Wood-Mizer®
KILN DRYING SYSTEMS

INTRODUCTION *to* KILN DRYING

Maximize the Value of Your Lumber

This resourceful guide is designed to provide you with basic information on kiln drying and discuss the many advantages of drying your own lumber including:

- Properly dried lumber typically **sells for over 30% more** than undried lumber
- Dry lumber **kills infestations, hardens pitch, preserves color,** and **controls shrinkage**
- Lumber under 22% moisture content has **no risk of developing fungal stain, decay, rot,** or **mold**
- Dry lumber **machines better, glues better, and finishes easier**
- Nails and screws in dry lumber have **higher holding power**
- Dry lumber weighs **over 50% less** and is **over twice as strong** and stiff as wet lumber

Lumber that is not dried under controlled conditions is prone to warping and other degrade that diminishes its selling price and workability. With a Wood-Mizer Kiln, successful drying for better profitability is easy and affordable for virtually any size operation. Learn how you can maximize the value of your lumber throughout the following pages.

Contents

Basic Facts on Drying Lumber

How Much Water is in Lumber?

In a living tree, wood typically has a **moisture content** (MC)* of 75% or higher. In fact, some species of wood are more than half water in terms of their weight when they're fresh cut. In order to use lumber for furniture, cabinets, millwork, and interior projects, almost all of the water must be removed by drying to 7% MC, which is equivalent to the MC that wood will achieve in a **relative humidity** (RH) of 38% – the average RH for most homes and offices.

It's really astounding how much water has to be removed from wood to make it suitable for finished products. For example, fresh cut oak weighs about 2.45kg per cubic meter (5.4 pounds per board foot), so a truckload of 18.88m^3 (8,000 board feet) of oak weighs about 19,595kg (43,200 pounds). Once you remove enough water to get the oak down to a MC of 6%-8%, it will weigh 1.6kg per cubic meter (3.5 pounds per board foot) resulting in the truckload of oak now weighing 12,700kg (28,000 pounds). This means you have to remove 6,895kg (15,200 pounds) of water -almost seven metric tons - (almost eight US tons) to completely dry an 18.88m^3 (8,000 board foot) truckload of oak. That's why choosing the right drying system and using the proper method are so important.

What is Free and Bound Water?

Free water is liquid water that moves through the cells of the wood of a growing tree and can be removed relatively easily. **Bound water** is the water that becomes part of the wood fiber itself and is more difficult to remove. When wood is dried, the first thing that happens is that the free water evaporates until the lumber drops to what's called fiber saturation which is generally reached at 28% MC. At this point, all the free water is gone and only bound water remains. Wood does not shrink until it is below **fiber saturation** and the bound water begins to be removed from the cells of the wood.

***Moisture Content (MC)** is the amount of water in lumber measured as a percentage of the lumber's oven-dry weight. For example, if a 4.5kg (10 pound) piece of lumber has 1.8kg (4 pounds) of water and 2.7kg (6 pounds) of dry wood, the moisture content is 67%. This value is calculated as the weight of the water divided by the oven-dry weight, times 100 to convert to a percentage. In this example, 1.8 ÷ 2.7 x 100 = 67% (4 ÷ 6 x 100 = 67%) MC. *Learn more about measuring moisture content on Page 10.*

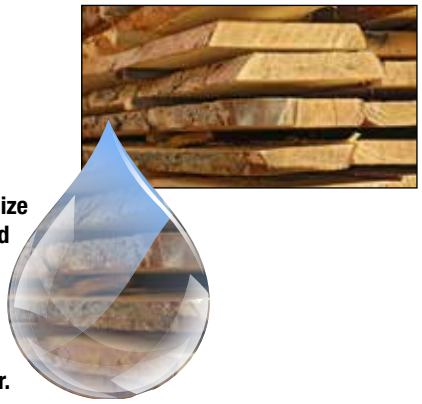
Basic Facts on Drying Lumber

What is the difference between drying hardwoods and softwoods?

Although a common question, the actual species of the wood is really more important to consider than whether it's a hardwood or softwood. Different species require drying at different temperatures and speeds to produce the best results. For example, oak has to be dried slowly or it will degrade badly while pine needs to be dried at a fast rate or it can stain or mold. There's a proper method that's been determined for nearly every species of lumber to produce the best results. *See page 17 for information on drying a particular species.*

Does the thickness of lumber affect the drying rate?

Yes. Generally speaking, drying times are roughly proportional to the thickness. That is, 8/4, or 5.1cm (2 inch) lumber usually takes a little more than twice as long to dry as 4/4 or 2.54cm (1 inch) lumber.



In order to equalize with the air, wood gives up water to dry air and absorbs water from more humid air.

Can drying cause the wood to split or check?

Wood does shrink while it dries, but the shrinking doesn't start until the lumber is below fiber saturation of about 28% MC. If the outside surface is below 28%, while the center of the board is still above, the outside will try to shrink while the center doesn't. If this pattern continues until the surface becomes too dry in relation to the core, the lumber will split or check. When lumber is air dried, there is no control over the drying process, and the weather can easily cause splitting and checking that results in losses. Controlled drying in a kiln reduces or eliminates the potential of checking. *Learn more about kiln drying on page 9.*

Once wood is dry, will it remain dry?

Since wood expands when it absorbs water and shrinks when it gives up water, it is always trying to come into equilibrium with the air surrounding it, so the MC of wood can change even after it's been dried.

Additional Quality Characteristics of the Drying Process

Freedom from Checks and Splits

All lumber should be end-coated as soon as possible after it is sawn. Good stacking and good control of lumber lengths will help prevent the ends from drying too quickly. High relative humidity at MCs above 40% are critical while moderate air flows and lower temperatures are also important. Above all, the drying rate must be controlled to within narrow limits – the precise rate depends on the species and thickness of the lumber.

