodies. Inasmuch as pyropissit is not a definite chemical compound but a mixture, being a transition product[2] from the resin of plants to fuel-lignite, there is a difference in the analyses given by different chemists. According to Riebeck, pyropissit has the following proximate analysis:[3]

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[1]Jour. für Prak. Chem., Vol. 57, p. 1.

[2]Graefe, Die Braunkohlenteer Industrie, 1906, p. 3.

[3]Zts. für Berg-Hütten und Salinenw., Vol. 24, p. 356.

	Per cent.
Hygroscopic water	4.40
Organic matter	83.97
Ash	11.63
	100.00

Its ultimate analysis is as follows:

	Per cent.
Carbon	66.24
Hydrogen	10.55
Nitrogen	0.01
Oxygen	13.34
Ash	9.86
	100.00

Fuel-lignite has the following composition by ultimate analysis, on an air-dried sample (V. Bredlik):

	Per cent.
Carbon	58.21
Hydrogen	5.09
Oxygen	26.11
Nitrogen	0.54
Ash	0.55
Moisture	9.50
	100.00

The distilling-lignite deteriorates on exposure to the air, as Thede has shown analytically.[1]

If pyropissit be subjected to dry distillation, it is decomposed, according to Riebeck, into

	Per cent.
Tar	64.2
Water	7.7
Coke	16.3
Gas and loss	11.8
	100.0

Distilling-lignite, on the other hand, yields

	Per cent.
Tar	33.0
Water	23.0
Coke	35.0
Gas and loss	9.0
	100.0

[1]Allgem. Oesterr. Chem. u. Techn. Ztg., 1892, p. 917.

Fuel-lignite yields by distillation:

	Per cent.
Tar	5.0
Water	63.5
Coke	25.0
Gas and loss	6.5
	100.0

From these figures, it is seen that these substances give different yields of tar. In former times, great care was taken to separate the distilling-lignite from fuel-lignite. To the pure pyropissit, fuel-lignite had to be added, since, when alone in the distilling oven, it melted and flowed, making distillation difficult. At the present time, the supply of very bituminous lignites has been exhausted and the operator must be satisfied with a much poorer grade for distillation. Those now treated by this method yield but 5 per cent tar. The primary purpose of distilling these lignites is to obtain tar through the decomposition effected by heat. In Saxon-Thuringen the lignite coke is the by-product.

Formerly, the lignite was distilled in cast iron retorts. Since 1858, vertical coke ovens have been used exclusively. They are about 18 feet high. Within is a system of beveled cast iron rings placed one upon the other in the form of a column. A cross section gives an appearance of Venetian blinds. These flanges are fastened to each other in the central axis by a vertical rod passing through the cylinder. Inside this cylinder then a hollow space is formed about 4 feet in diameter. This column of circular flanges is walled in with a fire-proof material called Dinas tiling. The space between this shell of tiling and the column of flanges is about 6 inches, and is the space occupied by the lignite during the process of distillation. The flame from the burning gases for distilling the lignite passes upward through spaces provided in the Dinas tiling, which is so constructed that it is in reality a hollow column with passages so arranged that the flame instead of going directly upward is forced to follow passageways around, spirally. The lignite is distilled by coming in contact with this heated tiling and in reality is heated by radiation, the flame not coming in contact with the lignite. The exterior of this Dinas tiling is enclosed with fire brick and these in turn with ordinary brick. At its lower end the distillation cylinder is conical. To this cone is joined a round box. The top of the cylinder is covered with an inverted funnel-shaped hat. Two pipes carry off the products of distillation, one in the upper part and one in the lower. Outside they unite and carry the distillation products to the condensing apparatus. The lignite is charged at the top and passes vertically downwards between the cast iron rings and the heated tiling. The oven is fired with the gas produced by distillation after the gas has passed through the condensation apparatus and has been relieved of its tar and ammonia contents. The temperature is lowest in the upper portion and distills off the water first. As the lignite sinks it encounters the hotter part of the furnace. Distillation occurs in the lower third of the oven. At the bottom of the oven the residue, a lignite coke, is drawn off and quenched with water. The temperature from the top to the bottom increases gradually to a maximum of 1,184 degrees Fahrenheit (640 degrees C.). Gas begins to form at from 248 to 302 degrees Fahrenheit (120 to 150 degrees C.), is drawn from the interior space of the oven by means of an exhauster and passed to the condensation plant, through the two pipes mentioned above.

The condensation plant consists of a system of pipes through which passes the gas with its burden of tar. Cooling was formerly done with air, but of late water cooling has been introduced to save space and to lessen the amount of piping necessary. The condensed substance flows into a reservoir.

Distillation-lignite now being treated yields about 4,900 cubic feet of gas per ton, with a heat value of 340 B. t. u. per cubic foot. The gas has:[1]

	Per cent.
Carbon dioxide	10.9
Heavy hydrocarbons	1.1
Oxygen	6.3
Carbon monoxide	8.5
Hydrogen	22.6
Methane	6.4
Ethane	2.0
Nitrogen	42.2
	100.0

Formerly the gas was allowed to escape into the air. Today it is used to heat the ovens and the surplus is utilized in gas engines for the generation of electric energy.

[1]Graefe, J'l für Gasbeleuchtung u. Wasserversorgung, 1903, p. 524.

The ammonia is not conserved, since only 0.07 per cent is found in the condensed water, in the Saxony-Thuringen industry.

The coke is a granular product of pale black color, containing 15 to 20 per cent ash and 20 per cent water (from quenching) and has a heat value of 8,500 to 9,000 B. t. u. If burned in a suitable furnace, it is an excellent fuel that emits no smoke, deposits no soot and has no flame.

The principal product in point of value is tar. When warm it is a liquid, when cold it grows stiff to a buttery consistency. It has a brown color and an aromatic odor. Its specific gravity is between 0.85 and 0.91. The lighter the tar the greater is the paraffin content and therefore the greater its value. Tar boils between 302 degrees Fahrenheit (150 degrees C.) and 752 degrees Fahrenheit (400 degrees C.), but contains a small quantity of substances of lower and higher boiling points. It consists chiefly of liquid and solid members of the paraffin and olefin series, and other hydrocarbons of low hydrogen content. Of aromatic substance it contains only traces of benzol and its homologues. Besides these there occur small quantities of free acids and their esters with alcohols of high molecular weight, derived from undecomposed bitumen. An integral constituent of lignite tar is sulphur in organic combination. Coal and coke dust as well as water are found in tar as impurities. To separate the water, the tar is collected in pits where it remains warm and fluid for some time, which permits the suspended water to settle out.

The tar, after the water has been separated, is treated for tar oil and paraffin and the by-products gas, cresole, and coke. This is effected by (1) fractional distillation, (2) chemical treatment of the distillates, and (3) crystallization. The method of treating the tar from bituminous lignites in Saxony-Thuringen, the tar from bituminous shales, and the tar from the Bohemian lignites, is pretty much the same. For this reason, the method common for all will be described.

The Scottish industry since 1872 has used exclusively a bituminous shale as a distillation material. This is found in Linlithgow and Mid-Gotham counties. It is deposited in the lower bituminous coal formation, not between layers of coal, but between limestone and sandstone. A distinction is made between two kinds of shale, one which has a shale-like fracture and is gray, while the other has a conchoidal fracture and is black. In a moist condition it has a greasy feel and is tough, with the odor of clay. When dried it is shaly and with leaflike layers. The chemical composition of Scotch shale is as follows:[1]

	Per cent.
Carbon	25.27
Hydrogen	3.67
Oxygen	5.65
Nitrogen	1.14
Sulphur	0.49
Ash	63.74
	99.96

The bituminous shale of France is analogous to boghead coal, compact and massive like compressed peat, and has about the following composition:[2]

	Per cent.
Carbon	60.80
Hydrogen	9.18
Nitrogen	0.78
Oxygen	4.38
Sulphur	0.32
Ash	24.18
Moisture	0.39
	100.03

The bituminous shales which are distilled in Germany, France, England, etc., differ from the distilling-lignites of Saxony-Thuringen in composition and in yield of the principal by-products. In the case of the lignites, the principal product is tar, the by-products are coke and gas. Shale is distilled for tar and ammonia, and the by-products, coke and gas, are not considered. Since shale in England contains 60 per cent, in Germany 50 per cent, and in France 24 per cent of mineral matter, the residue from the retorts is of little value as a fuel. The yield of gas is not sufficient even to supply the necessary fuel for distillation and the retorts must be heated with coal direct or with producer gas.

The following summary shows the yield of different bituminous shales, in percentages:

[1]Destruct. Distill. Mills, p. 38.

[2]Dict. de Chemie, Wurz, Vol. I, part 1, p. 638.

		Tar.	Ammonia water.	Residue.	Gas.
(1.)	Messel, Hessia, Germany	6–10	40–45	40–50	....
(2.)	Broxburn, England	12	8	76	4
(3.)	Bagnas and Autunois, France	6	10	81.5	2.5
(4.)	Subotioi, Servia	34	8	36.53	11.47

The distillation apparatus used in the shale industry is quite different from that employed in Saxon-Thuringen. Essentially it consists of a vertical cast-iron cylinder, from 12 to 14 or even to 16 feet in height, and from 1½ to 3 feet in diameter. It is heated directly with coal or with producer gas supplemented with the gas from the distillation. In order to obtain the greatest possible yield of ammonia, superheated steam is blown into the retorts. By this means, the fixed carbon present is consumed. The gases are drawn off by suction and condensed by air and water cooling and by washing the gas in paraffin oil. The cooled gas is also compressed to obtain liquid hydrocarbons.

The gas of the Scotch industry has the following composition:[5]

	Per cent.
Carbon dioxide	15.40
Carbon monoxide	10.72
Hydrogen	34.53
Methane	4.02
Nitrogen	35.33
	100.00

One ton of shale yields about 3,000 cubic feet of gas. If the distillation residue contains some carbon, it is burned and the ash used to make bricks. The tar of the Scotch industry from retorts of the older system (without the use of superheated steam) had a specific gravity of 0.88 to 0.90, the tar of the new system (with superheated steam) has a specific gravity of 0.85 to 0.875. It stiffens at 50 to 68 degrees Fahrenheit (10 to 20 degrees C.). Its color is brownish red, the odor is mild, and it boils from 158 to 752 degrees Fahrenheit (70 to 400 degrees C.). Its composition is similar to that of the lignite tar of Saxon-Thuringen, except that its nitrogen content is higher, 1.16 to 1.45 per cent.[6]

[1]Scheithauer, Die Fabrik der Mineralöle, p. 28.
[2]J'l Soc. Chem. Indust., Vol. 8, p. 100.
[3]Dict. de Chemie, Wurz, Vol. 1, p. 638.
[4]"Verlag Berliner," 1887, p. 2717.
[5]J'l Gas Lighting, 1893, Vol. II, p. 399.
[6]J'l Soc. Chem. Indust., 1891, p. 126.

The yield of ammonia is high in comparison to the yield in other distillation processes, being increased by blowing in the superheated steam. According to Young and Beilby, the nitrogen content of the crude material is as follows:[3]

	Per cent, without steam.	Per cent, with steam.
As ammonia in ammonia water	17.0	74.3
Nitrogen in tar	20.0	20.4
Nitrogen in residue	62.6	4.9

The specific gravity of the water is 1.03, and it contains, besides ammonia, pyridine and other organic bases. The water is usually distilled out in horizontal cylindrical vessels, after adding 5 per cent slaked lime. The vessels have a capacity of 175 to 560 cubic feet and are heated by direct fire or by indirect steam. The gaseous ammonia goes through a scrubber and is passed into a trough lined with lead and containing sulphuric acid of 1.4 specific gravity. The crystals of ammonium sulphate formed are dried by decantation. They are not quite pure but contain some free sulphuric acid, traces of sulphurous pyridine that does not crystallize, and a little water.[1] One ton of shale yields 59 pounds of ammonium sulphate, from which 15 pounds of ammonia is derived.

As already stated, the working of the tar of the German lignite distillation and shale distillation is practically the same and for this reason the two processes will be described together.

Lignite distillation and shale tar distillation may be considered under three heads:

1. Fractionating distillation.
2. Treatment of the distillates with chemicals.
3. Manufacture of paraffin.

After the coal tar has been freed from moisture, coke and coal dust, it is subjected to the first distillation, yielding the following fractions:

I. Paraffin-free oil.
II. Paraffin mass.
III. Residue.

The distillation is made in a cast-iron retort of 70 to 100 cubic feet capacity, which has a special discharge for the residue.

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[3]Zeitsch. für angew. Chem., 1893, p. 108.
[1]Destruct. Distill. Mills, p. 20.

The retort has a fire-brick setting and the firing is done on horizontal stationary grates.

The first part of the distillation is carried on under atmospheric pressure. When the water has been removed, the distillation is continued under vacuum, about two-thirds of the distillation being done in this way. The products are separated into paraffin-free oil and paraffin mass. These are distinguished in this way. The paraffin-free oil comes over first. Samples are repeatedly taken and allowed to drop on ice. As soon as the oil stiffens, indicating the presence of paraffin, the receiver is changed.

The tar is seldom distilled to dryness, that is, to coke, in the same retort. Usually about two-thirds is distilled off and the remainder is discharged into another retort and there dried to coke. In this way, there are fewer retorts to be heated to a high heat, and there is also a higher yield of paraffin. These second retorts are similar to the first except that they do not have the pipe for emptying at the bottom. The residue of coke is removed by chipping it off.

This second distillation is also made under reduced pressure. The reduction in pressure is made either by means of the Körting steam exhaust or with a pump.

In this pitch retort the hard paraffin mass is obtained. Toward the end of the distillation as a result of the destruction of pyrogene there appear greasy reddish brown masses, the so-called red products. These must be carefully separated from the paraffin mass, since they interfere with the purification of the paraffin. They contain a considerable amount of aromatic hydrocarbons, principally picene and chrysene. Anthracene has not been proven to be present. While the retort is glowing hot there appear great masses of gas which are drawn off by the vacuum pump.

The first gases to be removed are those that have been absorbed, especially hydrogen sulphide. Then follow products due to pyrogene destruction. The gases by weight amount to about 2 per cent, so that one ton of pitch will yield from 30,000 to 40,000 cubic feet of gas.

The analysis is as follows:

	Per cent.
Lighter hydrocarbons	3.0
Hydrogen sulphide	3.2
Carbon dioxide	2.4

	Per cent.
Heavier hydrocarbons	6.8
Oxygen	3.4
Carbon monoxide	1.9
Hydrogen	4.9
Methane	28.5
Ethane	32.2
Nitrogen	13.7

These gases may be used for lighting, after the hydrogen sulphide has been removed. Otherwise they are used for heating and lately they are used as fuel for gas engines. Ten cubic feet will generate one horse-power per hour.

The distillation residue, which amounts to 2 per cent of the tar, is coke. Since it contains but a trace of ash, it finds a market as carbon for electric purposes, after being freed of undecomposed hydrocarbons by heating to redness.

A tar having a specific gravity of 0.86, yields the following products during the first distillation:

	Per cent.
Moisture	some
Paraffin free oils	30.0
Paraffin mass	64.0
Red products	2.0
Coke	2.0

Of the 64 per cent paraffin mass, 20 to 25 per cent is paraffin.

All distillation products of tar are treated chemically before being worked further; some are treated several times in their different fractions, after a second or even a third distillation. The chemicals ordinarily used are sulphuric acid of 50 to 60 degrees Baumé, and sodium hydrate, 38 degrees Baumé. The products are washed in the following order.

1. Treated with 50 degree acid.
2. Treated with 60 degree acid.
3. Washed with hot water.
4. Treated with a small amount of 38 degree sodium hydrate.
5. Treated with a large amount of 38 degree sodium hydrate.
6. Washed with hot water.

The tar distillates are washed with dilute sulphuric acid to remove the last trace of water and to wash out the basic components. such as pyridine bases. They are treated with 66 degree Baumè sulphuric acid to remove the coloring components, not only those present as such, but also those which although originally colorless will cause the products to darken when stored away. The part played by the 66 degree acid in this washing is quite complicated from a chemist's point of view.

After the distillates have been treated with sulphuric acid, they are washed with water and then with sodium hydrate. This is done to fix the dissolved and suspended reaction products, but especially to remove the phenol-like bodies, especially all the homologues of the phenols.

After the treatment with hydrate solution, wash water is again applied. Washing the distillation products is carried on in large covered or uncovered cylinders or vats lined with lead. At the lower part a conical base is soldered on. Mixing is done by means of a horizontal or vertical propeller or better still, by means of compressed air, which can also be used to transport the liquid tar products and the chemicals. The reaction products obtained are acid rosins and sodium creosoles.

The acid rosins are boiled with steam in lead-lined vessels. By this means, the sulphuric acid formed by splitting of sulpho-acids is removed as a brown acid waste of 30 to 40 degrees Baumé. This is then used to decompose the sodium cresoles. During this decomposition, crude creosote and a solution of sodium sulphate are formed. The separated rosin and crude creosote are mixed together and distilled, the products being creosote oil and tar asphalt. The paraffin mass and the distillation products of the paraffin-free oil, i. e. benzene and photogen, are washed in a similar manner.

The loss in washing consists of:

	Per cent.
Benzene	4
Photogen	4
Raw oil	15
Paraffin mass	10 to 11

The washed crude oil is fractionated in similar retorts into:

1. Light brown coal tar oil, specific gravity 0.79-81; flash point 77 to 85 degrees F. (25 to 35 degrees C.); boiling point 212 to 392 degrees F. (100 to 200 C.).

2. Light crude photogen, specific gravity 0.835 to 0.840; flash point 86 to 104 degrees F. (30 to 40 degrees C.); boiling point 302 degrees F. (150 dgrees C.).

It gives, up to 392 degrees F. (200 degrees C.), 35 per cent distillate; up to 482 degrees F. (250 degrees C.), 60 per cent; and the remainder up to 572 degrees F. (300 degrees C.).

3. Clear paraffin oil, specific gravity 0.83 to 0.865; boils between 428 and 608 degrees F. (220 to 320 degrees C.).

The light brown coal tar oil, after being washed, is fractionated again into benzine (colorless, specific gravity 0.790 to 0.805) and solar oil (colorless, specific gravity, 0.825 to 0.830), with boiling point 302 to 338 degrees F. (150 to 175 degrees C.). The crude photogen and the clear paraffin oil are fractionated the same way as the light tar oil. The fractionating distillation is done in the column apparatus known to the petroleum and coal tar industries.

The crude petroleum products of different specific gravity, boiling point, etc., are fractionated according to special demands of the market, and are given different trade names, as "cleaning oil," "gas oil," yellow oil," etc.

The residue of the fractionation is added to the pitch and treated as already described. The paraffin mass after chemical treatment is cooled to 29 to 25 degrees F. (—3 to —7 degrees C.), whereby paraffin is crystallized out. The congealed mass is pressed in a hydraulic press. The separated oil, called press oil, is fractionated as already described. The residue from the distillation of this oil is a tar known as *goudran*.

The following scheme represents the treatment of lignite tar. The commercial petroleum products are in bold-faced type.

