

CARBONIZATION OF DOUGLAS-FIR MILL WASTE

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INTRODUCTION

The utilization of sawmill waste in the Douglas-fir region has been a problem with which the lumberman has had to meet since the organization of the first mill. Until 1915 the sawmills in the Douglas-fir region sent practically all waste material contained in logs, which was not converted into rough green lumber, to their burners. This waste accumulated so rapidly and in such great quantities that it was necessary to dispose of it in the fastest and most inexpensive method obtainable. For this reason each sawmill was equipped with large burners which required a high initial outlay of capital and an overburdening maintenance cost. This method was by no means inexpensive but did acquire the speed of disposal needed. One of the most famous and favorite boasts of mill operators of this period was, "My burner has been running continuously for thirty years."¹

Since the year of 1915 the lumberman has become more and more conscientious of his waste problem. During this time the economic conditions of the Pacific Northwest changed somewhat and the operators found a desirable market for slabwood, planer ends, and hogged fuel; but this was not enough so trade associations and the government, both federal and state, appropriated money for the purpose of research in the field of waste utilization. These programs have continued and the results obtained should be given considerable credit, but it seems as though this region was not ready for some of the products obtained, chiefly due to economic conditions and costs involved.

The degree to which the mill refuse is used at present varies widely in a given locality, even at different plants owned by the same operator, some

utilizing the entire volume while others send all in excess of personal needs to the incinerator. To the layman this does not seem unusual or out of the ordinary, until it is put into facts and figures which he can understand and hence obtain a clear picture of an important economic problem.

To get that picture, let us first see what goes into making up the total amount of waste material from a Douglas-fir mill. For every thousand board feet of logs (log scale) manufactured, 89.90 cubic feet, or about 48% of the total volume, occurs as waste. Sawdust and shavings from the headsaw and planing mill make up the largest item (37.96 cu. ft. or 42.2%) followed by bark from the headsaw (20.81 cu. ft. or 23.15%), small slab and edgings from the edger and horizontal resaw (14.91 cu. ft. or 16.59%), mill trim and planer ends from cut-off saws used in remanufacturing (9.37 cu. ft. or 10.42%), and large clear slabs and edgings from the headsaw (6.85 cu. ft. or 7.62%). From this amount 19.89 cubic feet, or about 20%, of the total waste was used as² fuel for the mill.

When one stops to think that there is an annual accumulation of sawmill¹ waste which totals 619,000,000 cubic feet, it is almost beyond his ability to comprehend a volume so large; yet if this material were stacked on a square acre of ground, it would make a solid pile towering 2.7 miles into¹ the air. As a further comparison it might be noted that if this waste were suitable, and could be converted into pulpwood, it would make about 6,900,000¹ cords, an amount almost equivalent to the yearly consumption of pulpwood by the entire pulp and paper industry of the United States. To the lumberman this figure has long been a liability on his books, but yet because of the narrow margin of profit in lumber manufacturing he has had to encourage mass

production with high-speed machinery and a minimum of man power which has also encouraged waste.

With the outbreak of World War II our country found itself lacking in vitally needed defense materials. In the Pacific Northwest this was particularly true when it came to the reduction of iron ore. They found that the coke and briquets which were being manufactured were not in sufficient quantity to meet the demand. With the large amount of waste from sawmills on hand, it seems highly probable that this refuse can be changed from a waste product to a saleable commodity. It has been demonstrated that very good charcoal briquets can be made from sawdust. A number of companies have formed at various times, for the purpose of manufacturing these products, but none of them have developed into large operations because of the lack of markets at the time of their origin. In addition to recovering the charcoal, it would also be an easy matter to catch the gases, oils and acids thrown off during the process of manufacturing and hence reduce the cost of production.

From these facts it can be seen that if profitable carbonization of the waste could be undertaken, it would develop a new industry in the Pacific Northwest. It would likewise increase the lumbermans profits in untold amounts, and also aid in the war effort by relieving the shortage of a vitally needed war material.

ABSTRACT OF HISTORY OF WOOD DISTILLATION

Destructive distillation of wood might be said to be as old as the world itself. It has been found true that the ancient races made charcoal and also devised crude methods for recovering distillation products which resulted from

the process of carbonization. In the works of ancient writers can be found proof that the Egyptians recovered fluid wood-tar and pyroligneous acid which they used for embalming their dead.

The process of wood carbonization was originally carried on in open-air pits which were later followed by heaps or "meilers". All processes of this nature were designated primarily for the production of charcoal, little thought being given to the other distillate products. This remained true for a long period of time, but by the end of the eighteenth century both metallurgists and chemists were busily engaged with the problem of developing the processes to the highest state of efficiency. Records of the workings of these metallurgists and chemists were recorded in several countries and can still be found in most libraries today.