Freedom from Warp

Except for cupping and warp caused by bad stacking (such as non-uniform sticker thickness, poor sticker alignment, or non-flat foundations), all warp results because of wood factors and sawmilling procedures. Cup is a result of rewetting partially-dried lumber or over-dried lumber.

Freedom from Casehardening

The procedures for proper stress relief or conditioning require the rapid addition of moisture to the lumber surface when the lumber is warm. Often the heat in the steam used for stress relief will increase the kiln temperature above the required level, leading to poor relief. Use of water to cool the steam or cooling the lumber prior to steaming should be considered. Using 82°C (180°F) air temperature (often called the dry-bulb temperature) is suggested. Note that stress relief will be erratic if the lumber's MC is not uniform when stress relief begins. Solar kilns do not require stress relief, as the nighttime high humidities provide freedom from casehardening.

Good Color

By far, the most critical factor determining lumber's color, or discoloration, is log freshness. Old logs have 20 times or more risk of developing stain-fungal stains, sticker stains, browning, pinking, graying, and so on. Freshly sawn lumber requires low humidities, low temperatures, and brisk velocities immediately after stacking and until the lumber is under 30% moisture content to control stain. Narrow loads and partially-filled dryers will help. Poor stacking and exposure to rain increase the risk of stain.

High Strength

Low humidities and low dryer temperatures will maximize the strength. Other strength-lowering factors, including bacterial and fungal effects and species effects, are beyond our control.

Good Machinability

Wood that is too wet will fuzz while wood that is too dry (under 6% MC) will chip, split, and develop other machining defects. Make sure that you monitor the driest pieces of wood in the dryer as well as the wet ones. Don't underestimate the effect of over-drying on machining. Avoid temperatures over 71°C (160°F) and avoid very low humidities in the drying schedule. Conditioning or setting the resin at 82°C (180°F) is acceptable.

Good Gluability

Good gluing requires accurate final MCs. Check for pieces that are too wet (over 8% MC) or too dry (under 5.5% MC) and avoid temperatures over 71°C (160°F) in the main drying schedule. Conditioning or setting the resin at 82°C (180°F) is acceptable.

Proper Drying Starts at the Sawmill

As soon as the lumber is sawn, there are three major risks including attack from insects, stain from mold and mildew, and cracking if it is exposed to sun or dry air for hours before stacking. To keep lumber valuable, it must be handled correctly from the moment it leaves the sawmill.

Sorting

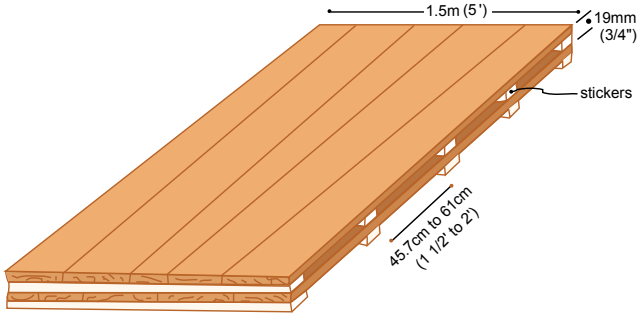
Once lumber is sawn, it is usually sorted into different size and value groups in order to facilitate handling and obtain the highest quality. Lumber is always sorted by species and thickness. It is not advisable to mix thicknesses in the same pile or stack of lumber. If thick and thin lumber is a problem, then run the lumber through a single-headed planer to achieve more uniform thickness.

Lumber is usually sorted by grade or quality classification and often only two sorts are used – valuable lumber intended for furniture, cabinets, etc. and the less valuable, industrial grade lumber. This grade sorting is done so that the higher-valued lumber can be treated more carefully than the low-quality lumber which is often sold green and is rarely kiln dried.

Stacking

Once sorted, the green lumber is stacked for drying in order to maintain the highest quality. Lumber is stacked in layers typically 1.2m to 1.8m (4 to 6 feet) wide, with all the lumber in each layer being the same thickness. Narrow layers result in faster drying, but also result in piles that can tip over more easily. The length of the layer is the length of the lumber, with the longer pieces being used on the outside edges.

Each layer of lumber is separated from the one above by wooden spacers called **stickers**. The stickers, made of DRY species of wood, are placed perpendicular to the lumber's length. The width of the layer is the length of the sticker. The stickers are spaced every 61cm (24 inches) starting at one end of the lumber, although many operations use 30.5cm, 40.6cm, 45.7cm (12, 16, or 18 inch) spacings in order to keep the lumber even flatter. The stickers keep the lumber flat and provide space for air flow in the drying process. The stickers in one layer must be perfectly vertically aligned – no greater than 1.3cm (½ inch) variation – with the stickers in layers below and above. A **pile** or **stack** is several layers of stickered lumber.



It would be best if the lumber within one stack is all the same length, however if a few shorter pieces are included – but never more than a 0.61m (2-foot) difference between the shortest and longest – then place the longer pieces on the outside edges of the layer and keep the shorter ones inside. The ends of the shorter pieces should always be supported with a sticker; therefore, an extra sticker may have to be used in some layers.

Once stacked, the lumber is placed in a good drying location (even if it will be sold in a few days) where the air can move through the package.

Different Drying Methods

Air Drying

Using the natural wind and sun to dry, air drying is accomplished by stacking lumber on stickers and allowing the prevailing winds to blow through the pile for drying. Slow drying from slow airflow or high humidity may result in stain, while fast drying from excessive airflow or low humidities can result in excessive cracking and splitting. For lumber that is to be used in furniture or some other finished product which requires 6% - 8% MC, air drying can't do the entire job by itself. It's often used as a first step, with the lumber being placed in a kiln for final drying. Although air-drying is simple and easy, it is not unusual to have in excess of 10% loss in quality due to the variability and extremes of the weather. Can you afford this? If not, consider shed drying. In other words, if someone stole 10% of your lumber, wouldn't you do something about it? Air drying poses real problems with damage and degrade and is often the most expensive way to dry once you include interest on the money tied up, labor, land costs, and especially degrade loss.