TAR
- 1. Crude oil
  - **Gas oil**
  - Light photogen
    - **Benzine**
    - **Solar oil**
    - **Cleaning oil**
    - Residue
      - **Yellow oil**
      - Residue
        - **Hard scale**
        - **Coke**
- 3. Red products.
- 4. Coke and gas.
- 2. Paraffin mass
  - Hard paraffin scales
  - Press oil
    - Heavy photogen
      - **Light photogen**
      - **Red oil**
    - **Gas oil**
    - Soft paraffin mass
      - **Soft scale**
      - **Paraffin oil**
    - Hard paraffin mass
      - **Hard scale**
      - Press oil
    - **Goudran**

The paraffin scales, separated from the oils by pressing, are treated in the same manner as the paraffin scales of the petroleum industry. A description is unnecessary since the American practice is well known. It should be mentioned, however, that the paraffin scales of the petroleum industry contain no homologues of the phenols, while those of the lignite tar industry do contain these homologues in considerable quantities, 10 to 15 per cent. When washed with sodium hydrate, a disagreeable odor is sometimes perceptible and a yellowish color in the light that can be removed only by refining. The lignite paraffin, therefore, must be treated more thoroughly with benzine and decoloring powder (potassium ferrocyanide, potassium ferricyanide and pulverized clay) than is necessary with the paraffin from petroleum.

It has been shown that from the lignite tar are manufactured oils, paraffin, and coke. A brief description of them and their uses is as follows:

Benzine is a colorless liquid with a bluish fluorescence, specific gravity 0.790 to 0.810, boiling point between 230 and 392 degrees F. (110 to 300 degrees C.). It is largely used in the manufacture of paraffin.

Solar oil, a colorless liquid, specific gravity 0.825 to 0.830, boiling point 284 to 464 degrees F. (140 to 240 degrees C.), can be used in lamps instead of kerosene, only it requires a strong draught like Russian coal oil; the reason for this being that the percentage of carbon is higher than in ordinary American kerosene. Its principal use is in explosion motors.

Cleaning oil shows a yellowish luster. The specific gravity is 0.850 to 0.865, boiling point between 392 and 575 degrees F. (200 and 300 degrees C.). It is used for cleaning fatty substances; for example, the extraction and prepration of wagon grease.

Yellow oil and red oil have a still darker color than cleaning oil, specific gravity 0.865 to 0.880, boiling point between 392 and 617 degrees F. (200 to 325 degrees C.). They are used in the preparation of oil gas.

Gas oil, reddish brown color, specific gravity 0.880 to 0.900, is used as the name indicates, for generating gas. One ton of gas oil yields 16,000 to 20,000 cubic feet of gas, 30 to 40 per cent tar, and 3 to 8 per cent coke, depending on the temperature of the retort and the rapidity of the process. The gas has an illuminating power of 8 to 12 candles, when using 1¼ cubic feet per hour. Gas oil is also used to enrich water gas.

Paraffin oil, specific gravity 0.900 to 0.930, has about the same uses as yellow oil, red oil and gas oil. With the rapid increase in the use of the Diesel engine in Germany, a new and almost exclusive market has been found for this oil as fuel for this motor. The Diesel engine utilizes about 30 per cent of the heat energy of the oil, which has a heating power of 18,000 B. t. u. per pound. In 1901, about 5,600 tons of this oil were consumed in Diesel engines in Germany. It is also used as a lubricating oil.

Goudran, a glossy deep black mass, brittle and of conchoidal fracture, melts at 158 to 212 degrees F. (70 to 100 degrees C.), and dissolves completely in benzol. It is used, in addition to natural asphalt, in the manufacture of varnish.

Paraffin, specific gravity 0.874 to 0.915, melting point 99.5 to 136.4 degrees F. (37 to 58 degrees C.), has a crystalline structure, is transparent, of bluish tint, tasteless and odorless. The harder varieties have a slight ring when struck. The most general use of paraffin is in the manufacture of candles. It is also used for impregnating paper, for dressing leather, fabrics and turned railings made of vegetable and animal fiber, etc. It serves as a protective coating against acid and alkali, and as a covering for easily oxidized bodies.

Soft paraffin mixed with clay is used as a finish for glazed paper. It is also used to absorb the odor of flowers in the manufacture of perfume and lotions. In glass-blowing it is used to fill the lamps and in the hard glass factory it is used in the cooling baths. In electric wiring it serves as an insulator. The production of paraffin is increasing, for it can serve many purposes and as an article of commerce it is always saleable.

According to Scheithauer, the products from lignite tar may be expressed as follows:

	Per cent.*
Benzine	To 5
Solar oil	5–10
Light paraffin oil	10
Heavy paraffin oil	30–50
Hard paraffin	10–15
Soft paraffin	3– 6
Goudran	3– 5
Coke, gas, water and waste	20–30

The process of distillation of the tar from bituminous shale is quite similar to that of lignite. The same methods are employed, with one exception. In the Saxon-Thuringen tar there are three fractionations—paraffin-free oils, paraffin mass and red products—but in the Scotch and German tar distillations from bituminous shales, the oils and paraffin mass are mixed together and only the red products are separated out.

The various products derived from Scotch shales are shown in the following scheme:

CRUDE OIL
- 3. Coke.
- 2. Red products.
- 1. Distillate
  - Heavy oils
    - Hard scale
    - Green oils
  - Light oils
    - 1. Naphtha
    - 3. Burning oils
    - 2. Intermediate oils
      - Oils of specific gravity 0.850
      - Blue oils
        - Soft scale
        - Lubricating oils

It is worthy of note that a gas is generated during the distillation of shale tar and that it differs from that of lignite tar in composition. It has an illuminating power of 36 candles. According to Beilby, its composition is as follows:[1]

	Per cent.
Carbon dioxide	none
Oxygen	none
Heavy hydrocarbons	14.5
Carbon monoxide	none
Methane	59.0
Ethane	26.5
Hydrogen	trace

The percentage of heavy hydrocarbons is sometimes as much as 20.6.

The yield of single products in Scotland is as follows:

	Per cent.
Naphtha	4.0
Light oil	25.0
Intermediate oil	15.0
Lubricating oil	8.0
Hard paraffin	8.0
Soft paraffin	4.0
Red products	1.0
Coke, gas, waste	35.0
	100.0

[1]The Chemistry of Illuminating Gas, Humphry, p. 172.

The distillation scheme for the treatment of tar from German bituminous shales is as follows:

- TAR
  - Oils
    - Naphtha
    - Gas oil
  - Paraffin mass
    - Hard paraffin
    - Press oil
      - Gas oil
      - Soft paraffin } Crude mass }
        - Paraffin scale
        - Gas oil
        - Crude oil or lubricating oil
          - Cleaning oil
          - Fat oil
          - Spindle oil
          - Lubricating oil
          - Crude mass
  - Coke

The yield is as follows:

	Per cent.
Naphtha	4.0
Gas oil	50–55.0
Crude paraffin	12–15.0
Coke, gas, waste	33.0

Note: The descriptions of the lignite tar and shale tar distillations are taken from Scheithauer's "Die Fabrikation der Mineralöle," and from Graefe's "Die Braunkohlen Industrie."

Having described the bituminous lignite and bituminous shale distillations, there remains to be described the distillation of Bohemian lignite. This is of special interest since it resembles very closely the Texas lignites.

The first attempts to utilize Bohemian lignite through dry distillation were made during the last forty years of the preceding century. Why the work was abandoned is not known, but it was probably due to the fact that these efforts were for the purpose of obtaining tar for paraffin manufacture only, without regard to the utilization of the gas, ammonia, and coke.

The Bohemian lignite yields 5 to 10 per cent tar by dry distillation, while the pyropissits of Saxon-Thuringen yield from 50 to 60 per cent tar. A distillation plant on a large scale was established in Aussig on the Elbe, by a Hamburg bank, in 1895. Originally, the object was to distill a mixture of English bituminous coal and Bohemian lignite to make coke for metallurgical purposes. As long as the price of bituminous coal in England was low, and the price of coke in Bohemia was high, all went well. In the second year, the price of English coal became so high that the plant sustained a loss. The coke works were used then entirely for distilling lignite. The lignite was distilled in vertical coke ovens (modified Appolt ovens), yielding tar and ammonia as by-products. The surplus gas, which amounted to 40 per cent, was used partly as a fuel under the boilers and partly in gas engines. The residue from the distillation, a lignite coke, was used mostly for steam heating and as a fuel in general. Only a part of it was made into briquettes with the addition of tar pitch as a binder. Since the plant at Aussig was not designed for lignite distillation in the first place, and furthermore, since there were gross errors in its construction, a loss was sustained. When the price of lignite increased, the plant resorted to the purchase of dusty waste lignite. On this account, the quality of the coke suffered and the yield of by-products diminished. Finally, changes were made in the construction, but the main drawback was the distance from the lignite mines and the cost for freight could not be reduced. The result was plants were established in the lignite districts, and the old plant was used only for working the by-products. Although the production of ammonia was satisfactory, the results from the tar distillation were not. The mistake lay in not understanding how to treat the tar, since the tar from Bohemia (and also from Texas lignite) is quite different from that of Saxon-Thuringen. It is in reality a transition product between the Saxon-Thuringen tar and coal tar, and of course should be treated as such.

The three plants that had been established in Bohemia came into the possession of people who own practically all the lignite mines of Bohemia. As soon as they came into possession of the lignite mines, they closed down the lignite distillation works with one exception. The lignite is sold as a fuel directly to consumers only, and no lignite is sold to any distillation works because the by-product coke is a competitive fuel with the raw lignite. The one plant continued to treat about 125,000 tons of lignite per annum, but lignite coke briquettes are not to be seen in Bohemia; all are exported to Germany. The by-products, tar and ammonia, are utilized, the surplus gas is used in gas engines to generate electric power which is supplied to neighboring lignite mines.

The lignite distilled in Bohemia at present comes from the vicinity of Teplitz and has an average specific gravity of 1.15. It is screened and the $\frac{1}{4}$ to $\frac{1}{2}$ inch sizes are used for distillation. An average of thirty-eight analyses is as follows:

	Per cent.
Moisture	27
Volatile combustible matter	30
Fixed carbon	35
Ash	8
	100

Upon distillation, this lignite yields the following products:

	Per cent.
Coke (residue)	43.0
Tar	4.8
Ammonia water	30.0
Gas	22.2
	100.0

One ton yields 6,350 cubic feet of gas, the analysis of which is as follows:

	Per cent.
Carbon dioxide	21.60
Oxygen	2.60
Carbon monoxide	7.20
Methane	22.86
Hydrogen	20.00
Nitrogen	25.74
	100.00

The heat value of this gas is 300 to 350 B. t. u. per cubic foot. The ammonia water contains 0.23 per cent of ammonia, hence one ton of raw lignite yields 1.4 pounds of ammonia which corresponds theoretically to 5.6 pounds of ammonium sulphate. Allowing for a 5 per cent loss in the manufacture, the yield is 5.3 pounds per ton. The residue contains 17 per cent ash, 3 to 4 per cent moisture, 3 per cent volatile combustible matter. Its heat value is 11,000 to 12,000 B. t. u. per pound. If good lignite is used, having a low ash content, an excellent residue is obtained that has a heat value of 13,000 B. t. u.

In Scotland the purpose of the distillation is to obtain tar and more especially ammonia; in Saxon-Thuringen the yield of tar is the important item; but in Bohemia, just as in the distillation of bituminous coal, coke is the principal object, the by-products are tar, ammonia and surplus gas.

As already stated, the distillation of lignite is carried on in vertical ovens which are heated by firing with a portion of the gas made in distilling the lignite.

Of the gas resulting from the distillation, 6,350 cubic feet per ton on the average, 60 per cent. is used for heating the ovens, 40 per cent being surplus gas, which can be used for other purposes, such as the generation of electrical energy, etc.

According to observations made at Aussig, one horse-power hour requires 35 cubic feet of this gas if used in a gas engine. In a recently installed lignite distillation plant, where about 270 tons are worked up daily, there is a gas surplus of 680,000 cubic feet. This corresponds to about 20,000 horse-power hours. To utilize this energy a central power station was established of 1,000 horse-power. The gas engines are directly connected with the generators and after deducting the power required at the plant, the remainder is sold to neighboring cities.

The ammonia condensation plant is according to the Feld system (patented in the United States and England). In this system the gas is not cooled to low temperature and thus a mixture of ammonia water and tar is obtained. The condensation is partial only depending on the dew point of the tar and ammonia. By this method of procedure, we do not obtain a tar mixture but a series of fractional components which are limited in their condensation to their boiling points, those of high boiling point being condensed first as the temperature of the gas is gradually lowered. Since the gas is not cooled under the dew point of water while these oils are condensing out, they are obtained free from moisture. The separation of water occurs in a special washer at a temperature of 140 to 203 degrees F. (60 to 95 degrees C.), at which temperature no ammonia compounds with sulphur can be formed. In a second washer cyanic acid is removed with precipitated iron oxide in the presence of lime (the lime prevents absorption of ammonia) with the formation of iron cyanide. The gas being free from tar, from cyanogen and the most of the water (only 2 grams per cubic foot remaining) the separation of the ammonia is effected. This is done in the last washing at a temperature of 113 degrees F. (45 degrees C.), and with the aid of the carbon dioxide in the gas. The gas is washed in a solution of milk of gypsum (finely ground sypsum suspended in water). The reactions result in ammonium sulphate in solution and carbonate of lime which precipitates out. According to Köhler, this method (the Feld process) is in successful operation in the United States at a plant in New York City.[1]

The coke is cooled in an air-tight vessel. The greater portion is sold as a fuel for making steam (under forced draft) or for the manufacture of producer gas, for which it is well suited, being practically free from volatile tar compounds which are so objectionable in a gas engine. The smaller portion of it is briquetted with pitch as a binder.

The oils are mixed and sold as wood-preserving material under the name Carbolineum. These tar oils contain mostly hydrocarbons of the aliphatic series, but members of the aromatic series are also present, such as benzol, pyridine bases, and phenols. Formerly the brown coal tars were chemically treated and the industry was quite profitable, especially to the paraffin manufacturers.

Diagram of Bohemian Lignite Tar Treatment.

The commercial products are in bold-faced type.

TAR
- Tar water
- Light oil 392 deg. F. (200 deg. C.)
  - Raw benzol 383 deg. F. (195 deg. C.)
    - **Benzol and its homologues**
    - Phenol
    - **Pyridin**
  - Creosote oil
- Intermediate oils 455 deg. F. (235. deg. C.)
  - Raw heavy benzol
    - Refined heavy benzol and its homologues
    - Cresols
  - **Gas oil**
  - **Creosote oil**
- Heavy oils 527 deg. F. (275 deg. C.)
  - Carbolineum
  - Paraffin mass
- Soft paraffin mass
  - Paraffin oil
  - Paraffin mass
  - Pitch
- Pitch
  - Soft paraffin mass
    - Soft paraffin
    - Paraffin oil
  - Hard paraffin mass
    - Hard paraffin
    - Paraffin oil
  - Red products
  - Gas
  - Coke

[1]Lunge and Köhler, "Steinkohlenteer und Ammoniak," 1912, p. 166.

But since brown coal tar oils are known to possess wood-preserving qualities, they are sold undistilled at high prices.

The profit of a lignite distillation plant in Bohemia, per ton of lignite coke, is shown in the following schedule.

For 1 ton (2,000 lbs.) are needed 2.32 tons of raw lignite, at $0.97 per ton		$2.25
Running expenses, amortisation, and general management		.88
Total		$3.13
Profit on by-products	$0.73	
Profit on electric power	.24	
Total	$0.97	0.97
Cost, per ton		$2.16

Thus one ton of lignite coke costs $2.16. Since the selling price is $2.75, there is a profit of 59 cents per ton. A plant working up 100,000 tons of raw lignite annually, produces 43,000 tons of lignite coke, and gives a profit of $25,000. The necessary capital amounts to $170,000, which gives a profit of almost 15 per cent on the investment. The by-products and surplus gas represent 45 per cent of the expense of lignite coke.

Only a general idea of the profitableness of the lignite distillation in Saxon-Thuringen and of the bituminous shale in Scotland can be obtained. The Germans publish no reports on their industry and the English give only general data.

The plants of Saxon-Thuringen pay 12 per cent dividend. One plant with a capital of $750,000 works up 510,000 tons of lignite annually, and shows a profit of $90,000, which corresponds to a profit of 17.65 cents per ton of raw lignite. It must be remembered that the amortisation rate is high in Germany in order to reduce the profit because of the occupation tax, personal tax and income tax.

According to Beilby, the results of Scotch shale distillation give the following:[1]

Cost per ton—cents		Yield per ton—	Cents.
Shale	96	Burning oil, 8.4 gal. at 6.82 cents	57.28
Retorting	44	Lubricating oil, 3.4 gal. at 6.38 cents	21.69
Refining	28	Paraffin wax, 3.0 gal. at 28.00 cents	84.00
		Ammonium sulphate, 60 lbs. at 1.00 cent	60.00
Total	168		
		Total	224.00
		Less	168.00
		Gross profit	56.00

[1]J'l Soc. Chem. Ind., 1897, p. 886.

The profitableness of the Scotch shale industry represented by the four leading plants is seen from the following table. The amounts given are in pounds Sterling.[2]

[2]Petroleum World, 1912, p. 247.

TABLE XV.

Name.	Obligations in bonds.	Preferred stock.	Original stock.	Dividends and profits.			
				1908.	1909.	1910.	1911.
				Per cent.		Per cent.	
1. Brasburn	55,350	100,000	149,750	17.5	10.0	21.09	23.33
2. Oakbank	50,000	100,000	170,000	15.0	10.0	30.21	27.22
3. Pumpherstone	41,750	100,000	110,500	50.0	50.0	62.89	69.00
4. Tarbras	15,900	50,000	85,000	15.0	7.5	13.89	14.49

Amount of profit carried forward--pounds Sterling:

Name.	1911.	1912.
1. Brasburn	6,603	747
2. Oakbank	4,255	5,783
3. Pumpherstone	12,021	12,598
4. Tarbras	1,648	3,895

In 1911, Germany produced:

	Tons
Bituminous coal	160,742,272
Brown coal	73,516,789
Briquettes	16,836,679

One ton of briquettes requires 1.75 tons raw lignite as material and 0.88 tons as fuel, total 2.63. The 16,836,679 tons of briquettes mentioned above required for their manufacture 44,280,000 tons of lignite. The distillation plants of Saxon-Thuringen used 1,575,000 tons. The total amount of lignite treated then was 45,855,000 tons, or 62.4 per cent of the entire lignite production.

Notwithstanding the fact that the more concentrated fuels, English and Westphalian coal and anthracite, are marketed in Germany, lignite mining continues to flourish. But the lignite, in order to compete successfully with the other coals; must be put into a concentrated form, or, as is done in Saxon-Thuringen, the lignite must be treated chemically.

CHAPTER XI.

DISTILLATION OF A TEXAS LIGNITE, FOR RECOVERY OF BY-PRODUCTS.