Methods of using wood-tar and other distillate products had been discovered long before the beginning of the nineteenth century but it was not until this period that technical applications were found for the more highly volatile distillation products. The operation of charcoal-burning processes in these early days was crude and it is little wonder that very little attention was paid to the recovery of these volatile products, which in former days were worthless. In addition to this, the production of charcoal was so widely used in metallurgy and was also looked upon as essential for the manufacturing of iron, that sufficient profits were obtained from the charcoal alone.

However, during this period the investigations of the chemist Lowitz and the introduction of column-stills, enabled the industry to produce

chemically pure acetic acid from pyroligneous acid at a reasonable cost. This product tested to such a high degree of purity that no objection could be raised against it, even for edible purposes. For this acetic acid a ready market was found in the textile-printing and cotton-dyeing industries. Along with the acetic acid, acetone and wood-spirit also came into popular demand.

The charcoal pits were replaced by heaps or "meilers", which permitted the recovery of certain amounts of pyroligneous acid and tar; these in turn faded from the picture to be succeeded by brickwork kilns. The process was then changed from kilns to ovens and the system of what may be termed "movable arrangements"³ for carbonizing wood was abandoned. The introduction of ovens established the principle of stationary carbonization plant to which it was necessary to convey the wood. These were the most radical changes in the wood distillation industry of this period.

At the beginning of the twentieth century, efforts were being made along the entire line of the wood-distillation industry to improve the methods of operation. Greater attention has been paid to the possibilities of utilizing the heat which is lost during the process of carbonization; gases which leave the retort fires are being used to preheat the wood; and some of the waste heat is used to preheat the non-condensable gases from the retort condensers before combustion. It was also proved that by using larger charges, equal or superior yields could be obtained, thereby reducing costs of fuel, wages and maintenance. This tendency of abandoning the small carbonizing apparatus and returning to that of larger capacity represents the first advance by the industry in this century.

At the present time a continuous process is in operation for the carbonization of sawdust and shavings. With this method the raw material enters one end of the kiln and merges from the other in the form of charcoal. The description and operation of this process will be discussed under the description of equipment.

MOISTURE CONTENT OF WASTE

The variables which are necessarily encountered in the carbonization of mill waste are as many as the homogeneous characteristics of the wood itself. It has been found by experimentation that temperature, moisture content, density, and specie of the waste all have a direct effect on the yield, both as to quantity and quality of carbonized and distilled products. Each variable deserves special attention and will therefore be discussed separately. Density and specie will not be discussed however, since we are concerned only with Douglas-fir.

The moisture content of the waste wood will, of course, have a direct effect upon the amount of time and heat which will be necessary for the carbonization to take place. For an example, let us consider what amount of water will be found in each cubic foot of mill waste. Using the average acceptable standard of 38% moisture content for Douglas-fir, and a weight of 3400#/1000 bd. ft. it was found that for every cubic foot of waste it would necessitate the evaporation of 12.11 pounds of water. By further calculations it was found that it would require 1142 BTU/hour for evaporation of each pound of water. This would mean a total of 13,829 BTU/hour.

Since it would require a great initial and handling cost, it would not be practical to dry this waste by mechanical methods. (This is an exception to the continuous carbonization process, whereby the material is dried as it moves through the retort.) At the present time there are various opinions on the practicability of air drying the waste until it has lost the greater percentage of its moisture. To accomplish this it would require great storage space, more invested capital and higher labor charges.

However, on the other hand, some experts claim that by storing the waste until it loses the greater percentage of its moisture content, (this will depend on the climatic location of the mill) the manufacturing costs can be reduced considerably. These opinions are based on the reasoning that lower temperature during the first period and less time in the retort will be required. This, however, will vary with the different mills according to their facilities and type of equipment.

TEMPERATURE

Since wood consists primarily of cellulose, lignin, and water, practically the only chemical elements it contains are hydrogen, carbon and oxygen. Therefore it can be easily understood that the temperature used during the carbonization period will have a varying effect on the quantity and quality of the products obtained.

If we were to place a piece of wood in a closed vessel which was equipped with a vapor outlet pipe, we would observe that as heat was applied the water contained in the wood would escape first. Upon increasing the amount of heat, the appearance of the wood will change to a brown color and acetic acid will be found in the aqueous distillate. This changing of color and the forming of acetic acid in the distillate indicates that the application of heat is causing intensive decomposition of cellulose and lignin molecules.