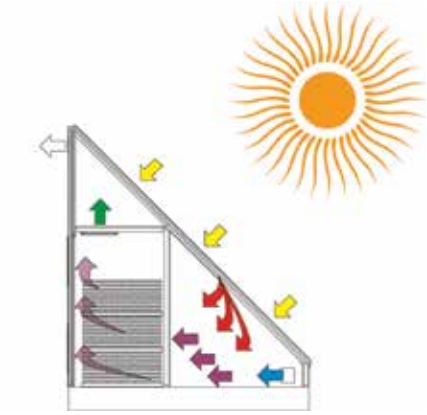
Shed Drying

In shed-drying, lumber is placed in a shed without walls thereby avoiding direct sunlight and rainfall, while allowing for good air flow. Drying rates can be regulated by using plastic mesh curtains and pulling them closed during hot, dry weather while opening them during cool or damp weather. The final moisture content of lumber using this method is typically over 20% MC. Fans can also be used to force air through the lumber rather than relying on natural wind. This is faster than air drying or shed drying, but the cost of operating the fans is quite high. Also, the capital investment is fairly high in proportion to the amount of drying that can be accomplished. By shed drying before kiln-drying, the annual volume of lumber dried in the kiln can be quadrupled, compared to kiln-drying green from the saw.

Kiln Drying

In kiln drying, lumber is placed in a chamber where airflow, temperature and humidity are controlled to provide as rapid drying as can be tolerated by the lumber without increasing defects. There are several types of kilns which are defined by the manner in which the temperature and humidity are controlled.

Different Types of Kiln Drying



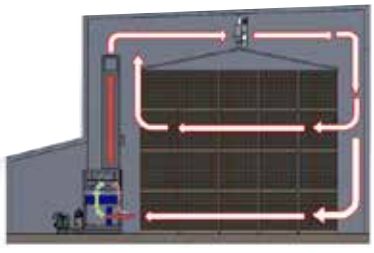
Solar Kiln

Solar kilns generally rely on some type of solar collector to provide the heat energy that evaporates the water in the lumber. Drying times in a solar kiln are dependent on the weather, and thus unpredictable. In hot climates they can degrade lumber due to excessive drying, while in cold climates they can be unreliable and slow. However, a solar kiln is attractively priced for entry-level operations and often will pay for itself after drying just three or four loads of lumber.

See Page 18 for information on the Wood-Mizer Solar Kiln.

Dehumidification Kiln

A dehumidification kiln uses a heat pump system to remove the water from lumber. One primary advantage of this type of system is that it recycles heat continuously instead of venting away heated air, as a conventional kiln does, making it more energy efficient and its operating costs are usually lower. The reason a dehumidification system costs less to run even though a conventional system burns cheaper fuel lies in the dehumidification system's ability to conserve energy by recycling heat. With the heat being constantly recycled, the amount of electricity demanded by the system is limited.



In a dehumidification kiln, heated air usually starting at about 29°C (85°F) is circulated over the lumber with separate circulating fans, evaporating the water contained in the wood. The hot, moist air then passes over a cold refrigeration coil where air is cooled to about 15°C (60°F). At the cooling coil, the evaporated water in the air condenses into liquid form and flows down the drain as a stream of cool water – instead of a cloud of steam carried by heated air, as in a conventional kiln.

When the air is cooled at the cold coil, the heat removed from the air is immediately used by the system to heat the air back up again. The energy efficiency of the heat return is such that each time this process occurs, the air leaves the dehumidifier at an even hotter temperature than when it entered. As the air temperature in the kiln rises, it can ultimately reach temperatures as high as 71°C (160°F). If the temperature becomes higher than desired, the operator can vent surplus heat to the outside.

Dehumidification kilns are very easy to operate and are popular with beginning lumber dryers as well as experienced operators who want a system that requires minimum attention to get zero defect drying. Dehumidification kilns are more expensive than solar, but can provide top quality kiln-dried lumber year-round regardless of the weather.

See Pages 19-22 for information on Wood-Mizer Dehumidification Kilns.

Moisture Content

Moisture content (MC) is a key parameter in wood processing. The MC values are measured daily when operating a dry kiln and temperature may be raised or the relative humidity lowered depending on the MC. In the dried product, any change in MC is accompanied by warping, shrinkage (moisture loss), and swelling (moisture gain). As a result, it is important to measure the MC accurately. Moisture can be measured in two ways: Oven-drying and electrically.

Oven-drying

In the oven-dry test, a small piece of wood called a **moisture section** representing a larger piece of lumber is first weighed to the closest 0.28g (0.01 ounces), then the moisture section is placed in an oven heated to 102°C (215°F). A microwave can also be used if the oven has a carousel tray, and is set to medium or low for 20 to 40 minutes. Do not leave the oven unattended however as the section sometimes may begin to smoke. After approximately 24 hours, the section is weighed again, dried for one more hour, and then weighed again. If these two final weights are the same, then all the moisture has been evaporated. Note the section weight is the oven-dry weight.

Electric Meters

Although oven-drying is the most reliable MC measuring system for most kiln operations, it is a destructive test and requires 24 hours to get the reading. The MC can be measured rapidly and non-destructively by using electrical methods such as a moisture meter. Using pin-free, electromagnetic wave sensor technology to take accurate measurements without destroying a board, a moisture meter can eliminate time-consuming manual corrections with features such as species settings. One disadvantage of electric meters is that they cannot be accurately used above 30% MC which means they cannot be used to run a kiln drying lumber “green from the saw”.

The MC is calculated using this formula:

$$\%\ MC = \frac{(\text{wet weight} - \text{oven-dry weight})}{(\text{oven-dry weight})} \times 100$$

An alternate formula is:

$$\%\ MC = \left[\frac{(\text{wet weight})}{(\text{oven-dry weight})} - 1\right] \times 100$$

How Dry is Dry Enough?

