Processing and Finishing Western Juniper
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&

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"You have to change your mind set about how you work with wood - juniper doesn't like to be treated like alder or oak - you really have to know and understand your raw material, starting with the standing tree." (Mike Connolly, Connolly Wood Products)

Introduction

There are many misconceptions about juniper within the wood products industry.

- "It's really difficult to dry."

- "Kiln-dried lumber is not readily available."

- "It tears up saws and knives."

- "It's a very unstable wood."

- "There are no markets for the wood."

This paper reviews what has been learned in working with juniper over the past five years, and why a manufacturer may want to work with the existing network of juniper manufacturers to develop and expand juniper markets.

Inventory

There are approximately 3.8 million acres of western juniper (*Juniperus occidentalis*) woodlands within its primary range of eastern Oregon, northeastern California, and southwestern Idaho (10% canopy cover or more). About 58% of this acreage is on public lands managed by the Bureau of Land Management, U.S. Forest Service, State, Indian tribes, and other Federal agencies, and about 42% is privately owned. There are literally millions more acres of scattered juniper and areas in which young juniper are just now becoming visible on standard resolution aerial photography.

Western juniper is the least-utilized wood fiber resource in this region. Total woodland volume is estimated to be at least 691 million cubic feet (MMCF). About 39% of the volume is on private lands and 61% on public lands. Volume data, for the most part, do not include western juniper on forested lands which, according to industry, has the best commercial potential because of form and access (Swan 1997).(3)

Western juniper has less than one-tenth the standing volume of red alder (7,436 MMCF), but more than twice as much standing volume as myrtlewood (California-laurel) (297 MMCF). Current western juniper volume estimates rank it fifth among 10 common Pacific Northwest hardwood species (number one is red alder and number 10 is giant chinkapin). Western juniper standing volume estimates are compared to standing volume estimates of 10 common Pacific Northwest Hardwoods in Table 1 (*Selected Pacific Northwest Hardwood*

Growing Stock Estimates Compared to Western Juniper Growing Stock Estimate) (Niemiec et al. 1995).

Land Management Issues and Costs

"I feel like I'm having to buy my land twice due to the costs of beating back the juniper." (Fred Otley, Otley Bros. Ranch, Burns)

The area dominated by western juniper represents a three- to ten-fold increase since the late 1800s. The expansion and increasing densities of juniper woodlands greatly concern private landowners, government land managers, and scientists. Many juniper-dominated sites show clear evidence of watershed degradation, loss of site productivity, decrease in forage production, loss of wildlife habitat, and overall-reduction in biodiversity (Beddell et al. 1993).

Numerous private landowners undertake juniper thinning or clearing operations every year in eastern Oregon and northeastern California, affecting an estimated 5,000 to 10,000 acres per year. Due to lack of demand and markets, as well as economics, the juniper removed is often piled and burnt, or simply left to decompose after being knocked-down or cut (estimated to amount to 1.1 to 2.3 million cubic feet of juniper bole wood per year [(4)]). Government agencies are currently less active in clearing juniper than private landowners, due to concerns about legal challenges and lack of funding for such projects.

Landowner costs for simply knocking trees over with mechanical equipment, a common method used to thin juniper woodlands, average $35-$50 per acre. Manual falling, delimbing, and slash dispersal can run as high as $250 per acre.

Thinning and clearing operations are expected to continue whether or not a commercial industry develops for juniper, and despite a decrease in government subsidies. According to Tom Birch, a Forest Service scientist who summarized data from a national study of forested land owners and their harvest plans, there are probably at least 3,000 ranchers in Oregon and California who plan to thin their juniper woodlands within the next 10 years, at a minimum cost of more than $13 million dollars (Birch personal communication).[(5)]

Historic Use

Although the majority of western juniper harvested over the years has been used for fence posts and firewood, there are reports going back at least 50 years of mills which tried to commercially process the species (Loveness personal communication). The earliest wood products research known to involve western juniper began in 1949, as part of an Oregon State University study of the service life of treated and untreated posts (Miller 1986).[(6)] The research literature also indicates temporary interest in the 1950s for use in composites and extractive oil, and some interest in the late 1970s due to the perception of an energy crisis.

The most successful commercial western juniper operation of any size was a mill owned and operated by Gary Gumpert in Prineville in the mid to late 1970s (five to 10 employees). Primary product emphasis was interior paneling, but other products were made in the course of refining the panel product (such as furniture and mantel pieces). At the time the mill was sold, about one-third of the production was juniper and the remainder incense cedar (Gumpert personal communication in Swan 1996).

