The Production of Lump Charcoal from Pine Sawdust Without a Binder

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ACKNOWLEDGEMENT

This work is a cooperative project between the Tennessee Valley Authority and the Engineering Experiment Station of the Alabama Polytechnic Institute.

The writers are particularly indebted to Mr. R. D. Lambert, Mr. O. Folkovitch, and Mr. A. M. Miller of the Tennessee Valley Authority.

AUBURN, ALABAMA
1942

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ABSTRACT

The object of this investigation was to find a satisfactory method for the profitable disposal of the large amounts of finely divided wood wastes available in the South and West.

As a result of this investigation, a process has been developed for the briquetting of finely divided charcoal involving the following steps:

1. The wood waste in the form of sawdust is dried and partly carbonized under such conditions that the cohesive forces of the charcoal becomes effective.
2. Pressure of several hundred pounds per square inch is applied to the hot charcoal during the completion of the carbonization process.
3. Finally the briquettes are further heat treated for smoke removal. The resulting briquettes are firm and strong enough to stand rough handling and they resist weathering to an extent which should permit shipment and storage. They also are smokeless and of satisfactory heating value.
4. Optimum conditions for the various steps in the process have been determined on an experimental scale and a study made of costs of plant and operation of a plant with a capacity of 2000 tons per year.

The proposed process seems to be suitable for small scale installations and apparently would permit the use of a plant of simple design requiring the minimum amount of equipment and labor. Consequently it seems adapted to the disposal of saw mill waste from small mills.

INTRODUCTION

In the production of lumber from the Southern pine the waste is high, probably less than half of the weight of the tree being converted into lumber. Much of this waste is in the form of sawdust and shavings. These are more than sufficient for producing the steam needed by the mills and consequently sawdust burners are in constant operation. In some localities huge piles of sawdust accumulate and at times are a fire menace to the community.

Although a variety of processes have been proposed for the ultilization of sawdust and shavings, few have made appreciable headway on account of the mechanical difficulties involved in the handling of a bulky material of low heat conductivity and the poor financial return due to the low price and uncertain market existing for the chief products recovered from wood waste.

With the increasing costs of fuels and the growing interest in conservation of natural resources, it seemed desirable to make a further effort to obtain a marketable product from this waste material.

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* See page 29 for oak sawdust.

BIBLIOGRAPHICAL REVIEW

The methods for the utilization of sawdust may be conveniently classified as follows:

Briquetting of Raw Sawdust Without Binder.—The process employed by the Pacific Coal & Wood Company(2) consists of briquetting the wood waste at a light pressure in a special brick press. The briquettes are bound with baling wire to hold them together.

At the chemical works of Carl Feuerlein(3) near Stuttgart, the residue from which pharmaceuticals have been extracted is briquetted in an Exter press. The briquettes are a mixture of quebracho, logwood, and fustic with some chestnut and oak.

The Arnold process(4) controlled by Ganz & Company of Ratibor, Upper Silesia, is of some interest. Sawdust is cascaded over steam heated pipes and then over a steam heated plate. The dried sawdust is then briquetted in the Arnold press, a modification of the Exter press. This process has been developed on a commercial scale.

A method (5) recently introduced into Germany known as the "Berner Process" consists in the formation of a "rope" of briquettes. These are made on a light pressure press.

It does not appear however that any of these processes would be feasible for the waste material we are considering.

The Briquetting of Raw Sawdust With A Binder.—While it is true that sawdust has been briquetted with a great variety of binders still, as far as is known, none of these processes have attained any particular importance in this country. Typical processes are as follows: J. Armstrong(6) briquettes a mixture of coal, peat and sawdust with tar. Bunn(7) employs dehydrated mineral tar, resins and petroleum pitch for coal, sawdust or other fuels. Hughes and Loveli(8) employ pitch or other hydrocarbons or a carbohydrate as molasses, together with soot for the briquetting of coal, peat, sawdust, etc. Fallet(9) used clay for the agglutination of fine carbon or sawdust.

Briquetting of Charcoal.—The two methods for the conversion of comminuted wood into charcoal and by-products are as follows: (1) Distillation of the finely divided wood with subsequent briquetting of the fine charcoal. (2) Briquetting the wood waste and distilling the briquettes.

The Seaman process(10) is typical of the first class. The finely divided wood is distilled in a revolving retort provided with special charging and discharging devices. It is said that the distillation is completed within three minutes. The resulting charcoal is then briquetted with wood tar.

Processes typical of the second class include the unsuccessful attempts of Bergmann, Heidenstamm and others(11) to produce a strong, compact, coherent, charcoal by distillation of sawdust briquettes, the Heidenstamm process(12) of distillation of sawdust briquettes under mechanical pressure, the Hawley process(13) where the sawdust is briquetted at very high pressure (30,000 pounds per square inch) and subsequently distilled at 300 pounds per square inch, and the process employed by the Kingsport Wood Reduction Company(14) at Kingsport, Tennessee. In this process the sawdust is briquetted in a Duryea press at high pressure, and distilled under pressure by a method similar to the Heidenstamm process or Hawley process.

Special Process for the Destructive Distillation of Sawdust and Shavings.—The mechanical difficulties involved in the distillation of sawdust and shavings are great. Consequently many processes have been proposed to avoid these difficulties as far as possible. In the Stafford process(15) the heat liberated by the exothermic reactions involved in the decomposition of the wood, serves to initiate a fresh charge, the process being continuous.

Blair(16) divides the retort into a series of trays. The sawdust passes from the top of the retort to the bottom, being pushed from each tray by scrappers.

In the Sautelle(17) process the distillation products from the lower part of the charge pass through the upper part.

Halliday(18) carries out the carbonization of sawdust by means of a screw conveyer in a closed and heated retort.

In the Bower(19) retort an endless belt working inside the retort is employed.

Felzat(20) showers the fine sawdust into the retort.

According to Klar(21) sawdust has been used for fuel gas in a special form of gas producer.

Bueschlein (22) distills the fine wood in a special type of rotary kiln. Use is made of the exothermic heat liberated by the decompostion of the dry sawdust for the predrying and preheating of the wood to the temperature of decomposition.

A recently developed method of Mason(23) consists in subjecting the waste wood (chips) to steam at high pressure and then suddenly removing the pressure. The fibre obtained by exploding the chips by sudden release of the pressure is beaten roughly and made into a wall board somewhat similar to Beaver board.

MORE RECENT PROCESSES FOR THE UTILIZATION OF WASTE WOOD

Basore(24) preheats sawdust in a closed retort to a temperature of 275° C. whereby it loses its elasticity and the brown partly charred residue is moistened and briquetted hot without a binder.

Bruneau(25) developed an apparatus for treating wood chips under heat and pressure comprising one or more endless screws turning in a resistant groove for compressing the material and forcing it through a die.

Carpenter's(26) method consists of predrying the sawdust and molding it into a briquette by means of a die. The sawdust briquette thus formed is compressed and heated to form a hard crust (charcoal) on the surface.

Holdaway(27) dries the sawdust, preheats it to 300° F. and presses hot to one-sixth of its free volume.

The Wood Briquettes, Inc.,(28) Lewiston, Idaho, recently has developed a new wood briquetting machine which applies from 15,000 to 25,000 pounds pressure per square inch and produces a very dense (density 1.3) wood briquette.

Typical binders used in recent years for fine charcoal are rosin and oil,(29) starch from broken rice,(30)(31) highly bituminous coals,(32) wood tar,(33)(34)(35) an aqueous solution of trisodium phosphate and sodium aluminate,(36) molasses sirup and sugar sirup,(37)(38) coal tar pitch and similar materials. (39)(40)(41)(42)

A method developed by Beandequin(43) for the briquetting of brown coal, peat, lignite, etc., consists of pre-distilling the material to remove water and the more volatile hydrocarbons, forming briquettes of the residue, feeding them into a tube, heating under pressure in such a way that the hydrocarbon gases given off are forced through the briquettes, and cooling the briquettes under pressure.

The Hawley process(44) previously mentioned deserves special consideration. A block of comminuated wood is formed under a mechanical pressure of 30,000 pounds per square inch. This is followed by distillation at 300° C. under a mechanical pressure first increasing from 50 to 120 pounds and later decreasing through the same range in successive alternations.

Relative to the use of charcoal, it should be mentioned that Germany, Japan, Austria and other foreign countries are operating trucks and other motor vehicles on producer gas made from charcoal.(45)(46) In the United States already there is a committee on the emergency conversion of motor vehicles to producer gas operation.(47)

CHARCOAL BRIQUETTES FROM SAWDUST WITHOUT A BINDER

Few of the processes for the utilization of sawdust seem worthy of serious consideration. Methods depending upon the eventual recovery of lump charcoal seem to have promise because of the growing peace-time and war-time demands for charcoal.