Lumber should be dried to a final MC that is as close to the expected MC that the wood will achieve in use. The following table is established to avoid warping and size change problems in the final product. The MC of wood in-use is related to the relative humidity (RH) that the wood is exposed to; temperature is irrelevant. Different species have the same in-use MC if exposed to the same RH. A special term is used to relate RH to MC in wood called the **Equilibrium Moisture Content** (EMC). The EMC of air is numerically equal to the MC that wood will have when exposed to a given RH. The following table summarizes this relationship.

RULE: The basic rule for drying lumber is that the final MC in the kiln should be within 2% MC of the expected EMC in-use to avoid moisture-related problems. Failure to observe this rule can easily result in large manufacturing losses, as well as loss of future sales and customers.

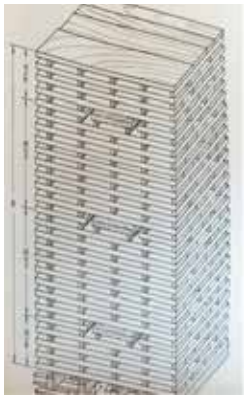
As a general rule, wood shrinks in width or thickness about 1% for every 4% MC change.* This means that if a 6.3cm (2 ½") wide piece of oak loses 3% MC, it will shrink 1% or 0.635mm (0.025 inches)! This seems like a small amount of shrinkage, but when gluing, the maximum gap allowed between two pieces of wood is only 0.1524mm (0.006 inches). If this oak piece is actually a piece of flooring in a 9.14m (30-foot) wide floor and the entire floor is losing 3% MC, the total shrinkage is 10.16cm (4 inches), which distributed across the floor will result in objectionable cracks every 0.3m (foot) or so.

*This rule varies from species to species. For example teak shrinks 1% for every 8% MC change and oak shrinks 1% for every 3% MC change.

The relationship between humidity, EMC and wood use in North America.

RH	MC	EMC	Condition
%	%	%	
0	0	0	Oven-dry
30	6	6	Lower limit in most homes and offices Lower limit for hardwood furniture and cabinet lumber
36	7	7	Average for hardwood furniture and cabinet lumber
44	8	8	Lower limit for softwood remanufacturing lumber
50	9	9	Upper limit in most homes and offices Upper limit for softwood remanufacturing lumber
65	12	12	Average outside condition, winter and summer Average for softwood construction lumber
80	16	16	Outside condition for coastal areas Average for lumber in unheated buildings and outdoor use

How Dry is Dry Enough? Cont.



Achieving Proper Final Moisture Content

- Properly stack lumber with sticker openings uniform in size
- Narrow piles of 1.8m (6 feet) or under have more consistent drying than wider piles
- Uniformity is most critical when lumber is above 40% MC or below 10% MC
- Dry kilns require uniform temperature, relative humidity, and velocity
- Uniform and frequent airflow reversal improve uniformity in kilns
- Equalization should be used as long as needed to achieve desired final MC
- Lumber should be as uniform in thickness and initial MC as possble

Moisture samples need to be accurate and properly prepared. With as many as 5,000 pieces of lumber in a kiln, will just 8 or 10 samples give an adequate picture of the final MC? It is recommended that 30 samples be taken using a moisture meter when the kiln is being unloaded to establish the correct final MC. When such sampling is done, also look for areas in the kiln that are consistently wetter or drier than other areas and make sure that your moisture measuring technique can detect pieces under 6% MC because over-dried lumber is a serious quality problem when machining or gluing.

More Facts on Drying Lumber

What is conditioning?

Conditioning is adding moisture back to the surface of the lumber to relieve any stress that occurs in the outer surface, which dries and shrinks faster than the interior. Stress can also occur because of how the lumber is sawn or where the tree grew. For example, a tree that grows on the side of a hill or mountain may have stresses that a tree on level ground may not.

If proper drying schedules are not used, the outer surface of the lumber will dry much faster, and the surface will tend to shrink more than the interior. This stress remains after the lumber is dried, and if it is not relieved it can cause the wood to deform, especially when it is being worked.

Air-dried lumber tends to have less stress at the end of drying because of variations in the weather. Air drying offers little control over drying rates, so damage can occur easily in some hardwoods. If the lumber isn't used immediately out of the kiln, it will condition itself naturally with time. Not all species are prone to stress, and the final use of the lumber may not require stress relief. For example, if the lumber is going to be planed on 4 sides, the stressed wood will be lost.

Can pitch be set in pine?

When softwoods are dried, pitch sets at the final temperature of the drying cycle. For example, if the last step of drying is 49°C (120°F), then the lumber has to reach above that temperature again before the pitch starts to run. Some high-speed sanding equipment used by furniture manufacturers heat the wood to 71°C (160°F), so these manufacturers require pitch set to that temperature to avoid wasting sanding belts. If the pitch must be set, it can be done by heating the lumber at the end of the drying cycle to the necessary temperature, because during pitch setting you are not removing water with the dehumidifier, you're just applying heat.

Selecting a Kiln

How Do I Determine The Size System I Need?

First, project how much lumber you'll dry in a year, then figure your average drying time for each of the species you'll be drying, and you can calculate the size kiln you need from there. For example, a requirement to dry 1,180m^3 (500,000 board feet) of oak per year would take about 28-30 days to dry fresh off the saw, so you'll be able to dry 12 loads in a year. Each load will need to be 99m^3 (42,000 board feet) which means you could build a single 94.4m^3 - 106.2m^3 (40,000 – 45,000 board feet) chamber or two 47m^3 - 59m^3 (20,000 – 25,000 board foot) kilns to reach the 1,180m^3 (500,000 board feet) requirement.

