DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
JOSEPH A. HOLMES, DIRECTOR

BRIQUETTING TESTS OF LIGNITE

AT PITTSBURG, PA., 1908-9

WITH A CHAPTER ON SULPHITE-PITCH BINDER

BY

CHARLES L. WRIGHT

WASHINGTON
GOVERNMENT PRINTING OFFICE
1912

Revised edition, April, 1912.
First edition issued in June, 1911.

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BRIQUETTING TESTS OF LIGNITE AT PITTSBURG, PA. JULY 1, 1908, TO JUNE 30, 1909.

By Charles L. Wright.

INTRODUCTION.

PROPERTIES OF LIGNITE.

Coals may be divided into six classes—anthracite, semianthracite, semibituminous, bituminous, subbituminous, and lignite. The first three classes can be distinguished by differences of composition, particularly the proportions of fixed carbon and the ratios of the fixed carbon to the volatile matter in the coals. The last three classes can be distinguished by differences in physical character, chiefly in color and in manner of weathering.

Lignite is brown, not black, and has generally a woody look, but it weathers in much the same way as subbituminous coals. On exposure to the air lignite slacks or crumbles. The lumps check and fall into small irregular pieces that exhibit a decided tendency to separate into extremely thin plates. Hence lignite deteriorates greatly during storage or long transportation.

The most characteristic feature of the composition of lignite is a large percentage of moisture. This high moisture content reduces the fuel value of freshly mined lignite, and the partial evaporation of moisture, on exposure, causes the fuel to check and fall to pieces. Consequently, attempts to increase the efficiency of lignite as a fuel involve reducing its percentage of moisture and increasing its ability to endure storage and transportation. Both these results are accomplished by briquetting.

LIGNITE FIELDS IN THE UNITED STATES.

The total extent of territory in the United States that may contain workable beds of lignite is much greater than the extent of the deposits known to be workable. The total area underlain by possibly workable beds is estimated to be 148,609 square miles. Millions of acres of this land belong to the Government.

The principal workable deposits of lignite are within the northern Great Plains province, which occupies most of the western half of

North Dakota, part of the northwest portion of South Dakota and much of the eastern half of Montana. In this province many thousand square miles of land are underlain by workable beds, the workable beds in North Dakota alone, according to the United States Geological Survey, underlying 31,240 square miles. Deposits of lignite extend completely across the State of Texas, but the deposits regarded as workable are in scattered districts that have a total area of about 2,000 square miles. Workable lignite deposits occur in several other States.

UTILIZATION OF LOW-GRADE FUELS IN EUROPE.

For many years European countries have been developing supplies of fuels that have low heat values, and have succeeded in making the utilization of peat, lignite, and the screenings of bituminous coal and anthracite the basis of important industries. In several countries large amounts of capital have been invested in the manufacture of fuel briquets. The magnitude of the briquet industry in Germany and the part it plays in utilizing the lignite or brown-coal deposits of that country are shown by the fact that in 1910 the German Empire produced 19,561,494 metric tons (21,575,000 short tons) of briquets, of which 15,120,255 metric tons (16,675,000 short tons), or 77 per cent of the total output, were made from lignite. These lignite briquets are much liked for domestic use, and form the chief household fuel in many large cities.

TESTS OF LIGNITE BY THE UNITED STATES GOVERNMENT.

The United States Geological Survey in connection with the work of the coal-testing plant erected at St. Louis, Mo., in 1904, undertook an investigation of the merits of lignite as a fuel, with the object of ascertaining the most efficient methods of utilizing it. The Survey made briquetting tests of lignite and also combustion tests of lignite briquets and of raw lignite in boiler furnaces and in gas producers at St. Louis, Mo., and at Pittsburg, Pa. The results of the tests of lignite at St. Louis are to be found in United States Geological Survey Bulletins Nos. 261, 290, 332, 343, and 363, and Professional Paper 48. (See Bibliography.)

In the spring of 1907 the steam-engineering, gas-producer, and briquetting sections of the fuel-testing plant were removed from St. Louis, Mo., to Norfolk, Va., where the Jamestown Exposition Company provided a building for their use. The briquetting tests at Norfolk were confined to coals from Virginia and West Virginia.

During the fall and winter of 1908 most of the fuel-testing equipment used at Norfolk was removed to Pittsburg, Pa., and erected there. Various improvements were made, and early in 1909 the briquetting plant was in operating condition.

The briquetting tests described in this bulletin were of lignites from North Dakota, Texas, and California. Steaming tests of North Dakota lignite were made at the Reclamation Service pumping plant at Williston, N. Dak., under the direction of D. T. Randall and Henry Kreisinger, and have been described in Bureau of Mines Bulletin 2. Combustion tests of raw lignite in house stoves of special design have also been made.

The act establishing the Bureau of Mines authorized the transfer of fuel-testing investigations from the Geological Survey to the new bureau. This act became effective July 1, 1910, and in consequence of the transfer of the investigations this bulletin is published by the Bureau of Mines, though it deals with work done by the technologic branch of the Geological Survey in the fiscal year ended June 30, 1909. The funds available for fuel investigations by the Bureau of Mines are not sufficient to enable the bureau to carry on the lignite-briquetting investigations on a practical scale.

PURPOSE OF BRIQUETTING TESTS.

Briquetting tests of lignite were undertaken at the fuel-testing plant at Pittsburg to ascertain the following facts:

1. The possibility of briquetting American lignites without adding binder to them.
2. The suitability of the German brown-coal briquet presses for briquetting American lignites.
3. The percentage of moisture needed in the briquet material to give the best briquets.
4. The approximate commercial cost of briquetting lignites.
5. The weathering qualities of briquets as compared with raw lignites.

An additional purpose of the tests was to provide a supply of lignite briquets from which to determine their value as (*a*) steaming fuel under boilers, (*b*) gas-producer fuel, and (*c*) domestic fuel.

RESULTS OF BRIQUETTING TESTS.

The results of the briquetting investigations conducted by the Government are expected to prove of considerable value, not only to the Government itself as the owner of extensive lignite deposits and the largest single purchaser of fuel, but also to the people living in the regions where lignite is found. The problem of a fuel supply in those regions is of peculiar interest, for many of the lignite deposits are situated long distances from fields of high-grade coal. The problem assumes still larger proportions when one realizes that the development of manufacturing industries in those regions depends upon the ability to obtain a cheap and satisfactory fuel.

Although the results presented in this bulletin are not conclusive, they warrant the continuation of the investigations as soon as funds can be made available for the purpose. Enough testing has been done to indicate that some American lignites equal German lignites in fuel value and can probably be made into briquets on a commercial scale without the use of binding materials. Three samples of lignite, one from Texas, one from North Dakota, and one from California, were made into satisfactory briquets without the addition of a binder. It was proved that some lignites after having slacked by exposure can be made into briquets without the use of binding material, notwithstanding a general opinion that this could not be done. Cohesion and weathering tests demonstrated that good briquets endure handling and resist weathering much better than the lignite from which they are made.

PERSONNEL.

A. W. Belden had general supervision of the work of the coking, washing, and briquetting sections of the testing plant at Pittsburg. Charles L. Wright designed the briquetting plant and was responsible for its erection; he also had charge of the briquetting and other tests of the raw fuel and the various physical tests of the briquets. H. L. Gardner rendered valuable aid in recording observations and assisted in making the physical tests. Otto Lehman, a machinist in the employ of the manufacturers of the German lignite press, was engaged from November, 1908, to April, 1909, to superintend the erection of the press and to assist in its operation. The writer takes this opportunity to acknowledge the faithful and efficient work of the pressmen and laborers engaged on the briquetting tests.

BRIQUETTING PLANT AT PITTSBURG.

GENERAL DESCRIPTION.

At the experiment station of the Bureau of Mines, at Pittsburg, a complete lignite-briquetting plant is installed in the main part of the briquetting building. This plant was built by the Maschinenfabrik Buckau Actien Gesellschaft zu Magdeburg, Germany. As received from the maker, the plant included the following equipment: A tubular drier, a sorting sieve, auxiliary crushing rolls, a cooler, a screw conveyer, a large storage hopper, a briquetting press directly connected to a steam engine, apparatus for conveying the briquets, shafting, hangers, and extra sets of dies. To complete the plant, the Survey erected a coal elevator, a crushing roll, and the necessary belting and piping, in addition to the building and stacks.

The English machine used at St. Louis and Norfolk for briquetting anthracite and bituminous slack and coke breeze was set up in the

BRIQUETTING-PLANT BUILDING.

building, but no provision was made for using it to briquet large quantities of fuels during the period covered by this report. Instead, work was concentrated on tests of lignite with the German machine.

BUILDING.

The briquetting machines and their equipment are housed in a steel-framed building inclosed with curtain walls of reinforced concrete 2 inches thick. The steel work is of heavy construction, for it has to carry not only the machinery, but also, on the third floor, a storage room to hold 100 tons of coal or lignite. Plate I illustrates the general appearance of the building.

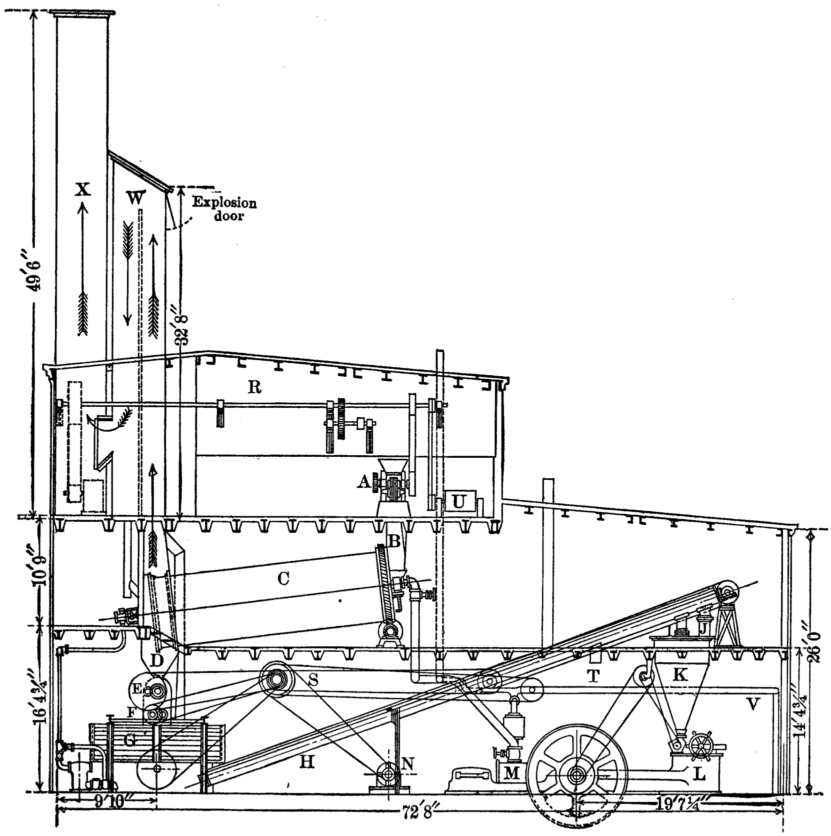


FIGURE 1.—Longitudinal section of lignite-briquetting plant.

EQUIPMENT AND OPERATION OF PLANT.

CONVEYER AND CRUSHER.

Two bins of 60 tons capacity each for storing the raw lignite were built near the car track at one side of the briquetting building, so that the lignite could be shoveled directly into them from the box cars in which it had been shipped from the mine.

A bucket elevator (figs. 2, 3) of the link-belt type was erected to carry the raw lignite from the ground to the third floor of the building.

The single-roll crusher A (figs. 1, 2) was installed in the bin room on the third floor. The roll had a corrugated surface and the material passed between it and a dead plate. The crusher and the raw-material elevator were driven by a motor through line shaft R, as shown in figure 2.

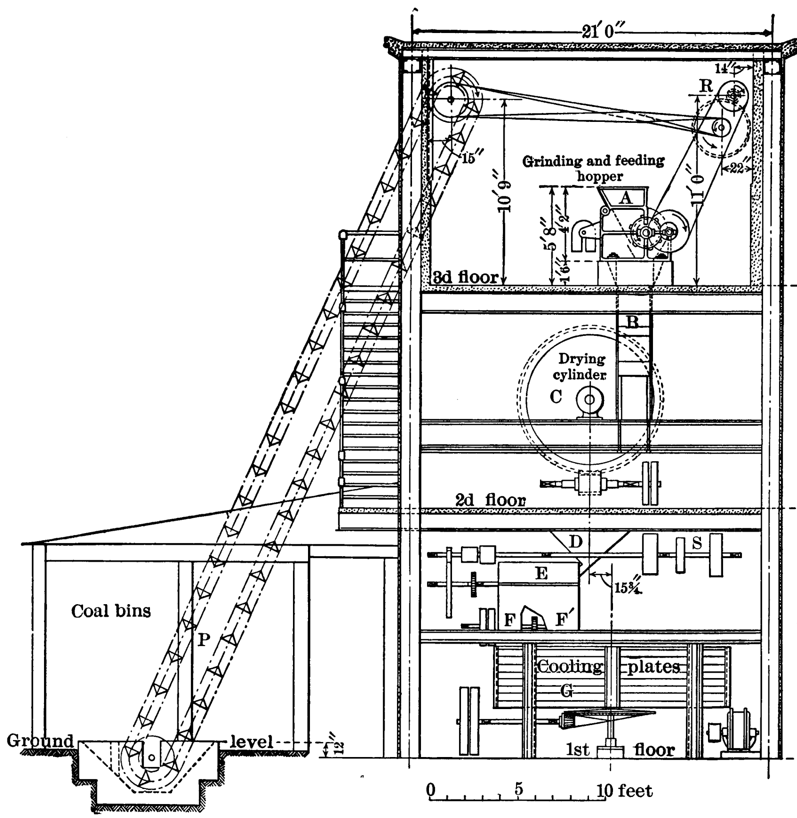
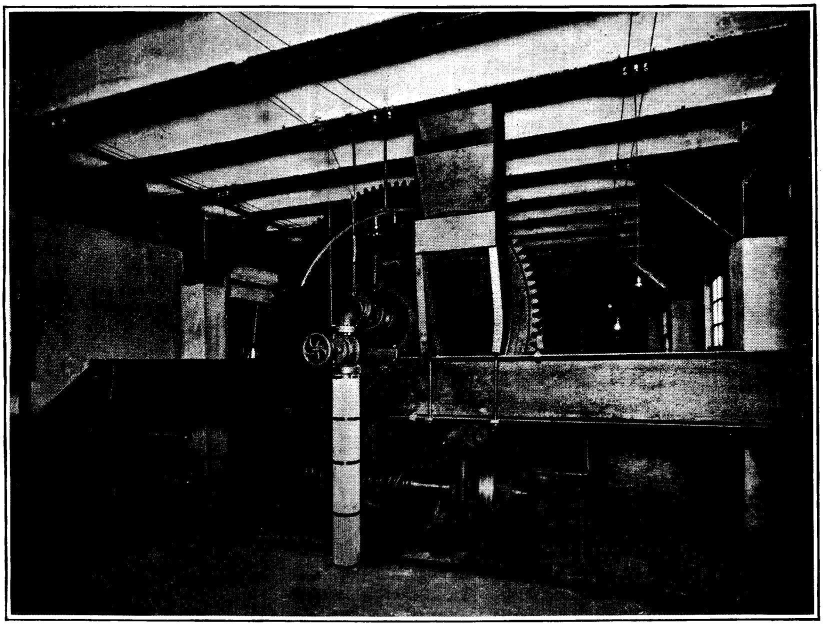


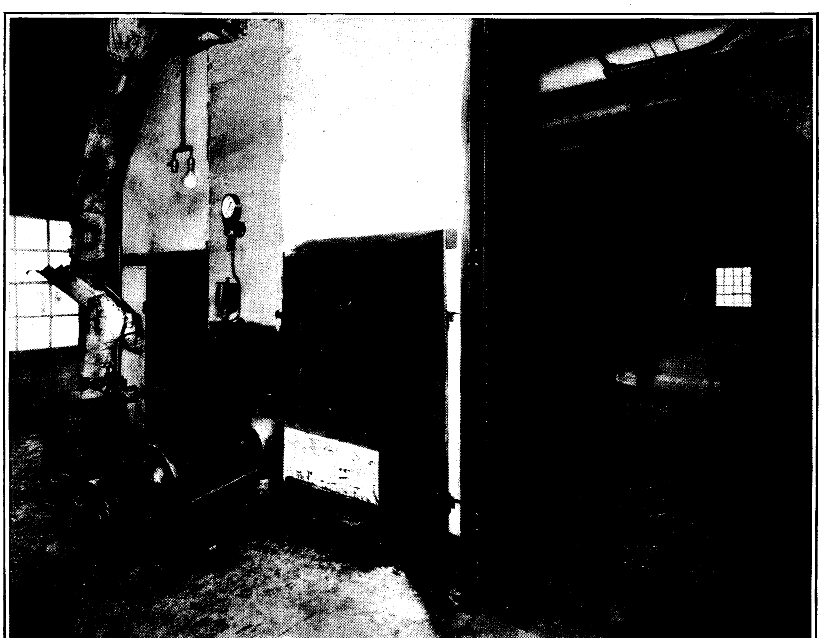
Figure 2.—Cross section of lignite-briquetting plant.

The crusher was expected to break run-of-mine lignite down to pieces ⅜ inch in diameter or smaller, but it would not do so at one pass. Some samples of lignite had to be run through the crusher several times after the larger pieces had been broken with a hammer. The North Dakota lignite acted like tough wood and was especially hard to crush.

The experience gained from the tests indicates that lignite should be crushed in stages; first by a toothed roll and then by a smooth or corrugated roll or by a disintegrator. In Germany three sets of crushers are used in lignite-briquetting plants.



A. RECEIVING END OF SCHULZ DRIER.



B. DELIVERY END OF SCHULZ DRIER.

DRIER.

The Schulz tubular drier C (figs. 1, 2) was installed on the second floor of the building. It was similar in shape to an ordinary multitubular boiler, 22½ feet long, 7½ feet in diameter, and had 195 tubes of 3¾ inches inside diameter, evenly spaced around the drum. The material to be dried passed through the tubes, which had a drying surface of 4,310 square feet.

This drier, which weighed 27 tons, was supported at the ends, the receiving end (Pl. II *A*) being about 3 feet higher than the delivery end (Pl. II *B*). A step bearing at the lower end took the end thrust. A worm gear turned the drier at a speed of 5.2 revolutions per minute; the material to be dried passed through the tubes by gravity.

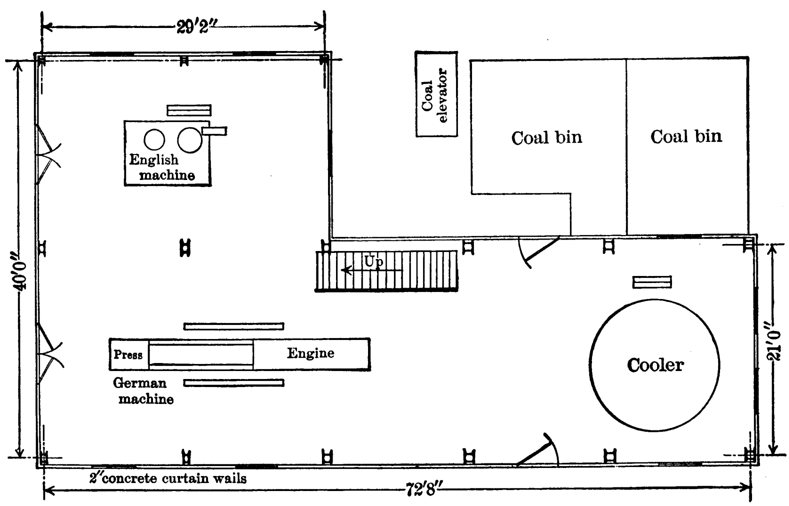


FIGURE 3.—Plan of first floor of briquetting plant.

A 5-inch pipe carried the exhaust steam from the engine of the briquet machine to the drier, the steam entering the latter through the upper bearing. A safety valve on the pipe could be set to keep any desired pressure on the drier. During the tests steam pressures of 3 to 30 pounds per square inch were used, according to the degree of dryness desired. A 2-inch pipe fed live steam into the drier when the engine was not running. The ground lignite was fed into the drier tubes by a chute (shown in Pl. II *A*) that led from an opening in the third floor, under the roll crusher.

The lower or delivery end of the drier was connected with a revolving screen by a hopper (D, figs. 1, 2 and Pl. III *A*). This screen had openings of two sizes; those in the receiving half were $\frac{3}{16}$ inch square, and those in the other half were ⅜ inch square. Material larger than $\frac{3}{8}$ inch was discharged from the end of the screen through a waste pipe.

The sheet-metal casing under the screen had two legs. The material that passed the $\frac{3}{16}$-inch openings fell through one leg, F′, (fig. 2) into the cooler, while the material passing the $\frac{3}{8}$-inch section of the screen fell on a pair of rolls, was crushed to a fine powder, and then fell into the cooler through the other leg, F.

COOLER.

The cooler (G, figs. 1, 2, and Pl. III *A*) was of the plate type. It had four circular stationary plates 13 feet in diameter, arranged one above the other, with raised edges and closing plates to keep the dust from escaping. Over each plate four radial arms, each carrying several scrapers set at an angle of 45° with the arms, were revolved by a vertical central shaft. The material was scraped from the outer edge of the highest plate toward the center, where it fell through holes to the plate below; another set of scrapers moved it to the outer edge of that plate and another set of holes. Thus it reached the bottom plate, from which it went to a worm conveyer (H, fig. 1 and Pl. III *A*). This conveyer elevated the cooled material to the second floor where it fell, through chute I, into large hopper K over the German press L (fig. 1).

