Burning West Coast Hemlock Hogged Fuel in Boiler Furnaces

By George H. Atherton

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Forest Products Research
FOREST RESEARCH LABORATORY
OREGON STATE UNIVERSITY
Corvallis
FOREST RESEARCH LABORATORY

The Forest Research Laboratory is part of the Forest Research Division of the Agricultural Experiment Station, Oregon State University. The industry-supported program of the Laboratory is aimed at improving and expanding values from timberlands of the State.

A team of forest scientists is investigating problems in forestry research of growing and protecting the crop, while wood scientists engaged in forest products research endeavor to make the most of the timber produced.

The current report stems from studies of forest products.

Purpose

Fully utilize the resource by:

- developing more by-products from mill and logging residues to use the material burned or left in the woods.
- expanding markets for forest products through advanced treatments, improved drying, and new designs.
- directing the prospective user's attention to available wood and bark supplies, and to species as yet not fully utilized.
- creating new jobs and additional dollar returns by suggesting an increased variety of salable products. New products and growing values can offset rising costs.

Further the interests of forestry and forest products industries within the State.

Program

Identify and develop uses for chemicals in wood and bark to provide markets for residues.

Improve pulping of residue materials.

Develop manufacturing techniques to improve products of wood industries.

Extend service life of wood products by improved preserving methods.

Develop and improve methods of seasoning wood to raise quality of wood products.

Create new uses and products for wood.

Evaluate mechanical properties of wood and wood-based materials and structures to increase and improve use of wood.
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SUMMARY

Steam production decreases as moisture content of fuel increases, because:

1. Additional heat is consumed in evaporating moisture from the fuel.

2. Increased volume of gas in the furnace (steam from wet wood) may cause a decrease in rate at which air enters the furnace.

3. Moisture from fuel in the form of steam may blanket the fuel and interfere with adequate mixing of air and fuel.

These three factors may combine to cause slow and incomplete burning of fuel. Under these conditions, radiating surfaces cool, flame temperature lowers, and steam production decreases.

Steam-production capacity of any boiler fired with hogged fuel will decrease as moisture content of the fuel increases. Decrease in steam production may be serious if boilers and furnaces have not been designed for excessively wet fuels. Moreover, boilers designed for wet fuels will maintain stable fire with fuel at moisture content too high to burn reliably in boilers designed for fairly dry fuels.

Over-all efficiency of boiler, grate, and furnace decreases with increasing moisture content of fuel mainly because of heat required to evaporate the moisture.

Heating values of dry West Coast hemlock and Douglas fir are not greatly different, but hemlock usually contains excessive moisture. Unit volumes of hogged fuel probably contain about the same weight of wood for the two species, because the excessive moisture serves to compact the hemlock. The theoretically lower availability of heat from West Coast hemlock as compared to Douglas fir results mainly from consumption of heat in evaporating this excessive moisture from the hemlock.
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INTRODUCTION

Information presented was assembled to provide non-technical answers to numerous questions received on burning characteristics of West Coast hemlock hogged fuel.

Hogged fuel is made from such mill residues as sawdust, trim, edgings, slabs, shavings, and veneer. Large pieces are passed through a "hog", where revolving knives cut them into irregular chips and splinters, which range occasionally to about a foot in length.

Although some dried materials may be incorporated, most hogged fuel is high in moisture content. This high content of moisture can cause difficulty during burning.

HEATING VALUE OF HOGGED FUEL

Combustion of hogged fuel takes place in several overlapping stages (7)*. First, heat is absorbed to raise the temperature of the fuel and moisture and to evaporate the moisture. Second, gases amounting to about 80 per cent of the weight of oven-dry wood are distilled. These gases ignite at about 1000 degrees Fahrenheit. The third stage is reached when the remaining carbon glows and burns on contact with air. All of these reactions may be occurring simultaneously within a piece of wood.

