Fuel Briquettes from Alabama Lignite by Destructive Distillation at Low Temperatures and Briquetting the Residue without a Binder

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BULLETIN NO. 8

OCTOBER 1937

Contents

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ABSTRACT

The object of this investigation is to call attention to the presence of the Alabama lignite and, if possible, to find a method for the profitable utilization of this material.

As a result of this investigation, a process has been developed for the manufacture of a good grade fuel briquette involving the following steps:

(1) The raw lignite is air-dried and then preheated or subjected to low temperature distillation at a temperature sufficient to remove practically all the water and much of the volatile matter of the lignite. As a result, the weight is decreased about one-third, much of the smoke is eliminated and the heating value of the lignite is appreciably increased.

(2) The preheated lignite residue is then ground, moistened with water and briquetted hot without the addition of a binder. The resulting briquettes are firm and strong enough to withstand rough handling, and they resist weathering to an extent which would permit shipment and storage if protected from direct rainfall.

(3) The optimum conditions for carrying out the various steps in the process have been determined and a study made of the probable large-scale equipment and cost of manufacture.

(4) Judging from the apparent quality of the briquette and the estimated cost of production, the briquettes have considerable promise.

Note.—Alabama lignite deposits have not been developed sufficiently for the variation in the lignite from different localities to be determined. Apparently there is considerable variation in Alabama lignite. While the samples employed for this work are believed to be representative of much of the lignite, the process described above is not necessarily applicable to all Alabama lignites. Preliminary briquetting tests should be carried out on an unknown deposit in order to determine if this method is applicable.

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INTRODUCTION

IN SOUTHERN Alabama raw materials are available which apparently are sufficient for several important industries if a cheap fuel was available. Apparently there is also a need for a cheap domestic fuel in this region. Consequently, efforts to produce a high-grade fuel from the lignite deposits which underlie much of south Alabama appeared to be a worth-while undertaking.

This paper should be considered a preliminary report as far as the briquetting of Alabama lignite is concerned. Its chief object is to call attention to the presence of the Alabama lignite and the effort that has been made to produce from it a good domestic or industrial fuel. The extent to which the process described in this paper can be applied to the various lignite deposits of the State cannot be determined at the present time. It is hoped to provide additional information along this line at a later date when more information regarding the out crops, quantity, and purity of the lignite is available.

BIBLIOGRAPHICAL REVIEW

According to Stillman (1), three widely different methods for briquetting lignites are employed. These are as follows:

(1) According to the German method, the lignite is dried to proper consistency and briquetted without a binder in an Exter press.

(2) The second method consists of the addition of a binder followed by briquetting.

(3) The third method consists of carbonizing or distilling the lignite and briquetting the residue with a binder.

A bulletin by C. L. Wright (2), entitled "Fuel Briquetting Investigation," discusses in detail the briquetting of various lignites by the Bureau of Mines.

A similar bulletin by Wright (3) is entitled "Briquetting Tests of Lignites."

A method (4) recommended for recovery of high-value briquettes from low-value brown coal consists of preheating, allowing about 20 per cent of the volatile matter to remain, adding 10 per cent petroleum residue as a binder, and briquetting.

A method employed by Duval (5) for briquetting of lignite consists of drying and compressing, partial carbonization, the addition of agglomerates, and briquetting.

According to Thompson (6), the Lignite Board of Canada recommends the following procedure:

(1) Heat to a low temperature (i. e. Approx. 600° F.)

(2) Mix with coal tar pitch

(3) Briquette

The "Low Temperature Distillation of Lignites and Briquetting of the Residue" is discussed in Bulletin 221 (7) of the Bureau of Mines.

The advantages of briquetting also are discussed in this bulletin.

Explanation of the various adaptabilities of different lignites to briquetting is given by Heutze (8).

A summary of the various methods for the utilization of brown coal is given by a publication (9) of the Engineering Experiment Station of the Alabama Polytechnic Institute.

A description of a method recommended for the utilization of lignite is given by Ab-der-Holden (10). This is as follows:

(1) Distill i.e. low temperature carbonization to 425° C. in a special furnace.

(2) Crack the tar vapors by passing vapors over heated metal surfaces.

(3) Continuous steam distillation of the cracked tar.

(4) Agglomeration of the semi-coke into briquettes by oxidizing the tar residues and conversion into a smokeless fuel by baking at temperatures up to 700° C.

Various methods for the carbonizing of lignite both at high and low temperatures, gas making processes, application of the Trent process, the hydrogenation of lignite, the briquetting of lignite, the use of powdered lignite, and miscellaneous developments are discussed by Basore (11). A complete bibliography is included.

The occurrence and distribution of lignite in Alabama is discussed by Barksdale (12). The method developed by the North Dakota School of Mines, which consists of drying and then heating in a closed retort to a low temperature, followed by briquetting of the residue with coal tar pitch, is mentioned as having possible application to Alabama lignite.

Disadvantages of the Present Methods for Utilization of Lignites.—The use of raw lignite as a fuel is not desirable because of the low heating value and the fact that the lignite crumbles to dust on aging or weathering.