It's not a good idea to mix species, thicknesses, or moisture content of lumber in one kiln, as all the wood will have to be dried based on the schedule of the slowest drying species and thickness. All the lumber in the kiln will dry at the same rate, and the MC will equalize in the load. If you're going to be drying several species and thicknesses of lumber during the year, it's better to use multiple small chambers rather than one large one so you can keep each species and thickness in its own kiln. Benefits of flexibility, loading times, and control of the drying process will favor multiple smaller kiln chambers over a single large kiln. However, if you are only drying one species and thickness of lumber within a month, a single kiln would be appropriate.

Should the fans reverse?

Fans usually reverse in larger kilns which prevents uneven drying by forcing the air to enter the lumber pile first from one direction then from the other. It also corrects for dead air spots which may result from the way the lumber is stacked. Generally, lumber that is stacked over 3.65m (12 feet) deep in the direction of airflow should have reversing fans. If the lumber stack is less than 3.65m (12 feet) thick, reversing the fans will not make any significant difference in the drying process.

Should the drying unit be in the kiln or in an equipment room?

Generally, the most efficient configuration is to have the blower coil cabinet inside the kiln chamber, with the compressor, controls, and electronics in the control room. This offers the best environment for the machinery while reducing installation and operating costs.

Selecting a Kiln

Capacity Chart

The following chart can be used to compare drying times, annual production, and electric cost for drying a load. The return on investment of a Wood-Mizer Kiln has to take into account the variances in lumber pricing, the cost of the kiln chamber, and the amount of lumber dried during a year. This chart will prove close to what you will see in the majority of applications.

In the chart below we've grouped similar drying woods to reflect different types of woods that are dried at different rates. Softwoods generally need to be dried fast in order to avoid mold and stain, while hardwoods such as oak have to be dried slowly to avoid checks and honeycomb.

Group 1- Softwoods and fast drying hardwoods *(pine, fir, cedar, poplar, aspen)*

Group 2- Medium drying hardwoods *(cherry, birch, maple, ash, beech, walnut, elm)*

Group 3- Slow drying hardwoods *(red and white oak, rock elm)*

This chart is based on $0.10/kWh electricity, 10°C (50°F) outside temperature, building sized for the load size listed and as a separate building, while also assuming electric pre-heat. The drying times are based on drying 2.54cm (4/4) lumber. Keep in mind that thicker lumber generally will take longer to dry and has to be dried slower.

			Moisture Content Green to 7%			Moisture Content Green to 30% to 7%		
MODEL	WOOD GROUP	LOAD SIZE BF	ANNUAL PRODUCTION BF	DRYING DAYS	DRYING COST PER MBF	ANNUAL PRODUCTION BF	DRYING DAYS	DRYING COST PER MBF
KD250	1	1,500	43,000	12	$44.27	180,000	3	$11.56
	2	3,000	48,000	22	41.27	135,000	8	15.66
	3	4,000	40,000	35	44.31	88,000	16	19.23
KD450	1	3,000	135,000	8	$43.21	360,000	3	$16.67
	2	8,000	320,000	22	45.24	264,000	8	17.12
	3	12,000	144,000	30	46.11	312,000	14	19.61
KD550	1	10,000	400,000	9	$41.82	1,200,000	3	$14.73
	2	20,000	400,000	18	43.69	1,040,000	7	16.26
	3	30,000	360,000	28	46.94	900,000	12	19.36

MBF = 1,000 Board Feet

Building a Kiln Chamber

How Do I Design The Kiln Chamber?

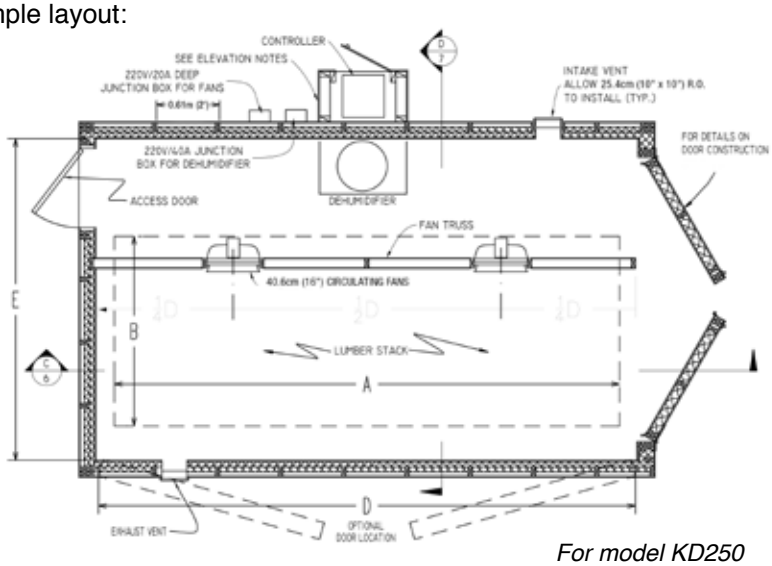
The chamber for a dehumidification kiln can be built from wood, concrete block, steel, aluminum, or almost any combination of these materials. It is important that the chamber be tight and insulated to about R-30. Almost all kilns under 59m^3 (25,000 board feet) are wood frame chambers because they are fairly easy to insulate properly and is basically built like a well-insulated garage.

Generally, the first step is to determine the proper stack of lumber for the operator's needs. Then the chamber is designed around that stack. A tight, well-insulated chamber serves two important purposes: it allows the recovery of as much heat as possible to provide low drying costs and it prevents damage to the lumber that can result from loss of control of temperature and humidity when there are air leaks and poor insulation.