Variation in heating value** of different species of wood is accounted for mainly by content of resin (pitch) (2). For example, Douglas fir wood has slightly greater heating value than West Coast hemlock. Heating values of bark from both Douglas fir and West Coast hemlock are

*Numbers in parentheses refer to similarly numbered references.
** Heating value as considered in this report is defined technically as higher heat value (HHV), which is determined experimentally by measuring heat evolved when a quantity of fuel is burned in a calorimeter and the products of combustion are cooled to the initial temperature at time of ignition.
higher than those of the respective woods. Consequently, heating value of hogged fuel varies with quantity of bark present. Heating value of wood also varies from heartwood to sapwood, but this variation is minor and was neglected in this report.

Dry bark of Douglas fir and West Coast hemlock has heating value of 10,100 Btu (British thermal units) to a pound (5, 6) (Figure 1). West Coast hemlock wood (no bark) has heating value of 8,500 Btu a pound, dry weight, and Douglas fir wood produces 8,800 Btu a pound, dry weight (6). Table 1 may be helpful in estimating average quantity of bark in hogged fuel from sawmills.

For those unfamiliar with sawmill practice in Oregon, explanation of Table 1 may be necessary. Some sawmills sell pulp chips that are cut from trim, slabs, and edgings. Pulp chips must be free of bark. If a sawmill does not have a log barker, not all residues are free of bark, and common practice is to hand-select bark-free wood for chipping. If a mill has a log barker, nearly all slabs, edgings, and trim may be chipped, since the material is bark-free. Therefore, use of bark-free wood for chips results in high proportion of bark in hogged fuel made from the remaining residues.

Heating values as determined from Figure 1 must be reduced to practical values by accounting for moisture in fuel. Douglas fir hogged
Table 1. Estimated Quantity of Bark and Heat in a Pound of Dry Hogged Fuel From Various Sources*.

<table>
<thead>
<tr>
<th>Barker</th>
<th>Chips sold</th>
<th>Shavings included</th>
<th>Bark in fuel</th>
<th>Heat value**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>%</td>
<td>Btu</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Douglas fir, young growth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>6</td>
<td>8.9x10^3</td>
</tr>
<tr>
<td><strong>Douglas fir, old growth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>24</td>
<td>9.1</td>
</tr>
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<td>No</td>
<td>No</td>
<td>No</td>
<td>28</td>
<td>9.2</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>30</td>
<td>9.2</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>37</td>
<td>9.3</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>36</td>
<td>9.3</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>48</td>
<td>9.4</td>
</tr>
<tr>
<td><strong>West Coast hemlock, diam. 24-36 in.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>18</td>
<td>8.8</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>24</td>
<td>8.9</td>
</tr>
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<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>24</td>
<td>8.9</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>31</td>
<td>9.0</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>30</td>
<td>9.0</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>43</td>
<td>9.2</td>
</tr>
</tbody>
</table>

*Data in this table were calculated from several references (1, 3, 5, 6, 9, 10) and from unpublished data at Forest Research Laboratory.

**Data in this column are rounded to 2 significant figures, hence all values should be multiplied by about 10^3.

fuel averages about 45 per cent moisture* as cut at the sawmill. West Coast hemlock averages about 57 per cent moisture (7, 10). If hogged

*All values for moisture content in this report are computed on the wet basis; i.e., one pound of wet fuel at 45 per cent moisture content contains 0.45 pound of water and 0.55 pound of moisture-free wood. Average value is from unpublished data, Forest Research Laboratory.
fuel consists entirely of sapwood, it may contain as much as 55 per cent (Douglas fir) or 65 per cent (West Coast hemlock) moisture (10). Pro-
longed storage in water of logs and open storage of hogged fuel also may result in excessive moisture in hogged fuel.

Because hogged fuel is sold by volume, where the standard vol-
ume is a "unit" (equal to 200 cubic feet), heating values may be com-
pared conveniently on this basis. This comparison introduces another variable. As moisture content of hogged fuel increases, more wood and bark can be packed into the same volume (200 cubic feet); that is, if all moisture were evaporated from hogged fuel, oven-dry weight of wood and bark would be greater for the fuel that had the higher initial mois-
ture content (Figure 2). Data for Douglas fir in Figure 2 were taken
from records of a large heating plant (1) and the curve for West Coast hemlock was added by correcting data for Douglas fir by the ratio of specific gravities of the two species (10). All curves were extrapolated below 30 per cent and above 50 per cent moisture content.