During this period of heat application the cellulose produces acetic acid but no methyl alcohol, whereas the encrusting substance, lignin, produces both methyl alcohol and acetic acid. These yields are, however, largely dependent on the proportions in which the cellulose and lignin make up the wood composition.

A further insight into this complicated process has been determined by Edward Joun,⁶ who made a survey (see table) of the gases given off at different temperatures during the carbonization period. His system of tabulation shows that up to and including 280° C. nothing but water vapor accompanied by carbon gas, is given off by the wood. From 280° C. to 380° C. oxygen decreases in quantity and hydrogen replaces it. Above this

temperature the aqueous distillate diminishes in quantity, the gases become dryer, and the tar becomes more numerous and viscous. During the initial period, that is, up to 280° C, it is necessary to supply heat. However, after this period has been passed, carbonization of the wood proceeds without supplying heat. In other words, an edotheomic reaction sets in.

From what has already been stated, it is obvious that maintaining of definite temperature during the process, that is the method of heating the kiln, will have a definite action on the yield of products and course of the process. Hence by controlling the temperatures it is possible to regulate the yields one way or another. By using slower carbonization and lower temperatures it is possible to lessen the production of gas and increase production of acetic acid and charcoal. This is what we will strive to obtain in this case.

ANALYSIS AND DESCRIPTION OF PRODUCTS OF DISTILLATION

During the process of destructive distillation of wood there are obtained several predominant products. The ones of chief importance or those with which we are mainly concerned are: wood gas, pyroligneous acid, wood-tar and its components, and in this case our main product, charcoal.

The gaseous mixture produced during normal operation of the destructive distillation process has the following chemical composition. (Percent by volume).

Carbon dioxide	59.0
Carbon monoxide	33.0
Methane	3.5
Hydrogen	3.0
Pyroligneous acid vapors	1.5

At first the evolution rate of the various components is not uniform, in fact the only gas noticeable is the air contained in the wood. As the process continues a gas consisting almost entirely of a mixture of carbon monoxide and dioxide is found. These are barely inflammable. When the wood has given up all its moisture, the flow of gas then becomes vigorous. During this same period the acetic acid content of the pyroligneous acid rises and the gas becomes highly inflammable due to the abundance of hydrocarbons. Therefore the following points should be kept in mind:

1. Operate the kiln at the lowest possible temperature to reduce the quantity of gas.
2. Use condensers capable of cooling the gas before its entrance

to water.

3. Excess air entrance into kiln should be kept at a minimum in order to reduce amount of gas and losses due to oxidation.

The pyroligneous acid obtained during the destructive distillation period is a brown liquid with a definite characteristic odor. This product is found mixed in with the tar and can be separated by a settling process since the tar has a higher specific gravity.

The principal component of the pyroligneous acid is water, obtained chiefly during the period of the decomposition of the wood. This is usually found in amounts of 80-90% according to the moisture content of the wood. The remaining 10-20% consists of numerous organic compounds, some of the more common ones being acetic acid, butyric acid, methyl alcohol, acetone, methyl acetate and ammonia.

The tar, to which we refer, is a group of chemical products which possess similar characteristics both in appearance and chemical compositions. It is very similar to coal-tar except that it contains only small quantities of ammonia derivatives. When this tar mixture is allowed to stand or is run through a tar-settling box, it will appear below the surface as a brownish black, more or less viscous, liquid.

The distillation of this tar down to pitch is no longer carried out. The tar itself finds a ready market and is highly valued as a paint because of the undecomposed rosin which has been melted out of the wood.

The residue which is formed from the destructive distillation of wood is commonly called charcoal. However, in our particular case it is the chief product in which we are interested, the remaining substances

being the by-products. Charcoal can best be described as a black, glistening substance with a distinct bluish tinge, often resembling graphite in its powdered form.

When the charcoal is taken from the retort it will be found to be at a temperature of about 350° C. It is at this point that caution must be taken to see that extra air does not enter and cause oxidation to take place. After being cooled in the absence of air the charcoal will increase in weight, due to the absorption of gas and water vapor. This condition changes, however, and equilibrium is again reached in about three weeks.

The charcoal produced is usually rich in carbon according to the temperature at which the process is stopped. This high carbon content found in the charcoal is highly desirable, especially for all metallurgical industries. Two methods which are used for obtaining a high carbon content are accomplished by slowly carbonizing or cooling the wood within the carbonizing apparatus itself.

