HEATING RATES FOR LOGS, BOLTS, AND FLITCHES TO BE CUT INTO VENEER

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Summary

The heating of logs, bolts, and flitches to be cut into high-quality rotary or sliced veneer requires a knowledge of the temperatures appropriate for various species and conditions, and of the factors that control the attainment of these temperatures during the heating process. Good equipment and good control of the heating process are essential. Under the guidelines given in this paper, optimum temperature levels for different woods and different conditions can be determined, and time schedules can be calculated for heating in steam or water.

Optimum temperatures can be determined by following suggested values given for a number of veneer species. Adjustments must be made, depending on the quality of cutting obtained and taking into consideration other species factors, such as tendencies for end-splitting, presence of hard knots, and color changes in the woods.

Three steps are involved in arriving at a heating schedule applicable to a given set of conditions. Mathematical analyses have provided graphic shortcuts to aid in taking each step. The first step is to adjust for temperature differences from those assumed in this paper, namely a 70°F initial wood temperature and a 212°F heating medium temperature. The second step is to determine the time required to attain the desired temperature under conditions where the heat diffusivity factor is 0.00027. The third step is to adjust the time thus determined to take into account different diffusivity factors that apply to woods of different densities, and that depend on whether the heating is done in steam or in water.

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1Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

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Irregularities may occur in the wood or in the heating conditions that may necessitate further adjustment of heating schedules. A number of these are discussed briefly.

Introduction

The veneer cutting industry of the United States has made considerable progress in recent years in the heating of logs, bolts, and flitches to be cut into high-quality veneer. The haphazard and uncontrolled heating practiced in former years has to a great extent given way to systematic heating procedures. Equipment has also been improved. Sawdust pile heating, which defies all efforts at good temperature control, is no longer generally practiced. Poorly constructed, leaky steaming rooms have been replaced by well-constructed chambers. Instruments are now often used to measure temperatures and sometimes to operate control valves for maintaining proper temperature levels in steaming chambers or water vats.

The log heating operation in the veneer industry is assuming greater importance as time goes on. Logs of poorer quality, are appearing in greater percentages at veneer plants. These can be cut into good veneer only with careful control of the preparatory heating process, in order that the wood, whether it contain knots, crossgrain, or other irregularities, may be properly softened for good cutting. The operator cannot assure himself of proper heating unless he has good equipment that can be maintained continuously at a predetermined temperature level, and that will provide constant and uniform temperatures throughout the heating area.

This paper describes a method for quickly and easily determining schedules for heating logs in water or in steam. Before the correct schedule can be established it is necessary to determine the minimum temperature for good cutting of the species in question. The problem is complicated by the fact that the common heating methods usually do not result in a uniform temperature throughout the wood being heated. Veneer bolts are sometimes heated in water or steam at a temperature far above the optimum temperature for good cutting. At the end of the heating cycle the temperature near the surface of the heated bolt, particularly if it is of a substantial size, may be well above the optimum, but within the bolt a sharp gradient may exist, with temperatures dropping with increasing depth to a level far below the optimum.

For practical purposes, moderate temperature gradients may be permitted. For best cutting they should be kept at a minimum by heating at a temperature not greatly above the "optimum." The heating should be continued until all the wood that is to be cut into veneer reaches the minimum temperature for good cutting.

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Proper Temperatures for Good Cutting

It is not possible to recommend a single optimum temperature for wood of a given species, that will result in the best cutting under all conditions. Most heating schedules involve compromises; to save time, temperatures well above optimum may be applied to the logs; because of inadequate heating capacity, logs may be heated for one day instead of two or three; other factors, such as a tendency for log end-splitting, or the effect of heating on the color of the wood, may result in further compromises.