In order to determine the quantity and nature of the by-products to be obtained from the destructive distillation of lignite, a sample was secured from the Texas Coal Company, Rockdale, Milam county. The composition of this lignite was as follows:

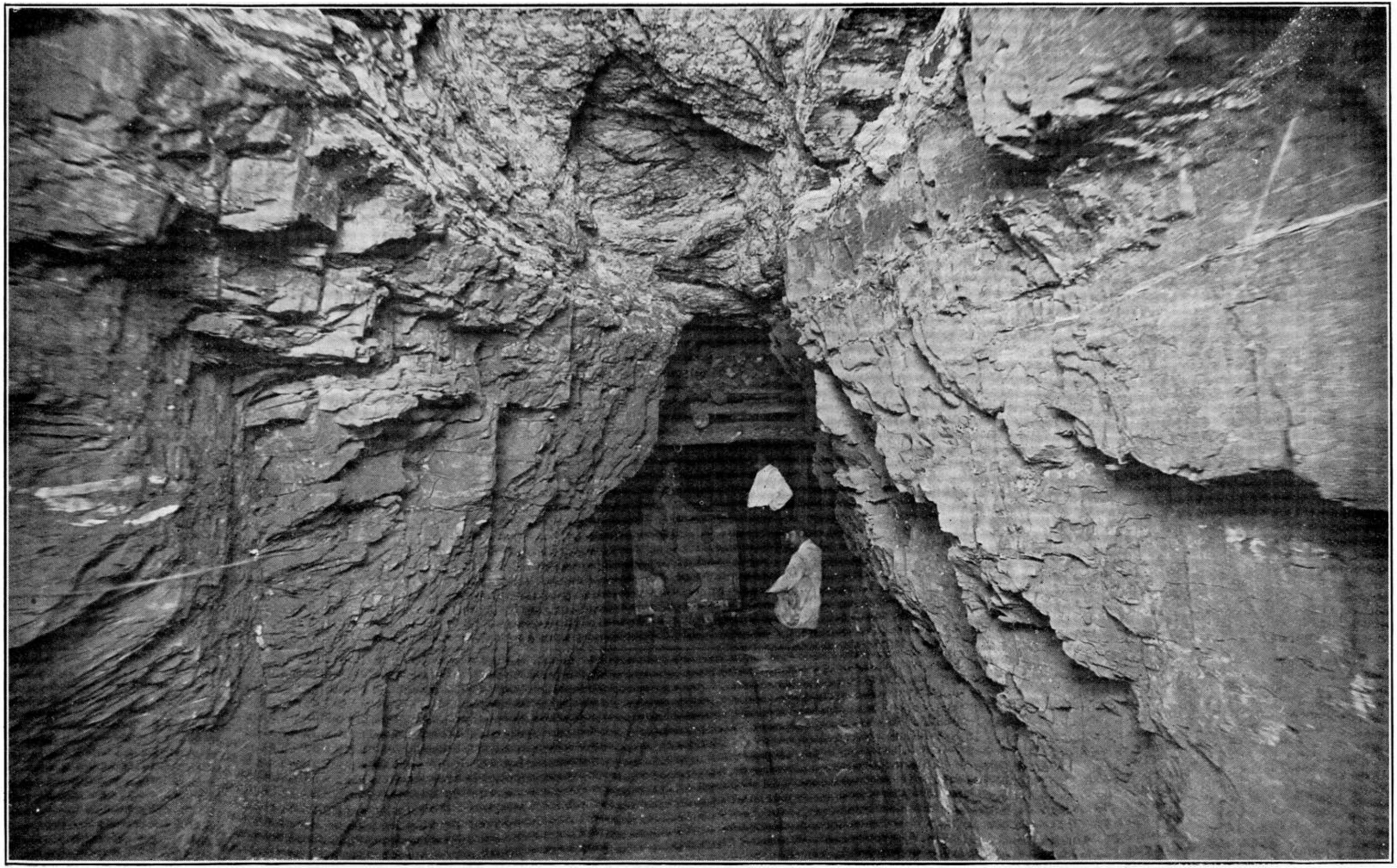
Composition.	Per cent.	
	As rec'd.	Dry.
Moisture	29.83	....
Volatile combustible matter	35.46	50.50
Fixed carbon	27.03	38.50
Ash	7.98	11.00
Sulphur	0.88	1.25
Nitrogen	1.78	2.53

The distillation was made in a cast iron vertical retort, placed in the furnace and covered over with coke, which was kept burning with a gasoline burner as needed. The products from the distillation were led into a water-cooled condenser, then into a wash-bottle, then into dilute sulphuric acid, and then through a tower filled with absorbent cotton. The gas was stored in a large tank.

At first the heat was applied slowly. In about twenty minutes steam appeared in the condenser, and in thirty minutes, a yellowish gas (tar vapor). During the first hour of distillation, about 14 per cent of the total gases passed over, and the distillation was completed in about 2½ hours. The yield of gas was disregarded, since the amount, heating power, candle-power, etc., had been already determined.

The results of four separate determinations are given below, in percentages.

Amount of.	I.	II.	III.	IV.
Residue from lignite, as charged	38.81	40.60	41.90	40.70
Residue from dry lignite	55.44	56.38	56.62	55.75
Ammoniacal liquor	36.10	34.00	33.00	34.30
Total ammonia in raw lignite	0.85	0.63	0.84	0.71
Tar, raw lignite	6.90	7.40	7.87	10.10
Tar, dry basis	9.86	10.28	11.04	13.83



Texas Coal Co. (Lignite), Rockdale, Milam County. A tunnel in lignite.

The composition of the residue was as follows:

	I.	II.	III.	IV.
Moisture	0.95	0.93	1.00	1.00
Volatile combustible matter	2.27	6.64	2.77	4.85
Fixed carbon	75.28	76.68	73.66	72.17
Ash	21.50	15.75	22.57	21.98
	100.00	100.00	100.00	100.00
Sulphur	1.54	1.45	1.48	1.36
B. t. u., per pound	10,708	11,287	10,224	10,462

It will be noticed that the ash content of I, III, and IV, is about the same. Residue No. II had only 15.75 per cent of ash, but in this particular case the lignite carried 8 per cent of ash. It will be noticed, also, that the volatile matter in Residue No. II is 6.64 per cent, showing that the heating was not carried far enough. The yield of ammonia in this case was also less, since the ammonia compounds require a high heat to break them up, and they are among the last products to come off.

During the distillation, about 10 per cent of the lignite crumbled into dust. Lignite residue is dark gray in color, glossy, slightly porous, hard, and has a clear metallic ring. There was no agglomeration of the particles and no coking. The residue burns without flame or smoke, and has an average heating power of 10,500 B. t. u. per pound.

The yield of tar, as well as the nature of it, appears to depend on a variety of circumstances, such as the water contained in the raw material; the pressure in the distillation space; the size of the distillation apparatus; the surface of the walls of the apparatus; the rapidity of the suction of the gases; the temperature of the distillation, especially at the end of the process; hence it is not possible to duplicate conditions very closely, especially when one considers, also, the variation in the raw material itself.

Tar.

The tar has a specific gravity of 0.865 at 72 degrees F. It clogs at 60 degrees F. and is of butter-like consistency at 50 degrees F. The color is dark brown and the free carbon content (dust, residue, etc.) is 1.3 per cent.

It was examined by fractional distillation for its content of oils, by "cracking" for the content of paraffin, and by washing with alkali and acid for acid and basic content. Since the tar of Texas lignite seems to occupy a position between the tar of bituminous coals and that of pyropissit, and since, therefore, aromatic as well as aliphatic substances are to be expected, the phenols and pyridine bases of the first series must be separated from the paraffins of the other.

The tar from Texas lignites was distilled into four fractions. The residue of pitch was "cracked". The oils, paraffin masses, acid and basic substances, and then paraffin were determined.

The results were as follows:

Fraction.	Per cent.
Water	0.40
1st fraction, to 392 deg. F., light oil	6.81
2nd fraction, to 527 deg. F., middle oil	17.95
3rd fraction, to 600 deg. F., heavy oil	28.75
4th fraction, to 660 deg. F., soft paraffin oil	12.00
Residue, soft pitch	32.57
When "cracked" the pitch gave the following:	
Hard paraffin mass	19.01
Red products	1.30
Coke	11.00
Gas and loss	1.26
Total	32.57

Distillation of Tar.

		Per cent.
I.	Fraction, light oils, specific gravity 0.830	
	Active phenol content	19.51
	Bases	3.20
II.	Fraction, intermediate oils, specific gravity 0.983	
	Active phenol content	27.50
	Bases	6.00
III.	Fraction, heavy oils, specific gravity 0.951	
	Active phenol content	20.90
	Bases	3.00
IV.	Fraction, soft paraffin oil, specific gravity 0.951	
	Active phenol content	24.00
	Bases	3.00
V.	Fraction, hard paraffin oil, specific gravity 0.921	
	Active phenol content	18.00
	Bases	3.00

The coke contained 7 per cent of volatile combustible matter.

Paraffin estimation in the acid and base free oils:

In the heavy oils	4.28 per cent.,	melting point	122 deg. F.
In the soft paraffin oils	12.37 per cent.,	melting point	129 deg. F.
In the hard paraffin oils	12.43 per cent.,	melting point	138 deg. F.

Total Paraffin from Raw Tar.

	Per cent.		
	Heavy oils.	Soft paraffin oils.	Hard parafin oils.
Yield of oils	28.75	12.00	19.00
Loss by washing to remove acids and bases	24.00	27.00	21.00
Remainder after washing	21.85	8.76	15.00
Paraffin content of washed residue	4.30	12.40	12.50
Melting point, Centigrade	50 deg.	54 deg.	59 deg.
Melting point, Fahrenheit	122 deg.	129 deg.	138 deg.

Total paraffin in tar .... 3.88 per ccent

As the congealing points show, these are only the hard paraffins. As a matter of fact, the tar contains about 8 per cent of paraffin.

From a technical standpoint, three forms of ammonia may be obtained: 1. So-called "free" ammonia, which can be driven off from ammonia water and wash water, but it is doubtful if there is any free ammonia in such gases as we are now dealing with. 2. Combined ammonia which can be made volatile by adding an alkali earth. 3. Ammonia which can be taken up completely by sulphuric acid only.

In order to determine how much nitrogen contained in lignite is changed into ammonia, the third distillate above was taken as a basis. The nitrogen content was as follows:

Nitrogen content.	Per cent.
In dry lignite	2.53
In tar	2.82
In the residue	0.18
In the gas	4.90

Another way of stating this is as follows:

1,000 parts of raw lignite with 26 per cent of water, gives 18.72 parts of nitrogen; 419 parts of residue, 78.4 parts of tar, and 330 parts of water. The yield of gas in cubic feet per net ton is 7,500. On this basis, a net ton, 2,000 pounds, of raw lignite would contain as follows:

Compound.	Pounds.
Nitrogen, calculated as ammonia	45.36
Residue	838
Tar	156.8
Water	660
Gas	300

The nitrogen compound in the condensed water may consist of cyanogen compounds and members of the pyridine and chinolin groups. Of these compounds, 3.98 per cent are in the coke, 6.46 per cent in the tar, 9.30 per cent are in the ammonia, 45.50 per cent are in the gas, and 34.76 per cent are unaccounted for.

The distribution of the nitrogen is quite different from that of other bituminous materials subjected to dry distillation. In the Scotch shales, 75 per cent of the nitrogen is changed to ammonia by the use of steam, but in this case the carbon of the residue would be consumed.

Watson Smith[1] found nitrogen in:

	Per cent.
Ordinary gas coke	1.37
Bee-hive coke	0.53
Simon-Carves coke	0.38

A. Hennin[2] is of the opinion that ammonia is found in coal only in minute amounts, but that it is formed as soon as the coal has risen to a temperature of 1,800 degrees F. (1,000 degrees C.). Higher temperatures than this do not seem favorable to its formation, while at a temperature below red heat, the formation of ammonia ceases.

In the Texas lignite which was investigated, about 10 per cent of the nitrogen is changed to ammonia; while in the Saxony bituminous coal only 6.4 per cent is changed, and in some English coal, 10.8 per cent.

In treating the brown coal in vertical ovens in Saxony, the heating of the material is more gradual than in the horizontal ovens and the operation of carbonizing can be divided into three definite zones. The first is the uppermost and coolest zone, and may be called the drainage zone, for the steam escapes with little or no tar, or ammonia. The second zone is that of the formation of gas and tar, with some ammonia. The third zone is the zone of the highest heat, and completes the distillation with the formation of ammonia.

In order to test the separation of the water from the ammonia, a distillation was made in which the first portion of water that

[1]J'l Chem. Soc., 43, p. 105.

[2]J'l Gas Lighting, 1892, p. 296.

came over was separated from the remainder, then another portion was separated, and the gas washed in the remainder of the water. The lignite treated contained 28 per cent of moisture. The water contained ammonia as follows:

	Per cent.
1st portion	0.013
2nd portion	0.042
3rd portion	0.990

The amount of water to be treated can thus be reduced one-half, and the ammonia can be recovered in a column still, and the gas passed into 60 degrees B. sulphuric acid, for the manufacture of ammonium sulphate. The gases formed during carbonization can be used to heat the oven, and, according to European practice, there is an excess of 40 per cent to be thus used, or sent to gas engines.

There could be recovered from a ton of ordinary Rockdale lignite carrying 26 per cent of moisture and 9 per cent of ash, the following:

Residue	800 pounds
Tar	156 pounds—16.17 gals.
Sulphate of ammonia	18 pounds
Surplus gas	3,000 cu. ft.

The following calculation of the value of these separate products is made with the distinct understanding that local conditions will often affect the result seriously.

The value of the residue can be calculated in two ways, as an industrial fuel, and as a household fuel. As an industrial fuel it can be used in the form in which it comes from the retorts or ovens without any preparation. Its value would depend on the local price of fuels with which it would compete. In San Antonio, for instance, Rockdale lignite and Beaumont oil are used as fuels, among others. The price of lignite is $1.69 per ton, and it has a heat value of 7,500 B. t. u. per pound. On account of the high content of moisture, we will allow that only 50 per cent heat effect can be obtained. The heating power of the Beaumont oil may be taken at 19,000 with a heat effect of 78 per cent.

To determine the relative value of lignite, crude oil, and lignite residue for steaming purposes, the following calculation is made; with an allowance of 50 per cent heat efficiency for the lignite, 78 per cent for the oil, and 72 per cent for the lignite residue.

If we allow that the value of the lignite residue is $3.00 per ton, and that it has 11,134 B. t. u. per pound, the price per hundred pounds is 15 cents. To generate 100 pounds of normal steam requires 1,150 B. t. u.

Lignite.

$$\frac{7500 \text{ B. t. u.} \times 50}{1150} = 3.26 \text{ pounds normal steam.}$$

100 pounds lignite costs 8.25 cents=3.26 pounds normal steam, and we have then 100 pounds normal steam costs 2.53 cents.

Fuel Oil.

$$\frac{19{,}000 \text{ B. t. u.} \times 78}{1150} = 12.88 \text{ pounds normal steam per pound of oil.}$$

1 barrel, 42 gals., costing $1.20, will give a cost per hundred pounds of 37½ cents. As 100 pounds of oil will give 1,288 pounds of normal steam for 37½ cents, we have the cost of 100 pounds of normal steam, 2.91 cents.

Lignite Residue.

$$\frac{11{,}134 \times 72}{1150} = 6.97 \text{ pounds of normal steam.}$$

At $3.00 per ton, 100 pounds costs 15 cents, or 697 pounds of normal steam, costs 15 cents; and 100 pounds of normal steam would cost 2.15 cents.

The 800 pounds of residue obtained would be worth $1.20, for fuel purposes.

Tar.

The 156 pounds (16.17 gallons) of tar recoverable from the ton of lignite could be used for the manufacture of heavy oils, soft paraffin oils and hard paraffin oils. After removing the acids and bases by washing, there would remain in the washed tar 21.85 per cent of heavy oils, 8.76 per cent of soft paraffin oils, and 15 per cent of hard paraffin oils. The total hard paraffin in the tar is probably about 3.88 per cent, the total paraffin being about 8 per cent.

After these oils are distilled from the tar, there remain 32.57

per cent of soft pitch and, as already stated, when "cracked" the pitch gave the following:

	Per cent.
Hard paraffin mass	19.01
Red products	1.30
Residue	11.00
Gas and loss	1.26

There was of paraffin, in the acid and base free oils, as follows:

	Per cent.
In the heavy oils	4.28
In the soft paraffin oils	12.37
In the hard paraffin oils	12.43

The valuation of tar is a highly technical matter, and we do not propose at this time to enter upon it, except to point out the products obtainable by distillation.

In a briquetting plant, both the soft and the hard pitch could be used as a binding material.

Sulphate of Ammonia.

There could be recovered from a ton of lignite 18 pounds of sulphate of ammonia, worth, at 3 cents a pound, 54 cents.

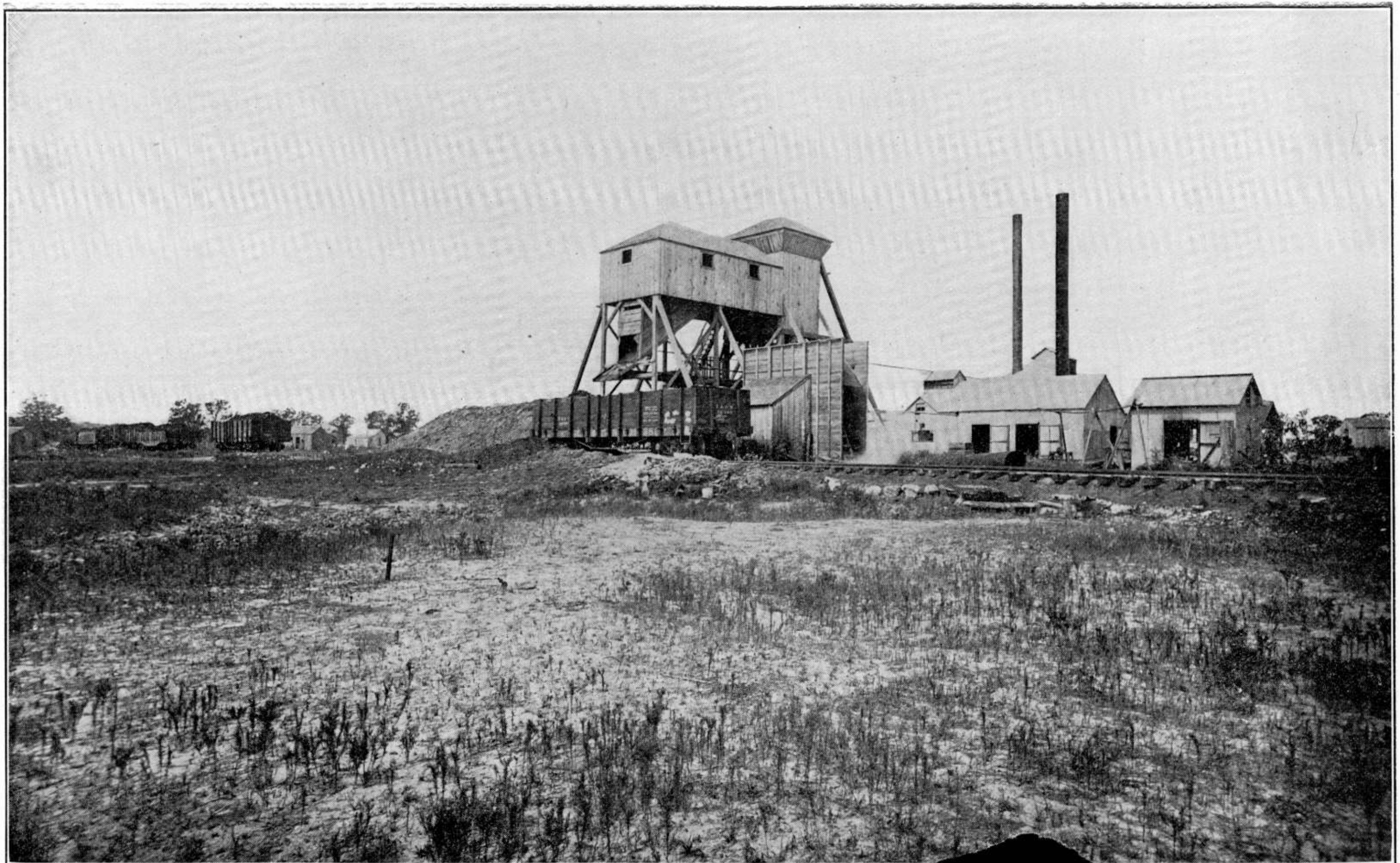
Surplus Gas.

The surplus gas would be 3,000 cubic feet, and we think it should be worth 30 cents per thousand cubic feet at the works; a total value of 90 cents.

