1951

Use of wood waste as fuel in Western Montana

Eric M. Ammann
The University of Montana

Recommended Citation

Ammann, Eric M., "Use of wood waste as fuel in Western Montana" (1951). *Graduate Student Theses, Dissertations, & Professional Papers*. 3982.
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USE
of
WOOD WASTE AS FUEL
in
Western Montana

by

Eric M. Ammann
B.S., Montana State University 1950

Presented in partial fulfillment of
the requirement for the degree of
Master of Forestry

Montana State University

1951

Approved:

Williams
Chairman of Board
of Examiners

W. P. Clark
Dean, Graduate School

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CHAPTER I

FACTORS INFLUENCING THE USE OF WOOD WASTE AS FUEL

Wood has been man's principal source of fuel from prehistoric times until about a hundred years ago; today, wood plays a minor but definite part as fuel; it is used mostly in areas where other fuels are not locally produced and therefore more expensive.

The Pacific Northwest, including British Columbia, Washington, Oregon, Northern Idaho, and Western Montana, is probably the largest area of this kind. Although this paper will be restricted to the area of Western Montana, especially Missoula, it is reasonable to assume that conditions are similar in most of the timbered areas of the Northwest.

Geographic location. The location of Western Montana isolates it from most of the major sources of coal and oil. The high cost of transportation makes the use of these two materials for fuel very expensive. The cost of electrically-produced heat is even higher. Thus, in the search for a more economical fuel, wood waste has been found to be a very satisfactory material.

Advantages of burning wood. Wood has certain distinct advantages as a fuel, particularly in regions where plentiful supplies are locally grown. It is cheap. It burns well, with little smoke, provided certain simple rules are observed. It has a high heat-producing potential. In addition, it is a renewable resource, widely distributed and usually easily accessible.

Disadvantages of burning wood. On the other hand, wood often has a high moisture content, which reduces its heating value. It is also bulkier than other common solid or liquid fuels. An exception are prestologs, which are almost perfectly dry and very compact.

Low cost of fuel. Obviously, the greatest single factor determining the use of wood -- in years past as well as today -- is its low cost. According to Jenkins and Guernsey there were approximately 15,000 sawdust burners in Vancouver alone in 1937, with an average cost of $35 per winter.[1] Even at today's high prices, the average annual cost for heating a five-room home with sawdust is $60 in Missoula. More detailed information on local wood-waste fuel costs will be given in Chapter VIII.

Types of local industry. Another major factor influencing the use of wood waste as fuel is the type of industrial plant prevalent in the community. In communities with many sawmills, like Missoula, wood waste is plentiful and cheap. As there is no industry in this area which could utilize wood waste for any commercial purposes, such as the production of alcohol, cellulose, or wood flower, use as fuel is the highest form of use possible.

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[1] J. L. Jenkins and F. W. Guernsey, "Utilization of Sawmill Waste for Fuel," Journal of Forestry, XXXV (September, 1937), 887.

As already mentioned, wood in its various forms has been burned as fuel for a long time. However, there is little published information on the combustion of waste wood. This paper tries to analyze and combine some of the information available, and furthermore report on a survey of existing waste burning plants used for heating homes in the Missoula area of Western Montana.

CHAPTER II

TYPES OF WOOD WASTE

Sources of waste wood. The volume of wood cut for fuel (about 2,002 million cubic feet a year) is second only to that cut for lumber (about 2,142 million cubic feet a year) and therefore merits serious consideration. Cutting of wood for fuel is not necessarily a drain on the nation's forests; instead, such wood can be gained from necessary thinnings -- thus improving timber stands at the same time -- and from salvaging of waste. It is estimated that an additional 2,478 million cubic feet of wood, wasted annually in making various wood products, is used for fuel.[1]

Only about forty per cent of the wood from the trees cut in our forests reach the consumer in finished products. An average of thirty to fifty per cent of the lumber delivered to the mills is waste[2], available for fuel. The percentage and character of this waste depends primarily on whether the mill is of the "finishing" or "rough" type. Waste from finish mills runs about twenty-five to forty per cent of the lumber processed.[3] It contains a smaller percentage of moisture than waste from rough mills and is usually finer in composition,

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[1] L. H. Reineke, Wood Fuel Preparation (Madison, Wisconsin: Forest Service Laboratory Publication R1666-19), p.1.

[2] L. E. Webber, "Basic Facts on Wood Burning," Power, LXXXV (March, 1948), 156.

[3] Loc. cit.

containing less bark and foreign material (sand). It forms a good raw material for prestologs and stoker briquettes.

Wood waste occurs as harvesting or manufacturing wastes and residues, which are basically due to the great variation in size, form, quality, species, and accessibility of the raw material. Wood which is used in industrial furnaces may be in the form of cord wood, slabs, edgings, bark, sawdust, or shavings. Most of these forms of waste are also used for domestic furnaces and stoves.

Hog Fuel. In some installations, mostly the larger ones, a "hog" chops all of the fuel to a fixed maximum size. The term "hog fuel" is applied to this material. Unfortunately, this term has been used loosely in reference to sawdust, shavings, and bark. To be technically correct, hog fuel should include only wood which has been cut in one of several types of hogs.

Dull knives in hogs of the knife type tend to shred the wood rather than cut it. Shredded wood becomes a liability; long stringy pieces can clog mechanical fuel feeders and often cause "packing" and "bridging" of the fuel in gravity-feed hoppers and chuters.

Hog fuel is ordinarily burned without pre-drying, since a furnace properly designed for burning such fuel does the necessary drying as part of the combustion cycle, a procedure that is more satisfactory than separate drying.

Sawdust and shavings. Sawdust and shavings are often burned in a mixture with hogged fuel in industrial furnaces and require no special treatment. Shavings are unsuitable for burning alone because of their lightness and lack of body; they are, however, well suited for the production of wood briquettes (prestologs and stoker fuel).

