DISCLAIMER

Trade names, commercial brands, and equipment sources and costs mentioned in this report are solely for information. No endorsement by the author is implied.

When considering the use of underutilized species, it is important to understand the limits of the raw material and manufacturing processes, and the expectations and demands of the market. These are common concerns for all types of business structures (small business, cooperative, large company). As a general rule, most of the underutilized hardwoods are high density and will present more manufacturing difficulties than forest grown conifers and the low to moderate density commercial hardwoods. This does not mean that valuable products are unattainable from high-density species, but rather that extra processing steps and great care are necessary. In many situations, the extra effort and care required to deal with these difficulties may not pay for low-value products, but higher-value uses are feasible. Obviously, some species are better suited for particular products than other species. Factors such as ecological concerns, resource availability, cost of production, and quality of the end product are important in determining the long-term utilization potential of these species.

Lumber Drying Principals and Practice

LUMBER DRYING AND QUALITY ASSURANCE

Quality should be a prime consideration every step of the way, from harvesting a tree to drying the lumber (Shelly, 1995). Most California native hardwoods and urban trees present definite manufacturing challenges. However, there are techniques that can be used to minimize the problems and maximize the quality of the lumber produced. The following discussion refers specifically to the manufacture of lumber for high value uses, but many of the same ideas can be applied to the lower value uses. A basic knowledge of wood behavior and processing techniques are important tools to minimize the problems associated with lumber production.

There are many challenges to drying quality lumber. Little experiential knowledge exists for drying many of the species small mills work with. But with an understanding of basic wood properties and proper care good results can be obtained. For example, the same lack of experience exists for many native California hardwoods, and they have a reputation for being hard to dry. However, as discussed by Shelly (1998), techniques exist to increase success in even the most difficult-to-dry species. Density is a good predictor of ease of drying, the magnitude of dimensional change expected in response to changes in wood moisture content, and the potential to warp. The higher density species (specific gravity of 0.5 or greater) are generally more difficult to dry and less dimensionally stable than species with a lower density (specific gravity less than 0.5). The following discussion presents a basic description of drying methods, recommended techniques, and how to minimize drying defects.

The Drying Process
Wood dries naturally and will eventually reach a moisture content (MC) that is in equilibrium with the amount of moisture in the air surrounding it, called the equilibrium moisture content (EMC). In most California locations, air-drying of wood will result in moisture content no lower than 12%. For most interior uses of wood, the EMC of wood should be in the range of 6-8%. To reach these recommended final moisture contents for interior uses, it is necessary to kiln dry the wood. Construction lumber or wood used in exterior environments does not need to be dried to as low a moisture content as interior-use lumber. Green lumber is often used in construction in California and the EMC for exterior uses is in the range of 12-16% in most California climates. Although these moisture contents can be achieved by air-drying, it is often required to kiln-dry for other reasons, such as killing wood boring insects that may be present and solidifying the pitch that is often present in many softwood species.

Controlling Drying Conditions
Energy is needed to evaporate and move water out of wood. Heat supplies the energy and air currents forced through stickered lumber carry the moisture away. The temperature and humidity of the air determine how fast the wood will dry and its final MC. Rapid drying from high temperatures and/or low humidities can cause serious drying defects. Many costly mistakes are a direct result of poorly controlled drying conditions, which can occur in controlled kilns or during air-drying.

Drying schedules and the critical stage
Drying defects occur because stresses are created inside wood as the water leaves and the wood shrinks. If these stresses are large enough, they can cause defects such as checks, honeycomb, casehardening, and collapse. Although most of these defects are not apparent until the wood is nearly dry, they actually begin to develop very early in drying. The critical stage is from the initial green MC (when the lumber is first cut from a fresh log) down to about 25%. When in this critical stage, the drying rate for 1-inch thick lumber should not exceed a 2-3% decrease in MC per day for the high-density species (specific gravity > 0.5). Lower density hardwoods can be dried at a rate of 3-6% decrease in MC per day, and many softwoods can be dried at rates as high as 20% decrease per day. Once the MC reaches about 25%, then more severe drying conditions can safely be used. The actual schedule of air temperature and relative humidity settings recommended for drying wood is influenced by the inherent wood characteristics of a species, lumber thickness, and the type of drying method used. Drying schedules for many of the more common domestic and tropical species are available and serve as a good starting point for developing your own schedule (Boone, et al., 1988). The various steps in a kiln schedule provide the recommended drying conditions based on the MC of the lumber. A schedule is

presented as a series of MC steps. Examples of drying schedules for a high density hardwood species and a low density softwood species are given in **Tables 4** and **5.** To use these schedules, it is necessary to monitor the MC of the wood as it is drying by measuring the MC of sample boards. The target or final MC that the lumber will be dried to is based on the intended use of the lumber. The recommended final MC for most interior uses of wood, including softwoods and hardwoods used for flooring, furniture, cabinets, millwork, etc., is 8%. For exterior uses of wood, the recommended MC is either 15% or 19%.