Call us to request a FREE chamber design layout for the Wood-Mizer Kiln that best fits your needs.*

**Kiln chamber designs only available for Wood-Mizer KD150, KD250, KD450, and KD550 models.*

Sample layout:



For model KD250


Wood-Mizer
KD250
Wood-Mizer
KD250

Drying Chart

North American Measure

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

Species	Oven Dry Weight #/MBF	Ave. 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

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

KS50
KILN DRYING SYSTEM

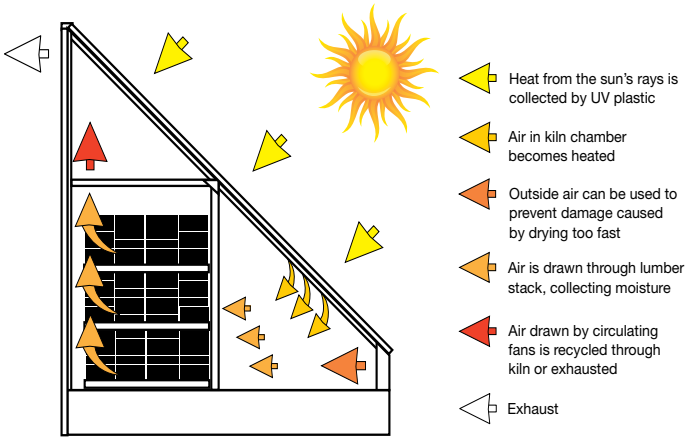
The Most Economical Way To Start Drying

PERFORMANCE SPECIFICATIONS

Load Capacity	7m³ (3,000 board feet)
Nominal Water Removal	3.5% per day max
Drying Time	R. Oak/W. Oak 6-10 weeks
Operation Costs	373 w per day
Temperature Range	32°-54°C (90°-130°F) with sun
Circulating Fans	Two 0.18kw (¼ HP)
Electrical Requirements	220V/60hz single phase
Shipping Weight	58.5kg (129 lbs)

This **COST-EFFECTIVE** solar kiln is a simple system sold in kit form. The kit includes blueprints, assembly instructions, circulation fans, specialty hardware, and a list of materials needed for construction.

BUILD YOUR OWN CHAMBER* - building plans with technical drawings included!



*Chamber not included.

KD150
KILN DRYING SYSTEM

Big on Features
Small on Price

PERFORMANCE SPECIFICATIONS

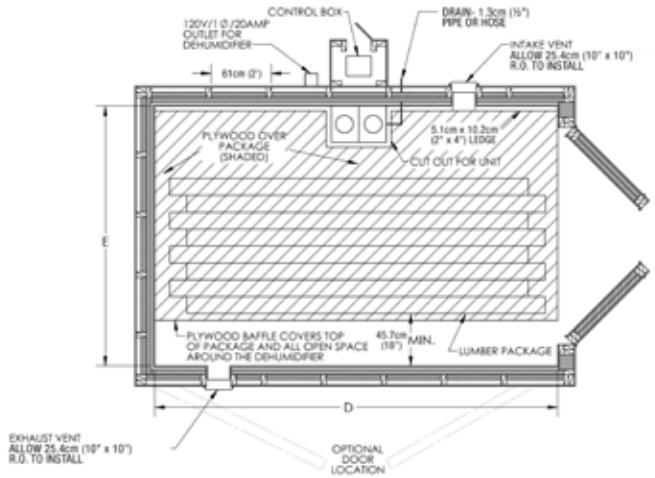
Load Capacity	0.71m³ (300 board feet) for softwoods and fast drying hardwood 2.36m³ (1,000 board feet) for slow drying hardwoods such as oak
Nominal Water Removal	28kg (60 lbs) per 24 hours
Drying Time	0.71m³ (300 board feet) 2.54cm (4/4) green pine (80% to 8%) in approximately 12 days 2.36m³ (1,000 board feet) 2.54cm (4/4) green oak (65% to 8%) in approximately 35 days
Operation Costs	Green pine (80% to 10%-12%) approximately 350kwh per 2.36m³ (1,000 board feet) Green oak (65% to 6%) approximately 450kwh per 2.36m³ (1,000 board feet)
Temperature Range	21°-49°C (70°-120°F)
Pitch Setting Temperature	Auxiliary heater can be used to set the pitch, sterilize the load (kill any bugs), and for preheat
Compressor Nominal HP	0.37kW (½ HP)
Internal Blower Motor HP	2 internal fans, 50 watts each
Auxiliary Electric Heat	1,000 watts
Over Temperature Vents	Two manual included
Electrical Requirements	110V/60hz or 50hz single phase
Shipping Weight	79.4kg (175 lbs)
Dimensions	56cm (22") wide x 36.8cm (14½") deep x 95.3cm (37½") high

QUALITY AND AFFORDABILITY

is what you get with the KD150 Kiln System. Delivering superb results load after load, the KD150 features:

- Coils are heavy duty and coated to prevent them from corrosion
- Chassis is 100% corrosion resistant aluminum
- Remote controller has been proven in thousands of applications

BUILD YOUR OWN CHAMBER* - building plans with technical drawings included!



*Chamber not included.