Probably the greatest use of juniper over the last 10 years has been as a source of fuel for power generation. In the early to mid-1990s, at least a thousand acres of juniper woodlands in Northeastern California were harvested for power generation biomass (Ward personal communication). Power generation markets for juniper have virtually disappeared over the last several years though, due to changes in laws governing alternative power purchases.

Western Juniper Commercialization Status

There has been a steady increase in manufacturer interest in western juniper and market trials since around 1992, due mainly to a few committed companies, a limited amount of financing from the Oregon Regional Strategies Program, and leadership of the ad hoc Western Juniper Commercialization Steering Committee. Serious market interest has been confirmed for chips, sliced veneer, logs for log homes, landscape timbers, decking, flooring, interior paneling, doors, cabinetry, rustic furniture, store displays, picture frame moulding, and miscellaneous gifts and accessories. There are between five and 10 "cottage industry" size (fewer than two employees) and one medium-size manufacturer (about 10 employees) who consistently use juniper for value-added products, and twenty or more who do so for custom orders.

Although juniper lumber production is small by normal industry standards, the growth curve looks good. There are currently five to 10 portable mills and one medium-size mill which cut juniper on a special order or custom basis. Total aggregated lumber production at this time is estimated to average 15 to 20 MBF (thousand board feet) per month. Total combined capacity and interest far exceeds current orders (for example, if maximum daily output for most of the portable mills is around 2 MBF and maximum daily output of the medium-sized sawmill is around 20-25 MBF, there is at least 440 MBF capacity).

Kiln-dried juniper lumber inventory and availability continue to improve. Currently, truckload quantities of kiln-dried lumber are available on a 30-45 day turnaround basis. Depending on specifications, there is normally sufficient inventory to ship thousand board foot-units within days of receiving an order.

Harvest

"If it was easy, someone else would have figured this out long ago." (Walt McGee, 4-Mac Industries)

One of the biggest barriers to commercial use of juniper is harvest costs. Juniper trees have numerous and large limbs, average volume per acre is much less than current commercial species (such as ponderosa pine or fir), terrain is often rocky, and road systems are primitive. The cost of harvesting juniper with a conventional system (rubber-tired skidders and chainsaws) is probably at least twice that of pine or fir ($30 to $35 per green ton for juniper versus $15 to $20 per green ton for lodgepole pine or white fir) (Swan 1997).

On the other hand, stumpage is rarely paid. Many landowners (not all) will consider exchanging logs for assistance in thinning their juniper woodlands. On the rare occasion when stumpage is paid, it is normally only for sawlog-quality material and averages $5 per green ton or less.

Most standing juniper will not make saw logs. Some estimate that no more than 20% of the total volume can be sawed using current technology (Swan personal observation). Sites vary greatly though - some parcels may average 60% to 80% saw logs and others have no saw log-quality trees. Most landowners want their woodlands thinned, not "high-graded". Harvesters are often required to dispose of material either by piling and burning or, if the landowner is well-informed about the "best science available", by scattering at least a portion of the slash.

Log sort criteria are in draft form and should be available within the next three months (see contact information at beginning and end of this paper).

Primary Breakdown

"Big is not necessarily beautiful, and old does not equate with better quality material." (Howard McGee, 4-Mac Industries)

Contrary to industry stereotypes, juniper can be debarked with a variety of debarkers (chips average less than 2% bark content) and saw wear has not been an issue, at least in the production runs monitored. According to one former incense-cedar sawmill sawyer: "It holds together on the carriage better than incense-cedar." (W. McGee personal communication).

In order to optimize recovery, primary processors have to work with harvesters to institute log sort criteria in the woods. For example, many juniper have butt rot or pencil rot, deep barks seams, and/or large butt swell. If there are not viable chip or hog fuel markets, it is a waste of time and money to haul many of these logs to a mill. Larger juniper (20+ inches at the butt) also tend to have more defect than smaller juniper (12- to 20-inches at the butt).

A rudimentary recovery study conducted at 4-Mac Industries (Dairy, OR.) indicated that in terms of fencing grades, significantly better grade recovery was obtained from smaller diameter logs (12- to 18-inches at the butt) (Swan 1993). A rough rule-of-thumb for primary breakdown of sawlog-quality juniper is about five green tons per 1 MBF lumber tally.

