HEATING VENEER BOLTS TO IMPROVE QUALITY OF DOUGLAS-FIR PLYWOOD

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HEATING VENEER BOLTS TO IMPROVE QUALITY OF DOUGLAS-FIR PLYWOOD

By

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Summary

The quality of Douglas-fir plywood is directly related to the quality of the veneer. Veneer quality, particularly its smoothness and tightness, can be improved by heating the bolts. This paper describes three methods of heating—hot water, steam, or electricity—and discusses the advantages and limitations of each.

Introduction

In the past few years, interest in the heating of Douglas-fir veneer bolts has been renewed. At several plants (2, 11, 12) Douglas-fir bolts

1Presented at Section Meeting of the Forest Products Research Society, Bellingham, Wash., February 8, 9, 1960.
2Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
3Underlined numbers in parentheses refer to Literature Cited.

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are heated before they are put on the lathe. Abandoned and broken concrete heating chambers at some of the older mills are evidence that this is a revival of an early practice in the Douglas-fir plywood industry. Some pioneers had had previous experience in the hardwood veneer industry, where heating of dense or moderately dense woods is routine. Consequently, early softwood veneer mills generally had steaming chambers. The large size of the old-growth Douglas-fir peelers made the required heating time very long. For example, a Douglas-fir log 48 inches in diameter would have to be heated for 66 hours in steam at 212° F. to bring the 12-inch core to a temperature of 120° F. (13).

In 1925 the roller pressure bar was developed (1), and about 10 years later the router-head type of mechanical barker came into use. Prior to these developments, heating was an almost indispensable part of producing Douglas-fir veneer. Heating in steam or water near the boiling point permitted the removal of bark by hand. Heating also reduced problems of splinters and pitch that tend to stick on a rigid pressure bar. The disadvantage of the long heating periods required for large old-growth peeler logs, the ease of removing bark with mechanical barkers, and the ability to cut satisfactory veneer from unheated bolts brought about by the roller pressure bar resulted in the abandonment of heating in most Douglas-fir veneer plants.

One or two plants cutting veneer on a lathe and all of the plants slicing veneer from Douglas-fir flitches have always recognized, however, that veneer of improved quality is obtainable by heating the wood, and the practice of heating bolts and flitches has continued at these plants.

The renewed general interest in the heating of Douglas-fir bolts is apparently related to the high cost of logs, the smaller diameters of the average veneer bolt, and the desire to maintain quality of the product in spite of the necessity to use fast-grown, coarse-textured material containing a large percentage of sapwood and knotty material. All of these factors make the heating of Douglas-fir veneer bolts more advantageous than in the past. With the continuing decline anticipated in the quality of the raw material, the advantages of heating should be even more pronounced in the future.

In addition to heating Douglas-fir bolts, other factors influencing the quality of veneer produced on a lathe include the quality of the bolt, the condition of the lathe, the sharpness of the knife, and the pressure applied by the nosebar. Heartwood veneer cut cold from a large old-
growth peeler composed of fine-textured wood, and on a lathe in top operating condition, is likely to be of better quality than veneer cut from a heated, small, coarse-textured bolt on a lathe that is in poor condition. When factors other than heating remain constant, veneer cut from heated bolts will be measurably smoother and tighter. The poorer the quality of the logs, the more obvious is the improvement attainable by heating the bolts.

Any improvement in plywood glue bonds attributable to the use of smooth veneer, or in the resistance of plywood to face checking due to a tightly cut face veneer, is certainly desirable at a time when poor quality raw material makes it difficult to produce consistently plywood of top quality. The advantages of heating Douglas-fir veneer bolts are not fully recognized in the industry. This report describes some of the advantages and limitations of heating and discusses three methods of heating.

Advantages and Limitations of Heating

The main purpose of heating veneer bolts is to plasticize or soften the wood. Green Douglas-fir is measurably plasticized at a temperature of 120° F, but the effect is more pronounced at temperatures of 160° to 180° F. Consequently, veneer cut from Douglas-fir bolts heated between 120° and 180° F will be improved by the preconditioning of the bolt, with the higher temperatures giving the more favorable results.

