

# Demonstration of the In-Service Shrinking and Swelling Properties of the Wood of Western Juniper (*Juniperus occidentalis* Hook.)

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## Introduction

Manufacturers and users of western juniper (*Juniperus occidentalis* Hook.) have reported panel-cracking<sup>1</sup> and splitting<sup>2</sup> during manufacturing trials and in typical use environments. Inspection of the broken and unusable panels showed radially oriented cracks, the common orientation of normal seasoning checks<sup>3</sup>. It is highly probable that loss of moisture from the green-sawn lumber was responsible for some of the checks seen in both lumber and in the remanufactured panels. Often overlooked, however, is the potential for checking to develop in previously-dried wood that is allowed to cycle through a wide range of moisture contents. The objective of this project was to document and exhibit the effects of moisture-content cycling on the integrity of sample pieces using solid, fingerjointed, edge-glued, and edge-glued fingerjointed stock.

## Methods and Materials

Lumber used for the demonstration study was green-sawn and dried in two locations: Sycan Forest Products, Dairy, Oregon, late summer, 1993 (steam-kiln dried in Klamath Falls), and at the University of Montana School of Forestry's sawmill at the Lubrecht Experimental Forest in Missoula, MT., January, 1994 (air-dried in a heated laboratory, where the Sycan lumber was also stored, to approximately 10% moisture content prior to use).

The sawn trees came from two different lots:

1. The lumber sawn by Sycan was part of a short production run to test the marketability of

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<sup>1</sup> Crack is defined as a separation of the wood either at any angle to the grain. Cracks may be the result of seasoning checks (see footnote #2), ring shake (see footnote #3) or mechanical damage.

<sup>2</sup> Split is any separation of the wood parallel to the grain, often extending through the thickness of the piece. A split does not necessarily lie in either the radial or tangential anatomical planes. The terms split, crack, check and shake are often mistakenly interchanged.

<sup>3</sup> Checks are separations of the wood normally occurring across (radially) the rings of annual growth, and generally are the result of the wood's loss of moisture content during drying.

the species and harvested southeast of Klamath Falls, Oregon, in the summer and early autumn of 1993. Trees were growing mixed with ponderosa pine (*Pinus ponderosa* Laws.) on what is anecdotally reported by land managers to be productive sites for western juniper. Trees varied in diameter-breast-height from 12 to 16 inches, and 40 to 60 feet tall.

2. The lumber sawn at the School of Forestry came from part of a collection of 39 trees from throughout the range of western juniper in California and Oregon that were to be used in a project to determine the mechanical properties of the species.

The principal criterion for lumber used in the demonstration study was that it be free of checks, shakes<sup>4</sup>, warp and other drying-related defects. Lumber used for test samples exhibited ring counts of approximately 15 to 20 rings-per-inch, with lumber having exceptionally wide and narrow growth rings excluded. Pieces that were totally sapwood were difficult to obtain from the material available, so test samples were made up entirely of heartwood or mostly heartwood and a small amount of sapwood.

Knots up to 2.5-inches in diameter and bark pockets around small (1/4" dia.), live and dead limbs up to 1-inch in width (measured perpendicular to the long axis of the board) were allowed in the demonstration. Unsound wood was generally not allowed in any of the samples, except for small (<1" diameter), widely-spaced pockets of stringy, white pocket rot. Wane was not allowed inside a fingerjoint or in an edge-glueline. No distinction between the Sycan and Forestry School-produced lumber was made in the demonstration.

This demonstration used eighteen-inch long panels of three thicknesses (0.375, 0.750 and 1.5 inches) and three widths (3, 12 and 24 inches) and three types (solid, edge-glued and edge-glued and fingerjointed), with the panels were constructed accordingly: All three thicknesses of the 3 inch-wide panels were either 1-piece or fingerjointed; all three thicknesses of the 12 inch-wide pieces were edge-glued from 3 or 6 inch-wide solid or fingerjointed stock, while all three thicknesses of the 24 inch-wide pieces were edge-glued from 3 or 6 inch-wide solid or fingerjointed stock. Three replications of each panel type, width and thickness resulted in 54 panels for evaluation.