Methods for charcoal briquettes produced by briquetting finely divided charcoal made by distillation of sawdust, with large quantities of binders appear unattractive because of the ash or smoke introduced by the binder, and the considerable cost of the binder. Methods for producing lump charcoal from sawdust without a binder would be attractive if such methods are possible.

Lump charcoal has been produced indirectly from sawdust without a binder by taking advantage of the fact that sawdust can be briquetted successfully at very high pressures without a binder. When the resulting briquettes are carbonized in a closed retort under pressure, lump charcoal is secured. Methods of this type include the Heidenstamm process,(12 the Hawley process, (13) (44) and the process employed at Kingsport, Tennessee, where briquettes have been made for some years by this method. Methods of this type require very high pressure for briquetting the sawdust, a considerable variety of equipment, i. e., storage hoppers, Duryea gasoline driven presses, hydraulic presses, charging devices for the retorts, heated retorts, and similar equipment.

Throughout the south large piles of sawdust exist in many localities while others are being formed through the activities of the lumber industry. Consequently a simple method for utilizing this material that permits small relatively inexpensive portable or semiportable installations that might be operated with unskilled labor appears to be desirable. With the above ideas in mind experiments were started involving predrying or partial carbonization followed by the simultaneous completion of the carbonization and the application of light pressure to the partly carbonized material. The possibilities along this line soon were evident and it became apparent that it was possible to produce a briquette of a desirable type without a binder. The record of this investigation is given below.

EXPERIMENTAL WORK

Laboratory Apparatus.—In early experiments it was found that both carbonization and application of pressure could be effected in cylindrical steel molds. A mold six inches long and one and three quarter inches in diameter, provided with a piston seven inches long and one and twenty-one thirty-seconds inches in diameter was provided. The piston fitted rather loosely in the mold to permit the escape of gases and other decomposition products. The mold was provided with a thermometer well five inches deep. The mold rested on a steel plate one fourth of an inch thick.

The method of heating the mold and plunger was the subject of considerable study. A rapid method of heating the mold and one which permitted accurate temperature control and ease of handling of the mold (i. e., the mold must be transferred to the briquetting press, the briquette removed, and the mold reheated to the desired temperature) is essential. A cylindrical electric furnace controlled with a rheostat first was used to heat the mold, and hold it at the desired temperature. The manipulation was found to be difficult and results were not very satisfactory. Consequently, this was discarded. A sand bath was found to be very slow for the temperature desired and an oil bath undesirable. Under the circumstances direct heating with gas appeared to be the most satisfactory method of heating. The mold was mounted on a steel plate one fourth of an inch thick which in turn was supported by a steel stand, the top of which was perforated. The mold was heated by three burners, distributed uniformly around the circumference of the mold, and by one Merkle burner placed under the steel support. The flames from the side burners contacted the mold one and one-half inches from the bottom in such a way that a belt or zone of flames played virtually completely around the mold. The themometer in the well was protected by a cylinder of asbestos paper. The pressure was applied to the plunger by a Carver hydraulic press.

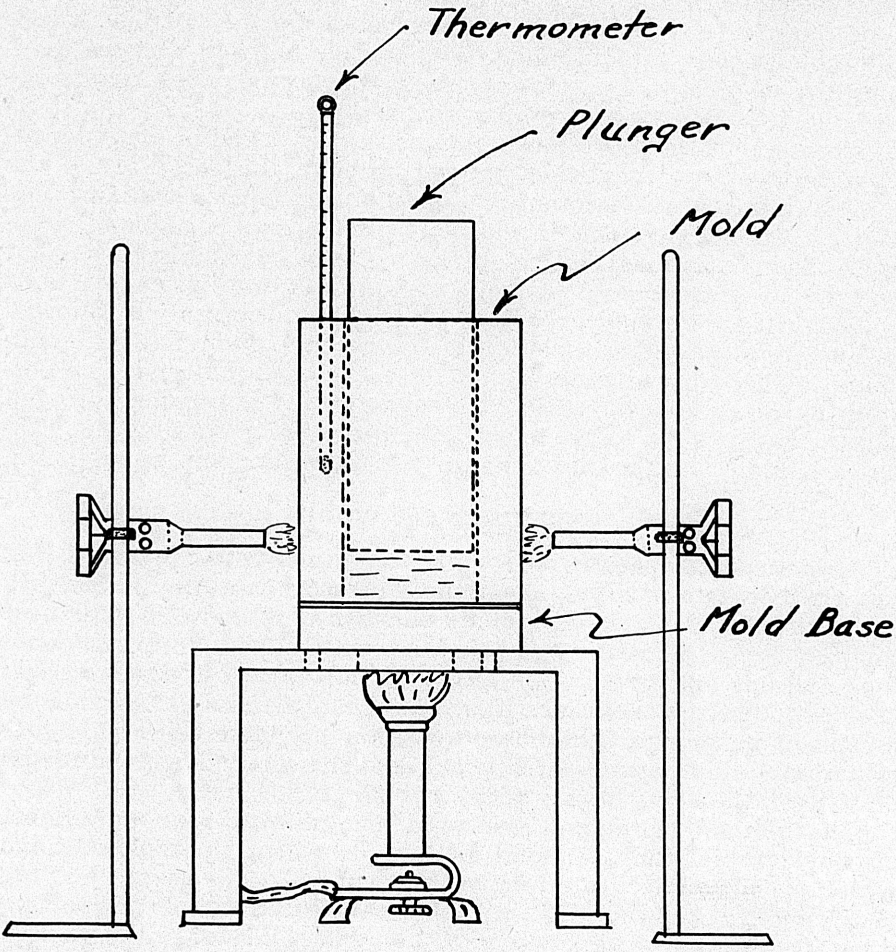

Figure 1.—Briquetting Mold

The carbonization of the briquettes was completed and the smoke removed in a retort 2.067 inches in diameter and 6¾ inches long made from an iron pipe, which was heated to 400° C. in a crucible type electric furnace controlled by a rheostat.

A diagram of the apparatus employed is shown in Figures I and II. As shown by the yields in Tables I, III, IV and V, accurate temperature control was secured with this apparatus.

Material and General Procedure.—A considerable variety of fine sawdust and shavings differing in size of particles have been tried. Entirely satisfactory results were obtained in each case. It was decided that the sawdust requiring the most rigorous treatment and that most readily available be selected for this work.

The sawdust was air dried until constant in weight, mixed thoroughly and stored in large air-tight containers. Analysis of the sawdust is given below:

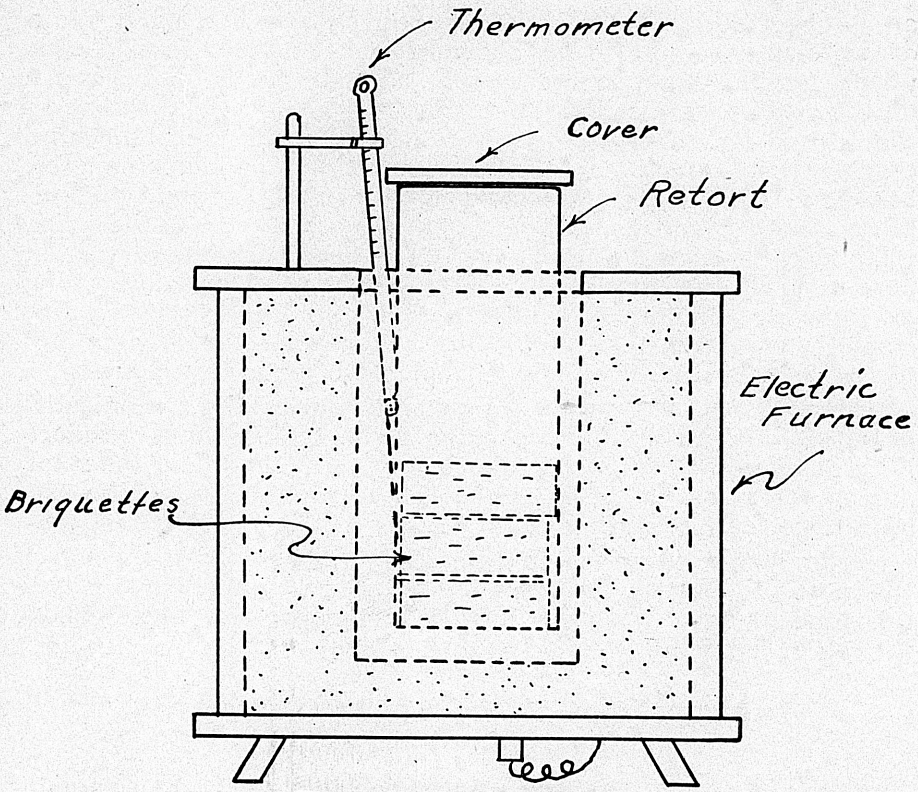

Figure 2.—Smoke Remover

Moisture Per cent by weight	**Rosin*** Per cent by weight	**Ash** Per cent by weight
8.1	5.4	0.98