Kiln schedules are typically based on MC increments (steps) of 5 percent. The last two steps of the schedule, i.e. the equalizing and conditioning steps, are needed to produce high quality lumber. The equalizing step is used to narrow the moisture content range of the wood in the kiln (some lumber dries faster, some slower). It is a 24-hour period in which the final temperature setting of the kiln is maintained, but the relative humidity is controlled at 60% for an 8% final MC and 85% for a 15% final MC. The conditioning step is used to reduce casehardening stresses if they are present in the lumber. It takes from 4 to 48 hours to accomplish this with careful addition of steam to the kiln, maintaining the final temperature of the schedule, and a humidity of at least 80%. This step is necessary for lumber that will be resawn into smaller dimension pieces after it has been dried, but if it is not done properly the wood can be irreversibly damaged. A procedure for monitoring the casehardening stresses is outlined in the Dry Kiln Operator's Manual (Simpson, 1991).

Moisture content step schedules can be converted to schedules based on time once a kiln operator develops a data record from at least 6 different kiln runs with lumber of the same thickness and species. However, because wood from different trees of the same species can dry very differently, it is always a good idea to periodically check a time-based schedule with MC measurements of sample boards. The time required to dry the appropriate species with the following schedules ranges from 4-6 weeks for the hardwood schedule and 4-6 days for the softwood schedule.

Table 4. Drying schedule for a typical western hardwood species (Oregon white oak)

Step	Moisture Content	Temperature	Relative Humidity
1	Above 35% MC (critical zone)	110° F	90%
2	35% to 30% (critical zone)	110° F	87%
3	30% to 25% (critical zone)	120° F	83%
4	25% to 20%	130° F	74%
5	20% to 15%	140° F	46%
6	15% to final MC	160° F	21%
7	Equalize (24 hours)	160° F	60 to 85%
8	Condition (4-48 hours)	160° F	> 80%

Table 5. Drying schedule for a typical western softwood species (Ponderosa pine)

Step	Moisture Content	Temperature	Relative Humidity
1	Above 40% MC (critical zone)	140° F	64%
2	40% to 35% (critical zone)	140° F	54%
3	35% to 30% (critical zone)	140° F	46%
4	30% to 25% (critical zone)	150° F	41%
5	25% to 20%	160° F	36%
6	20% to 15%	160° F	35%
7	Equalize (24 hours)	160° F	60 to 85%
8	Condition (4-48 hours)	160° F	> 80%

Drying Principles and Practice

The basic principle of any drying method is one of energy (heat) and mass (moisture) transfer. It doesn't matter if the heat comes from the sun, a dehumidifier, a steam-heated coil, or some other heat source.

With knowledge of drying principles and adequate control over the drying conditions, quality dry lumber can be produced with any drying method. If long drying times are not a concern, air-drying can be an effective method for the critical drying stage. But remember, even in an air yard the drying conditions can be too severe. A kiln is needed if moisture content lower than 15% is required, or if the wood needs to be heat-treated to kill insects. Any lumber that will be remanufactured into other dimensions needs to be conditioned if casehardening stresses are present. Although it is believed by some that difficult to dry hardwoods must be air-dried before they are put into a kiln, this is generally not the case. All hardwoods can be dried from the green condition in any of the kilns discussed here. The decision to air-dry should be based on an economic analysis of the cost of operating the kiln and the length of time required to keep the lumber in process for the different drying methods. Long inventory times have a negative effect on cash flow as the money is tied up in inventory.

Air-drying

This method is effective if moisture contents less than 15% are not needed, if long drying times are not a concern, and if exposure to extreme temperatures and low humidity is avoided during the critical stage of drying (from green to 25% MC). Drying conditions can be too severe in an air yard. Good results can be achieved if the air temperature is kept below 90_{o} F and the humidity above 80% during the critical stage. In many California regions, these ambient conditions cannot be expected, especially during the summer months. Some control over nature's drying conditions can be attained by taking the following steps:

1. Avoid direct sun exposure on the wood,
2. Position lumber stacks (relative to wind direction) to increase or decrease the amount of air that passes through the lumber stack, and
3. Partially enclose the stack of lumber (with a shed or plastic tarp) to capture some of the moisture given up by the wood and increase the humidity of the air surrounding the wood.

