PRES-TO-LOG PRODUCTION

by

August Rauch

A Thesis

Presented to the Faculty

of the

School of Forestry

Oregon State College

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Forestry

December 1941

Approved:

____

Assistant Professor of Wood Products

Table of Contents

---Acknowledgements---

The author wishes to express especial appreciation of the aid and advice of officials of the Longview branch of the Weyerhaeuser Timber Company throughout the time the field study was conducted.

It is the authors wish also to acknowledge the information and advice received by correspondence from Leo V. Bodine, Assistant General Manager of Wood Briquettes Incorporated at Lewiston, Idaho.

Introduction

The purpose of this thesis is to discuss the past and present methods of production of wood briquettes in the United States. A presentation on some of the future aspects will also be included.

Wood briquettes include any of the small logs or blocks produced by the compression of wood waste and used for fuel. The waste is usually in the form of sawdust and shavings or their ground up remains. Pres-to-log is the trade name of the briquette produced by the Pres-to-logs machine which has been patented by Wood Briquettes, Incorporated. The use of Pres-to-log in the title was prompted by the fact that it most nearly connotes the desired meaning to the average reader.

The wood briquetting industry is an important one in the utilization of wood waste. Some mills convert into briquettes as much as one hundred and twenty tons of waste per day. Hence, the publicising of information such as will be included in this paper should be important to those lumber operators who haven't as yet thoroughly investigated this field as a possibility of utilizing much of their wood waste. It is also hoped that this thesis will prove to be of some value to other men of the industry who wish to know more about this particular phase of wood utilization.

The field work consisted mainly of observation and work in the Pres-to-log Plant of the Weyerhaeuser Timber Company at Longview, Washington, and to this extent was rather limited. This lack of a broad coverage in field work was compensated for by a thorough study of all written material on plants in other sections of the nation.

The office work consisted of a study of all available written material and a rehashing of this material to get at the important parts and classify or put them in order. Most of the written material was found in United States Department of Agriculture bulletins and periodicals of lumber and engineering associations. The remainder was obtained by writting directly to Wood Briquettes, Incorporated of Lewiston, Idaho.

Chapter I History of the Industry

Briquette manufacturing has been carried on successfully in European countries for several years. These manufacturers have depended on some type of binder mixed with the wood waste, or the resinous material in the wood to hold the briquette together. In addition to shavings and sawdust, spent tanbark and chemical bark were utilized in this fashion by many of the countries.

Due to the relative cheapness of other fuels wood briquettes didn't become commercially important in this country until about 1935, although several experimentations had been made before that time. In 1929 and early 1930 Basore[1], Doctor of Philosophy at Alabama Polytechnic Institute, conducted an experiment in the briquetting of southern pine waste. He developed a process for removing the natural elasticity of sawdust and shavings by heating. It was found that to remove the desired amount of elasticity the sawdust had to be pre-heated to two hundred and seventy-five degrees Centigrade[2]. Since this temperature is considerably above that readily obtainable by steam, gas was used in the experiment. The pre-heated sawdust was briquetted in a steel mold six inches long which was provided with a piston seven inches long and one and three quarter inches in diameter. The pressure amounting to 6500 pounds per square inch was applied by means of a Richle compound lever press. It was found that to develop the strongest briquette the waste should have a moisture content of about five percent[3]. Basore estimated the cost of building a plant with capacity to produce twenty tons of briquettes per day at $25,000. The cost per ton was estimated to be $1.64[4].

In 1934 F. W. Bender[5], superintendant of Pacific Lumber Company at Scotia, California, conducted some experiments with the utilization of Redwood waste by conversion into briquettes. He had a carload of Redwood sawdust and shavings sent to Lewiston, Idaho, where he experimented with the Pres-to-logs Machine in full cooperation with Wood Briquettes, Incorporated of that city. The shavings and sawdust were dried down to below ten percent moisture content by working them down through steam heated coils. From storage bins below these coils the waste was conveyed to a hammer-mill grinder where it was ground into fine uniform particals. After grinding the fuel was deposited in another bin from which it moved directly to the Pres-to-logs Machine. The compression process of of the machine was very similar to that used for the Douglas

Fir machines which will be discussed in detail in the next chapter. Mister Bender found that Redwood briquettes made in this fashion burned longer and had more heat units per pound than any other kind of compressed sawdust with the exception of cedar. Two machines with a twenty-four hour capacity of twenty tons were installed, and the demand for their product is brisk in all the San Fransico Bay area. The cost of the entire department including the new drying unit was about $25,000.