How do heating and plasticizing improve veneer quality? Heating makes it easier to produce face veneer from sapwood; it softens the knots so that they can be cut with a sharp knife; it softens the hard summerwood of the annual rings so that it can be cut relatively smoothly; and it enables the wood to be compressed and bent at the knife edge so that the breaks or knife checks in the veneer will be less pronounced. Heating also softens pitch and reduces splinters. These primary effects of heating are accompanied by a number of beneficial secondary effects on the veneer and the plywood.

Effect of Heating on Sapwood

Heating makes it easier to produce a face-grade veneer from the sapwood, and reportedly it reduces the time required to dry the sapwood
veneer. When peeling unheated bolts, the nosebar pressure on the sapwood must be carefully regulated. Insufficient pressure results in veneer that is too loose to use as faces, and heavy pressure often causes shattering. Smooth, tight veneer, however, can be cut from the sapwood of heated bolts without using a nosebar pressure heavy enough to cause shattering. The management of a Douglas-fir plant that now heats peeler blocks believes that the most important advantage of heating is the ability to cut face-quality veneer consistently from sapwood.

The Oregon Forest Products Research Center (2) found that sapwood veneer cut from heated bolts dried slightly faster than matched veneer cut from unheated bolts, but noticed no reduction of drying time for heartwood veneer. Similar observations have been made at the U. S. Forest Products Laboratory on the drying time of heartwood veneer. C. W. Lickess (12) also reports reduced drying time for veneer cut from heated bolts.

Since it comes from the outside of the log, sapwood veneer is often free of knots, and consequently, if smooth and tight, will generally qualify as face grade. If production demands require the use of short heating schedules, the benefits of heating the sapwood, the first portion of the bolt to be heated, will probably still be realized.

Relation of Heating to Knot Cutting and to Lathe Maintenance and Operation

Heating was found to be particularly beneficial when cutting knotty second-growth Douglas-fir (7). Knots encountered in the unheated blocks often nicked and sometimes chipped the lathe knife. The knife, of medium temper, was ground to an angle of 21 degrees. This angle gives a face of 1-13/16 inches on a knife 5/8 inch thick. The dulled knife edge produced a roughly cut veneer in spite of frequent stops to hone it. When the bolts were heated to 160° F., the knots softened and did not damage the knife.

Knotty wood in unheated bolts is generally cut with a knife ground to a blunt angle, so that the face of a 5/8-inch-thick knife is about 1-9/16 inches. The back of the knife is sometimes dubbed to strengthen the edge. These methods make it possible to cut knotty bolts, but dull the knife, increasing the depth of roughness depressions. A blunt knife also causes the veneer to bend in a shorter radius, thus producing deeper knife checks.
Whether a rigid bar is better than a roller bar for cutting heated Douglas-fir is still undetermined. Theoretically, a rigid bar can be set up more accurately than a roller bar, and so should be more suitable for cutting veneer of the best quality. Tight, smooth Douglas-fir veneer has been cut from heated bolts on the 4-foot lathe equipped with a rigid pressure bar at the U. S. Forest Products Laboratory. Personnel in one plant that has cut heated bolts with both types of bars prefer the roller bar, however, because the roller bar pushes through any chips and slivers that develop and permits peeling closer to shakes.

Heated bolts may distort lathe parts, spoiling a good lathe setup. Distortion can be reduced to a negligible amount by installing heating devices on the lathe, or by dissipating the heat with water-cooling elements (4). These methods are used successfully in some hardwood veneer plants. Uniform heating of the knife and nosebar also reduces moisture condensation on the metal parts, which may drip on the veneer and cause a ferric-tannate stain.