Kiln-drying
Ideally, the drying method should be capable of drying wood to 8% MC, achieving a temperature of 150° F (the temperature required to sterilize insect infested wood), and having a method to reintroduce moisture into the kiln so that casehardened lumber can be conditioned to relieve the drying stresses. A kiln is needed to accomplish these goals. Types of lumber dry kilns available include solar, steam-heated, hot water-heated, dehumidification, vacuum, radio frequency, and microwave kilns.

Drying Defects and How to Avoid Them
Most of the problems encountered in drying are related to stresses that develop during drying. Warp, collapse, honeycomb, and casehardening are drying defects that occur because stresses are created inside wood as the water leaves and the wood shrinks. Although these defects are not apparent until the wood is nearly dry, they actually begin developing very early in drying, during the critical stage (from green to 25% MC).

Warp – Warp is defined as the condition when a piece of lumber or wood no longer is straight and/or flat; the geometry has deviated from the three planes that originally defined the shape. The stresses that cause lumber to warp are a direct result of the inherent differential shrinkage that occurs in wood across the grain, that is, between the tangential (tangent to the growth rings) and radial directions (parallel to the rays). Grain deviation is also a contributing factor to warp in lumber. It can be growth related such as spiral or interlocked grain (e.g. common in blue gum eucalyptus); a result of the sawing method, especially in crooked logs; or, due to the presence of knots. The high degree of grain deviation expected in most urban trees suggests that lumber cut from them would have a tendency to warp. Drying lumber in thicker dimensions or placing a uniformly distributed dead weight restraint on the boards to keep them flat during drying can minimize warp. Also, narrow boards will warp less than wider boards.

A method known as Saw-Dry-Rip takes advantage of the inherent resistance to warp in thicker dimensions by drying 4-inch or thicker flitches and cants and then resawing them to final sizes. The disadvantage of this technique is that it lengthens the time to dry the lumber, and it increases the chance of developing other drying defects such as collapse, honeycomb, and casehardening. If time is not a concern, this method has great potential for producing high quality lumber. However, if time is an important consideration in the optimization of the drying process, the risk of creating other drying defects can be too great. This is especially true with the high-density California hardwood species.

Surface Checks and End Checks – These defects are created in the critical stage of drying when the exposed surfaces of wood are rapidly drying and the shrinkage of the surface zone (shell) is restrained by a wetter core. **Slow drying during the critical stage minimizes this condition.**

Honeycomb – These are internal checks that develop perpendicular to the grain (separations along the rays that are planes of weakness). Honeycomb checks appear during the final stage of drying, but the conditions for their development are created in the critical stage when the dry shell is set in tension. **Slow drying during the critical stage minimizes this condition** . (End seal will help minimize end checks.)

Collapse – This term describes the condition where the wood cells collapse during drying creating a wavy, distorted appearance with unusual thickness variations in the piece. Collapse is caused by rapid removal of water from weakened, saturated cells. **Slow drying during the critical stage minimizes this condition.**

Casehardened Lumber. – This term describes the condition where the shell is stressed in compression and the core in tension. Casehardening appears in the final stage of drying, but the conditions for its development are created in the critical stage when the shell is set in tension. **Slow drying during the critical stage minimizes this condition.**

Recovering from Defects
Surface checks, end checks, and honeycomb are permanent defects, nothing can be done to correct the defect once it occurs. Collapse and casehardening can be at least partially corrected. Much of the collapse can be recovered by exposing the dried lumber to saturated steam in a closed chamber for two hours. Casehardening is relieved by adding moisture back into the kiln at the end of the drying period to re-hydrate the surface zone, which causes a reduction of the compression stress in the shell. However, if the re-hydration is carried too far then reverse casehardening will occur; this is a permanent condition.

Recommendations for Drying Quality Lumber
The following is a list of eleven steps that that should be followed to help guarantee drying quality lumber.

1. Segregate lumber by species and thickness. A general rule of thumb is that doubling the thickness of a board at least triples the drying time to the desired MC.
2. Stack the lumber with strong, dry stickers of a uniform thickness (3/4 or 1 inch thick by 1-1/4 inch wide). Lumber dries faster with thicker stickers that allow more air movement through the stack.
3. Align stickers vertically so that the weight of each board is carried by the load supports.
4. Seal the end grain of each board with a paraffin-based end sealant to reduce end checking. Commercial end sealers are available, check with forestry and lumber manufacturing suppliers.
5. Monitor the MC of sample boards during drying.
6. Control the drying conditions according to the MC of the lumber. **Be conservative during the critical stage**. As you gain experience with a particular species, thickness, and drying method, you can gradually alter

the drying schedule to shorten the drying time. Remember, most drying defects don't appear until it's too late to do anything about them!