To overcome the various objections mentioned above, various methods employing drying or carbonization followed by briquetting have been employed. When the lignite is simply air-dried and then briquetted without a binder (applicable only to certain lignites), the briquettes are of low heating value and produce much smoke. Where the lignite is partly or completely carbonized to overcome these objections, a binder (coal tar pitch as a rule) is necessary in order to briquette the residue. The binder produces much smoke and adds considerably to the cost. In view of the above, the basic objections to present methods of utilization of lignite are obvious.

A NEW BRIQUETTE FROM ALABAMA LIGNITE: DESTRUCTIVE DISTILLATION AT LOW TEMPERATURES AND BRIQUETTING OF THE RESIDUE WITHOUT A BINDER.

Examination of various Alabama lignites disclosed the fact that they air-dry rapidly to 10 to 12 per cent water. Examination indicated that not only is it possible to briquette many of these lignites without a binder, but some of these briquettes can be preheated successfully at temperatures comparable to low temperature distillation and the residue briquetted without a binder.

A study of the possibilities along this line appeared to be worth-while since it appeared possible to produce a superior briquette at the lowest possible cost.

Examination of a number of samples of Alabama lignite from various localities indicated that all of those examined could be briquetted without a binder if the temperature of preheating was not too high. However, they did not briquette with equal readiness, nor did they all give briquettes of the same strength. As a matter of fact, the lignites examined might be divided into two classes: (1) Those which on partial carbonization briquette readily, and (2) Those which on partial carbonization briquette with difficulty and do not give very strong briquettes. Note: As will be shown later, the process developed for the first class at times can be modified to include the second class. For example, in the case of one lignite sample, it was necessary to reduce the temperature of preheating to 400° F., increase the water 33.3 per cent, and increase the pressure to 20,000 pounds per square inch before satisfactory briquettes could be secured.

This difference in behavior of the various lignites is not entirely understood. It apparently is not due to difference in bituminen content, one sample from Wilcox County containing 3.08 per cent on an air-dried basis giving briquettes which were inferior to a sample from Crenshaw County which on an air-dried basis contained only 2.52 per cent bituminen. The explanation probably lies in the amount of colloidal material or humus in the various lignites.

This investigation was based essentially on the first class of lignite indicated above.

Experimental Work—Preheating of Lignite.—Lignite occurs (12) in veins in the southern part of the State running almost east and west across practically the entire state.

Lignite samples from Crenshaw County (Glenwood) were considered representative of the first type, which was readily briquetted after preheating and partial carbonization, and which formed strong briquettes. These samples were selected for this work.

Analysis of this lignite is given in Table I:

Table I

Analysis of Lignite	Proximate Analysis	
	Air-Dried (Per cent)	Bone-Dry (Per cent)
Moisture	11.2	0.0
Volatile matter	44.8	50.6
Fixed carbon	31.4	35.4
Ash	12.6	14.0
Sulphur	2.1	2.2
Additional:		
Heating value air-dried lignite	8,810 B.T.U. per pound	
Ignition temperature-dried lignite	350° F.	
Bitumen content-dried lignite	2.52 per cent	

The ash content of the above sample while lower than some, is considerably higher than many samples secured in the State. In Bulletin 33, "Lignite in Alabama," University of Alabama, there are a number of samples which on a bone-dry basis contain only 5 to 12 per cent ash. On the air-dried basis employed above this is only from 4.5 to 10.8 per cent ash.

Preliminary experiments indicated that the above lignite preheated up to 900° F., after cooling and the addition of a small amount of water could be readily briquetted without a binder.

At the above temperature small amounts of gas, tar and water are given off by the lignite. Consequently the apparatus employed should permit the recovery of the above products. In modified form the apparatus employed by Schmidt, Elder and Davis (*Ind. Eng. Chem.*, Vol. 28, p. 1,346) was selected for this work. The apparatus employed is shown in Figure I.

The gas holder contained water saturated with the gas.

The course of a run was as follows: The retort was filled about three-quarters full of the lignite which was roughly ground to one-half to one inch. The current was then turned on and the temperature increased until a temperature of 900° F. was reached when the current was cut off.

Water begins to appear at about 400° F. and the distillate consists almost entirely of water until a temperature of 750° to 800° F. when tar first appears. Gas in relatively small amounts appears during the last few minutes of the distillation. The time for a complete distillation is about 100 minutes. The average loss in weight of the lignite is 25 to 30 per cent.