Commercial experience shows that heating veneer bolts results in longer life for lathe knives and easier peeling from a mechanical standpoint (12). Longer knife wear is predicated on the assumption that the bolts are clean when they reach the lathe. Heating does not soften gravel and cinders picked up by carelessly handled logs.

Effect of Heating on Veneer Smoothness

Heating, by softening the knots and summerwood, generally results in smoother veneer. Smooth veneer gives better glue bonds, and less material is lost in sanding. One-tenth-inch veneer cut at the Forest Products Laboratory from six Douglas-fir bolts at a temperature of about 60° F. had many areas where the roughness depressions averaged about 0.030 inch. Veneer cut from matched bolts heated at 160° F. had corresponding roughness depressions averaging about 0.018 inch. Other Laboratory tests have shown that rough, loose, 3/16-inch Douglas-fir veneer cut from bolts at room temperature and with poor lathe settings is difficult to glue with a cold-setting soybean glue under typical conditions. These veneers had roughness depressions varying from 0.033 to 0.041 inch. In veneer from heated bolts, depressions did not exceed 0.028 inch, and this veneer was successfully glued with a cold-setting soybean glue.
Figure 1 illustrates the effect of roughness on the quality of the glue bond. Smooth veneer obtained from heated bolts requires less glue than rough veneer cut from cold bolts. Lower glue spreads are not only more economical, but introduce less water into the panels. Consequently, it is expected that there will be fewer "blows" during hot pressing, and warping and face checking will be lessened in cold pressed plywood.

The relatively smoother veneer cut from heated bolts is reported to yield more face veneer, and less material is removed during sanding (2, 11, 12).

**Effect of Heating on Veneer Tightness**

Perhaps the most important beneficial effect of heating the bolts is that tight veneer may be cut without excessive nosebar pressure. Improved veneer tightness gives less breakage, retards face checking of the plywood, and may make it possible to use thinner face veneers.

In the experiment described in the previous section, knife checks extended through about four-fifths of the thickness of 1/10-inch veneer cut from unheated bolts, but extended through only two-fifths of the thickness of the veneer cut at 160° F. In another experiment, 1/10-inch veneer was cut from three matched bolts. One bolt was at 60° F., the second bolt had been heated electrically to about 140° F., and the third bolt had been heated in water to about 160° F. As illustrated in figure 2, heating reduced the depth of knife checks in the sapwood and heartwood. The greatest improvement occurred in the veneer cut from the bolt heated in water to about 160° F. Veneer from the bolt heated electrically was intermediate in tightness between that obtained from the other two.

Tight veneer cut from heated bolts means less handling breakage, with a corresponding increased recovery of veneer (2, 12). Breakage at the lathe and tipple is less because the veneer is tight, warm, and plastic. Consequently, it can be bent without breaking to a sharper radius than cold veneer. Tight veneer is stronger in tension across the grain than loose veneer, hence breaks less at the clipper, dryer, and sorting table, or while jointing, edge gluing, glue spreading, and laying up the panels.
Face checking is a common problem with Douglas-fir plywood in service. Accelerated tests have shown that tight veneer, such as that produced from heated bolts, results in less face checking (3). The smoother, tighter, more easily handled veneer cut from heated bolts may make it possible to use thinner veneer, such as 1/16-inch, for faces. This not only would conserve scarce high-grade material, but would probably also result in even smoother and tighter veneer with a corresponding improvement in the quality of the plywood.

Bolt End Checks

Heating causes green wood to expand tangentially and to shrink radially, resulting in the development or enlargement of end checks radiating from the pith. End checks, in turn, cause splits in the veneer. The severity of the end checks varies with species and with the temperature to which the bolt is heated. As discussed by MacLean (14), the end checking of Douglas-fir is small if the temperature of the bolt does not go above 160° F. More pronounced end checks will develop if the wood is heated at 200° F. or higher.