"Old growth" should not be an issue for this industry. The vast majority of juniper are less than 100 years old (probably 95%). "Old growth" juniper also tends to be limby and full of rot. "Old growth" trees are recognizable in the field by their complex limb structure and location in fire-resistant areas, such as rocky ridges, flats, or benches. Some scientists consider any tree over 140 years "old growth" because there is such a sharp break in the stand structure at that age. Artisans may use pieces of "old growth" for architectural accents, furniture, or art pieces, but in comparatively minute quantities.

Draft lumber grading rules are being developed. These grades will be based on appearance, not structural properties. Contrary to hardwood grading rules, juniper will be graded from a "sound, tight-knot" basis rather than "clear cuttings". Prices should be similar to the current red alder pricing structure.

Drying

"Juniper gives off moisture readily and poses no extraordinary problems for well-trained kiln operators." (Mike Milota, Oregon State University)

A common industry stereotype is that juniper is difficult to dry. During the last five years, hundreds of thousands of board feet have been dried in a variety of kilns including three different steam kilns, a dehumidification kiln, a vacuum kiln, a solar kiln, and a radio-frequency dryer (sliced veneer). No problems were encountered when drying juniper by itself. Milota notes (in Leavengood and Swan 1997) that, similar to other species, the presence of pith and knots greater than one-half inch will increase potential for splitting, checking, and warp.

Juniper can be successfully kiln-dried with pine, however, minor modifications of pine drying schedules are needed to prevent over-drying. Tests also indicate that juniper air-dries well. Air-dried material needs to be carefully prepared (e.g. trim all bark) to reduce the possibility of wood borers (Leavengood and Swan 1997).

Manufacturers who are just starting to work juniper frequently forget to use a correction factor with their moisture meters, or end up using the wrong one (such as for another species). Western juniper (0.44 specific gravity) is denser than alder or pine (0.41 specific gravity), and moisture meters set for other species can be off as much as 2% to 3%.

Secondary Processing

"You have to treat this wood differently than pine, alder, or oak." (Mike Connolly, Connolly Wood Products)

According to Mike Connolly (Connolly Wood Products, Bend), primary and secondary manufacturers have to change their thinking to work with juniper. For example, although there are exceptions, the primary processor needs to think in terms of eight-foot log segments and the secondary processor should be thinking in lengths of

four-foot or less. The reasons for this go back to limb structure and size of limbs, maximizing recovery and quality, and the economics of logging and processing material which should go to a fiber application, not boards.

Based on Connolly's experience, secondary manufacturers should avoid "high-speed metal and heat". "Resawing, sanding, and shaping appear more effective than moulders and planers." According to Mark Hanson (Hanson Designs, Portland), a wood products designer and custom furniture maker: "Juniper shapes like butter and is easy to sand."

"This is one of the best and easiest woods I have ever refinished." (Eddie Voskanian, Jones Refinishing)

Manufacturers report no difficulty with fillers, glues, or finishes. According to one furniture refinisher, juniper is about the easiest wood he has ever worked with because of its even absorption (Voskanian personal communication). There are, however, scattered reports of at least one commercial filler that discolors the wood and problems with using only one-coat of very thin varathane finishes (wood around knots tends to absorb more finish - simply follow finish manufacturer product instructions) (see technical updates in *Western Juniper Newsletter*, Summer, 1996 and 1997).

Marketing

Juniper is being sold into 11 main markets or distribution channels:

- Firewood and posts/poles;

- Chips;

- Animal bedding (expected to come on line summer, 1998);

- Green and air-dried, unfinished "farm" lumber;

- Kiln-dried, surfaced lumber;

- Log cabins and doweled logs/furniture stock;

- High-end, natural-form rustic furniture and architectural accents;

- Rustic, roundwood furniture;

- High-end, rustic and traditional furniture;

- Gifts and accessories, and store displays;

- Doors, cabinets, flooring, and millwork;

There are at least 35 companies or individuals who manufacture juniper products for these markets on at least a custom-order or part-time basis (includes both primary and secondary manufacturers). Of these 35, probably five to 10 use juniper almost exclusively; and none have juniper sales exceeding $250,000 per year. The marketing emphasis for log/lumber products has changed during the last couple of years from commodity products (e.g. fencing and decking) to specialized niches (e.g. gifts and novelties, architectural accents, store displays, and custom log and timber frame homes).