Many of the early experiments were conducted with a lightly compressed type of briquette bound together mechanically by rope or wire or by an internal binder. Pressures on this type of briquette averaged about 6500 pounds per square inch, and they would not hold together any length of time without some kind of binder. In the rope core briquette there was a hollow center through which a rope was passed and knotted on either end. The wire bound briquette had wire bindings similar to a bale of hay. This wire had a low melting point and was supposed to oxidize readily causing no special problems of refuse removal. Nevertheless the formation of clinkers

Footnotes:

1. "Fuel Briquettes from Southern Pine Sawdust," Cleburne A. Basore, Doctor of Philosophy, Engineering Experiment Station of Alabama Polytechnic Institute, Bulletin No.1, May, 1930.
2. See Appendix I.
3. See Appendix II.
4. See Appendix III.
5. "Making Pres-to-log Fuel from Redwood Waste," F. F. Flaherty, Timberman, Volume 36, No. 3, January, 1935.

was usually the case, and their removal considerably reduced the usefulness of this type of briquette. In the case of the internally bound briquette the binder is usually coal tar pitch, petroleum refuse, or sulphite waste liquor. The Vancouver Company[6] of Vancouver, British Columbia makes a briquette composed of sixty-five percent sawdust, twenty-five percent coaldust, and ten percent binder. The resin present in the wood waste itself is sometimes used as a binder, but the high temperatures used in getting the waste dry often causes the volatilization of many of these resins.

In 1929 the invention of the Pres-to-logs Machine by R. T. Bowling, Chief Engineer of Wood Briquettes, Incorporated, somewhat revolutionized the wood briquetting industry. This new process relies on high pressures to make the briquette self-binding rather than using a mechanical or internal binder. At present there are thirty-nine Pres-to-logs machines operating in the United States. If operated at capacity, these machines could produce about 4,000 tons per machine annually or a total of 156,000 tons of Pres-to-logs. Plants using this machine are located at Potlatch, Lewiston, and Coeur d'Alene, Idaho; at Everett and Longview, Washington; at Scotia and Scramento, California; and at Reno, Nevada. There is also a machine inoperation at Capetown, South Africa.

---

6. "Briquetting Sawdust on a Commercial Basis," Rolf Thelan, In Charge of Section of Commercial Extension, Forest Products Laboratory, Madison, Wisconsin.

Chapter II The Pres-to-logs Machine

From previous experiments it was known that the requirements for a satisfactory briquette are pressure, heat, moisture, and cooling, but up until the time of the invention of the Pres-to-logs Machine manufacturers had never been able to apply sufficient pressure to make a self-binding briquette. These early machines provided for pressure by a tapered pressing screw. They also had a die or series of dies in which to form and cool the briquette, and a yielding pressure control for the purpose of governing the density of the briquette. This theory of pressing, holding, and controlling was all right, but the area under pressure at a given time was too great to obtain the desired density. The main problem confronting the inventors of the Pres-to-logs Machine, then, was one of compressing the material yet more by this gradual continuous method. This was accomplished by the tip forming head which was attached to the front end of the pressing screw. The development of this forming head proved to be the solution to the practical production of wood briquettes.

The essential parts (see figure 2)[7] of the Pres-to-logs Machine, invented between 1929 and 1933 by R. T. Bowling, are the pressing screw, tip forming head, pressing screw shaft bearing housing, pressing screw and tip forming head housing, dies, die wheel, die wheel indexing mechanism, and the yielding control pressure mechanism.

---

7. "The Mechanical Development of a Wood-Briquetting Machine," R. T. Bowling, Mechanical Engineering, February, 1941.