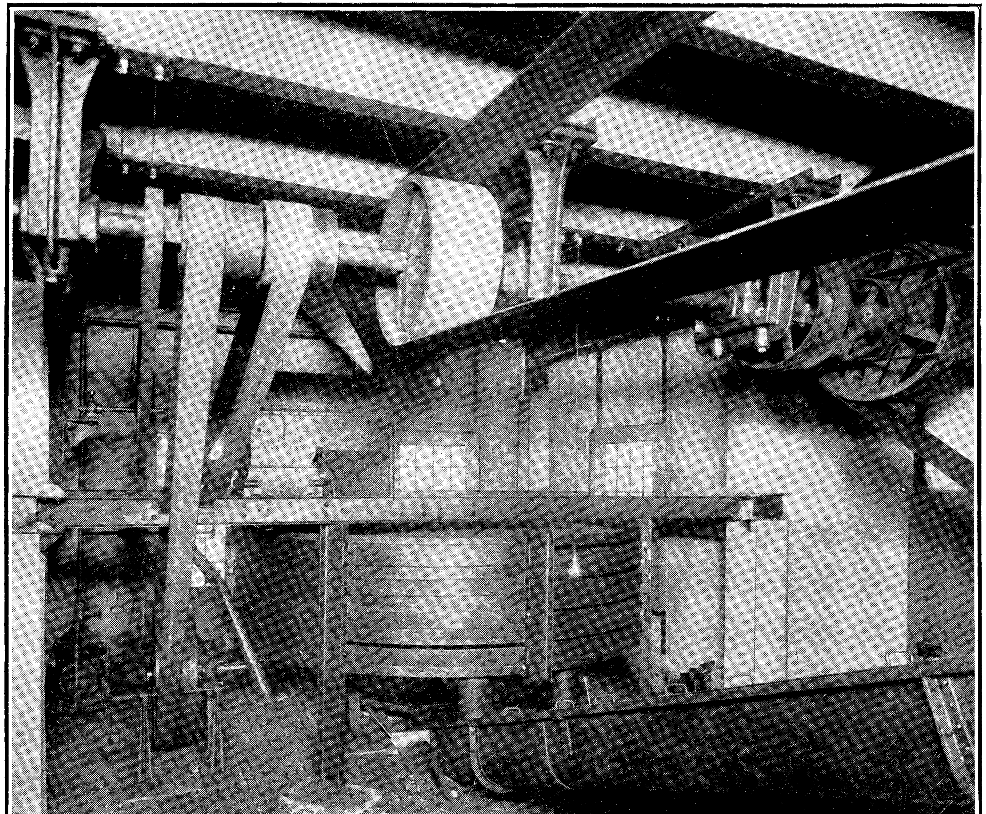
The drier C, sorting sieve E, crushing rolls F, cooler G, and worm conveyer H were driven from the main shaft S, which in turn was driven by the 50-horsepower motor N.

DUST STACKS.

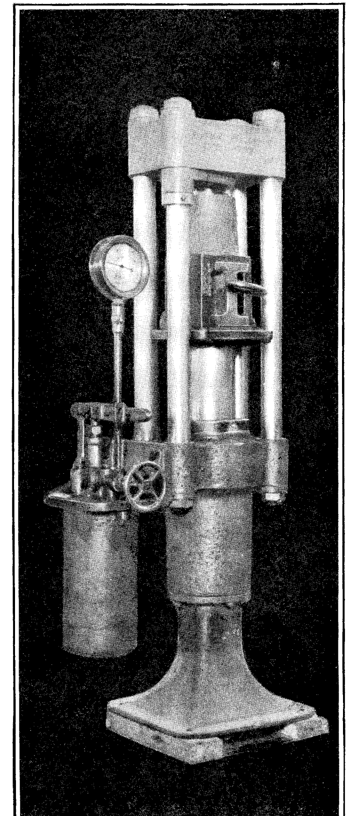
The dust and gases from drying lignite may form explosive mixtures with air; hence stacks W and X (fig. 1) were erected over the delivery end of the drier to carry off the dust and gases, as shown by the arrows in figure 1, and to keep them from coming back into the room through the ends of the tubes near B. An explosion door was placed at the upper end of stack W. Most of the dust settled in the down-coming section of stack W and went to hopper D through a chute. A spray was put in stack X to wash out any dust that remained in the gases, and to condense steam and other vapors. The air current up the stacks tended to increase the capacity of the drier.

GERMAN MACHINE.

The German machine (Pl. IV) was designed to briquet either peat or lignite that will cohere under pressure because of inherent bituminous matter. The press was not intended for briquetting ma-



A. SCREEN, CRUSHING ROLLS, COOLER, AND ELEVATOR TO SECOND FLOOR OF BUILDING.



B. LABORATORY HAND PRESS.

terials to which a binder has been added, and attempts to use a similar press for briquetting materials containing artificial binder will probably result in a stalled machine or a broken stamp.

The machine is of the open-mold type, and the material pressed passes through the mold. In its passage the material is reduced in volume, because the opening in the delivery end of the mold is smaller than the one in the receiving end. This difference in size of the two openings is shown by the vertical sections through the mold given in figure 4, the vertical height being greater at *a* than at *b*. The dimensions given in the figures are in millimeters.

A charge of the prepared material sufficient for one briquet enters the mold at C, is pressed by the stamp E into the end of the mold and is pushed along to D, the end of the travel of the stamp E. The stamp moves back, and then presses another charge to D. The first charge is forced along under heavy pressure in the direction of the

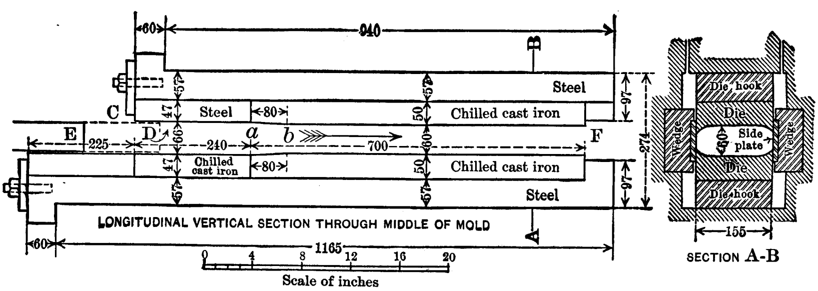


FIGURE 4.—Vertical sections through mold box of lignite-briquetting press; dimensions are in millimeters.

arrow until it reaches *a*; as it passes from *a* to *b*, in what is called the die angle, it is compressed at top and bottom by the reduction in height of the mold. From *b* the briquet is forced along by the successive charges of material and its sides are hardened and polished. When it leaves the mold at F, the briquet is hot, but after it has traveled in a trough for a few feet from the machine it is ready for storage or loading into cars. The press L (fig. 1) is directly connected to the steam engine M. The stamp E (fig. 4) is bolted to a sliding headblock that is actuated by a connecting rod and eccentric. The throw of the eccentric is 7 inches.

ENGLISH MACHINE.

The English machine,[a] shown in Plate V, consists of a heating and mixing chamber of cylindrical shape; a die-filling box, also of cylindrical shape; a die-filling plunger; a vertical die plate; and double-

[a] For a detailed description of the English machine, see U. S. Geol. Survey Bull. 385, pp. 12–14.

compression plungers. This machine is suited for briquetting any solid fuel with added binder. It was built by William Johnson & Sons, of Leeds, England.

No provision was made for experiments with this machine during the fiscal year ended June 30, 1909, and its equipment was not completed. However, a short conveyer was put in to connect the machine with a chute shown at T (fig. 1) on the worm conveyer H, so that material could be crushed and mixed with the binder on the third floor of the building and transported to the machine by the hopper D, cooler G, and conveyer H. This arrangement was not intended for making large lots of briquets, but only for short runs to determine the briquetting qualities of a sample of fuel.

COMPARISON OF GERMAN AND ENGLISH MACHINES.

The capacity of the German and of the English machine, the horsepower required to drive each, and other details are summarized in the following table:

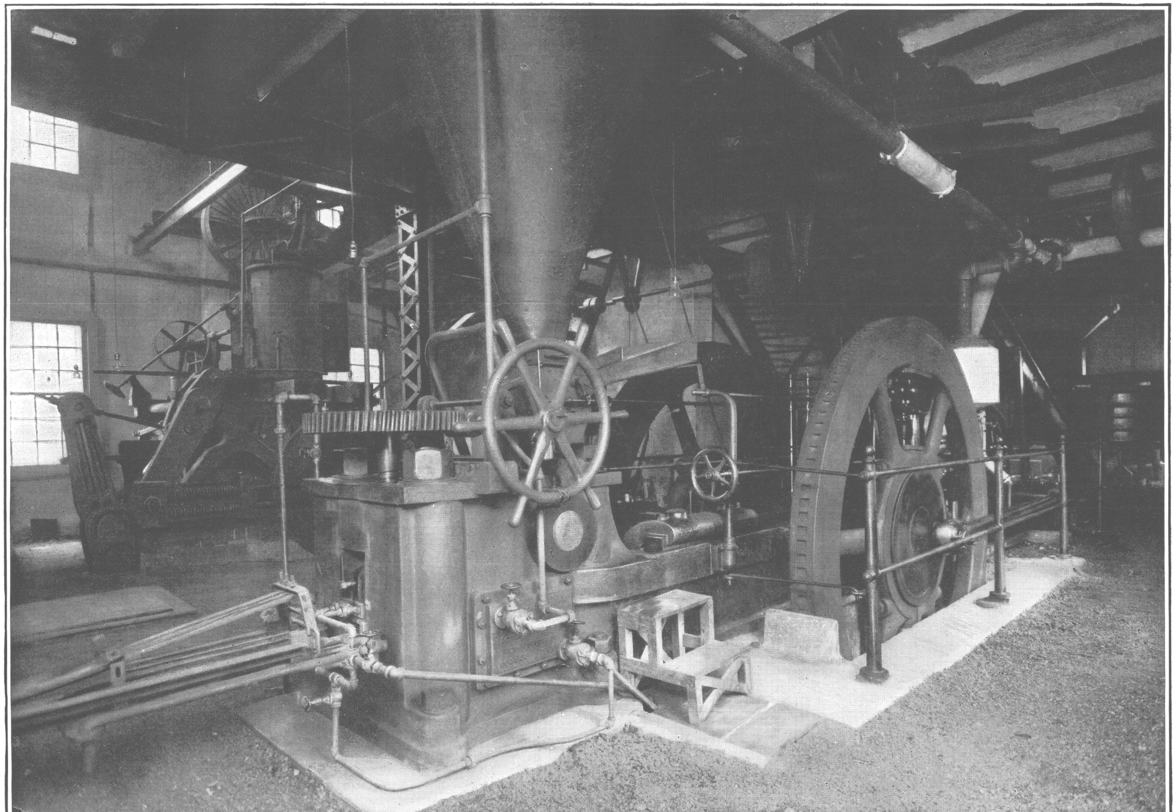
Details of briquetting machines.

Machines.	Horsepower required.	Working strokes per minute.	Briquets per minute.	Average weight of 1 briquet.	Capacity.		Average pressure per square inch used on briquet.
					Per hour.	Per 8-hour day.	
				Pounds.	*Tons.*	*Tons.*	*Pounds.*
English	25	17	34	3.75	3.8	30	2,500
German	100	100	100	1.00	3.0	24	20,000

The briquets made by the German press have flat sides and rounded ends. A good idea of their appearance may be obtained by referring to Plates VI to XI. They measure approximately 6¼ by 2½ by 1 inch, and weigh about 1 pound apiece. The briquets produced by the English machine are parallelopipeds, with the edges rounded off. Their average weight is 3.75 pounds.

LABORATORY HAND PRESS.

A laboratory hydraulic press (Pl. III, *B*), operated by hand, was used for preliminary investigations. It contained a mold 3 inches in diameter and 9 inches long, around which was a steam jacket. This press was adapted for tests with or without binding material and with hot or cold dies. The pressure obtainable with the 3-inch mold was 50 tons, or 14,000 pounds per square inch. By using a smaller mold that was made, a pressure of 32,000 pounds per square inch could be obtained. The press proved very useful and many tests were made with it, but since these tests were preliminary, they are not included in this report.



GERMAN BRIQUET MACHINE; ENGLISH MACHINE IN BACKGROUND.

COST OF A BRIQUETTING PLANT.

It is estimated that a plant capable of producing 25 tons of lignite briquets per 10-hour day can be erected for $56,000. This estimate is based on the cost of the plant at Pittsburg, Pa., as shown below:

Cost of German lignite-briquetting plant.

German lignite-briquetting press with engine complete, with Schulz drier, cooler, worm conveyer, shafting, hangers, pulleys, etc., f. o. b. Hamburg	$16,000
Freight on outfit, Hamburg to mine in United States, 100 tons	4,000
Duty, at 45 per cent ad valorem	7,200
Building complete with foundation	15,000
Crushing machinery and necessary elevators	2,500
One 30-horsepower motor to drive crushers and elevators, with rheostat	800
One 50-horsepower motor to drive drier, cooler, etc., with rheostat	1,000
Erection of machinery	3,000
Two 100-horsepower boilers, with equipment	2,500
Surface grinder to dress dies, etc	1,000
Superintendence, miscellaneous supplies, freight, etc	3,000
	56,000

Nystrom[a] estimates the cost of a complete plant of about the same capacity to be $54,000 to $60,000, so that his figures agree with the cost of the plant at Pittsburg, including the cost of necessary changes in the crushing equipment of the latter.

The following table shows in detail the cost of a briquetting plant equipped with an English (Johnson) machine having a capacity of 38 tons per 10-hour day:

Cost of English briquetting plant.

Johnson briquetting machine complete, with heater and press	[b] $4,500
Freight, England to mine in United States, 20 tons	1,200
Duty, at 45 per cent ad valorem	2,025
Building	10,000
Crushing machinery and necessary elevators	2,500
One 50-horsepower engine	500
Boiler, piping, etc	2,000
Erection of machinery	2,000
Superintendence, miscellaneous supplies, freight, etc	3,000
	18,325

[a] Nystrom, E., Peat and lignite; manufacture and use in Europe. Canada Dept. of Mines, Ottawa, 1908, pp. 130–170.

[b] Consular Reports, No. 26, p. 100.

BRIQUETTING TESTS.

LIGNITES TESTED.

Briquetting tests were made on the following samples, which were considered typical of the lignites in the more important fields in the United States:

Samples of lignite tested.

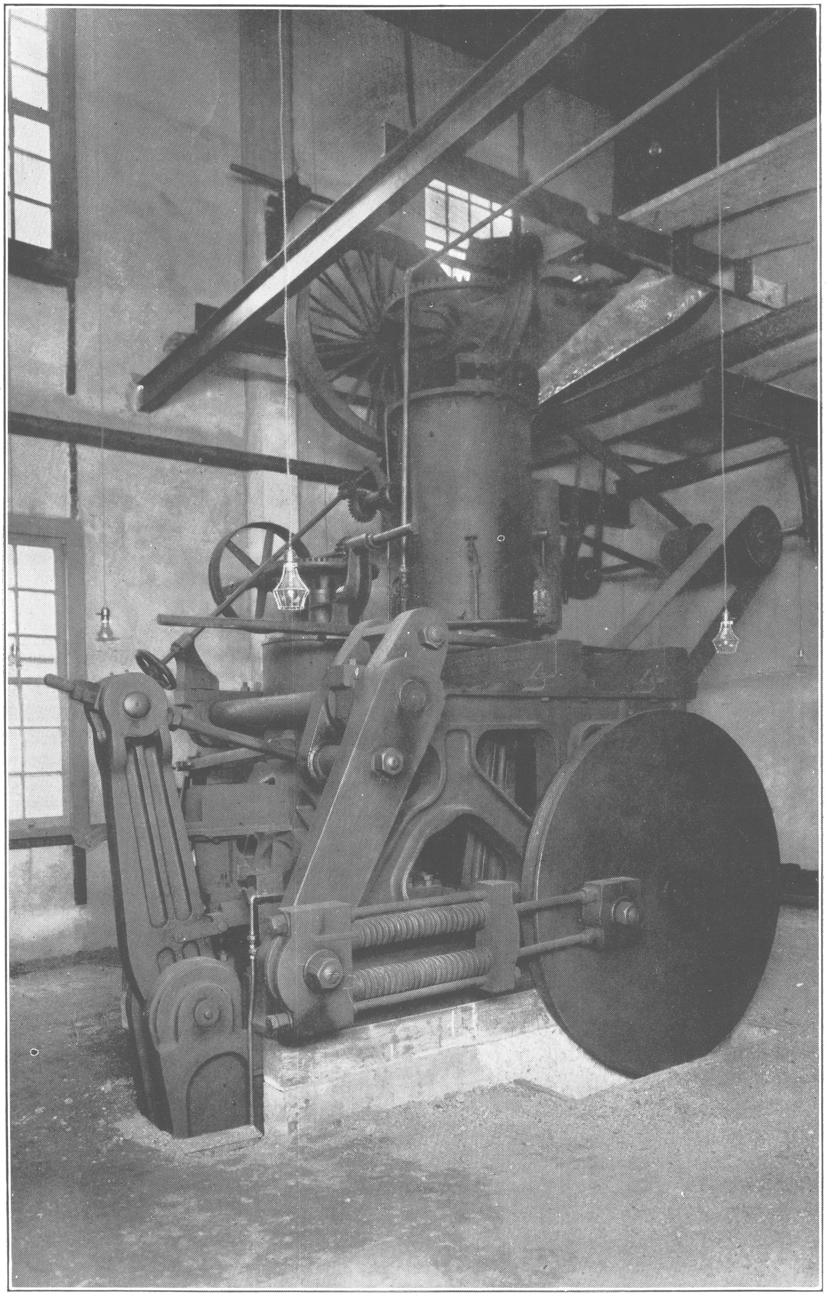
Field designation.	Source.	Size.	Number of tests.
Pittsburg:			
No. 7	Rockdale, Milam County, Tex	$\frac{3}{4}$-inch lump	(a)
No. 8	Lytle, Medina County, Tex	$\frac{1}{2}$-inch lump	[b] 3
No. 9	Calvert, Robertson County, Tex	$\frac{3}{4}$-inch lump	5
No. 11	Scranton, Bowman County, N. Dak	Run of mine	5
No. 13	Lehigh mine, Stark County, N. Dak	do	11
No. 14	Ione, Amador County, Cal	do	8
No. 15	Vanderwalker, Ward County, N. Dak	3-inch lump	4

[a] No official tests made on this sample, which was used in adjusting the machine.
[b] Several preliminary tests also made.

METHOD OF MAKING TESTS.

The samples of lignite to be tested were either kept in one of the two storage bins previously mentioned or were piled upon the ground near by. All the samples were shipped to the plant in box cars.

In making a briquetting test about 3 tons of lignite were taken by elevator P (fig. 2) to the third floor and dumped there in a pile. The lignite was then shoveled into crusher A (figs. 1, 2), which reduced it to $\frac{3}{8}$-inch or smaller pieces. The crushed material passed through a hole in the floor and chute B (figs. 1, 2) into the tubes of a drier (C, figs. 1, 2, and Pl. II *A*, *B*). The dried lignite fell into hopper D (figs. 1, 2), and the part that was fine enough to pass the $\frac{3}{16}$-inch sieve fell directly into the cooler G (figs. 1, 2) through leg F (fig. 2). The pieces larger than $\frac{3}{16}$ inch and smaller than $\frac{3}{8}$ inch fell on a pair of crushing rolls at F (fig. 2), and when crushed dropped into the cooler (G, figs. 1, 2, and Pl. III *A*). All material that passed through the cooler was elevated by a screw conveyer (H, fig. 1 and Pl. III *A*) to the second floor and dropped through chute I (fig. 1) into a hopper (K, fig. 1 and Pl. IV). Overflow chute J (fig. 1) was intended to prevent damage to the screw conveyer H, in case the hopper K became full, by permitting the excess material to pass to the second floor through chute J. From hopper K (fig. 1) the material was fed at a uniform rate to the press L. The briquets were cooled by lying for several minutes in a trough or "slideway," shown at the front of the machine in Plate IV, from which they were carried in barrows to storage piles under cover.



SIDE VIEW OF ENGLISH MACHINE.

At each test the raw material, as it was fed into the drier, was sampled for chemical analysis and determination of heat value. The dried and cooled material was sampled as it fell into the hopper K (fig. 1), and its temperature and moisture content were determined. A sample of the briquets was taken for analysis and determination of heat value.

CHARACTER OF TESTS.

The tests described in this bulletin, as has been stated, were made on the German machine without the use of any artificial binder, the natural inherent bitumen of the lignites themselves yielding the binding material. Therefore those lignites that were not made into good briquets in the German press may be made into excellent briquets in a machine adapted to working with an artificial binder. Certainly there is opportunity for further experiments in this direction, and it is hoped that the Bureau of Mines may be able to conduct briquetting tests of lignites and different binders with the English machine.

Only small lots of lignite could be tested at a time, since the size of the large hopper over the press controlled the quantity of material dried. Until the press started, one was never sure that the material would not stall the machine. Therefore only enough material was fed to the drier to fill the large hopper, so that should difficulty be experienced in getting the material through the press, there would not be an excess to overflow on the floor. The necessity of drying small lots was unfortunate, as about 6 tons of material could be put through in the time needed to get the apparatus warmed to working temperature, and the use of only about 3 tons of lignite for a test resulted in the first part of each lot being dried more than the last part.

DIE ANGLES USED.

The "die angle," or "angle of dies," is the angle to which one end of the long die blocks is ground to decrease the sectional area of the mold, and thus compress the material passing through. The situation of this angle may be seen by referring to figure 4, in which the die angle extends from *a* to *b;* the size of the angle may be found with sufficient accuracy by dividing the decrease in vertical height of the mold (*a* minus *b*) by the length of the part ground off, and finding from a table of natural tangents the angle having a tangent equal to this quotient. To define it in another way, the die angle is the angle whose $\text{tangent} = \frac{\text{Decrease in vertical height}}{\text{Length ground away}}$.

As the angular measure in degrees does not convey such exact information as do the dimensions of the portion removed by grinding, the latter are styled the "die angle" in the notes on the tests.