The secondary manufacturer with the most experience and investment in juniper is Connolly Wood Products

(Bend). Mike Connolly has personally manufactured at least 14 different product lines using juniper. These include: 1) Wall and ceiling paneling; 2) Wainscot; 3) Flooring; 4) Decking; 5) Railings; 6) Stair systems; 7) Mantles; 8) Moulding (base, casing, and crown); 9) Gifts and accessories (boxes and awards); 10) Plywood; 11) Cabinets; 12) Doors (interior passage and entrance); 13) Store displays; and 14) Furniture. He reports that his current best lines are doors, cabinets, and traditional furniture.

"The wood was remarkably stable during severe solid panel shrink/swell tests." (Ed Burke, Wood Scientist)

Western juniper has a number of unique or special characteristics which may prove useful for product line and market development. A partial list includes:

- Appearance and Feel - The wood is often richly colored with dramatic heart and sapwood differentiation. Once finished, it is often characterized by end-users as "sensual". Swirling grain patterns, created by numerous knots and bark pockets, suggest potential for both traditional and rustic product lines.

- Fragrance - The wood is aromatic and offers the perception of moth-repellent characteristics similar to eastern redcedar (*Juniperus virginiana*), a closely related species.

- Machining Characteristics - As one manufacturer states, "juniper machines like butter and surfaces well" (Hanson personal communication). Light sanding is often all that is necessary to finish a piece after thin band resaw.

- Physical Characteristics - Juniper is significantly more stable in shrink/swell tests than other commonly-used Pacific Northwest species, such as Douglas-fir and ponderosa pine, and most hardwoods (Burke 1994d). The wood bends well and holds its form, similar to beech, birch, and ash. It is also denser and harder than ponderosa pine and red alder (Burke 1994a, 1994e, and 1994f).

- Other Manufacturing Characteristics - The wood glues well and finishes well with a variety of commercial lacquers and common consumer finishes. Joinery results are similar to other species and it has excellent nail withdrawal strength (Burke 1994b and 1994c). Juniper generally does not split without lead holes or near ends of boards.

- In-Service Below-Ground Durability - The results of a long-term fence post service life study conducted by Oregon State University (Miller 1986) indicate that the heartwood of western juniper is more durable than any other Pacific Northwest species.

- Wood and Leaf Oil Properties - Tests in progress at Oregon State University indicate that western juniper wood and leaf oil may offer a competitive advantage for animal bedding and a few specialty markets.

The unique characteristics of juniper also may constrain fabrication techniques and potential product line development. These include:

- Numerous Knots and Grain Differentiation - What makes juniper beautiful also makes it difficult to maintain consistent quality using standard, commodity-oriented manufacturing techniques. It is difficult to obtain large, clear, solid pieces greater than one-inch thick, four-inches wide, and 18 inches or longer (Hanson personal communication).

Splits Easily Along the Grain - Juniper splits easily along the grain and can chip if a sharp corner or edge is exposed in service. Seasoning checks, even small ones, will continue to propagate during moisture cycling. Severe moisture cycling, however, did not generate new seasoning checks in previously dried wood.

See Table 2 (*Mechanical and Physical Properties of Western Juniper*) for a comparison of western juniper mechanical and physical characteristics with wood commonly-used by Pacific Northwest manufacturers for

value-added applications.

What Does the Future Hold for Manufacturers Interested in Working With Juniper?

There are several reasons why a manufacturer may want to invest time and money into developing markets and product lines made from juniper:

- Special and Unique Characteristics - The special and unique characteristics mentioned above may offer a competitive advantage and increased profits in niche markets;

- Groundfloor - Where were you when alder was still considered a "trash tree" by industry? This may be an opportunity to get in on the groundfloor of an industry, albeit smaller.

- Ecologically Beneficial - When were you last on the "green" side of the environmental debate? Most of the raw material for the juniper industry will come from rangeland habitat restoration projects. Private landowners, landowner associations (for example, Small Woodland Association and Oregon Cattleman's Association), and government land management agencies very much want to work with private industry to find ways to rehabilitate areas which are now woodlands and lower management costs;

- Access to Cooperative Networks and Assistance - An ad hoc Steering Committee has generated financial and logistical support for juniper commercialization projects, and wants to connect manufacturers with supply and flexible manufacturing networks. The contract of the Western Juniper Industry Facilitator (Bill Breedlove) was extended until June, 1999, because of his success in filling orders and creating flexible networks. Juniper manufacturers are also cooperating to attend and display at targeted trade shows.