The following statement, therefore, includes the value of the by-products to be obtained from a ton of lignite:

	Value.
Residue from retorts, 800 pounds, at $3.00 a ton	$1.20
16 gals. of tar, at 5 cents	80
18 pounds sulphate of ammonia, at 3 cents	54
3000 cubic feet surplus gas, at 30 cents	90
	$3.44

In order to arrive at an approximation of the value of the surplus gas when used to generate power in a gas engine, the following calculation may be used: to guarantee 1 horse-power in an economically working gas motor, 10,700 B. t. u. are necessary. One cubic foot of this gas has 387 B. t. u. and 28 cubic feet are required for 1 horse-power hour, or 1,000 cubic feet are equivalent to 35.7 horse-power hours. The 3,000 cubic feet of surplus gas from the ton of lignite will generate 107 horse-power hours, and the cost is about 1 cent per horse-power hour.



Texas Coal Co. (Lignite), Rockdale, Milam

CHAPTER XII.

DRY DISTILLATION OF TEXAS LIGNITES.*

In order to study lignites with reference to the amount and quality of the gas and solid residue to be obtained from them by dry distillation we selected 22 typical lignites from different parts of the State.

The methods used have already been described in Chapter IV, relating to the dry distillation of coals. In Chapter XI we gave the results of the detailed examination of a sample of Rockdale lignite for all of the recoverable products, but in this chapter we consider merely the gas and solid residue.

Tables XVI and XVII give the results obtained.

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*In the Second Annual Report, Texas Geol. Sur., 1890, pp. 38-52, there is an article by Dr. Otto Lerch on "Lignites and Their Utilization with Special Reference to the Texas Brown Coals." This paper describes, to a certain extent, the condition of the industry in Germany at that time. For information as to present methods, etc., the reader is referred to Chapter X of this Bulletin, prepared by Dr. W. Bredlick.

Table XVI.

Results of Distillation Tests on Texas Lignites. Analyses by S. H. Worrell.

Analysis No.	Yield of gas, cubic feet per net ton dry lignite.	Gas—Dry.									Lignite—Dry.								
		Composition.					Specific Gravity.	Candle Power.	B. t. u. per cubic foot.		Proximate analysis.				Ultimate analysis.				B. t. u. per Pound.
		Illuminants.	Carbon Monoxide.	Hydrogen.	Methane.	Nitrogen.			Calc.	Obs.	Volatile combustible matter.	Fixed Carbon.	Ash.	Sulphur.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	
667	6,149	1.6	15.4	46.4	25.4	8.8	.458	—1.	492	489	48.10	41.05	10.85	0.80	56.00	4.35	26.48	1.54	10,220
361	9,755	1.8	9.8	56.2	24.4	7.4	.368	—1.	494	496	55.70	30.09	14.31	0.78	53.80	4.18	24.95	2.08	8,979
328	8,157	1.7	2.6	49.3	41.6	5.5	.353	—1.	538	569	59.50	31.71	8.75	1.00	62.77	4.11	21.14	2.23	9,855
368	5,358	2.1	11.2	48.7	32.6	5.4	.400	4.	574	564	55.00	31.91	13.00	1.33	58.42	4.96	20.00	2.20	10,510
329	6,240	2.3	11.3	46.2	32.7	7.5	.423	—1.	550	570	44.80	33.89	21.31	0.97	55.69	4.75	15.57	1.71	9,244
668	7,996	1.8	11.8	51.2	20.6	8.0	.457	—1.	518	560	44.70	42.63	12.67	0.64	57.06	4.40	23.70	1.53	10,600
327	6,329	1.5	3.8	46.8	33.3	14.6	.409	2.5	580	560	52.14	38.22	9.64	0.81	61.14	4.75	21.95	1.71	10,510
671	6,058	2.0	17.2	48.0	23.4	9.0	.446	—1.	494	489	46.18	43.63	10.20	0.68	54.70	3.15	29.13	2.14	10,840
429	9,560	4.6	19.4	50.4	19.4	6.2	.537	3.	558	513	58.60	30.64	10.76	1.05	57.77	4.70	23.74	1.98	9,782
616	6,685	1.0	15.5	46.8	28.7	7.0	.465	2.	520	513	56.18	37.20	6.62	0.65	61.42	5.12	24.63	1.56	10,540
430	9,028	2.1	8.0	44.2	31.2	11.6	.454	9.3	544	525	52.90	33.99	13.11	0.80	57.20	5.36	21.67	1.86	10,120
354	6,500	2.1	11.5	52.5	29.4	4.5	.326	1.5	533	575	45.00	43.00	12.00	1.40	n. d.	n. d.	n. d.	n. d.	10,980
499	8,135	2.5	9.0	46.4	30.0	10.0	.474	3.4	524	519	50.76	39.54	9.70	0.90	60.72	5.03	21.92	1.73	10,226
517	9,140	1.4	14.0	55.0	22.2	6.8	.373	—1.	450	466	48.54	37.65	13.81	1.00	59.58	4.29	20.09	1.33	9,700
519	6,435	2.2	21.9	44.2	19.7	10.8	.492	—1.	458	458	49.28	32.90	17.82	1.34	56.67	4.70	18.14	1.33	9,709
670	5,576	4.8	22.6	41.4	23.4	7.0	.449	6.	533	540	51.20	38.78	10.02	0.72	64.20	4.56	19.30	1.20	11,182
669	6,195	2.0	17.0	50.0	23.8	6.2	.427	1.	512	498	43.38	41.43	15.19	0.54	57.42	4.03	20.48	2.34	10,900
597	8,751	1.5	20.0	51.0	23.3	0.8	.437	1.5	510	496	47.60	41.31	11.09	0.98	61.20	4.06	20.58	2.09	10,030
576	8,842	1.8	21.6	47.8	15.9	7.7	.503	—1.	425	422	49.00	44.00	7.00	0.87	60.47	4.78	25.20	1.70	9,957
590	9,118	1.6	16.6	50.2	28.1	3.5	.372	1.	539	534	47.00	40.71	11.49	1.29	57.82	4.63	23.09	1.68	10,030
630	7,352	2.0	19.4	43.8	24.6	8.7	.468	3.	485	498	45.66	41.12	13.22	0.80	58.81	4.46	20.21	2.50	10,410
601	9,217	0.8	17.9	46.2	20.5	5.0	.514	—1.	460	440	50.52	39.20	10.28	1.20	59.16	3.82	22.96	2.58	9,855
Average	7,571	2.2	14.4	48.3	25.1	7.5	.436	1.2	513	549	50.51	37.55	11.94	0.93	58.66	4.48	22.14	1.85	10,200

The key to Table XVI is as follows:

No. 667. Alba-Malakoff Lignite Co., Alba, Wood county.

No. 361. American Lignite Briquette Co., Big Lump, Milam county.

No. 328. Bear Grass Coal Co., Jewett, Leon county.

No. 368. Bertetti Coal Co., Lytle, Medina county.

No. 329. Carr Wood & Coal Co., Lytle, Medina county.

No. 668. Como Lignite Co., Como, Hopkins county.

No. 327. Consumers Lignite Co., Hoyt, Wood county.

No. 429. Cookville Coal & Lumber Co., Mt. Pleasant, Titus county.

No. 616. Edgewood Coal & Fuel Co., Edgewood, Van Zandt county.

No. 430. Houston County Coal & Manufacturing Co., Crockett, Houston county.

No. 354. Houston County Coal & Manufacturing Co., Evansville, Leon county.

No. 499. Independence Mining Co., Phelan, Bastrop county.

No. 517. Lone Star Lignite Mining Co., Como, Hopkins county.

No. 519. *Melcher Coal & Clay Co., O'Quinn, Fayette county,

No. 670. Rockdale Coal Co., Hicks, Lee county.

No. 669. Rockdale Consolidated Coal Co., Rockdale, Milam county.

No. 597. Rockdale Lignite Co., Rockdale, Milam county.

No. 576. Rowlett & Wells, Rockdale, Milam county.

No. 590. Southwestern Fuel Co. (formerly Southwestern Fuel & Mfg. Co.), Calvert, Robertson county.

No. 630. Texas Coal Co., Rockdale, Milam county.

No. 601. Vogel Coal and Manufacturing Co., Rockdale, Milam county.

This key applies also to Table XVII. The other figures in that table, under head of Analysis No. —, refer to our current laboratory numbers.

There are 8 principal things to be observed from a study of Table XVI:

---

*This lignite is not mined.

1. The yield of gas per net ton of dry lignite varied from 5,358 to 9,755 cubic feet, the general average being 7,591 cubic feet.

2. The candle-power of the gas was low, only two samples giving as much a 6 candle-power, one of these giving 9.3 candle-power.

3. The B. t. u. per cubic foot varied from 425 to 580, the general average being 513.

4. A high yield of gas seemed to be accompanied by a tendency towards a lower heating value in the gas, but the differences were not especially noteworthy. Thus:

When the yield of gas was:

Cubic feet.	The B. t. u. per cubic foot ranged	With an average of
From 5,000 to 6,000	from 533 to 574	553
From 6,000 to 7,000	from 494 to 580	517
From 7,000 to 8,000	from 485 to 518	501
From 8,000 to 9,000	from 425 to 538	499
From 9,000 to 10,000	from 450 to 558	507

5. With respect to the composition of the gas, the following variations and averages were observed:

	From.	To.	Average.
Illuminants	0.8	4.8	2.2
Carbon monoxide	2.6	22.6	14.4
Hydrogen	41.4	56.2	48.3
Methane	15.9	41.6	25.1

6. With respect to the composition of the dry lignites the following variations and averages are to be observed:

	From.	To.	Average.
Volatile combustible matter	43.38	59.50	50.51
Fixed carbon	30.09	44.00	37.55
Ash	6.62	21.31	11.94
Sulphur	0.54	1.40	0.93
Carbon	53.80	64.20	58.66
Hydrogen	3.15	5.36	4.48
Oxygen	15.57	29.13	22.14
Nitrogen	1.20	2.58	1.85
British thermal units, per pound	8,979	11,182	10,200

7. When the volatile combustible matter was:

Per cent.	The yield of gas in cubic feet per ton was	Average.	The B. t. u. in the gas were from	Average.
From 40 to 45	from 6195 to 7996	6810	512 to 550	526
From 45 to 50	from 6058 to 9140	7594	425 to 539	487
From 50 to 55	from 5576 to 9217	7637	460 to 580	528
From 55 to 60	from 5358 to 9755	7903	494 to 574	537

8. The most noteworthy circumstance in connection with Table XVI is that from lignites of extreme variation in composition, it is possible to secure, on the average, from 6,800 to 7,900 cubic feet of gas per net ton, and this gas carried from 487 to 537 B. t. u. per cubic foot. In heating power, this gas compares favorably with ordinary city gas at 600 B. t. u. per cubic foot. If we allow that good gas coal costs $6.00 a ton, and yields 9,000 cubic feet of 600 B. t. u. gas, we would have 15 cubic feet (=9,000 B. t. u.) for one cent. If we allow that dry lignite costs $2.00 a ton and that it yields 7,500 cubic feet of 500 B. t. u. gas we would have 37.5 cubic feet (=18,750 B. t. u.) for one cent. The raw material cost of coal gas for fuel purposes is twice as great as that of lignite gas.

TABLE XVII.

Composition and yield of residue left in retort after distilling the lignites represented in Table XVI. Dry.

Analysis No.	Volatile combustible matter	Fixed carbon.	Ash.	Sulphur.	B. t. u. per lb.	Yield of residue, per cent.	With complete removal of volatile combustible matter.			
							Fixed carbon.	Ash.	B. t. u. per lb.	Yield of residue.
667–771....	6.21	76.09	17.70	1.90	11,786	50.00	81.14	18.86	12,566	53.31
361–743....	4.95	74.38	20.67	1.69	11,269	50.00	77.20	22.80	11,855	52.60
328–748....	8.07	77.53	14.40	1.42	12,144	56.20	84.33	15.67	13,210	61.13
368–749....	6.67	71.58	21.75	2.27	11,592	50.00	76.69	23.31	12,420	53.57
329–750....	4.05	68.86	27.09	1.54	9,561	50.00	71.76	28.24	9,964	52.11
668–772....	5.29	70.79	23.92	1.08	10,963	57.00	74.74	25.26	11,575	60.17
327–754....	7.69	74.23	18.08	1.15	11,579	54.70	80.41	19.59	12,543	59.25
429–755....	4.64	71.43	23.93	1.44	11,093	67.50	74.89	25.11	11,632	70.78
616–766....	5.27	79.01	15.72	1.20	12,566	50.00	83.40	16.60	13,265	52.78
430–756....	6.25	71.35	22.40	0.99	10,937	56.00	76.10	23.90	11,666	59.73
354–775....	6.48	74.61	18.91	1.64	11,807	50.00	79.77	20.23	12,491	53.46
499–757....	7.20	75.41	17.39	1.29	11,682	50.00	81.26	18.74	12,588	53.87
517–761....	5.41	71.10	23.49	0.71	10,806	51.00	75.16	24.84	11,423	53.91
519–758....	5.41	65.41	29.18	2.85	10,179	57.30	69.15	30.85	10,761	60.57
670–776....	5.30	69.22	25.48	4.36	11,121	60.00	73.09	26.91	11,743	65.99
669–774....	6.31	71.99	21.70	1.80	11,520	62.50	76.83	23.17	12,295	66.70
597–760....	5.87	74.51	19.62	1.52	11,565	50.00	79.15	20.85	12,286	53.11
576–759....	4.55	74.04	21.41	1.51	11,126	56.20	77.56	22.44	11,656	58.87
590–762....	4.18	75.62	20.20	1.57	11,379	62.50	78.91	21.09	11,875	65.22
630–770....	7.16	71.09	21.75	1.23	11,429	56.00	71.18	28.82	12,310	60.31
601–763....	7.40	73.57	19.03	0.89	11,450	56.20	79.44	20.56	12,364	60.69
Average..	5.92	72.94	22.14	1.62	11,312	54.90	77.52	22.48	12,023	58.35

A study of Table XVII, the key to which appears under Table XVI, shows:

1. The volatile combustible matter was not completely removed. The amount remaining in the residue varied from 4.05 to 8.07 per cent, with an average of 5.92 per cent.

2. The fixed carbon in the residue varied from 65.41 to 79.01 per cent, with an average of 72.94 per cent. With complete removal of the volatile combustible matter, the fixed carbon would vary from 69.15 to 84.33 per cent, with an average of 77.52 per cent.

3. The ash in the residue varied from 14.40 to 29.18 per cent, the average being 22.14 per cent. With complete removal of the volatile combustible matter, the ash would vary from 15.67 to 30.85 per cent, the average being 22.48 per cent.

4. The sulphur in the residue showed a marked increase over that in the dry lignite. Excluding two abnormally high results, the increase was from 1.22 to 2.37 times, with an average of 1.64. In two cases out of twenty-one, the sulphur in the dry lignite was more than it was in the residue. For the most part the sulphur appeared to be as calcium sulphate (gypsum).

5. The B. t. u. per pound varied from 9,561 to 12,566, the average being 11,312. This has an important bearing on the manufacture of briquettes from the residue. For further information on this subject, see Chapters IX and XI. As some of the volatile combustible matter would probably contain certain heat units, it is useless to calculate what the B. t. u. would be in the residue, if this matter were entirely removed. It is, however, not probable that there would be any loss in the heat units in such residue.

6. The yield of solid residue varied from 50.00 to 67.5 per cent, the average being 54.9 per cent. With complete removal of the volatile combustible matter, the yield would vary from 52.11 to 70.78 per cent, the average being 58.35 per cent.

We may assume, for the moment, that in the ordinary practice of distilling lignites in a closed, or practically closed, retort, the residue will contain about 6 per cent of volatile combustible matter; that the yield of this residue, from dry lignite, will be about 55 per cent, and that it will contain from 73 to 75 per cent of fixed carbon. It is not likely that there will be any economy in completely removing the volatile combustible matter, for the purpose will be to discharge the retorts as soon as the B. t. u. in the gas begin to show a markedly less value. Just where this point may be depends on a number of conditions which, for the most part, have not been ascertained. The yield and the nature of the volatile matter distilled from such substances as coal and lignite depend on many factors, some of them of varying moment. The principal ones appear to be as follows: the size of the material; the amount of disposable hydrogen, i. e., the hydrogen that is free to combine with carbon as a hydro-carbon; the rapidity with which the temperature is raised; the length of time during which a uniform temperature is maintained; the maximum temperature within the retort and within the coal itself; the size and temperature of the space into which the gas is conducted; the rapidity with which the gas is removed from the retort; and the depth of the bed of coal which is being distilled. In dealing with coal and lignite, we have to remember that they are substances which, under the influence of heat, are decomposable into a large number of compounds and that the original compounds formed may react among themselves and produce other and, perhaps, more complicated substances. With the chemico-physical side of this matter we have but little to do at present, our main purpose being to call attention to the fact that Texas lignites are capable of yielding, in dry condition, 7,500 cubic feet of gas per net ton and that this gas carried 500 B. t. u. per cubic foot.

Irrespective of the heating value of the solid residue from the retorts, we have in lignite gas a source of cheap and effective energy, whether this energy be used in mere heating effects or converted into electric power through the medium of gas engines and generators. A plant consuming 100 tons of dry lignite a day would produce 750,000 cubic feet of gas that would contain 375,000,000 B. t. u., and leave 55 tons of solid residue containing 1,100,000,000 B. t. u. In Chapter IX, Professor E. J. Babcock, has described a method for the utilization of the solid residue in the manufacture of briquettes, and reference is here made to that Chapter.

CHAPER XIII.

FUEL OIL.

Fuel oil is of two kinds:

1. Crude petroleum, such as Texas crude, Mexican crude, etc.
2. Petroleum from which certain distillates, such as benzine, gasoline, etc., have been removed in the refineries. The demand for these products during the last year has been so active that a good deal of Texas crude that was formerly sold for fuel purposes direct now goes to the refineries for the recovery of the lighter distillates.

There are no statistics bearing on the proportion of these two kinds of fuel oil now used in Texas.[1]

Some contracts may take this matter into consideration, but ordinarily the specifications call for fuel oil of such and such a gravity and of so many B. t. u. per pound without regard to whether the oil is crude or residue from the stills. The oil must be commercially free of sand, sediment and water. Owing to the advent of Mexican crude in our markets, this oil having a gravity of 0.934 to 0.942, attention will have to be given to the kind of pumps supplying the oil to the burners. The viscosity of this oil is below that of some of the other fuel oils now being used, and it is pumped with more difficulty.

According to the Fuel Oil Journal, Houston, February, 1913, the consumption of fuel oil by Southwestern railroads during the year 1912, was as follows, in barrels of 42 gallons:

System.	Barrels.
Southern Pacific (Texas and Louisiana)	3,924,403
Santa Fe (Texas lines)	2,000,000
Frisco main lines (Texas and Louisiana)	1,630,222
Kansas City Southern (all lines)	1,254,668
All others	700,000
	9,509,293

[1]In 1904 there were manufactured in the United States 7,209,428 barrels of fuel oil of 50 gallons and in 1909 34,034,577 barrels.

[illegible] of fuel oil cars. Sour Lake, Hardin County.

If we allow that, on the average, four barrels of fuel oil are equivalent to one ton of ordinary bituminous coal, this quantity of oil would replace 2,377,323 tons of coal. This is, perhaps, a generous allowance, so if we allow 3½ barrels as equivalent to a ton of coal we have a replacement of 2,716,941 tons of coal, an amount considerably more than the entire coal and lignite production of Texas during that year.