In figure 4 the normal or standard die angle is shown, and its size is here reported as $\frac{6}{80}$, for the decrease in vertical height in this instance is 66—60=6 mm., and the length ground off is 80 mm. The angle whose tangent is $\frac{6}{80}$ is 4° 20′. In the tests here reported various die angles were used, ranging from $\frac{1}{60}$ to $\frac{8}{68}$.

The height and length of the metal ground off the sets of dies used, the ratios of these dimensions, and the angles corresponding to these ratios are shown in the following table:

Die angles used.

Decrease in vertical height.	Length of die angle.	Ratio or tangent.	Angle of which ratio is tangent.	Decrease in vertical height.	Length of die angle.	Ratio or tangent.	Angle of which ratio is tangent.
Mm.	*Mm.*		° ′	*Mm.*	*Mm.*		° ′
1.0	60	0.016	0 55	5.0	89	0.0562	3 13
1.5	60	.025	1 26	5.5	89	.0618	3 32
3.0	76	.0394	2 15	6.0	89	.0674	3 51
4.0	110	.0364	2 5	7.0	89	.0786	4 30
4.0	89	.0450	2 35	8.0	68	.1176	6 42

PRESSURES USED.

The German briquetting press was built to give a working pressure of 14,000 to 28,000 pounds per square inch, and as the area of the face of a briquet was 15.55 square inches, the total pressure developed by the machine was 217,700 to 435,400 pounds. The pressure actually used in the different tests could not be determined, and could be approximated only when the material stalled the machine, the pressure then being maximum.

INCIDENTAL CHEMICAL TESTS.

MOISTURE CONTROL.

Most of the chemical analyses in this report were made at the general chemical laboratory of the fuel-testing division under the direction of F. M. Stanton and, later, A. C. Fieldner, but as it was impossible for that laboratory to make moisture tests and report results the same day, a laboratory was arranged by the briquetting section for making control moisture tests, using a method devised by Mr. Stanton. The procedure was as follows: Fifty grams of coarsely crushed lignite were placed in a distilling flask of about 200-c. c. capacity, covered with 70 c. c. of kerosene, and heated over a gas flame. The moisture driven off was condensed in a Liebig condenser and run into a tall 25-c. c. measuring cylinder or burette. The distillation was carried on until a thermometer in the flask showed a final temperature of 350° F. The cubic centimeters of water in the measuring cylinder were noted when the thermometer in the flask registered 250° F., 300° F., and 350° F., and the percentage of moisture in the sample was taken as the percentage of moisture distilled at 300° F. Of course, some of the kerosene distilled over, but it readily separated from the water and the quantity of the latter in the measuring cylinder could be accurately read.

EXTRACTION TEST.

To determine the percentage of bitumen or natural binding material in the raw or briquetted lignite, samples were extracted with carbon bisulphide in a Soxhlet apparatus in the following manner:

Five grams of the finely ground material were weighed in an extraction thimble and extracted in a flask that had been dried for one-half hour at 108° C., cooled in a desiccator, and weighed. After the material had been in the extractor five hours the carbon bisulphide in the flask was distilled off and recovered in the Soxhlet extractor; the flask and its contents were dried at 108° C. for one hour, cooled and weighed, and the percentage of material extracted was calculated from the weight of the residue. The result was computed to a moisture-free basis for convenience of comparison and the results of the extraction tests herein reported are on this basis.

Since the percentage of material soluble in carbon bisulphide indicates the percentage of natural binder in the lignite, the results of an extraction test are valuable aids in determining whether a sample under investigation can be briquetted without adding artificial binder. If it can not be, the results are a guide in determining how much binder must be added to make satisfactory briquets.

The results of extraction tests of the lignites briquetted are shown in the following table:

Extraction-test results.

Sample used.	Number of samples tested.	Average per cent of dry sample soluble in CS_2.	Remarks.
Pittsburg:			
No. 7 (Rockdale, Tex.)	2	1.20	No satisfactory briquets made.
No. 8 (Lytle, Tex.)	3	2.01	Satisfactory briquets made.
No. 9 (Calvert, Tex.)	4	1.24	No satisfactory briquets made.
No. 11 (Scranton, N. Dak.)	4	1.72	Satisfactory briquets made.
No. 13 (Lehigh, N. Dak.)	13	1.43	Difficult to briquet.
No. 14 (Ione, Cal.)	7	7.60	Satisfactory briquets made.
No. 15 (Vanderwalker, N. Dak.)	2	1.08	No satisfactory briquets made.

The following important conclusions, some of which are indicated by the table, can be drawn from the results of the briquetting and the extraction tests described above:

1. Lignites containing less than 1.4 per cent of matter soluble in carbon bisulphide (calculated to a moisture-free basis) have not been

briquetted with the German machine, nor with any other machine, without the addition of a binder.

2. Lignites containing 1.4 to 1.5 per cent of matter soluble in carbon bisulphide are difficult to briquet, and further tests are needed to determine whether entirely satisfactory briquets can be made from them with the German machine.

3. The few lignites tested that contained more than 1.5 per cent of matter soluble in carbon bisulphide were briquetted with the German machine without binder.

4. The percentage of moisture that the dried lignite must contain to give satisfactory briquets with the German machine is, within limits, proportional to the percentage of matter soluble in carbon bisulphide. Hence, if two lignites have the same ash content the one that is richer in bitumen may be dried more and will give briquets of higher heat value (because of the lower moisture content) than the other.

TESTS TO WHICH BRIQUETS WERE SUBJECTED.

PHYSICAL TESTS.

Samples of the better lots of briquets made were subjected to the drop test and the tumbler test to determine their cohesive strength and to show their ability to endure handling.

DROP TEST.

Fifty pounds of briquets were placed in a drop-bottom box, 24 inches square and 12 inches deep inside, that was supported 6 feet above a concrete floor. The briquets were suddenly dropped on this floor; then the pieces were gathered up and those that were held by a 1-inch screen (square holes) were returned to the box and dropped again. The floor was swept clean before each drop. This procedure was repeated five times, after which the weight of pieces that would not pass through the screen was determined. The percentage that the weight of these pieces bore to the original weight is here reported as "per cent held by 1-inch screen," and the difference between this figure and 100 per cent is reported as "per cent passed by 1-inch screen."

TUMBLER TEST.

A weighed quantity of the briquets (as nearly as possible 50 pounds) was placed in a tumbler, a horizontal sheet-steel cylinder, and rotated 2 minutes at a uniform speed of 28 revolutions per minute. The contents of the tumbler were then sized by a 1-inch mesh screen, and the portion that passed through was screened through a

10-mesh sieve. The weight of the pieces held by each screen was determined and the "percentage held" computed and reported as in the drop test.

WEATHERING TEST.

To determine the comparative weather-resisting qualities of the lignite briquets and the samples of lignite from which they were made, small piles of each lot of satisfactory briquets and lumps of the raw lignites were exposed to the action of sun, wind, and rain on the roof of the briquet building from September, 1909, to May, 1910. Plates VI to XI, made from photographs taken at various intervals up to 286 days, show the different stages of weathering. The length of time the briquets had been exposed before examination and the condition of the briquets when examined are stated in the tabulated results of tests. The key to the conditions designated A, B, C, D, and E is that stated in Bulletins 332 and 385 of the United States Geological Survey and is as follows:

A. Briquets practically in same condition as when put out. Surfaces show no signs of erosion or pitting. Briquets hard, with sharp edges, and fracture same as that of new briquets.

B. Shape of briquets unchanged. Surfaces of those on top of pile have lost luster, with evidences of pitting, corners and edges worn off by erosion. All briquets firm, with fracture practically the same as that of new briquets.

C. Top briquets appear similar to those in condition B, and show signs of further disintegration, having lost original sharp fracture. Erosion more evident on all briquets on outside of the pile. Inside briquets still firm, retaining original characteristics.

D. Top briquets so badly disintegrated that they crumble to pieces on handling. Briquets in center of pile show signs of disintegration; luster of surfaces gone, edges soft, and break easily in the hand. Fracture not so sharp as when newly made, but briquets firm and handled without breaking.

E. Entire pile disintegrated. In many cases the only briquets retaining their original shape are those protected from the weather. Briquets can not be handled safely, but crush easily in the hand.

DETAILS OF TESTS.

PITTSBURG No. 7.

A sample shipment, 3 cars, of lignite from the Big Lump Mine, 3½ miles northeast of Rockdale, Milam County, Tex., was designated Pittsburg No. 7.

House-heating boiler tests Nos. H23, H24, H30, H45, and H46 were made on this fuel, but the larger part of the shipment was used in preliminary briquetting experiments to adjust the drier, cooler, and press of the German plant. This lot was the first to arrive at the testing station, considerable difficulty was experienced in making it into briquets and the shipment was exhausted before satisfactory results were obtained. It is hoped that further tests of this lignite may be made under more favorable conditions.

The following proximate analyses show the changes in composition of the sample during transportation from the mine to the plant, a period of 29 days, and after storage at the plant for 17 and 38 days, respectively.

Proximate analyses of lignite from Rockdale, Tex.

	Mine sample.	Car sample.	Plant samples.	
			After 17 days.	After 38 days.
Date taken	Feb. 1	Mar. 1	Mar. 18	Apr. 8
Laboratory No.	7270	7350	7433	7554
Air-drying loss ....per cent..	31.50	25.10	25.70	25.30
Moisture ....do....	35.30	33.38	31.72	30.98
Volatile matter ....do....	26.22	27.44	26.81	29.04
Fixed carbon ....do....	29.58	29.62	31.97	30.41
Ash ....do....	8.90	9.56	9.50	9.57
Sulphur ....do....	.76	.94	.91	.92
Heat value ....B. t. u..	6,898	7,189	7,423	7,301

Mr. Lehmann, the representative of the German company that furnished the lignite-briquetting plant, remained at Pittsburg until the plant was in good working condition. The tests of the first sample of lignite were therefore under his direction. Most of these tests were preliminary and it was impossible to obtain a complete record of them, so only a general statement of conditions and results can be given.

The briquet material in the various tests contained different proportions of water, ranging from 2.3 to 11.2 per cent, and different pressures, from very light to the heaviest possible, were applied to it. From some of the tests the briquets were poorly formed, rough, and scaly, but were fairly strong; from other tests the briquets were well formed but weak.

Only one cohesion (drop) test was made on the briquets obtained, because most of the tests gave only pieces of briquets. The results of this test were as follows: Held by 1-inch screen, 24 per cent; through 1-inch screen, 76 per cent.

The best briquets were made by using material that contained 11.2 per cent moisture and applying a rather light pressure. The results seemed to show that for best results with the German machine the ground and dried lignite should contain between 8 and 12 per cent moisture, and the pressure used should be moderate, about that obtained by using a set of dies so ground that in a length of about 80 mm. the decrease in height would be 3 to 4 mm.

As a general conclusion, it may be said that this lignite is deficient in natural binding material, and although it can be briquetted without artificial binder on a machine of the type used, such a machine did not make briquets of satisfactory form and strength from it. To determine the best conditions for briquetting, further tests are needed. It is probable that the lignite will make entirely satisfactory briquets if an artificial binder and a different type of press are used.

PITTSBURG No. 8.

A sample shipment, 2 cars, of ½-inch lump lignite from the Carr mine No. 3, 2 miles southwest of Lytle, Medina County, Tex., was designated Pittsburg No. 8.

This lignite had a dark-brown color. It weathered very rapidly, exposure to a single rainstorm causing lumps to crack in all directions. After it had been wet and dried a few times the sample crumbled entirely to slack.

Gas-producer test 180 and briquetting tests 293, 295, and 296 were made on this fuel, and several preliminary briquetting tests for adjusting the press.

The changes in composition of the lignite during transportation from the mines to the plant (25 days), and during storage (42 days) at the plant till used, for one of the last tests, are shown by the following proximate analyses:

Proximate analyses of lignite from Lytle, Tex.

	Mine sample.	Car sample.	Sample as used on last test.
Date taken	Feb. 5	Mar. 2	Apr. 13
Laboratory No	7330	7461	7584
Air-drying loss ... per cent	24.20	26.30	19.40
Moisture ... do	32.92	30.77	28.00
Volatile combustible ... do	27.42	27.36	27.50
Fixed carbon ... do	27.08	28.39	32.30
Ash ... do	12.58	13.48	12.20
Sulphur ... do	1.46	1.62	1.60
Heat value ... B. t. u	6,840	7,079	7,580

Several preliminary tests were made under the direction of Mr. Lehmann. In the first of these, with a steam pressure of 5 pounds in the drier, the percentage of moisture in the fuel was reduced from 30 per cent to 11.2 per cent. A rather low pressure in the molds produced well-formed but weak briquets.

Material containing 10 per cent moisture, and subjected to a high pressure, furnished briquets that had poor form and rough surfaces, but were much stronger than those made in the first test. The roughness of surface was largely caused by steam (generated while the briquet was being formed under high pressure) that blew out around the sides of each briquet just before it left the mold. The dust blown out by the steam was disagreeable to breathe and at times formed clouds which darkened the whole room.

In the next test, material containing 8.4 per cent moisture was subjected to a high pressure. The briquets were better formed and smoother than in the previous test and were the strongest yet made from the lignite.

In the fourth test the material contained 6 per cent moisture, but the same high pressure was used. The briquets were still better, being well formed and strong. Another test, with the material containing only 3.6 per cent moisture, gave the best briquet obtained from this fuel. However, with this low moisture content the mold pressure was too great for the press, and after an hour's run the main bearing of the connecting rod became so hot that the press had to be stopped.

The following table summarizes the essential data of the tests made with this sample of lignite:

Summary of tests.

Test No.	Moisture in briquet material.	Pressure in mold.	Character of briquets.		Remarks.
			Form.	Strength.	
	Per cent.				
Preliminary	11.2	Low	Good	Weak	Pressure insufficient.
Do	10.0	High	Poor	Strong	Briquets rough.
Do	8.4	do	Fair	do	
Do	6.0	do	Good	do	Better than previous lot.
Do	3.6	do	do	do	Best lot.
293	8.7	do	do	Good	
295	7.7	Very high	None made		Material too dry.
296	12.2	do	Fair	Weak	Material too fine.

In the first official test (293) the material contained 8.7 per cent moisture and a high pressure was applied. About 61 per cent of the material that reached the press was coarser than $\frac{1}{20}$ inch, but practically all of this 61 per cent passed through a screen with $\frac{1}{4}$-inch meshes. The results indicate that it is well to have the material as evenly sized as possible and without much dust. If the proportion of dust is excessive, the material does not bind well and blows out of the mold when pressed. Even sizing is also desirable because it permits even drying. The writer believes that this fuel should be crushed so that it will all pass through a $\frac{1}{4}$-inch screen, and yet about 60 per cent of it will be retained on a $\frac{1}{20}$-inch screen.

In tests 295 and 296 the dies were set to give a very high pressure. In test 295 the briquet material contained 7.7 per cent moisture and was probably too dry; it did not bind but fell from the press in the form of powder, accompanied by clouds of dust.

In test 296 the dried material had 12.2 per cent moisture. The material probably contained too much dust, for the briquets crumbled easily and were not strong enough to handle.

Plates VI to XI show how the briquets from tests 293 and 296 withstood exposure to the weather.

This lignite was made into excellent briquets without the addition of any binder. The moisture content of the dried material should be between 8 and 10 per cent if a moderate pressure is used, but only about 5 per cent, or even less, if an extremely high pressure is used. For best results the writer recommends that the material be pulverized so that about 60 per cent of the particles are between $\frac{1}{4}$ inch and $\frac{1}{20}$ inch in diameter, that it go to the press containing 10 per cent moisture, and that the briquetting pressure be 20,000 pounds per square inch.

The best briquets made from this fuel had strength enough to stand handling. They took the shape of the mold well, their edges were firm, and they had jet-black, lustrous surfaces. Such briquets should make a satisfactory steam or household fuel. No steaming tests were made on either the raw or briquetted lignite. The ash content (about 17 per cent) of the briquets is considerably higher than that of good quality bituminous coal.

Briquetting this lignite should improve its heat value 30 to 40 per cent by reducing the percentage of moisture. On the assumption that in briquetting the uncombined moisture is reduced from 30 per cent to 10 per cent, 1 ton (2,000 pounds) of raw fuel will make 1,600 pounds of briquets, or 2,500 pounds of raw fuel will make 1 ton of briquets. The raw fuel has a heat value of 6,800 B. t. u. per pound and the briquetted fuel has a heat value of 9,300 B. t. u.; therefore the fuel value of the briquets is 37 per cent higher than that of the raw fuel. Moreover, the briquets have the following additional advantages over raw fuel:

(*a*) Being of uniform size, they burn more freely and give off less smoke, a decided merit when used as a household fuel in a residence district.

(*b*) The briquets resist the effects of the weather much better than the raw fuel, and therefore can be stored for a longer time without serious deterioration. The briquets are not, however, much more waterproof than the raw fuel, and should be stored under cover; there they will remain in perfect condition for several months at least, while the raw fuel under similar conditions will disintegrate rapidly.

(*c*) The cost of transporting the briquetted fuel should be only 80 per cent of the cost of transporting enough raw fuel to furnish the same heat value.

Briquetting tests.

	Test 293.	Test 295.	Test 296.
Size as shipped	½" lump.	½" lump.	½" lump.
Size as used:			
Over ¼ inch ... per cent	0.5	0.5	0.5
$\frac{1}{10}$ inch to ¼ inch ... do	30.5	18.0	18.0
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	30.0	28.5	28 5
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	24.5	21.0	21.0
Through $\frac{1}{40}$ inch ... do	14.5	·32.0	32.0
Details of manufacture:			
Machine used	German.	German.	German.
Briquetting temperature ... °F.	90	94	101
Binder used	None.	None.	None.
Tangent of die angle	$\frac{5.5}{89}$	$\frac{6}{89}$	$\frac{6}{89}$
Steam pressure on drier ... pounds	13	15	11
Weight of—			
Fuel briquetted ... do	11,440	None.	4,840
Briquets, average ... do	0.9	....	0.7
Heat value per pound:			
Fuel as received ... B. t. u.	7,580	7,395	....
Briquets ... do	9,448	....	9,223
Moisture in briquet mixture ... per cent	8.73	7.68	12.17
Drop test (1-inch screen):			
Held ... do	44.	([a])	([b])
Passed ... do	66.	....	....
Tumbler test (1-inch screen):			
Held ... do	37.	....	([b])
Passed ... do	63.	....	....
Fines through 10-mesh sieve ... do	74.	....	....
Weather test:			
Time exposed when examined ... days	66	....	....
Condition when examined	D	....	....

[a] No briquets.
[b] Briquets too weak for cohesion test.

PROXIMATE ANALYSES OF BRIQUETS.

Laboratory No	7,583	7,623	....
Moisture ... per cent	8.07	9.96	....
Volatile matter ... do	37.31	37.84	....
Fixed carbon ... do	35.87	35.99	....
Ash ... do	18.75	16.21	....
Sulphur ... do	1.97	1.98	....

PITTSBURG No. 9.

A sample shipment, 3 cars, of ¾-inch lump lignite from the Calvert mine, 6 miles west of Calvert, Robertson County, Tex., was designated Pittsburg No. 9.

Gas-producer tests 181 and 182, house-heating boiler tests H41 and H43, and briquet tests 297, 320, 321, 323, 327, and 328 were made on the raw lignite.

The following proximate analyses show the changes in composition of this lignite during transportation from the mine to the plant, a period of 26 days, and in storage at the plant for 81 days until used for the last test. The last column gives an average of 6 analyses made on different dates.

Proximate analyses of lignite from near Calvert, Tex.

	Mine sample.	Car sample.	Sample as used on last test.	Average of 6 samples.
Date taken	Mar. 6	Apr. 1	June 21	....
Laboratory No.	7,403	7,513	7,950	....
Air-drying loss ... per cent	29.30	25.40	12.10	13.17
Moisture ... do	34.33	29.62	23.50	24.01
Volatile matter ... do	25.94	27.60	29.07	29.75
Fixed carbon ... do	30.93	29.37	35.74	34.74
Ash ... do	8.80	13.41	11.69	11.50
Sulphur ... do	.95	.98	.82	.91
Heat value ... B. t. u.	7,214	7,040	8,089	8,021

Test 297 did not yield any briquets. Apparently the pressure in the mold was excessive; there may have been too little moisture in the material or the die angle may have been too great.

In test 320 a high pressure was used. The briquets were poorly formed and too weak to handle. The moisture content of the material was evidently too high for the pressure used. Much dust was blown out around the sides of each briquet.

In test 321 the same pressure was used, but the material was still too moist and no satisfactory briquets were obtained. The briquets made had poor forms and were too weak to handle.

The material was drier in test 323 than in tests 297, 320, and 321, and contained only 3 per cent moisture when it reached the machine. It was also finer. This material, however, stalled the press. After several attempts to operate the machine the test was stopped and the material remaining in the hopper was thrown away.

In test 327 the material was dried less than in test 323, and contained 4.6 per cent moisture when it reached the machine. The dies were changed so as to give less pressure. The briquets obtained were better than those made in test 323, but although they had good form they lacked strength, and crumbled when handled.

In the next test (328) the percentage of moisture in the briquet material was raised to 6.4 per cent with beneficial results. The same pressure was used as in test 327. The briquets were the best so far obtained, but they were not strong enough to handle. The test was not completed, however, for a strong steel brace having a cross section of 3 by 5½ inches snapped without warning and put the press out of commission until another brace could be forged. The tests were suspended before other pressures could be tried.

Following is a summary of the most important features of the tests on this sample of lignite:

Summary of tests.

Test No.	Moisture in briquet material.	Pressure in mold.	Character of briquets.		Remarks.
			Form.	Strength.	
	Per cent.				
327	4.6	High	Good	Weak	Too much moisture.
328	6.4	do	do	do	Better than test 327.
297	7.0	do	None made		Too much pressure.
323	3.0	Very high	do		Stalled machine; too little moisture and too much pressure.
321	6.4	do	Poor	Weak	Too much moisture and dust.
320	9.47	do	do	do	Do.

It will be seen that the moisture content in the briquet material varied from 3 per cent to $9\frac{1}{2}$ per cent. Two different pressures were used, but, although some of the tests gave briquets of good form, no briquets were of satisfactory strength.