EQUIPMENT AND ITS OPERATION

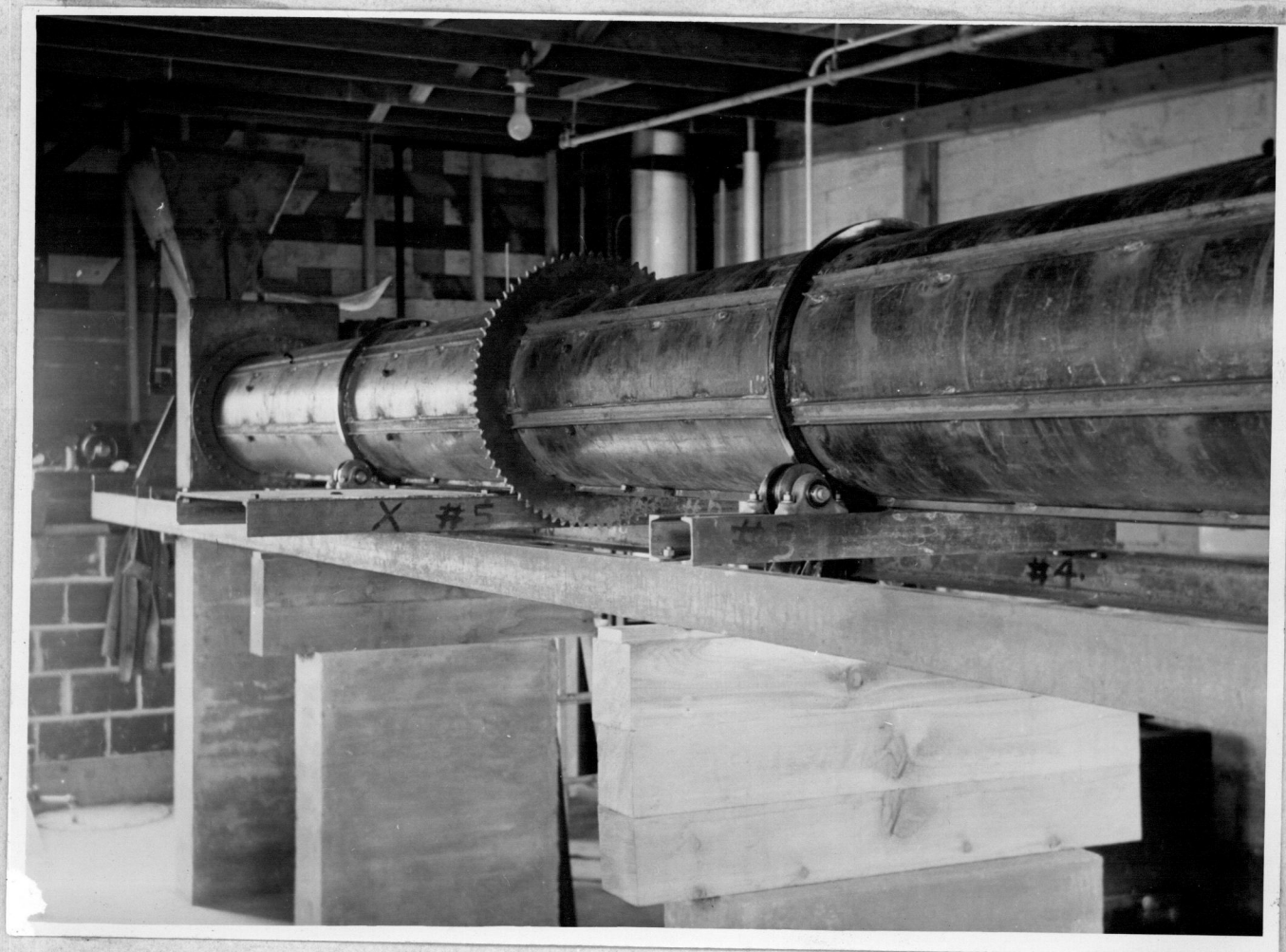
In order to make the carbonization of Douglas-fir mill waste a sound economic venture it will be necessary to install equipment which requires a small initial investment, a minimum amount of manpower, and a rapid carbonization process. All three of these conditions we hope will be fulfilled by an experiment which is now being carried on by the Oregon State College Chemical Engineering and Wood Products Department. This continuous process is not a new venture in the field as a whole, but is one which at the present time seems to be the most practical to all mill operations in the Pacific Northwest and hence will be used as a pilot plant. The following descriptions are meant to give a general picture of the equipment and process involved.

The hog used for the breaking down of slabs and other waste into sawdust for carbonization should be sufficiently large to take care of all the mill's waste during the working period. This is a problem which will have to be decided by each individual mill according to the number of board feet cut per eight-hour shift.

