AN INTRO TO

KILN DRYING

A Comprehensive Guide to Lumber Drying

nyle Dry Kilns

About Nyle

Since 1977, Nyle has been building the world's most energy-efficient lumber drying kilns. We pioneered the development of dehumidification drying as a practical and economical drying method. We work closely with manufacturers to meet large commercial needs, as well as smaller scale companies or individuals with our L-Series line of Low Temp DH kilns.

Intro

Lumber drying can be a complicated process. There is so much variety with different situations, equipment, and practices. It's important to have a good understanding of these variables in order to give yourself the greatest opportunity to succeed. We've prepared this booklet to assist those completely new to drying lumber, as well as included some information that may be helpful to those individuals with years of experience. If you want to know more, then read on!

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Facts About Drying Lumber

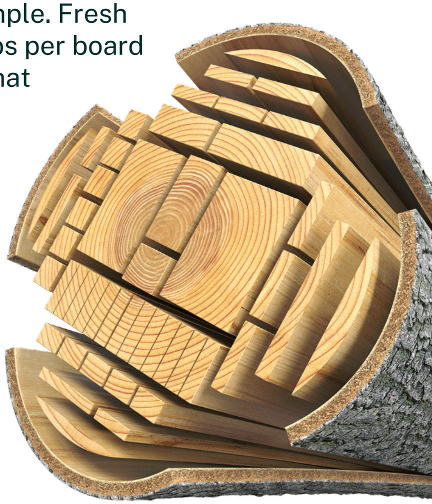
Why Dry Lumber at All?

Drying lumber has large benefits for the final use of the product. It improves strength, kills bugs/infestations, hardens pitch/sap, preserves color, reduces weight, and controls shrinkage. It also makes milling and other secondary processes more effective. Machining, gluing, and finishing all have higher success rates with dry lumber.

How Much Water Is In Lumber?

The exact amount will depend on species, location, and time of year. However, some species are over half water (in terms of weight) when freshly cut. It's really astounding how much water has to be removed from wood to make it suitable for finished products.

Let's look at a single Oak board as an example. Fresh cut Oak can commonly weigh around 5.4 lbs per board foot. That would make a 10-ft long board that was 12 inches wide and 1 inch thick weigh around 54 lbs. Once Oak is dried to around 6-8% moisture, it typically weighs around 3.5 lbs per board foot. Our 10 ft by 12-inch example board would now only weigh 35 lbs. Water weighs around 8.3 pounds per gallon, meaning our example board had over 2.25 gallons of water removed from one board. If you scale these numbers up to a 50,000 board ft kiln, 95,000 lbs of water would be removed. That's nearly 50 tons or almost 11,500 gallons of water!



Does Lumber Stay Dry?

Lumber will eventually equalize to the moisture content of the air around it. This can lead to seasonal shrinking or swelling in wooden doors or flooring. The higher humidity in the summer can cause the wood to gain moisture, and the lower humidity during wintertime can cause the wood to lose moisture. That's why having lumber dried to a correct moisture content for final usage and location can be so critical to mitigate these issues.

Can Drying Cause Splitting, Checking, or Cracking?

There are two ways drying can cause these types of defects. Number one is simply drying too quickly. A given species of lumber can only handle up to a certain drying rate, and exceeding that can cause checks and cracks. We will touch on this more later in this booklet. The second way drying can cause these issues is if the shell of a piece of lumber dries much faster than the core. The stress of the shell trying to shrink around the core can cause splitting and cracking in some cases. Lastly, splits can be caused after drying during milling. If a board has cupping or twisting, sometimes the pressure of running it through a planer or moulder can split the piece.

What Is Fiber Saturation?

There are two types of water stored in trees and fresh-cut lumber. The free water is stored in void spaces in and around the wood cells. The bound water is stored within the wood cells and is chemically bound to the cellulose molecules. When drying begins, all the free water evaporates and leaves the lumber first. Fiber saturation is above the tipping point where there is no more free water left, and bound water needs to be removed to continue drying. This is typically around 28% moisture content and the wood begins to shrink physically as it dries once it's below this number.

Does The Thickness of Lumber Affect Drying Rate?

Yes. The lumber industry frequently refers to lumber thickness in terms of quarter-inch multiples. Therefore, one-inch lumber is referred to as 4/4 (four-quarter), one-and-a-half inch lumber is 6/4 (six-quarter), etc. Generally speaking, drying times are roughly proportional to the thickness. For example, 8/4 should take slightly more than twice as long to dry as 4/4.

Drying Hardwoods vs Softwoods

Hardwoods typically refer to trees with leaves, while softwoods refer to trees with needles. However, when it comes to the actual density of the wood, some hardwoods are softer than many softwoods. Poplar is an excellent example of this. Because of the great variety of traits amongst species, it's best to approach each species individually. Oak needs to be dried slowly or it will crack or check easily. Pine needs to be dried quickly to avoid staining and other discoloration. We will discuss more specifics when we discuss scheduling later in this booklet.

Drying Terminology

Dry Bulb: The temperature in the kiln is controlled by a heat source that turns on and off. In DH kilns using a standard program, venting occurs only for excess heat.

Wet Bulb: The temperature in the kiln accounts for the additional cooling effects of evaporation. It is usually calculated using a dry bulb and a water-soaked fabric or an electronic relative humidity sensor. In a conventional kiln, it is controlled by venting and by operating a compressor in a DH kiln.

Relative Humidity: Reflects how much water vapor is in the air as a percentage of the maximum water that air can hold at a given temperature. Every dry bulb/wet bulb combination has a corresponding relative humidity. If the dry bulb and wet bulb temperatures are exactly the same, the air is saturated and at 100% humidity.

EMC (Equilibrium Moisture Content): A value that reflects the equalizing point of lumber in a specific environment. If a room has an EMC of 12%, all lumber in that room will eventually gain or lose moisture to reach 12% moisture content. Each EMC at a specific temperature corresponds to a particular relative humidity at that temperature

Depression: The difference between the dry bulb and wet bulb temperatures. For example, if the dry bulb temperature is 95 and the wet bulb temperature is 90, the depression would be 5 degrees.

Moisture Content (MC%): Expressed as a percentage of the lumber's zero moisture weight. For example, if a piece of wood weighs 1000 grams with absolutely no water and 1500 grams when freshly cut, the fresh-cut piece has a 50% moisture content. If the same piece weighs 2000 grams when freshly cut, it has a 100% moisture content. Therefore, it is possible to have greater than 100% moisture content.

Drop Across The Load: The difference in dry bulb temperature between the air on the entering and exiting sides of the lumber is relative to the airflow direction. Since evaporation cools the air temperature, this temperature drop, combined with the wet bulb, can approximate how saturated the air has become.

Standard Deviation: The target (or actual) range of moisture content in the lumber. For example, a hardwood mill in the Northeastern United States might target a final MC% of 6-8%, resulting in a 2% standard deviation. Conversely, a dimension Spruce/Fir mill producing products for the Southeastern United States might target a final MC% of 14-18%, resulting in a 4% standard deviation.

Conditioning: The process of treating dried lumber to relieve stresses and equalize moisture content throughout the wood. This usually involves raising the humidity in the kiln at the end of the drying cycle.

Reconditioning: A process of reintroducing moisture into over-dried or dried lumber to achieve a uniform and desired moisture content, often involving steaming.