Stovewood. Much wood is burned in short length (12 to 18 inches) in stoves, ranges, and room heaters. For cooking purposes, dry wood is needed. For room heating, green wood can be used in a magazine-type, slow-combustion heater if sufficient dry kindling is used at the start and if the magazines are recharged before the fuel bed gets too low.

Standard measurements. Hog fuel, sawdust, and shavings are sold for fuel extensively only in the Northwest; the "unit" of 200 cubic feet is the standard measure.[4] 200 cubic feet are the approximate amount which will be produced by hogging one cord (128 cubic feet) of round wood. It should be pointed out that "unit" is not an entirely satisfactory term inasmuch as the weight of a unit may vary from 2,500 to 5,000 pounds[5], depending on the moisture content and the manner in which it is packed down.

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[4] Reineke, op. cit., p.

[5] Webber, op. cit., 156.

CHAPTER III

MOISTURE CONTENT

Hygroscopicity of wood. Wood is a hygroscopic material. This means that originally well-dried hogged fuel will absorb water from the air and thus attain a greater weight than it had originally. The amount of moisture absorbed depends on the temperature and humidity of the air. The moisture content is furthermore influenced by the particle size of the material. The larger particles will admit some air and lose moisture, while the finer, dust-like particles will absorb moisture. Since hogged fuel is fairly well mixed in the process of loading from the storage pile, the average moisture content should be fairly even.

Moisture Percentages. According to figures provided by the Missoula heating plant of the Montana Power Company[1], the moisture content of hog fuel burned at their local plant runs from forty to fifty per cent of moisture, the average being slightly closer to fifty than forty-five per cent. Despite this high moisture content, hog fuel compares very favorably with other fuels available in this area (see Table V), as far as the fuel cost per pound of steam generated is concerned.

Finish mills use air-dried or kiln-dried lumber. Air-dried

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[1] Kindness of Earl Holzknecht, Engineer.

wood seldom contains less than twelve per cent moisture. Kiln-dried lumber sometimes contains as little as one or two per cent moisture; the average runs from five to seven per cent.

Rough mills may produce waste of almost any moisture content, but the average is about thirty to fifty per cent. Waste of logs floated to the mill or kept in water storage often contains as much as seventy per cent moisture.

The moisture content for hog fuel is usually determined by the weight method; the required apparatus includes a scale sensitive to 0.01 grams, and a drying oven. A sample of the wood or wood waste is first weighed on the scale and then dried to a constant weight in the oven, at 212-225°F. The percents of moisture in the sample are found by dividing the loss in weight by the original weight of the sample and multiplying it by 100.

In the type of climate prevailing in the Pacific Northwest it is desirable that wood used for domestic purposes be seasoned for approximately nine months. Seasoning is not a rigid requirement for wood burned in specially-designed industrial furnaces or slow-combustion stoves, because the gain in heat value is only 6.7 per cent for wood dried from sixty to twenty per cent moisture content. This gain is too little to repay drying, piling, and other seasoning costs.

CHAPTER IV

HEAT VALUE OF WOOD AND WOOD WASTE

Heat value of wood. In burning wood it is essential to have the wood as dry as possible in order to obtain more heat per pound of fuel and to hold creosote deposits to a minimum. Moisture content in wood markedly decreases the heat content per pound of fuel delivered to the furnace.

The following table gives heating values for oven-dried specimens of different species (given in B.T.U., British thermal unit):

TABLE I

CHEMICAL COMPOSITION OF DRY WOODS [1]

Species	Carbon %	Hydrogen %	Nitrogen %	Oxygen %	Ash %	Heating Value BTU per pound
Oak	50.16	6.02	0.09	43.36	0.37	8,316
Ash	49.18	6.27	0.07	43.91	0.57	8,480
Elm	48.99	6.20	0.06	44.25	0.50	8,510
Beech	49.06	6.11	0.09	44.17	0.57	8,591
Birch	48.88	6.06	0.10	44.67	0.29	8,586
Fir	50.36	5.92	0.05	43.49	0.28	9,063
Pine	50.31	6.20	0.04	43.08	0.37	9,153
Average	49.56	6.11	0.07	43.83	0.42	8,671

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[1] L. S. Marks, *Engineer's Handbook* (New York: McGraw-Hill Book Company, Inc., 1941), p. 115.

Generally speaking, the heat value of thoroughly dried wood is in direct proportion to its weight per cubic foot. One pound of oven-dried wood substance has a calorific value of 8,600 B.T.U.[2] Such wood, if burned under favorable conditions, will yield around 7,250 B.T.U. per pound; the yield of air-dried wood, containing about twenty per cent moisture will be about 5,800 B.T.U. and that of green wood at sixty per cent moisture will be only around 4,100 B.T.U. per pound.[3] Oils, tannins, resins, and similar substances in the wood will slightly change the actual calorific value of different species.

In comparing one pound of dry fuel having the average heat content of 8,600 B.T.U. with a pound of the same fuel containing fifty per cent moisture, it will be noted that the latter has only half that heat content, since only half is wood. Furthermore, each pound of water in the fuel must be evaporated in the furnace and superheated to the temperature of flue gas. Part of the heat from burning is used for this unavoidable process.

Heat value of sawdust fuels. The Forest Division of the Canadian Department of Interior Laboratory at Vancouver, B.C., gives the following data on Pacific Northwest sawdust heat values:[4]

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[2] Wood Fuels and Wood Stoves (Madison: Forest Service Laboratory Publication R1279, June 1942), p. 2.

[3] L. H. Reineke, Wood Fuel Combustion Practice (Madison: Forest Service Laboratory Publication R 1666-18, 1947), p. 2.

[4] E. C. Willey, "Rating and Care of Domestic Sawdust Burners," Bulletin Series, No. 15, Oregon State Agricultural Experiment Station, July, 1941, 7.