Fingerjointed stock was prepared on an industrial fingerjointing machine at a Missoula window plant. Catalyzed, polyvinyl, water resistant adhesive was used in the fingerjoints, and cross-linking polyvinyl acetate adhesive was used for the edge-glued joints. After lay-up and adhesive curing, all panels were surfaced to nominal thicknesses of 0.375", 0.750" and 1.500".

Moisture content cycling was accomplished by placing panels in the warm and wet ( $\approx 120^{\circ}$  F; 95-100% RH) environment of a steam room, heated with saturated steam, for several hours, and then drying in the hot and dry ( $\approx 160^{\circ}$  F;  $\approx 20\%$  RH) environment of a dry sauna. After 5 moisture cycles and final

<sup>4</sup> Ring shake is a separation of growth rings in the tangential direction (perpendicular to the radial), extending along the grain for indeterminate distances and sometimes encircling the pith.

evaluation, the panels were finish-sanded to remove most water stains from condensation and overspray, and to smooth the raised grain.

Since grain orientation and deviation caused by plane of sawing, knots and other stem anomalies were not controlled (as would be the case in a factory production setting), the radial and tangential movement values were only obtained from monitoring individual, 3 inch-wide solid pieces. Coefficient of radial and tangential movement values (Table AI-1) were based on eighteen (18) 3"-wide panels whose grain orientation was appropriate for exact measurements (either quarter- or flat-sawn).

Shrinking and swelling behavior for the thirty-six (36) 12"- and 24"-wide panels were qualitatively assessed through observations of warping, delaminating and checking; and are recorded in Table AI-2.

## Results

### Quantitative Measurements

Quantitative evaluation through direct measurement (see Appendix I for detailed data records) revealed that western juniper showed moisture-caused dimensional changes in service (movement) values lower than most western North American woods and approximately equivalent to the values listed for eastern redcedar, *Juniperus virginiana* (see Figures 1 and 2). Table AI-1 lists the dimensional change coefficients for western juniper and other woods of interest. The coefficients, listed for both the tangential and radial directions, have units expressed as a positive or negative change in dimension (in. / in. of width) / 1% change in dry-basis moisture content (wt. H<sub>2</sub>O/ wt. of wood). When used with the following formula, these coefficients can be used to predict the approximate sizes of lumber at moisture contents between 6% and 14%.

$$DD = D_I [C_{T \text{ or } R} (M_F - M_I)] \quad [\text{Eq. 1}]$$

where:

DD	=	change in dimension.
D <sub>I</sub>	=	dimension in inches or other units at start of change
C <sub>T or R</sub>	=	dimension change coefficient for tangential or radial directions
M <sub>F</sub>	=	moisture content (percent) at end of change
M <sub>I</sub>	=	moisture content (percent) at start of change

### Qualitative Measurements

Table AI-2 shows the summary of qualitative evaluations of wide panel products during moisture cycling. Fingerjointing, and its inherent mixing of grain patterns, was an effective method of limiting

many of the effects of defects likely to show up in panels of solid western juniper. Warping (cup), was nearly eliminated with fingerjointing, as were splits and surface checks extending through the panels, from face to face. Shake was not perceived to be a problem in either panel type.

Panel thickness appears to have had a significant effect on surface checking and warp. The two thicker panels exhibited more defects than the 3/8" panel, as the larger volume of wood appears to generate larger stresses, resulting in more defects related to moisture content cycling.

The large ray volume (based on informal microscopic study) of western juniper seems to have been responsible for an inherent weakness in the radial plane. This was especially apparent in relatively thin, wide panels where seasoning checks, both visible and those that had closed and were invisible to the naked eye, allowed bending stresses to concentrate at the ends of the checks and cleave the wood in the relatively weak radial plane. Splits generated by seasoning were nearly all perfectly aligned in the radial plane.

The results of the qualitative review of the wide-panel moisture cycling demonstration show that the fingerjointed and edge-glued panels maintained their glue-line integrity, with no exhibited delaminations recorded. Seasoning checks that were present prior to the cycling demonstration were noted and monitored, with most increasing slightly in size after the initial drying below 3% MC. Subsequent cycling did not appear to enhance the checks, or any warps that developed during the first cycle.