7. Dry to a target MC suitable for your customer's needs.
8. Check for casehardening and condition the lumber if necessary.
9. Check for honeycomb and collapse. A customer surprised by these defects will probably not be a repeat customer.
10. Store dried lumber in flat, solid stacks (no stickers) in a closed shed; a heated shed is ideal.
11. Re-check the MC before you ship the lumber, you may need to re-dry it.
12. Remember, 8% MC lumber will gradually increase to the equilibrium moisture content (EMC) of its environment (about 14 - 16% MC in unheated storage shed near the coast or about 10 -12% in most inland locations).

Kiln Drying Methods

Solar kiln

This method is attractive to many small producers because it can be the least expensive kiln to build and operate. There are numerous design plans for solar kilns available (Wengert, 1985) and at least one company sells a complete package of materials and design specifications (i.e. Wood-Mizer). The simplest solar kilns are the greenhouse type that passively collect solar heat and distribute it through the lumber with a fan. It is important to monitor the kiln temperature and humidity and provide venting as a means of regulating the drying conditions. Improved solar designs, that separate the solar collector from the lumber, work better because they provide better control of the drying conditions and can optimize solar gain when more heat is needed and provide less heat during the critical stage of drying. The major limitations of solar kilns are the lack of complete control of drying conditions, the inability to achieve 150° F (to kill insects), and the inability to condition the lumber without auxiliary heat and humidification equipment.

Steam-heated kiln

The workhorse of the lumber drying industry is the steam-heated kiln, sometimes referred to as a conventional kiln. Steam is used to deliver heat from a steam boiler (gas or wood residue fired) to fin-tube heat exchangers in an insulated drying chamber. Manufacturers of these kilns provide continuous recorder/controllers to monitor and regulate the drying conditions according to predetermined drying schedules. Excellent control of drying conditions is achieved by regulating the amount of heat delivered by the steam system, venting the chamber to discharge excess heat or bring in drier outside air to lower the humidity, or increasing the humidity by spraying steam into the chamber. Typically temperatures as high as 185 F can be reached and moisture can be added to raise the humidity and condition the lumber. A major disadvantage of these kilns, especially for small operators, is the high cost of the equipment. If a steam boiler does not need to be purchased because an inexpensive source of steam is available, then they become more economical for the small producer.

Hot water kiln
This type of kiln is similar to a small steam-heated kiln except that hot water is used to deliver the heat to the drying chamber instead of steam. The maximum temperature of these units is about 150° F and they have the capability of adding humidity to the chamber to condition lumber. Because a steam boiler is not required, these units are quite a bit less expensive than steam-heated kilns.

Dehumidification kiln
Dehumidification kilns are very popular with small producers and woodworkers because of their low capital cost compared to all other lumber kilns except solar kilns. These kilns use a dehumidifier to both remove moisture from the air in the drying chamber and to supply the heat needed to dry the wood. A dehumidifier operates on the same thermodynamic heat-pump principle as a refrigerator or air conditioner. When moist air from the drying lumber passes over a cold, refrigeration coil (heat exchanger) the moisture in the air condenses onto the surface of the coil. When water condenses it gives off heat (latent heat of vaporization). This heat is recycled by the refrigerant cycle, back into the air stream that conducts the heat to the lumber. In all other convection lumber-drying methods discussed here, this latent heat held by the water molecules in air is lost when moist air is vented from the kiln. In a sense, dehumidification drying is very energy efficient. Some dehumidification units have a maximum operating temperature of only 120° F, but units are available that can reach 160° F. Dehumidification kilns do not normally come from the manufacturer with a method for humidifying the air; however, a small steam generator should be added to condition and minimize the occurrence of casehardened lumber.

Vacuum kiln
Wood can be successfully dried in a vacuum chamber. Because water vaporizes at a lower temperature in a vacuum than it does at atmospheric pressure wood can be dried faster and at lower temperatures than it can be in the convection methods described above. In theory, because wood losses strength as its temperature increases the wood dried in a vacuum will have few drying defects because the critical stage of drying is occurring at low wood temperatures when the wood is strong. Drying times can be reduced by as much as 50 to 70%, depending on the species. In practice, the best results are obtained when drying short pieces of wood (up to 2 feet in length) because the water vapor travels along the grain of the wood faster than it does across the grain. In longer boards it is common to have a great deal of moisture content variation in the dried product because moisture was trapped within the wood. Compared to the convection drying methods, capital, operating and maintenance costs are high, but the reduced drying time may offset these costs. It is important to evaluate these costs for your specific needs. For a small operator, the economic analysis

will be more favorable when drying products with a higher value than grade lumber.