Ultimate Analysis—Per cent by Weight
(Dry basis)

Carbon	48.90
Hydrogen	4.27
Nitrogen	46.83
Oxygen, etc.	
Total	100.00

Screen Analysis of Sawdust
(Tyler Standard Screens)

Through ¼ mesh held on 20 mesh (openings .0328 inch) = 85.8 per cent
Through 20 mesh held on 42 mesh (openings .0136 inch) = 11.5 per cent
Through 42 mesh held on 60 mesh (openings .0097 inch) = 2.0 per cent
Through 60 mesh held on 80 mesh (openings .0069 inch = 0.7 per cent

The general course of a run is as follows: The mold and piston

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* Extracted with ether.

are preheated to the desired temperature (400° C.). Forty grams of sawdust are placed in the hot mold and the piston inserted. The piston fits the mold rather loosely and allows the hot gases to escape readily. The temperature of the mold is held constant for the desired length of time, after which the mold and plunger are quickly transferred to the press, the pressure applied, the green briquette removed from the mold by application of slight pressure to the plunger, and the briquette quickly transferred to the smoke remover where it is heated at 400° C. for the desired time with exclusion of air. The finished briquette is then quickly removed to an air tight container where it is allowed to cool. The briquettes, after cooling, were transferred to a desiccator where they were protected from the air. The yield is from 29 to 30 per cent charcoal.

Considerable gas and tar are given off during the carbonization of the sawdust. Before the application of the pressure these products burn at the top of the mold. They also burn at the top of the retort during the smoke removal period. These products might be used advantageously in heating the mold.

After charging the piston extends six inches above the top of the mold. When ready to press the wood has been reduced in volume, the plunger extending only four and one-half inches above the top of the mold.

DETERMINATION OF OPTIMUM CONDITIONS FOR PINE SAWDUST BRIQUETTES

Temperature of Mold.—As stated previously the mold was maintained at 400° C., since this is probably the most common temperature for wood distillation. The important temperature is not so much the mold temperature but the actual temperature of the semi-charcoal when the pressure is applied. Consequently a mold temperature was selected above the desired charcoal temperature, and the temperature of the semi-charcoal at the time of application of the pressure regulated by the time of heating before application of the pressure.

Time of Heating Before Pressing (Optimum Temperature of Charcoal for Pressing).—Preliminary experiments indicated that it was important how long the sawdust was heated in the mold maintained at 400° C. before the application of the pressure. If this period is too short, time is not sufficient for the transfer of heat from the outside to the center of the sawdust in the mold, and consequently the outer surface of the briquette is a hard, charred mass while the interior is undecomposed sawdust. If the time is too long, the briquette is overheated and is weak and fragile.

A time of ten minutes was employed in the preliminary work. To determine if this was the best time, suitable points were taken on either side of ten minutes. The strength of the various briquettes was recorded by the Drop Test (See page 19).

The results of the various tests are given in Table I.

TABLE I.—Time before Pressing

Time	Yield before smoke removal. Per cent by weight	Yield after smoke removal. Per cent by weight	Strength drop test. Per cent held by one-inch screen.	Thickness* of briquette at edge. Inches	Remarks
8 min.	64.2	30.9	00.0 Crumbles	1.00	Briquettes not completely charred.
10 min.	56.62	30.2	82.3	0.81	Not completely charred in center. Ends somewhat shrunk in center.
12 min.	47.0	30.6	93.6	0.75	Briquettes withstand one fall of 14 ft. on cement. Uniformly charred. Ends of briquettes somewhat shrunk in center.
14 min.	38.43	29.18	90.6	0.69	Briquettes withstand one fall of 14 ft. on cement. Uniformly charred. Ends of briquettes somewhat shrunk in center.
16 min.	35.33	29.34	90.3	0.64	Briquettes withstand one fall of 14 ft. on cement. Uniformly charred. Ends of briquettes somewhat shrunk in center. Briquettes crumbled readily.
18 min.	34.43	30.3	76.7	0.69	Some withstand one fall of 14 ft. on cement. Little shrinkage of ends.
20 min.	31.7	29.3	14.04	0.76	Little shrinkage of ends. Crumbles.

* Density not strictly comparable.

NOTE: In the preliminary work good results were secured with heating for 10 minutes before pressing and 28 minutes for smoke removal or a total of 38 minutes. In varying the time before pressing the total time was kept constant at 38 minutes, i. e., if the time before pressing was increased the time for smoke removal was reduced accordingly.

Examination of Table I indicates that the total yield (after smoke removal) was nearly constant, the variation being from 29.18 per cent to 30.9 per cent. The strength of the briquettes, as indicated by the Drop Test, rapidly increased and reached a maximum at 12 minutes. From twelve minutes to sixteen minutes there was a very slight reduction in strength which became appreciable at eighteen minutes. Beyond eighteen minutes there was a rapid decrease in strength. The thickness of the briquettes which gave an indication of the volume, was reduced regularly until sixteen minutes was reached. Beyond sixteen minutes there was an increase in the thickness. Practically no shrinkage of the ends of the briquettes was secured at this point. Briquettes made at eight and ten minutes before pressing were not uniformly charred in the center and even at twelve minutes there were slight indications of lack of uniform charring. This of course is explained by the fact that there is a temperature lag in the center of the briquettes, i. e., the temperature at a given time being considerably below that of the exterior (mold temperature). The column showing the yield before smoke removal indicates that even where the loss of weight of the sawdust is 100—31.7 or 68.3 per cent (See 20 minutes) the residual material may be briquetted at low pressure by this method. The residual material at this point before pressing is really charcoal. Little difference was observed in the combustion of the briquettes at different times.

Selection of the optimum time involves several factors. Briquettes at twelve, fourteen, and sixteen minutes have the maximum strength and density. There is no increase in strength after twelve minutes but there is an increase in density up to and including sixteen minutes. This is considered an advantage. On the other hand the strength of the briquettes fluctuates considerably at sixteen minutes and there is a noticable tendency for the briquettes to crumble. Further, briquettes at fourteen minutes are nearly as dense as those at sixteen minutes. From an industrial standpoint, if the total time is kept constant, it probably is advantageous to reduce the time of heating before pressing as much as possible and increase the time of smoke removal since in the first period a bulky material of low conductivity is encountered while in the last period the resulting briquettes are much more dense and are much better heat conductor. Because of these reasons sixteen minutes was discarded.

The selection between twelve and fourteen minutes likewise involved several factors. Twelve minutes has the advantage of reducing the time before pressing, but the sawdust is more uniformly charred at fourteen minutes and the briquettes are considerably more dense. The considerable increase in density more than balances the slight reduction in strength, consequently fourteen minutes was adopted as the optimum time.

Examination of Table II indicates that at 14 minutes the temperature of the center of the charcoal was 355° C. while the outer edge was the same temperature as the mold (400° C.). The average temperature is 377.5° C. Consequently this is the optimum temperature of the charcoal when pressed.

The time of heating before pressure application may be greatly reduced by preheating the sawdust to a medium brown color (temperature 250° C.) before heating in the mold. Preheating drives out practically all the water and also there is some decomposition of the wood itself. Several test runs using preheated sawdust indicated that preheating before pressure application for not more than six to seven minutes was sufficient to produce briquettes of good strength and other qualities. The time of heating before pressure application probably may be still further reduced by reduction of the diameter of the mold.

Effect of Moisture on Time of Heating before Pressing.—Sawdust of course is a poor conductor of heat. During the heating of the sawdust before the application of the pressure, the temperature of the interior of the sawdust usually is well below the temperature of the mold. As the time of heating increases the temperature of the interior of the sawdust increases, i. e., the temperature lag decreases.

Efforts were made to measure the temperature of the interior of the sawdust during the heating period. The mold was maintained at 400° C. as usual, the piston was removed, and a thermocouple placed in the center of the mold filled with the usual charge of sawdust and placed two inches from the bottom, i. e., at about same height as the thermometer used for measuring the temperature of the mold. The results are given in Table II.

TABLE II.—Comparison Between the Interior and Exterior Temperatures of the Sawdust

Time of heating (minutes)	Mold temperature (°C.)	Temperature of the sawdust Center °C.	Average °C.
0	400	40	
2	400	100	
4	400	105	
6	400	122	261.0
8	400	175	287.5
10	400	230	315.0
12	400	310	355.0
14	400	355	377.5
16	400	395	397.5
18	400	405	402.5
20	400	405	402.5
22	400	405	402.5

The results in Table II were secured under somewhat different conditions than an actual run. Nevertheless these results are believed to give a fairly good indication of the truth. Table II shows that the temperature of the interior of the sawdust during heating remained practically constant until all the water was removed. This required several minutes. This indicated the marked effect of the moisture content on the time of heating.