The kiln is of the rotary type and is constructed of black iron pipe 5/8" thick, twenty feet long and eighteen inches in diameter. It is supported by two steel tires or rings which revolve in thrust bearings attached to a channel iron frame that runs the entire length of the kiln. Attached to each end of the kiln are sheet iron gas and coke boxes. These boxes are made to fit as tightly as possible by means of a ring and packing gland assembly fitted with graphite bushings. These boxes are, as their names imply, boxes into which the boke and gas are discharged. The power

for rotation is supplied by an electric motor and chain drive which have been geared down so that the kiln will revolve about eight to ten times per minute.

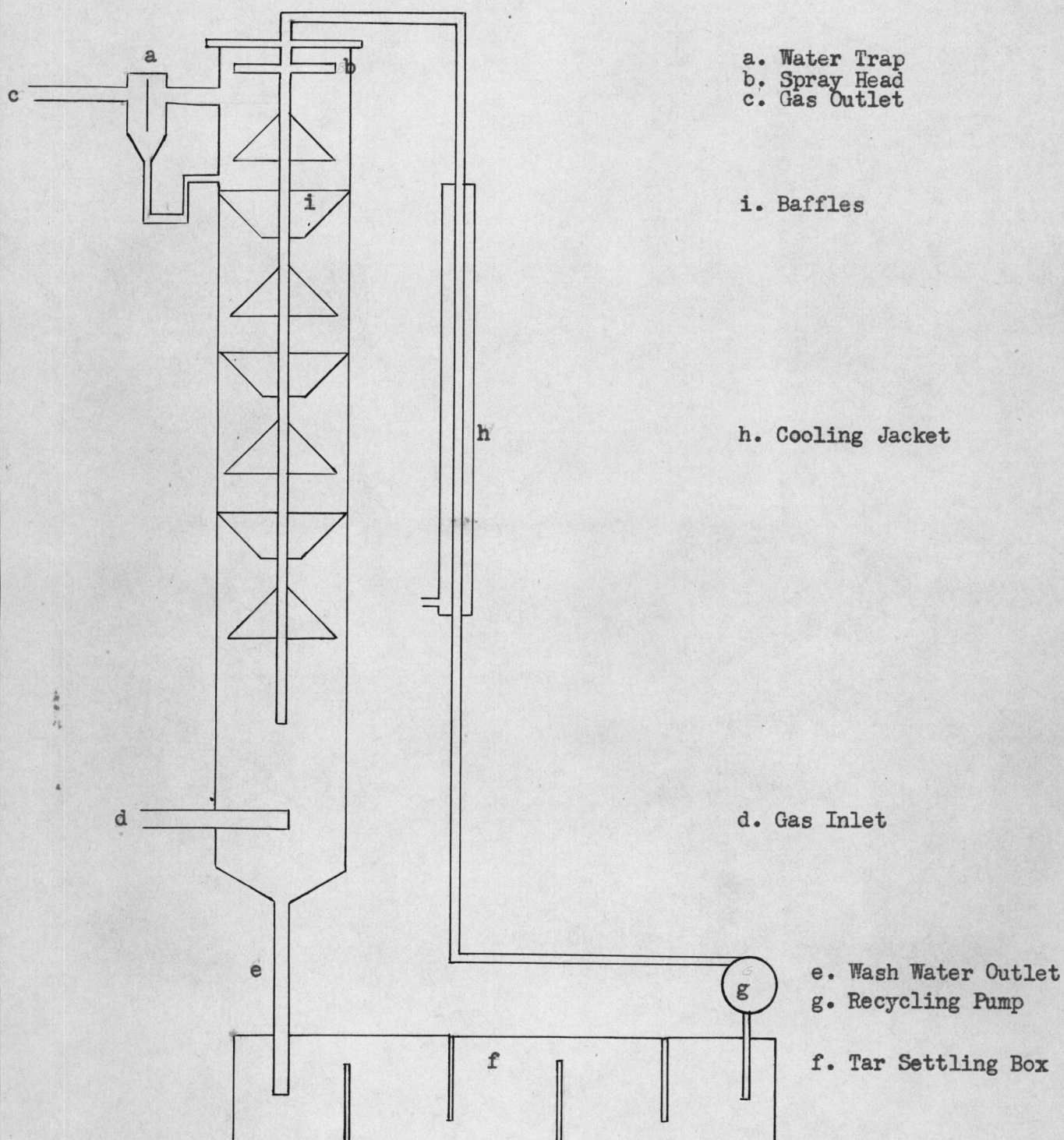
PICTURE OF KILN
(Rotary Retort)