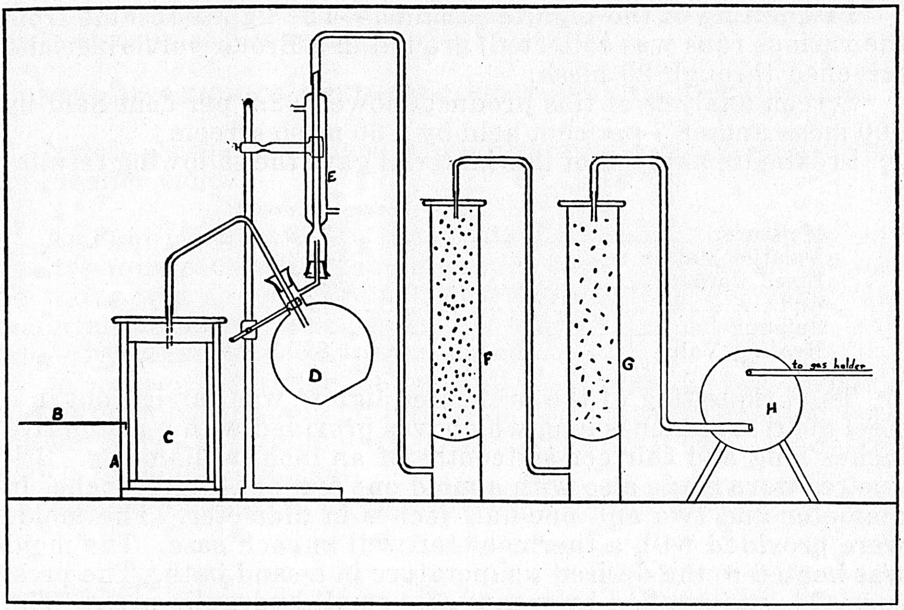

FIGURE I.—EXPERIMENT RETORT (SCALE - 1″ = 5″).

A—Electric Furnace; B—Calibrated Thermocouple; C—Retort; D—Receiver; E—Condenser; F—Filter (Cotton); G—H_2S Purifier (Na_2CO_3); H—Wet Gas Meter.

The yields from a typical run are as follows:

Charge	300 grams
Lignite residue	208 grams (69.3 per cent)
Tar	6 grams (2 per cent)
Liquor	59.7 grams (19.9 per cent)
Gas	0.494 cu. ft. (cor. to °C and 760 min.)

As will be seen from the above, the by-products are secured in very small amounts and apparently are practically worthless, with the possible exception of the tar. The latter contains a large amount of high boiling constituents, over 40 per cent boiling above 300° C.

The aqueous liquor mentioned above apparently contains small quantities of phenolic bodies. The disposal of this liquor apparently would not be a serious problem since the phenolic bodies are readily absorbed by raw lignite when used as a filter. Lignite to the amount of 15 to 20 per cent of the weight of the liquor is sufficient. This represents from 3 to 4 per cent of the weight of the lignite carbonized.

The gas is secured in very small amount and is largely carbon dioxide. Only that coming off during the last few minutes will burn, and even then only after the gas is dried.

Briquetting of the Lignite Residue.—The lignite residue from the various runs was collected, ground in a Broun pulverizer and screened through 20 mesh.

Screen analysis of this product showed 62.2 per cent held by 100 mesh and 48.7 per cent held by a 60 mesh screen.

Proximate analysis of this material gave the following results:

	Per cent by weight
Moisture	3.38
Volatile Matter	34.12
Fixed Carbon	45.55
Ash	16.95
Sulphur	2.94
Heating Value	9,890 B.T.U. per pound

The briquetting of the preheated lignite was carried out in a steel mold four inches long which was provided with a piston five inches long and thirteen-sixteenths of an inch in diameter. Briquettes were made also with a mold one and one-eighth inches in diameter and two and one-half inches in diameter. The molds were provided with a thermometer well in each case. The mold was heated to the desired temperature in a sand bath. The pressure (1) was applied by means of a small hydraulic press. The mold employed for briquetting of the preheated lignite is shown in Figure II:

The preheated lignite was briquetted as follows: The preheated lignite was thoroughly mixed to insure an uniform product. The charge (15 grams) was moistened with a carefully determined amount of water, thoroughly stirred, quickly transferred to the mold, where it was lightly tampped, the piston placed in the mold, and the latter placed in the sand bath where it was heated to the desired temperature. After allowing sufficient time (10 minutes) for the contents of the mold to become uniformly heated, the mold and sand bath were transferred to the press, where the desired pressure was quickly applied. The briquettes were then immediately removed from the mold. They weighed from 12 to 30 grams, depending upon the diameter of the mold.

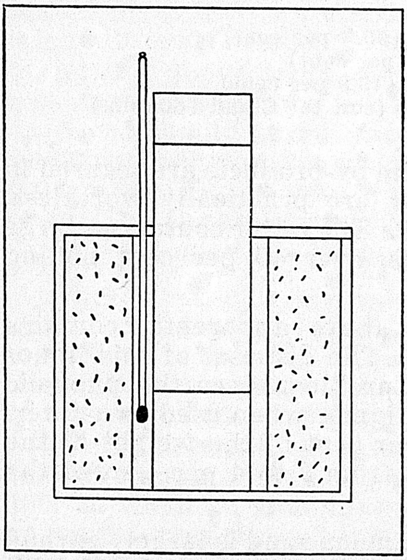

FIGURE II.—BRIQUETTING MOLD
(SCALE - 13/16" = 2½")

The preliminary conditions used above which gave good results were as follows: Amount of water added, 6 per cent; temperature of briquetting, 100° C.; briquetting pressure, 13,500 pounds per square inch; duration of pressure, 30 seconds; temperature of removal of briquettes, same as temperature of briquetting.