Fortunately, in any species good cutting can usually be obtained over a moderately wide range of temperatures. In hardwood species the temperature that results in the best cutting is roughly related to the density of the wood. Hardwoods of low density (below a specific gravity of 0.40) such as aspen or cottonwood can be cut well at room temperature. Hardwoods of medium density, such as sweetgum with an average specific gravity of 0.46, cut well when at a temperature of 140° F.; yellow birch, with a specific gravity of 0.55, requires a higher temperature of 160° F. Very dense woods such as white oak (0.60) or shagbark hickory (0.64) cut best at a temperature of about 200° F.

The relation between some typical temperatures required for good cutting of hardwood species and their average specific gravity is shown in figure 1. Temperatures to be used for other hardwood species not shown in figure 1 can be estimated from the graph.

Unfortunately the relation between specific gravity and proper cutting temperature is not so simple in the case of softwoods. The temperatures required are generally higher than those required for hardwoods of comparable density. This may be due to the fact that many softwood species are made up of alternate bands of soft springwood and dense summerwood. In order to properly soften the dense summerwood band for good cutting, a temperature considerably above that indicated by the average density of the wood is required. Good cutting temperatures for some softwood species are shown below. These temperatures apply to the rotary cutting of veneer 1/8-inch thick of straight-grained wood, free of hard knots or other defects. The proper temperatures for other softwood species must be determined by trial.

<table>
<thead>
<tr>
<th>Species</th>
<th>Favorable temperature range °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Douglas-fir (coast type)</td>
<td>140 - 170</td>
</tr>
<tr>
<td>Fir, true (Abies sp.)</td>
<td>130 - 160</td>
</tr>
<tr>
<td>Hemlock, western</td>
<td>130 - 160</td>
</tr>
<tr>
<td>Larch, western</td>
<td>140 - 170</td>
</tr>
<tr>
<td>Pine, ponderosa</td>
<td>120 - 150</td>
</tr>
<tr>
<td>Pine, southern yellow</td>
<td>160 - 190</td>
</tr>
<tr>
<td>Redwood</td>
<td>150 - 180</td>
</tr>
</tbody>
</table>

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The temperature values indicated in figure 1 and in the above tabulation should be used only in arriving at a first approximation of a proper schedule. The results obtained will determine what further adjustments must be made. The indicated temperatures are intended for use in the rotary cutting of straight-grained wood of average density for the species indicated. In general thin veneer, 1/16 inch thick or thinner, may be cut at lower temperatures than those indicated without serious degrade. For highly figured wood, wood with considerable crossgrain, or wood containing hard knots, the temperatures should be raised by 20 to 30 degrees. Temperatures used for slicing flitches are usually 10 to 20 degrees higher than those indicated for rotary cutting. If the logs or bolts become severely end checked during heating at high temperatures, temperatures may have to be dropped to a level of 150 to 160 degrees.

The adequacy of the heating process should be judged from the quality of the veneer produced (1). \(^2\) If the veneer is loosely cut in spite of adjustments of the nosebar, a higher temperature or a longer heating period is indicated. Fuzzy cutting around the circumference, not restricted to limited segments of the log, indicates an excessive amount of heat has oversoftened the wood.

Factors Affecting the Rate of Heat Transfer in Green Wood

The subject of heat transfer in green wood, upon which the methods outlined in this paper are based, has been thoroughly studied at the Forest Products Laboratory by Dr. J. D. MacLean (5). The various factors that affect the rate of heating have been isolated and formulas have been developed for dealing with these factors. The mathematics involved may become very complicated at times.

The main variables that must be taken into account, other than temperature itself, are (1) type of heating medium, (2) differences in moisture content of the wood, (3) grain direction of the wood, and (4) density or specific gravity of the species.

The rate at which wood heats in different mediums is influenced by such variables as type of surface contact, rate of circulation of liquids and gases, when used, specific heat of the heating substance, and the heat of vaporization, as in the case of steam. In general it may be said that water will heat wood about 5 to 10 percent more slowly than steam. In Forest Products Laboratory tests the slowest rate of heating was obtained in air at low humidity, but the rate was increased as the humidity of the air increased.