Knots appeared to be the most adversely affected during cycling, with increasing check size seen for the first three of the five cycles. It must be noted, however, that the checks did not extend into the body of the panels, and stayed confined to the limits of the limb wood. Live knots exhibited the largest checks, while the encased, or black, knots generally loosened during the first cycle and remained loose throughout the demonstration. Few, however, fell out of the panels.

### **Juniper/Pine Mixed Fingerjoint Trial**

In a related "side experiment", 1.5-inch thick x 3.675 -inch wide western juniper blocks, with relatively high (20-25%) moisture contents, were mixed with both kiln-dried (8-10% MC) and partially air-dried (20-25% MC) ponderosa pine blocks, fingerjointed, and the 8-foot long composite sample boards placed in a laboratory with an equilibrium moisture content of 8%. After two months, the sample boards, most with large round or spike knots on the wide face, were warped and/or shrunken appreciably, and were rendered unusable. Twist, crook and bow were the three most common defects, with radially-oriented seasoning checks readily visible. The pine blocks appeared to have not contributed to the degrade, but continued drying without much checking or warping. It was also observed that checks in blocks of both species rarely crossed fingerjoints from one piece to another. While expected, this ability of the joint to "stop" the check is a major benefit of fingerjointed wood products.

Fingerjoint geometry for the western juniper lumber was the same as that used for ponderosa pine and

was found by the window plant's general manager to be adequate. It was his opinion that the joint could be improved on by "loosening" the joint slightly, in order to prevent the joints from opening during curing. The "too-tight" joint seen in most of the juniper panels is characterized by a small gap between the tip of the finger and the bottom of its pocket on the adjacent piece. The fingerjoint machine operator reported that second-growth ponderosa pine (a.k.a. "bull pine") often exhibits the same tendency to produce "too-tight" joints. The gap is caused by the fingers springing away from or being compressed by the cutterhead and not being machined to the proper dimensions. Although less than 0.003" is involved, a small, critical adjustment in the cutterhead is all that should be needed to close the gap and produce better joints at the same rate as ponderosa pine and Douglas-fir.

The same operator stated that longer end-clamping time would help keep the pieces from "backing out" or "backing away from each other" and that the tackiness of the adhesive could be increased to increase the friction in the joint during curing, preventing adherend movement. The operator felt that the best solution would be to alter the cutterhead and "loosen" the joint. She also thought that this loosened joint should still work with the ponderosa pine, and would allow the two species to be mixed during production when needed. This ability to mix species during fingerjointing operations is quite important to manufacturers looking to utilize western juniper while still using ponderosa pine.

## **Eastern Redcedar/Western Juniper Comparative Observations**

A unique opportunity presented itself during this study to grossly compare western juniper characteristics with eastern redcedar (*Juniperus virginiana*) (Leavengood and Swan, 1994)<sup>5</sup>. Generally, western juniper has more and larger knots, bark pockets, decay pockets, and a wider sapwood band. Also, the grain of eastern redcedar boles observed in mill yards appeared less twisted than western juniper.

In addition, a defect showed up in eastern redcedar slats produced from green cants which has not yet been observed in western juniper. According to some eastern redcedar secondary manufacturers, light-colored specks or streaks in the heartwood (included sapwood) are sometimes the location of small ring shakes, which manifest themselves as "breaks" in the surface of the slats when clear finish is applied. It is unknown whether the surface cracking observed in western juniper glued panels, and which was a primary stimulus to this study, is in any way related.

## **Conclusions**

- 1. Severe moisture content cycling does not usually generate checks or cracks in properly seasoned and equilibrated panels.**

<sup>5</sup> Leavengood, Scott and L. Swan. 1994. Summary of Missouri eastern redcedar industry study (September 26-29, 1994). Unpublished report. On file USDA Forest Service, Winema National Forest, Klamath Falls, Oregon.