- Product Differentiation and Brand Development - Western juniper industry members have adopted an informal policy of maintaining strong product differentiation from traditional "cedars", there is a trademarked logo available for use with juniper products, and products made from juniper link well with Pacific Northwest and "Brand Oregon" marketing campaign assistance and images.

Many major technical issues which normally confront manufacturers who want to work with a new species have been addressed, thanks to financial assistance from Eastern Oregon Economic Development Boards, technical assistance from the U.S. Forest Service and Oregon State University, and over 100 other private and public partners. Several issues though, because of their complexity, will require more time and resources to solve, but are being worked on. These include:

- Harvest Costs - Special techniques and equipment design are needed to significantly reduce costs. These are being worked on, but costs are not going to drop overnight.

- Economies of Scale - The western juniper industry needs higher volume logging and manufacturing operations to obtain economies of scale, and assure consistent supply quantity and quality.

- Marketing - Before higher volume operations can be developed, markets must be identified and entered which will absorb additional volume. A group of private investors is working on a business plan which appears to address both the "economies of scale" and some of the marketing issues (contact Mike Connolly, Connolly Wood Products, for more information).

- Falldown and Residuals - Markets have to be developed for falldown and residuals. On-going work with Oregon State University and the first, whole-log shavings mill west of the Rockies show promise, but it will take time to develop the infrastructure that the wood products industry takes for granted for other species.

Contacts For More Information

Web Sites: There are two western juniper web sites, one for non-commercial purposes and the other for commercial purposes.

Commercial Web Site - www.westernjuniper.org

Non-Commercial Web Site - juniper.orst.edu

Besides the authors of this paper, you may wish to contact:

Bill Breedlove, Western Juniper Industry Facilitator, 2029 Gettle, Klamath Falls, OR. 97603; Phone 541/850-4317; Cell Phone 541/891-4506; FAX 541/884-7472

Scott Leavengood, Oregon State University Wood Products Extension Agent, 3328 Vandenberg Rd., Klamath Falls, OR. 97603; Phone 541/883-7131; FAX 541/883-4582; e-mail

Special Note: If you wish to be added to the Western Juniper Newsletter Mailing List, please contact Scott Leavengood, OSU Extension. If you want to try juniper in your manufacturing process, or explore markets, please contact Bill Breedlove, Western Juniper Industry Facilitator. If you want to work with an existing manufacturer to produce prototypes, conduct field tests, introduce products at a retail level, or enter into joint marketing agreements, contact Mike Connolly (see page one of this paper for contact information).

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1. Larry Swan, U.S. Forest Service, 2819 Dahlia St., Klamath Falls, OR. 97601; Phone 541/883-6714; FAX 541/883-6709; lswan01@fs.fed.us. Return to Document

2. Mike Connolly, Connolly Wood Products, 131 SE 9th St., Bend, OR. 97702; Phone 541/385-8641; FAX 541/385-8697 Return to Document

3. A significant portion of forested lands which have western juniper in their understory are within National Forest System boundaries, and are not included in Pacific Northwest Research Station Oregon and California field sample plots. Return to Document

4. Assuming 10,000 ac./yr. at an average of 225 cu. ft./ac = 2.25 million cubic ft. (cubic foot per acre estimate

provided by Don Gedney, Pacific Northwest Research Station, Portland) Return to Document

5. Key assumption is that ranchers who intend to thin their woodlands over the next 10 years will treat 25% of the average 350 woodland acres/landowner, at a minimum cost of $50 per acre. Return to Document

6. According to Miller (1986), western juniper is the most durable heartwood species in the Pacific Northwest, with an average service life in western Oregon exceeding 30 years. Other species included in the study were Pacific yew, redwood, various cedar species, and Oregon white oak. Return to Document

7. Growing stock is the volume of main stems 5.0 inches DBH and larger, from a 1-ft. stump to a 4-in. top (diameter inside bark) Return to Document

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Selected Pacific Northwest Hardwood Growing Stock Estimates Compared to Western Juniper (*Juniperus occidentalis*) Growing Stock Estimate(7)

Species	Growing Stock Volume (million cubic feet)
red alder	7436
bigleaf maple	2170
tanoak	1788
Pacific madrone	1067
western juniper	692
California black oak	476
Oregon white oak	463
black cottonwood	458
California-laurel (aka myrtlewood)	297
Oregon ash	184
giant chinkapin	136

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Mechanical and Physical Properties of Western Juniper and Other Commonly Used Woods