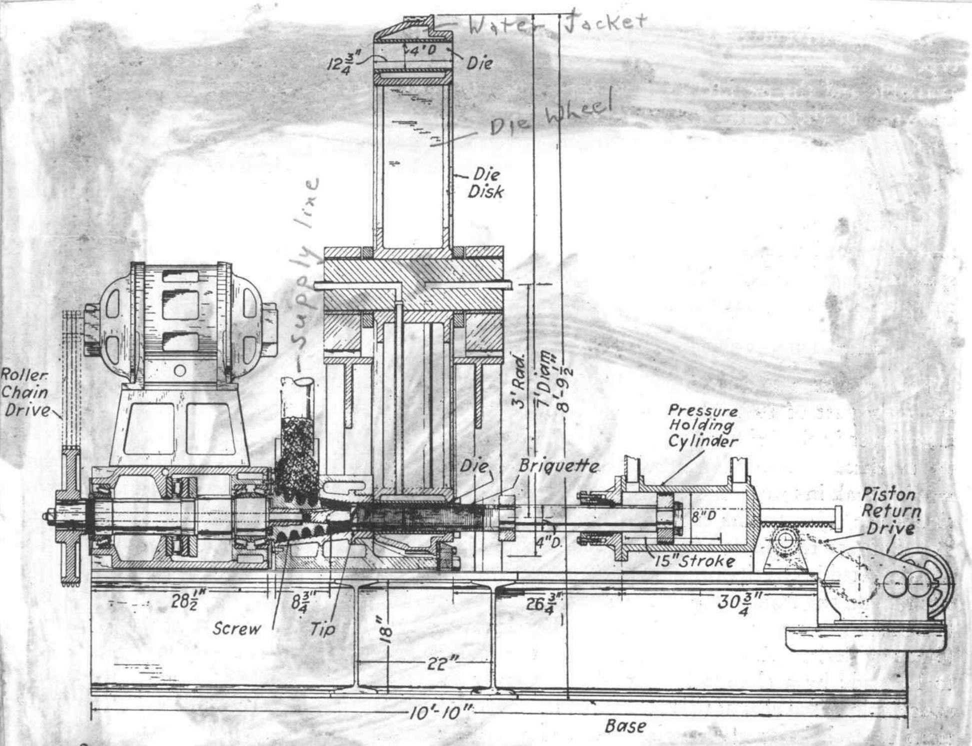


FIG. 2 SECTIONAL DRAWING SHOWING COMPLETE DETAILS OF WOOD-BRIQUETTING MACHINE

Figure 2.

The pressing screw is made of 3140 chrome nickel and surfaced with number one Stellite from the small end back two threads. It is eight inches in diameter at the large end and ten and one quarter inches long, the amount of taper depending upon the particular type of material to be briquetted. The angle of threads is fifteen degrees. This pressing screw has two functions; it receives material from the scource of supply, and it presses this material through the first stage of compression, keeping the space directly ahead of the screw and up to the tip forming head full of tightly compressed material.

The tip forming head is a round, flat piece of metal about four inches in diameter and an inch thick which is attached to and rotates with the pressing screw. It is designed with a cam on both front and rear faces, and at the high point in the lead on the rear face, a slot is cut diagonally through the head. This slot enters the front face of the head at the low point of the lead. The high point on the rear face forms the start of one side of the slot through the head, and it is, therefore, a cutting edge by which material may be sliced from the first stage of compression. As the screw and head turns the material is forced through the slot out the front side of the head in spiral layers and compressed by this cam face to its final density. The function of the tip forming head is, therefore, to take material from the first stage of compression and feed and press it into the second and final stage.

The pressing screw shaft bearing housing is a large piece of metal housing four sets of bearings through which the screw shaft passes. Its function is to hold the bearings in place and take their thrusts when the screw rotates in compression.

The pressing screw and tip forming head housing is a box-shaped piece of metal immediately ahead of and joining the pressing screw shaft bearing housing. It encloses the pres-singscrew and tip forming head, and its function is to confine the material to an increasingly smaller cylindrical space as it is forced ahead to the die.

Just ahead of the above described housing is the lower rim of a large die wheel. This wheel is seven feet in diameter, and its periphery contains about sixty-five die. These die are metal sleeves about four inches in diameter and are emplaced in a water jacket in the outer rim of the die wheel at a distance apart of about five inches center to center. Their purpose is to keep the briquette at an even diameter while it is formed and cool it down to handling temperature. The reason for the water jacket around these die is to aid in the cooling process.

The indexing mechanism is the means of rotating the die wheel. The mechanism consists of a hydraulic cylinder with its piston and rod, and it is brought in contact with the outer rim of the die wheel by a system of arms and a rachet pawl. The rim of the die wheel is marked at regular intervals with notches into which the pawl drops each time the wheel is actuated. The indexing mechanism starts automatically every time the pressing screw stops, and the screws stoppage is in turn automatically accomplished when the yielding control mechanism has been pushed back the length of a briquette.

It is the purpose of the yielding control mechanism to supply a continuous increasing resistance to the pressure applied by the pressing screw. The amount of this resistance can by controlled by a dial setting. The mechanism consists of a hydraulic cylinder with its piston rod which is attached to a crosshead. This crosshead is connected to two guide rods for mechanical actuation. The rod, therefore, may be moved mechanically or hydraulically; the hydraulic means being for the purpose of holding a given pressure against a briquette during its formation and the mechanical method for the purpose of releasing the cooled briquette and returning the piston rod to its starting position.

Many problems of a mechanical nature were encountered in the development of the Pres-to-logs Machine. A trial and error method was used in developing the pressing screw, and it was found that a screw eight inches in diameter at the large end, ten and one quarter inches long, and tapering four inches per foot of diameter gave the best results. The type and specie of wood will determine the amount of lead and depth of thread. The right hand thread has an angle of fifteen degrees.

Since the material is under great pressure as the screw and forming head revolve, there is a tendancy for the partially formed briquette to turn with the screw inside the housing or cylinder. To prevent this, the inside wall of the cylinder in which the screw revolves was grooved for the length of the screw. In order to also keep the material from turning in the space ahead of the screw the surface of that cylinder was ribbed by electrically welding Stellite to it.

The pressing screw shaft must take the heavy thrust of the screw as it compresses the material to the desired density. Many bearings were designed to take this load before it was found that a vertical tapered roller thrust type would function best.