TABLE II

Species	B.T.U. per pound of oven-dried fuel
Douglas Fir	9,200
Western Hemlock	8,500
Western Red Cedar	9,700
Western Yellow Pine	9,100

For comparison, the following figures, available through the Missoula heating plant of the Montana Power Company, are given: [5]

Hog fuel (at an average moisture of 45%, taken from storage piles at local mills)	4,550 B.T.U. per pound of oven-dried fuel
Pine shavings	7,000 B.T.U. per pound of oven-dried fuel
Wood briquettes	8,000 " " " " " " "

The average moisture content of fir and pine sawdust as well as hog fuel runs about forty-five to fifty per cent. An average unit of fuel of 200 cubic feet (at approximately nineteen pounds per cubic foot) at this moisture content will weigh around 3,800 pounds. It will contain about 17.3 million B.T.U. The average installation using fifty per cent excess air and 500°F stack temperature, will leave about 13 million B.T.U. available for useful heat.

The greatest efficiency is generally found in large commercial plants where trained attendants, using instruments, keep constant watch over the equipment. As high as sixty-five per cent efficiency is sometimes attained under these conditions, whereas the small domestic unit will do well to get from twenty-five to forty per cent.

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[5] Kindness of Earl Holzknecht, Engineer.

CHAPTER V

PROCESS OF BURNING WOOD

Phases of burning. Three basic phases in the burning process have to be recognized if highest efficiency in the burning of various types of wood and wood waste is to be achieved. In the first phase, the moisture is driven off. In the second phase, the volatile matter is distilled off; when heated to temperatures of approximately 1,100°F or greater, this volatile matter bursts into flames and burns if mixed with sufficient air. In the third and final phase, the fixed carbon burns.[1]

All three phases of burning may, of course, go on at the same time, but the first two stages are largely carried on when the fire is started or when fresh fuel is added.

Importance of combustion of volatiles. In the first two phases of burning heat is consumed. The evaporation of one pound of H_2O requires about 1,000 B.T.U. and one pound of volatile matter absorbs about 200 B.T.U. when driven off. According to Webber, the volatile matter comprises about eighty per cent of the weight of bone-dry wood, less than twenty per cent being fixed carbon;[2] thus, the amount of heat absorbed may be sufficient to cool the furnace when a new fuel charge is added.

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[1] L. H. Reineke, Wood Fuel Combustion Practice (Madison, Wisconsin: Forest Service Laboratory Publication R1666-18), p. 5.

[2] L. E. Webber, "Basic Facts on Wood Burning," Power, LXXXV (March, 1941), 157.

This percentage relation shows that the greater part of the heat liberated in the furnace comes from burning the volatiles and only a small part from combustion of fixed carbon. Obviously, incomplete combustion of the volatile matter can be one of the greatest losses of efficiency. Incomplete combustion may result from lack of air or, more probably, from poor mixing of air and products distilled from the wood. Since the volatile matter distilled from the wood will not burn below a temperature of approximately 1,100°F, the furnace has to be so designed as to provide sufficient space for the long flame of the wood to heat and completely burn the volatiles. Whenever the volatiles reach the flue too soon, become cooled, and escape unburned, incomplete combustion and the loss of heat is the result. In addition, creosote will be deposited in the pipes, causing chimney fires and necessitating frequent cleaning.

Space and air for combustion. Due to the high percentage of volatile matter, wood has a long flame; therefore, the combustion space above the fuel level must be greater than that for coal. When the air supplied through the grates passes through approximately two inches of glowing embers almost all the oxygen in it is consumed or combined with the carbon to form carbon dioxide. This carbon dioxide is reduced to carbon monoxide as it passes through more glowing carbon. [3] For this reason, eighty per cent of the air needed should

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[3] Reineke, _loc_. _cit_.

be supplied over and around the fuel; admitting more air through the grate will not help the situation; it will only increase the rate of gasification of glowing carbon.

Speed of combustion. The speed with which complete combustion of wood takes place depends on several factors, the most important of which is the particle size.

> The surface of freshly fired fuel receives heat by radiation and convection from the already burning volatile matter. From the surface the heat travels by conduction to the inner parts of the piece. Large pieces of fuel have a comparatively small surface and a large interior mass to which heat must be transferred by conduction. Inasmuch as the heat conductivity of wood is low, it takes a longer time to drive off the moisture and the volatile matter from a single large piece of fuel than from several smaller pieces of equal weight. A bunch of excelsior or wood shavings burns in a few seconds because they have a very large surface to receive heat and practically no interior to which heat must be transferred by conduction to drive off the moisture and volatile matter. ...
>
> Therefore, the size of the pieces of fuel has a marked effect on the rapidity of combustion. Wood-waste fuel should be chopped up into reasonably small pieces to increase the surface and to reduce the amount of combustible inside of the pieces to which heat must be transmitted by conduction for driving off moisture and volatile matter, and to which oxygen must be supplied through a layer of ash to burn the fixed carbon.[4]

Advantages of hog fuel. The small size of particles (usually not over one inch long and one-fourth to one-half inch thick) makes hog fuel quite readily combustible, allows for unobstructed evaporation of moisture and makes the fuel easily accessible to oxygen on the comparatively large surface area. The uniformity of the particle size makes handling by machinery like belts, chains, and augers quite feasible.

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[4] E. C. Willey, "Rating and Care of Domestic Sawdust Burners," Bulletin Series, No. 15, Oregon State Agricultural Experiment Station, July, 1941, 19.

CHAPTER VI

WOOD BRIQUETTES

Briquetting in general. The art of briquetting is relatively old and widespread in its application to a great variety of substances. It is applied to the metering of uniform quantities (pills), to consolidation of fine material into convenient units (sugar cubes, coal dust), to densification of bulky material (metal turnings, peat), and to improvement of physical qualities (powder metallurgy, charcoal).[1]

The equipment, technique, and experience of this broad field are available for guidance in wood briquetting since the consolidation, densification, and improvement of physical qualities desired for utilization of finely divided wood refuse apparently parallels the customary briquetting methods used for other materials.

Briquetting of sawdust, shavings, and bark with the methods mentioned above has been done in Europe for many years. In this country, briquetting of wood waste has been successful only where wood waste is cheap and plentiful and where other fuels are comparatively expensive. The method used represents a radically different process.