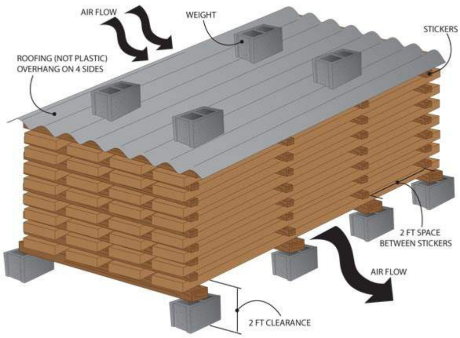
Free Water: The moisture in lumber that is present in the cell cavities and intercellular spaces. Free water is the first to be removed during the drying process, as it is not bound to the wood fibers. Removing free water primarily affects the weight of the lumber but does not cause significant shrinkage. Once the free water is removed, the drying process moves on to removing bound water, which is held within the cell walls and can cause the wood to shrink and potentially warp.

Bound Water: The moisture in lumber that is held within the cell walls of the wood fibers. Unlike free water, bound water is chemically bound to the cellulose molecules in the wood. The removal of bound water occurs after the free water has been evaporated and is responsible for the shrinkage and potential distortion of the wood. The drying process that removes bound water is critical for reducing the moisture content of the lumber to its equilibrium moisture content (EMC) and ensuring its stability in various environmental conditions.

It's important to remember that Dry Bulb/Wet Bulb, Relative Humidity, EMC, and depression are all derivatives of each other. There are different ways of calculating the same thing, and different kiln systems will use different versions of these.

Drying Methods

The following section provides a brief overview of different types of lumber drying. Later in this booklet, we will discuss the value of each type and how they can be used during various processes.



Demrow, C. (2013, August 21). Building a Lumber Pile | Summer 2013 | Articles | Tricks of the. https://northernwoodlands.org/articles/article/lumber-pile

Air Drying

Air drying is when lumber is stacked outside, and the natural airflow from the wind plus heat from the sun is allowed to dry the wood. In some ways, this is the cheapest method of drying, but there are a lot of limitations and potential pitfalls as well. Outdoor climates can vary wildly, adding a lot of inconsistency to air drying.

Forced Air, or Fan Shed Drying

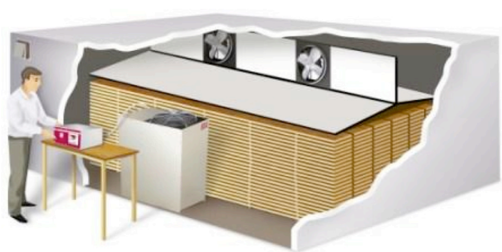
This is when the lumber is stacked in a shed to protect it from rain and direct sun, and airflow is added with circulation fans. There is no heat source, and the environment is still not climate-controlled.

Pre-dryers

Pre-dryers are used to remove most of the free water from lumber before it is placed in a kiln for final drying. A pre-dryer is a sealed building where temperature and humidity are controlled. Low temperatures are typically used. A pre-dryer will significantly reduce the time lumber will need to be in a kiln, but it obviously requires an investment in another structure and the labor costs associated with loading and unloading.

Kiln Drying

In kiln drying, lumber is placed in a chamber where airflow, temperature, and humidity are controlled. The goal is to provide as rapid drying as the lumber can tolerate without causing defects. There are several types of kilns, with the three common examples being conventional, dehumidification, and vacuum.



Different Types of Dry Kilns

Dehumidification Kilns

A dehumidification kiln starts the same as a conventional kiln, with airflow and a heat source to remove water from the lumber and then evaporate it into water vapor. The most significant difference between the two is the manner in which this water vapor is removed from the chamber. In a dehumidification (DH) kiln, the humid air is passed over a refrigeration coil, which is operated by a compressor. This causes the water vapor to condense, and it can be easily drained out of the chamber. This allows the still warm but dry air to be circulated back into the chamber to reuse all the energy spent to warm it up. This process results in DH kilns using significantly less energy for heating.

Conventional Kilns

A conventional kiln uses a heat source, frequently steam/hot water coils, electric coils or a gas furnace to warm up the air in the kiln chamber. This energy will drive the water out of the lumber more quickly, and the airflow will evaporate the water into water vapor. This humid air will then be exhausted through vents, and fresh, cool, dry air will be brought in to reheat and start the process over again. Conventional kilns are the oldest and most common style of commercial kilns.
Since part of the regular operation involves venting the heated air, they are considered significantly less energy efficient than other types of kilns.

Vacuum Kilns

Vacuum kilns take advantage of the fact that water boils at a lower temperature based on lower atmospheric pressure. Vacuum kilns can use this to achieve swift drying times. Since there is very little air to move around to transfer energy to the lumber during a vacuum, other methods have been developed to heat the wood. Some vacuum kilns will cycle between being in a vacuum and not, allowing heat to be transferred to the product when not in a vacuum. Other designs use metal plates in between each layer. Hot water is pumped through these plates, and the energy transfer to the lumber comes from direct contact. Vacuum kilns are very efficient with energy usage but have other factors that can add cost. They typically have very small chambers and can't be set outside in the weather. They are also the most expensive type of kiln when it comes to initial purchase and installation.

Design and operation of a Solar-Heated dry kiln. (n.d.). VCE Publications | Virginia Tech. https://www.pubs.ext.vt.edu/420/420-030/420-030.html

Solar Kilns

Solar kilns are a method used for drying wood by harnessing energy from the sun. These kilns typically consist of a structure similar to a greenhouse, designed to capture and retain solar heat. The wood is placed inside the kiln, where the heat and airflow work together to gradually reduce the moisture content of the lumber.

One of the primary benefits of solar kilns is their low operational cost, as they primarily rely on solar energy. However, solar kilns generally require more time to dry wood compared to conventional kilns and are dependent on weather conditions, which can affect drying efficiency and consistency. Despite these limitations, solar kilns offer a practical and sustainable option for those interested in an eco-friendly approach to wood drying.

Styles of Kiln Chambers

Container Kilns

Container kilns utilize shipping containers for wood drying. Insulated shipping containers, specifically reefer containers, are highly encouraged. Not only does the insulation in these containers help maintain consistent temperatures, enhancing energy efficiency during the drying process, but the interiors of reefer containers are less susceptible to rust and rot, which is crucial due to acids in specific wood species. These acids can erode less protected materials, leading to maintenance challenges. Container kilns are best suited for small to medium-sized operations that require a durable and efficient drying solution. Their design also allows for scalability, as multiple containers can be added to meet growing production needs.