Radio Frequency and Microwave kilns
Wood can also be dried using radio frequency or microwave energy. In these kilns the energy waves heat the wood and the water in the wood by exciting the substance molecules; the water heats up much faster than the wood. These methods will dry most species of wood 80 to 90% faster than the convection kiln methods. The capital, operating, and maintenance costs are however very high and the same problem of non-uniform wet pockets that is found in vacuum drying also occurs with these methods. They can only be justified in special circumstances.

Equipment Manufacturers

LUMBER DRY KILNS

Ebac Lumber Driers
106 John Jefferson Rd., Suite 102
Williamsburg, VA 23185
Phone: (800) 433-9011   FAX: (804) 229-3321
http://www.ebacusa.com/
Dehumidification units from 0.5 to 50 MBF capacity (1/2 to 25 compressor horsepower)

Nyle Dry Kiln Systems
P.O. Box 1107
Bangor, Main 04402-1107
Phone: (800) 777-6953   FAX: (207) 989-1101
http://www.nyle.com/
Dehumidification units from 0.5 to 50 MBF capacity (1/2 to 25 compressor horsepower)

American Kilns
1614 Industrial Drive
Wilkesboro, NC 28697
Phone: (910) 838-6348
Radio frequency/vacuum lumber drying systems ranging from 1.5 to 8 MBF capacity

American Wood Dryers, Inc.
15495 S.E. For-Mor Court
Clackamas, OR 97015
Phone: (503) 655-1955
http://www.drykilns.com/
Steam-heated commercial lumber kilns (50 MBF + capacity) and a low-pressure steam (10 psi), 4MBF capacity unit

US Natural Resources -- Irvington Moore Division
P.O. Box 40666
Jacksonville, FL 32203
Phone: 904-354-2301 or 800-289-8767
Fax: 904-353-2833
http://www.usnr.com/prod/model.asp?model_id=350
Large steam-heated kilns (50 MBF + capacity) and small low-pressure steam 2MBF unit

Koetter Dry Kiln
607 Louis Smith Rd
Borden, IN 47106
Phone: 812-923-0635 Fax: 812-923-0640
http://www.koetterkiln.com/indexeng.html
Hot water-heated/power venting system. Capacity ranges from 0.5 to 50 MBF

Wood-Mizer Products
8180 West 10th St.
Indianapolis, IN 46214
Phone: 317.271.1542 or 800.553.0182 Fax: 317-273-1011
http://www.woodmizer.com/welcome.html
Small dehumidification unit (2MBF capacity) and a solar kiln kit (3 MBF capacity)

Vacutherm
PO Box 305, Airport Road
Warren, VT 05674
Phone 802/496-4241 FAX (802) 496-9176
http://www.vacutherm.com/
Vacuum drying chambers from 500 board feet to 30 MBF capacities

Moisture Meters and In-Kiln Control Units

Delmhorst Instrument Company
51 Indian Lane East
Towaco, NJ 07082-1025
Phone: (201) 334-2557 or 1-877-DELMHORST FAX: (201) 334-2657
http://www.delmhorst.com/
Resistance and capacitance MC meters and resistance in-kiln systems

Lignomat USA Ltd.
14345 NE Morris Court
Portland, OR 97230
Phone: 800-227-2105
Fax: 503-255-1430
http://www.lignomat.com/
Resistance and capacitance MC meters and resistance in-kiln systems

Wagner Electronics Inc.
326 Pine Grove Road
Rogue River Oregon 97537
Phone: 541-582-0541 or 800-585-7609 FAX: 541-582-4138
http://www.wwwagner.com/
Capacitance type MC meters and in-kiln systems

END SEAL MANUFACTURERS

U-C Coatings Corp.
P.O. Box 1066
Buffalo, N.Y. 14215
Website: http://www. uccoatings.co
Phone: (716) 833-9366 FAX: (716) 833-0120

Quality Assessment and Lumber Grading

When lumber is bought or sold there must be an agreement over the quality and price between the buyer and seller. This can be accomplished by an implicit agreement or explicit contract between the two parties or by assigning quality classifications or grades with a commonly understood definition. When lumber is marketed locally or in niche markets it is often done by agreement or contract. When lumber is marketed as a commodity it must conform to the commonly accepted lumber grades established in the commodity market. Lumber manufacturers can train their own employees to grade lumber according to these rules, or they can contract with a lumber inspection service. One such service in California is the California Lumber Inspection Service, 5025 Wayland Ave., San Jose, CA 95118 (Phone: (408) 993-1633). For more information it is suggested you contact the appropriate grading agency or manufacturing association.
Many of the species being milled in small scale, custom sawmills will not be covered by the commodity rules as they only directly apply to the recognized commercial lumber species. However, because these grades are well understood by buyers and consumers it is helpful for the niche marketer to be familiar with the grade descriptions so that the niche product can be defined as “similar to”. The standard grades are established by many different grading organizations. A few include:

Softwood Lumber
Western Wood Products Association
1500 Yeon Building
Portland, OR 97204
Phone: (503) 224-3930 FAX: (503) 224-3924
http://www.wwpa.org

West Coast Lumber Inspection Bureau
Box 23145
Portland, OR 97223
Phone: (503) 639-0651 FAX: (503) 684-8928

Hardwood Lumber
National Hardwood Lumber Association
6830 Raleigh-LaGrange Road
Memphis, TN 38184-0518
Phone: (901) 377-1818 or (800) 933 0318
http:// www.natlhardwood.org

Hardwood Flooring
National Oak Flooring Manufacturers Assoc. (NOFMA)
P.O. Box 3009
Memphis, Tennessee, 38173-0009
Phone: 901-526-5016 FAX: 901-526-7022
http:// www.NOFMA.org

The standard commodity grades or quality specifications are defined by nationally recognized lumber grading organizations. These organizations establish the rules on the bases of the intended use of the lumber. Most grades are based on a visual inspection system that relates the defects in the wood to its intended use. All grades fall into one of three major categories:

1. Lumber intended for construction,
2. Lumber used where appearance is more important than strength (architectural uses), and
3. Lumber intended to be remanufactured into other products.

Within these categories the highest grades will have the fewest defects that would be detrimental to the performance of the wood for an intended use. In general, the grades are identified by numbers or letters with the highest grades being labeled as Firsts, No. 1, A or some other character or phrase that clearly indicates the beginning of a sequence or few defects. Grading rules not only establish the specific requirements for each grade but they also specify the standard sizes for each commodity product. **Tables 6 and 7** presents the standard thickness and width sizes for the more common softwood and hardwood products. Most standard lumber widths vary by 2-inch increments for softwoods and 1-inch increments for hardwoods. Standard lengths vary by 2-foot increments for softwoods and 1-foot increments for hardwoods. Information on more specialized commodity products can be obtained by referring to the grading rulebooks published by the grading organizations. A list of some of the more common grading organizations is presented at the end of this section.

The grades and rules are different for hardwoods and softwoods, and there are often exceptions and variations for specific species within a group. **Table 6**

(Softwood lumber grades) and **Table 7** (Hardwood lumber grades) are provided as an overview of the major grade classifications. In addition to these grades there are also numerous grades and specifications for special categories such as scaffolding planks, stadium seats, paneling, and siding. There are also special rules for certain species, such as redwood and western red cedar. As an example, the more common redwood grades are listed in **Table 9**

Because of the large number of potential uses of wood there are numerous grade categories, too numerous to cover in this report. The following discussion is intended as an overview that will focus on the major categories and grading rules. However, keep in mind, the rules are very complicated and a thorough understanding requires diligent study of the specific rulebooks.

Softwood lumber grades

Graded softwood lumber is divided into three major use categories as discussed above and shown in **Table 8.**

- Construction,
- Architectural,
- Remanufacturing

Although lumber within each of these categories may have similar grade names, the grades are based on a different set of criteria for each use. Construction lumber is based on strength, architectural lumber is based on appearance, and remanufacturing lumber is based on the quantity of defect free material that can be cut from each piece (a.k.a. cuttings). The grades within each of these use categories are based on how the defects in the lumber are expected to affect the quality of the piece in its intended use.

Species with unusual or unique characteristics are often manufactured for uses that capitalize on the unique properties. Examples include redwood, western red cedar, and cypress siding; redwood deck and fence lumber, and redwood architectural lumber.

These species are commonly used for siding, deck construction and architectural uses because of the attractive color and high levels of natural resistance to attack by wood boring insects and wood decay fungi. Although these are commercial softwood species that are covered by the National Lumber Grading Standards, special rules exist for

these higher-value uses. In fact, in today's market most of the lumber of these species is graded for the higher-value uses. For example, even though redwood can be stress-graded for construction uses following the softwood structural grades it is rarely done. Most redwood is graded for landscape, deck, or architectural uses following the rules of the California Redwood Inspection Service.

Construction lumber – This category of softwood lumber is often referred to as "dimension" lumber. It is used for most of the wood construction applications in the
United States. The lumber is manufactured to specific dimensions that are standard for building design and engineering. The size classifications within this category are based on the intended use for the material. For example, boards are used for sheathing purposes (e.g. 1" x 6"), light framing sizes (e.g. 2" x 4", 2" x 6") are intended for framing walls; joists are intended to be loaded on edge or used as beams and are significantly wider than they are thick (e.g. 2" x 6"), and larger structural members used as columns are designated as posts. Most dimension lumber is stress-rated, which means that minimum strength and stiffness design values are assigned to each grade. The grading system is based on the knowledge of how the defects present in the lumber affect the mechanical properties of the piece as a whole. The lumber can be graded visually, by following a set of rules established by grading agencies, or machine-graded. The visual grades are based on an assessment of the size, distribution, and location of defects in the lumber and how those defects affect the strength and stiffness of the lumber. Machine-graded lumber is individually proof-tested by being passed through a machine that measures the strength and stiffness of the piece.