KD250
KILN DRYING SYSTEM

Quality and Performance Easy to Operate

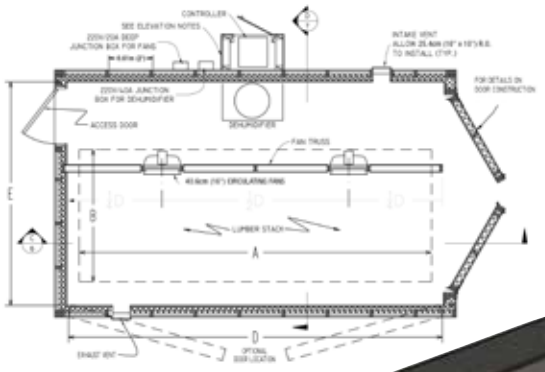
PERFORMANCE SPECIFICATIONS

Load Capacity	3.54m³—5.9m³ (1,500—2,500 board feet) for softwoods and fast drying hardwood 9.4m³ (4,000 board feet) for slow drying hardwoods such as oak
Nominal Water Removal	114kg (250 lbs) per 24 hours
Drying Time	3.54m³ (1,500 board feet) 2.54cm (4/4) green pine (80% to 8%) in approximately 12 days 9.4m³ (4,000 board feet) 2.54cm (4/4) green oak (65% to 8%) in approximately 35 days
Operation Costs	Green pine (80% to 10%-12%) approximately 250kwh per 2.36m³ (1,000 board feet) Green oak (65% to 6%) approximately 450kwh per 2.36m³ (1,000 board feet)
Temperature Range	21°-49°C (70°-120°F)
Pitch Setting Temperature	Auxiliary heater can be used to set the pitch, sterilize the load (kill any bugs), and for preheat
Compressor Nominal HP	1.5kW (2 HP)
Internal Blower Motor HP	0.18kW (¼ HP)/1000 cfm
Auxiliary Electric Heat	4,000 watts
Circulating Fans	Two included: 40cm (16") diameter; 0.18kW (¼ HP); 1,500 cfm
Over Temperature Vents	Two manual included (powered vents optional)
Electrical Requirements	220V/60hz or 50hz single phase
Shipping Weight	172kg (380 lbs)

THE KD250 is a compact, high performance kiln drying system with a precise, simple and easy to operate control system that requires just a few minutes of daily monitoring and features:

- Thermostat with remote sensor
- Repeat cycle compressor timer
- Switches and indicator lights

BUILD YOUR OWN CHAMBER* - building plans with technical drawings included!



Another chamber option - repurpose an existing container

*Chamber not included.

KD450
KILN DRYING SYSTEM

Outstanding Performance Incredible Efficiency

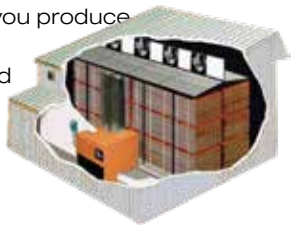
PERFORMANCE SPECIFICATIONS

Load Capacity	9.4m³—35.4m³ (4,000—15,000 board feet)
Nominal Water Removal	327kg (720 lbs) per day
Drying Time	9.4m³ (4,000 board feet) 2.54cm (1 inch) eastern white pine in approximately 8 days 35.4m³ (15,000 board feet) 2.54cm (4/4) green oak (68% to 7%) in approximately 28 days
Operation Costs	Green pine (80% to 10%-12%) approximately 350kwh per 2.36m³ (1,000 board feet) Green oak (65% to 6%) approximately 450kwh per 2.36m³ (1,000 board feet)
Temperature Range	26°-71°C (80°-160°F)
Pitch Setting Temperature	Set at the highest temperature reached while drying or after drying
Compressor Nominal HP	3.7kW (5 HP)
Internal Blower Motor HP	1.1kW (1½ HP)
Auxiliary Electric Heat	12 kW (16 HP)
Circulating Fans	Five 0.37kW 61cm (½ HP 24")
Reversing Fans	Optional
Over Temperature Vents	Two automatic
Number of Duct Risers	1 at 35cm x 35cm (14"x14")
Electrical Requirements	220V/60hz or 50hz single phase 220V/60hz or 50hz three phase 460V/60hz three phase 380V/50hz three phase 575V/60hz three phase
Shipping Weight	385.5kg (850 lbs)

THE KD450 kiln drying system is ideal for mid-size operations. This unit takes on **COMMERCIAL-LEVEL** drying demands with its **3.73 (5HP)** compressor and **FIVE 0.37kW 61cm (½ HP 24")** fans to provide outstanding performance for businesses that are growth oriented and performance minded.

TIPS TO HELP DETERMINE YOUR KILN SIZE

1. **KNOW YOUR LUMBER**
   - How much lumber volume will you dry in a year
   - What species/lumber group will you produce
   - Know the sizes of your lumber
   - Understand your drying times and moisture contents



2. **CHOOSING A CHAMBER**
   - Volume divided by # cycles determine size – 4/4 basis
   - Will one or more small chambers meet your production needs
   - Consider one large chamber for common species
   - Optimize flexibility, loading times and drying process with multiple chambers
3. **LOADING VARIABLES**
   - Size chamber for best load efficiency
   - Load with forklift or track system

KD550
KILN DRYING SYSTEM

Outstanding Performance for Mid-Size Commercial Operations

PERFORMANCE SPECIFICATIONS

Load Capacity	23.6m³—82.6m³ (10,000—35,000 board feet)
Nominal Water Removal	930 kg (1800 lbs) per day
Drying Time	23.6m³ (10,000 board feet) 2.54cm (1 inch) eastern white pine in approximately 8 days 82.6m³ (35,000 board feet) 2.54cm (4/4) green oak (68% to 7%) in approximately 28 days
Operation Costs	Green pine (80% to 10%-12%) approximately 350kwh per 2.36m³ (1,000 board feet) Green oak (65% to 6%) approximately 450kwh per 2.36m³ (1,000 board feet)
Temperature Range	26°-71°C (80°-160°F)
Pitch Setting Temperature	Set at the highest temperature reached while drying or after drying
Compressor Nominal HP	11.2kW (15 HP)
Internal Blower Motor HP	2.2kW (3 HP)
Auxiliary Electric Heat	48 kW (64 HP)
Circulating Fans	Four 1.5kW 75cm (2 HP 30")
Reversing Fans	Standard
Over Temperature Vents	Two automatic
Number of Duct Risers	2 at 35cm x 35cm (14"x14")
Electrical Requirements	220V/60hz or 50hz three phase 460V/60hz three phase 380V/50hz three phase 575V/60hz three phase
Shipping Weight	544kg (1200 lbs)

THE KD550 is a high performance kiln drying system for commercial operations. This unit is loaded with **HEAVY DUTY** features and functions including a **11.2kW (15HP)** compressor and **FOUR 1.5kW 76.2cm (2HP 30")** fans to produce top quality results and short drying times with incredible efficiency.