Strength

Heating wood at high temperatures for long periods of time may affect the strength properties. However, MacLean (15) has shown that Douglas-fir can be heated at 150° F. for 20 days without any detectable loss in either work to maximum load or modulus of rupture. Douglas-fir heated at 200° F. for 10 to 12 days was reduced about 10 percent in modulus of rupture. These data indicate that veneer cut from Douglas-fir bolts heated by recommended schedules would undergo no detectable loss of strength.

Possible Means of Heating

Submersion in hot water and steaming are the two methods used commercially to heat veneer bolts, with steaming preferred in Douglas-fir veneer plants. Bolts and flitches of Douglas-fir have been electrically heated at the Forest Products Laboratory. Of the three methods, electricity is fastest, steam is next, and hot water is slowest. If uniformity of heating is the main consideration, the order of preference is reversed.

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Heating in Water

The chief advantage of heating in water is the accurate control of temperature below 212° F. (5). When water vats are properly equipped with automatic temperature controls, logs can be heated to any temperature between atmospheric and the temperature of boiling water. Disadvantages of water are the need for hold downs to keep logs from floating, the danger to workmen, and slower heating. Some disadvantages can be overcome by having several vats with a system of pumps that allow hot water from one vat to be pumped into another. To unload a vat, the hot water is pumped into another vat that has recently been loaded (6). This conserves heat and is safer than having men work around a vat full of hot water.

Heating by Steaming

Under the same time and temperature conditions, steam heats wood 5 to 10 percent faster than water (13). This, together with the safety factor and the relative ease of handling veneer bolts in and out of the steam chambers (fig. 3), has made steaming the preferred method in Douglas-fir veneer mills (2, 11, 12).

It is desirable to load the vats so that the steam can readily circulate to all surfaces of the blocks. Circulation can be facilitated by using spacers (fig. 4).

Low-pressure steam or exhaust steam should be used to heat the chamber; high-pressure steam may dry the bolts. Some plants inject a fine spray of water with the steam to help maintain a high humidity in the chamber. Steam spray pipes are preferable to a single steam orifice. The pipes should be installed in the heating chambers in such a way as to support good circulation (figs. 3, 4, 5). Automatic temperature control equipment maintains the desired temperature in the chamber (6).

Steam-air mixtures below 212° F. can be used to heat veneer bolts. Once the desired temperature has been reached, only enough steam is supplied to replace that lost by condensation or to the outer atmosphere. The steam supply should be regulated to allow a nearly constant flow of steam into the chamber. Long periods without steam flowing into
the chamber are undesirable, because they permit stratification of the atmosphere in the chamber and consequently irregular and inefficient heating.

Steaming sometimes was done by covering a load of logs with sawdust and bubbling steam into the lower portion of the pile. With such a method the steam is likely to follow channels through the sawdust resulting in nonuniform and inefficient heating (6). The method is slow, inefficient, and no longer used extensively.

Some interest has been shown in reducing heating time by conditioning logs in steam under pressure. Limited laboratory tests (8) indicate, however, that the method gives only a minor saving of heating time, and the improvement of veneer quality is not comparable to that obtained by slower steaming at atmospheric pressure.

Heating by Electricity

Tests at the Forest Products Laboratory (9) show that veneer bolts can be heated with an electrical current at ordinary frequency and high voltages. Electric current is forced through the bolt by means of electrodes fastened to each end. The resistance of the wood to the current causes the bolt to become hot. Equipment needed depends on the size and type of material to be heated. For 8-foot Douglas-fir bolts, a transformer with output voltages to 10,000 volts, a circuit breaker, suitable electrodes, and safety devices that prevent workers from accidentally coming into contact with the equipment are required.

The main appeal of the electrical method is the rapid heating of the wood. A Douglas-fir bolt 42 inches in diameter and about 3 feet long was electrically heated to an average temperature of 140° F. in 55 minutes. A matched bolt required 72 hours of heating in water at 153° F. to reach 140° F.