The development of the tip forming head also required much experimentation. One of the most difficult problems was to get the tip-forming head to a hardness sufficient to withstand the abrasive action of the material going into the final stage of compression. The hardness could be obtained by treating the steel, but it would lose its temper upon going into operation because of the heat developed by friction. As an alternative to heat-treating the application of hard-surfacing material was tried and proved to be successful. In order to keep from overheating the metal in applying the hard-surfacing material with the acetylene torch, the entire head was pre-heated before the hard-surfacing operation. After hard-surfacing of the tip head and spindle had been completed, they were ground to size by special grinding equipment.

In order to clarify the operation of the machine the route of one briquette will be followed from the time the raw material hits the screw until the cooled briquette falls away from the machine. Dry, ground sawdust from the storage bins keeps falling through the supply line directly onto the pressing screw (see figure 2-a). As this material contacts the right-handed screw revolving counterclockwise, it is forced ahead and into an increasingly smaller space, thus giving it the first stage of compression. The material is thus forced forward along the tapered cylinder ahead of the screw until it comes in contact with the cutting edge of the slot on the rear surface of the tip forming head. For the purpose of this explanation it will be assumed that the machine has been in operation and that the dies all around the wheel are consequently full, each containing one briquette. As the tip forming head cuts into the partially compressed material it is forced forward into one of the die in the wheel at the rate of seven cubic inches per second. This does not mean that seven cubic inches is pressed in one instant, but that, since the screw and forming head rotate at a speed of four and one half revolutions per second, this seven cubic inches is pressed in a thin spiral layer of material approximately one eighth inch thick over an area of sixty square inches in one second. As this material, heated to about four hundred and fifty degrees Fahr'enheit by compression, is moved forward it forces a cooled briquette out of the die and forms itself in the shape of a briquette in that die. As soon as the cooled briquette has been pushed out to the desired length the pressing screw automatically stops, and the indexing mechanism moves the wheel one die ahead. This process is repeated for each die as the wheel goes round. It takes about twenty minutes for the wheel to make a complete revolution, and, with the aid of the water jacket, the briquette has by that time been cooled down to handling temperature. When the die containing the above mentioned briquette arrives at its original position, the formation of a new briquette begins forcing the old one out against the yielding control pressure mechanism. As the piston is pushed back it forces the oil in the cylinder against an automatic relief valve which has been set at a pressure insuring the desired density of briquette. When the briquette has been pushed out the desired length the pressing screw stops automatically, and at the same time the indexing mechanism starts operating and moves the wheel forward one die position. After the index arm has completed about one half of its movement, a mechanism of the counter pressure control is energized, which releases pressure on the cylinder. The piston rod of this cylinder then moves away from the cooled briquette allowing it to drop by gravity out of line with the rod and die. As soon as the above stroke is completed the mechanism is automatically reversed permitting the piston rod to move forward and come into contact with the end of the next cooled briquette to be removed from the die wheel. As soon as the rod contacts this next briquette the pressing screw is automatically started and the cycle is complete. This process is repeated over and over in making wood briquettes.

The briquette formed by the above machine is twelve and three quater inches long, four and one quarter inches in diameter, weighs eight pounds, and has a density of one point three. The total thrust against the pressing screw shaft while in operation is 165,000 pounds. Since much of this pressure is due to the resistance to compression of the material as it is forced along the tapered housing, the counterpressure of the yielding control pressure mechanism is only 15,000 to 25,000 pounds per square inch. The electric controls are of the latest and best types available and operate from 2,500 to 3,000 times per day. The total load of the machine is sixty-five and three quarters horse power. Fifty horse power is required to drive the pressing screw and tip forming head, fifteen to drive the index oil pump, and three quarters to operate the yielding-pressure-control cylinder. Sixty-five kilowatt hours are required to make one ton of briquettes. The capacity of one machine is twelve tons per twenty-four hour day.