DETERMINATION OF OPTIMUM CONDITIONS FOR BRIQUETTING

Note.—These conditions were determined while employing the smaller mold.

Amount of Water.—In the preliminary work, improved briquettes were secured as the amount of water increased. Where no water was added (actual water present 3.38 per cent) the material crumbled to a powder, but when 6 per cent water was added, strong briquettes were secured.

In order to determine if 6 per cent water was the best amount, the water was varied on both sides of this figure. The other conditions were the preliminary ones discussed on page 10, all of which were held constant.

The results secured in the work are given in Table II:

Table II.—Amount of Water.

Amount of Water Added (Per cent of pre-heated residue)	Total Water Present (Per cent of residue)	Nature of Briquette	Drop Test (Per cent held by ½" screen)	Remarks
3.0	6.38	Poor	3.33	Briquettes unsatisfactory
4.5	7.88	Good	33.3	
6.0	9.38	Very good	55.5	Briquettes much better than those with 4.5 per cent water
9.0	12.38	Very good	61.5	Briquettes little, if any, better than those with 6 per cent water

A study of Table II indicates that while the briquettes made on the addition of 9 per cent water are somewhat stronger than those made with the addition of 6 per cent water, it is doubtful if the slight increase in strength would warrant the addition of so much water which lowers the heating value of the finished briquette. Under the circumstances the addition of 6 per cent water was adopted and was employed in all future work.

Temperature of Briquetting.—In the preliminary work a temperature of 100° C. was employed as the temperature of briquetting. In order to determine if this was the best temperature, the temperature was varied on both sides of 100° C., i.e., 125° C., 75° C., 50° C., and 25° C. (room temperature).

In the briquetting of this material, the optimum amount of water (6 per cent) was used. The other conditions were the preliminary conditions discussed on page 10.

The results of this work are given in Table III:

Table III.—Temperature of Briquetting.

Number	Temperature of Briquetting	Nature of Briquette	Drop Test (Per cent held)	Remarks
1	25°C	Good	63.8	
2	50°C	Very good	71.4	Briquettes satisfactory
3	75°C	Excellent	81.2	
4	100°C	Excellent	86.7	
5	125°C	Excellent	85.5	

A study of Table III indicates that there is a steady increase in the strength of the briquettes as the temperature increases. At 50° C. the briquettes are uniform, free from cracks, and have considerable strength. It is questionable whether the relatively small increase in strength justifies an increase in temperature from 50° C. to 100° C. Consequently 50° C. was adopted and was employed for all future work.

Briquetting Pressure.—In the preliminary work, good results were secured at a pressure of 13,500 pounds per square inch. Since these briquettes are entirely satisfactory, there is no object in exceeding this pressure. On the other hand, if a lower pressure could be employed, the pressure applied would be within the limits of the mechanical presses. According to Stillman (1), the limit of such presses is 10,000 pounds per square inch.

Consequently, attempts were made to briquette the preheated briquettes at lower pressures. In this work the optimum conditions previously determined were employed, the remaining conditions being the preliminary conditions discussed on page 10.

The results of this work are given in Table IV:

Table IV.—Briquetting Pressure.

Number	Pressure (lbs. per sq. inch)	Nature of Briquette	Drop Test (Per cent held)	Remarks
1	4,500	Poor	41.2	Briquettes unsatisfactory
2	7,000	Fair	55.2	Results not consistent
3	9,000	Good	81.7	Briquettes satisfactory
4	13,500	Very good	90.2	Briquettes very satisfactory

A study of Table IV shows that there is a regular increase in the strength of the briquettes as the pressure increases. Results secured at 9,000 pounds per square inch are entirely satisfactory showing over 80 per cent held by a one-half inch screen. A 50 per cent increase in pressure gives only a relatively small increase in strength. In view of the fact that the increased pressure is above the range of the mechanical press, it is doubtful if there is sufficient advantage to warrant this increase. Consequently, the lower pressure of 9,000 pounds was adopted and employed in all future work.

Duration of the Pressure.—In the preliminary work, the duration of the pressure was 30 seconds. There is no object in trying a longer period than this since excellent briquettes were secured. On the other hand, there is a definite object in studying the effects of shorter periods, since, if a mechanical press is employed in the large scale, the time interval is quite short. Consequently, shorter periods of time were tried ranging downward to zero.

The briquettes were made from the preheated lignite employing all the optimum conditions previously determined.

The results of this work are given in Table V:

Table V.—Duration of the Pressure.