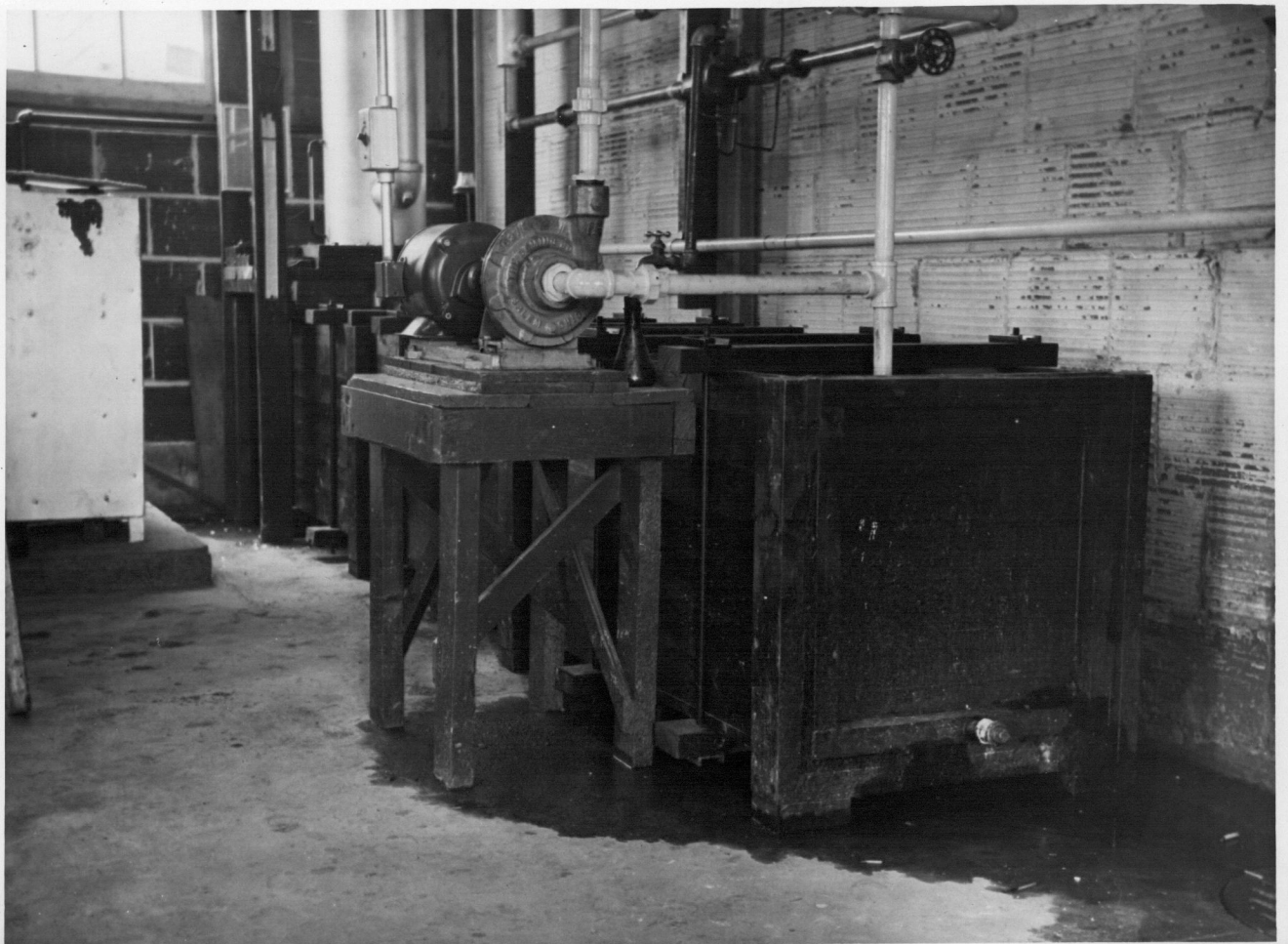
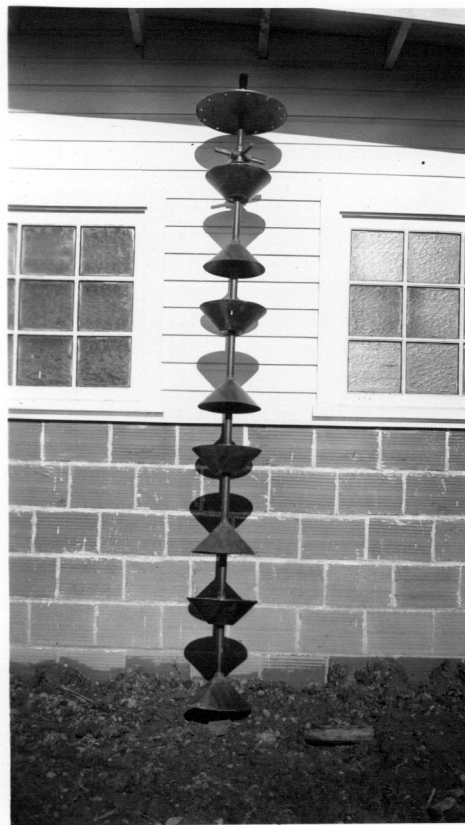
A link belt conveyor from the storage hopper passes through the gas box and drops the fuel into the end of the retort. This material is passed through the kiln by its slope and rotation. The slope of the kiln is regulated by a jack at the outlet end. Inside the retort are angle iron flights that agitate the fuel, causing pyrolysis to take place more readily. The last eight feet of the kiln are without flights to avoid undue oxidation of the charcoal. The charcoal is discharged from the low end of the kiln into the coke box, and removed by a screw conveyor. Both the link belt and the screw conveyor are supposed to be gas tight to prevent the loss of wood gas or the entrance of air.