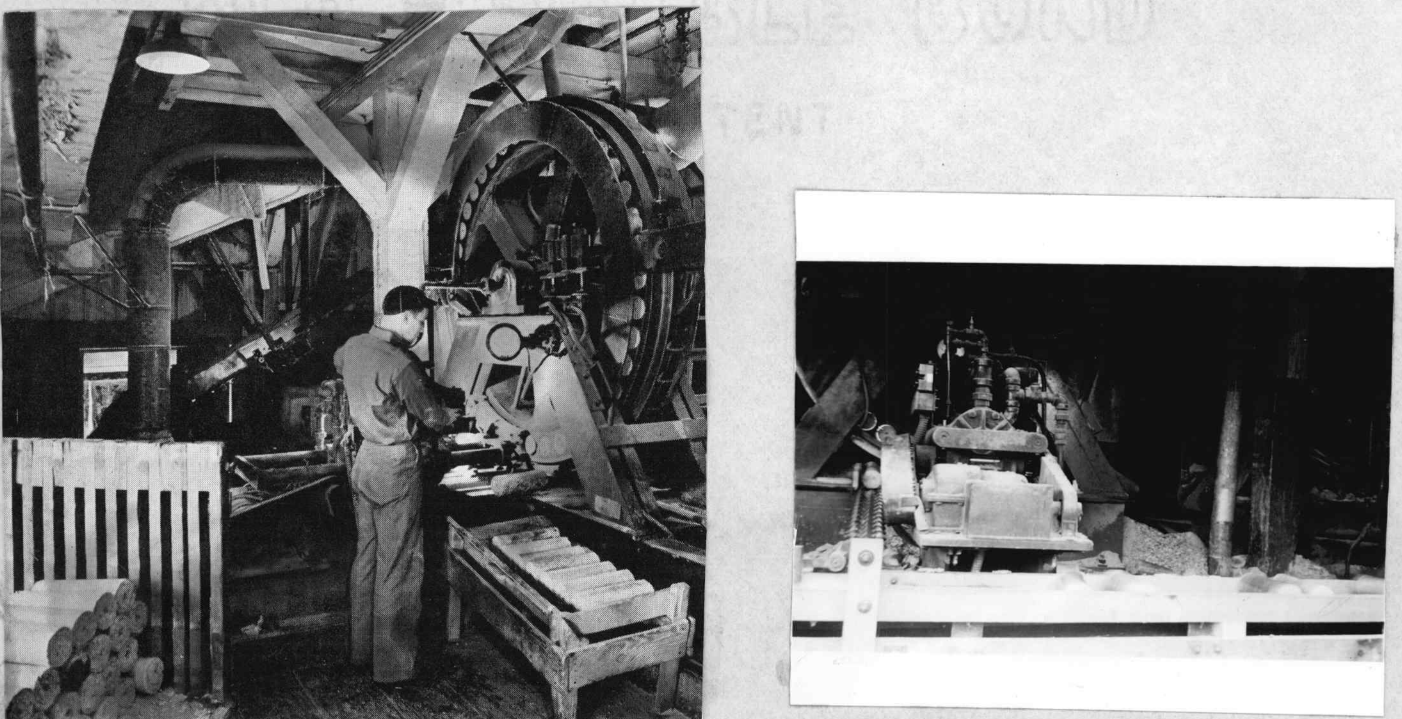
The handling of the supply of waste is carried on in a variety of different ways by the different plants. One common method is to convey the shavings and sawdust from the planer mill by a "cyclone" wind tunnel to a grinding mill near the Pres-to-log plant. This grinding mill reduces the waste to particals of approximately uniform small size. The material is then conveyed to storage bins which are higher than the Pres-to-logs machines and from which the waste falls by gravity down onto the pressing screws.

There have been several recent improvements in the Pres-to-logs Machine. Before 1939 the tip head had been flat and smooth giving the briquette a smooth surfaced layer as it was formed. This gave the briquette a tendancy to break into two pieces, and layers often fell off the ends. In order to overcome this weakness the tip forming head was improved by putting three concentric rings on the front cam face. The raised ribs of the cam face caused undulations in the layers of material as they were formed, thereby giving them an interlocking effect which makes a mechanically stronger briquette.

Another improvement in the tip forming head is the double-headed forming head. Its main purpose is to increase production, which would enable producers to make briquettes at a lower cost. This new head provides for a three-stage compression the theory of which is the application of more heat and pressure to a given quantity of material in the same length of time. With the three-stage compression unit more material may be pressed into a briquette per unit of time than with the old two-stage unit.

Still another improvement aimed at reducing the cost of production is the installation of a conveyer belt for the removal of briquettes as they fall away from the machine.

Previously one man had been required to every two or three machines to remove the briquettes and place them on small hand carts (see figure 3-a). This new improvement carries the briquettes away from a row of any number of machines and delivers them at a central point at the end of the line. A belt about twelve inches wide and of a length depending on the number of machines served is emplaced in a wooden trough running parallel to the row of machines (see figure 3-b).



a, b.

Figure 3.

This belt has small cleats every foot or so to prevent the briquettes from rolling, and it is powered by a small electric motor. The whole conveyor is about one foot below the level at which the briquettes leave the machine, thus allowing the briquettes to be conveyed from the machine to the main belt by gravity (see figure 4 for illustration). These gravity rollers run at right angles to each other forming a V down which the briquettes roll endways. As the briquette reaches the main conveyor it slides into a half-moon shaped dipper which is hinged so as to balance when empty at a level slightly lower than the last roll of the gravity conveyor. If the belt conveyor is empty under this "dipper," the briquette will be tripped onto the belt be its own weight. But, if briquettes from machines further up the line are under the trip, it will be held up by contact with these briquettes until they have been pulled past by the belt. The above trip prevents briquettes from becoming entangled and plugging up the conveyor.