To yield best results with the German machine, this lignite should be ground so that all of it will pass a $\frac{1}{4}$-inch screen, but about 60 per cent will be retained by a $\frac{1}{20}$-inch screen, and should be dried till it contains 10 per cent moisture. The die angle should be small enough to give a moderate pressure. However, the indications are that this lignite does not contain enough natural binder to make good briquets on the German press, and it should be tested with a little artificial binder on a press similar to the English machine. The writer is inclined to doubt whether this lignite can be briquetted at all without the addition of binding material. However, further tests should be made before a final conclusion is reached.

Briquetting tests.

	Test 297.	Test 320.	Test 321.	Test 323.	Test 327.	Test 328.
Size as shipped	$\frac{3}{4}$'' lump.	$\frac{3}{4}$'' lump.	$\frac{3}{4}$'' lump.	$\frac{3}{4}$'' lump.	$\frac{3}{4}$'' lump.	$\frac{3}{4}$'' lump.
Size as used:						
Over $\frac{1}{4}$ inch ... per cent	2.0	3.0	2.5	2.5	2.0	2.0
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	18.0	23.0	25.0	30.0	31.5	30.5
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	30.0	28.0	28.5	28.5	29.0	30.5
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	27.0	22.5	21.0	20.5	19.5	19.0
Through $\frac{1}{40}$ inch ... do	23.0	23.5	23.0	18.5	18.0	18.0
Details of manufacture:						
Machine used	German.	German.	German.	German.	German.	German.
Briquetting temperature ... °F	84	100	102	97	93	116
Binder used	None.	None.	None.	None.	None.	None.
Tangent of die angle	$\frac{6}{89}$	$\frac{7}{89}$	$\frac{7}{89}$	$\frac{7}{89}$	$\frac{6}{89}$	$\frac{6}{89}$
Steam pressure on drier ... pounds	10	4	10	15	10	12
Weight of—						
Fuel briquetted ... do	None.	None.	None.	None.	None.	None.
Briquets, average ... do						
Heat value per pound:						
Fuel as received ... B. t. u.	7,920	7,925	8,114	7,900	8,176	8,089
Briquets ... do		9,574	9,929		10,028	
Moisture in briquet mixture ... per cent	6.98	9.47	6.40	3.0	4.6	6.4

PITTSBURG No. 11.

A car of run-of-mine lignite from the Scranton Mine, Scranton, Bowman County, N. Dak., was designated Pittsburg No. 11. This lignite had a dark-brown color, almost black, but became somewhat lighter colored after drying.

Producer-gas test 187 and briquetting tests 312, 317, 318, 319, and 322 were made on the raw lignite. House-heating boiler tests H86 and H87 were made on briquets from briquetting test 322.

The following table shows the changes in composition of this lignite during transportation from the mine to the plant, a period of 38 days, and during storage at the plant until used for the last briquetting test, a period of 50 days. The last column gives an average of 5 proximate analyses made on different dates:

Proximate analyses of raw lignite.

	Mine sample.	Car sample.	Sample used on last test.	Average of 5 samples.
Date taken	Mar. 20	Apr. 23	June 12	....
Laboratory No.	7499	7677	7942	....
Air-drying loss ... per cent.	36.00	27.50	22.70	20.7
Moisture ... do.	41.43	38.81	32.30	32.68
Volatile matter ... do.	23.86	25.48	18.81	26.24
Fixed carbon ... do.	28.45	27.29	40.71	33.45
Ash ... do.	6.26	8.42	8.18	7.62
Sulphur ... do.	.74	.97	.85	.93
Heat value ... B. t. u.	6,241	6,347	7,160	7,243

Test 312, of material dried till it held 10.6 per cent moisture, furnished some fairly strong briquets during the latter half of the run when conditions had become constant. The shape of these briquets was good, their surfaces were smooth, and their edges were sharp. They could be handled without too much breakage. The best briquets were made by running the machine at moderate speed, about 60 revolutions per minute.

Test 317, in which the material was dried until it contained 11 per cent moisture, and the pressure was heavier than in test 312, failed to produce satisfactory briquets. Those formed were too weak to handle, and crumbled to pieces soon after leaving the mold. The chemical analysis reported was made on the broken briquets.

Test 318, in which the material contained 11.7 per cent moisture and the pressure was the same as in test 317, furnished some fair briquets during the latter part of the run, but they were not strong enough to handle. As in test 317, pieces of briquets were analyzed.

Test 319, in which the material contained 15 per cent moisture, produced excellent briquets; they had smooth surfaces, sharp edges, and were strong enough to bear handling.

The conditions during test 322 differed from those during test 319 only in the moisture content of the material. The briquets were strong and well formed, with smooth, polished surfaces.

Plates VI to XI show how briquets from tests 312, 319, and 322 withstood exposure to the weather.

This lignite was made into good briquets without the use of a binder. Satisfactory briquets can be made by drying the ground lignite till it contains 11 per cent moisture, and better briquets can be made if the moisture content is about 15 per cent. The indications are that material containing more than 15 per cent moisture can be worked on this press and will probably furnish stronger briquets than any mentioned in this report. Unfortunately the control of the drier at the Pittsburg plant did not permit the material, if dried at all, to contain more than 15 per cent moisture. This defect can be remedied, however, by changing the proportions or the speed of the drier.

Data relating to the test made with this lignite are summarized in the table appended.

Briquetting tests.

	Test 312.	Test 317.	Test 318.	Test 319.	Test 322.
Size as shipped	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.
Size as used:					
Over $\frac{1}{4}$ inch ... per cent	2.00	3.00	1.00	3.00	1.50
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	21.00	29.50	17.50	32.00	29.00
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	28.00	25.00	32.50	29.50	29.00
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	26.00	16.50	22.00	16.50	20.00
Through $\frac{1}{40}$ inch ... do	23.00	26.00	27.00	19.00	20.50
Details of manufacture:					
Machine used	German.	German.	German.	German.	German.
Briquetting temperature ... °F	103	98	101	99	102
Binder used	None.	None.	None.	None.	None.
Tangent of die angle	$\frac{6}{89}$	$\frac{7}{89}$	$\frac{7}{89}$	$\frac{7}{89}$	$\frac{7}{89}$
Steam pressure on drier ... pounds	10	10	5	4	4
Weight of—					
Fuel briquetted ... do	4,383	[a] None.	2,000	4,000	6,300
Briquets, average ... do	1.00	....	1.00	1.03	1.07
Heat value per pound:					
Fuel as received ... B.t.u.	7,265	7,270	7,510	7,034	7,160
Briquets ... do	9,434	9,470	9,189	9,184	9,445
Moisture in briquet mixture ... per cent	10.60	11.06	11.73	14.96	12.60
Drop test (1-inch screen):					
Held ... do	42	....	....	44	34
Passed ... do	58	....	....	56	66
Tumbler test (1-inch screen):					
Held ... do	36	....	....	43	37
Passed ... do	64	....	....	57	63
Fines through 10-mesh sieve ... do	65	....	....	56	59
Weather test:					
Time exposed when examined ... days	66	....	....	66	66
Condition when examined	E	....	....	E	D

[a] The few briquets made fell to pieces when handled.

PROXIMATE ANALYSES OF BRIQUETS.

Laboratory No	7807	7886	7893	7901	7944
Moisture ... per cent	10.76	10.70	12.09	12.48	11.93
Volatile matter ... do	38.97	38.95	38.11	38.92	36.87
Fixed carbon ... do	40.94	40.69	39.68	39.47	41.37
Ash ... do	9.33	9.66	10.12	9.13	9.83
Sulphur ... do	1.22	1.20	1.27	1.20	1.21

PITTSBURG No. 13.

This sample consisted of 1 car of run-of-mine lignite from the Lehigh mine, Stark County, N. Dak. It was used in making gas-producer test 184, and briquetting tests 294, 298, 299, 300, 301, 302, 303, 304, 305, 306, and 307.

The following table shows the changes in composition of this fuel during transportation from the mine to the plant, a period of 12 days, and during storage at the plant until used for the last briquet test, a period of 30 days. The last column is an average of 8 proximate analyses of samples used on different dates.

Proximate analyses of raw lignite.

	Mine sample.	Car sample.	Sample as used on last test.	Average of 8 samples.
Date taken	Mar. 29	Apr. 10	May 10	....
Laboratory No.	7537	7553	7752	....
Air-drying loss ... per cent.	37.8	34.3	28.9	28.68
Moisture ... do.	42.04	40.23	38.95	38.08
Volatile matter ... do.	23.40	24.89	24.44	24.86
Fixed carbon ... do.	27.67	28.03	29.38	29.74
Ash ... do.	6.89	6.85	7.23	7.32
Sulphur ... do.	.68	.62	.91	.90
Heat value ... B. t. u.	6,079	6,246	6,327	6,579

The ground and dried lignite used in test 294 contained 11 per cent moisture. It made well-formed briquets that had rather brittle edges and cracked sides. They were strong enough to endure careful handling and were the strongest lot made from this fuel.

In tests 298, 299, 300, 301, 302, 303, and 304 the moisture content and the pressure were varied in an endeavor to get the best conditions, but the few briquets made were too weak to handle and were not kept.

In test 305 the material contained about 15 per cent moisture; some of the briquets were strong enough to endure careful handling, but they were softer than those from test 294 and crumbled more easily. Apparently the material was too coarse and contained too much moisture. The briquets were, however, a great improvement over those from tests 298 to 304, inclusive.

Tests 306 produced some fairly good briquets, there being little choice between the lot and those from test 305. Apparently the moisture content of the dried material was too high. The briquets crumbled easily and when struck gave a dull sound instead of the sharp, metallic ring of good briquets. The briquets from tests 305 and 306 were mixed in storage, and the cohesion tests were made from a mixed sample.

The briquets made by test 307 had better forms than those from any other test on this fuel, but were not so strong as those from tests 294, 305, or 306.

This lignite can be made into briquets but further tests are desirable to determine the best conditions. Fine grinding is a requisite. About 10 to 12 per cent moisture in the material seems desirable and a heavy pressure is necessary. The proportion of natural binder in the lignite being rather low, briquets made without adding artificial binder are likely to be weak. Probably the use of a small proportion, perhaps 2 to 4 per cent, of artificial binder and a different type of press would give better briquets.

Summary of briquetting tests.

	Test 294.	Test 298.	Test 299.	Test 300.	Test 301.
Size as shipped	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.
Size as used:					
Over $\frac{1}{4}$ inch ... per cent	0.0	1.0	0.0	0.0	0.5
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	27.7	21.0	20.0	20.0	12.0
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	40.0	31.5	36.0	36.0	28.5
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	22.3	25.5	25.0	25.0	27.0
Through $\frac{1}{40}$ inch ... do	10.0	21.0	19.0	19.0	32.0
Details of manufacture:					
Machine used	German.	German.	German	German.	German.
Briquetting temperature ... °F	90	75	75	75	68
Binder used	None.	None.	None.	None.	None.
Tangent of die angle	$\frac{5.5}{89}$	$\frac{6}{89}$	$\frac{6}{89}$	$\frac{4}{89}$	$\frac{4}{89}$
Steam pressure on drier ... pounds	20	20	20	20	15
Weight of—					
Fuel briquetted ... do	2,840	None.	*a* None.	*a* None.	*a* None.
Briquets, average ... do	0.775	....	....	....	....
Heat value per pound:					
Fuel as received ... B. t. u.	6,311	6,586	6,840	6,840	6,653
Briquets ... do	9,191	....	....	....	....
Moisture in briquet mixture ... per cent	11.13	9.19	9.88	9.88	9.19
Drop test (1-inch screen):					
Held ... do	25	....	....	....	....
Passed ... do	75	....	....	....	....
Tumbler test (1-inch screen):					
Held ... do	30	....	....	....	....
Passed ... do	70	....	....	....	....
Fines through 10-mesh sieve ... do	67	....	....	....	....

	Test 302.	Test 303.	Test 304.	Test 305.	Test 306.	Test 307.
Size as shipped	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.
Size as used:						
Over $\frac{1}{4}$ inch ... per cent	0.5	0.5	0.5	2.0	0.8	0.8
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	18.0	20.0	21.0	22.5	21.5	21.5
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch ... do	24.0	34.5	31.5	30.5	32.2	32.2
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	26.0	25.5	24.5	21.5	22.5	22.5
Through $\frac{1}{40}$ inch ... do	31.5	19.5	22.5	23.5	23.0	23.0
Details of manufacture:						
Machine used	German.	German.	German.	German.	German.	German.
Briquetting temperature ... °F	78	74	88	81	85	102
Binder used	None.	None.	None.	None.	None.	None.
Tangent of die angle	$\frac{4}{89}$	$\frac{5}{89}$	$\frac{6}{89}$	$\frac{6}{89}$	$\frac{6}{89}$	$\frac{6}{89}$
Steam pressure on drier ... pounds	10	10	10	8	12	16
Weight of—						
Fuel briquetted ... do	*b* 500	*b* 700	*b* 1,950	1,880	2,138	700
Briquet, average ... do	....	....	0.9	0.77	0.77	0.82
Heat value per pound:						
Fuel as received ... B. t. u.	6,586	6,397	6,520	6,995	6,327	6,327
Briquets ... do	9,504	9,691	9,684	8,995	9,490	9,698
Moisture in briquet mixture ... per cent	9.81	11.02	11.56	14.80	12.12	9.29
Drop test (1-inch screen):						
Held ... do	....	....	....	16.00	16.00	5.00
Passed ... do	....	....	....	84.00	84.00	95.00
Tumbler test (1-inch screen):						
Held ... do	....	....	....	17.00	17.00	7.00
Passed ... do	....	....	....	83.00	83.00	93.00
Fines through 10-mesh sieve ... do	....	....	....	60.00	60.00	60.00

a The few briquets made were too weak to handle.
b Briquets were scrapped, as they were too weak to handle.

PROXIMATE ANALYSES OF BRIQUETS.

	Test 294.	Test 301.	Test 302.	Test 303.	Test 304.	Test 305.	Test 306.	Test 307.
Laboratory No.	7611	7702	7703	7719	7723	7726	7755	7751
Moisture.........per cent..	8.56	8.30	10.87	10.26	10.18	12.10	11.41	10.29
Volatile matter.........do....	37.51	37.00	36.83	38.79	37.82	35.00	36.52	37.14
Fixed carbon.........do....	41.23	42.80	42.71	42.35	43.00	44.10	42.55	43.93
Ash.........do....	12.70	11.90	9.59	8.60	9.00	8.80	9.52	8.64
Sulphur.........do....	2.24	1.90	1.58	1.12	1.21	1.35	1.40	1.02

PITTSBURG No. 14.

A sample lot, 3 cars, of run-of-mine lignite from the Ione mine, at Ione, Amador County, Cal., was designated Pittsburg No. 14.

Briquetting tests 308, 309, 310, 311, 313, 314, 315, and 329 were made on it. Gas-producer test 185 and house-heating boiler test H90 were made on the raw lignite, and gas-producer test 188 and house-heating boiler tests H88 and H89 were made on the briquets.

When received at the plant this lignite was light brown in color. The pieces could be easily polished by rubbing and had a peculiar waxy feel, like that of soapstone. It was evident from a casual inspection that the lignite was rich in binding material. The results of subsequent tests and analyses confirmed this fact.

The following table shows the changes in composition of this fuel after storage at the plant for 68 days, until used for the last briquet test. The last column gives the average of proximate analyses of 8 samples used for tests on different dates. No mine sample was taken.

Proximate analyses of raw lignite.

	Car sample.	Sample as used on last test.	Average of 8 samples.
Date taken	Apr. 22.	June 29.	....
Laboratory No.	7621	8019	....
Air-drying loss.........Per cent..	32.3	22.7	26.09
Moisture.........do.....	39.46	27.97	34.52
Volatile matter.........do.....	29.50	34.54	33.84
Fixed carbon.........do.....	17.55	22.66	18.61
Ash.........do.....	13.49	14.83	13.02
Sulphur.........do.....	.97	1.58	1.08
Heat value.........B. t. u..	6,080	7,546	6,764

In the first test (308) of this sample of lignite, the press worked much more easily than in the tests of Texas and North Dakota lignites. The dried material contained about 9.75 per cent moisture and the dies were set to give a high pressure. The briquets had rough surfaces, especially at the edges, but were of good shape. The cohesion test showed them to be stronger than the briquets made from any other lignite, in fact they were surpassed in strength only by those made from the same lignite in test 329.

In test 309 the briquets were of excellent shape as they left the press, but on slight handling most of them broke in two along a shearing plane that extended diagonally from one long edge to another. Investigation indicated that this weakness resulted from the material being too dry to flow perfectly in the mold.

In the next test (310) the moisture content of the briquet mixture was 1 per cent higher ($8\frac{1}{2}$ per cent) and the shearing was practically eliminated, although there were still some signs of it. On account of this defect none of the briquets from tests 309 and 310 were saved; the pieces were scrapped, and no cohesion tests were made.

Test 311 was made to see if weathering injured the briquetting qualities of this lignite. The material used had been spread on the ground back of the briquet building for 22 days and had become fine slack. In comparison with the car sample the only change shown by proximate analysis was a smaller percentage of moisture. Apparently the weathering did not affect the briquetting qualities at all, for the test produced briquets having good shapes and surfaces and satisfactory strength.

In test 313 the moisture in the briquet material was a little over 9 per cent, and a set of dies, ground to give a very heavy pressure, was used. The briquets were the weakest of any made from this lignite. Their lack of strength may have resulted in part from the dies being new, since dies work better after being polished by use.

Tests 314 and 315 were made to determine if better briquets could be obtained by passing the undried material through a screen having $\frac{5}{16}$-inch openings. The undried material for test 314 was not screened, but that for 315 was screened. With the same steam pressure in the drier, the dried material contained 14.6 per cent moisture in test 314 and only 10.13 per cent in test 315. The two lots of briquets had satisfactory strength, but both the drop and tumbler tests showed that the screened material made the stronger briquets, the gain in strength being 12 per cent by the drop test and 26 per cent by the tumbler test. The two lots, however, did not differ much in general appearance, both being well formed and smooth.

Test 329 furnished the best lot of briquets made from this lignite. There was 10 per cent moisture in the briquet material; the pressure used was high, but lower than in tests 313, 314, and 315. The briquets had well-polished surfaces, and were the strongest made from any of the lignites named in this report. A "cohesive strength" of 71 per cent was shown by the drop test and 68 per cent by the tumbler test.

This lignite briquets very easily, since it contains more than enough natural binder. Weathering to slack does not reduce its briquetting properties appreciably. Excellent briquets were made with the German press by drying the ground lignite till it contains from $8\frac{1}{2}$ to 15 per cent moisture. The best briquets will be obtained when the material is ground so that all of it passes a $\frac{1}{4}$-inch screen and 40 per cent passes a $\frac{1}{20}$-inch screen, when it contains 10 to 12 per cent moisture, and when it is subjected to a moderately high pressure. An extremely high pressure does not give the best results and increases the cost of briquetting. The right pressure can be had by using a set of dies so ground that the tangent of the die angle is $\frac{6}{89}$.

The following is a summary of the principal features of the tests on this sample:

Summary of tests.

Test No.	Moisture in briquet material.	Pressure in mold.	Character of briquets.		Remarks.
			Form.	Strength.	
	Per cent.				
308	9.74	High	Good	Very good	Sides slightly cracked.
309	7.78	do	Excellent	Weak	Sheared diagonally.
310	8.51	do	Good	Good	No shearing evident.
311	7.68	do	do	do	Material too dry.
313	9.14	Very high	do	Fair	Do.
314	14.61	do	Very good	Very good	
315	10.13	do	do	do	
329	10.00	High	Excellent	Excellent	

In laboratory experiments a mixture of this lignite with 25 and with 50 per cent of a Pittsburg coal made excellent briquets, and further tests should be made with the mixture on the German machine. Patents have been granted for utilizing the natural binder of certain lignites to briquet mixtures of these lignites with bituminous coal slack, and thus produce a fuel superior to either constituent without using artificial binder. Anthracite screenings can be used in place of the bituminous slack, and the substitution of such screenings would lessen the production of smoke in stoves or under boilers.

Preliminary results from gas-producer tests of raw and briquetted samples of this lignite showed that the consumption of fuel, as fired per hour per brake horsepower developed, was 4.06 pounds for the raw lignite and only 2.84 pounds for the briquets. The relative efficiency of the raw and the briquetted lignite as boiler fuel was roughly shown by house-heating boiler tests H88, H89, and H90. Each pound of raw lignite evaporated 2.82 pounds of water from and at 212° F., and each pound of briquets evaporated 3.23 pounds.

The briquets resisted weathering well; samples showed little change after exposure for several months to autumn and winter weather (see Pls. VI to XI).

Briquetting tests.

	Test 308.	Test 309.	Test 310.	Test 311.	Test 313.	Test 314.	Test 315.	Test 329.
Size as shipped	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.	r. o. m.
Size as used:								
Over $\frac{1}{4}$ inch...per cent..	2.0	3.5	2.0	2.0	6.5	10.0	5.0	3.0
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch...do....	18.5	21.0	18.5	18.5	29.0	33.0	29.0	29.0
$\frac{1}{20}$ inch to $\frac{1}{10}$ inch...do....	31.0	33.0	29.0	32.5	23.0	21.5	23.5	26.0
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch...do....	23.5	24.0	24.5	22.5	17.5	14.5	18.5	18.0
Through $\frac{1}{40}$ inch...do....	25.0	18.5	26.0	24.5	24.0	21.0	24.0	24.0
Details of manufacture:								
Machine used	German	German	German	German	German	German	German	German
Briquetting temperature....°F..	102	95	86	91	92	104	95	107
Binder used	None.	None.	None.	None.	None.	None.	None.	None.
Tangent of die angle	$\frac{6}{89}$	$\frac{6}{89}$	$\frac{6}{89}$	$\frac{6}{89}$	$\frac{7}{89}$	$\frac{7}{89}$	$\frac{7}{89}$	$\frac{6}{89}$
Steam pressure on drier..pounds..	10	15	13	10	10	5	5	7
Weight of—								
Fuel briquetted...do....	6,875	[a] 1,790	2,457	3,407	2,915	13,937	8,304	9,000
Briquets, average...do....	0.88	0.85	0.90	0.86	....	1.05	1.02	0.92
Heat value per pound:								
Fuel as received...B. t. u..	6,422	6,829	6,556	7,090	6,545	6,545	6,491	7,546
Briquets...do....	9,227	10,138	9,704	9,734	9,360	8,942	9,131	9,187
Moisture in briquet mixture, per cent	9.74	7.78	8.51	7.68	9.14	14.61	10.13	10.00
Drop test, 1-inch screen:								
Held...per cent..	68	(a)	....	52	28.00	50	62	71
Passed...do....	32	(a)	....	48	72.00	50	38	29
Tumbler test, 1-inch screen:								
Held...do....	68	(a)	....	48	....	38	64	68
Passed...do....	32	(a)	....	52	....	62	36	32
Fines through 10-mesh sieve, per cent	63.5	(a)	....	65.5	....	40	45.5	58.5
Weather test:								
Time exposed when examined...days..	66	....	....	66	66	66	66	66
Condition when examined	A	....	....	A	B	A	A	A

a Briquets scrapped on account of diagonal cracks in them.