Self-bonding method of wood-waste briquetting. It has been found that some materials require no added binder, because they are self-binding when briquetted at high temperatures. Among these is

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[1] Briquettes from Wood Waste. Forest Service Products Laboratory Publication R1666-13; Madison, Wisconsin: June, 1947. p. 1.

wood. At temperatures above the minimum plastic temperature (325°F for wood[2]), the elastic strains set up in the material under briquetting pressure are completely relieved and the particle surfaces are bound together into intimate contact.

Cohesion of the interfaces, interlocking of broomed-out, fibrous parts of the particles, and a possible adhesion of the heat-softened lignin, all contribute to a binding action that imports satisfactory strength to briquettes after they have cooled under pressure.

Production and production equipment. "The self-bonding feature of wood waste is the basis of the only wood-briquetting process commercially successful in this country at present."[3]

All plants operating with this process use one type of machine, the "Pres-to-log", made by Wood Briquettes, Inc., Lewiston, Idaho. Up to the present, these machines are available only on lease. The machine operates by compressing waste wood (sawdust, shavings, and other scrap, ground to oatmeal size) into a primary compression chamber by means of a feed screw developing a pressure of approximately 3,000 pounds per square inch. At the outlet from this chamber a secondary head cuts the compressed material into a spiral ribbon and forces it into a mold under a local pressure of 25,000 to 30,000 pounds per square inch. At this extreme pressure the friction generates

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[2] Ibid., p.2.

[3] Ibid., p.1.

sufficient heat to partly plasticize and self-bond the wood. The molds are cylindrical in diameter and twelve inches deep, spaced at regular intervals in a large wheel of twelve inches rim width. The axes of the molds are parallel to the axis of the wheel (see Fig. 4). The bottom of the mold is closed by hydraulically-operated extractor pistons, which supply the necessary resistance during filling. The piston retracts with one cooled briquette while the one being manufactured displaces it in the mold.

After the simultaneous filling and extracting process is completed, the wheel revolves slightly to bring the next mold into line for filling. The mold-wheel is water-cooled to bring the briquettes below their plastic temperature.

The extrusion press. A different type of machine is used for stoker briquettes, as the four-by-twelve-inch briquettes produced by the prestolog machine are only suitable for hand-firing. In this process the self-bonded material is "extruded" through several one-inch round holes to form continuous rods. As these rods emerge from the extrusion head rotating knives cut them into one-inch length, suitable for mechanical stoking. "The extrusion machine is small enough to be mounted on a truck for portable use and may be powered by the truck motor." [4]

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[4] Ibid., p. 2.

Dry waste a prerequisite. At present, waste from coniferous species only is used for briquetting. It is essential to secure dry waste of a moisture content of less than ten per cent, preferably six per cent, in order to obtain a briquette of high fuel value and good handling quality. In a local plant in Missoula, briquettes made of wood waste of too high a moisture content turned out to be almost completely plasticized and gave the appearance of being coated with varnish. The reason for this seems to be the higher pressure and heat generated in the compression of material of higher moisture content, as the compressibility decreases with increasing moisture content.

Various types of dryers may be used to bring the wood to the desired moisture content. They include drums, steam-heated plates, and steam pipes over which the waste is cascaded. A recent dryer installation, the Raymond Flash Dryer[5], uses a short exposure to hot gases to reduce the moisture content of the waste to the desired level.

Specifications for the final product. Prestologs weigh around eight pounds a piece; they have a fuel value of about 8,000 B.T.U. per pound.[6]

Prestologs will stand handling, and occupy about thirty-five cubic feet per ton — much less space than is required for a ton of coal.

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[5] *Loc. cit.*

[6] Robert S. Aries, "Wood Waste Makes Fuel Briquets," *American Lumberman* (May 15, 1943), 27.

CHAPTER VII

WOOD-BURNING FURNACES

Special considerations in wood furnace design. In order to burn wood or wood waste efficiently and economically, furnace construction has to allow for the specific burning properties of wood. How little attention this field of furnace design has received is illustrated by the fact that up to the development of the modern slow-combustion or complete-combustion furnace hardly any changes had been made on the old Franklin stove.

The long flame of burning wood, its usually high moisture content, and special needs in air supply, all have to be considered in the development of a wood-burning furnace, particularly if it is to burn hog fuel and sawdust.

Domestic sawdust burners. The burning of waste wood in the form of sawdust is relatively new to the heating industry. Crudely constructed equipment, mostly homemade, has been used for twenty years and longer, but it has only been during the last fifteen years that attempts have been made to perfect small domestic equipment to the point where it is acceptable to the general public.

The main difficulties with early-type burners came from excessive smoke, backfiring, and creosoting. Some of these difficulties can be traced to the use of burners that were too large. Burners now on the market seem to meet requirements more satisfactorily.

Types of burners. There is no great difference among the various makes of sawdust burners on the market today. This is true not only of the domestic type, but of the large, commercial-type burner as well. In general, the burner consists of a combustion chamber, sometimes called a Dutch oven, which holds grates and refractory brick lining. On the top of the oven is an opening over which the sawdust hopper is fitted. On the large industrial burners this opening is connected with a chute into which a sawdust conveyor discharges. So far there are no automatic conveyor units on the market for domestic sawdust heating systems.

A typical domestic-type burner is illustrated in Fig. 1 . Note that the grates are removable and adjustable, a feature of most burners. The top and the sides of the oven are protected by refractory brick linings.

Most sawdust burners are built as individual units, separate from the furnace; they are placed in front of and connected with the furnace. In most cases they are attached to the ashpit door after removing the coal or wood grates and relining the furnace with fire brick. The passage from the sawdust burner to the furnace is also lined with fire brick to provide a continuous sealed fire passage.

Combination or burner units with most any type of furnace using solid or oil fuels is feasible. The heating system may be a gravity hot-air, a forced hot-air, or a hot-water radiator system.