Tests were made on moisture free sawdust (dried for two hours at 105° C.). It was found that the time of heating before pressing could be appreciably reduced. A new test made on sawdust containing as much as 50 per cent moisture showed that heating for one hour was insufficient.

As stated previously the time of heating before pressure application may be greatly reduced by preheating the sawdust to a medium brown color. Several test runs using preheated sawdust and a one and three fourths inch mold showed that six to seven minutes was sufficient to produce a briquette of good strength. This probably could be further reduced if reduction was made in the diameter of the mold.

As stated previously the moisture content of the sawdust used in this work was 8.1 per cent.

Briquetting Pressure.—Briquetting at high pressure is likely to be rather expensive. This is particularly true in this process since a standard briquetting press may not be suitable and it may be necessary to apply pressure to a mold or container of relatively large cross section.

In the determination of the best briquetting pressure a series of briquettes was made at various pressures. The first pressure tried was below the pressure required to give an entirely satisfactory briquette. The pressure was then increased at regular intervals. In all other respects the briquettes were made in the usual way. The time of preheating before pressing was fourteen minutes. The strength of the briquettes was determined by the Drop Test. (See page 19.) The density of the briquettes was calculated from the weight and volume. The results of these runs are summarized in Table III.

TABLE III.—Briquetting Pressure

Pressure (lbs. per sq. in)	Yield of Charcoal (per cent by wt.)	Strength (Drop Test)	Density
75	30	74.7	0.28
150	30.3	89.7	0.37
300	29.8	91.9	0.51
450	30.7	94.5	0.55

Examination of Table III indicates that the briquettes made at 75 pounds per square inch are only of moderate strength and are of low density. Briquettes at 150 pounds are much stronger and more dense. The briquettes at 300 pounds are stronger than those at 150 pounds and considerably more dense. The briquettes at 450 pounds are slightly stronger than those at 300 pounds (additional strength seems to be of little advantage) and there is an increase of density of several per cent.

Whether a slight increase in density would justify a fifty per cent increase in pressure is questionable. The briquettes on a commercial scale probably would be produced in a rectangular mold or die of considerable cross section thereby producing a bar or rope of charcoal. This is necessary in order to secure any considerable capacity. Consequently, an increase of fifty per cent in the pressure is of some importance. Under the circumstances a pressure of 300 pounds per square inch is considered preferable to 450 pounds. Under these conditions a good grade briquette two or more times as dense as ordinary charcoal is readily produced.

Rate of Application of the Pressure.—In order to secure the maximum output from a mechanical 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 approximately one minute for the application of the pressure at the best speed that could be attained conveniently. 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 two minutes for the application of the pressure. The results at the two different speeds are given in Table IV.

TABLE IV.—Rate of Application of the Pressure

Time of Application of Pressure	Yield	Drop Test (per cent held by 1" screen)	Density
1 min.	29.8	91.9	0.51
2 min.	30.0	93.5	0.50

Examination of Table IV indicates that there is little if any advantage in a time of two minutes. The slight increase in strength apparently is of little importance. No definite advantage being obtained at two minutes, one minute was adopted.

Duration of the Pressure.—The duration of the pressure has reference to the time that the maximum pressure employed is maintained on the briquettes. It is desirable that this period be as short as possible, since an increase in this period will appreciably reduce the output of the press. This period usually is very short.

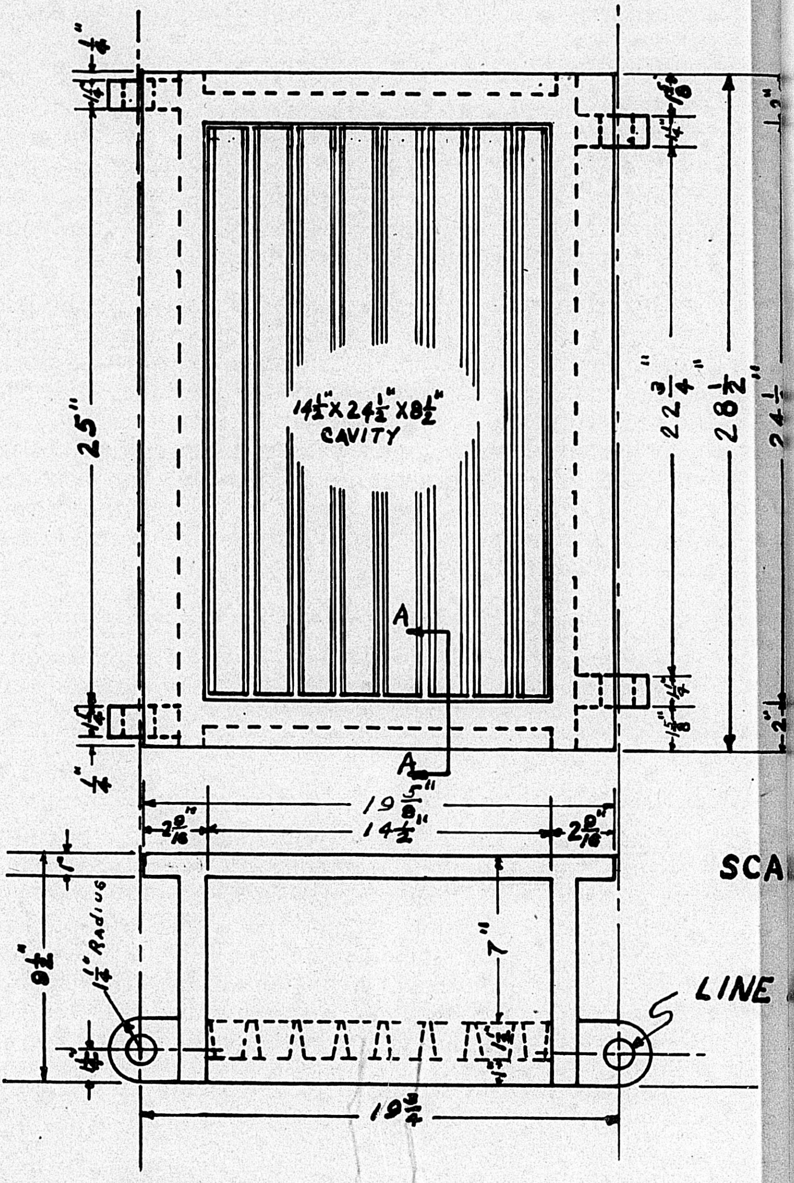
A period of ten seconds was used successfully in the preliminary work. In order to determine if this was the best time interval, a series of briquettes was made in which the time interval was varied on both sides of ten seconds. The results of these runs are summarized in Table V.

TABLE V.—Duration of the Pressure

Time (seconds)	Yield per cent by weight	Strength Drop Test	Density
Zero	30.2	78.3	0.39
Ten	29.8	91.9	0.51
Twenty	30.3	85.3	0.52

Examination of Table V indicates that the briquettes where the pressure was removed immediately (zero seconds) are considerably weaker and less dense than those where the pressure was maintained for ten seconds. Briquettes where the pressure was maintained for twenty seconds showed no improvement over those made at ten seconds. As a matter of fact they were weaker than those made at ten seconds. Consequently ten seconds was adopted as the optimum time for the duration of the pressure.

Temperature of Removal of the Briquettes from the Mold.—To insure any appreciable output on a large scale it is necessary that the briquettes be removed immediately from the mold without allowing them to cool. Further, it is necessary to subject the briquettes to smoke removal before they are allowed to cool. NOTE: The briquettes if allowed to cool and then re-heated for smoke removal are a great deal weaker than they are if treated for smoke removal before cooling. Consequently the briquettes were quickly removed from the hot mold and immediately transferred to a separate retort maintained at 400° C. where they were heated in the absence of air until smokeless.