Number	Time (seconds)	Nature of Briquette	Drop Test	Remarks
1	0	Very good	68.2	Briquettes of good quality (few cracks)
2	10	Good	57.7	A few cracks
3	30	Very good	81.7	Smooth, no cracks

A study of Table V indicates that the briquettes made at zero seconds are satisfactory. For some reason not understood, the briquettes made at 10 seconds were not only no better, but were actually inferior to those made at zero seconds. When the time was increased to 30 seconds, somewhat stronger briquettes were secured. In view of the fact that the briquettes made at zero seconds were satisfactory and in view of the fact that it is desirable for this time interval to be as short as possible, zero seconds was adopted as the most satisfactory time interval.

Rate of Application of the Pressure.—In order to secure the maximum output from a mechanical or hydraulic briquetting press, it is evident that the rate of application of the pressure should be as great as possible. With the press available it required 30 seconds for the application of the pressure at the best speed that could be conveniently attained. Briquettes made at this speed were entirely satisfactory. In order to determine if there was any appreciable improvement in the strength of the briquettes when the pressure was applied at a slower rate, a series of briquettes was made where it required 60 seconds for the application of the pressure. The results at the two different speeds are given in Table VI:

Table VI.—Comparative Strength of the Briquettes Where the Pressure Was Applied at Different Rates.

Number	Rate of Application of Pressure	Drop Test (Per cent held by ½" screen)
1	30 seconds	69.0
2	60 seconds	72.0

While it is evident that the briquettes made at the slower speed are slightly stronger, still the slight increase in the strength is not sufficient to counter-balance the increase in cost brought about by the decided reduction in capacity of the briquetting press at the slower rate. Consequently, unless otherwise specified, the pressure was applied at the more rapid rate (30 seconds) in the production of all briquettes.

Temperature of Removal of the Briquettes from the Mold.—To insure any appreciable output on a large scale it is necessary that the briquetting press be operated continuously. Consequently, it is necessary that the briquettes be removed immediately from the mold without allowing the latter to cool. This idea was carried out in this work, the briquettes being removed while the temperature of the mold was 50° C. The results were good. The briquettes slid evenly and smoothly from the mold and were of good quality.

REVISION OF OPTIMUM CONDITIONS TO MEET COMMERCIAL REQUIREMENTS

Before the optimum conditions could be determined, some method of testing the quality of the briquettes was necessary. The Drop Test (13) (see page 15), appeared to be the most practical test since it quickly indicated the strength of the briquettes. However, when the testing of the briquettes was studied more thoroughly, it was discovered that even though the briquettes when first made were of sufficient strength, they deteriorated considerably on aging, and hence to satisfy commercial requirements an increase in the strength of the briquettes was necessary.

A study of the optimum conditions with the object of increasing the strength of the briquettes indicated that increased strength could be secured by increasing the temperature, the amount of water, and the briquetting pressure. It was found also that increasing the diameter of the briquette with respect to their length also was effective.

The conditions which were finally adopted for making the briquettes were as follows:

Temperature	100°C
Water (added)	8 per cent
Briquetting pressure	13,500 lbs. per square inch
Diameter of mold	1.18 inch
Length of briquette	1.25 inch
Charge	20 grams

The resulting briquettes were of excellent quality.

All the briquettes tested in the following section were made by this method.

METHODS AND RESULTS OF TESTING THE BRIQUETTES

The most important physical properties of the briquettes from a commercial standpoint are their strength when first made, their resistance to aging, their heating and burning qualities, and to a somewhat lesser degree their crushing strength and specific gravity. In view of the fact that the experience of other investigators apparently has indicated that lignite briquettes, even when made with a binder, disintegrate rather rapidly when exposed to direct rainfall and other weathering conditions, these briquettes were tested with the idea of protecting them from direct rainfall, etc. The details and results of the various tests to which the briquettes were subjected are given below:

Drop Test.—The Drop Test employed by the Bureau of Mines (13) for the testing of lignite briquettes was slightly modified for this purpose. The details of this test as carried out are given below:

The briquettes were dropped on a cement floor from a vertical height of six feet. The pieces were collected and those that were held by a one-half inch screen were dropped again. This procedure was repeated four times, after which the weight of the pieces which would not pass through a one-half inch screen was determined. The briquettes were dropped five times in all.

Tumbler Test.—This test also was based on the one employed by the Bureau of Mines (13). The details as carried out are as follows:

A tin can eight inches long and six inches in diameter was half filled with quartz pebbles approximately one inch in diameter. The briquettes were placed in the can and same rotated for two minutes at twenty-eight revolutions per minute. The can was then opened and the contents screened on a one-half inch screen. The weight of the pieces retained on the screen was recorded.

Aging Tests:

Exposure of Briquettes to Climatic Conditions, the Briquettes Being Protected from Rainfall.—Since, as will be shown later, the briquettes are weakened by submergence in or exposure to water, it will be necessary to protect the briquettes in storage from direct rainfall. Consequently, the most important test is one where the briquettes are protected from direct rainfall but exposed to conditions similar to those to which they would be exposed in a dealer's coal yard. The time of exposure should be sufficient to allow for the transportation of the briquettes and a reasonable period for their disposal. A period of six weeks was considered sufficient for this. Consequently, the briquettes were placed in a rough shed where they were protected from direct rainfall but exposed to both high and low humidity. The average temperature during the tests varied from 50° to 80° F. Note: Several other series of briquettes were exposed to freezing weather apparently without effect. The shed under which the briquettes were stored had a roof but practically no sides. At the end of the test period the briquettes were tested by the Drop and Tumbler Tests.