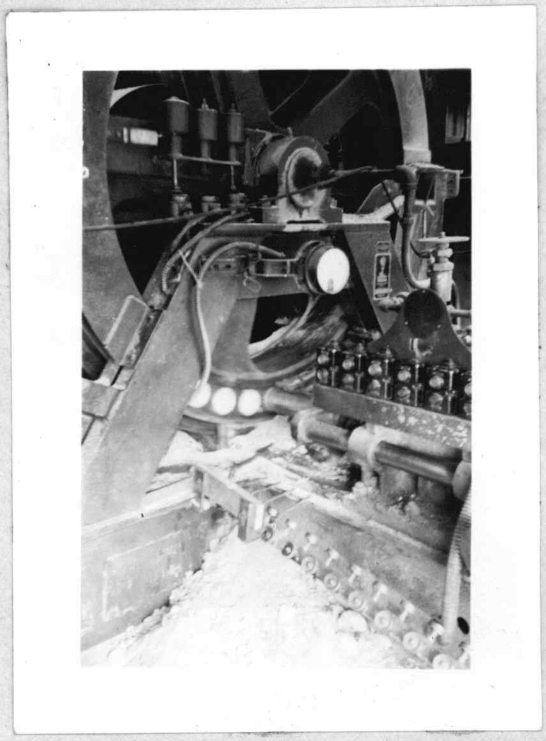


Figure 4.

At the station where the conveyor belt delivers briquettes from all machines, two men can easily handle the stacking and bundling of eight machines. This is a reduction in labor of one man for this number of machines. When briquettes are bundled, six of them are bound together with a piece of bailing wire similarly to the way that hay is wired up in bails. This makes a more convenient unit for retailing in some cases.

Chapter III Future Aspects

It is the belief of this writer that many of the problems of wood utilization will be solved by future developments in the wood briquetting field. To show what is meant some of the possibilities will be theorized upon.

One of the first things likely to come into common use is a process of drying material directly from the saws and using it to make briquettes. From experiments conducted by Wood Briquettes, Incorporated and others it is believed that a commercially practical dryer could quite readily be developed. Once this was developed it would only be a matter of conveying the sawdust to the dryer and from there to the wood briquetting plant. The dry material could probably best be conveyed by a cyclone and wind tunnel. Of the type of dryers experimented with, two seem to offer the best chances of success. One a process whereby sawdust passes over steam heated plates or floors, and the other a procedure in which the sawdust is carried along in a stream of air which has been heated by forcing it through steam heated coils of pipe.

Another possibility would be the briquetting of Douglas Fir bark. Large quantities of almost pure bark go out the conveyor under the log deck and end up in fuel house or burner. This is especially true in mills handling virgin timber, although almost any mill has plenty of bark going to waste. It is a well known fact that dry Douglas Fir bark has about

2,000 more British Thermal Units[8] per ton than either heart or sapwood. Therefore, if this material were dried and converted into the compact form of a briquette, it should be a very valuable fuel. A set of conveyors could be arranged to conduct the bark directly from the mill to a nearby dryer. This dryer could be similar to any kiln, except that the bark would have to rest on layers of heavy screen or something along that order. From the dry kiln the bark could be carried by one or two conveyors to a grinder near the briquetting plant. This grinder would be on the order of a hammer-mill and ordinary waste grinder combined. It would have to be sturdy enough handle any piece of wood that might happen to come through, yet be fast enough to handle large quantities of material in relatively short periods of time. From here the dry, ground material would be conveyed to a nearby starage bin which would be located above a group of briquetting machines similar to the Pres-to-logs Machine. It would, of course, require considerable experimentation to determine the proper dryness of material, speed of various parts of the machine, and pressure to be used, but it might well prove worth the while of some concern to make these experimentations. Whether or not the production of this type of briquette would be monetarily feasible would also have to be determined through experimentation.

"Fuel Value of Old Growth versus Second Growth Douglas Fir," Lee Gabie, Senior Forest Products, Oregon State School of Forestry, Timberman, Jume, 1939.

The field of usefulness of the wood-briquetting machine may soon be broadened by changing the size of the briquette produced. It is contended that a smaller briquette suitable for firing domestic and commercial stokers would aid considerably in increasing the briquette market. Experiments are now being conducted along this line, and they should prove successful as no particular problems of design are involved.