Some dimension lumber is available as non stress-graded lumber, which is intended for general construction, or utility uses. This lumber is still graded on the basis of the effect of defects on the expected performance for the intended use, but the rules are less rigorous than the stress-graded rules and the grades do not have design values associated with them. Boards are generally graded as non-stress graded lumber.

Architectural lumber – Architectural lumber is construction lumber that is manufactured to a specific pattern or size for uses where the appearance of the board is the most important property. Siding, trim, molding, and flooring are examples of appearance lumber.

Remanufacturing lumber –This is also know as factory or shop lumber, is intended to be used as the raw material for a higher-value manufactured wood product. This lumber is the stock for products such as flooring, furniture, cabinets, molding, millwork, boxes, etc.

Table 6. Standard Softwood Lumber Sizes.

Dimension Lumber (used for framing and general construction)*

Nominal Thickness	Actual Thickness	Nominal Width	Actual Width
2"	1-1/2"	2"	1-1/2"
3"	2-1/2"	3"	2-1/2"
4"	3-1/2"	4"	3-1/2"
5"	4-1/2"	8" and wider	3/4" less than nominal
6"	5-1/2"		
7"	6-1/2"		

Boards, Factory, and Shop Lumber**

Nominal Thickness***	Actual Thickness	Nominal Width	Actual Width
3/4"	5/8"	2"	1-1/2"
4/4"	3/4"	3"	2-1/2"
5/4"	1-5/32"	4"	3-1/2"
6/4"	1-13/32"	5"	4-1/2"
7/4"	1-19/32"	6"	5-1/2"
8/4"	1-13/16"	7"	6-1/2"
9/4"	2-3/32"	8" and wider	3/4" less than nominal
10/4"	2-3/8"		
11/4"	2-9/16"		
12/4"	2-3/4"		
16/4"	3-3/4"		

* Actual dimensions are specified for lumber after it is surfaced smooth and dried to 19% moisture content

**Actual dimensions are specified for lumber after it is surfaced smooth and dried to 12% moisture content

*** Board thickness is generally designated by quarter inch increments, e.g. 4/4 is I-inch thick.

Table 7. Standard Hardwood Lumber Sizes*

Nominal Thickness	Actual Thickness	Nominal Width	Actual Width
3/8"	3/16"	up to 8" wide	3/8" less than nominal
1/2"	5/16" 8" and wider	1/2" less than nominal	
5/8"	7/16"		
3/4"	9/16"		
1"	13/16"		
1-1/4"	1-1/16"		
1-1/2"	1-5/16"		
1-3/4" and thicker	1/4" less than nominal		

* Actual dimensions are specified for lumber after it is surfaced smooth and dried to 8% moisture content.

Table 8. Softwood lumber grades by Use Categories

Construction Uses -- Dimension lumber used for framing and sheathing

Group	Dimensions	Grades (from highest to lowest)
Stress-Rated (SR)		
Structural Light Framing	2 to 4-inch thick x 2 to 4-inch wide, e.g. 2" x 4"	Select Structural No. 1 No. 2 No. 3
Structural Joists & Planks	2 to 4-inch thick x 5-inch wide and wider, e.g. 2" x 6"	
Timbers	5-inch thick and thicker x width greater than thickness plus 2-inch	
Posts & Timbers	5"x5" and larger with width no more than 2" > thickness	
SR Boards	3/4 to 4-inch thick x 4" and wider, e.g. 1" x 6"	
Light Framing	2 to 4-inch thick x 2 to 4-inch wide, e.g. 2" x 4"	Construction Standard Utility
Stud	2" x 4" and 2" x 6" (length of 10-foot or less)	Stud
Non Stress-Rated		
Economy Stud	2" x 4" and 2" x 6" (length of 10-foot or less)	Economy
Boards	3/4 to 4inch thick x 4-inch and wider	1 Common (Select Merchantable), 2 Common (Construction), 3 Common (Standard), 4 Common (Utility), 5 Common (Economy)

Architectural Uses -- Appearance is more important than strength

Appearance Framing	2 to 4-inch thick x 4-inch and wider	A (clear) -- stress-rated
Boards	3/4 to 4inch thick x 4-inch and wider	1 Common, 2 Common
Selects and Finish	Sizes vary depending on intended product – e.g. Molding, Trim, Cabinets, Flooring	B & Better, C, D

Remanufacturing Uses-- Stock for furniture, flooring, molding, doors, boxes, etc.