Forklift Kilns

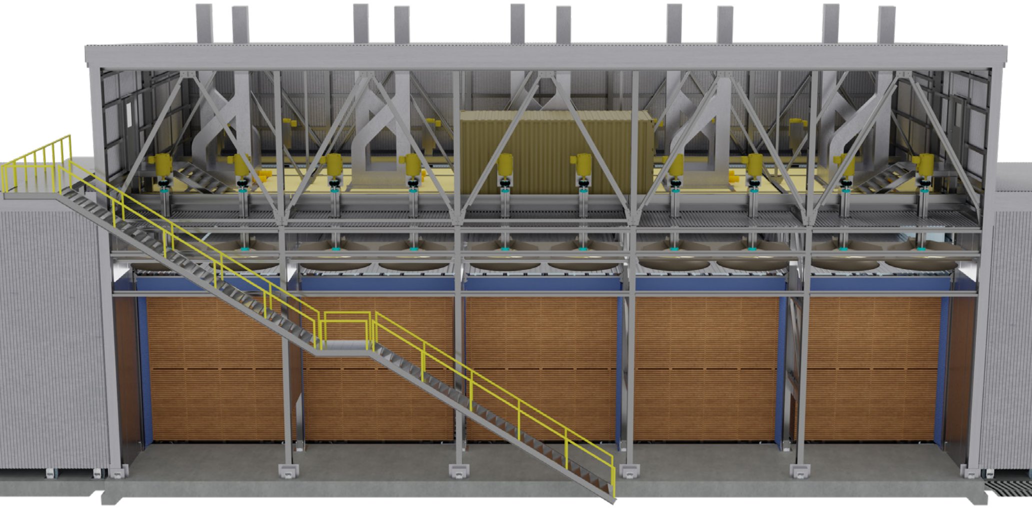
Forklift kilns are designed for flexibility and ease of operation. In these kilns, lumber stacks are loaded into the kiln using forklifts. Forklift kilns offer the advantage of quick loading and unloading, as well as the ability to handle varying sizes and shapes of lumber stacks. They are well-suited for operations that require a high degree of versatility and for facilities that process a wide range of wood types and dimensions. This type of kiln is often favored by medium to large-scale sawmills and woodworking businesses that need adaptable drying solutions.

Track Kilns

In this system, lumber is loaded onto rail-mounted carts that are then moved into the kiln chamber on tracks. This setup allows for easy loading and unloading of large volumes of wood, making track kilns ideal for operations that handle substantial quantities of lumber. The kiln can be loaded and unloaded in one continuous motion, which helps minimize downtime and increases productivity. Track kilns are typically used in large-scale industrial settings where efficiency and throughput are paramount.

Continuous Kilns

Continuous kilns represent the pinnacle of efficiency in wood drying. Unlike batch kilns, where lumber is loaded and dried in separate cycles, continuous kilns operate by moving lumber through different drying zones in a continuous, unbroken process. This system allows for constant processing, leading to increased throughput and more uniform drying. Continuous kilns are particularly advantageous in large-scale industrial operations where high volumes of wood need to be processed quickly and consistently. However, they require significant investment and are more complex to operate and maintain compared to other kiln types.



How To Dry Lumber?

The exact method of drying lumber will vary greatly from location to location. One individual might have the time and space to stack lumber in a shed to air dry for months, while others might prefer to put their lumber in the kiln fresh off the sawmill. One individual may be drying in the Southwest, where it's very hot and dry, while someone else could be drying in the Southeast, where it's equally hot but has an extremely high humidity.

Everything from log storage to how an air-dry yard is laid out, species availability, kiln selection, and many other factors can all contribute to the final product's outcome. Because of this, it's important to have a good grasp of the entire drying process from beginning to end.

Understanding the species you're working with is the most important factor in successful drying. We will touch on this in detail in the scheduling section; the rest of this current section will be about the different types of drying and how to get the most out of them.

Air Drying

The location needs to be evaluated when air drying to determine the best possible layout. Stacking lumber completely unprotected outside leaves it at the mercy of direct sunlight, rain, and inconsistent airflow. Knowing the direction of prevailing winds would allow stacking the lumber perpendicular to the air direction to increase air across the lumber for faster water removal. This would be best for faster-drying products like pine.

Stacking the lumber parallel to the air would help limit airflow through the stack, which would be better on slower-drying products like oak. If putting the product undercover, like in a shed or a pole barn, isn't an option, then putting something on top of the packs is a good idea to block direct sun and rain exposure. Materials such as plywood or corrugated aluminum can be used for this. If a shed is available to protect from sun and rain, then ensuring there's enough air to prevent mold or stains is also essential.

Fan Shed Drying

If a fan shed is available, then direct rain and sun should no longer be as critical of a factor. However, temperature and humidity are still not directly controlled. Therefore, extreme weather conditions can still affect the drying process. Having an appropriate level of airflow for the species being dried becomes the most critical level of control with this type of drying.

Pre-drying

These are relatively uncommon except at large commercial facilities since the investment required to build pre-dryers is nearly comparable to building kilns. Pre-drying can be treated like an extremely gentle kiln or perfect air-drying environment, mimicking the optimal conditions for lumber to smoothly and safely dry down to 25-30%. It's important to have the appropriate airflow and temperature for the species in the pre-dryer.

Kiln Drying

Kiln drying is the most complicated type of drying from the operator's perspective. With air-drying or fan-shed drying, there are degrees of uncontrolled variables. With kiln drying, every variable is technically controlled. However, the level of control depends on the quality and design of the kiln and how well it is kept or maintained.

There is a lot of information to know to effectively kiln dry lumber. It can be done without some of this information. Unfortunately, that means that if something goes wrong with the final product, the operator may not realize the cause. Starting MC% and a safe drying rate for the species are critical. Operational practices like level stacking that's well supported with sticks and blocks, not mixing species or thicknesses, good baffling, and proper maintenance are all contributors to a good final product.

While it is possible to mix species and thicknesses in a single kiln chamber, it's important to note that this can lead to complications. To safely dry the load, it will have to dry at the rate and settings of the slowest drying, thickest product in the kiln. This is a factor that operators should consider when planning their drying process.

Preparing Your Lumber for Drying

Seal the Ends

After cutting, immediately apply a sealant to the ends of the lumber. This step is crucial to prevent rapid moisture loss, which can cause end-checking and splitting. A good sealant will help maintain the lumber's quality throughout the drying process.

Boyt, D. (2015, April 10). How to Air-Dry Lumber. Woodcraft. https://www.woodcraft.com/blogs/wood/how-to-air-dry-lumber-turn-freshly-cut-stock-into-a-cash-crop-of-woodworking-woods

Remove the Bark

Removing any bark from the lumber is essential, as bark can harbor pests and slow drying. Ensuring the lumber is clean and bark-free will promote better drying efficiency.

Sort the Lumber

Your role in the wood drying process is crucial. Sort the lumber by species, grade, and thickness. Each wood species has unique drying characteristics, and your sorting efforts will help create uniform drying stacks, a critical factor for achieving consistent drying results.

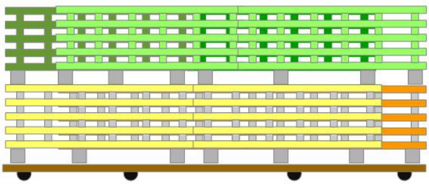
Drying different wood species together in the same kiln is generally not recommended due to variations in their drying characteristics. Each wood species has unique properties that require specific drying schedules to ensure optimal results and minimize defects.

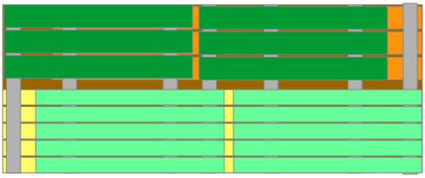
Use Proper Stickers

Use dry, hardwood stickers, typically around 1 to 1.5 inches thick and 1.5 to 2 inches wide. It's essential that the length of the stickers matches the width of the lumber stack, as this is a fundamental principle in maintaining stability and uniform spacing.