Boiler operators often find that production of steam (quantity of
steam produced in a given length of time, usually expressed in pounds
an hour) is reduced when firing with West Coast hemlock. Because of
this, heating values for average moisture contents of Douglas fir at 45
per cent and West Coast hemlock at 57 per cent are compared. A cal-
culation for West Coast hemlock at 65 per cent moisture content also is
included, as this is the approximate maximum for this fuel.

As shown in Table 1, 24 per cent seems a reasonable choice of
proportion of bark in fuel for both species. The heating value of a pound

![Figure 2. Influence of moisture content on weight of a unit (200 cubic feet) of hogged fuel.](image-url)
of dry hemlock fuel is about 8,900 Btu when it contains 24 per cent bark (Figure 1). At 57 per cent moisture content, a unit contains about 2,100 pounds of dry wood and 2,800 pounds of water (Figure 2). That weight of dry hemlock theoretically can provide:

\[ 2,100 \text{ lb} \times 8,900 \text{ Btu} = 18,700,000 \text{ Btu in a unit}, \]

But 2,800 pounds of water requires for evaporation

\[ 2,800 \text{ lb} \times (1335-28) \times Btu = 3,700,000 \text{ Btu for a unit}, \]

if fuel enters the furnace at 60 F and evaporated moisture leaves the stack at 600 F. This heat is lost and is not available for making steam. Heat available now becomes:

\[ 18,700,000 - 3,700,000 = 15,000,000 \text{ Btu from a unit of wet fuel}. \]

Following this same line of reasoning for Douglas fir, a comparison can be made between the 2 species, as in Table 2. Note that at 57 and 65 per cent moisture content, theoretical heat from West Coast hemlock is 85 and 77 per cent of that from Douglas fir. These percentages would be less, but for the compacting effect of the additional moisture. At 65 per cent moisture content, hemlock contains 3,900 pounds of water as compared to 1,800 pounds for Douglas fir at 45 per cent moisture content. Weight of wood in a unit of fuel is nearly equal for the 2 species at 2,200 pounds for Douglas fir and 2,100 pounds for West Coast hemlock. The lower heat theoretically available from dry hemlock as compared to Douglas fir in Table 2 is reduced further by high moisture content of the fuel.

Effect of moisture content on rate at which fuel burns in a furnace may be more important than lower theoretical availability of heat from fuel. For example, data in Table 2 indicate that 77 per cent as much steam could be produced from hemlock at 65 per cent moisture content as could be produced from Douglas fir at 45 per cent moisture content. In practice, a fire may be difficult to maintain in the furnace with fuel at 65 per cent moisture content. Therefore, the effect of moisture content on burning rate of fuel in a furnace should be considered.

\* (1335-28) = 1307 Btu is the heat necessary to raise temperature of each pound of water in the fuel from 60 F to 600 F.
Table 2. Estimated Heat Available from Douglas Fir and West Coast Hemlock Hogged Fuel Containing 24 Per Cent Bark by Weight.

<table>
<thead>
<tr>
<th>Item</th>
<th>Douglas fir</th>
<th>West Coast hemlock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content, %</td>
<td>45</td>
<td>57</td>
</tr>
<tr>
<td>Heat of dry fuel, Btu/lb</td>
<td>9,100</td>
<td>8,900</td>
</tr>
<tr>
<td>Dry fuel in unit, lb</td>
<td>2,200</td>
<td>2,100</td>
</tr>
<tr>
<td>Total heat, dry fuel, Btu/unit</td>
<td>20,000,000</td>
<td>18,700,000</td>
</tr>
<tr>
<td>Water in unit, lb</td>
<td>1,800</td>
<td>2,800</td>
</tr>
<tr>
<td>Heat loss to water, Btu/unit</td>
<td>2,350,000</td>
<td>3,700,000</td>
</tr>
<tr>
<td>Theoretically available heat from wet fuel, Btu/unit</td>
<td>17,700,000</td>
<td>15,000,000</td>
</tr>
<tr>
<td>Theoretically available heat, per cent of Douglas fir</td>
<td>100</td>
<td>85</td>
</tr>
</tbody>
</table>

* Estimated by further extrapolation of Figure 2.
HOGGED FUEL FURNACES

A limited discussion of furnace design is presented to aid in understanding the effect of moisture content of fuel on production of steam.