\(^2\)Underscored numbers in parentheses refer to references listed at the end of this paper.
Seasoned wood having a moisture content below 30 percent was found to heat more slowly than green wood. The tests showed, however, that in the heating of green wood, differences in moisture content above the fiber saturation point have no significant effect on the rate of heating in the range of temperatures commonly employed.

In the heating of veneer logs, the rate of heating in the radial direction (at right angles to the rings) is of greatest importance, because of the relatively long length of veneer logs or bolts with respect to their diameter. For practical purposes, it may be assumed that, on the average, the rate of temperature change lengthwise in the log is about 2-1/2 times faster than it is at right angles to the axis.

Experiments on specimens of the same species and on those of different species have shown that the rate of heating varies inversely with specific gravity. Species differences, other than specific gravity, are negligible.

Determination of Heating Schedules for Bolts

Based on the earlier work described above, several charts have been developed that are useful for quickly calculating the time required for heating veneer bolts or logs to any desired cutting temperature at several depths, at midlength. The depth of heating can be made to correspond to the desired average core diameter. Between the specified core diameter and the outer surface of the log the temperature will vary from a minimum at the core to a maximum, essentially equal to that of the heating medium, at the outer surface of the log.

The data that form the basis for these calculations were developed for green wood having a specific gravity of about 0.5. For such wood the "diffusivity factor" for radial heating (a measure of the rate of heating in inch-second units) was found to be 0.00027, when heated in water (5).

If woods of other densities are to be heated, or if the heating is to be in steam instead of water, some adjustment of the required heating time must be made. Since the charts in figures 2, 3, and 4 are based on wood at an initial temperature of 70° F., and water at 212° F., an adjustment must also be made if the initial temperature of the wood is at some level other than 70° F., or if the temperature of the heating medium, whether steam, water, or air, or mixtures thereof, is at a level other than 212° F.

The conversion to different temperature conditions is made most easily by the use of figure 5. If, for example, the initial temperature of the wood is 50° F., this point is chosen on the left-hand margin of the chart. If the temperature of the heating medium is 180° F. instead of 212°, the 180° figure
is chosen on the right-hand margin. A straight line is drawn between these two points.

Now let it be assumed that the temperature to be attained at core diameter of the particular veneer bolts in question is 140° F. Going again to the left-hand margin, the 140° point is chosen and a horizontal line is drawn from it to the diagonal line drawn previously, then dropped vertically to the temperature scale at the bottom of the chart. A temperature of 168° F. is indicated. This figure of 168° F. must be used in further calculations, instead of the 140° figure, in order to compensate for the lower initial temperature of the wood and the lower level of heating medium temperature.

If the veneer operation is such that cutting is normally done to a core diameter of 6 inches, figure 2 should be used next. The 168° temperature is chosen on the lower horizontal scale. A line is drawn vertically from the desired temperature value on the lower scale to a point where it intersects the diameter curve for the particular size of logs under consideration; for example, 18 inches. From this point of intersection a line is drawn horizontally to the left margin. The value indicated in this example is 22. The time required to attain a temperature of 140° at a 6-inch core diameter, at midlength in the veneer bolt, is therefore tentatively found to be 22 hours. When cutting to a core diameter of 8 inches, figure 3 should be used and the comparable figure is found to be 19-1/2 hours. Figure 4 is used for larger logs where the cutting stops at a large core diameter of 12 inches, as is the practice when cutting face veneer from larger softwood logs.

Next the species and density of the wood must be taken into account. At the same time the adjustment for type of heating medium is also made. This combined adjustment is made on the basis of the "diffusivity factor." The average specific gravity (based on volume when green and weight when ovendry) for the species in question must first be determined. Average specific gravity values may be taken from the Wood Handbook (6) or from some other source. The "diffusivity factor" varies with density and with the type of heating medium, whether steam or water.

Calculations have been made to show the ratio of diffusivity between that applying under any given conditions and that used in computing the curves in figures 2, 3, and 4, namely, 0.00027, when heating in water. Figure 6 contains two curves, the upper of which indicates the diffusivity ratio when heating in water; the lower when heating in steam.