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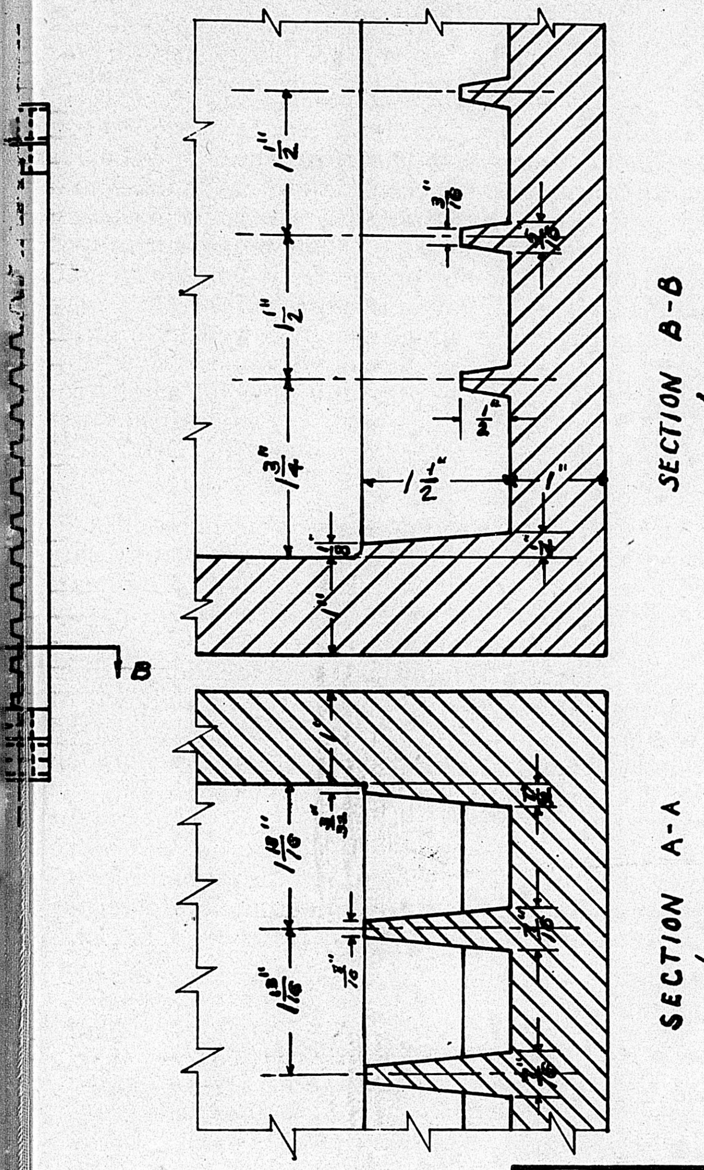
MACHINED C I CORE BOX



BRIQUETTING
MOLD
SCALE SHOWN

SMOKE REMOVAL

As previously explained, after compressing the preheated and partly carbonized wood into briquettes, the briquettes are further heated in an air tight retort to complete the carbonization and to eliminate the smoke.

Temperature for Smoke Removal.—The temperature of the retort should be such that the wood is completely carbonized and "brands" are eliminated. Probably the most common finishing temperature employed in industry is 400° C. This temperature was used successfully in this work. The hot briquettes when transferred to the retort maintained at 400° C. gave off dense smoke (this may be burned) for six to eight minutes which was followed by a gradual decline, practically all the smoke having disappeared within fifteen to twenty minutes. Efforts to reduce the time for smoke removal by heating to a higher temperature (450° C.) were unsuccessful, the strength of the briquettes as indicated by the Drop Test being only 50.2 per cent held as compared to 91.9 per cent at 400° C.

Time of Smoke Removal.—In the manufacture of charcoal from cord wood, the heating is continued long enough to completely carbonize the wood and to remove practically all the smoke. The heating should be continued until a seasoned charcoal free from partly carbonized charcoal "brands" is secured.

In the production of charcoal briquettes the same line of reasoning applies. Briquettes made with a time for smoke removal of much less than twenty-four minutes, on combustion, produced some smoke and flame which are indications of green charcoal. At twenty-four minutes they were practically smokeless and the combustion was comparable to commercial charcoal. At twenty-eight minutes the briquettes were slightly more friable and uneven, were slightly weaker and showed signs of overheating. Additional information secured at twenty-four and twenty-eight minutes is given in Table VI.

NOTE: These briquettes were made as usual. The time for preheating was fourteen minutes.

TABLE VI.—Time for Smoke Removal

Time (min.)	Yield (per cent)	Strength (Drop Test)	Density	Combustion
20	30.2	92.1	0.47	Some flame and smoke
24	29.8	91.9	0.51	No smoke or flame.
28	28.6	91.6	0.48	No smoke or flame Briquettes have some tendency to crumble.

NOTE: The short time required for smoke removal as compared to the production of commercial charcoal is explained by the fact that the charcoal briquettes are quite small and hence the heat is conducted to the center rapidly, and by the fact that the original sawdust, unlike cord wood, contains no knots which carbonize very slowly.

Taking all the factors into consideration, twenty-four minutes was adopted as the optimum time for smoke removal since the briquettes at twenty-eight minutes show no improvement over those at twenty-four minutes. As a matter of fact the briquettes at twenty-four minutes are slightly more dense than at either twenty or twenty-eight minutes.

SUMMARY OF OPTIMUM CONDITIONS

In summing up the above results, it may be stated that the most favorable conditions for the production of lump charcoal from pine sawdust have been shown to be: (1) Time of heating before pressing, 14 minutes; (2) Briquetting pressure 300 pounds per square inch; (3) Rate of application of the pressure, one minute; (4) Duration of the pressure, 10 seconds; (5) Temperature of removal of the briquettes from the mold, 400° C.; (6) Temperature for smoke removal 400° C.; (7) Time of smoke removal, twenty-four minutes.

METHODS AND RESULTS OF TESTING BRIQUETTES

The most important physical properties of the briquettes are their strength and density, resistance to aging and weathering agencies, and combustion characteristics including the heating value. The first and second tests mentioned demonstrate the ability of the briquettes to withstand handling and shipping while the combustion characteristics determine the storage conditions necessary and the suitability of the briquettes for various purposes.

Drop Test.—The Drop Test employed by the Bureau of Mines(48) for the testing of lignite briquettes was slightly modified for this particular 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 on a one inch screen were dropped again. This procedure was repeated until all pieces had been dropped five times. The weight of the pieces that would not pass through the screen was determined. It will be noted later that the results of this test agree rather closely with these of the Tumbler Test given below, although no attempt was made to standardize the two tests, the first being a shatter test while the latter was of the nature of an abrasion test. The Drop Test as applied here is a rather severe test since the briquettes are relatively small.

Tumbler Test.—This test was based on the one employed by the Bureau of Mines.(48) The details as carried out are as follows:

A small ball mill nine and one fourth inches long and eight and one half inches in diameter was half filled with one inch porcelain balls. The briquettes were placed in same and the can rotated for two minutes at twenty-eight revolutions per minute. The can was then opened and the contents screened on a one inch screen. The weight of the pieces retained on the screen was recorded.

Aging Tests.—In view of the fact that the briquettes do not disintegrate when submerged in water, it was not considered likely that exposure to climatic conditions would have any appreciable effect on the briquettes. However, to verify this deduction it was considered necessary to subject the briquettes to varying climatic conditions for a considerable time. 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 eight weeks would be considered sufficient for this. Consequently the briquettes were placed in a container where they were protected from direct rainfall but exposed to varying climatic conditions The container had a roof but practically no sides. The briquettes, after the aging test was completed were subjected to the Drop Test and the Tumbler Test.

Submergence of Briquettes in Water.—The briquettes were submerged in water for various periods and the Drop Test applied after the briquettes had regained their original dry weight.

Wet Drop Test.—The briquettes were submerged for twenty-four hours and subjected to the usual Drop Test while wet.

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 in making them.

RESULTS OF TESTS ON BRIQUETTES

TABLE VII.—Strength of Fresh Briquettes

Bqt. No.	Drop Test Per cent held by one-inch screen	Tumbler Test Per cent held by one-inch screen	Crushing Strength Pressure applied on end of bqt. (lbs. pressure per sq. in.)	Crushing Strength Pressure applied on lateral edge. (lbs. pressure)
1	90.7	85.6	500	150
2	90.0	88.0	600	100
3	94.01	91.53	600	140
4	88.5	85.70	500	60
5	92.3		800	100
6	93.8			
7	89.9			
8	86.2			
Averages	90.67	87.71	600	110

TABLE VIII.—Strength of Aged Briquettes

After aging the Drop Test was applied in the usual way. Figures in the table refer to per cent held by a one-inch screen after five falls on a cement floor from a height of six feet.

Bqt. No.	Exposed for 8 weeks Drop Test Per cent held by one-inch screen after five falls on cement	 Tumbler Test Per cent held by one-inch screen
1	94.9	94.9
2	95.7	90.0
3	97.0	90.3
4	93.5	90.3
5	94.9	92.0
6	81.3	92.0
7	96.9	92.0
Average	93.46	91.6

Submergence of Briquettes in Water.—The briquettes rapidly adsorb water and after six hours have increased in weight 72.5 per cent. Most of this was gained during the first two hours. After six hours the weight is practically constant. The briquettes after removal from the water and exposure to air, regained their original weight in several days.

The briquettes were of only moderate strength when wet, i. e., on application the Drop Test showed 74.4 per cent held by one inch screen. On air drying to their original weight they regained all their original strength, i. e., on application of the Drop Test 96.4 per cent was held by a one inch screen. Only one of the briquettes broke (fifth fall).