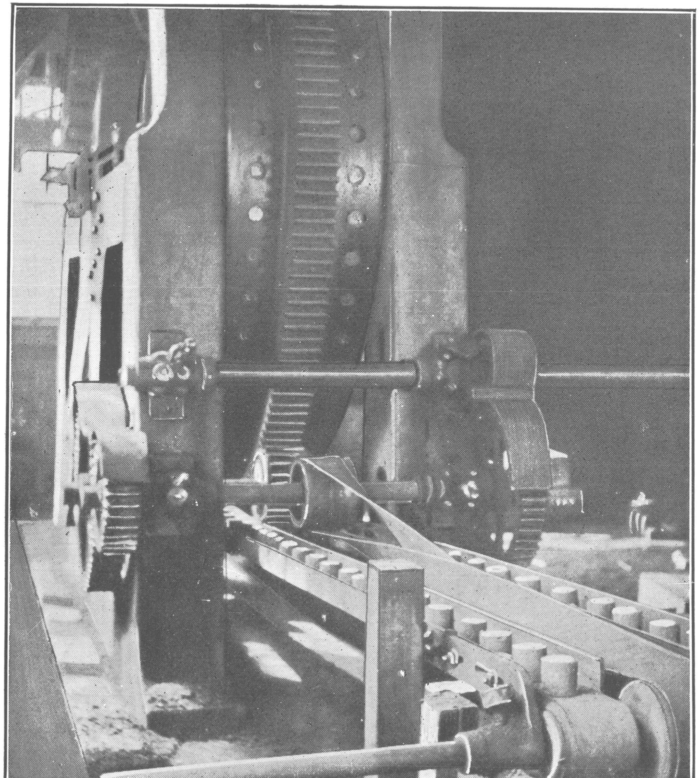
PROXIMATE ANALYSES OF BRIQUETS.

Laboratory No...Per cent..	7774	7757	7773	7775	7846	7861	7864	8018
Moisture...do....	9.07	6.66	7.85	7.34	9.17	12.66	10.40	9.82
Volatile matter...do....	46.53	43.99	47.53	49.04	46.28	44.95	46.60	46.48
Fixed carbon...do....	25.01	32.80	27.01	25.97	26.75	24.59	25.31	24.54
Ash...do....	19.39	16.55	17.61	17.65	17.80	17.80	17.69	19.16
Sulphur...do....	1.83	1.70	1.56	1.51	1.48	1.24	1.47	1.77

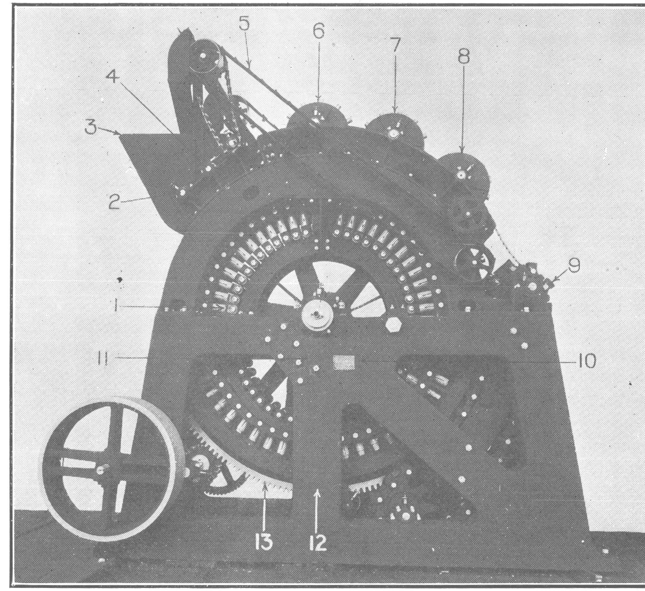
TESTS ON THE LADLEY PRESS.

The briquetting section had an opportunity to make tests of this lignite with the Ladley briquetting press of the Indianapolis Pressed Fuel Co., Indianapolis, Ind. The press is of the rotary plunger type and has two rows of molds, 108 molds in each row, arranged in the heavy rim of a wheel. The machine exerts a pressure of 5,000 to 6,000 pounds per square inch. The construction of the press is shown by the views in Plate VI. The lignite was dried in the Schulz drier at the Pittsburg plant until it contained 6.79 per cent moisture and was then shipped to Indianapolis.

The tests were made as follows: Enough of the dried material to make two or three briquets was heated in an iron pail. One mold was filled as full as possible by hand; the material was then packed in



A. FRONT VIEW OF LADLEY BRIQUET PRESS.



B. SIDE VIEW.

1, One of the 108 rams; 2 and 4, shafts of mold-filling device; 3, feed box; 5, belt conveyor to return superfluous dust to feed box; 6, 7, 8, tamping wheels to fill molds under pressure; 9, link or anvil-blocks belt closing outer end of molds to permit application of pressure by rams; travels tangentially to mold wheel during part of revolution; 10, cams moving rams are behind frame at this point; 11, relief springs holding cams in place are attached to frame at this point; 12, point at which briquets are ejected from molds; 13, gear turning mold wheel.

the mold with a round bar and a sledge hammer, and the mold was again filled and tamped. Then the machine was started and the briquet was formed and ejected.

METHOD OF HEATING THE MOLDS.

Hot molds were needed for these tests, but, although the molds on this machine had steam jackets, the steam piping was disconnected to keep any water that might be pocketed in the rim from freezing, so it was necessary to heat the molds in another way. In the first test a red-hot iron was put in a mold for some time. In the other tests a gasoline torch, which gave a more even heat, was used.

METHOD OF HEATING LIGNITE.

In tests 1, 4, 5, 6, 7, 8, and 9 each pailful of the material was heated by dry steam from the nozzle of a hose, the steam being taken from the dome of the boiler. The steam escaping from the nozzle was slightly superheated, and although the loss of heat from radiation was relatively large, the lignite could be heated to a temperature of 208° F. The length of the heating was from one to two and a half minutes; the temperatures obtained were from 194° to 208° F. In tests 2, 3, and 10 the material was heated over a forge fire before pressing.

SHAPE AND WEIGHT OF BRIQUETS.

The briquets had a cylindrical shape and were 2½ inches in diameter and 3 inches long. The weight of a briquet varied from 10 to 10½ ounces.

The analyses of the briquet material before and after drying, and of the briquets made from material heated by the two methods described, are given in the following table:

Analyses of lignite and briquets.

	Material.		Briquets.	
	Before drying.	After drying.	Material heated by live steam.	Material heated by forge fire.
Moisture....Per cent..	39.46	6.79	13.37	4.47
Volatile combustible....do.....	29.50	48.72	44.36	47.43
Fixed carbon....do.....	17.55	23.49	23.48	26.23
Ash....do.....	13.49	21.00	18.79	21.87
Sulphur....do.....	.97	1.86	1.54	1.82
Heat value....B. t. u..	6,080	9,126	8,662	9,538

The principal details of the tests are summarized as follows:

Details of tests 1 to 10 on the Ladley press.

Test No.	Heating of material.				Remarks.
	Method used.	Time of heating.	Temperature of material before pressing.	Quality of briquets obtained.	
		Min.	*° F.*		
1	Steam jet......	(*a*)	(*b*)	Poor; too soft and dusty.	Mold too cold.
2	Forge fire......	(*a*)	(*b*)	Poor; too dry.	
3	.....do.........	(*a*)	199	Fair..........	Water added before heating to replace evaporation.
4	Steam jet......	(*a*)	199	Good.........	Improvement made.
5	.....do.........	(*a*)	(*b*)	Fair..........	Mold too cold.
6	.....do.........	1½	208	Good.........	Satisfactory briquet.
c 7	.....do.........	2	205	Excellent.....	Do.
8	.....do.........	2½	194	.....do........	Do.
9	.....do.........	1	176	Good.........	Do.
10	Forge fire......	(*a*)	212-230	Excellent.....	Do.

a Not noted.
b Not taken.
c A test, 7A, was made under same conditions as test 7 on the following day.

The briquets made in tests 7 and 10 had a satisfactory appearance, their surfaces being smooth and hard and their edges sharp and firm. The briquets from test 7 had fewer surface cracks than those from test 10, although both lots were smooth enough. With steam in the steam jackets the molds would be hotter and the results might be even better.

The condensation of the steam used for heating the material in test 10 increased the moisture content of the material and of the resulting briquets. For this reason the briquets from that test had a lower heat value than those from test 7, in which the material was heated over a forge fire.

The tests demonstrated that without added binding material at least one American lignite could be made into good briquets in an American press.

STOVE AND GRATE COMBUSTION TESTS OF BRIQUETS.

OBJECT OF TESTS.

Combustion tests of briquets of this California lignite were made at Pittsburg, Pa., in a range and in an open heating grate. The object of these tests was—

1. To study the behavior of the briquets in the fire and note: (*a*) Whether they fell to pieces before they were consumed; (*b*) the length of flame; (*c*) the quantity of smoke.

2. To determine the completeness of combustion as shown by the percentage of combustible matter in the refuse.

TESTS IN A RANGE.

The range used for the test was owned by Mr. Dietz, an employee of the United States Geological Survey. It had Dockash grates with openings one-half inch wide, and could burn hard or soft coal. In the first trial, the attempt was made to burn the briquets under the same conditions as the Pittsburg coal regularly used. Some of this coal was mixed with the briquets, however, and the fire box was filled so high that proper combustion was impossible. For the next trial, most of the coal was raked from the fire box, and a fire gradually built with briquets alone. The results were excellent. It was claimed that the briquets gave a better fire than the best Pittsburg coal.

Briquets were added at half-hour intervals. The fire did not require much poking, but it was raised slightly with a slice bar when it packed too much at the bottom. This slicing did not cause excessive loss of unburned material through the grate, as was shown by the results of the test.

In five hours 32 briquets, or 32 pounds of fuel, were burned. The refuse weighed 8 pounds and was therefore 25 per cent of the fuel as fired. An analysis of the briquets showed the ash content to be 19.16 per cent.

Analysis of the refuse or "ashes" gave the following results:

Moisture	2.52
Combustible matter	33.05
Ash (actual)	64.43

Only one-third of the refuse was combustible matter, and since the refuse was 25 per cent of the fuel fired, the loss of combustible through the grates was $33.05 \times 25 = 8.3$ per cent of the coal, or 11.5 per cent of the combustible fired. This loss of 8.3 per cent is low for a kitchen stove, which at best does not burn fuel with high efficiency, and compares favorably with the percentage of loss for good bituminous coal burned in such a stove.

The proximate analyses of the briquets and of the refuse from the kitchen-stove and the heating-grate tests compare as follows:

Proximate analyses of briquets and of refuse from kitchen-stove and heating-grate tests.

Material.	Briquets.	Refuse from—	
		Kitchen-stove test.	Heating-grate test.
Moisture ... per cent..	9.82	2.52	0.77
Volatile matter ... do....	46.48	....	....
Fixed carbon ... do....	24.54	....	....
Ash ... do....	19.16	64.43	72.60
Sulphur ... do....	1.77	....	....
Heat value ... B. t. u..	9,187	....	....
Combustible matter ... per cent..	71.02	33.05	26.63

TESTS IN A HEATING GRATE.

Through the courtesy of the quartermaster's office, the author obtained the use of a heating grate in one of the vacant buildings on the arsenal grounds at Pittsburg, Pa., for testing the combustion of the briquets in a heating grate. The grate was 24 inches wide, 9 inches deep at the center, and slightly less at the sides. The grate bars were of cast iron. The bottom bars ran from the back to the front and were spaced 1 inch apart.

A fire was started in the grate with paper and a little wood, upon which were placed 25 pounds of briquets, or enough to fill the grate to the top.

A thermometer was hung on the outside of the building and another on the wall of the room about 4 feet in front of and to one side of the fire and about 2 feet above the level of the grate.

The temperatures taken were not expected to furnish data of interest. The main object of the tests was to note the combustion of the briquets and whether the economic results obtained were better than from tests under steam boilers.

Observations on grate test.

Time.	Temperature.		Weight of fuel as fired.
	Outside.	Inside.	
	° *F.*	° *F.*	*Pounds.*
9.30 a. m.	37	51	25
9.45 a. m.	37	55	20
10.30 a. m.	36	67	20
12 noon.	34	[a] 65	35
1.30 p. m.	31	64	0
4 p. m.	30	60	0
5 p. m.	29	55	0

[a] Drop of temperature caused by opening an outside door.

No fuel was added to the fire after 12 noon. At 5 p. m., after burning five hours without attention, the fire was practically burned out.

The table shows that in seven and one-half hours 100 pounds of briquets were fired, giving 24 pounds or 24 per cent of refuse.

After the briquets were well ignited they burned freely—in fact, too freely for heating a room in moderate weather—but after they had burned an hour and a half the ash partly closed the open spaces between the grate bars and the fire became about right for moderately cold weather.

The briquets burned with a bright yellow flame, much cleaner than the smoky flame from some bituminous coals, and the chimney showed only a slight yellowish smoke even directly after firing fresh fuel. The fire was unpleasantly hot to the face at a distance of 8 feet. No unpleasant odor could be detected in the room, though the gases from burning lignite have a characteristic odor and irritate the eyes and nose.

The combustible in the refuse was only 26.63 per cent, and as there was 24 per cent of refuse, the loss of fuel through the grate bars was approximately 6 per cent of the total fuel fired. This loss is no greater than from a coking coal burned under the same conditions. The loss through the grate of the kitchen range was approximately 8 per cent, or 2 per cent more than through the fireplace grate. The latter grate had wider spaces between the grate bars, but the fire in it did not need raking, while some raking of the kitchen range grate was necessary.

The loss in both grates, however, was less than anticipated. The lignite used is noncoking and one would naturally expect from it a larger loss of unburned material through the grate than from a coking coal.

CONCLUSIONS.

From the observed results of these combustion tests the following conclusions may be drawn:

The briquets ignite readily, make a hot fire, and burn freely until consumed.

Little shaking or poking of the fire is needed to obtain maximum efficiency from the fuel.

The loss of unburned fuel through the grates, 6 to 8 per cent, is not excessive and could be reduced by using step grates, or grates with narrower spaces between the bars.

A grate measuring 8 by 24 inches is big enough for heating a large room with these briquets.

Under the test conditions little smoke was made; this smoke was light yellow and would not be offensive in residential districts.

The briquets should prove a satisfactory domestic fuel, and if they can be produced cheaply enough should compete with other fuels for steam production.

PITTSBURG No. 15.

A sample consisting of one car of 3-inch lump lignite from the McClure mine, Vanderwalker, Ward County, N. Dak., was designated Pittsburg No. 15.

Briquetting tests 324, 325, 326, and 330 were made on it, but no gas-producer or steaming tests.

The changes in composition of the fuel during transportation from the mine to the plant, a period of 14 days, and during storage at the plant for 73 days, are shown below. The figures in the last column represent an average of 3 analyses made on different dates.

Proximate analyses of raw-fuel lignite.

	Mine sample.	Car sample.	Sample as used on last test.	Average of 3 samples.
Date taken	Apr. 3	Apr. 17	June 29	....
Laboratory No	7587	7631	8020	....
Air-drying loss .... per cent	28.90	25.60	18.30	15.83
Moisture .... do	36.64	34.30	29.09	27.94
Volatile matter .... do	22.64	23.10	27.13	27.12
Fixed carbon .... do	30.74	29.93	34.88	34.99
Ash .... do	9.98	13.67	8.90	9.95
Sulphur .... do	.45	.52	.56	.54
Heat value .... B. t. u.	6,394	6,284	7,385	7,364

Dried lignite containing 7.4 per cent moisture was used for tests 324 and 325. In test 324 a set of dies, used in test 323, gave the heaviest pressure the machine would stand. The material stalled the machine, the end of a stamp broke, and no briquets were made. Another set of dies giving less pressure was used for test 325 on the same lot of material. The material would not work satisfactorily, however, with this set of dies, and after several attempts the test was stopped and the rest of the lignite in the hopper was thrown away.

The next lot of ground lignite, dried to contain 10.8 per cent moisture, was used for test 326. No briquets were made and the material came out of the press in a loose form. The lignite evidently lacked binding properties, a defect that was confirmed by extraction tests made later. Another test (330) was made on a lot of material dried to contain 11.6 per cent moisture, but no briquets were formed. Similar results were obtained on tests 326 and 330. No further tests could be made on this lignite at the time.

The lignite evidently does not contain enough binding material to give briquets on the German press. Without doubt it can be successfully briquetted by adding a binder and using a press made to work with a binder. It is desirable to make further tests of this lignite, first on the laboratory hand press and afterwards on the English machine belonging to the Bureau of Mines.

Briquetting tests.

	Test 324.	Test 325.	Test 326.	Test 330.
Size as shipped	3″ lump.	3″ lump.	3″ lump.	3″ lump.
Size as used:				
Over $\frac{1}{4}$ inch ... per cent	1.5	1.5	2.0	1.0
$\frac{1}{10}$ inch to $\frac{1}{4}$ inch ... do	28.0	28.0	30.0	30.0
$\frac{1}{20}$ to $\frac{1}{10}$ inch ... do	30.0	30.0	29.5	28.0
$\frac{1}{40}$ inch to $\frac{1}{20}$ inch ... do	20.5	20.5	18.5	19.0
Through $\frac{1}{40}$ inch ... do	20.0	20.0	20.0	22.0
Details of manufacture:				
Machine used	German.	German.	German.	German.
Briquetting temperature ... °F	93	93	93.6	111
Binder used	None	None.	None.	None.
Tangent of die angle	$\frac{7}{89}$	$\frac{6}{89}$	$\frac{6}{89}$	$\frac{6}{89}$
Steam pressure on drier ... pounds	5	5	4	3
Weight of—				
Fuel briquetted ... do	None.	None.	None.	None.
Briquets, average ... do	....	....	....	....
Heat value per pound:				
Fuel as received ... B. t. u.	7,738	7,738	6,970	7,385
Briquets ... do	....	....	....	....
Moisture in briquet mixture ... per cent	7.40	7.40	10.80	11.60

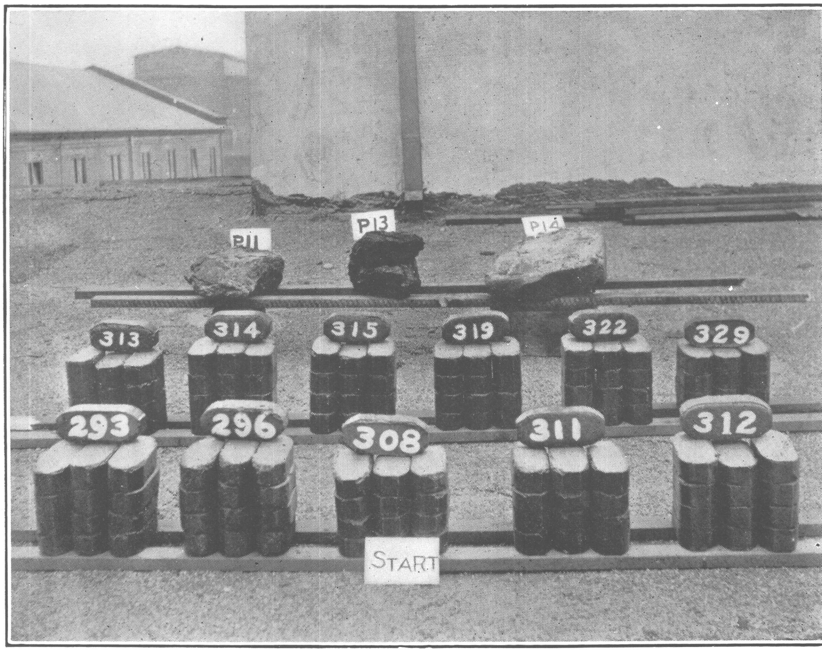
GENERAL SUMMARY OF RESULTS.

LIGNITES BRIQUETTED WITHOUT ARTIFICIAL BINDER.