Let it be assumed, for example, that a wood having a specific gravity of 0.6 is to be heated in water. From the specific gravity level of 0.6 on the lower horizontal scale of figure 6, a line is drawn vertically until it intersects the upper curve, whence a horizontal line drawn to the left marginal scale, indicates the diffusivity ratio of 1.19. The total heating time required must
therefore be adjusted by this ratio. For the examples given, the required heating time of 22 hours, when cutting to a 6-inch core, will be multiplied by 1.19 to give a total of 26 hours, and that required for the 8-inch core diameter of 19-1/2 hours will be increased to about 23 hours.

**Determination of Heating Schedules for Flitches**

Sawn timbers, flitches, or cants that may be used for veneer slicing are not round in cross section and may vary greatly in size. Therefore it is more difficult to calculate an average time for heating these sections to the proper temperature for good slicing. The "average core diameter," which must be considered in rotary cutting, does not enter into consideration in this case, since almost the entire flitch is sliced into veneer. The easiest method to use in this case is to make a rough estimate of time required by comparison with known heating times of sawn timbers of various cross-sectional areas. Test results (3, 4) indicate the number of hours that were required to reach desired temperatures below 200°F., in or near the middle of the cross section. In these tests the temperature of the wood initially was 60° F., and that of the water used as the heating medium was 200° F. The wood in this case had a diffusivity of 0.00025.

The original data (3, 4) have been adjusted in figure 7 to make them comparable to those shown in figures 2, 3, and 4. The curves shown in figure 7 therefore represent wood having a diffusivity of 0.00027, at an initial temperature of 70° F., heated at a temperature of 212° F. For different initial temperatures and heating conditions, and for different diffusivity ratios, adjustments are made by the same methods as those explained above for logs and bolts.

**Irregularities in Heating Calculations**

**Irregularly Shaped Logs**

The mathematical treatment that forms the basis for calculations of log or bolt heating assumes regularly shaped round pieces. If log cross sections are irregular, the safest procedure is to work with the average dimensions, although in some cases this might result in a slight overestimate of the required heating time.
Effect of Bark on Heating Schedules

Diameters should be measured to the outside surface of the log, whether that be a wood or a bark surface. The rate of heating through bark has not been measured, but for mathematical approximations its effect is assumed to be the same as that of an equal thickness of green wood. On species with thick bark, a reduction in heating time may be gained by removing the bark before the logs are heated.

Effect of a Warming-up Period

In some heating operations the temperature of the heating medium is gradually raised from room temperature to the final desired temperature over a period of some hours. A rough adjustment may be made for this gradual warming-up period by assuming that its effect is equivalent to that of heating at the final temperature for one-half of the warming-up period. Calculations should be made using the final holding temperature; the schedule thus determined should then be extended by adding to it one-half of the time required for warming up of the heating medium.

Uniformity of Heat Distribution

The methods described here for determining heating schedules are intended to give an estimate of the time required to attain a certain predetermined minimum temperature at a predetermined reference location. In rotary cutting, the reference location is at mid-length, at the core diameter. In the slicing of a flitch it is in the center. Between this location and the surfaces there will normally be a gradation in temperature with the highest temperature at the surface. Figure 8 shows isothermal lines indicating calculated temperature gradients from surface to center for a redwood bolt 5 feet in diameter and 8 feet long, heated in steam at 212° F. for 40 hours.

In some cases the wood may not cut properly because the temperature of the heating medium was so high that the outer portions were overheated. The cooling process proceeds at about the same rate as the heating process. While the outer portion of the log cools, the inner part will continue to be heated because of transfer of heat from the intermediate zone, which for a time will be at a higher temperature than either the outer zone or the inner zone. It would appear that heating schedules could be shortened by using higher than optimum temperature for a period, followed by an equalizing period at a lower temperature. Such schedules have not been developed to date.