The main disadvantage of the electrical method with Douglas-fir is nonuniform heating. In the example cited, two stages were necessary to heat the bolt. First, the entire bolt was heated for 25 minutes, bringing the sapwood to an average temperature of 140° F. with a range of from 119° to 165° F. In this time, the heartwood reached about 90° F. The sapwood was then cut into veneer, and the heartwood
core was removed from the lathe for further heating. After 30 minutes it had an average temperature of 138° F., varying from 100° to 210° F. in different parts of the piece.

The electrical resistance of wood depends primarily on its moisture content. The sapwood of Douglas-fir is wetter than the heartwood, and when both are present, the current flows mainly in the sapwood, heating it instead of the heartwood. The resistance within the heartwood also varies because of its nonuniform moisture content. Experiments show this variation may be as great as 10 to 1, with a corresponding variation in the rate of heating.

The electrical resistance of wood increases as its temperature decreases. The resistance of frozen wood is so high that thawing logs by the electrical method is impractical.

The ends of the bolt must be wet to use the electrical heating method. If they have dried to below 30 percent moisture content, the resistance will be high enough to cause arcing and the wood will char.

The electrical method might have practical applications in the Douglas-fir industry for heating the sapwood only, for heating all heartwood cores, or as a booster to reduce the heating time required in steam chambers or water vats.

There is some evidence (16) that the benefits of heating wood prior to cutting veneer depend on both time and temperature. For best results, Douglas-fir should be at 120° to 180° F. for some time prior to cutting. A Douglas-fir bolt heated electrically to 140° F. in 1 hour did not cut as well as the matched bolt heated to 140° F. in 72 hours in water. This observation suggests that the electrical method might be used to heat the bolts rapidly, and then continue the heating more slowly in a steaming chamber. This should allow the heat to distribute itself somewhat in the bolt and to maintain the desired temperature level long enough to obtain adequate conditioning.

When the electrical heating method was tried with redwood, the sapwood and the wet areas in the heartwood heated faster than the dryer areas in the heartwood. The redwood heated more uniformly than Douglas-fir, however, because of the generally higher moisture content in the heartwood. Other West Coast softwoods, such as hemlock and the true firs, also have a higher moisture content in the heartwood than Douglas-fir, and consequently should be better adapted to heating by electrical resistance.
At present, no veneer mill in the United States uses the electrical method. Because of this lack of operating experience, it would be desirable for a plant to make a pilot-scale study before installing the method.

Cost of Heating

Contributing to the general discontinuance of heating of Douglas-fir veneer bolts in the 1930's was its cost. Heating requires capital investment in steaming chambers, vats, or electrical apparatus. It also requires power in the form of steam or electrical current.

Approximately 2200 B.t.u.'s are required to raise the temperature of 1 cubic foot of Douglas-fir heartwood 100°F, based on a dry weight of 32 pounds per cubic foot and a moisture content of 35 percent. Additional heat needed to compensate for that lost through the walls of the vat or steam chamber might equal that required for heating the wood. A more thorough discussion of steam requirements is given in the article, "Design of Heating Equipment for Veneer Logs" (6).

Theoretically, electrical heating under conditions of 100 percent efficiency will require about 0.65 kilowatt-hour to raise the temperature of a cubic foot of Douglas-fir heartwood 100°F. Under the experimental conditions used at the Forest Products Laboratory, about 0.70 kilowatt-hour of electric energy was required. The difference was due to heat lost by radiation from the bolts and to a slight loss of efficiency in the transformer.

Heating by steam or water probably costs less than electrical heating. Assuming a gross consumption of 4,400 B.t.u.'s per cubic foot of wood, and a conversion ratio of 6 board feet per cubic foot, the heat required would be about 733,000 B.t.u.'s per thousand board feet of logs. At an operating cost of 1 cent per 12,000 B.t.u.'s, for steam or hot water heating, the cost of the energy consumed in heating a thousand board feet of logs would be about 60 cents. Based on power consumption measured in Laboratory experiments, about 120 kilowatt-hours are required per thousand board feet of logs heated by the electrical method. At a cost of 1 cent per kilowatt-hour, the electrical cost would be about $1.20 per thousand board feet of logs. The estimates do not include the cost and depreciation of capital invested in steaming chambers, vats, or electrical equipment.