We do not know what the average price of this oil was, but it is not likely that it was less than 85 cents a barrel. The authority just quoted gives the prices of fuel oil at different points in the State during the year 1912, as follows:

	Cents.
Houston	87.
Humble	84.3
Port Arthur	85.7
Sabine	85.7
Fort Worth, Corsicana, Dallas	91.8

The consumption of fuel oil by the railroads of the United States from 1906 to 1912, inclusive, was about as follows, in barrels of 42 gallons (David T. Day):

	Barrels.
1906	15,577,677
1907	18,849,803
1908	16,870,882
1909	19,905,335
1910	23,817,346
1911	29,748,845
1912	33,605,598

The average number of miles run per barrel of fuel oil consumed varied from 3.93 in 1907, to 3.61 in 1912. While some of the lines involved also used coal the mileage operated by the use of fuel oil was 13,573 in 1907; 15,474 in 1908; 17,676 in 1909; 22,709 in 1910; 30,039 in 1911 and 28,451 in 1912.

The following is taken from an article by Mr. Holland S. Reavis, Editor, Fuel Oil Journal, Houston, published in the Mineral Industry, Vol. XXI, page 641:

"In line with the general advance in crude oil prices, the Texas market strengthened appreciably during the year. In north Texas, the price of light oil at the wells on January 1, 1912, was 55 cents, and heavy oil, 50 cents. On December 31, 1912, light oil was 88 cents, and heavy, 70 cents. Contracts were made January 1, 1912, in the coastal fields for periods of 12 to 18 months at 72 and 72½ cents per barrel for heavy oil at the wells. Some of these contracts were renewed January 1, 1913, at $1.00 to $1.07⅞ per barrel at the wells. South Texas crude oil sold on January 1, 1912, at 70 cents per barrel, on board cars, for fuel use. A year later the price was $1.10 to $1.20 per barrel, on board cars.

"Pipe-line construction in Texas during 1912 was as follows: An 8-inch line, 449 miles long, was laid by the Magnolia Petroleum Company between Electra and Beaumont, connecting at the latter point with the same company's lines leading to deep water at Sabine, on the Gulf coast. Through the new line the Magnolia Company supplies crude to its refineries at Corsicana, about midway between Electra and the terminus, and at Beaumont. There are five stations, the distances between them being as follows: Electra to Alvord, 94 miles; Alvord to Corsicana, 117 miles; Corsicana to Richards, 120 miles; Richards to Beaumont, 118 miles. De La Vergne crude oil engines furnish the power at the stations for pumping the oil. The line traverses the various oil fields of north Texas.

"The Gulf Pipe Line Company constructed a 6-inch branch line from its main 8-inch Oklahoma-Texas trunk line at Saltillo to Fort Worth, a distance of 136 miles, for the purpose of furnishing crude to the Gulf Refining Company's new refinery at Fort Worth, which was completed and placed in operation in the spring of 1912. The Pierce-Fordyce Oil Association completed a refinery at Fort Worth in the spring of 1912, obtaining its crude supply by tank cars from Electra and Oklahoma, and also receiving oil from the pipe-line of another company, which passes through Fort Worth. The Texas Company constructed an 8-inch pipe-line from the north Texas oil fields to Dallas, by way of Fort Worth."

List of Refineries in Texas.

Name.	Location.	Daily capacity, barrels.
Pierce-Fordyce Oil Association	Texas City	2,000
Pierce-Fordyce Oil Association	Fort Worth	2,000
Gulf Refining Company	Port Arthur	30,000
Gulf Refining Company	Fort Worth	5,000
Magnolia Petroleum Company	Beaumont	20,000
Magnolia Petroleum Company	Corsicana	3,000
Texas Company	Port Arthur	18,000

Name.	Location.	Daily capacity, barrels.
Texas Company	Gates	15,000
Texas Company	Port Arthur	3,000
United Refinery Company	Beaumont	1,500
Webster Refining Company	Orange	500
Total		100,000

So far as we are aware, there are no statistics relating to the consumption of fuel oil by industrial establishments, hospitals, hotels, etc., but this quantity may be taken, we think, at a million barrels a year, with a tendency towards a lesser quantity, owing to the increasing price of oil.

During the first six months of 1913, average current quotations were as follows, per barrel of 42 gallons:

	Per barrel.
Houston	$1.22
Humble	1.125
Port Arthur	1.20
Sabine	1.20
Fort Worth, Corsicana, Dallas	1.191

Comparing these prices with those that maintained during the year 1912 it will be seen that the price of fuel oil at Houston increased from an average of 87 cents to $1.22; at Humble, from 84.3 cents to $1.125; at Port Arthur and Sabine, from 85.7 cents to $1.20; at Fort Worth, Corsicana and Dallas, from 91.8 cents to $1.191. In the early part of November, 1913, the price of Mexican crude, delivered to Gulf ports, varied from $1.00 to $1.20.

We have made in our own laboratory, a number of analyses of fuel oils. Between November 26, 1912, and June 3, 1913, we examined 19 samples for the State Purchasing Agent, Austin, of fuel oil delivered to the different State institutions for which he secured supplies. The specific gravity varied from 0.868 to 0.931, with an average of 0.90; the B. t. u. per pound varied from 18,964 to 19,500, with an average of 19,211. We examined 12 samples for flash point, and found the variation to be from 110 to 218 degrees F., with an average of 151 degrees F. We examined 10 samples for burning point and found the same to vary from 180 to

276 degrees F., with an average of 221 degrees F.[1] These samples were all commercially free from sand, sediment and water.

We have examined one sample of Mexican crude, used for fuel purposes. The color was black; specific gravity, 0.938; viscosity, 3,600 at 70 degrees F.; flash point, 140 degrees F.; burning point, 185 degrees F.; heating power, 19,232 B. t. u. per pound.

Mexican Crude Oil.

According to the Fuel Oil Journal, Houston, the production of crude petroleum in Mexico from 1907 to 1912, inclusive, was as follows, in barrels of 42 gallons:

	Barrels.		Barrels.
1907	1,000,000	1911	14,051,643
1908	3,481,410	1912	16,500,000
1909	2,488,742		
1910	3,332,807	Total	40,854,620

The importation of Mexican crude oil into Texas ports for this year, up to the 20th of June, was as follows, by districts:

	Barrels.	Total value.	Value per bbl., cents.
Sabine and Port Arthur	2,164,523	1,202,690	55.56
Galveston	1,273,599	718,687	58.00
Port Aransas	96,566	55,731	58.00
Total	3,534,688	1,977,108	

Heat Values in Mexican Crude.[2]

"Samples of Mexican crude oil taken from 8 cargoes shipped from Tuxpan and Tampico showed heat values as follows:

Specific gravity.	B. t. u., per pound.
0.942	19,620
0.941	19,638
0.937	19,170
0.937	19,170
0.937	19,224
0.936	19,476
0.935	19,440
0.934	19,620
Average 0.937	19,420

[1]In the British mercantile marine the minimum flash point for fuel oils is 150 deg. F. (Abel test), and in the navy 200 deg. F. In the United States the standard flash point is 140 deg. F. (Abel-Pensky or Pensky-Martens test). In Russia, Roumania and Germany it is 176 deg. F. (Boverton Redwood, Treatise on Petroleum, 3d Ed., 1913, p. 381.)

[2]Fuel Oil Journal, Vol. 4, No. 1, July, 1913, page 32.

The magnitude of the oil carrying trade, in steam and sailing vessels, is shown by the following statistics taken from Boverton Redwood's "Treatise on Petroleum," 3d edition, 1913:

Of tank steamers, he gives a list of 363, with a net tonnage varying from diminutive steamers of 37 tons, such as the "Carbolate," of Falmouth, to vessels of 5,776 tons, such as the Narragansett, of Greenock. He gives a list of 54 tank sailing vessels, with a net tonnage varying from 111 to 6,970. In his list of vessels fitted for using liquid fuel, he mentions 203, the gross tonnage varying from 75, as in the "Krungthep," of the East Asiatic Company, Limited, to 13,454, as in the "Tenyo Maru," of the Toyo Kisen Kabushiki Kaisha. The "Texan," of the American-Hawaiian S. S. Company, has a tonnage of 8,615, gross.

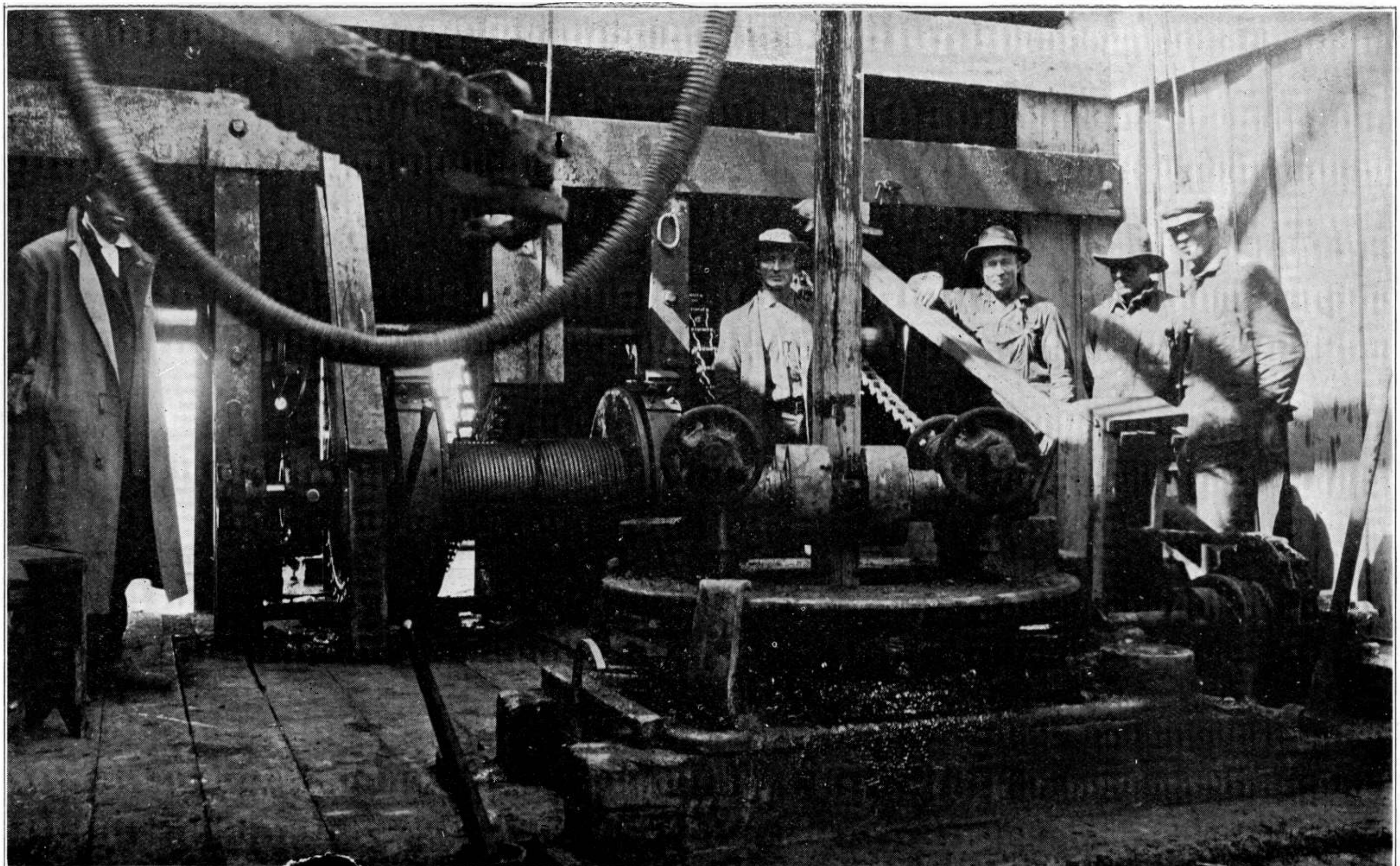
With respect to petroleum as fuel, the following is taken from Boverton Redwood's "Treatise on Petroleum," 3d edition, 1913, pages 381 to 383:

"For many years Russia was the only country producing and consuming liquid fuel on a scale of commercial magnitude, the crude petroleum from the prolific oil fields of Baku yielding a large proportion of a suitable product, but for some time past there has been in the United States a rapid growth in the general employment of liquid fuel, large supplies being obtained in California and elsewhere. The Kutei district of Borneo has also become an important factor in the industry, the petroleum found there yielding an excellent fuel oil and being apparently obtainable in very large quantities. Among other present and prospective sources of supply to which the now general recognition of the advantages of liquid fuel, especially for marine purposes, has caused attention to be directed, are those of Burma, Persia, Egypt, Trinidad, Mexico, Galicia and Roumania, and there can be no doubt that the efforts now being made to develop fresh sources of supply will result in a very considerable increase in the quantity at present available. It would, however, be misleading to suggest that there is any prospect of a general substitution of oil for coal as fuel in steam-raising and for other purposes. The author pointed out in giving evidence before the Royal Commission on Coal Supplies in 1903, that if the aggregate output of petroleum in the world were doubled, and the whole of the surplus thus created were used as fuel, this surplus would, taking into account the relative thermal efficiencies, only be equivalent to about 5 per cent of the world's output of coal.

It has also to be taken into account that with the development of most oil fields there is a progressive decrease in the proportion of fuel oil yielded by the crude petroleum, the oil obtained at greater depth usually containing a larger proportion of the more volatile hydrocarbons. Lastly, the exhaustion of the older oil fields, which is proceeding *pari passu* with the opening up of new fields, must not be lost sight of in forming an estimate of the extent to which the world's supplies may be augmented. In this connection, attention should be drawn to a report in which Dr. David T. Day, the expert of the United States Geological Survey, in charge of petroleum investigation, gave the data on which he arrived, some three years ago, at the somewhat startling conclusion that at the present rate of increase of the output of petroleum, the known oil fields of that country would, on the basis of the estimated minimum quantity of oil obtainable, be exhausted by the year 1935, whilst if the present output were only maintained the supply would on the same basis only last for ninety years. In these circumstances it is fortunate that through the success which has attended the introduction of the Diesel engine, to which reference will be made subsequently, attention is now being given to the substitution of the internal-combustion engine for the steam-engine, for with the Diesel type of engine, it is possible to obtain about three times as much power from a given quantity of oil as is usually yielded when the oil is used for steam-raising in conjunction with the best types of steam-engine, though, as is hereafter pointed out, modern improvements in the raising and use of steam may be held to necessitate a revision of this comparison.

In their final report, dated 7th January, 1905, the Commissioners express themselves on the subject of the substitution of oil for coal, in the following terms:

"There has been much disposition in recent years to speak of oil fuel as if it were a serious competitor of coal, and a real substitute for it. The facts before us do not bear out that view. Dr. Boverton Redwood in his evidence has given us a valuable account of the present and prospective sources of supply of petroleum and its allied products, and while he thought there was ample scope for energy and capital in searching for and opening up fresh



inside the derrick—1700-ft. hole. Putnam No. 16, Electra, Wichita County.

sources of supply, he expressed himself very strongly against the possibility of any largely extended use of petroleum as a substitute for coal. He pointed out that the world's production of coal in 1901 was 777 million tons, and that in the same year the world's production of petroleum was 22 million tons, or only 2.8 per cent of the weight of the coal.

"The conclusion we have arrived at as regards the use of oil fuel in this country is that which is expressed by Dr. Boverton Redwood in answer to Question 13,559, when he said: 'I think there will be certain selected applications of liquid fuel where the advantages of employing such a fuel are especially obvious; but for anything like general employment, I cannot see where we are to look for adequate supplies'."

Liquid fuel is largely applied in metallurgical operations and has replaced coal in many glass-works and other industrial establishments. It has also been found available for domestic use, but the principal application has hitherto been for steam-raising.

The following specifications for the purchase of fuel oil for the United States Government was issued by the Bureau of Mines in 1911:

"General Specifications.

"1. In determining the award of a contract, consideration will be given to the quality of the fuel offered by the bidders, as well as the price, and should it appear to be to the best interest of the Government to award a contract at a higher price than that named in the lowest bid or bids received, the contract will be so awarded.

"2. Fuel oil should be either a natural homogeneous oil or a homogeneous residue from a natural oil; if the latter, all constitents having a low flash-point should have been removed by distillation; it should not be composed of a light oil and a heavy residue mixed in such proportion as to give the density desired.

"3. It should not have been distilled at a temperature high enough to burn it, nor at a temperature so high that flecks of carbonaceous matter began to separate.

"4. It should not flash below 60 degrees C. (140 degrees Fahrenheit) in a closed Abel-Pensky or Pensky-Martens tester.

"5. Its specific gravity should range from 0.85 to 0.96 at 15 degrees C. (59 degrees Fahrenheit); the oil should be rejected if its specific gravity is above 0.97 at that temperature.

"6. It should be mobile, free from solid or semi-solid bodies, and should flow readily, at ordinary atmospheric temperatures, and under a head of one foot of oil, through a 4-inch pipe 10 feet in length.

"7. It should not congeal nor become too sluggish to flow at 0 degrees C. (32 degrees Fahrenheit).

"8. It should have a calorific value of not less than 18,000 British thermal units per pound; 18,360 B. t. u. to be the standard. A bonus is to be paid or a penalty deducted according to the method stated under Section 21, as the fuel oil delivered is above or below this standard.

"9. It should be rejected if it contains more than 2 per cent water.

"10. It should be rejected if it contains more than one per cent sulphur.

"11. It should not contain more than a trace of sand, clay, or dirt.

"12. Each bidder must submit an accurate statement regarding the fuel oil he proposes to furnish. This statement should show:

(a) The commercial name of the oil.

(b) The name or designation of the field from which the oil is obtained.

(c) Whether the oil is a crude oil, a refinery residue, or a distillate.

(d) The name and location of the refinery, if the oil has been refined at all.

"13. The fuel oil is to be delivered f. o. b. cars or vessel, according to the manner of shipment, at such places, at such times, and in such quantities as may be required, during the fiscal year ending.

"14. Should the contractor, for any reason, fail to comply with a written order to make delivery, the Government is to be at liberty to buy oil in the open market and charge against the contractor any excess of price, above the contract price, of the fuel oil so purchased."

The specifications adopted by the State Purchasing Agent, Austin, Texas, for fuel oil to be supplied to the various State institutions for which he secures supplies, are as follows:

Fuel Oil.

"To be natural, crude, distilled or reduced petroleum, free from sand or other solid matter that will impede or prevent handling freely through ordinary size pumps, pipes, or burners, and to be of such viscosity that will permit of its being handled freely at a temperature of 60 degrees Fahrenheit. It shall be commercially free of water, and wherever practicable, all free water must be drawn from the delivery tanks before discharging. The specific gravity, as determined by the Tagliabue Hydrometer, shall be between 25 degrees and 30 degrees Baumé. The buyer may refuse to accept any fuel oils showing a flash point of less than 200 degrees Fahrenheit when tested by the open cup Tagliabue method; namely, heating the oil at the rate of 2 degrees per minute, flame test to be applied every 2 degrees after the temperature of the oil is raised, beginning at 90 degrees Fahrenheit. The burning point of fuel oil shall not be below 212 degrees Fahrenheit. The British thermal units per pound of fuel oil shall not be less than 19,000."