Hardwood stickers are more durable and less likely to compress under the weight of the lumber stacks, ensuring consistent spacing throughout the drying period.

Proper Stacking





Place the stickers between each layer of lumber to ensure good air circulation. Align the stickers vertically to maintain even pressure distribution. Elevate the stack off the ground using a level, stable base to prevent moisture absorption and promote air circulation beneath the stack.

Proper placement of stickers, typically 12 to 24 inches apart, depending on the thickness of the lumber, is also essential for maintaining structural integrity and promoting efficient drying.

Protect the Lumber

Use breathable covers or place the stack in a shaded, well-ventilated area to protect the lumber from direct sunlight, rain, and excessive wind. This protection helps maintain the quality of the lumber during the drying process.

By following these steps, you can optimize the kiln drying process, reduce the risk of defects, and ensure that your lumber reaches the desired moisture content efficiently and uniformly.

Products & Services – MidWest. (n.d.). https://midwesttimber.com/products-services/

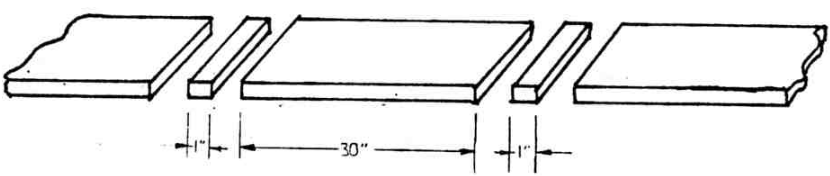
Measuring Moisture Content

Importance of Daily Measurements

Using sample boards to measure moisture content daily is essential for hardwood kiln drying. Moisture meters are often not accurate above 30% MC, especially for species like oak, where checks and honeycombing can occur between 40% MC and green. Close monitoring helps control the drying rate and maintain lumber quality.

Uses for Sample Boards

- To estimate the MC of the load in the chamber, so that kiln conditions can be regulated according to drying schedules.
- To measure the drying rate, which allows control of drying quality.
- To check on any degrade development.
- To check on final MC and drying stresses.
- To develop a MC vs. time curve.
- To study variations in drying within the kiln.
- To monitor changes in MC after drying (during storage and shipping) *Note: It is a good idea to keep sample boards with dried lumber so that they can be used to track moisture content changes in storage.*



Taking Samples

1. **Select Representative Boards:** Choose boards that represent the lumber in the kiln. Avoid junk boards and select both the slowest and fastest drying boards, typically six in total.
2. **Cut Samples:** Cut 30” samples at least 12” from the ends of each board, avoiding knots, splinters, or bark. Number the samples.
3. **Label and Coat:** Cut two 1” sections off each end and label them (e.g., 3A, 3B for board 3). Apply end coat to the 28” samples to simulate drying of larger pieces.
4. **Initial Weighing:** Weigh the 28” samples accurately (to 0.025 pounds or 1 gram) and record these values.

5. **Placement:** Place the 28” samples in the kiln stacks where they will dry at the same rate as the rest of the lumber. Avoid areas with higher airflow.
6. **Green Weight:** Weigh all the 1” sections accurately (to 0.1 gram) and record these values.

Drying and Monitoring

Oven Drying 1” Sections:

- Microwave Method: Use low power to avoid smoking, drying in 20-minute increments until no weight change occurs.
- Oven Method: Dry at 215°F (101°C) until weight stabilizes, checking hourly.

Calculate MC:

- Use the formula: $MC = \left(\frac{\text{Wet Weight - Oven Dry Weight}}{\text{Oven Dry Weight}}\right) X\ 100$
- Average the MC of the two 1” sections for each 28” sample to estimate the sample’s MC when cut.

Oven Dry Weight Calculation:

- Use the formula: $\text{Oven Dry Weight} = \left(\frac{\text{Wet Weight}}{100 + \%\ MC}\right) X\ 100$
- Write the calculated oven dry weight on the sample board.

Daily Monitoring

1. **Daily Weighing:** At the same time each day, weigh the sample boards and calculate the current MC using:

   $\%MC = \left(\frac{\text{Current Weight}}{\text{Oven Dry Weight}}\right) X\ 100$

2. **Replace Samples:** Place the sample boards back in the same kiln positions.
3. **Record and Adjust:** Record the daily drying rate and adjust the schedule based on the fastest drying sample.
4. **Cut New Sections Below 20% MC:** Cut new 1” sections from the center of the sample boards to continue monitoring.

Example Calculation

1. **Initial Weights:** Two 1" sections from board 1 weigh 2.5g and 2.3g.
2. **Oven Drying:** Final weights are 1.7g and 1.6g after microwave drying.
3. **MC Calculation:** MC for A = {(2.5 / 1.7) - 1} x 100 = 47.06%
   MC for B= {(2.3 / 1.6) - 1} x 100 = 43.75%
   Average MC= (47.06 = 43.75) / 2 = 45.40%
4. **Oven Dry Weight:** ODW = (1.64 / 145.4) x 100 = 1.13 kg
5. **Daily Weighing:** After a day, board 1 weighs 1.58 kg. Using the formula in step 13, the moisture content is:
   %MC = [(1.58 / 1.13) - 1] x 100 = 39.8
6. **Daily Change:** The daily change in moisture content is:
   45.4 - 39.8 = 5.6%.

Tips for Using Sample Boards Effectively

- **Consistency:** Ensure the sample boards are as representative as possible of the entire load.
- **Protection:** Handle the sample boards carefully to avoid any damage that could affect the weight and moisture readings.
- **Documentation:** Keep detailed records of all measurements, adjustments, and observations throughout the drying process.

By following these steps, you can effectively monitor and control the moisture content of lumber during kiln drying, ensuring high-quality, uniformly dried wood.

MM9 Pin/Pinless Moisture Meter. (2021, August 24). https://generaltools.com/mm9-pin-pinless-moisture-meter

Moisture Meters

Moisture meters are essential for measuring lumber's moisture content (MC) during the drying process. Choosing the right type of moisture meter is crucial for obtaining accurate readings and ensuring the quality of the dried wood. Here are the main types of moisture meters used in drying lumber:

1. **Pin-Type Moisture Meters:** Pin-type moisture meters use metal pins inserted into the wood to measure electrical resistance, which is then converted into a moisture content reading. These meters can measure moisture at different depths and provide direct contact readings. However, they leave small holes in the wood and require clean contact surfaces for accurate results. They are best for precise depth-specific measurements in kiln drying processes.

2. **Pinless Moisture Meters:** Pinless moisture meters use electromagnetic waves to measure moisture content without penetrating the wood. These meters are non-invasive and provide quick readings over larger areas. However, they only measure moisture at shallow depths, and surface moisture can affect their accuracy. They are ideal for non-invasive, quick assessments of large lumber quantities.

3. **All-in-one moisture meters:** All-in-one moisture meters combine pin and pinless technologies, offering versatility for various moisture measurement scenarios. They are suitable for different wood types and provide flexibility. However, they are more expensive and may require more knowledge to operate effectively. They are best for users needing both surface and depth measurements.

When selecting a moisture meter for drying lumber, consider the type of wood, the depth of measurement needed, the importance of non-invasiveness, and the level of accuracy required. This will help ensure you choose the best tool for your lumber drying process.