The dutch-oven and the spreader-stoker furnaces are the 2 types most used in Oregon for hogged fuel. The main difference between these furnaces is that in the dutch-oven, the fuel forms a conical pile that burns on the surface, but with a spreader-stoker, fuel is burned partially in suspension and partly from a thin layer on the grates.

As fuel heats and ignites in a dutch-oven furnace, hot gases from the surface of the pile are swept over a bridgewall and downward into a secondary combustion chamber by a drop-nose arch (Figure 3). The gases then make several passes over and along the boiler tubes and finally are discharged to the stack. Various auxiliaries, such as economizers and preheaters, may be added to the boiler to remove heat from gases before they are discharged to the stack.

When fuel burns in the dutch-oven furnace, heat is radiated to the drop-nose arch and to the furnace walls. Firing rate (and therefore steam production) is regulated by the operator to an extent by regulating feeding of fuel to cause the pile of fuel to build up close to, or shrink away from, the arch. When the pile is close to the arch (within limits), the fire is intense because heat radiates intensely from the arch back to the pile. When rate of firing is changed, flow of air through the furnace also is changed to maintain efficient combustion.

A spreader-stoker furnace for wood fuel is shown in Figure 4. The spreader is a paddle wheel that throws fuel onto the grates in the

![Figure 3. Dutch-oven furnace.](image-url)
manner indicated. Rather than traveling as shown in Figure 4, grates may be dump-type or completely stationary. In contrast to the dutch-oven furnace, where from 80 to 90 per cent of the air for combustion is supplied over the fire (7), from 75 to 95 per cent of the air is supplied through the grates in a spreader-stoker furnace (8). Firing rate in a spreader-stoker furnace is controlled by regulating the rate at which air and fuel are supplied to the furnace.

Volatile matter (gases) make up about 80 per cent by weight of the combustibles in hogged fuel. The large volume of these gases, plus the volume of evaporated moisture, requires that hogged-fuel furnaces have large capacity, to insure completeness of combustion. In the dutch-oven furnace (Figure 3) the furnace is divided into 2 chambers. Heating the fuel pile, evaporating moisture, and gasifying volatile matter take place in the primary chamber, and combustion is completed in the secondary chamber beyond the bridgewall. This large volume is provided vertically in the spreader-stoker furnace of Figure 4. With the spreader-stoker, large volume also serves to allow completion of combustion of suspended fuel particles within the furnace (8).
EFFECT OF FUEL MOISTURE ON FURNACE PERFORMANCE

Moisture content of hogged fuel affects furnace design, over-all efficiency, and capacity (steam rate) of a boiler.

Furnace design

Compared to fuel with low moisture content (30-45 per cent), fuel with high moisture (55-65 per cent) results in an increased volume of water vapor that must pass through the furnace and boiler. This requires enlarged volume for the furnace and increased capacity for the draft fan (8). Excessive moisture also retards combustion, lowers temperature of the flame, and results in a long flame. Therefore, a long path for the flame must be provided so that combustion will be complete by the time gases have reached the boiler surfaces.

In a dutch-oven furnace burning wet fuels, surface of the arch must be enlarged to increase radiation to the fuel pile to maintain gasification and ignition. The arch also should be lengthened downward to increase travel of the flame (7). With the spreader-fired furnace of Figure 4, refractory shielding of water wall tubes will improve operation with wet fuels, but may not be of advantage in increasing efficiency or rating (8).

Over-all efficiency

Over-all efficiency of a boiler, furnace, and grate is a measure of relative heat in a quantity of steam produced by a boiler compared to heat in the fuel consumed in producing the steam. For example, if 1000 pounds of steam at pressure of 200 pounds a square inch were produced in a certain time interval, heat content of the steam might be 1000 x 1100 = 1,100,000 Btu, the exact value depending upon temperature of feed water and pressure of the steam. If 400 pounds of fuel, with available heat of 8500 Btu to a pound when dry, were burned at 50 per cent moisture to produce the 1000 pounds of steam, heat available from the fuel would be 400 x 8500 x 0.50 = 1,700,000 Btu. Efficiency in this example would be \( \frac{1,100,000 \times 100}{1,700,000} = 64.7 \) per cent. In other words, 64.7 per cent of the theoretically available heat in the fuel actually was converted to heat in the steam.