Submergence of Briquettes in Water.—It is not considered that resistance of the briquettes to water is of vital importance, in view of the rather promising outlook for fuel briquettes employing sulfite liquor and other binders which are not impervious to water. It is believed that a reasonable resistance to water could be demonstrated by submerging the briquettes in water for two hours.

Crushing Strength.—In the absence of a more suitable testing machine, the crushing strength of the briquettes was determined by means of the press used for making them.

RESULTS OF TESTS

Using the methods just described, a series of briquettes, made under the conditions outlined, was tested. Because of the considerable number of briquettes employed, several days were required to make them. The results are given in Tables VII and VIII.

Table VII.—Strength of Fresh Briquettes.

Briquette Number	Drop Test (Per cent held by ½" screen)	Tumbler Test (Per cent held by ½" screen)	Crushing Strength: Pressure Applied on End of Bqt. (Lbs. per sq. in.)	Crushing Strength: Pressure Applied on Lateral Edge (Lbs. per sq. in.)
1	79.6	98.5	Above 200	Above 200
2	97.0	98.5	Above 200	Above 200
3	88.1	98.4	Above 200	Above 200
4	79.1	99.0	Above 200	Above 200
5	82.0	99.0	Above 200	Above 200
6	92.6		Above 200	Above 200
7	71.0			
8	98.5			
9	78.0			
10	76.7			
Average	84.26	98.7	Above 200	Above 200

Examination of Table VII indicates the fact that the strength of the briquettes when first made in such that losses on handling and shipping should be negligible. As a matter of fact the strength of the briquettes apparently compares favorably to the lignite briquettes made with a pitch binder by the Bureau of Mines (14). On application of the Drop Test several of the briquettes did not break at all, while on application of the Tumbler Test none of them broke. The crushing strength even in the weakest direction should easily be sufficient to permit storage and combustion of the briquettes.

Strength of Aged Briquettes.—The briquettes were allowed to stand six weeks in a shed provided with a cover but with no sides. Here the briquettes were exposed to widely varying conditions of humidity and temperature. A series of briquettes also was allowed to stand six weeks in an open container placed in a closed room. This would be similar to storing the briquettes in a closed building on a manufacturing scale. The results are given in Tables VIII and IX:

Table VIII.—Aging of Briquettes in Closed Room for Six Weeks.

Briquette Number	Drop Test (Per cent held by ½″ screen after five falls on cement)	Tumble Test (Per cent held by ½″ screen after 56 r. p. m.)
1	83.4	89.0
2	85.8	99.5
3	86.0	90.0
4	83.3	97.5
5	80.6	100.0
6	85.6	98.0
7	72.4	
8	99.0	
9	57.8	
Average	81.5	95.7

Remarks.—None of the briquettes broke on application of the Tumbler Test, while several did not break at all or broke on the last fall when the Drop Test was applied.

Table IX.—Aging of Briquettes in Shed for Six Weeks.

	Drop Test (Per cent held by ½″ screen after 5 falls from 6 feet in cement)	Tumbler Test (Per cent held by ½″ screen after 56 r. p. m.)
1	40.0	97.4
2	78.6	71.9
3	53.4	73.0
4	60.0	70.8
5	60.6	66.9
6	52.4	77.1
7	60.0	
8	54.5	
9	44.3	
10	42.7	
11	72.7	
Average	56.3	76.18

A study of Tables VII and VIII indicates that when the briquettes are aged for six weeks in a protected place, such as a closed room, the reduction in strength as indicated by the Drop Test and Tumbler Test is very slight. The reduction in the Drop Test was 2.76 per cent and the reduction in the Tumbler Test was 3.0 per cent. After six weeks the briquettes apparently were sufficiently strong to be handled or shipped with very little loss.

Examination of Table IX indicates that when the briquettes are protected from direct rainfall but exposed to other climatic conditions there is a considerable reduction in strength, the Drop Test falling from 84.26 to 56.3 per cent and the Tumbler Test from 98.7 per cent to 76.18 per cent. However, even briquettes with a Drop Test of 56.3 per cent are sufficiently strong to be handled or transported with little loss. As a matter of fact even these briquettes are as strong as some of those made by the Bureau of Mines with a pitch binder (14).

It follows from the above that the briquettes might be stored in a closed room or in a shed with open sides, the former being preferable.

Submergence of the Briquettes in Water.—After submergence of the briquettes in water for two hours, they were greatly weakened, though few of them disintegrated.

Specific Gravity of the Briquettes.—The average value secured by weighing the briquettes and measuring the volume with a micrometer was 1.114. This was roughly verified by the fact that the briquettes sink in water.