Species	Specific Gravity @12% MC	Density (lbs/ft^3) @12% MC	Compression Strength-parallel to grain @12% MC (psi)	MOE-Bending Stiffness @12% MC (Million psi)	MOR-Bending Strength @12% MC (psi)
western juniper	0.44	31	6340	0.80	8940
Coastal Douglas-fir	0.48	34	7230	1.95	12400
ponderosa pine	0.40	28	5320	1.29	9400
eastern redcedar	0.47	33	6020	0.88	8800
incense-cedar	0.37	25	5200	1.04	8000
northern red oak	0.63	44	6760	1.82	14300
red alder	0.41	29	5820	1.38	9800

Species	Hardness @12% MC (lbs.)	Volumetric Shrinkage (%)	Nail Withdrawal Strength (side grain) (psi)	Machining	Gluing	Finishing	Bending
western juniper	626	7.95	197	VG	E	E	VG

Coastal Douglas-fir	710	12.4	184	G	VG	F	F
ponderosa pine	460	9.7	117	VG	VG	G	P
eastern redcedar	900	7.8	175	VG	E	E	?
incense-cedar	470	7.7	96	E	E	E	P
northern red oak	1290	13.7	363	VG	F	F	E
red alder	590	12.6	124	VG	E	?	?

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Specific Gravity- Similar to density. Calculated as the weight of a sample of wood (oven dry) divided by the weight of an equal volume of water. In this instance, the wood's volume was measured when the wood was at 12% moisture content. Another way to look at specific gravity is- If a wood species has a specific gravity of 0.44, then the wood is 44% as heavy as water.

Density- Density of the wood in lbs. per cubic foot at 12% moisture content.

Compression Strength- Answers the question, "How strong is the wood when used as a column, such as a wall stud?". Determined by loading a wood sample as a column and recording the stress (psi) at the proportional limit. The proportional limit is a point on a graph of deformation versus load. The proportional limit is the point at which there is no longer a straight-line relationship between load (lbs.) and the amount the wood column deforms in inches. A low compression strength indicates the wood may crush fairly easily if used as a support column.

Bending Stiffness- Answers the question, "How **stiff** is the wood when bent like a floor joist?". Determined by loading a wood sample as a beam and recording the stress (psi) at the proportional limit. (see discussion of compression strength above for a description of proportional limit). A low stiffness value indicates the wood may be "spongy" or "springy" if not adequately supported in decking. Long, unsupported spans would be unwise for floor joists.

Bending Strength- Answers the question, "How **strong** is the wood when bent like a floor joist?". Similar to bending stiffness, except the wood beam is loaded until it breaks. Note the distinction between stiffness and strength. Stiffness is how easily the wood bends, strength is how much force it takes to break the sample.

Hardness- Answers the question, "How resistant is the wood to wear and marring, such as when used for flooring?". Hardness is measured by recording the amount of force it takes to embed a 0.444 inch diameter ball to half its diameter into the wood. A low hardness value means the wood would dent easily if used in flooring.

Volumetric Shrinkage- Answers the question, "How stable is the wood?". Table values are percent shrinkage from green to ovendry. This value is useful for comparisons to other species. As an example, a ponderosa pine board will shrink, on the average, 9.7% in total volume from green to oven dry. Western juniper will only shrink 82% as much as ponderosa pine. Actual inches of shrinkage in the radial and the tangential direction may be calculated using published shrinkage coefficients.

Nail Withdrawal Strength- Answers the question, "How well does the wood hold a nail?". Measured as the amount of force required to pull a nail from the wood. A low nail withdrawal value would indicate that nails may pop up easily if the wood shrinks or swells or that nailed joints may be excessively weak. Table values for species other than western juniper are estimated using a formula from the USDA's Wood Handbook.

The last 4 properties (machining, gluing, finishing, and bending) in the table are subjective. The table lists those properties as: E (excellent), VG (very good), G (good), F (fair), or P (poor).

Machining- How well does the wood machine? Does the wood tend to burn or chip during cutting, surfacing, and moulding operations?

Gluing- Does the wood glue well? Do chemical extractives in the wood prevent the formation of strong bonds?

Finishing- How easy is it to keep a finish on the surface?

Bending- How well does the wood bend? Does the wood split during bending?

Values for western juniper from Dr. Ed Burke, School of Forestry, University of Montana. Other values are from the Wood Handbook: Wood as an Engineering Material, USDA Forest Service, Forest Products Laboratory, Ag. Handbook #72, 1987.
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