Chapter IV Summary

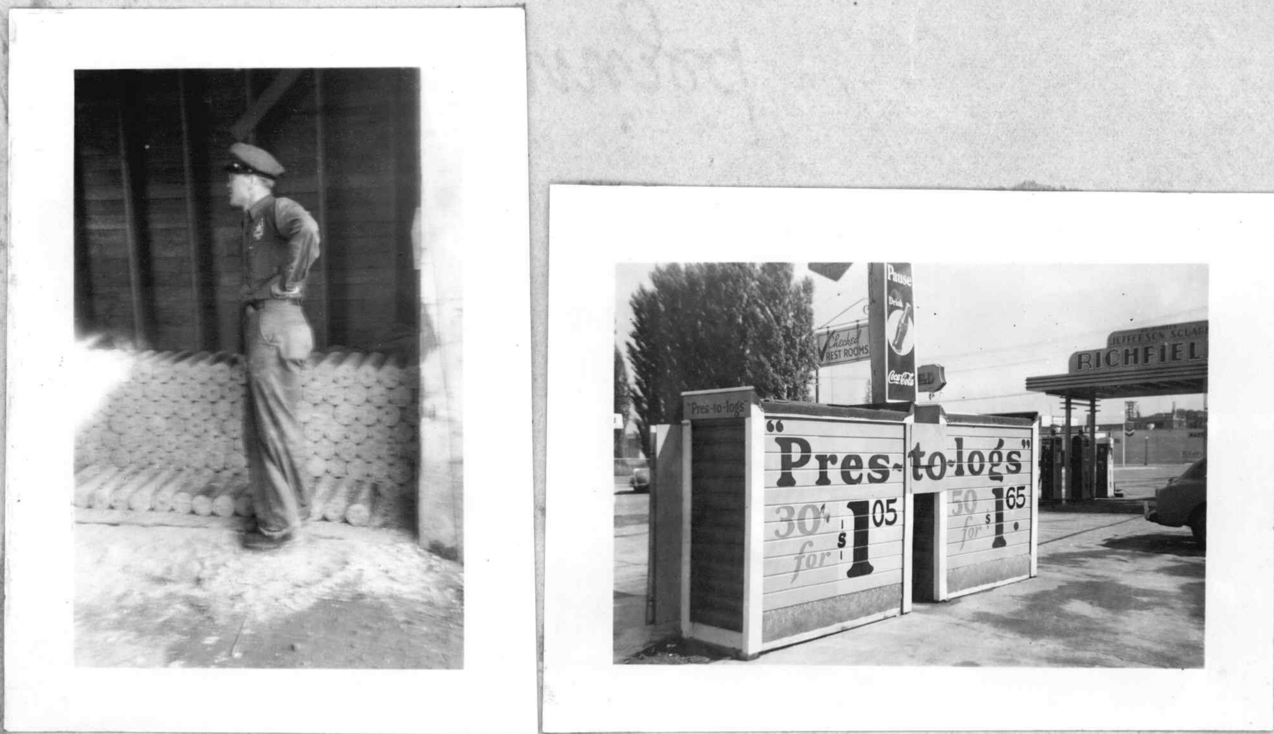
A fairly thorough discussion of the problems and accomplishments of the wood briquetting industry has been given. The reader has no doubt noticed that most of the material has been presented from the wood utilization or benefit to the industry stand point rather than the money making or business angle. The discussion was purposely limited to "Pres-to-log" production in order to keep the scope within the limitations of this thesis. However, a short summary of the sales possibilities may be in order here.

In addition to use as fuel in domestic and commercial buildings wood briquettes have many special uses. Following is a list of some of these special uses: as fuel in the kitchen of diner, lounge car, and in the buffet car range of all Union Pacific Streamliners; as fuel in rolling field kitchens of the United States Army; as galley fuel on intercoastal vessels; and, as fuel in Civilian Conservation Corp camps. From the above uses it is apparent that there is a wide variety of markets for the product. The problem is whether or not the manufacturer can offer the briquette at a price that will compare with other fuel of the same value. It is claimed by one author[9] that in order to conduct a successful wood waste briquetting operation the manufacturer must have: 1. A large and continuous supply of suitable raw materials, 2. A low production cost, and 3. A ready sale for finished product at a fair price. The first requirement isn't much of a problem to most sawmill operators. As to production cost it, in itself, is not very high, amounting on the average to about three or four dollars per ton, but companies operating Pres-to-logs machines have to pay a certain amount of royalty to the inventors, Wood Briquettes, Incorporated of Lewiston, Idaho. Therefore, the producers must charge about eight dollars per ton, which is two or three dollars more per ton than is charged for most fuel woods. However, in comparing briquettes with other fuel it must be remembered that briquettes are usually much drier and will generate more heat per pound of material than wood. It should also be noted that briquettes leave no dirt, soot, tar, pitch, or ash, make very little smoke and no sparks, are long burning, and have easily controlled, full combustion.