Nyle recommends the Delmhorst Navigator JX-30 Moisture Meter

Kiln Scheduling

Group 1 (L200 load size, 1500 BF, 3.5m³)
4/4 Softwoods
4/4 Soft Hardwoods
Group 2 (L200 load size, 3000 BF, 7m³)
4/4 Medium Hardwoods
8/4 Softwoods
8/4 Soft Hardwoods
Group 3 (L200 load size, 4000 BF, 9m³)
4/4 Hardwoods
8/4 Medium Hardwoods
Group 4
8/4 Hardwoods

	Normal Schedule		Alternate Schedule	
Moisture Content	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb
Group 2				
Above 45%	90° F	85° F	100° F	97° F
45% - 35%	100° F	87° F	105° F	93° F
35% - 25%	110° F	96° F	110° F	96° F
25% - Final	120 ° F	90° F	120° F	90° F
Group 3				
Above 45%	90° F	86° F	100° F	97° F
45% - 35%	100° F	96° F	105° F	101° F
35% - 25%	110° F	98° F	110° F	98° F
25% - Final	120° F	98° F	120° F	98° F
Group 4				
Above 50%	90° F	85° F	100° F	97° F
50% - 40%	95° F	89° F	100° F	96° F
40% - 35%	100° F	90° F	105° F	97° F
35% - 30%	110° F	98° F	110° F	98° F
30% - Final	120° F	95° F	120° F	95° F

Kiln scheduling is a process. The goal is to develop a schedule that works for specific kilns, operations, and species. We'll go over some basic schedules originally designed for a Nyle L200 and then discuss how we could safely modify and experiment with the settings to maximize a kiln's potential. These concepts can be scaled to any size kiln.

Therefore, an L200 can be set to 120 degrees Dry Bulb and 75 degrees Wet Bulb. This will cause the compressor to run nearly constantly, which is excellent for keeping up with the fast water removal from Group 1 species.

When dealing with 4/4 lumber, drying group 1 woods at less than 5% a day may result in mold or staining. Conversely, drying group 3 woods at greater than 3.5% a day may result in checking or other degradation in the lumber.

It is entirely acceptable to have a drying schedule with minimal steps, which can be effective for many operators. However, incorporating additional steps can potentially smooth the drying curve, leading to a faster overall drying cycle.

Let's consider the example of drying Red Oak using the Group 3 schedule, starting with an initial moisture content of 68%. According to our base schedule, these settings would be maintained until the lumber reaches 45% moisture content. The generally accepted safe moisture loss per day for Red Oak is 3.8% or less. Beginning at 68%, we might approach this 3.8% loss per day during the first 24 hours and possibly the second 24 hours as well. For instance, if we lose 3.5% on the first day and 3.2% on the second day, we would be at 61.3% moisture content at the start of the third day. With 16.3% more moisture to remove before the next adjustment, the water removal rate will decelerate, potentially dropping to 2% or less per day by the time we reach 45%.

These figures are hypothetical, but they suggest that we could have safely increased the set points between the initial 68% and the 45% target while staying within the safe drying rate per day. Actively striving to make schedules more aggressive can accelerate drying speed and maximize kiln throughput. However, this approach carries risks. Such adjustments should be made with a comprehensive understanding of these risks and an assessment of whether they are acceptable for a specific operator.

Conversely, schedules can be adjusted to be less aggressive to achieve better equalization or "optimal" quality.

Table 2.4—Stages of drying

Stage	Wood moisture content[a]	Major defect risk
I	Green to 2/3 green	Formation of surface and end checks, stain, warp
II	2/3 green to 30% MC	Aggravation of surface and end checks
III	30% MC to final	Conversion of checks to honeycomb, cupping, overdrying
IV	Final	Unequal final MC, casehardening

[a]Green denotes moisture content (MC) in the living tree, not when the lumber is received.

Fiber Saturation Point

Conditioning & Equalizing

Denig, Joseph, Eugene M. Wengert and William Turner Simpson. "Drying Hardwood Lumber." (2000).

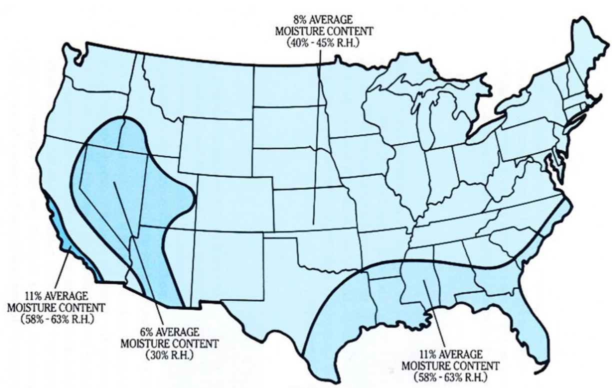


FIGURE II
RECOMMENDED MOISTURE CONTENT AVERAGES FOR INTERIOR-FINISHING WOODWORK FOR USE IN VARIOUS PARTS OF THE UNITED STATES

Forest Products Laboratory. 2021. Wood handbook—wood as an engineering material. General Technical Report FPL-GTR-282. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 543 p

Below is a chart detailing some common North American lumber species and their safe drying rates. The default loss per day assumes 4/4 thick lumber.

Drying Rates (North American Measure)

Species	Oven Dry Weight #/MBF	Avg. Green MC %	Green Weight #/MBF	# Water Per % MC	Max MC% Loss/ day
Cedar, Eastern White	1578	93	3046	16	11
Fir, Balsam	1739	118	3790	17	20
Hemlock, Eastern	2161	111	4558	22	20
Larch, Eastern	2532	52	3849	25	20
Pine, Red (Norway)	2051	83	3747	21	15
Pine, Eastern White	1950	90	3705	20	12
Spruce, Black	2110	80	3798	21	20
Spruce, Red	2000	89	3781	20	20
Spruce, White	1840	115	3967	18	20
Ash, Black	2532	95	4937	25	7
Ash, White	3055	45	4431	31	10.4
Basswood	1899	107	3933	19	12
Beech	3114	63	5089	31	4.5
Birch, White	2692	73	4659	27	10
Birch, Yellow	2954	69	4996	30	6.1
Cherry, Black	2633	58	4161	26	5.8
Elm, Rock	3165	50	4760	32	3.5
Elm, White	2692	93	5207	27	10.4
Hickory	3325	64	5452	33	6
Maple, Soft	2692	93	4389	27	13.8
Maple, Hard	3165	68	5317	32	6.5
Oak, Northern Red Upland	3277	74	5703	33	3.8
Oak, White Upland	3518	70	5981	35	2.5
Oak, Southern Red	3092	80	5567	31	3.8
Sweetgum (Red gum)	2740	100	5480	27	5.3
Walnut	2851	85	5274	29	8.2
Yellow Poplar, Cottonwood	1899	154	4819	19	13.8

Northeast Lumber - Based on 4/4 (1” or 25 mm)

To estimate maximum % MC loss per day for other thickness’ multiply % MC loss per day from the above table by 0.6 for 6/4 and 0.4 for 8/4.

This information is invaluable to experimenting and designing custom schedules. Knowing your current drying rate and what’s safe for the species allows you to determine if you can be more aggressive, dry slower for better quality, or hold course because you’re right on track.