An example of the manner in which over-all efficiency varies as moisture content of fuel increases is shown in Figure 5. According to the author (8) this curve is for 30 per cent excess air, stack-gas temperature of 600 degrees F, and wood with heating value of 8700 Btu a pound. Note that at 40 per cent moisture content, 65 per cent of the heat in the wood is converted to heat in the steam, but that at 65 per cent moisture content, only 47.5 per cent is converted.
Values for efficiency indicate how much fuel must be burned to produce a quantity of steam, but the values do not indicate how long will be required to produce that quantity of steam. Therefore, values for efficiency are not a measure of rate at which steam is produced.

With wet fuels, efficiency decreases mainly because more heat is carried out the boiler stack by the large volume of moisture (steam) evaporated from the fuel in the furnace. Other factors, such as inadequate supply of air, improper mixing of air and fuel, and reduced efficiency in transferring heat reduce overall efficiency to a lesser extent as moisture content increases.

Steam production

A boiler operator's first concern is to maintain rate of steam production so that machines and processes may continue to operate. Usually the first indication that production of steam is decreasing is a drop in pressure in the boiler. This drop means that steam is being drawn from the boiler faster than it can be produced.

Production of steam decreases with increasing moisture content of fuel because of several related factors. With wet, as compared to dry fuel, additional heat is consumed in evaporating moisture from the fuel. Most of this heat is lost out the stack and is not available for making steam.

Another factor tends to reduce production of steam as moisture in fuel increases. Moisture evaporated from the fuel must pass through
the furnace and out the stack. One pound of water, which occupied less than 1/60 cubic foot before evaporation in the furnace, occupies about 43 cubic feet at 600 F and about 84 cubic feet at 1600 F. With Douglas fir hogged fuel at 45 per cent moisture content, steam evaporated from moisture in the fuel would occupy about 13 per cent of furnace volume, but if moisture content of fuel were 65 per cent, water vapor would occu-

ppy 26 per cent of total furnace volume. These figures are based upon 30 per cent excess air supplied to furnace for combustion. Net re-

result of the increased volume of gas passing through a furnace is to re-

duce the amount of air available for combustion.

Finally, steam from wet fuels blankets the fuel bed and inter-

feres with adequate mixing of air and fuel. This inadequate mixing causes fuel to burn slowly, which in turn causes brickwork to cool and reduces radiation back to the fuel pile. As a result, less heat is liber-

ated in a given time, and production of steam decreases.

In the extreme case where fuel is of high moisture content, all factors combine to cause serious reduction in production of steam. When this happens, tendency of the operator is to increase air supply, fuel rate, or both. Doing so may aggravate the situation by blanketing the fuel pile or fuel bed with wet fuel to the extent that fire cannot be sustained. In a dutch-oven furnace, excessive fuel also may restrict flow of gas out of the primary chamber.

One author (8) has stated that increasing moisture in fuel from 60 to 70 per cent may reduce boiler rating (steam production for which boiler was designed) by 50 per cent.

In discussing the wet-fuel problem, a foreman of a large central-

station plant burning hogged fuel stated that the capacity of a dutch-oven furnace designed for Douglas fir at 45 per cent moisture content may be reduced by 50 per cent when burning hemlock at 60 per cent moisture content.

With respect to maximum moisture content at which fuel will burn, an authority on combustion stated, "An increasing moisture con-

tent retards combustion and lowers the flame temperature, but this does not seriously affect combustion until moisture exceeds 45 per cent. Somewhere between 65 per cent and 70 per cent moisture these two fac-

tors combine to create a condition in which the fuel will no longer pro-

duce a stable fire" (8). The author further noted that some authorities give limiting moisture contents as low as 63 per cent and as high as 75 per cent. He explained that these differences reflected variations in furnace designs as well as differences of personal opinion as to practi-

cal operating limitations.
REFERENCES


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