Examination of Table VII indicates that the strength of the briquettes when first made is such that losses on handling and shipping should be slight. The strength of the briquettes is comparable by direct test to many of the bituminous coal and superior to most of the lignite briquettes made with a pitch binder by the Bureau of Mines(49). The crushing strength even in the weakest direction should easily be sufficient to permit storage and combustion of the briquettes. The aging test (Table VIII) shows that when the briquettes are exposed to climatic conditions for a period sufficient to permit of their disposal (eight weeks), there is little if any reduction in strength and after aging the briquettes are of sufficient strength to permit handling and transportation. Results secured by the Tumbler Test, in general, confirm the Drop Test. The briquettes, as expected, when submerged in water, readily adsorb water, but in several days regain their original weight when exposed to the air. After regaining their original weight they possess their original strength. However, brquettes tested immediately after submergence in water are somewhat weaker than fresh briquettes and preferably should be handled rather carefully until they dry.

Specific Gravity of the Briquettes.—Because of rapid adsorbtion of water by the briquettes, the specific gravity could not be determined by suspending the briquettes in water. The specific gravity determined by weighing the briquettes in air and determining the volume by direct measurement was 0.51. This is at least twice the density of ordinary charcoal.

Combustion Characteristics, Ignition: Temperature and Heating Value.—Combustion characteristics were determined by observation. The ignition temperature was determined by heating briquettes to various temperatures in an electric furnace, removing the briquettes at various temperatures and determining the temperature at which they ignite. The heating value was determined in a bomb calorimeter in the usual way.

Combustion Characteristics.—Briquettes were burned singly on a tripod heated by a gas burner and also in piles burned on an improvised grate in a gas heated furnace. With a slight draft the briquettes burned readily and with no smoke. They developed superficial cracks but showed no tendency to crumble. As a matter of fact they remained hard and retained considerable strength until completely consumed. The nature of the combustion was comparable to that of actual charcoal burned under the same conditions.

Ignition Temperature.—The average ignition temperature of a series of briquettes was 325° C. (617° F.). This apparently is slightly lower than a sample of actual charcoal.

Heating Value.—The average value from a number of briquettes was 12,378 B. t. u. per pound. The heating value probably can be increased slightly by completing the smoke removal at 450° C. instead 400° C. but there is a considerable reduction in strength.

Analysis and Yield.—Average proximate analysis of the charcoal was as follows:

	Dry Basis (Per cent by weight)
Volatile matter	30.29
Ash	3.38
Fixed carbon	66.33
Total	100.00

Ultimate analysis of the charcoal is as follows:

	Dry Basis (Per cent)
Carbon	71.78
Hydrogen	2.90
Nitrogen	0.16
Sulphur	0.03
Ash	3.38
Oxygen (by dif.)	21.75
Total	100.00

According to Bunburry ("The Destructive Distillation of Wood," pages 109 and 110, D. Van Nostrand Company) there is a wide variation in the heating value of charcoal depending upon the nature of the wood. Values given vary from 11,000 to 13,864 B. t. u. per pound. The ash varies from 1.11 to 12.2 per cent, the sulphur from .07 to 0.28 per cent and the volatile matter from 7.03 to 32 per cent.

On the above basis the charcoal briquettes are low in ash, low in sulphur, high in volatile matter, with a heating value about midway between the two extremes.

Spontaneous Combustion of the Charcoal Briquettes.—The charcoal briquettes show no tendency to ignite spontaneously either singly or in piles. Softwood is said to give charcoal where this tendency is reduced to a minimum particularly if the wood contains no knots as is the case with pine sawdust.

PROBABLE LARGE SCALE APPARATUS AND COST ESTIMATES

Briquettes produced by the experimental equipment mentioned in this report probably are of full commercial size. Consequently the major problem involved in the transition of the process to full plant scale production is one involving the application of suitable continuous automatic equipment whereby the rate of production is increased to the point that the process becomes commercially feasible.

For the drying of material with as low heat conductivity as sawdust, efficient agitation is necessary. The most practical way of securing this result seemed to be by means of a rotary drier. A double shell type, counter current flow, gases making direct contact with the material with a diameter of five feet and eight inches and a length of thirty-five feet, has a capacity (see Perry's "Chemical Engineering Handbook," page 1504) for coal of 22,000 pounds of dry coal per hour. Water evaporated per hour was 2031 pounds. A drier of this type should be suitable for sawdust.

In order to make the operation of the rotary drier continuous it is proposed to feed the sawdust from a suitable storage hopper to the drier by means of a screw conveyor. The drier might be discharged by means of another screw conveyor into the hopper for the bone dry sawdust. This might be heated with steam coils to prevent the dried sawdust from adsorbing water. From the storage hopper, the dried sawdust might be discharged by a flexible hose into the molds. An automatic charging device here should save labor.

The shaping of the briquettes requires preheating of the sawdust followed by the simultaneous heating and pressing. Rectangular molds in units of eight similar in design to the units designed by Mr. O. Falkovitch of the Tennessee Valley Authority (see Figure 4), each mold one and three fourths of an inch wide, twenty-five inches long and about ten inches high might be used. The molds which have no bottoms might be placed on the bottom of a short rectangular kiln, filled from the hopper with bone dry sawdust, covered with a steel plate containing perforations for escape of products of combustion, and pushed slowly through the kiln where they are heated to the desired temperature. When each of the molds reaches the discharge end of the kiln, pressure might be applied to the molds by removing the steel plate from the top and inserting steel plungers each the shape of the mold but slightly smaller, to which the desired pressure is applied by means of a mechanical or hydraulic press.

NOTE: The plungers might be attached to the press, or form part of the press itself, so that each mold with eight compartments is pressed simultaneously. The molds might be discharged by inverting them or preferably allowing them to move to the next position where they are supported in such a way that when a slight pressure is applied from above, the contents (bars of charcoal) are discharged from the bottom where they fall upon the conveyor leading to the smoke remover. The treatment for smoke removal might consist of the passage of the charcoal slowly through a tunnel kiln maintained at 400° C. The charcoal then might be discharged into an air tight receiver where it is allowed to cool.

A flow sheet of the proposed process is shown in Figure 4. The water content (maximum) of the sawdust is taken as 66.6 per cent on a dry basis, in calculating the capacity of hopper for raw sawdust in the above flow sheet.

Control of this process involves regulation of the water in the sawdust fed to the molds. It should be bone dry when preheated so that the time of heating before pressing is constant. The presence of considerable water would reduce the rate of heat transfer through the sawdust in the mold and give a less charred product than is demanded for the best results. Consequently the time of heating for bone dry sawdust (i. e., six to seven minutes) must be increased where appreciable water is present.

Raw sawdust varies considerably in water content. If a fan is used to transfer the sawdust to the storage hopper, and if the hopper is exposed to the air at the top, considerable water will be evaporated. This is particularly true if fresh surfaces of sawdust occasionally are exposed to the air. One small sample of sawdust containing about 60 per cent of water on a dry basis lost 40 per cent of its water in two hours by exposure to the air with occasional mixing. The rotary drier should be of sufficient capacity to insure bone dry sawdust regardless of its moisture content. In exceptional cases the dried sawdust might be recycled, i. e., passed through the drier a second time. Further, a thermocouple might be placed in the center of the sawdust contained in the mold, and the pressure applied only after the temperature of the charred sawdust reaches 340° to 355° C.

Estimated Cost of a Plant With a Capacity of Two Thousand Tons per Year.—Since no binder is required in the proposed plant, the greatest cost items will probably be interest and plant depreciation and labor. These are closely related to plant output. Consequently before any reasonable estimate can be made of the cost of manufac-