Heating Value of the Briquettes.—The average heating value of a number of briquettes determined in a Parr calorimeter was 9,623.5 B. T. U. per pound.

Combustion of the Briquettes.—A number of briquettes were burned in a grate. They ignited rapidly in the hot coals from a fire. They gave a pale yellow to colorless flame, with little smoke. They cracked slightly but did not crumble or lose their shape in the fire. The briquettes burned fairly slowly.

PRODUCTION OF BRIQUETTES ON A LARGER SCALE

These briquettes were made in a mold 2.25 inches in diameter. The optimum conditions developed for the small briquettes were applied here with minor variations. Fine material screened through 20 mesh as well as coarse material containing 20 to 40 per cent held by 20 mesh was briquetted. The briquetting pressure for the coarser material was from 10,000 to 15,000 pounds per square inch. The briquettes weighed about 50 grams.

The briquettes were of good quality and were fully as strong, if not stronger, than the small briquettes. The Drop Test nominally showed from 60 to 80 per cent held on a one-half inch screen. They weakened slightly on aging.

The briquettes burned rather easily, gave off very little smoke, and cracked but did not crumble in the fire.

REDUCTION IN ASH CONTENT OF THE BRIQUETTES

Good briquettes have been made from preheated sawdust (16), i.e., preheated to 270° C. It was found that the preheated sawdust could be mixed with the preheated lignite in the proportions of one part of sawdust to two parts of lignite, and the mixture briquetted without a binder.

These briquettes made in the large mold were quite strong. The Drop Test showed from 70 to 80 per cent held by a half-inch screen when briquetting pressures from 10,000 to 12,000 pounds per square inch were employed. On aging for 6 weeks, the Drop Test recorded from 50 to 90 per cent. The briquettes behaved fairly well in the fire. They burned with a yellow flame but showed some tendency to crumble.

The estimated cost of making the sawdust briquettes is only $1.64 per ton (16), while the heating value is 10,440 B. T. U. per pound. The ash content is only 0.70 per cent. It follows that by adding sawdust to the lignite there should be a decided reduction in ash content and in cost.

NOTES ON PROBABLE LARGE SCALE APPARATUS AND COST ESTIMATE

The Bureau of Mines (Bulletin 14—"Briquetting Tests of Lignite") rather thoroughly develops the large scale equipment and cost of manufacture of lignite briquettes. Consequently, a comprehensive study of these items does not appear to be necessary in this case.

In the process which has been developed the following steps are necessary:

(1) Mining, storage, and air drying of raw lignite.
(2) Carbonizing, cooling, grinding, and screening.
(3) Addition of water and briquetting.

Since the lignite is on or near the surface, it probably could be mined by stripping.

For drying, the Bureau of Mines employs a rotary drier containing tubes of pipe through which the lignite passes by gravity and which is heated by steam (live or exhaust).

Probably the same type of equipment could be used for the preheating or destructive distillation except that it should be heated to a higher temperature for which hot air or gas would probably be employed. The dryer must be air-tight.

For the briquetting, a German or English press of the type employed by the Bureau of Mines probably would be satisfactory (see Bulletin 14).

A flow sheet of the proposed process is given below.

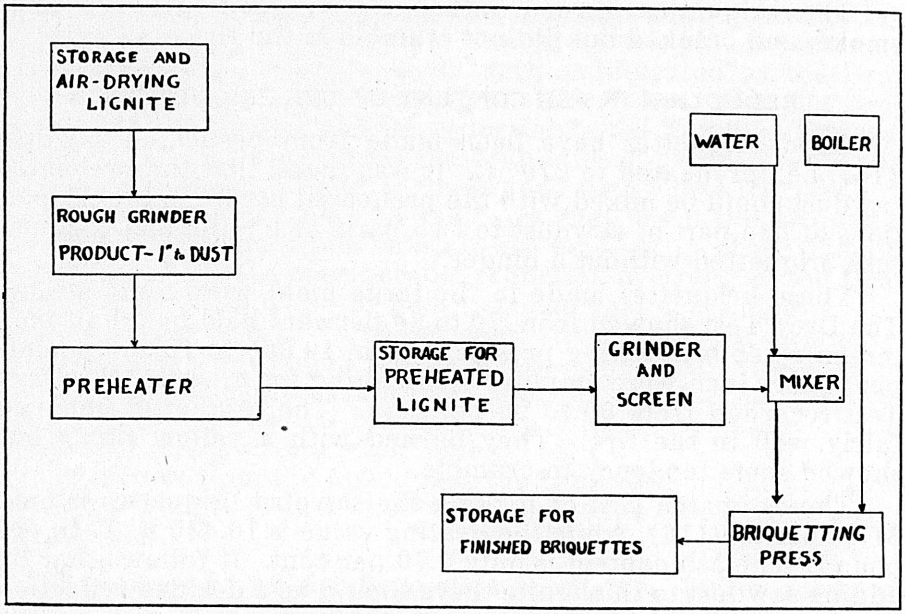

FIGURE III.—PROCESS DIAGRAM

Estimated Cost of Briquettes.—The Bureau of Mines (Bulletin 14, page 46, 1912) states that in Texas (the Alabama lignites apparently are similar to the Texas lignites) the cost per ton of briquettes at the mine would be as follows:

1.32 tons lignite (33 per cent moisture) for 1 ton briquettes	$1.18
Briquetting costs	1.33
Total	$2.51

There figures are based on the assumption that the plant costs $56,000, that it be located at the mine, that it be operated 2 shifts of 10 hours each, or 20 hours per day, and that it have a capacity of 50 tons of briquettes per day of 20 hours.