The following page has a drying chart that details various Dry Bulb and Wet Bulb temperature combinations. Since every combination of Dry Bulb and Wet Bulb will have a corresponding Relative Humidity and EMC, we can utilize this chart to know the EMC of the local environment for air drying, as well as various settings in the kiln. This chart is an invaluable tool for experimenting and designing custom schedules.

D.R.I (Drying Rate Index)

DRI is an index of relative drying rate. This can be used to estimate how much faster lumber will dry based on various adjustments. For example, if a kiln is operating at 120° Dry Bulb with a Wet Bulb depression of 12° and drying at a rate of 1.5% per day, the DRI is 1.1. If the conditions were changed to 130° with a 20° depression, the DRI is 2.2. This should make the wood dry at twice the rate. The new DRI divided by the old DRI equals the multiplier for the increased drying rate. (2.2/1.1=2) 2*1.5%=3%. According to the chart, if your settings are 120 dry bulb and 108 wet bulb and you're drying at 1.5% per day, increasing your settings to 130 dry bulb and 110 wet bulb should increase your drying rate to 3% per day.

If our starting point is the same with a 120 dry bulb and a 108 wet bulb (1.1 DRI) drying at 1.5% and we increase our settings even more to 140 dry bulb and 110 wet bulb (3.7 DRI), then the calculation would be as follows: 3.7/1.1=3.364, and then 3.364*1.5%=5.046%, or just over 5% loss per day.

It's important to keep in mind that these numbers depend on the kiln actually hitting the proper set points. For example, if you make an adjustment and the wet bulb is lower than intended, your drying rate index multiplier will actually be higher, and your adjustment could be more aggressive than intended.

Drying Chart

Wet Bulb Depression °F

Dry Bulb °F		2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	25°	30°	35°	40°	45°	50°
30°	RH	78	57	36	17												
	EMC	15.9	10.8	7.4	3.9												
	DRI	0.0	0.1	0.1	0.1												
35°	RH	81	63	45	28	11											
	EMC	16.8	11.9	8.8	6.0	2.9											
	DRI	0.0	0.1	0.1	0.1	0.2											
40°	RH	83	68	52	37	22	8										
	EMC	17.6	12.9	9.9	7.4	5.0	1.9										
	DRI	0.0	0.1	0.1	0.2	0.2	0.2										
45°	RH	85	72	58	44	31	19	6									
	EMC	18.3	13.7	10.7	8.5	6.5	4.2	1.5									
	DRI	0.0	0.1	0.1	0.2	0.2	0.2	0.3									
50°	RH	86	74	62	50	38	27	16	5								
	EMC	19.0	14.4	11.5	9.4	7.6	5.7	3.9	1.5								
	DRI	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3								
55°	RH	88	76	65	54	44	34	24	14	5							
	EMC	19.5	15.1	12.2	10.1	8.4	6.8	5.3	3.6	1.3							
	DRI	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4							
60°	RH	89	78	68	58	48	39	30	21	13	5						
	EMC	19.9	15.6	12.7	10.7	9.1	7.6	6.3	4.9	3.2	1.3						
	DRI	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5						
65°	RH	90	80	70	61	52	44	36	27	20	13						
	EMC	20.3	16.1	13.3	11.2	9.7	8.3	7.1	5.8	4.5	3.0						
	DRI	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.5						
70°	RH	90	81	72	64	55	48	40	33	25	19	3					
	EMC	20.6	16.5	13.2	11.6	10.1	8.8	7.7	6.6	5.5	4.3	0.7					
	DRI	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7					
75°	RH	91	82	74	66	58	51	44	37	31	24	10					
	EMC	20.6	16.8	14.0	12.0	10.5	9.3	8.2	7.2	6.2	5.1	2.3					
	DRI	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8					
80°	RH	91	83	75	68	61	54	47	41	35	29	15	3				
	EMC	21.0	17.0	14.3	12.3	10.9	9.7	8.6	7.7	6.8	5.8	3.5	0.3				
	DRI	0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.9	1.0				
85°	RH	92	84	76	70	63	56	50	44	38	33	20	9				
	EMC	21.2	17.2	14.5	12.5	11.2	10.0	9.0	8.1	7.2	6.3	4.3	1.7				
	DRI	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.8	1.0	1.1				
90°	RH	92	85	78	71	65	58	52	47	41	36	24	13	3			
	EMC	21.3	17.3	14.7	12.8	11.4	10.2	9.3	8.4	7.6	6.8	4.9	2.8	0.8			
	DRI	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1.1	1.2	1.4			
95°	RH	92	85	79	72	66	60	55	49	44	39	28	17	8			
	EMC	21.3	17.4	14.9	12.9	11.6	10.5	9.5	8.7	7.9	7.1	5.3	3.6	1.9			
	DRI	0.1	0.2	0.3	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.2	1.4	1.5			
100°	RH	93	86	80	73	68	62	56	51	46	41	30	21	12	4		
	EMC	21.3	17.5	15.0	13.1	11.8	10.6	9.6	8.9	8.1	7.4	5.7	4.2	2.8	0.7		
	DRI	0.1	0.3	0.4	0.5	0.6	0.7	0.9	0.9	1.0	1.1	1.4	1.5	1.7	1.9		
105°	RH	93	87	80	74	69	63	58	53	48	44	34	24	16	8		
	EMC	21.4	17.5	15.1	13.2	11.9	10.8	9.8	9.0	8.3	7.6	6.1	4.6	3.3	1.8		
	DRI	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.1	1.2	1.3	1.5	1.7	1.9	2.1		
110°	RH	93	87	81	75	70	65	60	55	50	46	36	26	19	11	4	
	EMC	21.4	17.5	15.1	13.3	12.0	10.8	9.9	9.2	8.4	7.7	6.3	4.8	3.8	2.5	1.1	
	DRI	0.2	0.3	0.5	0.6	0.8	0.9	1.0	1.2	1.3	1.4	1.7	1.9	2.1	2.3	2.5	
115°	RH	93	88	82	76	71	66	61	56	52	48	38	29	22	14	8	2
	EMC	21.4	17.5	15.1	13.4	12.1	10.9	10.0	9.3	8.6	7.8	6.5	5.2	4.1	2.9	1.7	0.4
	DRI	0.2	0.4	0.5	0.7	0.9	1.0	1.2	1.3	1.4	1.6	1.9	2.1	2.4	2.6	2.8	2.9
120°	RH	94	88	82	77	72	67	62	58	53	49	40	31	24	17	10	5
	EMC	21.3	17.4	15.1	13.4	12.1	11.0	10.0	9.4	8.7	7.9	6.6	5.4	4.4	3.3	2.3	1.1
	DRI	0.2	0.4	0.6	0.8	1.0	1.1	1.3	1.4	1.6	1.8	2.1	2.4	2.6	2.9	3.1	3.3
125°	RH	94	88	83	77	73	68	63	59	55	51	41	33	26	19	13	8
	EMC	21.2	17.3	15.0	13.4	12.1	11.0	10.0	9.4	8.7	8.0	6.7	5.5	4.6	3.6	2.7	1.6
	DRI	0.2	0.5	0.7	0.9	1.1	1.3	1.5	1.6	1.8	1.9	2.3	2.7	2.9	3.2	3.4	3.6
130°	RH	94	89	83	78	73	69	64	60	56	52	43	35	28	21	15	10
	EMC	21.0	17.2	14.9	13.4	12.1	11.0	10.0	9.4	8.7	8.0	6.8	5.6	4.8	3.8	3.0	2.0
	DRI	0.3	0.5	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.6	2.9	3.3	3.6	3.9	4.1
140°	RH	95	89	84	79	75	70	66	62	58	54	46	38	31	25	19	14
	EMC	20.0	16.9	14.8	13.2	11.9	10.9	10.0	9.4	8.7	8.0	6.9	5.8	4.9	4.1	3.4	2.6
	DRI	0.3	0.6	0.9	1.2	1.5	1.8	2.0	2.2	2.5	2.7	3.2	3.7	4.1	4.4	4.8	5.1
150°	RH	95	90	85	80	76	72	68	64	60	57	48	41	35	26	23	18
	EMC	20.2	16.6	14.5	13.0	11.8	10.8	9.9	9.2	8.6	8.0	6.9	5.8	5.0	4.2	3.6	2.9
	DRI	0.4	0.8	1.1	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.9	4.5	5.0	5.5	5.8	6.2
160°	RH	95	90	86	81	77	73	69	65	62	58	50	43	37	31	25	21
	EMC	19.8	16.2	14.2	12.7	11.5	10.6	9.7	9.1	8.5	7.9	6.8	5.8	5.0	4.3	3.7	3.2
	DRI	0.5	1.0	1.4	1.8	2.2	2.6	3.0	3.4	3.7	4.1	4.8	5.5	6.1	6.7	7.2	7.6
170°	RH	95	91	86	82	78	74	70	67	63	60	52	45	39	33	28	24
	EMC	19.4	15.8	13.9	12.4	11.3	10.4	9.6	9.0	8.4	7.8	6.7	5.7	5.1	4.4	3.7	3.2
	DRI	0.6	1.1	1.7	2.2	2.7	3.2	3.7	4.0	4.5	4.9	5.9	6.7	7.5	8.2	8.8	9.3
180°	RH	96	91	87	83	79	75	72	68	65	62	54	47	41	35	30	26
	EMC	18.9	15.5	13.7	12.2	11.1	10.1	9.4	8.8	8.1	7.6	6.5	5.7	5.1	4.4	3.8	3.3
	DRI	0.6	1.4	2.0	2.6	3.2	3.8	4.3	4.9	5.4	5.8	7.0	8.1	9.0	10.0	10.7	11.3
190°	RH	96	92	88	84	80	76	73	69	66	63	56	49	43	37	32	28
	EMC	18.5	15.2	13.4	12.0	10.9	10.0	9.2	8.6	7.9	7.4	6.4	5.5	4.9	4.4	3.8	3.3
	DRI	0.8	1.5	2.3	3.0	3.8	4.6	5.1	5.9	6.5	7.0	8.4	9.7	10.9	12.0	12.9	13.7
200°	RH	96	92	88	84	80	77	74	70	67	64	57	51	45	39	34	30
	EMC	18.1	14.9	13.2	11.8	10.8	9.8	9.1	8.4	7.7	7.2	6.2	5.4	4.8	4.3	3.8	3.3
	DRI	0.9	1.9	2.8	3.8	4.7	5.4	6.1	7.0	7.8	8.5	10.1	11.5	13.0	14.3	15.5	16.4
210°	RH	96	92	88	85	81	78	75	71	68	65	59	52	46	41	36	32
	EMC	17.7	14.6	13.0	11.7	10.6	9.7	9.0	8.3	7.6	7.1	6.1	5.3	4.7	4.2	3.7	3.2
	DRI	1.2	2.3	3.5	4.3	5.5	6.3	7.2	8.3	9.2	10.1	11.8	13.8	15.5	17.0	18.4	19.6