A recent study of the value of the face-grade veneer recovered from heated bolts compared to the cost of heating conducted by the Oregon Forest Products Research Center showed that the value of the veneer was increased approximately 10 times the cost of presteaming the Douglas-fir bolts (2).
The basic methods of determining schedules when heating in steam or hot water are given by MacLean (13). A simplified but comprehensive method of determining schedules for veneer bolts was reported by Fleischer (10). Heating schedules for Douglas-fir bolts depend primarily on the heating method, the diameter of the bolts, the original bolt temperature, and the desired final temperature at the core. Tables 1 and 2 were developed from MacLean's data to illustrate how these factors will affect the required heating time. Table 1 applies to bolts 2 feet in diameter and table 2 to bolts 3 feet in diameter, heated in steam chambers.

A suggested heating temperature for Douglas-fir is 180° F. For best results, the bolts should be heated until the cores reach at least 120° F. Assuming a core diameter of 6 inches, table 1 indicates that a bolt 2 feet in diameter and with an initial temperature of 50° F. should be heated at 180° F. for approximately 24 hours. From table 2, assuming the same conditions, a bolt 3 feet in diameter should be heated for about 55 hours.

From a practical standpoint, these schedules might be approximated by segregating the logs into several diameter groups, the smaller logs or bolts to be heated for 1 day and night, and the larger ones 2 full days.

The ideal condition would be to have a uniform temperature of 160° F. throughout the bolt at the time it is cut. Bolts heated as just outlined will have a temperature of 180° F. on the surface and about 120° F. at the core. A more uniform temperature would be obtained by turning off the steam to the vats at the end of the suggested heating period and allowing the bolts to remain in the warm steam chambers for several hours more. The outer (sapwood) portions of the bolts will cool, while the centers continue for a time to increase in temperature from heat stored in the bolt.

Heating in water requires about 5 to 10 percent more time than the periods listed in tables 1 and 2.

Since bark is a good insulator, its removal before heating bolts in hot water or steam is advantageous. Bark, however, should be left on bolts heated electrically to prevent drying and checking of the sapwood.
(1) Anonymous

(2) Atherton, G. A., and Grantham, J.

(3) Batey, T. E., Jr.

(4) Fiehl, A. O.

(5) Fleischer, H. O.


(8) and Lutz, J. F.

(9) and Downs, L. E.

(11) French, George E.
1958. The Challenge Before the Lumber and Plywood Industries.
Forest Products Journal, Vol. 8, No. 4.

(12) Lickess, C. W.

(13) MacLean, J. D.


(16) Plath, Eric, and Plath, Lore
Table 1.—Temperature in Douglas-fir bolts 2 feet in diameter and 8 feet long after heating for various times in steam or air-steam mixture

<table>
<thead>
<tr>
<th>Heating time (Hr.)</th>
<th>Temperature at distance from circumference of—</th>
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ORIGINAL BOLT TEMPERATURE, 70° F.; STEAM TEMPERATURE, 212° F.

| 16.5 | 200 | 188 | 176 | 164 | 152 | 142 | 134 | 126 | 120 | 116 | 112 | 110 |
| 25   | 204 | 196 | 188 | 180 | 172 | 165 | 158 | 153 | 148 | 145 | 143 | 142 |
| 33   | 206 | 200 | 195 | 190 | 185 | 180 | 176 | 172 | 168 | 167 | 166 | 165 |
| 41.5 | 210 | 206 | 202 | 198 | 194 | 191 | 188 | 186 | 184 | 182 | 181 | 180 |

ORIGINAL BOLT TEMPERATURE, 50° F.; STEAM TEMPERATURE, 212° F.