Differences in design. The differences in design are mostly in the shapes of hoppers, grates, and methods of introducing secondary air to the fuel bed.

Hopper. There has been considerable experimenting to find the proper shape of hopper for best feeding of the sawdust. It has been widely agreed upon that the side angles should be steep, but the exact shape of the hopper and devices to prevent packing and bridging of the fuel are still in question. Not only the shape of the hopper but also the shape and size of the throat are important to the proper feeding of fuel to the fire grates.

Grates. Recognition of the three phases of combustion has led to the adoption of inclined grates and zoned combustion.[1] Different types of feed grates are shown in Figs. 2a, 2b, and 2c. The multiple shelf grate may be so designed that the steps are adjustable in respect to angle, in order to accelerate or decelerate the fuel feed. The main grates are of two general types, the stationary or one-piece type and the movable or shaker type. An exposed air opening, either in the grate or through the secondary air intake, is an asset. It is the accidental covering of these air holes during the inrush of fresh fuel over a bed of hot coals that results in an explosion when the accumulated gas is finally ignited.[2]

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[1] L. S. Marks, *Engineer's Handbook* (New York: McGraw-Hill Book Company, Inc., 1941), p. 1151.

[2] E. C. Willey, "Rating and Care of Domestic Sawdust Burners," *Bulletin Series*, No. 15, Oregon State Agricultural Experiment Station, July, 1941, 11.

Air supply. The primary air is supplied to all burners alike, through the front draft door. The methods of bringing in the secondary air vary with each make of burner; Fig.2b shows one method.

Slow-combustion stoves: European stoves. In the United States considerable publicity has been given to the European slow-combustion stove or furnace within the last fifteen years. These stoves are of the hopper type, with the grate at the bottom of the hopper. A damper in the ash pit controls both the primary and secondary air supply. The primary air passes up through the grate and supports combustion in the limited area above the grate. The secondary air is introduced into the flame area at the bottom of the combustion chamber, which is in front of the hopper. This combustion chamber is lined with fire brick and provides for a long flame travel so that the gases can be more completely burned. The refractory lining is also an aid in promoting cleaner burning and in eliminating much of the creosote deposits. Very high efficiencies have been claimed for these stoves (some tests showed efficiencies of up to 79%, based on the actual heat value of the wood).

The best-known European makes of these stoves are the following: Norrhammer-Bruk (Sweden), Juno, Oranier, and Bergman (Germany).

Slow-combustion stoves: American Stoves. In the last few years, several new wood-burning stoves and furnaces have been introduced in the United States. Some of these stoves have incorporated the features of the European slow-combustion stove. These stoves of the hopper type have a combustion chamber either in front of or behind the hopper where the secondary air is introduced into the hopper flame area. The majority of these new stoves is equipped with thermostats which automatically regulate the rate of burning by controlling the air inlet, and in this way hold the room temperature constant. All the new stoves claim higher efficiency and less maintenance attention.

Some of these new stoves are: The Riteway Heater, the Charwood Heater, the Ashley Downdraft Heating System, and the Woodomat Furnace.

CHAPTER VIII

RESULTS OF THE SURVEY ON SAWDUST BURNERS IN THE MISSOULA AREA

During the winter of 1950/51 the writer conducted a survey in the Missoula area of people using sawdust to heat their homes. A large part of the survey was conducted by mail, while the more interesting replies were followed up by a personal interview.

A total of 150 questionnaires with return envelopes was sent out; ninety questionnaires were returned, of which 81 could be used in the survey. About 35 personal contacts were made, with sometimes interesting results.

Limitations of survey: It should be mentioned here that the survey had all the limitations of any public opinion survey: The answers are somewhat subjective and relative as the human factor produces many intangibles without statistical significance. For instance, some people do not mind shoveling sawdust -- regard it as good exercise --, while others do, regarding it as unneccesary exertion. Some people manage their furnaces and burner units better than others which results in more satisfaction in their heating system.

Evaluation of the questionnaire. The questionnaire and its answers are shown in Table III. As each answer represents slightly more than one per cent of the total answers received, the figures in the table indicate actual answers rather than per cent.

As can be seen from the table, a wide variety of makes of burners are in use in the area investigated. A burner made in Missoula by Mr. Tiemeyer seems to be most widely represented. According to his own estimate there should be about 130 of his burners in the Missoula area. One can assume that of the people that did not know the make of their burner, most have Tiemeyer burners, as he does not put his name on his product.

The Hercules burner is sold by both Sears and Roebuck and Montgomery Ward. The survey shows this particular burner to be second in popularity. Generally, the Tiemeyer burners are the older ones and have sometimes been in operation more than fifteen years; while the other commercial burners cam in during the last seven to ten years.

Automatic feed for burners. Of all the burners investigated none had automatic feed, although it should not be too difficult to devise an automatically-controlled mechanical feed. Many people would like to have sawdust heating plants if a mechanical feed were available, or, in the words of one of the people interviewed, if it could be "a little more developed."

One Missoula resident designed and built an automatically-operated sawdust feed unit for his own home. He had it operating for years without any failures. He used a four-inch conveyor belt, powered by an electric motor, as feed from the sawdust bin to the hopper. The motor was activated by a mercury switch, delicately balanced, which was operated by two hoe-shaped paddles (see Fig.3). When the sawdust in the hopper was nearly consumed, the lower paddle would trip the mercury switch and turn on the motor. As soon as the hopper was filled, up to the upper paddle, the switch would be pulled by the upper paddle and the feed be shut off. The whole unit could be left unattended for as much as one week.

Problems in Use of Sawdust for Fuel. The above-mentioned unit was replaced by an oil-heating system because its owner needed the space occupied by the sawdust bin . This indicates one of the major problems in the use of sawdust for fuel. Its bulk and the handling and storage difficulties connected with it, constitute the more frequent causes for dislike of sawdust heating. If sawdust could be stored in an outside funnel-shaped storage bin (below ground level for easy truck dumping) and this bin in any way connected with an automatic feed, the major problem in the use of sawdust for fuel would be overcome; the need for constant attention would be eliminated.