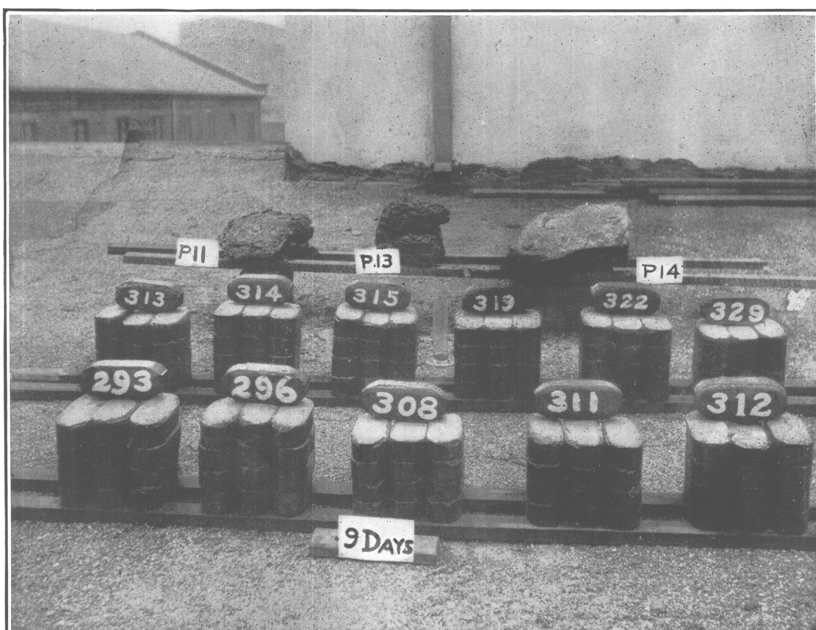
The following were the samples of lignite from which satisfactory briquets were made on the German press without adding a binder:

Field designation.	Situation of mine.	Field designation.	Situation of mine.
Pittsburg No. 8	Lytle, Medina County, Tex.	Pittsburg No. 13[a]	Lehigh, Stark County, N. Dak.
Pittsburg No. 11	Scranton, Bowman County, N. Dak.	Pittsburg No. 14	Ione, Amador County, Cal.

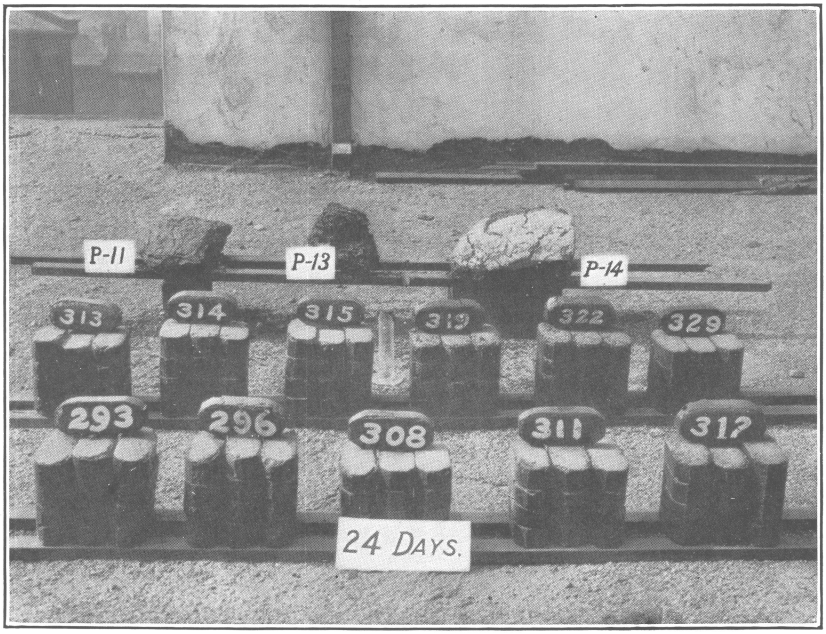
[a] Difficult to briquet.



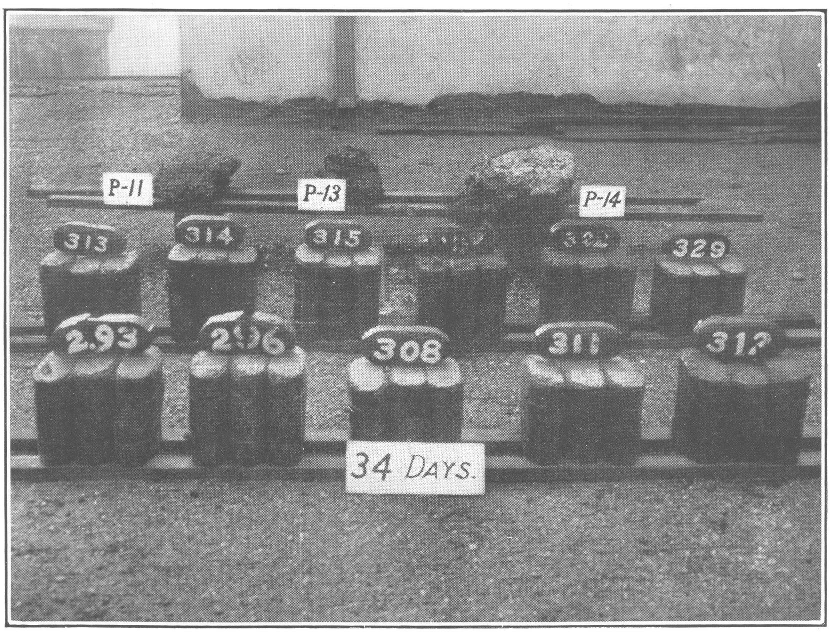
A. BRIQUETS AT BEGINNING OF WEATHERING TEST.



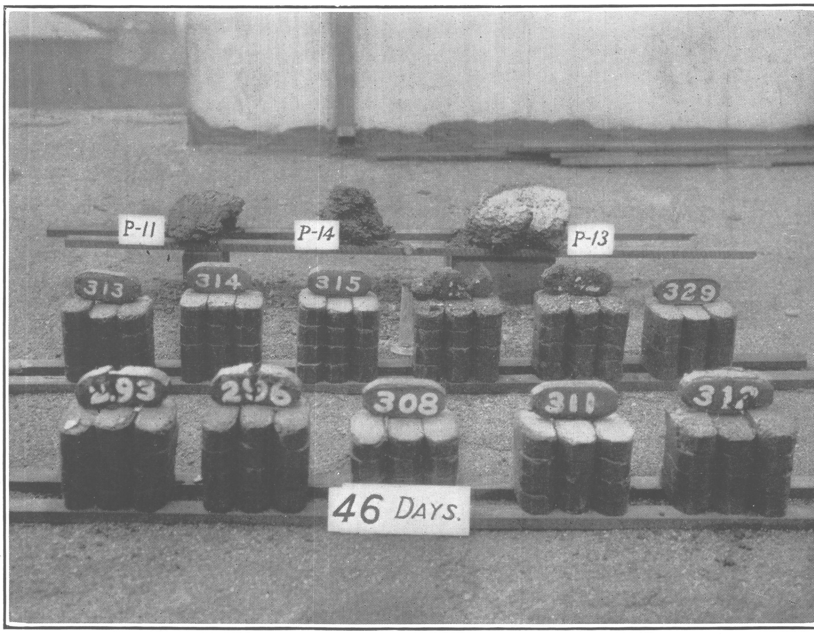
B. BRIQUETS AFTER EXPOSURE FOR 9 DAYS.



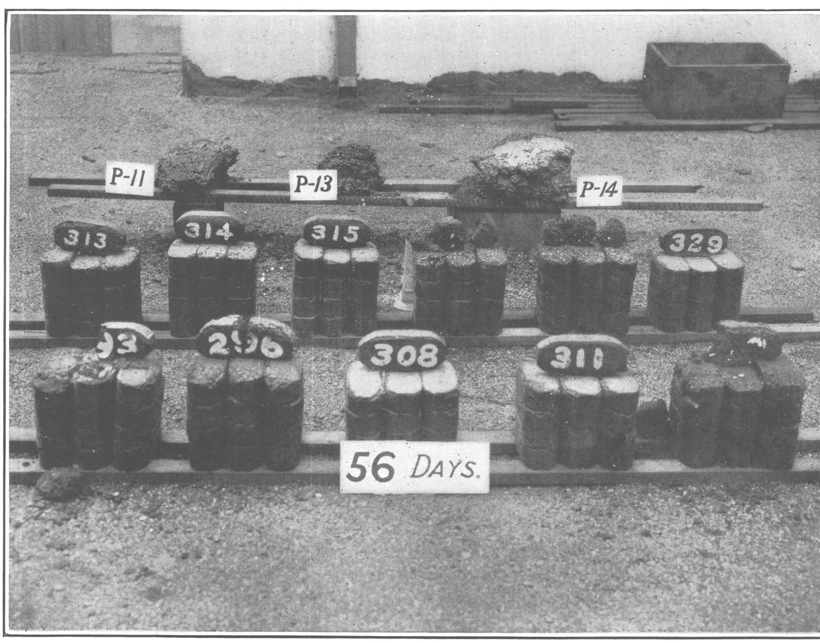
A. BRIQUETS AFTER EXPOSURE FOR 24 DAYS.



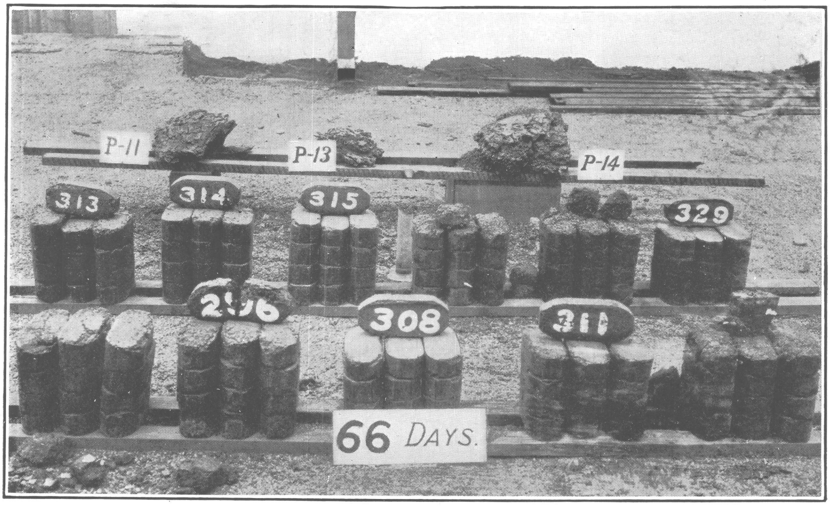
B. BRIQUETS AFTER EXPOSURE FOR 34 DAYS.



A. BRIQUETS AFTER EXPOSURE FOR 46 DAYS.

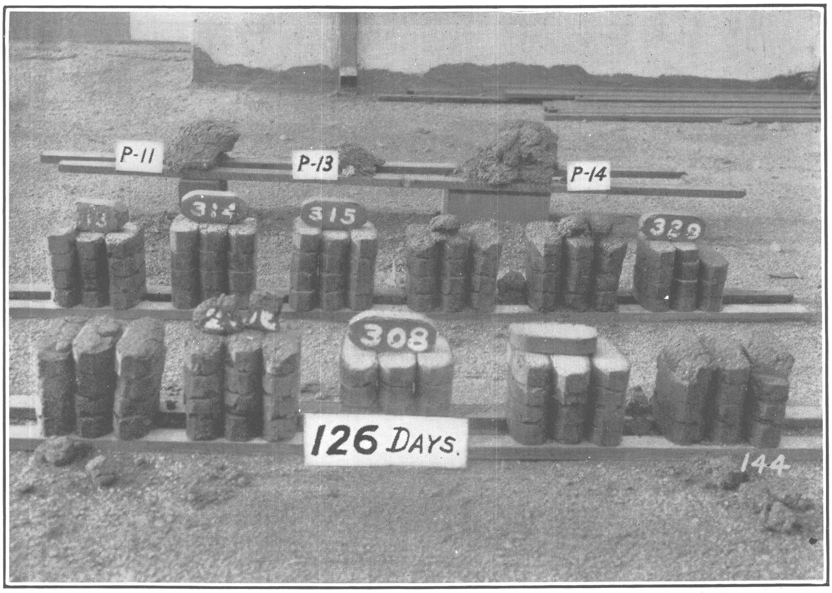


B. BRIQUETS AFTER EXPOSURE FOR 56 DAYS.

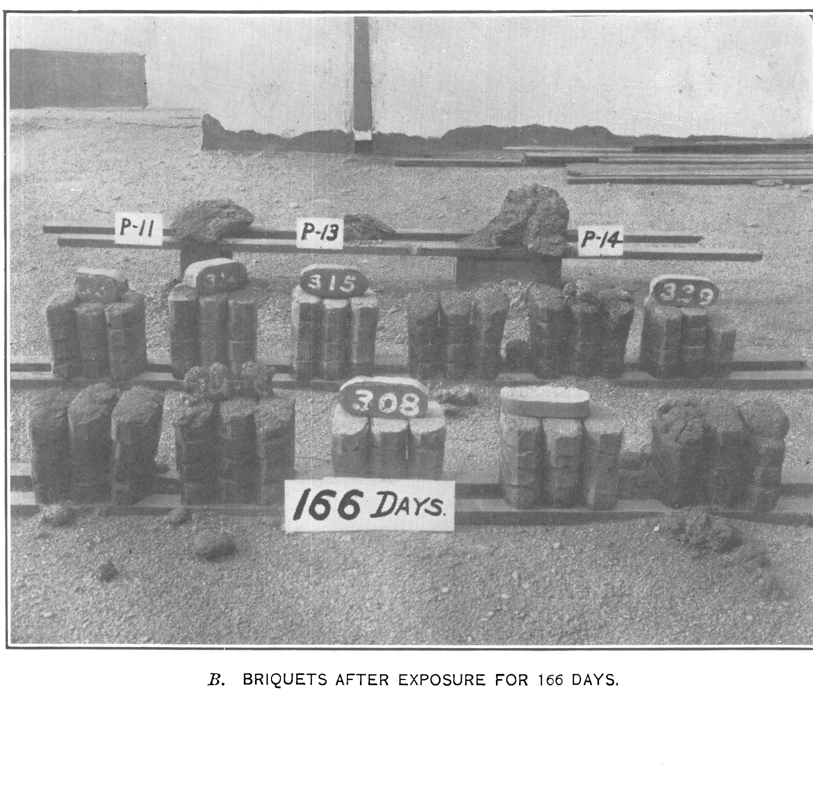


A. BRIQUETS AFTER EXPOSURE FOR 66 DAYS.

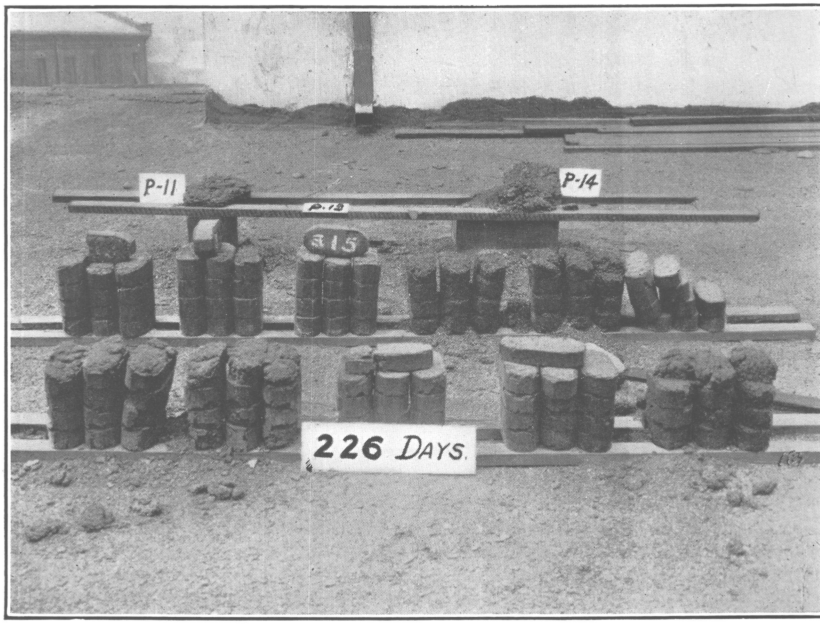
B. BRIQUETS AFTER EXPOSURE FOR 96 DAYS.



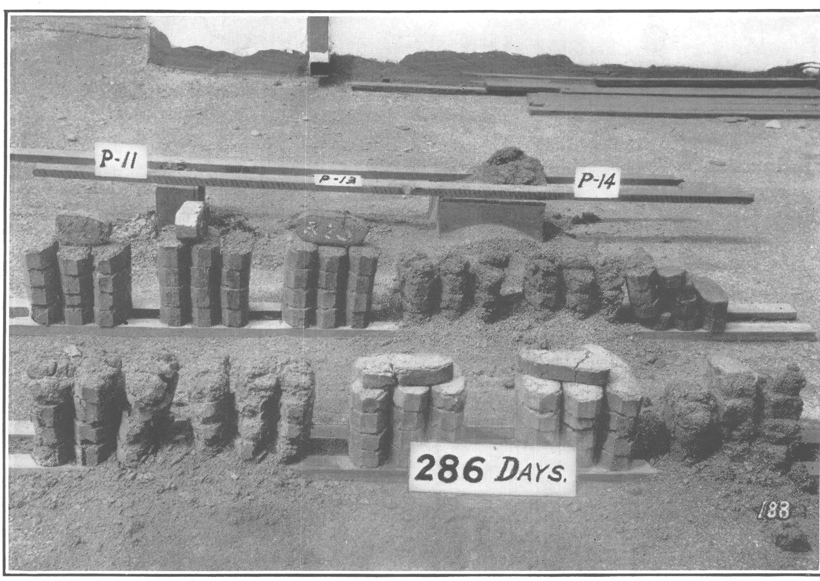
A. BRIQUETS AFTER EXPOSURE FOR 126 DAYS.



B. BRIQUETS AFTER EXPOSURE FOR 166 DAYS.



A. BRIQUETS AFTER EXPOSURE FOR 226 DAYS.



B. BRIQUETS AFTER EXPOSURE FOR 286 DAYS.

Of these samples, that from California was the most easily briquetted; that from Scranton, Bowman County, N. Dak., ranked next; that from Lytle, Medina County, Tex., ranked third; and that from Lehigh Mine, Stark County, N. Dak., ranked fourth.

The fact that no satisfactory briquets were made from Pittsburg Nos. 7, 9, and 15 without a binder does not show that these lignites, with added binder, will not make good briquets, and further tests must be made with such binders as coal-tar pitch, water-gas pitch, sulphite pitch, and some form of starch before a final opinion can be given as to briquetting qualities.

It is worthy of note that each of the States from which the samples came—Texas, North Dakota, and California—furnished at least one sample that made satisfactory briquets without the addition of artificial binder. This fact is encouraging, since it indicates that many American lignites may equal German lignites in briquetting qualities and that some may make better briquets.

VALUE OF EXTRACTION TESTS.

The writer wishes to emphasize the value of an extraction test as a reliable indicator of the briquetting qualities of any lignite. The results of extraction tests of the lignites mentioned in this bulletin bear such close relation to the results of the briquetting tests that the writer feels warranted in stating that a lignite containing 1½ per cent or more matter soluble in carbon bisulphide can probably be briquetted on a press of the German type without the aid of artificial binder.

COST OF BRIQUETS.

The tests described show seemingly that the cost of briquetting run-of-mine lignites with a German plant would be from $1.35 to $1.75 per ton, according to the location of the plant.

On the assumptions that the plant costs $56,000; that it is to be located at the mine; is to run 2 shifts of 10 hours each, or 20 hours per day; and is to have a capacity of 50 tons of briquets per day of 20 hours, the costs figure out as follows:

COST OF LIGNITE.

In 1907 the average price per ton of lignite at the mine was:[a] In California, $2.74; in Texas, $1.01; and in North Dakota, $1.61. The average cost of mining coal in the United States[b] may be taken as 90 per cent of the price at the mine; for the three States named the average cost of lignite at the mine would then be: Texas, 90 cents per ton; North Dakota, $1.45; and California, $2.46.

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[a] Parker, E. W., The production of coal in 1907. U. S. Geological Survey, Mineral Resources 1908, pp. 100, 157, and 187.

[b] Finlay, J. R., The cost of mining. 1909, p. 68.

COST OF MANUFACTURE.

The cost of briquetting may be subdivided as follows:

1. Labor for 2 shifts of 10 hours each:

1 superintendent, at $3 per day	$3.00
2 machine operators, at $2.50 per 10 hours	5.00
8 laborers, at $2 per 10 hours	16.00
Total labor per day for 50 tons of briquets	24.00

Labor cost per ton of briquets, 48 cents.

2. Depreciation and maintenance (10 per cent on machinery, 5 per cent on buildings) per day for 50 tons — 16.00
   Per ton of briquets, 32 cents.
3. Interest on investment (8 per cent per year on $56,000) per day for 50 tons — 15.00
   Per ton of briquets, 30 cents.
4. Power, 12½ tons lignite per day, or one-fourth ton lignite per ton of briquets made, this item varying for different localities.

The fixed charges (items 2 and 3) thus amount to 62 cents per ton, which, plus the labor charge, 48 cents, equals $1.10 per ton.

In the three States named the items of labor, fixed charges, and power (at mines) would show these totals:

Texas:	
Labor and fixed charges	$1.10
One-fourth ton lignite for power, at 90 cents per ton	.23
Total	1.33
North Dakota:	
Labor and fixed charges	1.10
One-fourth ton lignite for power, at $1.45 per ton	.36
Total	1.46
California:	
Labor and fixed charges	1.10
One-fourth ton lignite for power, at $2.46 per ton	.62
Total	1.72

TOTAL COST.

On the basis of the figures given, the cost per ton of briquets at the mine would be as follows:

Texas:	
1.32 tons lignite (33 per cent moisture) for 1 ton briquets	$1.18
Briquetting costs	1.33
Total	2.51
North Dakota:	
1.43 tons lignite (40 per cent moisture) for 1 ton briquets	2.07
Briquetting costs	1.46
Total	3.53

California:

1.43 tons lignite (40 per cent moisture) for 1 ton briquets	$3.52
Briquetting costs	1.72
Total	5.24

To recapitulate, the cost per ton of briquets, loaded on cars, from a briquet plant at the mine would be, in Texas, $2.51; in North Dakota, $3.53; and in California, $5.24.

It must be borne in mind that these figures are only approximate and are subject to wide changes because of local conditions. They apply to briquetting run-of-mine lignite to improve its heat value and weather-resisting properties rather than to briquetting slack or waste coal. Since the tests have shown that at least some lignites slacked by exposure to the weather can be made into excellent briquets, it may be possible to utilize lignite slack as well as bituminous slack and anthracite screenings for briquetting, the two latter materials having been made into briquets on a commercial scale both in this country and abroad.