Application of the above figures to the Alabama lignites would be as follows:

1.84 tons of lignite (water 33 per cent) for 1 ton of briquettes	$1.65
Briquetting costs	1.33
Total	$2.98

To the above should be added something for the somewhat higher drying or carbonizing temperature. In view of the fact that 0.10 ton of lignite is more than sufficient for this purpose on a theoretical basis, which would cost $0.09 at $0.90 per ton, $0.25

per ton appears to be adequate for this, bringing the total cost to $3.23 per ton.

If the English briquetting machine (Johnson) described by the Bureau of Mines (Bulletin 14, page 17) is employed, the cost would be considerably less. Since this plant with a capacity of 76 tons per day (20 hours) costs only $18,325 as compared with $56,000 for a German plant with a capacity of 50 tons per day (20 hours), there would be a reduction in fixed charges and interest on the investment amounting to about $0.47 per ton of briquettes.

As previously explained, if preheated sawdust is added to the preheated lignite in the proportions of one to two by weight, because of the lower cost of the sawdust briquettes ($1.64 per ton), the cost of the lignite briquettes apparently would be still further decreased. This also would amount to about $0.50 per ton of the briquettes.

It is obvious from what has been said that the cost of production of the lignite briquettes probably would vary between $2.26 and $3.23 per ton. It seems likely that the cost would not exceed $3.00 per ton in Alabama, assuming that present costs do not greatly exceed those in 1912.

Commercial Possibilities of the Process.—In Alabama for the process to be promising it would be necessary to briquette and utilize the lignite in the area in which it is located (South Alabama). Here it would come in competition with bituminous coal and to some extent with gas. Coal for domestic purposes in this southern part of the state costs from $6.00 to $10.00 per ton. If the apparently conservative figure of $7.50 per ton is taken as the average, the cost per heat unit of the lignite briquettes and the coal would be as follows:

	Cost per B. T. U.
Lignite Briquettes	0.03c
(Heating value taken at 10,000 B. T. U. per lb.)	
(Cost taken at $3.00 per ton)	
Bituminous Coal	0.0536c
(Heating value taken at 14,000 B. T. U. per lb.)	

On this basis, there is a decided advantage in favor of the lignite briquettes over coal. The advantage over gas would be even more decided.

The lignite briquettes also would have the advantage of much less smoke and dust, while the coal in some cases would have the advantage of lower ash content.

In recent years lignite and coal briquettes apparently have commanded a premium over coal in the United States.

If anything like the average value for coal briquettes (17), which in 1936 was $6.95 per ton in the Central States, can be realized, the process apparently would be quite profitable.

Comparison between the lignite briquettes and those made by the Bureau of Mines (15) with a pitch binder is as follows:

	Strength (Drop test)	Ash (Per cent)	Heating Value	Cost
Alabama Lignite Briquettes (No binder)	75-97	15.65	10,000 (approx.)	$3.00 per ton
Lignite Briquettes (Pitch binder)	50-90	9.65 to 23.91	6,000 to 15,000 B. T. U.	$2.80 to $4.34 per ton depending on location

The Alabama lignite briquettes, because of the fact that no binder is necessary, would have a decided advantage since much less smoke is liberated on combustion of the briquettes.

SUMMARY

(1) Good fuel briquettes have been made from Alabama lignite by subjecting the lignite to destructive distillation at low temperatures followed by briquetting of the residue without a binder. The development of a method for briquetting the residue without a pitch binder eliminates much smoke and reduces considerably the cost of the operation.

(2) This process is probably not applicable to all Alabama lignites. According to Barksdale (12) proximate analysis of a large number of Alabama lignite samples show reasonably constant results but there is a wide variation in the ash content which may affect the briquetting property. The lignite samples employed for this work are considered fairly representative, but it would be necessary to make a preliminary study of the briquetting properties of the lignite from a given locality before the application of this process could be determined.

(3) By the method described, a fuel briquette which is nearly smokeless and of a considerably higher heating value than raw lignite has been made at a moderate cost. In this way it is believed that the possibilities of employing the lignite as a domestic fuel have been much improved.

(4) The effect of variations in the process have been studied and the optimum conditions determined.

(5) The probable large scale installation has been outlined and the cost of manufacture of the briquettes estimated.

(6) The results of the experimental work indicate that, by the proposed process, a good grade fuel briquette can be produced at a cost that appears to be quite attractive when compared with the cost of other fuels in that vicinity.

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