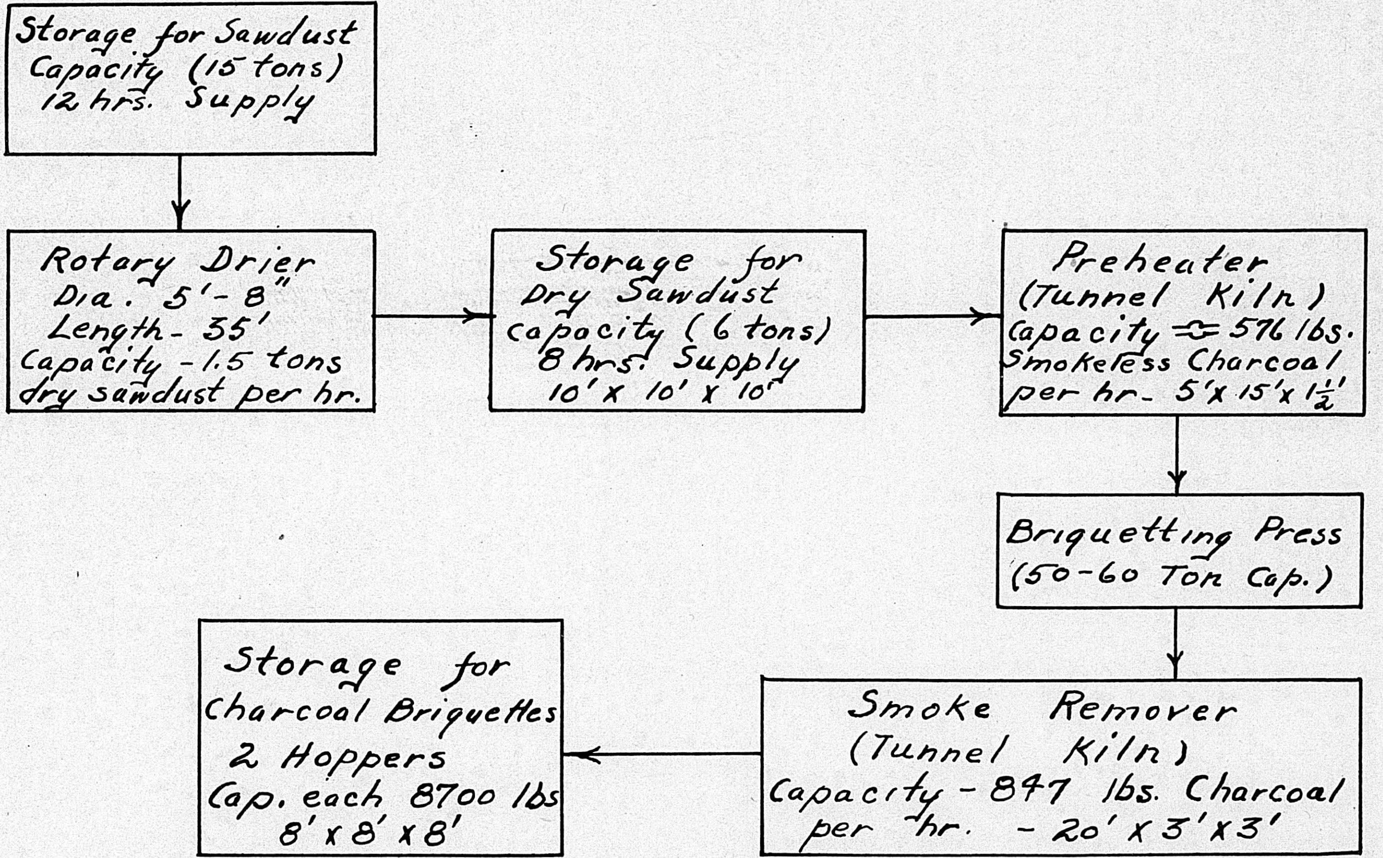


Figure 4.—Process Diagram

ture, it is necessary to form an estimate of the quantity of waste material available at the various mills. At least 30 tons of sawdust and shavings should be available for briquetting purposes with an equal amount available for preheating and the generation of steam at the larger mills. (Basore, "Fuel Briquettes from Southern Pine Sawdust," Bulletin 1, Engineering Experiment Station, Alabama Polytechnic Institute, Auburn, Alabama, page 34). However, many small mills would have a great deal less sawdust available. Under the circumstances a small plant with a capacity of 500 pounds of charcoal per hour (about 2,000 tons per year—see page 24—) seems reasonable. This would require approximately 1,500 pounds of bone dry sawdust per hour plus sawdust for heating purposes.

A double shell type, counter current flow rotary drier five feet in diameter and thirty-five feet long is described in Perry's "Chemical Engineering Handbook," page 1,504. This drier evaporates 2,031 pounds of water per hour which is more than double the required capacity. The cost of driers of this size and capacity varies from $5000 to $10,000. For example in 1930 a price of $5,500 was secured (Basore, "Fuel Briquettes from Southern Pine Sawdust," Bulletin 1, Engineering Experiment Station, Alabama Polytechnic Institute, Auburn, Alabama, page 38) on an Erbo type direct-indirect drier much larger than the one under consideration. A recent quotation on a dried similar to the one described in Perry was approximately $10,000. Pre-war quotations are considered much more reliable than the recent quotations. On a post war basis $6,000 would seem a reasonable price for a suitable drier. Allowing $1,000 for erection, the total cost is $7,000.

The preheater consists of a rectangular tunnel kiln. If standard multiple molds, eight compartments to a mold (see Fig. 3, pp. 16-17) each compartment 1.75"x24"x10", are used, the capacity of each mold will be about 2.0 cu. ft. and if 1,500 pounds of bone dry sawdust are heated each hour, it will be necessary to press one mold per minute. If the time of preheating for each charge is taken as seven minutes, which is about correct for bone dry sawdust then the kiln must hold seven molds plus the one being charged or a total of eight. Then seven molds will be in process of heating, seven will be returning to charging point (these are kept hot in kiln) one will be charging and one will be discharged or a total of 16 molds will be required. The molds probably can be cast and are estimated to cost not more than $2.00 each or a total of $32.00. Each mold will be little more than one and one half feet thick. This would require a kiln about 12 feet long, consequently a kiln 15 feet long should be ample. Suggested dimensions for the tunnel kiln might be five feet wide (allowing for return of empty molds), fifteen feet long and one and one half feet high. The kiln might be heated with firebox and flue from the bottom. The hot gases might come in direct contact with the molds. Since common brick might be used for construction of this kiln, the cost should be relatively low. Not more than 4,000 brick should be required for the construction of this kiln. Labor is estimated at not more than 70 hours. A simple type of chain conveyor might be used to convey molds through the kiln. The total cost of kiln including 16 molds probably would not exceed $350.

The smoke remover might consist of a chain conveyor moving through a horizontal kiln. At 17 pounds per cubic foot, 500 pounds of charcoal per hour would require less than 30 cubic feet. It the conveyor is three feet wide and charcoal is placed on the conveyor to a depth of four inches, one linear foot gives one cubic foot of charcoal. On this basis a conveyor 20 feet long would deliver 847 pounds of charcoal per hour. This takes into account that the charcoal must remain in the furnace 24 minutes. This equipment is very similar to a conveyor drier. According to Bliss*, conveyor driers cost from $2.10 to $11.10 per cu. ft. Allowing $8 per cu. ft. since this is a comparatively small installation the total cost would be $1,440

Four storage hoppers are required. The one for the raw sawdust is 5′ x 21′ x 21′; the one for the dried sawdust is 10′ x 10′ x 10′; while the two for the finished charcoal briquettes are each 8′ x 8′ x 8′ (i. e., each will hold more than four tons of charcoal). The first two hoppers are merely wooden boxes and no doubt could be built for about $100 each. The remaining two hoppers (for the charcoal) probably would be brick. These hoppers, two bricks thick, probably will not exceed $175 each.

According to Perry's "Chemical Engineering Handbook," page 2,333, conveyors with accessories for the process will cost not more than $350. This includes two six inch screw conveyors fifteen feet long with a capacity several times that required for the proposed process. According to the Chattanooga Blow Pipe and Roofing Company, a No. 40 American Type E slow speed fan which they recommend for the purpose would cost $251. This is for conveying sawdust to the storage hopper. This is reported to have ample capacity for the job.

A downward acting press is required with a capacity of 100,000 to 150,000 pounds. The area of pressing plates should be at least 24 x 18 inches. Attempts to secure a price on a suitable press have been unsuccessful. However, it is believed that $1,500 would be adequate for a suitable mechanical or hydraulic press of this type.

The power plant is the next item under consideration. The rotary drier requires 20 horse power for drum and fan (Perry, "Handbook of Chemical Engineering," page 1,504). Allowing one horse power for each conveyor and four horse power for the fans this is a total of 26 horse power. Motors for the rotary drier are included in the cost of this item. Consequently two additional one horse power motors for the conveyors and one five horse power motor for the fan would be sufficient. The cost of these motors should not exceed $300.

The total cost as enumerated is $11,741. Allowing $300 for controls, $400 for miscellaneous items and $1,059 for a rough shed over the plant, the total cost amounts to $13,500.

Estimated Cost per Ton of Manufacture of Charcoal Briquettes

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* The Costs of Process Equipment and Accessories. Trans. A. I. Ch. E. Vol. 37, No. 5, page 799.

from Pine Sawdust.—This estimate is based on the following assumptions:

a. Four 40 hour shifts per week.
b. Operation 50 weeks per year or 8000 hours.
c. Capacity—500 lbs. of charcoal per hour or 2000 tons per year.

(1) Labor—Two men at 40 cents per hour, plus 2.6 cents for Social Security, etc., or 42.6 cents per hour	$3.41
(2) Cost of Sawdust—Four tons of sawdust (dry basis) including one ton for heating purposes at $0.25 per ton	1.00
(3) Depreciation—According to "Chemical Engineering Plant Design," pages 353-358, by Vilbrandt (McGraw-Hill Company, depreciation figures for driers, conveyors and similar equipment in actual service, averages not more than 8 per cent, i. e., 8 per cent of $13,500 per year is charged to depreciation.)	0.56
(4) Power—26 H. P. at 1.5 cents per horse power hour	$1.56
(5) Repairs—6 per cent per year, i. e., 6 per cent of $13,500	0.41
(6) Insurance and Taxes—5 per cent per year, i. e., 5 per cent of $13,500	0.343
(7) Miscellaneous—5 per cent per year, i. e., 5 per cent of $13,500	0.343
(8) Overhead—$500 per year	0.250
(9) Packaging—20 sacks at 5 cents each	1.000
Total cost per ton	$8.880

The above estimated cost of production appears to be reasonable. It might be considerably reduced by an increase in the capacity of the plant (i. e., some items of expense should not increase as rapidly as the increase in capacity) or possibly by cheaper methods of drying the sawdust.