Quality of fuel. Another problem indicated by the survey is the uneven quality of the sawdust. Varying particle size and moisture content -- ice in the fuel in winter time -- makes it hard to maintain an even rate of combustion.

Advantages of heating with sawdust. Obviously, economy and cleanliness of sawdust fuel are its most outstanding features. For a comparison of cost, a heat loss calculation for a typical five-room house (insulated, with basement, 14 windows, 3 doors) is given in Table IV. The total heat loss for this house, calculated for a minimum temperature of 20°F below zero, and an inside temperature of 70°F (design difference $=$ 90) is approximately 82,180 B.T.U. per hour. The cost of heating this home with oil averaged about $21 monthly from October to May. The cost of heating a home almost exactly like it with sawdust averages $6 to $7 per month, with a $65 to $75 yearly average.

The original cost of the burners included in the survey ranged from $5 to $1,000, with the expensive units not performing any better than the cheaper ones. This seems to speak very much in favor of the lower-priced burner systems, costing around $50 to $75.

The cleanliness of sawdust fuel is outstanding; coal and oil both create more smoke and coal has far more ashes and clinkers than sawdust. Wood waste has a pleasant odor, is moist enough to bind the dust and does not stain walls and curtains in burning.

Another nice feature of sawdust heating systems is their even heat and their sufficiently high output of it, even during the coldest part of the year. From the interviews it can be concluded that most burner units have ample heat-producing capacity if properly installed and attended.

Popularity of sawdust fuel. Under present conditions, most people questioned in the survey, would again install a sawdust heating system if they had the choice. The reason for this is in most cases the low cost of heating with wood waste fuel. However, the majority of the users of sawdust fuel would prefer natural gas and have indicated that they will switch over to gas as soon as it is available in Missoula. For natural gas combines all advantages of an ideal fuel -- low cost, completely automatic heat for cooking and heating, and great cleanliness and safety. It is obvious that wood waste fuel, despite the advantages it has over other fuels presently available, cannot measure up to natural gas in the conveniences it provides.

CHAPTER IX

SUMMARY

If burned properly and in the correct type of furnace, wood and wood waste is one of the cheapest and best-suited fuels available in the area of Western Montana at present.

Hog fuel is burned in sawdust burner attachments or conversions, usable on most commercial furnaces, while wood briquettes can be burned in most conventional stoves or furnaces. The burning time of hog fuel can be considerably prolonged by mixing it with stoker pellets.

Other wood waste, such as planer blocks, sticks, limbwood, but also prestologs and stoker pellets, can be burned most economically in a slow-combustion type furnace or stove, as described previously.

If some solution is found to the storage problem of sawdust and if the feeding of the hopper is mechanized in a simple, inexpensive way, waste wood fuels will become far more popular.

It is quite possible that rising prices as well as shortages on other fuels due to the world situation, will hasten the development of a domestic sawdust burner unit which will not only give satisfactory and economical heat, but will be easy and convenient to handle at the same time.

TABLE III

THE QUESTIONNAIRE AND ITS EVALUATION

1. Q.: Kind of sawdust burner?

A.:

Tiemeyer (Local)	Hercules	Crater	Monk	Conifer	Others	No answer
16	16	14	6	5	12	12

2. Q.: How long in use?

A.:

Less than 1 year	1 - 3 years	3 - 7 years	7 - 14 years	more than 14 years (maximum 21 years)	No answer
7	18	8	31	12	5

3. Q.: Is it fully automatic?

A.:

Yes	No (gravity feed)	No answer
--	76	5

4. Q.: How often do you have to fill the hopper bin?

A.:

Every 3-5 hrs	Every 6-8 hrs	Every 9-11 hrs	Every 12-16hrs	Every 24 hrs	No answer
4	28	18	23	2	6

5. Q.: How many rooms do you heat with it?

A.:

2 - 4 rooms	5 - 6 rooms	7 - 8 rooms	9 - 10 rooms	11 - 12 rooms	No answer
8	43	21	7	1	1

6. Q.: What is your cost for heat per month?

A.:

$4 - 5	$5 - 7	$7 - 9	$9 - 11	$11 - 14
8	29	22	15	7

TABLE III (CONT)

7. Q.: What do you like about it?

A.:

Economy only	Cleanliness only	Econ & Clean. both	Even heat	Nice smell	No definite answer
15	7	53	17	5	6

8. Q.: What do you especially dislike about it?

A.:

Bulk, storage problem, feeding hopper	Need for constant attention, too much heat in mild weath.	Cleaning, Creosote Deposits	Uneven quality of sawdust	Nothing	No definite answer
41	16	14	7	9	5

9. Q.: What was original cost installed?

A.:

$5-25	$26-40	$41-55	$56-80	$81-110	$111-$170	between $200 and $1,000	no answer
2	6	8	14	12	6	6	27

10. Q.: Do you have forced draft?

A.:

No	Yes
67	14

11. Q.: Do you have warm-air or warm-water heating?

A.:

Warm-air	Warm-water	No answer
78	2	1

12. Q.: Do you have thermostat controls?

A.:

Yes	No
74	7

TABLE III (CONT)

13. Q.: Is it clean enough from a housewife's point of view?

A.:

Yes	No	Yes, with reservations
75	5	1

14. Q.: Do you regard it as safe enough?

A.:

Yes	No	Yes, with reservations
73	2	6

15. Q.: Would you ever again install a sawdust-burner heating system if you had the choice?

A.:

Yes	No	Yes, unless natural gas is available	Undecided
55	8	16	2

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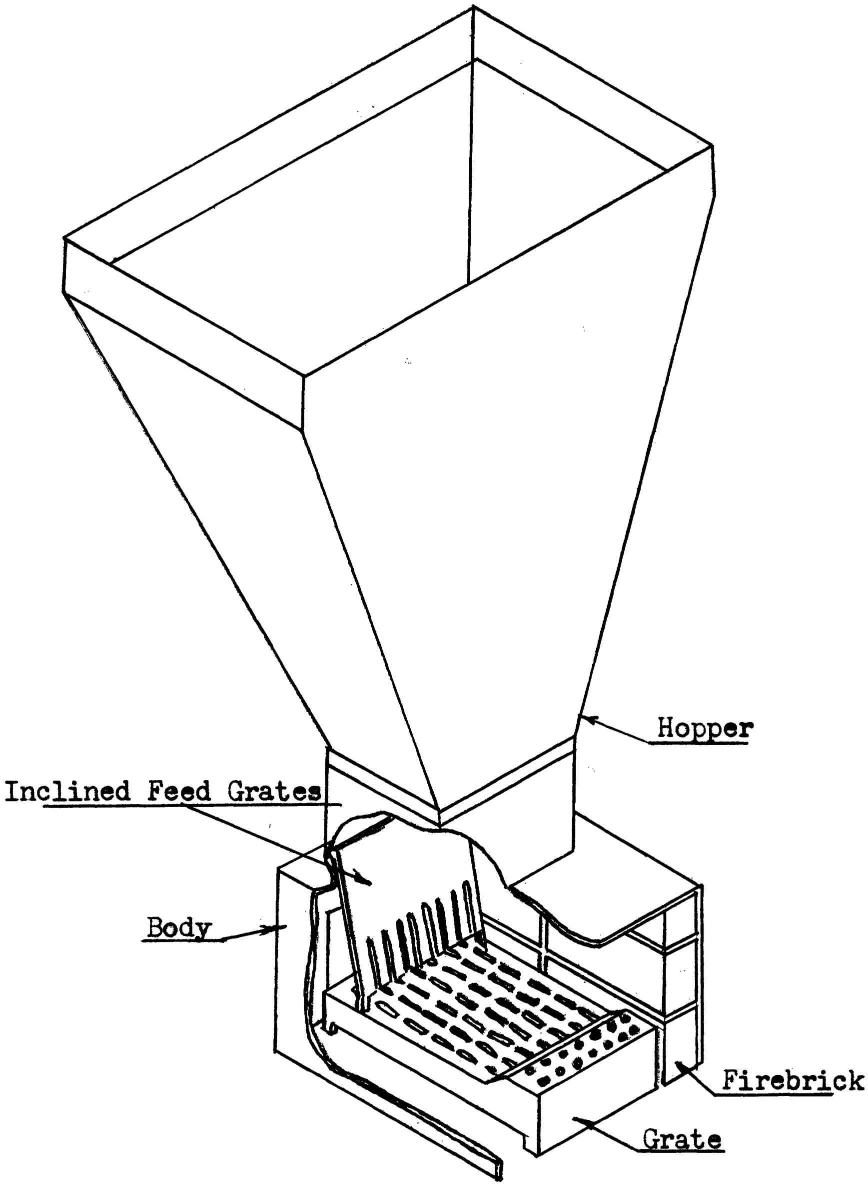

Fig. 1 - Cutaway View of Typical Sawdust Burner[1]

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[1] E. C. Willey, "Rating and Care of Domestic Sawdust Burners," Bulletin Series, No. 15. Corvallis Oregon: Oregon State Agricultural Experiment Station, June 1941, p.8.

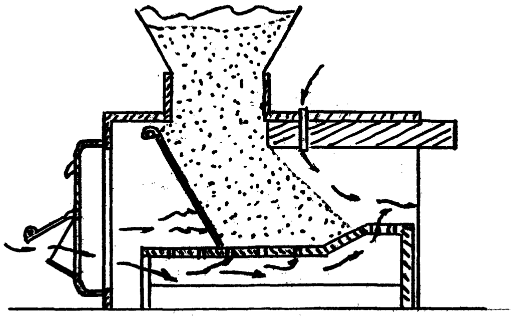

Fig. 2a - Section of Burner Having One-Piece Feed Grate

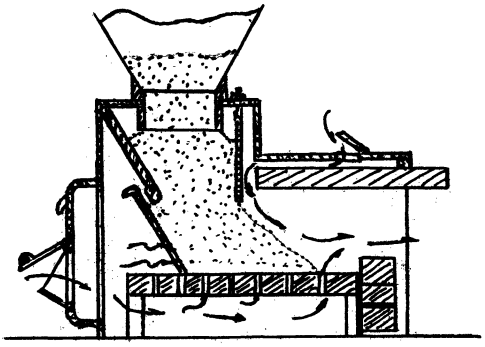

Fig. 2b - Section Showing Typical Two-Piece Feed Grate

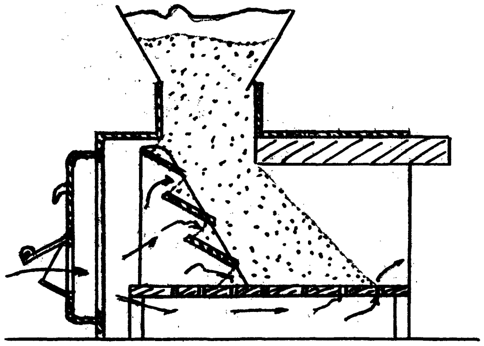

Fig. 2c - Section Showing Typical Multiple Shelf Feed Grates[2]

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[2] Willey, op. cit., pp.12, 13.