Factory and Shop Lumber	Sizes vary depending on intended product	Select Shop, No. 1 Shop, No. 2 Shop, No. 3 Shop

3.6.2 Hardwood lumber grades

Most of the hardwood lumber will be remanufactured into a higher-value product. As such, a hardwood lumber grading system has evolved that is based on how many clear wood (no defects) pieces of various standard sizes can be cut out of a board. These clear wood pieces are referred to as cuttings. The number of cuttings and the percentage of the board that is clear define the grades. These grades, known as the Standard Lumber Grades for hardwood, are presented in **Table 7.** Hardwoods are often used as non-standard lumber for special products. For example, the lumber can be graded for a specific use such as paneling or flooring. Hardwoods can also be manufactured to structural lumber sizes for use in construction. However, there are no structural grading rules that apply to specific hardwood species. The National Hardwood Lumber Association (NHLA) rulebook lists construction grades for oak but these are rarely used, if at all. If a hardwood species is to be used in construction it will likely need the approval of the local building officials. This can be done, but it usually requires the services of a structural or civil engineer to certify that its strength and stiffness are appropriate for the intended use.

Table 10. Hardwood Grades by Use Categories

Standard Lumber Grades	**Minimum Requirements** -- based on proportion of clear wood (cuttings)
FAS	83.3% clear minimum board dimensions: 6-inch width, 8-foot length
Select	83.3% clear minimum board dimensions: 4-inch width, 6-foot length
No. 1 Common	66.6% clear minimum board dimensions: 3-inch width, 4-foot length
No. 2 Common	50.0% clear minimum board dimensions: 3-inch width, 4-foot length
No. 3 Common	33.3% clear minimum board dimensions: 3-inch width, 4-foot length
Construction and Architectural Uses	
Interior wall paneling	
Natural	91.6% clear minimum board dimensions: 6-inch width, 8-foot length
Colonial	83.3% clear minimum board dimensions: 4.5-inch width, 6-foot length
Prime	83.3% clear minimum board dimensions: 4-inch width, 6-foot length
Custom	tight knots to 1-1/2-in. diameter are OK minimum dimensions: 4-in. width, 6-ft. length
Construction and Utility Boards (primary use is for government specificaitons)	See NHLA Rule Book
No.1 Construction (Utility)	
No.2 Construction (Utility)	
No.3 Construction (Utility)	
Flooring	Grades established by National Oak Flooring Manufacturers Association
Clear	Little discoloration or character marks, minimum length is 3-1/2 foot
Select	Slight discoloration and small, tight knots, minimum length is 3-1/2 foot
No. 1 Common	Moderate discoloration and defects allowed, minimum length is 1-1/4 foot
No. 2 Common	Very few limits on defects, minimum length is 1-1/4 foot
1-1/4' Shorts	Short pieces (9 to 18-inch) of the above grades
Bridge, Mine, and Industrial timbers and boards	See NHLA Rule Book
Railway Ties	Grades established by American Railway Engineers Association.

SUMMARY

The inherent working characteristics of the wood that are related to density, knots, grain deviation, and tree form determine whether the wood can be processed economically. The extra processing steps required to produce the quality demanded by the market place may result in manufacturing costs that are too high. A thorough understanding of the properties of the wood and the manufacturing techniques that minimize defects and maximize value are imperative to succeeding in this business. One of the most crucial steps in the process is drying. Many small start-up sawmills have failed because they didn't understand the importance of drying and how to minimize the drying losses due to excessive drying defects.

Another important consideration for any processing enterprise is to produce consistent quality products. For wood product operations targeted to niche or specialty markets this usually means a definition of product quality needs to be created. Once defined, in terms of moisture content, size tolerances, surface quality, etc., methods of measuring quality parameters during production should be created. Any materials not meeting the quality standards should be reprocessed to achieve desired quality or marketed as a below grade product. Although it's obvious, it is always a surprise when a producer loses site of the old adage, "unhappy customers are not repeat customers".

In addition to identifying the target market(s), determining the quality and volume needs of customers, and determining the resource availability to meet these needs, it is imperative to prepare a thorough business plan that includes realistic estimates of product value and manufacturing costs. As the size of the operation increases so does the need for more expensive equipment and the overall complexity of the business plan. Assistance in developing business plans can be obtained from various sources including local economic development agencies, and private and public business consultants.

Nearly any tree can be processed into a wood product. The question is can it be done profitably. The harder it is the higher the manufacturing costs will be. Can the market bear the cost?

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