Commercial Possibilities of the Process.—The present method for charcoal briquettes compares favorably with methods for making wood charcoal from cord wood. The two processes are compared below:

1. The yield of charcoal briquettes and heating value of the briquettes compares favorably with yield and heating value of charcoal from cord wood. It is well known that the yield and heating value depend to a great degree upon the nature of the wood and the method of heating. See Bunburry, "The Destructive Distillation of Wood," D. Van Nostrand Company, New York, pages 109 and 110.

2. The charcoal briquettes have a density of 0.51 as compared to charcoal from cord wood of 0.15 to 0.30. See Bunburry, page 108. Consequently much greater heating value can be packed in the same storage space in the case of the charcoal briquettes.

3. Unlike charcoal from cord wood no tendency to spontaneous combustion has been observed. This is probably due to the small size of the charcoal briquettes and the lack of knots.

4. The time of heating is much shorter than for charcoal from cord wood. This is probably due to the lack of knots and the small size of the briquettes.

5. The products of combustion are consumed in the process in the case of the charcoal briquettes. This is probably a definite advantage particularly in small installations since the by-products from pine wood, low in rosin and turpentine, are considered of little value. Considerable equipment and labor is eliminated by this procedure.

6. The production of charcoal briquettes from a waste material (sawdust) permits a considerable saving in the cost of the raw materials. This might amount to several dollars per ton of charcoal.

7. The usual method of cooling the charcoal (to room temperature) and screening and classifying the charcoal apparently may be considerably simplified in the case of the charcoal briquettes. The briquettes require practically no screening or classification and cooling to room temperature may not be necessary. Individual briquettes have been removed from the cooler as high as 195° C. with no indications of combustion.

8. The proposed plant for the charcoal briquettes is a small portable installation adapted to the utilization of comparatively small quantities of sawdust.

In view of the foregoing the possibilities of the charcoal briquettes are clear. Because of the shortage of wood and high labor and transportation costs, the cost of cord wood for domestic and commercial purposes has reached a high figure. Furthermore, because of war demands, the numerous uses of charcoal as a fuel and for other purposes have increased. Incidentally charcoal operated gas producers have been operated successfully for propelling motor vehicles. Consequently processes which are able to utilize waste wood for the production of charcoal should have considerable promise.

BRIQUETTING OF OAK SAWDUST

In order to determine the limitations of the method used in briquetting pine sawdust, several trials were made employing oak sawdust which is the most prevalent of the hardwoods in the South. Oak sawdust of the coarseness used in the pine sawdust briquetting was not available in this section, therefore a finer material, which could be made in a local wood shop, was used. This necessitated a further study of the pine briquetting in which a fine sawdust was used, thereby giving a direct comparison with the fine oak sawdust.

Table IX gives an analysis of the fine pine and fine oak sawdust.

TABLE IX.—Analysis of Sawdust

	Pine	Oak
Moisture, per cent by weight	8.0	7.4
Screen analysis, per cent held:		
(Tyler standard screens)		
Through ¼″ on 10 mesh	00.0	5.0
Through 10 on 20 mesh	29.0	24.5
Through 20 on 30 mesh	25.2	26.0
Through 30 on 40 mesh	12.0	13.5
Through 40 on pan	33.7	32.3

Briquetting Procedure.—The general procedure for briquetting the fine oak and pine sawdust was the same as previously described in briquetting the coarse pine sawdust.

Briquetting Conditions.—Several trials were made using both the one inch and one and three fourth inch round briquetting molds on the fine pine and on the fine oak sawdust. Table X gives the conditions found satisfactory for both kinds of sawdust and both size molds.

TABLE X.—Satisfactory Briquetting Conditions

	One-inch mold		One and three-fourths-inch mold	
Sawdust used	Pine	Oak	Pine	Oak
Weight of charge (gms)	10.0	10.0	40.0	40.0
Temperature of mold (° C.)	330.0	320.0	380.0	350.0
Time of heating (min.)	5.0	5.0	8.0	8.0
Pressure (lbs. per sq. inch)	300.0	300.0	300.0	300.0
Duration of pressure (min.)	1.0	1.0	1.0	1.0
Smoke removal temp. (° C.)	300.0	300.0	380.0	350.0
Smoke removal time (min.)	5.0	5.0	hold until smoke-less	hold until smoke-less

It will be noted from Table X that a lower heating temperature and a shorter heating time before pressing was required for briquetting fine sawdust than was required for coarse sawdust. Also, that oak sawdust required a slightly lower temperature than did pine sawdust.

Result of Testing Briquettes Made from Pine and Fine Oak Sawdust—Table XI gives the strength of the briquettes as indicated by the Drop Test.

TABLE XI.—Results of Drop Tests with One-inch briquettes

Briquette material	Size (in.)	Times dropped	Height dropped	Per cent held on ½" screen	Remarks, etc.
Pine	1	5	6′	95.6	Edges frayed slightly. Did not break.
Pine	1	5	6′	95.8	"
Pine	1	5	6′	93.5	"
Oak	1	5	6′	100.0	"
Oak	1	5	6′	91.0	Broke slightly on third drop
Oak	1	5	6′	95.8	"
Oak	1	5	6′	95.6	"

TABLE XI (Continued)—Part B.—One and three-fourths-inch briquettes

Briquette material	Diameter (in.)	Times dropped	Height dropped	Per cent on 1" screen	Per cent on one-half inch screen	Remarks, etc.
Pine	1¾	5	6′	29.6	77.5	Did not break
Pine	1¾	5	6′	89.5	89.5	Did not break
Pine	1¾	5	6′	81.0	81.0	Did not break
Pine	1¾	5	6′	30.0	88.5	Broke on 3rd drop
Oak	1¾	5	6′	33.0	61.0	Broke on 3rd drop
Oak	1¾	5	6′	19.5	83.5	Broke on 4th drop
Oak	1¾	5	6′	26.5	78.5	Broke on 3rd drop
Oak	1¾	5	6′	57.5	80.8	Broke on 2nd drop
Oak	1¾	5	6′	33.8	78.5	Broke on 2nd drop
Oak	1¾	5	6′	95.5	95.5	Did not break

NOTE: Variations in the strength of both pine and oak briquettes probably indicates that minor adjustments in the variables would have a beneficial effect.

Examination of Table XI indicates that the one inch oak briquettes were very slightly stronger than the pine briquettes, the average for the pine being 95 per cent, and for the oak 95.6 per cent. Both pine and oak one and three fourth inch briquettes were weaker than the one inch briquettes. The pine briquettes showed an average of 57.5 per cent held on a one inch screen and 84.3 per cent held on a one half inch screen, while the oak showed an average of 44.3 per cent held on a one inch screen and 80.0 per cent held on a one half inch screen.

Both the small and the larger oak briquettes were tested for combustion and burning qualities and were found to burn readily without smoke when subjected to a slight draft. They burned evenly and did not disintegrate during combustion.

Other properties of the oak briquettes were closely comparable to the pine charcoal briquettes. The chief difference seems to be that the hardwood sawdust requires a slightly lower temperature and slightly shorter period of heating than the pine. This seems to indicate the heat transmission through the oak is somewhat more rapid.

Evidence available seems to indicate that apparently hardwo sawdust, such as oak, can be briquetted using much the same ge eral procedure and nearly the same conditions as those used for pi sawdust of the same screen analysis.

Summary

A process for the manufacture of charcoal briquettes from wast wood (pine sawdust) has been developed and studied in detail. Th effect of variations in the process has been investigated and the opt mum conditions for the process determined.

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

The results of the experimental work indicate that by the proposed process charcoal briquettes can be produced from Souther pine sawdust at a nominal cost. These briquettes have been shown t have many qualities which should make them desirable as a low as , smokeless fuel for domestic and industrial purposes. With min modifications it has been found that apparently hardwoods such a oak also can be briquetted by this process.

The proposed process seems to be suitable for small scale installations and apparently it would permit the use of a plant of simple design requiring the minimum amount of equipment and labor. Consequently it seems adapted to the disposal of saw mill waste from small saw mills.

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(12) Sawdust Briquettes, Eng. and Min. Jr. Vol. 72, p. 627 (1901)
(13) The Production of Artificially Dense Charcoal, J. Ind. Eng. Chem. 13, p. 301, (1921)
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(16) British 116.960 (1917)
(17) U. S. 1,374.887 (1921) 34
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