Nystrom [a] gives the labor cost of briquetting lignite for plants with one press, 45.4 cents per ton; two presses, 40 cents; three presses, 36.4 cents; four presses, 31 cents; five presses, 27.3 cents; and six presses, 22.3 cents per ton. He further states that "As the wages in Canada are higher [than in Germany] this cost [of labor in a plant with one press] is assumed to be 60 cents per ton." He estimates the depreciation as 5 per cent per year and the maintenance as 3 per cent and the cost of a complete plant with one press and a yearly capacity of 13,000 tons as $75,000. Therefore his estimate of the charges for depreciation and maintenance is 8 per cent of $75,000, or $6,000 per year, 46 cents per ton. Hence the cost of labor and fixed charges, according to his estimate, is about $1.06 per ton, which agrees very closely with the writer's estimate of $1.10 per ton.

In a consular report [b] the cost per long ton of briquetting lignite in Germany is stated as follows:

Cost of manufacture of lignite briquets.

Description.	United States currency.
From lignite taken from the open working under good conditions, with water contents of about 46 per cent:	
In large briquet factories	$1.14–$1.29
In small briquet factories	1.19– 1.38
From lignite taken from the open working, with water contents of more than 46 per cent, in large briquet factories	1.38– 1.62
From lignite taken from the deep working, with water contents up to 46 per cent:	
In large briquet factories	1.31– 1.62
In small briquet factories	1.62– 1.74
From lignite taken from the deep working, with water contents of more than 46 per cent, in large briquet factories	1.66– 1.86

[a] Nystrom, E., Peat and lignite; their manufacture and uses in Europe: Bulletin of Canada Department of Mines, Mines Branch, 1908, p. 147.

[b] Special Consular Reports, No. 26, 1903, p. 107.

In the case of materials containing from 15 to 18 per cent water, for which a drying process is not necessary, the cost of manufacture is naturally considerably lower.

As the cost of labor is at least 25 per cent higher in the United States than it is in Germany, and as the cost of fuel is higher also, the above figures are too low for American practice, though they are useful for comparison.

Robert Schorr,[a] referring to the German lignite industry, states:

The raw brown coal costs from 22 to 31 cents per metric ton (2,204 pounds) at the works. The fixed charges, allowing 7 per cent for depreciation and 5 per cent for interest upon the total investment, amounts to about $1.30 per metric ton of briquets. The wholesale price f. o. b. works ranges from $16 to $23 per carload of 10 tons. The labor item rarely exceeds 24 cents per metric ton (2,204 pounds) in small (one or two press) installations. All other manufacturing items, exclusive of fuel and fixed charges, are fully covered by from 8 to 11 cents per ton. In view of the relatively small output of these expensive presses, and in view also of the elaborate character of German briquetting works, the fixed charges (depreciation and interest) are high. The largest brown-coal company owns 20 briquetting plants with 52 presses. There are a number of other concerns operating from 8 to 42 presses. Only a few factories employ less than 4 machines.

ADVANTAGES OF BRIQUETS COMPARED WITH RAW LIGNITE.

HEATING VALUE.

The following table shows how the heating value of lignite is increased by the removal of moisture during briquetting:

Improvement of heat value by briquetting.

Source.	Field designation.	Moisture.			Heat value, per pound.		
		In raw lignite.	In briquets.	Removed.	Raw lignite.	Briquets.	Increase.
		Per cent.	*Per cent.*	*Per cent.*	*B. t. u.*	*B. t. u.*	*Per cent.*
Texas	Pittsburg No. 8	33.0	9.0	24.0	6,840	9,336	36.5
North Dakota	Pittsburg No. 11	40.0	12.0	28.0	6,241	9,354	50.0
Do	Pittsburg No. 13	42.0	10.0	32.0	6,079	9,355	54.0
California	Pittsburg No. 14	40.0	10.0	30.0	6,080	9,264	52.4

Of the four samples of raw lignite named in the table, the three containing about 40 per cent of moisture had a fuel value of 6,079 to 6,241 B. t. u., while the Texas lignite, with a moisture content of 33 per cent, had a fuel value of 6,840 B. t. u. The percentage of moisture removed in the process of briquetting ranged from 24 to 32 per cent, and the heat value of the briquets was 36.5 to 54 per cent higher than that of the raw lignites.

Excessive moisture in fuel not only causes a waste of useful heat during combustion, because the moisture is vaporized and the vapor

[a] Schorr, Robert, Lignite briquetting in Germany; Eng. and Min. Jour., vol. 85, 1908, pp. 460–461.

superheated, but also is a source of expense to the consumer, who pays freight charges on useless water. For both these reasons lignite briquets have the advantage over raw lignite. In the case of one of the North Dakota lignites the removal of 32 per cent of moisture during briquetting permits a decided lessening of the cost of supplying a consumer with a given number of heat units. The advantage of the briquets in this respect is of especial importance when transportation to a distant market is involved. If the briquets possessed no other advantage over raw lignite than their higher heat value, they would be worth 50 per cent more than the raw fuel. The table shows that the heat value of the briquets was about 9,300 B. t. u., although the lignites came from three States and their fuel values varied considerably.

RESISTANCE TO WEATHERING.

The results of the weathering tests indicate that the lignite briquets resist weathering much better than the raw fuel. Some samples of briquets after exposure to autumn and winter weather for four months were in nearly as good condition as at first. Samples stored under cover did not show any signs of deterioration after six months, although the raw lignite stored under the same conditions turned to slack in two months.

RESISTANCE TO HANDLING.

The briquets bear handling better than the raw lignite. Their superiority is, of course, more striking after the lignite and the briquets made from it have been stored for several weeks.

EFFICIENCY AS FUEL.

Preliminary results of producer gas and steaming tests indicate that as gas-producer fuel the briquets were 43 per cent more efficient, and as boiler fuel were 14.5 per cent more efficient than the raw lignite.

LIGNITE-BRIQUET MANUFACTURE IN GERMANY.

The following description of lignite briquet manufacture in Germany,[a] though written several years ago, is reprinted here for the information it gives.

It has been repeatedly stated that the outward cleanliness of Berlin and other German cities is principally due to the general consumption of brown-coal briquets for household and steam fuel; further, that they are made from ordinary German lignite without the use of tar or other artificial binder; that they are compact to store, clean to handle, easy to kindle, burn with a clear,

[a] From Briquets as fuel in foreign countries; Special Consular Reports, No. 26, 1903, p. 93.

strong flame, are cheaper than good bituminous coal, and are made practically smokeless. Lignite varies in its value and adaptability for briquetting purposes according to its geologic age, hardness, and the percentage of water contained. A lignite with less than 30 per cent of water is very difficult to work by the usual processes, and it is for this reason that Austria-Hungary, which has an abundance of very old and hard brown coal that contains from 26 to 28 per cent of moisture, has practically no supply of briquets from that source. German lignite, on the other hand, is of much more recent formation; it contains from 46 to 52 per cent of water, and is usually so soft that it can be cut with a spade. Many lignite beds in this country are filled with logs and pieces of wood, so well preserved in the matrix of partially carbonized material that they burn readily and form a cheap and abundant fuel for steam and other heating at the briquet factories. The part played by the water contained in lignite forms the key to the whole economic briquetting process. The crude brown coal is brought from the mine, crushed and pulverized, and then run through a large revolving tubular cylinder, heated by exhaust steam from the driving engine, and hung on an inclined plane so that the powdered material runs downward through the tubes by gravity and is carried into the machine press that stamps it into briquets. During this passage through the cylinder it is dried and heated until there remains the right proportion of moisture, combined with the proper temperature to develop the latent bitumen in the lignite and make the powdered mass plastic and easy to mold under heavy pressure between heated iron jaws into a hard, clean briquet, with a glistening surface and sufficient firmness of structure to stand weather, transportation, and other contingencies. To do this perfectly and economically, the natural lignite should contain, as it comes from the mine, approximately enough water so that heating to the proper temperature for pressing will evaporate out just sufficient water to leave it at the proper degree of moisture. The ideal proportion is about 45 per cent of water, so that German lignite contains rather too much, while Austrian contains much too little, though this latter difficulty has lately been partially overcome by steaming. The important question to be now decided is how American lignite will fulfill these requirements.

During the past six weeks samples of lignite from near Bismarck, N. Dak., and from Troy, Ala., have been received at this consulate, turned over to the syndicate mentioned in the last report, and molded experimentally into briquets with entire success. The Dakota lignite is old and hard, contains 38 per cent of water, but crushes and pulverizes easily, and forms without binder briquets of firm structure, which burn readily, are practically smokeless, and leave only 4 per cent of ash, while the best German brown-coal briquets yield from 9 to 12 per cent of inorganic residue. The percentage of water contained is rather low, but by adapting the heating-drying process to that proportion of moisture this obstacle, such as it is, can be easily met, and the reduced task of evaporation will be an economy in the general process.

The Alabama lignite, on the other hand, is an ideal material, and from the one sample submitted is conceded here to be even superior to the standard brown coals of Germany. It contains the direct percentage of moisture, crushes easily, and molds readily into firm, shining, black briquets, so clean that, as one of the experts at Magdeburg said, "They might be used for paper weights."

The importance of these simple demonstrations will be inferred from the fact that, according to a recent State geological report, there are 55,000 square miles of lignite beds in the Dakotas and Montana, all near the surface of the ground, and ranging in thickness from 20 to 80 feet. The extent of the lignite deposits in the Gulf States is perhaps less exactly known, but they certainly cover a large area. There is also lignite in Missouri, Iowa, and several other Western States and Territories, and it is from all those hitherto practically neglected deposits that an inexhaustible future supply of smokeless domestic fuel will be derived.

It will therefore be of interest to state concisely what constitutes a first-class, up-to-date lignite-briquet factory in Germany, where the industry has reached, after many years' experience, its highest development. A typical example is the factory at Lauchhammer, about 80 miles south of Berlin, on the direct line to Dresden. This establishment, which is of the latest and most approved construction, has eight presses, with the necessary pulverizing, heating, and drying plant, run by electric motors, with current generated by steam evaporated with wood from the mines, the whole under handsome, substantial buildings of brick, stone, and iron, and cost, with tracks, switches, and full equipment for handling raw material and loading the briquets into cars, $371,000, of which $178,500 was paid for machinery. Each press weighs 32 metric tons and stamps out 100 to 200 briquets per minute, or 70 tons in a double-turn day's work of 20 hours. The heating and drying apparatus for each press weighs 18 tons. The power required for each press and drier is 125 horsepower, and both the driers and jaws of the press, between which the briquets are squeezed at enormous pressure, are heated by exhaust steam from the Corliss engine in the power house, the whole supply for the eight machines being equivalent to about 150 horsepower.

Thus equipped the plant at Lauchhammer turns out from 500 to 600 tons of briquets per day, which sell on cars at the factory for from 7 to 9 marks ($1.66 to $2.14), according to season and market, with an average of 8 marks ($1.90) per 1,000 kilograms, or metric ton of 2,204 pounds. Profits depend on the usual varying conditions, location, management, demands, etc., but it is common to read in the Berlin papers official notices announcing dividends of brown-coal briquet companies ranging from 15 to 20 per cent of their capital.

SULPHITE PITCH AS A BINDER.

GENERAL STATEMENT.

In the development of the briquetting industry many patents have been obtained for binding materials, but only a few binders have been found practicable for commercial use. Among these may be mentioned coal tar, coal-tar pitch, water-gas pitch, and asphalt pitch.

A new binding material called "sulphite liquor" also has been suggested for briquetting, but more recently a product called "sulphite pitch," obtained from this sulphite liquor, has attracted considerable attention and apparently possesses valuable properties as a binder. Hence a brief description of this new material is here given.

SULPHITE LIQUOR.

In the sulphite process of preparing pulp for paper making the wood is boiled under pressure with sulphurous acid, or, more commonly, with acid sulphite of calcium and magnesium. The action of sulphurous acid under pressure and at a high temperature upon the lignin and other incrusting matters of the wood fiber is probably a hydrolysis; that is, the complex molecules of the lignin, etc., are broken down and the resulting products, largely organic acids and aldehydes, become soluble in the liquor.

The waste liquors are light brown in color and contain much matter extracted from the wood. Until recently they had no commercial value and their proper disposal was often a serious matter; they polluted streams into which they were emptied, and under certain conditions killed the fish in these streams. It has been suggested they may furnish materials for making oxalic or pyroligneous acids, or alcohol, and investigations have been carried on to devise methods of utilizing them.

SULPHITE PITCH.

Several patents have been obtained in this country and abroad for converting the waste liquors into fertilizers, adhesive material, or other commercial products, but the most promising way of utilizing them at present seems to be by making a concentrated product known as "sulphite liquor," or a solid form known as "sulphite pitch" or "cell pitch" (selpech).

The method of preparing sulphite liquor or cell pitch from the waste lyes, according to W. Sembritski, manager of the Walsum Paper Mills, on the Rhine, is as described below:

At the Walsum factory the evaporation of waste sulphite liquors to a solid pitch, which is used for briquetting blast-furnace dust, promises to develop into a profitable industry. The liquors have a specific gravity of 1.05 and an acidity, calculated as sulphur dioxide, of 0.32 per cent. The thick sirup, density 35° B., from the evaporators has the following composition: Water, 28.88 per cent; insoluble matter, 13.96 per cent; extract, 57.16 per cent; tanning matters, 22.96 per cent; nontannins, 34.24 per cent. The solid cell pitch contains: Water, 13.76 per cent; soluble extract, 86.60; tanning matters, 31.84 per cent; nontannins, 54.76 per cent. The nontannins of the sirup consist of organic matter, 24.76 per cent; mineral matter, 9.44 per cent. The nontannins of the cell pitch consist of organic matter, 36.08 per cent; mineral matter, 18.68 per cent.

If the evaporators are made of iron, it is necessary to neutralize the acidity of the liquor with lime before concentration, and the incrustation of the tubes with calcium compounds is somewhat troublesome. If copper evaporators are used, the liquors may be concentrated in their acid state. If the concentrated liquor is to be used for briquetting flue dust, the author thinks that neutralization with lime is essential to the proper working of the briquets in the blast furnace. If, on the other hand, the concentrated liquors are intended for tanning purposes, neutralization is a drawback, as the calcium compounds make the leather brittle.

The success of the Walsum experiments is attributed in large part to the sextuple-effect Kestner evaporator used. Each effect has a heating surface of 55 square meters; the first vessel is heated with steam at 3 to 4 atmospheres and the boiling point in the last effect is 50° C. The liquor requires about three hours to reach a concentration of 35° B. The sirup is converted into solid pitch by two steam-heated drums which dip below its surface. The first drum concentrates the sirup from 35° B. to 60° B.; the second converts it into a solid film, which is removed with a scraper. Ten kilograms of waste lye yield 1 kilogram of dry substance. The fuel consumption is reckoned at 1 ton of coal per ton of pitch. It is stated that a selling price of $9.50 a ton would show a good profit.

The pitch has the appearance of black opaque resin, but is quite soluble in water. It is used as a binder for fuel and ore briquets. By its use the dust from blast furnaces, containing 40 per cent of iron and hitherto a waste product, has been formed into briquets for resmelting. It has also been used as a dressing for coarse canvas, etc. Large quantities of the sulphite liquor, having a density of about 35° B., are shipped from Germany to England in iron drums. The liquor is used in England as a binder for the sand cores and molds used in casting, and is sold there at $12.50 a ton.

SULPHITE PITCH IN GERMANY.

In a report, made in 1909, George E. Eager, United States consul at Barmen, Germany,[a] discussed the merits of sulphite pitch in some detail. He stated that sulphite pitch possesses many qualities which make it an excellent binding agent. It is intensely glutinous and its binding power is high. According to Mr. Eager, in briquetting bituminous coal from 7 to 10 per cent of coal tar is needed to give briquets of the proper firmness, but the same results can be obtained by the use of 5 per cent of sulphite pitch and some kinds of coal or ore that can be briquetted by using only 2 to 3 per cent of it.

Mr. Eager further says that sulphite pitch burns without smoke or odor and is an ideal fuel for the household, as well as for industrial purposes. The use of briquets made with this sulphite pitch will help solve the smoke question in cities. Coke briquets made with this new binder have been tried in blast furnaces and on torpedo boats with promising results. Ocean liners, war ships, railway engines, and factories could all use this fuel to advantage and not only economize in the amount of fuel necessary, but relieve cities from the smoke nuisance.

Sulphite pitch, says Mr. Eager, does not soften under heat and burns at a high temperature. It can be ground to any consistency or can be produced directly in any form of powder; it can be had in every country where there are cellulose mills, and it is very cheap. Anthracite briquets for household use, manufactured with sulphite pitch, burn without smoke or odor; therefore, they are not only an excellent substitute for the anthracite nuts, but are even superior to them.

Regarding other uses of sulphite pitch and its composition, the report states:

Recent trials to briquet coke gravel and dross, the remainder of coke (hitherto useless), with tar pitch have proved failures, but the situation changed immediately as soon as sulphite pitch was used as the binding agent, and the results show a briquet that can be considered a perfect substitute for coke. Practical trials of these briquets in both blast and cupola furnaces have shown that the briquets do not fall to pieces under the highest temperature, but burn while gradually shrinking. On account of their consistence they enter deeply into the melting zone of the furnace, thereby naturally contributing materially to the melting effect. Fine ore, bog-iron ore, brown ore, manganese ore, oxide, furnace cadmia (iron dust from blast furnaces), and other ores can all be briquetted by the use of sulphite pitch and successfully melted in the furnace. All trials of briquetting the above materials with coal-tar pitch have failed, because the binding agent burned away at a lower temperature, leaving the ma-

[a] Daily Consular Reports, No. 3361.

terial in dust as before. With sulphite pitch it is possible to briquet furnace cadmia so that it can be melted in a blast furnace. This alone means a great saving to the iron industry.

In general, sulphite pitch consists of the following substances: Fixed carbon, 25 to 35 per cent; volatile matter, 50 to 60 per cent; ash, 8 to 12 per cent; and water, 10 to 15 per cent.

The latest chemical tests have proved that the percentage of ash can be materially reduced. Through the origin of sulphite pitch its ashes contain sulphur up to 20 per cent, or 2.5 per cent of the sulphite pitch. The sulphur, however, is tied up to iron and lime, which latter substances are always present in abundance, so that the sulphur remains in the ashes and can not do any damage. It is true that sulphite pitch can be dissolved in water, and that briquets made from it are not waterproof; but this is of no great importance as in most cases a waterproof briquet is not needed. The sulphite-pitch briquet is, however, more waterproof than the lignite briquet, the making of which has become a flourishing industry. The sulphite briquet is not hygroscopic, and can be made absolutely waterproof, if it is necessary, by a simple special treatment.

The production of sulphite pitch, as well as its use in the process of briquetting, call for special processes and machinery which have taken years of expensive experiment to successfully develop, and both the material and its use for briquetting are patented in all the principal countries.

It is not supposed that sulphite pitch will in any way interfere with coal-tar pitch in its use for briquetting soft bituminous coals, but the superiority of sulphite as a binding agent, making possible the briquetting of harder coals and cokes, also iron dust and other ores, opens up a new and very important industry.

THE POLLACSEK BRIQUETTING PROCESS.

Richard Moldenke, consulting engineer on coking practice, Bureau of Mines, furnishes the following information about the Pollacsek briquetting process:

The Pollacsek briquetting process which employs the waste liquor of the sulphite paper-making process as the binder has been adopted by the Hungarian Government for its collieries, and that Government has erected the machinery for the first plant.

It is estimated that a plant producing 10 tons daily will cost about $5,000, and that the cost of operation in the United States will not exceed 60 cents a ton, and may be as low as 40 cents in favored places.

Size of the coal.—Fine coal or slack is used, pieces above a quarter of an inch being crushed. Such crushing is necessary because any large pieces of coal would be shattered in the molds of the press, and, since there would be no binder between the shattered fragments, the briquets would not be strong enough to stand transportation.

The binder.—The inventor has a process in which the waste liquor of the pulp mills may be reduced to a dry powder for convenience in transportation or evaporated to a sirup. Unquestionably the inventor must first neutralize the free acid and separate it by precipitation. In the United States this removal of free acid is, and has been for several years, accomplished in a commercial way by the use of lime. The evaporated sulphite liquor has a sirupy consistency and considering its price and efficiency is the best core binder for foundry use known to-day.

It is probable that about the same method of removing free acid is used in the Pollacsek process; but the evaporation is completed to make the weight of the product, for cheapness of transportation, as small as possible. In view of the fact that in making fuel briquets only 3 to 5 per cent of this binder is used, its cost per ton of coal briquetted is small. Another point in favor of the process is that by utilizing the waste liquor, which is given away by the mills, it helps protect streams from pollution and merits consideration for this reason alone.

The process.—If the binder is a sirup, it is diluted suitably; if solid pitch, it is dissolved in the proper quantity of water. The fine coal and the binder are then mixed by a machine. From the mixer the briquet material passes into a rotary drying kiln, where it is heated and partly dried. The success of the process depends upon maintaining the right temperature in this kiln, for the product goes directly from the kiln to the briquetting press. If the temperature varies only 10° F. either way from the standard the briquets are not hard and strong enough to stand transportation, but come out of the press uncompacted or fall to pieces. Evidently the adjustment of temperature must be precise.

If the kiln dries the material enough and the temperature in the kiln is kept at the right point, the coal will stick together when pressed, but will not adhere to the molds.

Dust from the rotating cylinder, moisture, etc., are drawn off by a fan. The dust is separated and returned to the mixing machine.

A belt conveyer takes the briquets from the press through a drying oven. If they are not to be waterproofed the briquets go directly to the cars for shipment. If they are to be waterproofed another belt takes the briquets from the drying oven, passes them through an emulsion of bitumen and water and again through a drying oven, and delivers them to the cars.

The actual briquetting process, with its mixing and drying, requires the labor of only a few men. One man gives his time to the drying kiln and the mixer, while another looks after the briquetting machine and keeps track of the briquets until they go into a car. The only other labor required is in connection with bringing in the coal and taking away the cars.