| 16.5 | 198 | 184 | 170 | 156 | 143 | 132 | 122 | 114 | 108 | 102 | 97  | 95  |
| 25   | 202 | 192 | 183 | 174 | 165 | 156 | 150 | 144 | 139 | 135 | 133 | 132 |
| 33   | 205 | 198 | 192 | 186 | 180 | 175 | 170 | 165 | 161 | 159 | 158 | 157 |
| 41.5 | 210 | 205 | 200 | 196 | 192 | 188 | 185 | 182 | 180 | 178 | 177 | 176 |

ORIGINAL BOLT TEMPERATURE, 50° F.; AIR-STEAM TEMPERATURE, 180° F.

| 16.5 | 168 | 157 | 146 | 136 | 126 | 116 | 107 | 100 | 96  | 92  | 88  | 86  |
| 25   | 174 | 166 | 158 | 150 | 143 | 136 | 131 | 126 | 122 | 118 | 116 | 115 |
| 33   | 176 | 170 | 165 | 160 | 155 | 150 | 146 | 143 | 140 | 138 | 136 | 135 |
| 41.5 | 178 | 174 | 170 | 166 | 163 | 160 | 158 | 156 | 154 | 152 | 151 | 150 |

ORIGINAL BOLT TEMPERATURE, 50° F.; AIR-STEAM TEMPERATURE, 150° F.

| 16.5 | 142 | 133 | 124 | 115 | 107 | 100 | 94  | 88  | 84  | 81  | 79  | 77  |
| 25   | 144 | 138 | 133 | 127 | 121 | 116 | 111 | 107 | 104 | 102 | 101 | 100 |
| 33   | 146 | 142 | 138 | 134 | 130 | 127 | 124 | 121 | 118 | 117 | 116 | 115 |
| 41.5 | 148 | 146 | 143 | 140 | 137 | 135 | 133 | 131 | 130 | 129 | 128 | 127 |

The temperatures listed are for the midsection. The temperatures near the ends of the bolts would be higher.
### Table 2.—Temperature in Douglas-fir bolts 3 feet in diameter and 8 feet long after

heating for various times in steam or air-steam mixtures

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**ORIGINAL BOLT TEMPERATURE, 50° F.; AIR-STEAM TEMPERATURE, 150° F.**

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—The temperatures listed are for the midsection. The temperatures near the ends of the bolts would be higher.
Figure 1. Appearance of 6- by 6-inch plywood test specimens after 2 cycles of soaking and drying. The pieces on the left made from relatively smooth veneer have not delaminated. Those on the right made of rough veneer have pronounced delamination.
Figure 2. --Effect of heating on depth of knife checks. The scarfed veneers on the left are sapwood, those on the right, heartwood. The bottom two samples were cut from a bolt at 59°F., the center two from a bolt heated electrically to about 140°F., and the top two from a bolt heated in water to about 160°F.
Figure 4. -- An illustration of the use of spacers to improve circulation in a steam chamber.
Figure 5. --A method of injecting steam into a heating chamber to promote uniformity of temperature. This is the method used in the chambers shown in figure 3.
The following are obtainable free on request from the Director, Forest Products Laboratory, Madison 5, Wisconsin:

List of publications on Box and Crate Construction and Packaging Data
List of publications on Chemistry of Wood and Derived Products
List of publications on Fungus Defects in Forest Products and Decay in Trees
List of publications on Glue, Glued Products and Veneer
List of publications on Growth, Structure, and Identification of Wood
List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products
Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen

List of publications on Fire Protection
List of publications on Logging, Milling, and Utilization of Timber Products
List of publications on Pulp and Paper
List of publications on Seasoning of Wood
List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components
List of publications on Wood Finishing
List of publications on Wood Preservation
Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

Note: Since Forest Products Laboratory publications are so varied in subject no single list is issued. Instead a list is made up for each Laboratory division. Twice a year, December 31 and June 30, a list is made up showing new reports for the previous six months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. Each subject list carries descriptions of all other subject lists.