TIPS TO HELP DETERMINE YOUR KILN SIZE

1. **KNOW YOUR LUMBER**
   - How much lumber volume will you dry in a year
   - What species/lumber group will you produce
   - Know the sizes of your lumber
   - Understand your drying times and moisture contents

2. **CHOOSING A CHAMBER**
   - Volume divided by # cycles determine size – 4/4 basis
   - Will one or more small chambers meet your production needs
   - Consider one large chamber for common species
   - Optimize flexibility, loading times and drying process with multiple chambers
3. **LOADING VARIABLES**
   - Size chamber for best load efficiency
   - Load with forklift or track system

KILN SYSTEM SPECIFICATIONS

	KS50	KD150	KD250	KD450	KD550
Load Capacity	7m³ (3,000 board feet)	0.71m³ (300 board feet) for softwoods and fast drying hardwood 2.36m³ (1,000 board feet) for slow drying hardwoods such as oak	3.54m³—5.9m³ (1,500—2,500 board feet) for softwoods and fast drying hardwood 9.4m³ (4,000 board feet) for slow drying hardwoods such as oak	9.4m³—35.4m³ (4,000—15,000 board feet)	23.6m³—82.6m³ (10,000—35,000 board feet)
Nominal Water Removal	3.5% per day max	28 kg(60 lbs) per 24 hours	114 kg(250 lbs) per 24 hours	327 kg (720 lbs) per 24 hours	930 kg (1,800 lbs) per 24 hours
Drying Time	R. Oak/W. Oak 6-10 weeks	0.71m³ (300 board feet) 2.54cm (4/4) green pine (80% to 8%) in approximately 12 days 2.36m³ (1,000 board feet) 2.54cm (4/4) green oak (65% to 8%) in approximately 35 days	3.54m³ (1,500 board feet) 2.54cm (4/4) green pine (80% to 8%) in approx 12 days 9.4m³ (4,000 board feet) 2.54cm (4/4) green oak (65% to 8%) in approx 35 days	9.4m³ (4,000 board feet) 2.54cm (1 inch) eastern white pine in approx. 8 days 35.4m³ (15,000 board feet) 2.54cm (4/4) green oak (65% to 7%) in approx 28 days	23.6m³ (10,000 board feet) 2.54cm (1 inch) eastern white pine in approx. 8 days 82.6m³ (35,000 board feet) 2.54cm (4/4) green oak (65% to 7%) in approximately 28 days
Operation Costs	373 w per day	Green pine (80% to 10%-12%) approximately 350kwh per 2.36m³ (1,000 board feet) Green oak (65% to 6%) approximately 450kwh per 2.36m³ (1,000 board feet)	Green pine (80% to 10%-12%) approximately 250kwh per 2.36m³ (1,000 board feet) Green oak (65% to 6%) approximately 450kwh per 2.36m³ (1,000 board feet)	Green pine (80% to 10%-12%) approximately 350kwh per 2.36m³ (1,000 board feet) Green oak (65% to 6%) approximately 450kwh per 2.36m³ (1,000 board feet)	Green pine (80% to 10%-12%) approximately 350kwh per 2.36m³ (1,000 board feet) Green oak (65% to 6%) approximately 450kwh per 2.36m³ (1,000 board feet)
Temperature Range	32°-54°C (90°-130°F) with sun	21°-49°C (70°-120°F)	21°-49°C (70°-120°F)	26°-71°C (80°-160°F)	26°-71°C (80°-160°F)
Pitch Setting Temperature	N/A	Auxiliary heater can be used to set the pitch, sterilize the load (kill any bugs), and for preheat	Auxiliary heater can be used to set the pitch, sterilize the load (kill any bugs), and for preheat	Set at the highest temperature reached while drying or after drying	Set at the highest temperature reached while drying or after drying
Compressor Nominal HP	N/A	0.37kW (½ HP)	1.5kW (2 HP)	3.7kW (5 HP)	11.2kW (15 HP)
Internal Blower Motor HP	N/A	2 internal fans, 50 watts each	0.19kW (¼ HP) /1000 cfm	1.1kW (1½ HP)	2.2kW (3 HP)
Auxiliary Electric Heat	N/A	1,000 watts	4,000 watts	12 kW (16 HP)	48 kW (64 HP)
Circulating Fans	Two 0.18kW (¼ HP)	N/A	Two included 40cm (16") diameter; 0.198kW (¼ HP); 1,500 cfm	Five 0.37kW 61cm (½ HP 24")	Four 1.5kW 75cm (2 HP 30")
Reversing Fans	N/A	N/A	N/A	Optional	Standard
Over Temperature Vents	N/A	Two manual included	Two manual included (power vents optional)	Two automatic	Two automatic
Number of Duct Risers	N/A	N/A	N/A	1 at 35cm x 35cm (14" x 14")	2 at 35cm x 35cm (14" x 14")
Electrical Requirements	220V/60hz single phase	110V/60hz or 50hz single phase	220V/60hz or 50hz single phase	220V/60hz or 50hz single phase 220V/60hz or 50hz three phase 460V/60hz three phase 380V/50hz three phase 575V/60hz three phase	220V/60hz or 50hz three phase 460V/60hz three phase 380V/50hz three phase 575V/60hz three phase
Warranty	1 year limited	1 year limited	1 year limited	1 year limited	1 year limited
Shipping Weight	58.5kg (129 lbs)	79kg (175 lbs)	172kg (380 lbs)	386kg (850 lbs)	544kg (1,200 lbs)
Cabinet Dimensions	N/A	56cm (22") wide x 36.8cm (14½") deep x 95.3cm (37½") high	82.5cm (32½") wide x 52.1cm (20½") deep x 101.6cm (40") high	111.8cm (44") wide x 114.3cm (45") deep x 129.5cm (51") high	162.6cm (64") wide x 167.6cm (66") deep x 129.5cm (51") high

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