2. The mixed grain orientation of the fingerjointed panels minimizes the additive effects of shrinking and swelling during moisture content cycling.
3. Wider panels have more shrinking and swelling-related defects than do the narrower panels.
4. Knots have a greater detrimental effect on shrinking and swelling performance than do bark-lined voids around small, dead limbs of the same external dimensions.
5. Knot size is directly related to knot checking, with larger knots exhibiting larger checks, that also increase in size during cycling.
6. Fingerjoints and edge-glue lines remained intact during the cycling.
7. The coefficients of radial and tangential dimension change,  $C_T$  and  $C_R$ , show western juniper to be equal or more stable than other Pacific Northwest gymnosperm species such as Douglas-fir, ponderosa pine, western redcedar and incense cedar (see Figures 1 and 2).
8. Western juniper and eastern redcedar, members of the genus *Juniperus*, have similar physical properties, including shrinking and swelling.

## Implications for Industry

1. Western juniper displays roughly one-half the shrinkage exhibited by Douglas-fir, 60% of that of ponderosa pine, 80% of that of incense-cedar, and about the same as that of eastern redcedar. The equation for determining Coefficient of Dimensional Change (DD) is especially helpful in estimating the range of sizes a particular piece will attain when wetting or drying in normal use.

Taking a severe case for example, the approximate shrinkage in width of a 6.00 inch-wide flatsawn western juniper board dried from 12 to 6 percent can be estimated using equation 1 and the " $C_T$ " for solid wood found in Table AI-1 of this report. Substituting the value 0.00155 for " $C_T$ ", and the desired moisture contents in the equation yields:

$$\begin{aligned}
 DD &= D_I [C_{T \text{ or } R} (M_F - M_I)] \\
 &= 6.000'' [0.00155 (6-12)] \\
 &= 6.000'' [0.00155 (-6)] \\
 &= 6.000'' [-0.0093] \\
 DD &= -0.056''
 \end{aligned}$$

To find the width at 6% MC, add the dimensional change of -0.056" from the width at 12% MC.

Thus;

$$\begin{aligned}D_{\text{Final}} &= D_I + DD \\ &= 6.000'' + (-0.056'') \\ D_{\text{Final}} &= \underline{5.944''}\end{aligned}$$

2. If seasoning checks, however small, are present in the stock before cycling, they will cause a reduction in the bending-moment resistance of the wood in the radial plane. Products that utilize wide solid and edge-glued panels and that can be stressed (table and case tops, chair bottoms, case sides, drawer parts) across the grain will be particularly sensitive to this reduction in strength. Careful inspection of raw material is critical for these applications.
3. Moisture content cycling (rotation from steam room to sauna) did not generate new checks in previously-dried, check-free wood. Properly dried western juniper in normal interior and exterior service should not present checking-related problems. Furniture and drawer components are clear possibilities for use of this species.
4. In terms of checking and shrinking and swelling, both fingerjointed and edge-glued panels performed as well as or better than the solid material. For example, if western juniper is used as slats in outdoor furniture, small cracks from checks or ring shake could lead to splitting. If fingerjointed material is used, however, the end joints would prevent extension of the crack. For the same reason, use as underlayment for veneered panels and "blockboard" appears to be a good potential product for western juniper. This example also highlights the importance of careful inspection for checks and shakes in one-piece members to be used in outdoor furniture,
5. Knots have a greater effect on checking and panel behavior than do bark-lined voids of the same size. This is probably due to the lower density of the wood surrounding the voids, as well as less radical grain deviation than that seen around knots. Making pallet parts from western juniper boards containing these voids may be a good way to utilize the lower visual quality material.
6. Moisture content cycling tests reconfirmed the validity of common practices used in joining wood such as limiting knot sizes and locations in panels, mixing grain patterns and utilization of short and narrow pieces by fingerjointing and edgegluing. No new manufacturing practices will be required to utilize western juniper in fingerjointing, edge-gluing and laminating plants.
7. Problems in machining and gluing western juniper for panel products are not foreseen. Fingerjoint cutterheads adjusted to machine ponderosa pine will most likely be able to produce good joints in western juniper with only minor adjustments in machine set-up and procedures. Proper cutterhead adjustment should allow the mixing of juniper and ponderosa or lodgepole pine throughout the entire fingerjointing and edgegluing process. Panels made from a mix of these species are not noticeably different in appearance from homogenous pine panels.