U.S.D.A. HANDBOOK #188 [1961] DRY KILN OPERATOR'S MANUAL - Relative Humidity and equilibrium moisture content values occurring at various dry bulb temperatures and wet bulb depressions

Red Flags When Drying Lumber

An operator should be on the lookout for many issues, both large and small, during the drying process. This section will detail some of the common areas of concern during drying, as well as possible causes and solutions.

Dry Bulb Is Higher Than The Set Point

- Overshooting the target temperature is not uncommon with steam heat to a small degree. If it is more than a couple of degrees, the heat source might not shut off when it should.
- It can also be caused by temperature probes mounted too close to the heat source.

Dry Bulb Is Lower Than The Set Point

- If only a degree or two can be associated with normal equipment function, it is not a concern.
- If it is several degrees or more, the heat might have failed or not be functioning properly.
- The kiln chamber may not be sealed well enough, or vents could be stuck open.

Wet Bulb Is Higher Than The Set Point

- Vents or compressors might not be keeping up with the water removal rate.
- Vents or compressors might not be functioning properly.
- The wet bulb wick could have dried out, providing a false high reading.
- A mechanical failure could be pumping water or steam into the chamber.

Wet Bulb Is Lower Than The Set Point

- Not enough water is being pulled from the lumber to increase the relative humidity.
- Usually caused by scheduling, occasionally exacerbated by leaky or poorly sealed kiln chambers.

Common Drying Defects

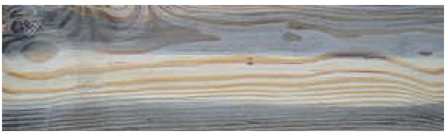
Surface Checks or Cracks

Robbyp. (n.d.). Surface checking! Help appreciated! : r/woodworking. https://www.reddit.com/r/woodworking/comments/9vg2pz/surface_checking_help_appreciated/#lightbox

Oaks are prone to this type of degradation, which is typically caused by the shell drying too quickly, often from uncontrolled air drying or too aggressive a depression in a scheduled step.

The terms surface checks or surface cracks are frequently used interchangeably.

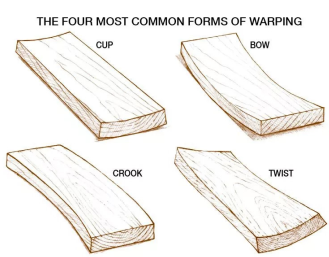
Blue Stain / Brown Stain



Blue stain (or sap stain) is caused by fungi growing in the wood. The fungi needs oxygen, warm temperatures, and plenty of moisture to grow.

Brown stain (or coffee stain) is a reaction from natural chemicals in the wood being exposed to high humidity and high temperatures.

Issues with improper venting, airflow, or scheduling can cause both types of stains. Inadequate airflow can come into play during air drying as well as kiln drying.



Staff, W. M. (2021, March 16). When good wood goes bad: WOOD Magazine. https://www.woodmagazine.com/wood-supplies/lumber/when-good-wood-goes-bad

Warping: Cup, Bow, Crook, & Twist

Lumber will naturally pull along its grain pattern as it dries. This can be limited with proper scheduling, but the easiest way to prevent it is to have uniform stick size and weight on top of the packs. This prevents the lumber from moving as it dries and will hold its flat shape.

Shake & Honeycomb

Shake is typically caused by stresses in the tree from felling or drying in log form and usually appears along the growth rings.

Rob. (2019, March 17). Heartwood » Blog Archive » Wood woes – the dread honeycomb. https://www.rpwoodwork.com/blog/2019/03/17/wood-woes-the-dread-honeycomb/

Honeycombs are checks or cracks along the wood rays — like surface checks, but internal. Wood rays are lines extending from the tree's center to the outside, perpendicular to the growth rings. They assist in water and nutrient transfer.