The total production and value of the petroleum in Texas for the years 1889 to 1912, inclusive, are as follows, barrels of 42 gallons:

Year.	Production.	Value.
1889	48	$ 340
1890	54	227
1891	54	227
1892	45	225
1893	50	210
1894	60	420
1895	50	350
1896	1,450	4,000
1897	65,975	65,975
1898	546,070	382,249
1899	669,013	473,443
1900	836,039	871,996
1901	4,393,658	1,247,351
1902	18,083,658	3,998,097
1903	17,955,572	7,517,479
1904	22,241,413	8,156,220
1905	28,136,189	7,552,262
1906	12,567,897	6,565,578
1907	12,322,696	10,410,865
1908	11,206,464	6,700,708
1909	9,534,467	6,793,050
1910	8,899,266	6,605,755
1911	9,526,474	6,554,552
1912	11,735,057	8,852,713
Total	168,721,719	$82,754,292

The following Tables, XVIII to XXI, give the production and value of Texas petroleum from 1902 to 1912, inclusive, in barrels of 42 gallons, the statistics used being those of the United States Geological Survey:

TABLE XVIII.

Production of Petroleum in Northern Texas, 1902-1912. Barrels of 42 Gallons. Statistics of the United States Geological Survey.

Year.	Corsicana, Navarro County.	Henrietta, (Petrolia) Clay County.	Powell, Navarro County.	Marion County.	Electra, Wichita County.	Total, including other districts.
1902	571,050	....	46,812	....	....	617,871
1903	401,817	....	100,143	....	....	501,960
1904	374,318	65,455	129,329	....	....	569,252
1905	311,554	75,592	132,866	....	....	520,282
1906	332,622	111,072	673,221	....	....	1,117,905
1907	226,311	83,260	596,897	....	....	912,618
1908	211,117	85,963	421,659	....	....	723,264
1909	180,764	113,485	383,137	....	....	681,940
1910	137,331	126,531	450,188	251,717	....	969,403
1911	128,526	168,965	373,055	677,689	899,579	2,251,193
1912	233,282	197,421	251,240	362,870	4,227,104	5,275,529
Total	3,108,692	967,744	3,558,547	1,292,276	5,126,683	14,141,217

TABLE XIX.

Value of petroleum in Northern Texas, 1902-1912. Barrels of 42 gallons.

Year.	Corsicana.		Powell.		Henrietta (Petrolia).		Electra.		Marion County.		Total value of all districts.
	Value.		Value.		Value.		Value.		Value.		
	Total.	Per bbl., cents.	Total.	Per bbl., cents.	Total.	Per bbl., cents.	Total.	Per bbl., cents.	Total.	Per bbl., cents.	
1902........	410,536	71.89	9,863	21.07	....	....	....	....	....	....	$ 420,399
1903........	458,071	114.	57,291	57.16	....	....	....	....	....	....	515,314
1904........	315,656	87.	55,611	43.	65,455	47.5	....	....	....	....	412,360
1905........	258,590	83.	66,433	50.	35,906	47.5	....	....	....	....	361,604
1906........	310,941	93.5	356,144	52.9	72,197	65.	....	....	....	....	740,542
1907........	228,845	101.1	407,186	68.2	78,946	94.8	....	....	....	....	721,577
1908........	153,489	72.7	274,536	65.1	46,947	54.6	....	....	....	....	479,072
1909........	130,335	72.1	199,952	52.2	58,694	51.7	....	....	....	....	393,732
1910........	87,623	63.8	242,440	53.8	69,086	54.6	....	....	....	....	505,396
1911........	74,439	57.9	186,528	50.	92,046	54.5	492,175	54.7	....	....	1,213,960
1912........	149,393	64.	193,439	76.9	134,681	68.2	3,340,828	79.	290,974	80.2	4,112,826
Total and average...	2,577,918	80.09	2,049,423	53.66	653,958	48.94	3,833,003	66.85	290,974	80.2	$9,876,782

TABLE XX.

Production of petroleum in Coastal Texas, 1902-1912. Barrels of 42 gallons. Statistics of the United States Geological Survey.

Year.	Batson, Hardin County.	Saratoga, Hardin County.	Sour Lake, Hardin County.	Matagorda County.	Spindle Top, Jefferson County.	Dayton, Liberty County.	Humble, Harris County.	Other districts.	Total, including other districts.
1902	...	44	838	...	17,420,949	...	...	...	17,465,787
1903	4,518	8,848	159	...	8,600,905	...	...	a.30	17,453,612
1904	10,904,737	739,239	6,442,357	151,936	3,433,842	...	...	a.50	21,672,161
1905	3,774,841	3,125,028	3,362,153	46,471	1,652,780	60,294	15,594,310	a.30	27,615,907
1906	2,289,507	2,182,057	2,156,010	3,600	1,077,492	92,850	3,571,445	77,031	11,449,992
1907	2,164,453	2,130,928	2,353,940	1,573	1,699,943	108,038	2,929,640	21,563	11,410,078
1908	1,593,570	1,634,786	1,595,060	62,640	1,747,537	39,901	3,778,521	31,185	10,483,200
1909	1,206,214	1,183,559	1,703,798	29,103	1,388,107	17,647	3,237,060	87,039	8,852,527
1910	1,113,767	1,024,348	1,518,723	455,999	1,182,436	9,582	2,495,511	129,497	7,929,863
1911	1,023,493	925,777	1,364,880	561,828	965,939	4,344	2,426,220	2,800	7,275,281
1912	844,563	1,116,655	1,175,108	613,292	822,916	12,151	1,829,923	44,920	6,459,528
Total	24,919,663	14,062,377	21,672,029	1,925,442	39,992,846	314,807	35,865,630	394,145	148,047,936

a Bexar county. Note.—The production of Saratoga and Sour Lake for 1902 and 1903 is included in the grand total.
The Spindle Top (Beaumont) field came into production in January, 1901. During that year the yield was 5,185,883 barrels, valued at $949,307, or 18.3 cents per barrel.

Table XXI.

Value of petroleum in Coastal Texas, 1902-1912. Barrels of 42 gallons. Statistics of the United States Geological Survey.

Year.	Batson.		Saratoga.		Sour Lake.		Matagorda County.		Spindle Top.		Dayton.		Humble.		Total, including other districts, dollars.
	Value.		Value.		Value.		Value.		Value.		Value.		Value.		
	Total, dollars.	Per bbl., cents.	Total, dollars.	Per bbl., cents.	Total, dollars.	Per bbl., cents.	Total, dollars.	Per bbl., cents.	Total, dollars.	Per bbl., cents.	Total, dollars.	Per bbl., cents.	Total, dollars.	Per bbl., cents.	
1902	....	......	8,967	20.	14,413	32.15	....	......	3,563,285	20.45	......	......	....	......	3,586,665
1903	1,125	25.	c2,212,039	25.	c	c	....	......	2,212,039	25.	......	......	....	......	7,002,165
1904	3,707,671	34.	244,660	33.	2,401,911	37.3	51,625	34.	1,337,655	38.9	......	......	....	......	7,743,860
1905	1,025,025	27.2	872,285	28.1	1,117,261	33.2	16,677	36.	612,282	37.	18,255	30.3	3,528,768	22.6	7,190,658
1906	1,199,625	52.4	985,543	45.	1,155,475	53.6	a41,556	51.6	666,287	61.8	40,265	43.4	1,736,165	48.6	5,825,036
1907	1,913,875	88.4	1,742,913	81.8	1,944,343	82.6	a10,811	81.5	1,521,304	89.5	80,559	74.6	2,456,892	83.9	.9,680,286
1908	885,965	55.6	989,167	60.5	982,769	61.6	b33,267	42.9	1,030,403	58.9	19,818	49.7	2,269,341	60.	6,221,636
1909	851,138	70.6	864,938	73.8	1,227,73[illegible]	72.1	21,918	75.3	1,041,791	75.1	11,471	65.0	2,314,082	71.5	6,399,318
1910	851,927	76.5	789,761	77.1	1,203,920	79.3	250,050	54.8	961,758	81.3	6,815	71.1	1,927,879	77.3	6,100,359
1911	704,788	68.8	739,247	79.8	995,807	72.9	305,588	54,3	724,978	75.	2,946	67.8	1,864,598	76.8	5,340,592
1912	625,812	74.1	827,847	74.1	874,897	74.5	406,032	66.2	654,778	79.6	8,473	69.7	1,313,229	71.8	4,739,887
Total	11,766,951	57.26	10,277,367	54.35	11,918,530	54.47	1,137,524	55.17	14,326,560	58.41	188,602	58.95	17,410,954	64.06	69,830,462

a–Includes Hoskins Mound. b–Includes Goose Creek. c–Values of Saratogs and Sour Lake combined, estimated at 25 cents a barrel. The Spindle Top (Beaumont) field came into production in January, 1901. During that year the yield was 5, 185,883 barrels, valued at $949,307, or 18.3 cents per bbl.

The high-water mark of production was reached in 1905, when the amount was 28,136,189 barrels, but the high-water mark of value was in 1907, when the total value was $10,410,865. The 12,322,696 barrels produced in 1907 were worth $2,858,603 more than the 28,136,189 barrels produced in 1905.

Prior to the year 1900 practically all of the petroleum produced in Texas came from the Corsicana field. Since 1898 that field has maintained its reputation for supplying high grade oil, the average price, per barrel, being 80.09 cents during the 11 years ending with 1912. The total production of the Corsicana field may be taken at 5,290,000 barrels, valued at $4,700.000. The Powell field, also in Navarro county, yields a heavier oil than the Corsicana field. It came into production in 1902 and has yielded 3,558,547 barrels, valued at $2,049,423, or 53.66 cents a barrel. The Henrietta field, Clay county, came into production in 1904, and has yielded 967,744 barrels, valued at $633,958, or 48.94 cents a barrel.

The Electra field, Wichita county, came into production in 1911 and has produced 5,126,683 barrels, valued at $3,833,003, or 66.85 cents a barrel. This is also a high-grade oil.

The other oil field classed as belonging to northern Texas is in Marion county, in northeast Texas. It is the Caddo Lake district in Texas, and may be the west extension of the Caddo fields in Louisiana. It came into production in 1910, and has yielded 1,292,276 barrels, valued at $290,974, or 80.2 cents a barrel.

The entire production of all of the northern Texas fields may be taken at 16,235,715 barrels, valued at $11,535,021.

In coastal Texas the first of the great fields to come into production was that at Spindle Top (Beaumont), Jefferson county. It began to produce in January, 1901, and since that time has yielded 45,178,729 barrels, valued at $15,285,867, or an average of 33.8 cents a barrel.

Saratoga and Sour Lake, Hardin county, came into production in 1902. The statistics for these two fields are combined for the years 1902 and 1903, but since 1904 Saratoga has yielded 14,062,-377 barrels, valued at $8,056,356, or 57.3 cents a barrel. Since 1904, Sour Lake has yielded 21,672,029 barrels, valued at $11,904,-117 or 55.3 cents per barrel.

The Batson field, Hardin county, came into production in 1903, but it was not until 1904 that the yield was considerable. Since 1903, it has produced 24,919,663 barrels, valued at $11,766,951 or 57.26 cents per barrel.

Matagorda county (Markham, etc.) came into production in 1904 and has yielded about 2,000,000 barrels, valued at $1,137,524, or 55.17 cents per barrel.

Dayton, Liberty county, came into production in 1905, and since that time has yielded 314,807 barrels, valued at $188,604, or 58.95 cents a barrel.

The Humble field, Harris county, came into production in 1905 and has yielded 35,865,630 barrels, valued at $17,410,954, or 64.06 cents per barrel. During its first year, this field produced 15,594,310 barrels, but fell to 3,571,445 barrels the following year, and in 1912 produced only 1,829,923 barrels.

CHAPTER XIV.

COMPARATIVE EFFICIENCY OF FUELS.

In the following Tables, XXII, XXIII, XXIV and XXV, which, for convenience of reference, are placed together, we have endeavored to calculate the fuel cost of evaporating 1,000 pounds of water by means of coal, lignite, fuel oil and natural gas. Before beginning a discussion of these tables, it may be well to explain, as briefly as possible, some of the terms used in stating an analysis of a fuel.

As ordinarily given, an analysis of coal and lignite contains six items, viz.: moisture, volatile combustible matter, fixed carbon, ash, sulphur and British thermal units per pound.

The moisture in such fuel is the usual atmospheric moisture and is removed at or near the boiling point of water, 212 degrees Fahrenheit. If the temperature be increased much beyond this point, incipient decomposition of the coal or lignite sets in and occasions a loss which is not chargeable to ordinary moisture alone. It includes certain volatile substances which may or may not contain appreciable heat units, according to circumstances. In drying coal and lignite, care must be taken that the temperature shall not exceed 215 to 220 degrees Fahrenheit. In some lignite a serious loss of volatile combustible matter is apt to occur above 220 degrees Fahrenheit and in exceptional cases at temperatures considerably below that of boiling water.

If we take the sample which has been deprived of its moisture and heat it in a platinum crucible set inside of another crucible, each being provided with a close fitting cover, we notice that vapors and smoke begin to arise, a flame appears and restricted combustion sets in. After a few minutes, the two crucibles being red-hot, these phenomena cease and there remains a solid residue in the inside crucible. The loss in weight that the fuel sustains is termed "volatile combustible matter." It may and often does contain gases that are not combustible, such as carbonic acid, etc.; but, irrespective of the content of such gases, it has been agreed among chemists to consider the loss as representing the volatile combustible matter in the fuel.

The solid residue in the crucible is the fixed carbon of the fuel, plus the mineral matter (ash). If the inner crucible be now exposed to the air and the carbon in the residue be burned away, we have only the ash remaining.

The volatile combustible matter and the fixed carbon are the heat producing constituents of the fuel, no account being taken of the sulphur, as this yields but little heat when burned.

The sulphur in coal and lignite exists, probably, in three conditions, as pyrite (sulphide of iron), as gypsum (sulphate of lime) or other analogous sulphates, and as more or less obscure organic compounds.

The expression "British thermal units per pound" is the method of stating the heat units in a pound of fuel, in the case of solid and liquid fuels, or in a cubic foot, as in gases. It means the quantity of heat required to raise the temperature of one pound of water one degree, the starting point being 39.1 degrees Fahrenheit. Some authorities prefer to take the starting point at 54 degrees Fahrenheit, others at 62 degrees Fahrenheit, but there is no practical difference in the results, inasmuch as the specific heat of water at all temperatures from the freezing point to the boiling point is virtually the same. If a fuel is said to have 12,000 British thermal units (abbreviated to B. t. u.) per pound, we understand that each pound of this fuel, when properly burned, will give enough heat to raise the temperature of 12,000 pounds of water from 39.1 degrees to 40.1 degrees Fahrenheit, from 54 degrees to 55 degrees Fahrenheit, or from 62 degrees to 63 degrees Fahrenheit.

The B. t. u., therefore, gives a convenient method of comparing one fuel with another, and it is in general use in England and the United States. In Continental Europe, the term "calorie" is used, and this means the quantity of heat required to raise the temperature of one kilogram (=2.22 pounds of water) one degree Centigrade; i. e., from 0 to 1 degree. To convert B. t. u. to calories multiply by 0.555; to convert calories to B. t. u., multiply by 1.8. The B. t. u. is equivalent to 778 foot-pounds of work.

To evaporate one pound of water from and at 212 degrees Fahrenheit requires 965.7 heat units, or 535.96 calories; and this is equivalent to the oxidation of 0.0664 pounds of carbon. One horsepower is equivalent to 2544.987 heat units per hour.

The heat units in various substances differ according to the chemical composition. When the purest form of carbon—crystallized diamond—is burned to carbonic acid, there are generated 20,041 B. t. u. per pound; ordinary soft coal gives from 12,000 to 14,000; lignite (natural condition) 7,000 to 7,500; natural gas from 600 to 1,170 per cubic foot; fuel oil from 18,000 to 21,000 per pound.

The B. t. u. per pound of the best fuel oils are about the same as the B. t. u. of the diamond, although the chemical composition is vastly different.

The quantity of air, in cubic feet, required for the perfect combustion of a pound of fuel, varies from 73, in the case of dry wood to 162 for coke. Ordinary soft coal requires 143 and lignite 112. Crude petroleum (fuel oil) requires 173 and natural gas 227. These figures are subject to variations depending on the composition of the fuels, methods of burning, etc.

Table XXII.

Fuel cost of evaporating 1000 pounds of water with coal.

$$\text{Cost of evaporating 1000 pounds of water} = \frac{\text{Price of coal per ton}}{2 \times \text{evaporation.}}$$

Cost of coal per ton of 2,000 pounds.	$3.00	$3.50	$4.00	$4.50	$5.00	$5.50	$6.00	$6.50	$7.00	$7.50	$8.00
Pounds of water evaporated per pound of coal. / Cost of coal consumed in evaporating 1,000 pounds of water.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.
5.0	30.00	35.00	40.00	45.00	50.00	55.00	60.00	65.00	70.00	75.00	80.00
5.5	27.27	31.82	36.36	40.91	45.45	50.00	54.54	59.09	63.63	68.19	72.73
6.0	25.00	29.16	33.33	37.50	41.67	45.83	50.00	54.17	58.33	62.50	66.67
6.5	23.07	26.92	30.77	34.61	38.46	42.31	46.16	50.00	53.84	57.69	61.54
7.0	21.43	25.00	28.57	32.14	35.71	39.29	42.86	46.43	50.00	53.57	57.14
7.5	20.00	23.33	26.67	30.00	33.33	36.67	40.00	43.33	46.67	50.00	53.33
8.0	18.75	21.87	25.00	28.12	31.25	34.38	37.50	40.62	43.75	46.87	50.00
8.5	17.64	20.59	23.53	27.06	29.41	32.35	35.29	38.23	41.18	44.12	47.06
9.0	16.67	19.44	22.22	25.00	27.77	30.56	33.33	36.11	38.88	41.67	44.44
9.5	15.78	18.42	21.05	23.68	26.32	28.95	31.58	34.21	36.84	39.47	42.11
10.0	15.00	17.50	20.00	22.50	25.00	27.50	30.00	32.50	35.00	37.50	40.00
10.5	14.28	16.67	19.04	21.43	23.81	26.19	28.57	30.95	33.33	35.71	38.10
11.0	13.60	15.91	18.18	20.45	22.72	25.00	27.27	29.54	31.81	34.09	36.36

TABLE XXIII.

Fuel cost of evaporating 1000 pounds of water with lignite.

$$\text{Cost of evaporating 1000 pounds of water} = \frac{\text{Price of lignite per ton}}{2 \times \text{evaporation.}}$$

Cost of lignite per ton of 2,000 pounds.		$1.00	$1.10	$1.20	$1.30	$1.40	$1.50	$1.60	$1.70	$1.80	$1.90	$2.00
Pounds of water evaporated per pound of lignite.	Cost of lignite consumed in evaporating 1,000 pounds of water.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.
3.0		16.67	18.33	20.00	21.67	23.33	25.00	26.67	28.33	30.00	31.67	33.33
3.5		14.28	15.71	17.14	18.57	20.00	21.43	22.86	24.28	25.71	27.14	28.57
4.0		12.50	13.75	15.00	16.25	17.50	18.75	20.00	21.25	22.50	23.75	25.00
4.5		11.11	12.22	13.33	14.44	15.55	16.67	17.78	18.89	20.00	21.11	22.22
5.0		10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00
5.5		9.09	10.00	10.91	11.82	12.73	13.64	14.56	15.45	16.37	17.27	18.18
6.0		8.33	9.17	10.00	10.83	11.67	12.50	13.33	14.16	15.00	15.83	16.66
6.5		7.69	8.46	9.23	10.00	10.77	11.54	12.31	13.07	13.84	14.61	15.39
7.0		7.04	7.85	8.57	9.28	10.00	10.71	11.43	12.14	12.85	13.57	14.28
7.5		6.67	7.33	8.00	8.67	9.33	10.00	10.67	11.34	12.00	12.67	13.33
8.0		6.25	6.87	7.50	8.12	8.75	9.37	10.00	10.62	11.25	11.87	12.50

TABLE XXIV.