Going back now to the entrance end of the kiln, the hot gases from the pyrolysis of the wood pass out over the entering fuel and are taken from the gas box to the scrubbing tower through a three-inch pipe. The scrubbing tower is made of twelve-inch diameter iron pipe, ten feet long, and has an interior design which is rather unconventional. All of the wash water used in scrubbing this gas is admitted through a cross-shaped spray bead in the top of the tower. A series of baffles are arranged alternately to give a suitable washing surface. One of the features of this scrubber is that by removing the cap on the top, the entire unit may be removed and cleaned.

SCRUBBING TOWER AND TAR BOX



PICTURE OF BAFFLES AND TAR BOX



The wash water, which flows counter current to the flue gases, is removed from the bottom of the tower and passes into a wooden trough, ten feet long, two feet wide and deep, where a baffle arrangement is supposed to cause the more viscous materials to settle out. It is the plan to recirculate the wash water after the tars have settled out. A portion of the return pipe is jacketed and the recirculated water will be heated or cooled according to which is required.

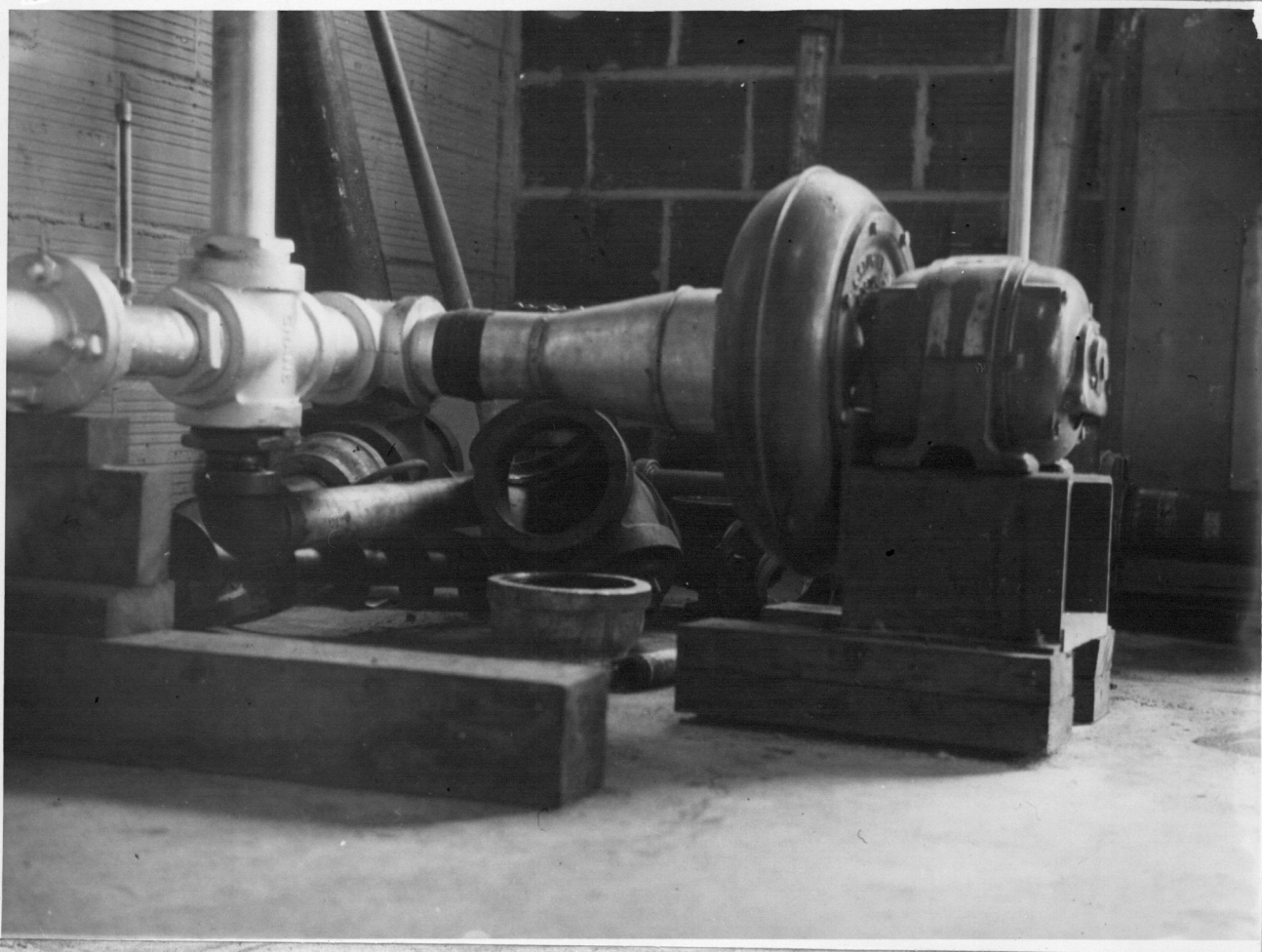
As the gas leaves the top of the scrubber, it passes through a water trap, then through a barrel of wood chips and shavings which serves to further filter it and condense any tars. It is then metered through an orifice and boosted to quite a high velocity by a fan. At this point the gas line connects with the charcoal conveyor from the retort. The charcoal drops into the gas stream and is blown to a cyclone where the charcoal settles out and the gas is exhausted to the air or taken back to the kiln to be burned. To obtain some means of control over the movement of the charcoal, it is planned to recycle some of the gas from the cyclone back into the main line and pass it through the fan again.

PICTURE OF DRY SCRUBBER



PICTURE OF BLOWER

(For Wood Gas)



This method of moving the charcoal has another function besides the movement alone. The charcoal as it comes from the kiln is at a high temperature and will take fire if exposed to air. The gas stream both cools and conditions it so that this difficulty is avoided.