Honeycomb is usually caused by drying too quickly for a particular species, while shake is often present before the product reaches the kiln.

Splits

Splits are cracks that go all the way through a piece of lumber and equal a total failure of the wood fiber.

Splits can be caused by aggressive drying but can be mitigated by end coating. They can also be caused after drying by planing or milling when a board is cupped or warped

Ekm. (2024, January 27). Why do timbers split and crack? Carolina Timberworks. https://www.carolinatimberworks.com/why-do-timbers-split-and-crack/

Running Pitch

Pirnik, E. (2011, October 14). How to set wood SAP. FineWoodworking. https://www.finewoodworking.com/2011/10/14/how-to-set-wood-sap

Running or leaking pitch/sap out of certain softwood trees can happen during or after drying. The treatment for this is a process called "setting the pitch." This is done by treating the lumber at a high enough temperature for a certain amount of time. This causes a chemical reaction where the sap crystallizes.

Frequently Asked Questions

How Important is Airflow?

Airflow is the tool that allows the kiln to turn water into vapor and then remove it from the chamber, so it is essential. The velocity of the air over the wood affects the drying rate, and lower airflow in certain spots can lead to wet pockets. Different species of lumber will have different optimal air speeds. Generally, higher moisture or faster-drying lumber will require more airflow. Check-prone species can be damaged by too high airflow.

Should Fans be Reversible?

It is possible for the air picking up water vapor to become saturated, which means it can no longer remove any moisture. This is only a potential issue with lumber stacked over 10 feet deep in a kiln. Anything less than 10 feet, there typically isn't enough water vapor to saturate the air. This is why small kilns with less lumber usually don't have reversible fans. Larger kilns, with lumber stacked deeper than 10 feet, should always have reversible fans.

How To Set Pitch in Pine & Other Softwoods

When softwoods are dried, pitch solidifies (sets) at the highest temperature of the drying cycle. For example, if the last step of drying has a dry bulb temperature of 120°F, then the lumber would have to get above that temperature before the pitch would start to run and leak from the board. Many secondary manufacturers have sanding and milling equipment that can heat the lumber to 160°F. Because of this, many customers will want softwood pitch set to at least 160°F. This can be done at the tail end of the cycle if the drying schedule doesn't typically go that high, but be wary of over-drying with the potential higher temperatures. Two common schedules for setting pitch are 160°F for 24 hours or 180°F for 8 hours. Smaller kilns with electric heat sources will typically have better luck with the lower temperature.

Lastly, if you are utilizing a DH kiln where the temperature required to set the pitch is higher than the safe operating temperature for the compressor, make sure to shut the compressor off and use the heat source to reach the desired set point for setting the pitch.

What is Conditioning?

As lumber dries, it will dry faster on the shell compared to the core of each piece. As the lumber reaches fiber saturation, the shell shrinks around the core, creating stress in the wood. Conditioning is the process of adding moisture back into the surface of the lumber to relieve this stress. This is typically done in a kiln with live steam or a high-pressure water spray. However, in kilns that are not equipped with either, pouring water on the floor and letting it evaporate can drive the wet bulb up and accomplish the same thing to a lesser degree. Gentle scheduling can also limit the intensity of stress in the lumber.

Air-dried lumber will usually have almost zero stress. This is due to the natural fluctuation of temperature and humidity during the day and night cycle. This also means that if lumber isn't used immediately when removed from the kiln, it will equalize and condition itself with the ambient environment over time. Not all species are prone to stress, and the final use of the product determines whether or not stress is a concern. For example, if lumber is going to be planned on all four sides, it may remove all the stressed wood, so it's not a concern.

Below are two examples of stress tests. The left photo shows a test with low stress, and the photo on the right shows a test with high stress.

Grace.Hershberg. (2021, October 7). CaseHardening of lumber: What it is and how to Relieve it |. https://forestrynews.blogs.govdelivery.com/2021/10/07/casehardening-of-lumber-what-it-is-and-how-to-relieve-it/

What Is Case Hardening, & How Can It Be Prevented?

Case hardening is a condition that occurs during lumber drying, where the outer layers dry and shrink faster than the inner core. This differential drying creates internal stresses, causing the outer shell to compress while the core remains swollen and moist. When the core eventually dries, it can lead to cracking, warping, and structural damage when the wood is cut or further processed.

Preventing case hardening involves controlled drying rates, proper kiln schedules, and ensuring uniform air circulation. Gradual drying and tailored kiln schedules help maintain even moisture loss throughout the wood. Incorporating a conditioning phase at the end of the drying cycle, which involves reintroducing moisture, can relieve internal stresses and equalize the moisture content. Consistent monitoring of moisture levels and avoiding overloading the kiln also prevents case hardening, ensuring high-quality, structurally sound lumber.

How Important is Baffling?

Baffling is crucial in the lumber drying process as it directly impacts the efficiency and uniformity of drying. Proper baffling ensures that the air flows evenly across the lumber stacks, essential for achieving consistent moisture content throughout the wood. Without effective baffling, air can bypass certain areas, leading to uneven drying where some sections might dry too quickly while others remain too moist. This inconsistency can result in defects such as warping, cracking, and uneven shrinkage, compromising the quality and structural integrity of the lumber.

Moreover, baffling helps optimize the drying process's energy consumption. By directing the airflow precisely where needed, baffling reduces the need for excessive heating and air circulation, leading to more efficient energy use and lower operational costs. In essence, proper baffling improves the quality of the dried lumber and enhances the overall efficiency and cost-effectiveness of the drying operation. For industries relying on high-quality lumber, investing in effective baffling systems is critical to their drying process.

Can I Dry Different Species Together In The Same Kiln?

Drying different species of wood together in the same kiln is generally not recommended due to variations in their drying characteristics. Each wood species has unique properties, such as density, initial moisture content, and cellular structure, which influence how it reacts to the drying process. These differences necessitate specific drying schedules tailored to each species to ensure optimal results and minimize defects.

For instance, hardwoods typically require slower drying rates and higher temperatures compared to softwoods, which dry faster and at lower temperatures. If mixed species are dried together, the risk of over-drying or under-drying parts of the load increases. Over-drying can lead to issues like checking, cracking, and warping, while under-drying can result in higher moisture content than desired, leading to future issues in use or storage.

However, in some cases, if the species have similar drying characteristics and moisture content, they might be dried together successfully. This requires careful planning and monitoring to ensure that the drying conditions are appropriate for all species involved.

In conclusion, it is possible to dry different species together in the same kiln under specific conditions. However, drying each species separately, adhering to their respective optimal drying schedules, is generally more efficient and yields better results.

Can Kiln Drying Eliminate Pests and Fungi?

Yes, kiln drying can effectively eliminate pests and fungi in lumber. The high temperatures reached during kiln drying, typically between 110°F to 180°F (43°C to 82°C), are sufficient to kill insects, larvae, and fungal spores present in the wood. This heat treatment ensures the lumber is free from pests and resistant to future infestations. Additional auxiliary heaters can be used to ensure the necessary temperatures are reached consistently throughout the kiln.

Additionally, kiln drying reduces the wood's moisture content to levels that prevent fungal growth and mold. By stabilizing the wood and reducing moisture-related issues such as warping and checking, kiln drying enhances the overall quality and durability of the lumber.

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