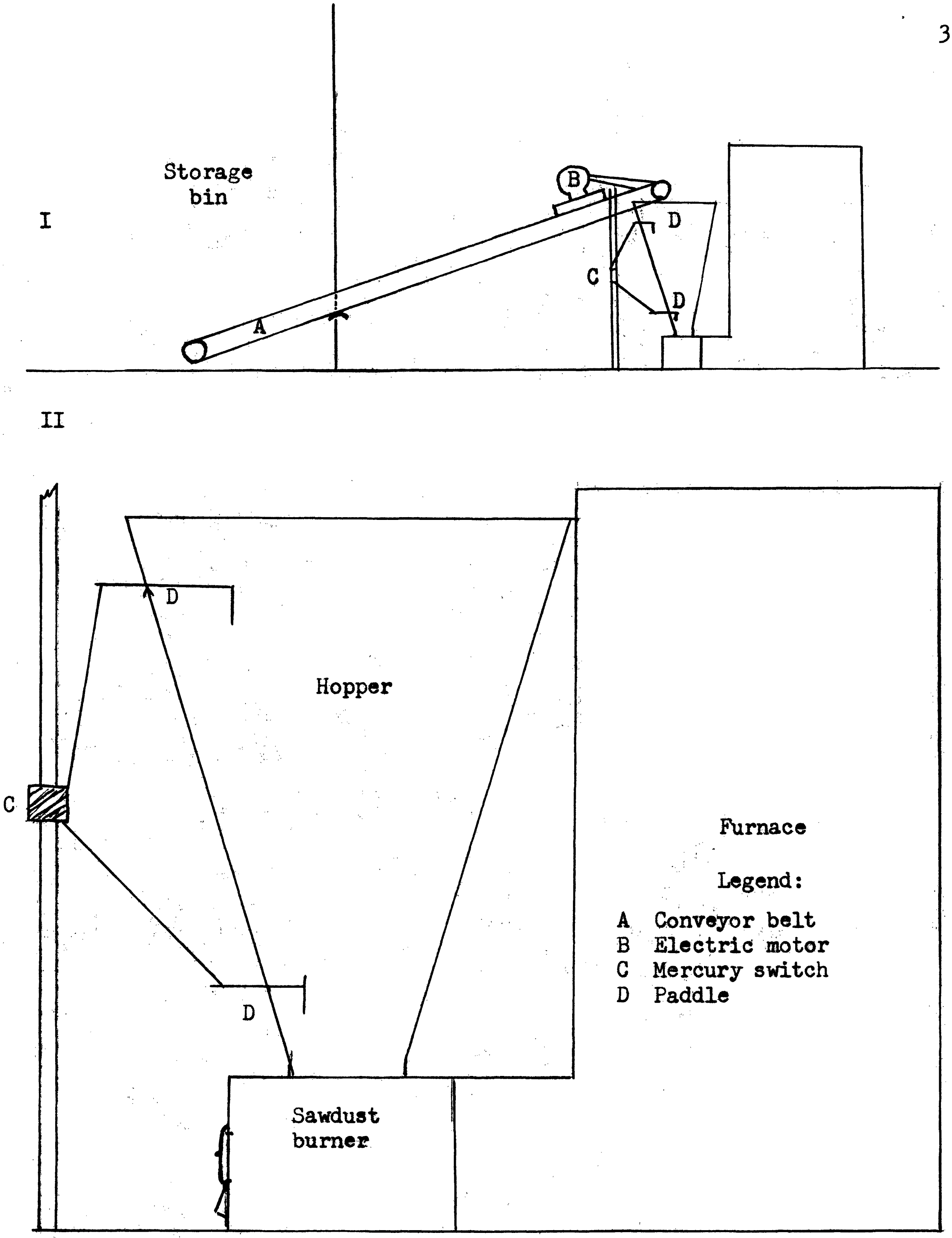

Fig. 3 - Sawdust Burner Desgined by Dr. Nelson
(Missoula)

TABLE IV

HEAT LOSS CALCULATION FOR A FIVE-ROOM HOUSE

Construction through which heat loss occurs	Type of constr.*	Area, sq.ft.	Heat loss factor	Heat loss BTU/hr
Net exposed wall	3c	1020	15	15,300
Glass surface (windows and doors)	1a	112	102	11,420
	1c	19	68	1,290
Cold ceiling	19a	870	30	26,100
Window infiltration	28b	69	38	2,650
Door infiltration	32a	48	180	9,000
Heat loss without basement				65,760
Basement wall above grade	13a	112	68	7,600
Basement wall below grade	13b	830	5	4,150
Basement windows	1a	16	102	1,630
Basement floor	27a	760	4	3,040
Total heat loss				82,180

House is insulated with one-half inch blanket insulation and building papaer, has cedar shake siding, full basement (7 ft. below grade, 1 ft. above), no floor on attic, oil heat.

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* For explanation of symbols please see next page.

APPENDIX TO TABLE IV

The preceding heat loss calculation was made according to tables provided by the National Warm Air Heating & Air Conditioning Association in Cleveland, Ohio.[1]

The meaning of the symbols in column 2 is as follows:

3c	Exposed walls with ½" flexible insulation between studs in contact with sheathing
1a	Single glass windows
1c	Storm sash put up and taken down annually, will probably be loose fitting
19a	Lath and plaster ceiling, no floor above
28b	Wood sash windows, average fit, weather-stripped or equipped with storm windows
32a	Well fitted door, not weatherstripped
13a	Concrete wall, above grade
13b	8" or 12" concrete wall, below grade
27a	Concrete floors in basement, in contact with ground.[2]

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[1] Service Manual for Continuous Air Circulation Technicians; Manual 6. Cleveland, Ohio: National Warm Air Heating and Air Conditioning Association, 1947. Pp. 1-12.

[2] S. Konzo and G. A. Voorhees, editors, Measuring Heat Losses; Manual 3. Cleveland, Ohio: National Warm Air Heating and Air Conditioning Association, 1950. Pp. 22-27.

TABLE V

COMPARATIVE COSTS TO PRODUCE 1,000 POUNDS OF STEAM AT THE MISSOULA HEATING PLANT OF THE MONTANA POWER COMPANY[1]

Fuel	Price	
Hog fuel	$.44	
Shavings	$.50	
Oil	$.81	
Coal	$.90	(at $9.26 per ton of Roundup coal, wholesale price)
Electricity	$.99	

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[1] Kindness of Earl Holzknecht, Engineer.

Fig. 4 - The Prestolog Machine

Fig. 5 - Sawdust Storage Pile and Truck Loading Bin