Fuel cost of evaporating 1000 pounds of water with fuel oil.

Assuming that 3.75 barrels of oil (=1200 pounds) are equivalent to one ton (2000 pounds) of coal we have:

$$\text{Cost of evaporating 1000 pounds of water} = \frac{\text{Price of oil per 3.75 bbls.}}{2 \times \text{evaporation.}}$$

The price per bbl. starts at 80 cents and increases by 5 cents up to $1.30.

Pounds of water evaporated per pound of oil.	Cost of oil per 3.75 barrels. (Equal one ton of coal.) $3.0	$3.05	$3.10	$3.15	$3.20	$3.25	$3.30	$3.35	$3.40	$3.45	$3.50
	Cost of oil consumed in evaporating 1,000 pounds of water. Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.
10.0	15.00	15.25	15.50	15.75	16.00	16.25	16.50	16.75	17.00	17.25	17.50
10.5	14.28	14.52	14.76	15.00	15.24	15.48	15.72	15.96	16.20	16.44	16.68
11.0	13.64	13.87	14.10	14.33	14.56	14.79	15.02	15.25	15.48	15.71	15.94
11.5	13.04	13.26	13.48	13.72	13.96	14.20	14.44	14.68	14.92	15.16	15.40
12.0	12.50	12.71	12.92	13.13	13.34	13.55	13.76	13.97	14.18	14.39	14.60
12.5	12.00	12.20	12.40	12.60	12.80	13.00	13.20	13.40	13.60	13.80	14.00
13.0	11.54	11.73	11.92	12.11	12.30	12.49	12.68	12.87	13.06	13.25	13.44
13.5	11.11	11.29	11.48	11.66	11.84	12.02	12.20	12.38	12.56	12.74	12.92
14.0	10.71	10.89	11.07	11.25	11.43	11.61	11.79	11.97	12.15	12.33	12.51
14.5	10.34	10.52	10.70	10.88	11.06	11.24	11.42	11.60	11.78	11.96	12.14
15.0	10.00	10.16	10.33	10.50	10.67	10.84	11.01	11.18	11.35	11.52	11.69
15.5	9.68	9.84	10.00	10.16	10.32	10.48	10.64	10.80	10.96	11.12	11.28
16.0	9.37	9.53	9.67	9.85	10.00	10.15	10.30	10.45	10.60	10.75	10.90

Table XXV.

Fuel cost of evaporating 1000 pounds of water with natural gas.

Assumption: 30,000 cubic feet of 800 B. t. u. gas=2000 pounds coal of 12,000 B. t. u.

Cost of natural gas per 1,000 cubic feet.			Cents. 10	Cents. 12.5	Cents. 15	Cents. 17.5	Cents. 20	Cents. 22.5	Cents. 25	Cents. 27.5	Cents. 30	Cents. 32.5	Cents. 35
Pounds of water evaporated per 1,000 cubic feet of gas.	500	Cost of gas consumed in evaporating 1000 pds. of water.	20.00	25.00	30.00	35.00	40.00	45.00	50.00	55.00	60.00	65.00	70.00
	550		18.18	22.73	27.27	31.82	36.36	40.90	45.44	49.98	54.52	59.06	63.60
	600		16.66	20 83	25.00	29.17	33.34	37.51	41.68	45.85	50.02	54.19	58.36
	650		15.38	19.23	23.08	26.93	40.78	44.63	48.48	52.33	56.18	60.03	63.88
	700		14.29	17.86	21.43	25.00	28.57	32.14	35.71	39.28	42.85	46.42	49.99
	750		13.33	16.67	20.00	23.33	26.67	30.00	33.33	36.67	40.00	43.33	46.67
	800		12.50	15.62	18.75	21.87	35.00	38.12	41.24	44.36	47.48	50.60	53.72
	850		11.76	14.70	17.65	20.59	23.53	26.47	29.41	32.35	35.29	38.23	41.17
	900		11.11	13.90	16.67	19.44	22.21	24.98	27.75	30.52	33.29	36.06	38.83

Explanation of Tables XXII, XXIII, XXIV, and XXV.

The tables relating to coal, lignite and fuel oil are based on the assumption that the cost of evaporating 1,000 pounds of water from and at 212 degrees Fahrenheit is equal to the price of the fuel, per ton or per barrel, divided by twice the evaporation. What has to be known, therefore, is the price of the fuel and the number of pounds of water that one pound of the fuel will evaporate. In the case of coal, Table XXII, we have assumed that the price of the coal varies from $3.00 to $8.00 per ton of 2,000 pounds and that the evaporative power, per pound of coal, varies from 5 to 11 pounds of water. It would be a singularly inefficient coal that would evaporate as little as 5 pounds of water per pound and it would be a coal of extraordinary quality, burned under very exceptional conditions, that would give a higher evaporation than 11 pounds.

If the coal costs $3.00 a ton, the fuel cost of evaporating 1,000 pounds of water, with an evaporative power of 5, would be 30 cents; it would be 25 cents with an evaporative power of 6; and 21.43 cents with an evaporate power of 7. If the coal should cost $4.00 a ton these figures become 45 cents, 37.50 cents, and 32.14 cents, respectively. If the coal should cost $5.00 a ton, these figures would be 50 cents, 41.67 cents, and 35.71 cents, respectively.

The higher the evaporative power, the more can one afford to pay for the coal. To evaporate 1,000 pounds of water with a coal costing $3.00 a ton, and an evaporation of 5, costs as much as the same service with coal at $4.50 a ton and an evaporation of 7.5, or as the same service with coal at $6.00 a ton and an evaporation of 10. There is a real economy in using the best coal and in burning this coal under conditions that will secure the highest evaporation. If the best coal cannot be secured, then a proper attention to the conservation and use of the heat units in the inferior coal will often counterbalance the difference in quality. This point is of especial importance in many places in Texas where there is a possibility of competition between coal and lignite, between coal and fuel oil, and between lignite and fuel oil.

In regard to lignite, Table XXIII, we have assured that the price will vary from $1.00 to $2.00 a ton and that the evaporative power will vary from 3 to 8 pounds per pound of lignite. Unless dry lignite should be used, it is not likely that we will have to consider as high an evaporative power as 8.

With lignite at $1.00 a ton and an evaporative power of 3 pounds, the fuel cost of evaporating 1,000 pounds of water will be 16.67 cents; with lignite at $1.50 a ton the cost will be 25 cents and with lignite at $2.00 a ton, the cost will be 33.33 cents.

If, however, we take lignite at $1.00 a ton, and an evaporation of 5, the fuel cost of evaporating 1,000 pounds of water will be 10 cents; with lignite at $1.50 a ton, the cost will be 15 cents; and at $2.00 a ton, 20 cents.

Let us now compare coal and lignite a little more in detail. We will assume that coal costs $4.00 a ton and that it will evaporate 6.5 pounds of water per pound. Under these conditions, the fuel cost of evaporating 1,000 pounds of water will be 30.77 cents. This fuel cost is very nearly equivalent to lignite at $2.00 a ton with an evaporation of 3 pounds of water per pound. An evaporation of 5 pounds of water per pound of lignite has been reached in actual practice and under this condition, if the lignite costs $2.00 a ton, the fuel cost of evaporating 1,000 pounds of water will be 20 cents.

In other words, if $4.00 coal, evaporating 6.5 pounds of water, has a fuel cost, per 1,000 gallons of water evaporated, of 30.77 cents, the same service can be performed for 20 cents with lignite at $2.00 a ton.

It would appear to be possible to secure from lignite an evaporation of 5.5. If this can be done, it would have an advantage of 12 cents per 1,000 pounds of water over $4.00 coal with an evaporation of 6.5.

In regard to fuel oil, we have assumed prices per barrel of 42 gallons (=320 pounds) varying from 80 cents to $1.30, and an evaporation from 10 to 16 pounds. The table is constructed on the basis of 3.75 barrels of oil being equivalent to one ton of coal. Results of extensive investigations have shown that the amount of oil equivalent to one ton of coal varies from 3½ to 4 barrels, so that we have taken 3.75 barrels as an average equivalent.

If we take fuel oil at 80 cents a barrel, allow that 3.75 barrels are equivalent to a ton of coal and that the evaporation is 10, we have 15 cents as the fuel cost of evaporating 1,000 pounds of water.

This cost is the same as the cost of evaporating 1,000 pounds of water with $3.00 coal having an evaporation of 10 and is the same as the cost of evaporating 1,000 pounds of water with lignite at $1.20 and an evaporation of 4.

These costs do not include the cost of handling the coal or lignite into the plant, the cost of firing or that of removal of ashes and refuse. Such matters involve local conditions that we do not here discuss, as each case has to be judged on its own merits.

At points of considerable consumption within the State, fuel oil is now selling at $1.20 a barrel. If we allow that 3.75 barrels are equivalent to a ton of coal, the cost of evaporating 1,000 pounds of water with this oil (evaporation, 10) is 17 cents; with evaporation 10.5, it is 16.20 cents; with evaporation 11, it is 15.48 cents; with evaporation 12, it is 14.18 cents.

We bring the matter into a more convenient form to show the relative values obtainable from $100 expended on coal, lignite and fuel oil. We will allow that the coal costs $5.00 a ton and has an evaporation of 7; that the lignite costs $2.00 a ton and has an evaporation of 4; and that the oil costs $1.20 a barrel and has an evaporation of 12. Under these assumptions, how many pounds of water can be evaporated for $100, no account being taken of the costs attendant on the handling of the fuel or the refuse from the coal and lignite?

$100 will buy 83.33 barrels of oil, which, with a factor of 12, will evaporate 319,987 pounds of water.

$100 will buy 20 tons of coal, which, with a factor of 7, will evaporate 280,000 pounds of water.

$100 will buy 50 tons of lignite which, with a factor of 4, will evaporate 400,000 pounds of water.

If we extend this comparison to include natural gas (see Table XXV) at 10 cents, per 1,000 cubic feet, and a factor of 700 we find that $100 will buy 1,000,000 cubic feet, which will evaporate 700,000 pounds of water.

Natural gas is by far the cheapest and best fuel, but it is not within reach of the greater part of the State. Even if it were, we think that its use should be restricted to domestic purposes, in order that the supply might be conserved.

Next in value to natural gas as a fuel, comes fuel oil. This is within reach of nearly all parts of the State, but we are unable to see how the supply is to keep pace with the demand. During the last few years, we have seen the price double itself twice, and the tendency now is steadily upward. If we have not already reached the point where the advantages of this fuel are debatable, owing to the increase of price, we are certainly not far from it. With oil at $1.20 a barrel and an evaporative factor of 12, it is cheaper to use lignite at $2.00 a ton and a factor of 4. This disparity increases with the increase in price of the oil, and the decrease in price of the lignite. Furthermore, the advances that have been made in the burning of lignite under steam boilers will probably result in greater economies in this direction and this movement is far more pronounced than the movement towards additional supplies of fuel oil or lower prices. In lignite, whether burned as such or converted into gas, fuel oil faces its most serious rival, outside of consumption for railroad purposes.

With respect to natural gas some assumptions have to be made. If we allow that it requires 30,000 cubic feet of gas to equal one ton of soft coal, in heating power, we have to assume that this gas carries a certain number of B. t. u. per cubic foot, and that it is burned at a certain temperature and under a certain pressure.

It is impractical to construct a table that will take all of these things into consideration, so that what we shall have to offer is more of a general than a specific statement. We will allow that 30,000 cubic feet of gas of 800 B. t. u. per cubic foot are equivalent to to one ton of soft coal carrying 12,000 B. t. u. per pound and that the gas is burned at 70 degrees Fahrenheit and under 4 ounces pressure. Under these conditions Table No. XXI gives the cost of evaporating 1,000 pounds of water, if the gas varies in price from 10 to 35 cents per thousand cubic feet.

CHAPTER XV.

FREIGHT RATES ON COAL, LIGNITE AND PETROLEUM PRODUCTS.

RAILROAD COMMISSION OF TEXAS.

Twenty-first Annual Report, 1912.

Commodity Tariff No. 4-B, Applying on Coal and Lignite—Carloads.
Effective March 10, 1899, with amendments in effect October 31, 1912.

Rates, in cents per ton of 2,000 pounds, for the transportation by railroads between points in Texas, of shipments of soft coal, slack coal, smithing coal, anthracite coal, coke, lignite and lignite briquettes, in carloads.

Section 1. Table of Rates—Explanation.

Columns headed No. 1 contain rates to apply on shipments transported over a single line of railroad or over two or more lines of railroad which are under the same management and control. Columns headed No. 2 contain joint rates to apply on shipments transported over two or more lines of railroad which are not under the same management and control.

Table No. 1.

Rates on Soft Coal (Except Slack), Smithing Coal and Coke.

Distances, miles	Rates		Distances, miles	Rates	
	No. 1	No. 2		No. 1	No. 2
30 and less	55	70	260 and over 250	170	185
40 and over 30	60	75	270 and over 260	175	190
50 and over 40	65	80	280 and over 270	180	195
60 and over 50	70	85	290 and over 280	185	200
70 and over 60	75	90	300 and over 290	190	205
80 and over 70	80	95	310 and over 300	195	210
90 and over 80	85	100	320 and over 310	200	215
100 and over 90	90	105	330 and over 320	203	217
110 and over 100	95	110	340 and over 330	206	219
120 and over 110	100	115	350 and over 340	209	221
130 and over 120	105	120	360 and over 350	212	223
140 and over 130	110	125	370 and over 360	215	225
150 and over 140	115	130	380 and over 370	219	229
160 and over 150	120	135	390 and over 380	223	233
170 and over 160	125	140	400 and over 390	227	237
180 and over 170	130	145	410 and over 400	231	241
190 and over 180	135	150	420 and over 410	235	245
200 and over 190	140	155	430 and over 420	239	249
210 and over 200	145	160	440 and over 430	243	253
220 and over 210	150	165	450 and over 440	247	257
230 and over 220	155	170	460 and over 450	251	261
240 and over 230	160	175	470 and over 460	255	265
250 and over 240	165	180	480 and over 470	259	269

Distances, miles	Rates		Distances, miles	Rates	
	No. 1	No. 2		No. 1	No. 2
490 and over 480..........	263	273	650 and over 640..........	335	345
500 and over 490..........	267	277	660 and over 650..........	340	350
510 and over 500..........	271	281	670 and over 660..........	345	355
520 and over 510..........	275	285	680 and over 670..........	350	360
530 and over 520..........	279	289	690 and over 680..........	355	365
540 and over 530..........	282	292	700 and over 690..........	360	370
550 and over 540..........	285	295	710 and over 700..........	365	375
560 and over 550..........	290	300	720 and over 710..........	370	380
570 and over 560..........	295	305	730 and over 720..........	375	385
580 and over 570..........	300	310	740 and over 730..........	380	390
590 and over 580..........	305	315	750 and over 740..........	385	395
600 and over 590..........	310	320	760 and over 750..........	390	400
610 and over 600..........	315	325	770 and over 760..........	395	405
620 and over 610..........	320	330	780 and over 770..........	400	410
630 and over 620..........	325	335	790 and over 780..........	405	415
640 and over 630..........	330	340	Over 790................	410	420

Note.—Rates on anthracite coal shall be ten (10) per cent higher than the rates in Table No. 1 above. (Circular No. 1939, effective December 5, 1903.).

TABLE NO. 2.

Rates on Slack Coal.

Distances, miles	Rates		Distances, miles	Rates	
	No. 1	No. 2		No. 1	No. 2
30 and less..............	40	55	390 and over 380..........	213	223
40 and over 30..........	45	60	400 and over 390..........	217	227
50 and over 40..........	50	65	410 and over 400..........	221	231
60 and over 50..........	55	70	420 and over 410..........	225	235
70 and over 60..........	60	75	430 and over 420..........	229	239
80 and over 70..........	65	80	440 and over 430..........	233	243
90 and over 80..........	70	85	450 and over 440..........	237	247
100 and over 90..........	75	90	460 and over 450..........	241	251
110 and over 100..........	80	95	470 and over 460..........	245	255
120 and over 110..........	85	100	480 and over 470..........	249	259
130 and over 120..........	90	105	490 and over 480..........	253	263
140 and over 130..........	95	110	500 and over 490..........	257	267
150 and over 140..........	100	115	510 and over 500..........	261	271
160 and over 150..........	105	120	520 and over 510..........	265	275
170 and over 160..........	110	125	530 and over 520..........	269	279
180 and over 170..........	115	130	540 and over 530..........	272	282
190 and over 180..........	120	135	550 and over 540..........	275	285
200 and over 190..........	125	140	560 and over 550..........	280	290
210 and over 200..........	130	145	570 and over 560..........	285	295
220 and over 210..........	135	150	580 and over 570..........	290	300
230 and over 220..........	140	155	590 and over 580..........	295	305
240 and over 230..........	145	160	600 and over 590..........	300	310
250 and over 240..........	150	165	610 and over 600..........	305	315
260 and over 250..........	155	170	620 and over 610..........	310	320
270 and over 260..........	160	175	630 and over 620..........	315	325
280 and over 270..........	165	180	640 and over 630..........	320	330
290 and over 280..........	170	185	650 and over 640..........	325	335
300 and over 290..........	175	190	660 and over 650..........	330	340
310 and over 300..........	180	195	670 and over 660..........	335	345
320 and over 310..........	185	200	680 and over 670..........	340	350
330 and over 320..........	189	203	690 and over 680..........	345	355
340 and over 330..........	193	206	700 and over 690..........	350	360
350 and over 340..........	197	209	710 and over 700..........	355	365
360 and over 350..........	201	212	720 and over 710..........	360	370
370 and over 360..........	205	215	730 and over 720..........	365	375
380 and over 370..........	209	219	740 and over 730..........	370	380

Distances, miles	Rates		Distances, miles	Rates	
	No. 1	No. 2		No. 1	No. 2
750 and over 740..........	375	385	780 and over 770..........	390	400
760 and over 750..........	380	390	790 and over 780..........	395	405
770 and over 760..........	385	395	Over 790................	400	410

Rates shown in the table above will apply on nut, pea and slack coal, straight or mixed carloads. Nut, pea and slack coal shall consist of any and all coal that will pass through a bar screen with bars 1⅛ inches apart, or through a screen with round holes two inches in diameter.

TABLE No. 3.

Rates on Lignite and Lignite Briquettes.

Distances, miles	Rates		Distances, miles	Rates	
	No. 1	No. 2		No. 1	No. 2
30 and less..............	32	47	380 and over 370..........	148	158
40 and over 30..........	35	50	390 and over 380..........	151	161
50 and over 40..........	40	55	400 and over 390..........	154	164
60 and over 50..........	44	59	410 and over 400..........	157	167
70 and over 60..........	48	63	420 and over 410..........	161	171
80 and over 70..........	53	68	430 and over 420..........	164	174
90 and over 80..........	57	72	440 and over 430..........	167	177
100 and over 90..........	60	75	450 and over 440..........	170	180
110 and over 100..........	63	78	460 and over 450..........	173	183
120 and over 110..........	66	81	470 and over 460..........	176	186
130 and over 120..........	69	84	480 and over 470..........	180	190
140 and over 130..........	72	87	490 and over 480..........	183	193
150 and over 140..........	76	91	500 and over 490..........	186	196
160 and over 150..........	79	94	510 and over 500..........	189	199
170 and over 160..........	82	97	520 and over 510..........	192	202
180 and over 170..........	85	100	530 and over 520..........	195	205
190 and over 180..........	88	103	540 and over 530..........	198	208
200 and over 190..........	91	106	550 and over 540..........	202	212
210 and over 200..........	95	110	560 and over 550..........	205	215
220 and over 210..........	98	113	570 and over 560..........	208	218
230 and over 220..........	101	116	580 and over 570..........	211	221
240 and over 230..........	104	119	590 and over 580..........	214	224
250 and over 240..........	107	122	600 and over 590..........	217	227
260 and over 250..........	110	125	610 and over 600..........	220	230
270 and over 260..........	113	128	620 and over 610..........	221	231
280 and over 270..........	117	132	630 and over 620..........	222	232
290 and over 280..........	120	135	640 and over 630..........	223	233
300 and over 290..........	123	138	650 and over 640..........	224	234
310 and over 300..........	126	141	660 and over 650..........	225	235
320 and over 310..........	129	143	670 and over 660..........	226	236
330 and over 320..........	132	145	680 and over 670..........	227	237
340 and over 330..........	135	147	690 and over 680..........	228	238
350 and over 340..........	139	150	700 and over 690..........	229	239
360 and over 350..........	143	152	Over 700................	230	240
370 and over 360..........	145	155			

Minimum Weight.—The minimum weight of each carload shall be twenty (20) tons; provided, that when the actual weight of a shipment contained in a car loaded to its full capacity shall be less than twenty tons, then the actual weight of such shipment shall be charged for at the rate per ton applicable under this tariff.