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Reference to figure 8 will serve to illustrate a question sometimes raised by those who must heat bolts that have a great diameter in relation to length. This is the case in the redwood veneer industry, where veneer bolts may be 8 feet long and almost that great in diameter. Since heat transfer endwise in the wood takes place at a faster rate than sideways, some advantage is obtained. For practical purposes the method of calculating heating schedules, however, remains unchanged because radial heat transfer at midlength still remains the major governing factor.

Heating Frozen Wood

The methods described above may be used to determine heating schedules for frozen wood. The effect of ice in the wood on the rate of heating is relatively small. Some additional heat is required to melt the ice, but ice has a lower density, a lower specific heat, and a much higher heat conductivity and diffusivity than water, so that the net effect is small. It is roughly estimated that the additional time needed to melt the ice in frozen wood will require an increase in the heating period equal to that needed to raise the temperature an additional 4 degrees. The adjustment is made with the aid of figure 5 at the same time as other adjustments are made for temperature.

Heating at Temperatures Above 212° F.

The advantages and disadvantages of heating veneer logs in pressure cylinders at temperatures above 212° F. are discussed in another paper (2). The main advantage to be gained is one of speed, in proportion to the ratio of temperatures involved. Figure 5 may be extrapolated to any desired temperature above 212° F. in order to make the proper time adjustment based on the higher temperature of the heating medium. This speed may be gained primarily at a sacrifice of veneer quality, because higher exterior temperatures will result in steeper temperature gradients in the wood, with the result that, within the limited time usually used, outer portions of logs are likely to be overheated, while inner portions are still at too low a temperature for good cutting.
References

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(2) and Lutz, John F.
   Digest, 55(12) 161-166.

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   1940. Relation of Wood Density to Rate of Temperature Change in Wood
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(4) 1946. Temperatures Obtained in Timbers When the Surface Tempera-
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(5) 1946. Rate of Temperature Change in Short-Length Round Timbers.

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Figure 1. Favorable temperature range (area between heavy lines) for cutting veneer of hardwood species of various specific gravities. Points show favorable temperatures for the individual hardwood species indicated. The data apply to the rotary cutting of veneer 1/8-inch thick, of straight-grained wood, free of defects such as knots or tension wood ("soft streaks").

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Figure 2. -- Time required to attain desired temperatures in veneer bolts at mid-length and with 6-inch core diameters. The curves were developed for wood having an approximate specific gravity of 0.5 and a diffusivity of 0.00027, heated in water. The heating times determined from these curves can be adjusted to fit other conditions.

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Figure 3. -- Time required to attain desired temperatures in veneer bolts at mid-length and with 8-inch core diameters. The curves were developed for wood having an approximate specific gravity of 0.5 and a diffusivity of 0.00027, heated in water. The heating times determined from these curves can be adjusted to fit other conditions.

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Figure 4.--Time required to attain desired temperatures in veneer bolts at mid-length and with 12-inch core diameter. The curves were developed for wood having an approximate specific gravity of 0.5 and a diffusivity of 0.00027, heated in water. The heating times determined from these curves can be adjusted to fit other conditions.
Figure 5. -- Nomograph for finding the temperature value to be used in calculations when the initial wood temperature or the temperature of the heating medium differs from 70° or 212° F., respectively.

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Figure 6. Relation between specific gravity and the diffusivity ratio used to adjust heating times for woods of different density, heated in steam or hot water. The "diffusivity ratio" expresses the ratio of diffusivities of wood of any gravity with that having a diffusivity of 0.00627.

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Figure 7.—Time required to attain desired temperatures at centers of timbers of various sizes, as given in inches. The curves have been adjusted to describe wood having an approximate specific gravity of 0.5 and a diffusivity of 0.00027, with an initial temperature of 70° F., heated in water at 212° F. The heating times can be adjusted to fit other conditions by the methods described for logs and bolts.

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Figure 8. — Diagrammatic representation of isothermal shells in a redwood bolt 8 feet long, 5 feet in diameter, after heating in steam at 212° F. for 40 hours. The temperature of the wood initially was 80° F. The diagram shows only about one quarter of a lengthwise section of the bolt.

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