CONCLUSION

The products which will be returned for each one hundred pounds of sawdust sent to the retort will be somewhat as follows: Light distillate 53.6 pounds; tar 13.4 pounds; charcoal 33.5 pounds; and gases 33.5 pounds. These are figures which have been calculated for this particular kiln and they check quite accurately with those of other investigators.

Since the carbonization plant here at the college is still unfinished and actual costs have not yet been determined, it will be some time before we will learn whether or not it will be economically practical to install similar plants at mills to take care of the waste problem. However, this plant should be in operation by June 1, 1943 at which time we will be able to check on the calculated yields and the costs per one hundred pounds of sawdust.

If the metallurgical industries are going to be a permanent industry in the Columbia River Basin, there is no apparent reason why this wood carbonization industry should not flourish. This, however, will depend upon operating costs and the selling price of the product. The calculated yield of 1/3 charcoal per 100 pounds of waste is extremely favorable. The further distillation of the light distillate and gases is something which will have to be worked out later. At the present time no plans for their use have been made other than those mentioned in the operation of the plant.

There will undoubtedly be numerous changes in the operation of the plant, yields, costs, etc., all of which will be obtainable upon the completion of the pilot plant.

BIBLIOGRAPHY

1. Present Utilization of Sawmill Waste in Douglas-fir Region
by Allen Hodgson
2. An Inventory of Sawmill Waste in Oregon
by Glenn Voorhies
3. The Technology of Wood Distillation
by Klar and Rule
4. Utilization of Sawmill Waste and Sawdust for Fuel
by J. H. Jenkins and F. W. Guernsey
5. Sawmill Waste and its Utilization in British Columbia
by J. H. Jenkins
6. Journal of the Society of Chemical Industry
7. Manufacturing of Wood Briquets
Timberman p. 5-9; 18, 19 July 1936
8. Utilization of Sawmill Waste in Pacific Northwest
by Pieper
9. Chemical Utilization of Waste Wood
Eng. Expr. Station Bulletin,
University of Washington
by Benson