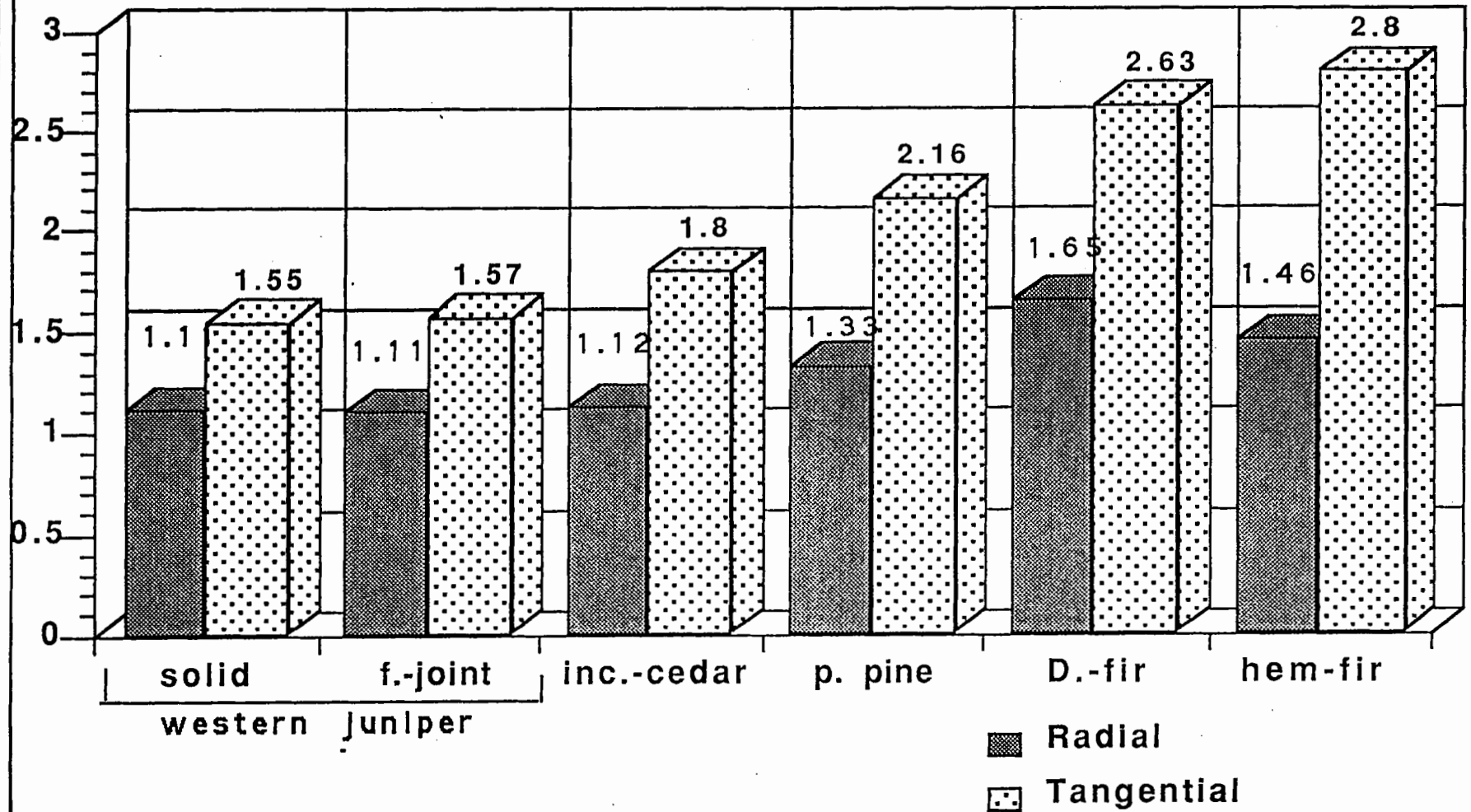
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# Mean Values for Coefficients of Radial and Tangential Dimensional Change

Coefficient of movement, C, in.<sup>-3</sup>/in./1% change in MC



33 465

# Shrinking and Swelling Behavior of Western Juniper and Comparable Species

Coefficient of movement,  $C$ , in.<sup>-3</sup>/in./1% change in MC.