Since little labor is needed and the cost of binder is small, claims of great cheapness are made for the process. The fact that information was refused pending the taking out of patents may indicate that there is little about the process to patent. The secrets of the process are the proper mixing of the coal and binder, the use of a certain kiln temperature, and the control of this temperature, and, finally, the weatherproofing of the briquets.

The briquets made by the Pollacsek process are excellent. They are hard, stand rough handling, and are sufficiently weatherproof for every purpose. Consequently it is not strange that the Hungarian Government has selected this process for use at the Government collieries, since it turns out a good product and removes a source of stream pollution.

A combination of companies making wood pulp and those mining coals that yield culm or slack might find it advantageous to look into the process as a means of solving two interesting problems, the disposal of the waste sulphite liquors and the utilization of waste coal.

The briquetting section of the Bureau of Mines is making laboratory tests with this sulphite pitch, the results of which will be published in a future bulletin.

REFERENCES TO SULPHITE LIQUOR AND CELL PITCH.

AHRENS, F. B. Chem. Zeitschr., 1905 (4), pp. 40–41; abstracted in Jour. Soc. Chem. Ind., 1905, p. 343.

KRAUSE, H. Chem. Ind., 1906 (29), pp. 217–227; abstracted in Jour. Soc. Chem. Ind., 1906, p. 493.

ROBESON, J. S. U. S. Patents 833635, 851378, 851379, 851380, 851381. For abstract see Jour. Soc. Chem. Ind., for 1906 and 1907.

SEMBRITZKI, W. Wochbl. Papier-fabr., 1908 (39), p. 658; abstracted in Chem. Abstracts, Amer. Soc. Chem., 1908, p. 1885. Wochbl. Papier-fabr., 1908 (39), pp. 2866–2867; abstracted in Jour. Soc. Chem. Ind., 1908, p. 915.

KNOESEL, T. Wochbl. Papier-fabr., 1908 (39), pp. 3276–3278, 4049.

EAGER, GEORGE E. Daily Consular Reports, No. 3361; also published in Power and the Engineer, March 9, 1909.

THORP, F. H. Outlines of industrial chemistry.

RECENT LITERATURE ON BRIQUETTING.

The following list of references to articles and books that have appeared within the last twelve years is based on the partial bibliographies of briquetting in Bulletins 290, 363, and 385 of the United States Geological Survey:

1899.

ATWATER, R. M. Domestic coke and briquettes from retort coke ovens. Iron Trade Review, January 26.

BINDER, O. Apparatus for testing pitch for briquette making. Colliery Guardian, June 16.

KOSMANN, ——. Welche Erfahrungen liegen über die Ofenfeuerung von Dampf-Kesseln und Brennofen mit Briketts vor? Mittheilungen des Deutschen Vereins für Fabrikation von Ziegeln u. s. w., Berlin, vol. 35, pp. 193–197.

Coal briquettes in Wales. U. S. Consular Reports, No. 327.

1900.

BUHLER, F. A. Fabrikation der Essigsäure und des Acetons, sowie von Briketts aus Hauskohlen. Zeitschr. angew. Chem., p. 637.

American coal briquettes. Sci. Am., December 8.

Briquettes à hydrocarbures; procédé de Velna. Revue industrielle, vol. 31, pp. 298–299.

Briquettes as steam fuel. Iron and Coal Trades Review, December.

The manufacture of patent fuel in Wales. U. S. Consular Reports, No. 852.

1901.

ANDREP, ALEPH. Swedish methods of preparing peat fuel. Engineering News, vol. 45, p. 434.

BOCK, OTTO. Die Ziegelfabrikation, Leipsig.

CATLETT, C. Note on briquetting coking coals. Eng. and Min. Jour., vol. 71, p. 329.

FISCHER, F. Technologie der Brennstoffe, Brunschweig.

HEIDENSTAM, G. V. Manufacture of briquettes from wood waste. Engineer, London, vol. 92, p. 465.

Brikett Maschine, System Edison. Praktische Maschinen-Konstrukteur, vol. 34, p. 125.

Note on Briquettes in Belgium. Eng. and Min. Jour., vol. 72, p. 850.

Note on briquette making in Germany. Eng. and Min. Jour., vol. 71, p. 593.

Untersuchungen von Torf-Briquettes. Dingler's Jour., Stuttgart, vol. 316, p. 225.

1902.

GRANVILLE, AUSTIN. Solidified crude-oil fuel. Railroad Gazette, vol. 46, p. 958.

HEUMANN, ——. Erfahrungen mit der Verfeuerung von Torf-Briquettes. Deutsche landwirtschaftliche Presse, vol. 29, p. 247.

IRWIN, W. G. Coal-briquetting industry in the United States. Iron Age, June 19.

———— The briquetting of fuels and fine mineral ores, Eng. Mag., March.

KEGEL, C. Briquetting of brown coal. Glückauf, July 5.

KROUPA, GUSTAV. New process for preparing peat for briquetting and other purposes. Colliery Guardian, March 7.

MASON, F. H. Manufacture and use of briquettes in Germany. Eng. and Min. Jour., vol. 74, p. 244.

SACHSE, ——. Peat fuel. Eng. Rec., vol. 46, p. 29.

SCHORR, ROBERT. Briquetting and peat fuel. Eng. and Min. Jour., vol. 74, p. 714.

———— The briquetting of fuels. Eng. and Min. Jour., vol. 74, p. 621.

STEGER, ——. Bindemittel für Brennstoffbriquetts. Oester. Zeit. Berg-Hüt.-Sal.-Wesen, vol. 50, pp. 311–320.

WENDT, ——. Ore concentration, coal preparation, briquetting, etc. Glückauf, July 12.

Apparatus for compressing coal before coking. Génie civil, November 15.

German processes and machinery for briquette manufacture. U. S. Consular Reports, No. 1466, October 11.

German briquet machinery for America. U. S. Consular Reports, No. 1527, December 27.

Making peat briquettes by electric power. Eng. and Min. Jour., vol. 74, p. 41.

Manufacture of briquettes. Engineering, November 14.

Note on briquette plant in New Mexico. Eng. and Min. Jour., vol. 73, p. 313.

Petroleum briquets in France. Mines and Minerals, July, p. 564.

Utilization of peat as fuel. Eng. News, vol. 47, p. 476.

Verwendung von Braunkohlenbriquetts für Dampfkesselfeuerung, Halle. Zeitschrift für Heizungs-, Luftungs- und Wasserleitungstechnik, vol. 7, p. 49.

1903.

Bjorling, P. R. Briquettes and patent fuel. London, p. 256.

Booth, W. H. Briquet fuel. Engineer (Chicago), April 1, p. 251.

Carter, W. E. H. Peat fuel, its manufacture and use. Ann. Rep. Ontario Bureau Mines.

Gehre, ——. New process for making briquettes. Sci. Am. Suppl., vol. 55, p. 22871.

Gifford, R. L. Briquetting of flue dust, fine ore, and fuel. Eng. News, vol. 49, p. 140.

Gifford, R. L. Briquetting of fuel. Eng. News, vol. 49, pp. 235–236.

Junemann, F. Die Briquette-Industrie und die Brennmaterialen, new ed., 320 pp.

Lozé, E. The briquette industry in France. Eng. and Min. Jour., vol. 76, pp. 277 and 431.

Mason, F. H. Lignite, peat, and coal-dust fuel in Germany. Elect. Rev., vol. 42, p. 612.

Steger, ——. Die Herstellung kleinstückiger Briquetts. Stahl und Eisen, vol. 23, p. 1313.

Mason, F. H. Lignite, peat, and coal-dust fuel. Sci. Am. Suppl., vol. 55, p. 22846.

Binding material for briquets. Mines and Minerals, December, p. 213.

Briketts. Gewerbeblatt aus Würtenberg, vol. 55, p. 361.

Briquettes as fuel in foreign countries. U. S. Consular Reports, vol. 26.

Desulfurit-Dauerbrand-Briketts der Gebr. Hopfner in Bleckendorf. Uhland's Technische Rundschau, Suppl., p. 101.

Die Braunkohlenbrikett fabrik der Aktiengesellschaft Lauchammer. Glückauf, August 29.

Fuel briquetting. Mines and Minerals, August, p. 8.

Fuel-briquetting machinery. Engineer (Chicago), vol. 40, p. 249.

Manufacture of peat fuel. Engineer, vol. 96, p. 500.

Versuche mit festem Petroleum als Heizstoff. Schiffbau, vol. 4, p. 517.

Waterproof briquets in Germany. Mines and Minerals, January, p. 257.

Zeitzer Eisengiesserei und Maschinenbau-A. G., Brikett-Fabrik. Praktische Maschinen-Konstrukteur, vol. 36, p. 203.

1904.

Constam, E. J., and Rougeot, R. Ueber die Emittlung des gehalts au Bindmittel bei Steinkohlenbriketts. Zeitschr. angew. Chem., 1904, vol. 17, pp. 845–848.

Fulton, John. Fuel-briquetting industry. Mines and Minerals, vol. 25, pp. 106, 162, 305, 362, 404.

GRADENWITZ, ALFRED. Coal briquetting. Mining Reporter, December 29.

HOFBAUER, ——. Kohlenbriquetts aus ausgelaugter Weinhefe und Steinkohlenklein. Neueste Erfindungen und Erfahrungen, vol. 31, p. 248. See also vol. 31, pp. 33 and 310.

SCHÖNDELING, H. Aufbesserung der Steinkohlen Briquets zwecks Rauchverminderung: Glückauf, November 5.

SCHORR, ROBERT. Fuel and mineral briquetting. Trans. Am. Inst. Min. Eng., vol. 35, p. 82.

———— The briquette plant at Stockton, Cal. Eng. and Min. Jour., vol. 78, p. 262.

———— The manufacture of oil briquets. Mines and Minerals, January, p. 256.

WALSH, G. E. Briquetting fuel materials. Power, April.

WHITE and GRIFFIN. Machine pour la fabrication des briquettes de tourbe. Revue industrielle, vol. 35, p. 234.

WOODHEAD, HENRY. Briquetting coal. Eng. and Min. Jour., vol. 78, p. 541.

WOTHERSPOON, H. H., Jr. Advances in the utilization of peat and lignite. Eng. and Min. Jour., April 7, p. 562. Abstract of paper read before New York Academy of Science.

Aglomeración de la hulla. Revista minera, metalúrgica y de ingeniería, vol. 55, p. 145.

Brikettfabrik. Braunkohle, vol. 3, pp. 225, 349.

Briquettfabrikation. Mittheilungen aus der Praxis des Dampfkesseln und Dampfmaschinen Betriebes, vol. 26, pp. 583–586.

1905.

CONSTAM, E. J. Der Einfluss der Festigkeit von Steinkohlenbriquetts auf ihre Verdampfungsfähigkeit. Zeitschr. Ver. deutscher Ing., vol. 48, pp. 973–975.

FULTON, JOHN. Coke, a treatise on the manufacture of coke and other prepared fuels and the saving of by-products. Scranton, Pa., pp. 406–462.

———— Fuel-briquetting industry. Mines and Minerals, January, p. 305; February, p. 362; March, p. 404.

GERCKE, ——. Die Verwertung minderwertiger Brennstoffe insbesondere des Torfes. Zeitschr. Ver. deutscher Ing., May 27.

GRADENWITZ, ALFRED. Washing and briquetting plant. Mines and Minerals, September.

LOESER, ——. Verwendung von Braunkohlenbriquetts für Ringofenstreufeuer. Braunkohle Halle, vol. 3, pp. 33–36.

RANDAL, W. M. Briquette fuels. Power, March, p. 204.

SCHONDELING, W. Die Verwertung der Kohlenasche auf der Böhmischen Braun-Konlengruben. Oester. Zeitschr. f. Berg-u. Huttenwesen, May 20, pp. 257–261.

SCHORR, ROBERT. Briquette press. Eng. and Min. Jour., October 7, p. 267.

———— The Western Fuel Company's Fuel briquetting plant at Oakland, Cal. Eng. and Min. Jour., vol. 80, September 2, p. 389.

WALSH, G. E. Briquetting fuel. Mining Reporter, April 13.

Coal briquets in Japan. Eng. and Min. Jour., vol. 80, p. 51.

Manufacture of briquettes. Sci. Am. Suppl., July 1.

The Zwoyer briquet process. Eng. and Min. Jour., vol. 80, p. 1022.

1906.

BARBER, C. M. Some notes on fuel briquetting in America. Sci. Am. Suppl., April 7.

KALLER, THEODOR. Artificial fuel. Sci. Am. Suppl., June 16.

MASHEK, J. G. Briquetting of fuels and minerals. Iron Age, April 19.

MUELLENHOFF, K. A. Briquetting of brown coal. Proc. Eng. Soc. Western Pennsylvania, May.

1907.

BLAUVELT, W. S. A brief record of progress in fuel briquetting at Detroit. Am. Gas Light Jour., September 23.

PARKER, E. W. Coal briquetting in the United States. Trans. Am. Inst. Min. Eng., pp. 581–620.

ROSENKRANZ, MAX. Brikets von Kohlenstaub. Jour. f. gasbel, March 9, pp. 197–199.

SAWARD, F. E. Southern coal for briquets. Manufacturers' Record, October 21.

THAU, A. Fortschritte im Kohlenstampfverfahren. Glückauf, July 27.

WALLER, E., and RENAUD, H. S. Lignite briquets. Eng. and Min. Jour., vol. 82, p. 637

Briquets in England. Progressive Age, vol. 25, p. 469.

1908.

BOCK, F. Die Brikettierung der Steinkohlen. Glückauf, January 4.

COALES, H. G. Coalescine fuel from refuse. Eng. Digest, August, pp. 146–147.

EAGER, G. E. Briquetting of coal. Sulphite pitch, a new binding material, and its application. Daily Consular Reports, 3361, December 21.

FRANKENTHAL, L. J. Coal briquets: Their importation and use on Swiss railways. Daily Consular Reports, April 18.

GERTNER, ——. Ueber Entstaubungsanlagen in Braunkohlen-Brikettfabriken. Zeit. Berg., Hüt. Sal.-Wesen, vol. 56, pt. 2, pp. 125–257.

D'INVILLIERS, R. Briquetted coal in Brooklyn. Eng. Rec., September 12.

LATHROP, L. A. Briquets made with tar, Shedlock process. Daily Consular Reports, June 13.

MASHEK, J. G. Briquetting of fuels in British Columbia, Canada. Can. Min. Jour., January 15, February 1.

MASON, F. H. Briquets in Europe. Their use as locomotive fuel in France. Daily Consular Reports, March 6.

MILLS, J. E., Practical binders for coal briquets. Oil, Paint, and Drug Reporter, July 20, July 27.

MEEKER, CLIFFORD D. Briquetted coal in Brooklyn, N. Y. Eng. Rec., August 15, pp. 178–180.

NYSTROM, E. Peat and lignite: Manufacture and use in Europe. Ottawa, Canada, Dept. of Mines, pp. 130–170.

PARKER, E. W. The coal-briquet plant at Bankhead, Alberta. Trans. Am. Inst. Min. Eng., pp. 354–362, 389–393.

———— Conditions of coal briquetting in the United States. Am. Gas Light Jour., vol. 88, pp. 492, 533.

ROSENKRANZ, MAX. Briquets from coal dust. Indust. World, April 27.

SCHOLZ, CARL. Coal briquetting. Eng. News, December 10, p. 642.

SCHORR, R. Lignite briquetting in Germany. Eng. and Min. Jour., February 29, pp. 460–461.

WADLEIGH, P. R. Coal briquets and their use in railroad, marine, and domestic service. Engineer, London, June 12.

Brikettierung. Verhütung der Staubbildung und Auftreiben der Pressformen. Zeit. Berg., Hüt. Sal.-Wesen, vol. 56, part 1, pp. 186–187.

HALE, R. M. New southern briquetting plant. Black Diamond, October 10, p. 16.

Tests of Russian coal and briquets. Colliery Guardian, November 22.

1909.

FERGUSON, M. Briquets and their effect on the market values of coal. Black Diamond, February 27.

FRANKE, G. Handbuch der Brikettbereitung, vol 1.

GOSS, W. F. M. Comparative tests of run-of-mine and briquetted coal. Eng. and Min. Jour., vol. 87, March 20, p. 611.

HALE, R. M. Coal briquetting. Iron Age, January 28, p. 291.

KNABENSHUE, PAULL. Manufacture of coal briquets in Belfast, Ireland. Daily Consular Reports, July 23.

MALCOLMSON, C. T. Coal briquetting at the Hartshorne plant. Mines and Minerals, March.

——— Briquetted coal. A paper read at the July meeting of the International Railway Fuel Association.

SCHOLZ, CARL. Coal briquetting. Jour. Western Soc. Eng., April, pp. 137–154.

SCHORR, ROBERT. Binder materials made from sulphite-pulp waste. Eng. and Min. Jour., September 4, p. 451.

Coal briquetting in the United States. Eng. and Min. Jour., vol. 87, April 10, p. 769.

Notes on briquetting. Eng. and Min. Jour., vol. 87, May 22, p. 1052.

The Durkee Coalette Company. Rocky Mountain Coal Journal, January, p. 41.

1910.

BLAUVELT, W. H. The Commercial Fuel briquette plant. Trans. Am. Inst. Min. Eng., vol. 39, p. 223. Abstract printed in Iron Age, March 17.

FRANKE, G. Handbuch der Brikettbereitung, vol. 2.

HUGHES, C. H. Devillers coal-briquetting machinery, Iron Age, February 24, p. 431.

MALCOLMSON, C. T. The Standard Briquette Fuel Company's plant. Am. Coal Jour., January, pp. 39–47.

——— Coal-briquetting plant at Livingston, Ill. Black Diamond, September 10, p. 17.

SCHORR, ROBERT. Progress in fuel briquetting. Eng. and Min. Jour., March 5, pp. 524–525.

WRIGHT, C. L. The fuel-briquetting industry. Eng. Mag., April, p. 45; May, p. 195.

The briquetting plant at Superior, Wis. Fuel, July 12.

PUBLICATIONS ON FUEL TESTING.

The following publications, except those to which a price is affixed, can be obtained free of cost by applying to the Director of the Bureau of Mines, Washington, D. C. The priced publications can be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

PUBLICATIONS OF THE BUREAU OF MINES.

BULLETIN 1. The volatile matter of coal, by H. C. Porter and F. K. Ovitz. 1910. 56 pp., 1 pl.

BULLETIN 2. North Dakota lignite as a fuel for power-plant boilers, by D. T. Randall and Henry Kreisinger. 1910. 42 pp., 1 pl.

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BULLETIN 7. Essential factor in the formation of producer gas, by J. K. Clement, L. H. Adams and C. N. Haskins. 1911. 58 pp., 1 pl.

BULLETIN 8. The flow of heat through furnace walls, by W. T. Ray and Henry Kreisinger. 1911. 32 pp.

BULLETIN 9. Recent development of the producer-gas plant in the United States, by R. H. Fernald. 82 pp., 2 pls. Reprint of United States Geological Survey Bulletin 416.

BULLETIN 11. The purchase of coal by the Government under specifications, with analyses of coal delivered for the fiscal year 1908–9, by G. S. Pope. 80 pp. Reprint of United States Geological Survey Bulletin 428.

BULLETIN 12. Apparatus and methods for the sampling and analysis of furnace gases, by J. C. W. Frazer and E. J. Hoffman. 1911. 22 pp.

PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

PROFESSIONAL PAPER 48. Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1906. In three parts. 1492 pp., 13 pls. $1.50.

BULLETIN 261. Preliminary report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, in St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. 1905. 172 pp. 10 cents.

BULLETIN 290. Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905, by J. A. Holmes. 1906. 240 pp. 20 cents.

BULLETIN 323. Experimental work conducted in the chemical laboratory of the United States fuel-testing plant at St. Louis, Mo., January 1, 1905, to July 31, 1906, by N. W. Lord. 1907. 49 pp.

BULLETIN 325. A study of four hundred steaming tests made at the fuel-testing plant, St. Louis, Mo., 1904, 1905, and 1906, by L. P. Breckenridge. 1907. 196 pp. 20 cents.

BULLETIN 332. Report of the United States fuel-testing plant at St. Louis, Mo., January 1, 1906, to June 30, 1907; J. A. Holmes, in charge. 1908. 299 pp. 25 cents.

BULLETIN 334. The burning of coal without smoke in boiler plants; a preliminary report, by D. T. Randall. 1908. 26 pp.

BULLETIN 336. Washing and coking tests of coal and cupola tests of coke, by Richard Moldenke, A. W. Belden, and G. R. Delamater. 1908. 76 pp. 10 cents.

BULLETIN 339. The purchase of coal under government and commercial specifications on the basis of its heating value, with analyses of coal delivered under government contracts, by D. T. Randall. 1908. 27 pp. 5 cents. (See Bull. 428.)

BULLETIN 343. Binders for coal briquets, by J. E. Mills. 1908. 56 pp.

BULLETIN 362. Mine sampling and chemical analyses of coals tested at the United States fuel-testing plant, Norfolk, Va., in 1907, by J. S. Burrows. 1908. 23 pp. 5 cents.

BULLETIN 363. Comparative tests of run-of-mine and briquetted coal on locomotives, including torpedo-boat tests and some foreign specifications for briquetted fuel, by W. F. M. Goss. 1908. 57 pp., 4 pls.

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BULLETIN 382. The effect of oxygen in coal, by David White. 1909. 78 pp., 3 pls.

BULLETIN 385. Briquetting tests at the United States fuel-testing plant, Norfolk, Va., 1907–8, by C. L. Wright. 1909. 41 pp., 9 pls.

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BULLETIN 403. Comparative tests of run-of-mine and briquetted coal on the torpedo boat *Biddle*, by Walter T. Ray and Henry Kreisinger. 1909. 49 pp.

BULLETIN 412. Tests of run-of-mine and briquetted coal in a locomotive boiler, by Walter T. Ray and Henry Kreisinger. 1909. 32 pp.

BULLETIN 428. The purchase of coal by the Government under specifications, with analyses of coal delivered for the fiscal year 1908–9, by G. S. Pope. 1910. 80 pp. 10 cents. Reprinted as Bureau of Mines Bulletin 11.