Many briquettes are sold in lots smaller than the ton, and in these cases are a considerably costlier fuel than cordwood or coal. In addition to being retailed by lumber companies

"Briquetting of Wood Waste," United States Department of Agriculture, Forest Service Branch, Forest Products Laboratory, Madison, Wisconsin, September, 1936.

and regular fuel stores briquettes are often sold by oil companies at their service stations (see figure 5-a&b). This is especially true when they are sold in small lots or bundles of six.



a. b.

Figure 5.

The retail situation can be summed up by saying that the best chance for success of the sawdust briquetting industry is a region where suitable wood waste is abundant and coal is espensive. At present the Pacific Coast best fulfills these conditions, and so far the industry has shown major growth in the coast area.

In conclusion may the reader be reminded that among other things one purpose of this thesis is to give the small lumber operator some ideas for waste utilization. Several possibilities have been discussed, and it is hoped that they will serve to help get the ball rolling in this direction. It is realized that the production of Pres-to-logs is pretty will sewed up with royalties of the inventors, but there are many other possibilities for making briquettes involving the same principles but using different procedures. The majority of the discussion has been relative to the Pres-to-logs machine , because it has been the one outstanding modern example to date. Since the principle is pretty much the same, it should be relatively easy to think of the discussion in the light of the problems of the industry as a whole.

Bibliography

Basore, Cleburne A., Doctor of Philosophy, "Fuel Briquettes from Southern Pine Sawdust, Bulliten No. 1, Engineering Experiment Station of the Alabama Polytechnic Institute, May, 1930.

Bowling, R. T., The Mechanical Development of a Wood-Briquetting Machine, Mechanical Engineering, February, 1941.

Flaherty, F. F., "Making Pres-to-log Fuel from Redwood Waste," Timberman, Vol. 36, No. 3, January, 1935.

Gabie, Lee, Senior Forest Products, Oregon State School of Forestry, "Fuel Value of Old Growth versus Second Growth Douglas Fir," Timberman, Portland, Oregon, Jume, 1939.

Huffman, Roy, General Manager of Wood Briquettes, Incorporated, Lewiston, Idaho, "Briquetting from Sawmill Waste," The Timberman, July, 1936.

Thelan, Rolf, In Charge of Section of Commercial Extension, Forest Products Laboratory, Madison, Wisconsin, "Briquetting of Sawdust on a Commercial Basis."

United States Department of Agriculture, Forest Service Branch, "Briquetting of Wood Waste," Forest Products Laboratory, Madison, Wisconsin, September, 1936.

Appendix:

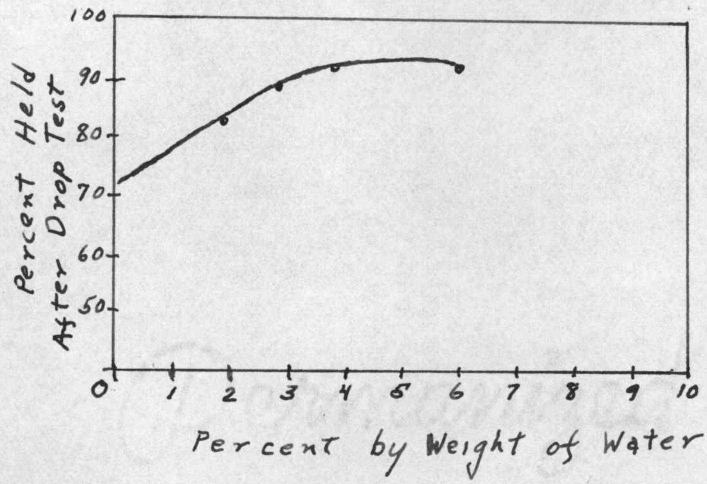
Comparison of Briquettes Made from Sawdust Pre-heated to Various Temperatures:

Material	Drop Test* of Briquettes When Made	Drop Test After Aging Six Weeks	Results of Submergence in H_2O for Two Hours
Raw Sawdust			Goes to Pulp
Sawdust Pre-heated to 170°C.	96	39	" " "
Pre-heated to 200°C.	96	61	Swells to 3 times Original length
Pre-heated to 225°C.	95	70	Swells to 2½ X Orig. Length.
Pre-heated to 250°C.	86	75	Swells to 1.4 X Orig. Length
Pre-heated to 275°C.	85-90	81	Swells Slightly No Crumbling
Pre-heated to 300°C.	25	20	Little Change

* Drop test values refer to percentage by weight held by a one inch screen when briquette is allowed to fall five times on a cement floor from a height on six feet.

Appendix II:

Effect of Water on Briquetting of Pre-heated Sawdust:



Appendix III:

Cost of Manufacturing Briquettes by Basore Process:

Expense Item	Cost per Day	Cost per Ton of Briquettes
Interest and Depreciation	$14.17	$0.709
Labor	15.50	.775
Raw Sawdust	No Charge	No Charge
Oil Waste and Light	1.40	.07
Repairs and Maintenance	1.74	.087
Totals	$32.81	$1.64