Section 2.—Exceptions.

1. Galveston, Harrisburg & San Antonio Railway: Rates on coal to San Antonio, from Hartz, 80 cents per ton, and from Eagle Pass, 90 cents per ton.

2. Rio Grande & Eagle Pass Railway and International & Great Northern Railroad: Rate on coal from Minera and Cannel to San Antonio, 90 cents per ton.

3. Rio Grande & Eagle Pass Railway: Rate on coal, carloads, from Minera, Cannel and San Jose to Sanchez and Laredo, sixty-five (65) cents per ton of 2,000 pounds (Circular No. 2764, effective January 1, 1908.)

4. Rio Grande & Eagle Pass Railway and International & Great Northern Railroad: Bone coal, in carloads, minimum weight 20 tons per car, from Cannel and Minera to San Antonio, 80 cents per ton of 2,000 pounds. (Circular No. 834, effective May 10, 1899.)

6. Texarkana & Fort Smith Railway: Coal, in carloads, from Beaumont to Port Arthur, 40 cents per ton of 2,000 pounds. (Circular No. 906, effective August 15, 1899.)

7. Houston East & West Texas Railway: Lignite, in carloads, from lignite mine at Garrison to brick yard at Garrison, $3.00 per car. (Circular No. 1107, effective April 12, 1900.)

8. Lignite, in carloads, from Lytle to San Antonio, 30 cents per ton of 2,000 pounds. (Circular No. 1109, effective May 2, 1900.)

9. Houston East & West Texas Railway: Lignite, in carloads, from Tandy to Timpson, $4.00 per car. (Circular No. 1126, effective May 18, 1900.)

10. Galveston, Harrisburg & San Antonio Railway: Rate on coal and screenings, in carloads, from Rio Bravo mines to San Antonio, 80 cents per ton. (Circular No. 1269, effective February 9, 1901.)

11. Galveston, Harrisburg & San Antonio Railway: Coal, including screenings, in carloads, minimum weight 20 tons per car, from Dolchburg (Rio Bravo) and Hartz mines to Eagle Pass,

twenty (20) cents per ton. (Circular No. 1996, effective January 22, 1904.)

13. Galveston, Harrisburg & San Antonio Railway: Rate on coal, in carloads, from Eagle Pass to El Paso, \$2.25 per ton of 2,000 pounds. (Circular No. 1552, effective March 8, 1902.)

14. Galveston, Harrisburg & San Antonio Railway: Rate on coal, in carloads, from Eagle Pass to Seguin, \$1.00 per ton of 2,000 pounds. (Circular No. 1651, effective August 16, 1902.)

15. Texas Central Railroad: Rate on coal, in carloads, from Coal Mine, M. P. 158, to Cisco, 37½ cents per ton of 2,000 pounds. (Circular No. 1840, effective June 15, 1903.)

18. Rio Grande & Eagle Pass Railway: Bone coal or cullings, in carloads, from points on the Rio Grande & Eagle Pass Railway to points on the St. Louis, Brownsville & Mexico Railway, same rates as apply on lignite to the same points. (Circular No. 2251, effective May 1, 1905.)

22. Texas & Pacific Railway: Coal, all kinds, in carloads, from Fort Worth, to Powell's Spur, minimum weight 30 tons per car, twenty (20) cents per ton, when consigned to and for use of the city of Fort Worth. (Circular No. 2683, effective October 21, 1907.)

23. Texas Short Line Railway: Slack lignite, in carloads, minimum weight 60,000 pounds per car, from Hoyt to Grand Saline, twenty (20) cents per ton. (Circular No. 2715, effective December 18, 1907.)

24. Lignite, in carloads, from Alba to Grand Saline, via the M., K. & T. Ry. of Texas and Texas Short Line Railway or T. & P. Ry., thirty-two (32) cents per ton of 2,000 pounds. Rates from intermediate points not to be higher, and to intermediate points not to be affected. (Circular No. 2819, effective June 17, 1908.)

25. Between Houston or Galveston and Texas City: Coal, hard, carloads, 71½ cents per ton; coke, carloads, 65 cents per ton. (Circular No. 2852, effective August 1, 1908.)

26. International & Great Northern Railroad: Lignite, carloads, from Carr Coal Spur to Lytle, twenty-five (25) cents per ton. (Circular No. 2864, effective August 20, 1908.)

27. International & Great Northern Railroad: Lignite, carloads, for distances named between points on the I. & G. N. R. R.,

shall be subject to the following rates in cents per ton of 2,000 pounds:

10 miles and less	28
20 miles and over 10 miles	30
30 miles and over 20 miles	32

Exceptions Nos. 8 and 26 will remain undisturbed. (Circular No. 2883, effective October 1, 1908.)

29. Rio Grand & Eagle Pass Railway and International & Great Northern Railway: Coal, in carloads, from points on the Rio Grande & Eagle Pass Railway to Houston, rates at intermediate points not to be affected, $1.75 per ton. (Circular No. 3610, effective November 18, 1910.)

30. Paris & Mt. Plesaant Railroad: (a) Coal, all kinds, in carloads, from Paris Station to East Side Well (two miles east of Paris), five ($5.00) dollars per car. (Circular No. 3634, effective December 7, 1910.)

(b) Slack coal, carloads, from Paris to Ragland, thirty (30) cents per ton of 2,000 pounds, for municipal purposes. (Circular No. 3934, effective November 6, 1911.)

31. Rio Grande & Eagle Pass Railway: Small sized coal—crushed bone, bone, nut and duff, from Minera, Cannel, San Jose and Duff Washer to Laredo, fifty-five (55) cents per ton. Effective January 1, 1912, and expiring December 31, 1912. Exception No. 3 will continue to apply on coal, all kinds, except as above described. (Circular No. 3975.)

32. Texas Mexican Railway: Bone coal, nut coal, washed duff and other by-products, from points on the Rio Grande & Eagle Pass Railway to points on the Texas Mexican Railway, lignite tariff rates. (Circular No. 4058, effective April 1, 1912. Expires April 1, 1913.)

34. Gulf & Interstate Railway of Texas: On coal, coke and lignite, carloads, from Port Bolivar to points in Texas. Galveston rates. (Circular No. 3997, effective January 1, 1912.)

35. Galveston, Harrisburg & San Antonio Railway: Coal, carloads, from Lamar Spur to Eagle Pass, twenty-five (25) cents per ton of 2,000 pounds. (Circular No. 4104, effective July 15, 1912. Expires December 31, 1913.)

In addition, authority was given to the Galveston, Houston &

Henderson Railroad Company, April 16, 1898, to charge 7½ cents per hundred pounds for the transportation of less than carloads of coal, in lots of 2,000 pounds or more, from Houston and Galveston, to all points on this line.

COMMODITY TARIFF NO. 27-C.

Crude and Fuel Petroleum, also Asphaltum, Carloads.

Section 1.—Table of Rates.

Explanation.—Columns headed No. 1 contain rates to apply on shipments transported over a single line of railroad or over two or more lines of railroad which are under the same management and control; columns headed No. 2 contain rates to apply on shipments transported over two or more lines of railroad which are not under the same management and control.

Distances, miles	Rates		Distances, miles	Rates	
	No. 1	No. 2		No. 1	No. 2
6 and less	2½	4	100 and over 80	7	8½
10 and over 6	3	4½	125 and over 100	7½	9
15 and over 10	3½	5	150 and over 125	8	9½
20 and over 15	4	5½	175 and over 150	8½	9½
30 and over 20	4½	6	200 and over 175	9	10
40 and over 30	5	6½	225 and over 200	9½	10
50 and over 40	5½	7	250 and over 225	10	10½
60 and over 50	6	7½	Over 250	10½	10½
80 and over 60	6½	8			

Section 2.—Exceptions.

1. *Differential Rates.*—Rates on shipments transported more than 250 miles from or to points in differential territory (as defined in General Tariff of Class Rates No. 3) shall be made by adding to the maximum common point rate of 10½ cents per 100 pounds the following differential rates, in cents per 100 pounds, to apply by continuous mileage:

Distances, miles	Rates	Distances, miles	Rates
50 and less	1	250 and over 200	5
100 and over 50	2	300 and over 250	5½
150 and over 100	3	Over 300	6
200 and over 150	4		

Crude oil in carload lots from Humble to Houston, 2½ cents per 100 pounds, minimum $15 per car. This rate is to be used only on shipments moving locally to Houston, and is not to be used as a factor in making through rates.

Solar oil, gas oil, steamer oil, in cans, boxed, in barrels or in tank cars, between points in Texas, will be subject to the rates named in this tariff for crude and fuel petroleum, plus 2½ cents per 100 pounds. Estimated weight of 7.4 pounds per gallon will also apply.

Section 3.—Minimum Carloads.

1. The minimum weight of shipments transported over lines of standard gauge shall be 38,000 pounds per car; provided, that when the actual weight of the petroleum contained in a car loaded to its full capacity shall be less than 38,000 pounds, then the actual weight of such shipment shall be charged for at the rates prescribed in this tariff.

2. The minimum weight of shipments transported over lines of narrow gauge shall be 20,000 pounds per car; provided, that shipments originating at points on lines of standard gauge and destined to points on or reached by lines of narrow gauge shall be charged for at the weight determined by the cars in which they were transported over lines of standard gauge.

3. The weight of 7.4 pounds per gallon shall be used in determining the carload weights above provided for.

Section 4.—Rates on Asphaltum.

Asphaltum, in carloads, minimum weight 24,000 pounds per car, transported by railroads between points in common point territory, fifteen (15) cents per 100 pounds, except where Class D is less.

Rates to or from points in differential territory shall be made by adding to the rate above authorized the current Class D differential.

Exceptions.

1. From Port Arthur and Port Neches to Galveston and Texas City (rates at intermediate points not to be affected), 12 cents.

2. From Galveston, Port Arthur and Port Neches to Laredo (rates to intermediate points not to be higher), 18 cents.

3. From Galveston, Port Arthur and Port Neches to Eagle Pass (rates to intermediate points not to be higher), 19 cents.

4. From Galveston, Port Arthur and Port Neches to El Paso (rates to intermediate points not to be higher), 22 cents. (Circular No. 2062, effective June 8, 1904.)

5. From Beaumont to Galveston, minimum weight 30,000 pounds per car (rates to, from or between intermediate points not to be affected), five (5) cents. (Circular No. 2070, effective June 28, 1904.)

Section 5.—Rates on Creosote Oil or Other Wood Preservative.

Creosote oil or other wood preservative, in carloads, transported by railroads between points in Texas, will be subject to the rates prescribed in this tariff for crude and fuel petroleum, plus 2½ cents per 100 pounds. Estimated weight per gallon 8.2 pounds, and minimum carload weight 38,000 pounds.

Existing rates, when lower than the rates herein prescribed, will remain in force. (Circular No. 2685, effective November 5, 1907.)

Exceptions.

1. Creosote oil, in barrels, carloads, from Sabine to Beaumont, five (5) cents per 100 pounds. (T. & N. O. Authority No. 97, effective June 5, 1903.)

2. Creosote oil, in carloads, minimum weight to be marked capacity of car used, at estimated weight per gallon of 8.2 pounds, from Galveston to Beaumont, six (6) cents per 100 pounds. (Circular No. 3236, effective October 26, 1909.)

CHAPTER XVI.

BIBLIOGRAPHY OF COAL, LIGNITE, NATURAL AND PRODUCER GAS AND PETROLEUM IN TEXAS.

BY WM. B. PHILLIPS.

The first mining company incorporated by the Republic of Texas seems to have been the Trinity Coal & Mining Company. The act creating this company was passed by the Fourth Congress of the Republic and was signed by David S. Kaufman, Speaker of the House, and David G. Burnet, President of the Senate. It was approved by President Mirabeau B. Lamar, January 25, 1840. The persons named as the incorporators were: Frederick B. Page, Elisha A. Rhodes, R. D. Johnson, Levi Jones, and William Henry Davidson. The Company was authorized to open and work mines of coal, lead, iron, and other minerals, and to quarry stone on or near the Trinity river. The capital stock was to be in 2500 shares of the value of $100 each, but permission was given to increase the capital stock of $500,000, if it should become necessary to do so. A curious provision of the act was that the company were required "from time to time to communicate to the President of the Republic or to the Congress their progess in mining, and such other information in geology, mineralogy, or the arts, as might be interesting in science or useful in any of the branches of domestic industry." It is interesting to note in this connection that the coal (lignite) seams within reach of the Trinity river were to be opened and worked, and this is one of the present purposes of the appropriation made by the United States Government for the improvement of the Trinity river. It would appear that as far back as 1840 there were persons who had in view the advantages to be offered by this river for the transportation of coal, etc. But four years previous to this time, and about the year 1836, the "literature" of the Texas & New Ireland Land Company contains references to the coal along the Rio Grande, below Laredo, and Lieut. B. P. Tilden, in "Notes on the Upper Rio Grande," Philadelphia, 1847, also speaks of the coal near Laredo.

William Kennedy, in his "Texas: the Rise, Progress and Prospects of the Republic of Texas," 1841, speaks of the coal as it was reported to him from various parts of the republic, and in Volume

I, page 118, he quotes from Almonte, who wrote about the year 1834, that bituminous coal was found on the river San Bernard, about 15 miles from San Felipe, by the road which leads from that town to Gonzales. He quotes Almonte as saying that precisely in the middle of the stream where he bathed at half past six in the afternoon of the month of August, 1834, he found the water so warm that he could not bear it for a minute.

It is not our intention in this bibliography to quote every single reference that has appeared in books and articles concerning Texas, for this would be an endless task, and we confine ourselves to references from which the student may derive useful information concerning coal, lignite, natural gas, producer gas and petroleum in this State. Before beginning this bibliography, however, we will quote, entire, a very interesting statement made concerning Texas, by R. C. Taylor in his "Statistics of Coal," Philadelphia, 1848. He gives as his authorities: the Houston Telegraph; the New Orleans Picayune; Notes sur le Texas, documens sur le Commerce extèrieur, Juillet, 1842; Kennedy's Texas; Report in 1834 to the "Rio Grande Land Company"; McCulloch, art. Texas; Iken's Texas, and "Notes on the Upper Rio Grande," by Lieut. B. P. Tilden, Philadelphia, 1847.

He says:

"*Pitch Lake.*—An announcement has been made of the existence, in Texas, within 100 miles from Houston, of a small lake that closely resembles the Pitch Lake of Trinidad. It is filled with bitumen or asphaltum, and is about a quarter of a mile in circumference. During the cool winter months its surface is hard, and is capable of sustaining a person. From November to March it is generally covered with water, which is acid to the taste; from which cause it has been commonly called the "Sour Pond." In the summer months a spring occurs, near the center of the lake, from which an oily liquid (probably petroleum) continually boils up, from the bottom. This liquid gradually hardens, on exposure to the air, and forms a black pitchy substance, similar to that which forms the sides of the lake. It is said to resemble, precisely, the bitumen of Trinidad; and the Texans conceive that, at some future day, it will be valuable for the production of gas for their cities. It burns with a very clear bright light, but gives out a pungent odor.

"Coal is now well known to exist abundantly in Texas, although the country has not been geologically examined. There is no doubt but coal prevails at intervals entirely across the country, in a northeast and southwest direction. Its general position is about two hundred miles from the coast.

"On the Trinity river, two hundred miles above Galveston, the coal region there was investigated in 1846, and found to be more extensive than was anticipated. A company, under the title of the 'Trinity Coal and Mining Company,' was incorporated by an act of the Texan Congress in 1840. Both anthracite and semi-bituminous coal, somewhat like the cannel, in appearance, occurs here.

"Mineral coal, in great abundance, prevails not far from the Mustang Prairie. It is also found, accompanied with excellent iron ore, in the vicinity of Nacogdoches. According to report, this coal is abundant, rich, and of a fine appearance.

"Mr. Kennedy, who has taken pains to collect information relative to the resources of Texas, although not an original investigator, says, in a work published in 1841, that 'in addition to iron, the utilitarian sovereign of metals, Texas possesses coal—the grand auxiliary of the arts which tend to enrich and civilize the world.' Coal, both anthracite and bituminous, abounds from the Trinity river to the Rio Grande. The coal on the latter river, above Dolores, has been represented by the agents of the *Texas and New Ireland Land Company* (an association broken up by the revolution in 1836) as of excellent bituminous quality.

"Formations of secondary limestone, with others of carboniferous sandstones, shales, argillaceous iron ore, and bituminous coal beds, are said to occupy a large portion of the interior of Texas. Westward of these occurs the inferior and Silurian strata, trilobite limestones, and transition slates. Beyond all, basaltic and primary rocks of the Rocky Mountains arise; while northward is the great salt lake of the Brazos, and the vast red saliferous region traversed by the exploring expeditions of Captain Pike and Major Long, and since made more familiar to us by Mr. Gregg and other travelers.

"A bed of coal extends across the Brazos river towards the Little Brazos and the San Andres, down which stream it may without difficulty be transported at high water.

"Near the city of Austin, on the eastern border of the Colorado, is a peak, called Mount Bonnell, overlooking Austin, and having a fall of seven hundred feet perpendicular to the bed of the Colorado. This and other hills, although not scientifically examined, are known to contain beds of anthracite coal.

"On the Rio Grande, southwest of Bexar, is a great abundance of bituminous coal. The navigation of this river is reported to be free for eight months in the year.

"In many parts of the rolling prairie region, coal, of fair quality, and iron ore have been found; and it is supposed that beds of these valuable minerals extend over a great part of the country.

"We have received some recent information of the character of the country bordering upon the Rio Grande, as far up as the Presidio de Rio Grande, from the notes of Lieutenant B. P. Tilden.

"On approaching Laredo, within forty or fifty miles, by the course of the river, and extending north of that town, a coal formation is traversed during that distance. Beds of coal are frequently to be seen, as are deposits of nitre and sulphur, and also thick beds of good fire-clay, at the bases of the bluffs. These strata, and the accompanying sandstone rocks, are supposed to be a prolongation of similar strata at Guerrera, on the Rio Salado, to the southwest; as they agree in their range and dip. The writer, who apparently is not very familiar with geological phenomena, dose not furnish any further details."

Mr. Taylor's statement in regard to the existence of beds of anthracite coal in Mount Bonnell, near Austin, seems to have been due to the exercise of a lively imagination, as also his statement with respect to the beds of nitre and sulphur on the Rio Grande, below Laredo. So far as known, there is no anthracite coal anywhere in Texas, nor any beds of nitre.

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