Intro to Kiln Drying

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World Leader in Kiln Drying Systems

Since 1977, Nyle has been building the world's most energy efficient lumber dry kilns. We pioneered the development of dehumidification drying as a practical, economical drying method. Today our systems set the standard for performance and efficiency around the world.

Nyle dry kilns are easy to install and use, yet they give you the power, precision control and outstanding reliability you need for optimum drying performance in almost any drying application. Our patented XDH system, a breakthrough in dehumidification drying, constantly monitors and regulates the airflow within the dehumidifier. It enables Nyle XDH Systems to work over a wider temperature range and with greater energy efficiency than any other system in the world. Compared to conventional kilns, which waste energy by venting heated air, our total recovery dehumidification systems use 60% to 80% less energy, and give you much lower operating costs.

First in Quality and Service

With Nyle, you get the kind of horsepower other companies don't offer. We give you up to three times more horsepower per dollar than some of our competition. We give you year-in, year-out reliability. Our units offer extra quality features like corrosion resistant aluminum cabinets, and dehumidification coils that are coated with a special coating. Nyle larger units have stainless steel evaporator coils and tubing as well as many other features that make your system last longer and perform better. You get more than just great systems with Nyle. You also get the best support in the industry. When you call us, you can talk with the people who actually build your system.

As the largest manufacturer of dehumidification dry kilns in the U.S., we have the know-how to answer your questions and give you the expert advice you need. If you're not sure what size drying system you need or how to best design and build your kiln chamber give us a call, we won't give you a selling pitch: we'll give you a realistic analysis of the numbers, and a straight answer on what type of system will work best for you.

We Invite You to Call

To answer some of your questions on lumber drying, we've prepared this booklet. It takes a look at things like the drying process itself, the different kinds of systems available, and the way dehumidification drying works. Call us with your questions. Let us show you why Nyle is the world's number one choice for economical, optimum performance drying systems.

Basic Facts on Drying Lumber

Why Dry Lumber?

Fresh cut lumber contains a great deal of water. If the water is not removed, the lumber can't be used to produce a high quality finished product. Properly dried lumber sells for a higher price and is much easier to work with than lumber that hasn't been dried. When lumber is dried right, it machines better, glues better, and finishes better. Drying also improves the strength of the lumber, kills infestations, hardens pitch, preserves color, reduces weight and controls shrinkage. Lumber that is not dried under controlled conditions is prone to warping, staining, and other degradation that diminishes its selling price and workability. With a Nyle dehumidification kiln, successful lumber drying for better profitability is easy and affordable for virtually any size operation.

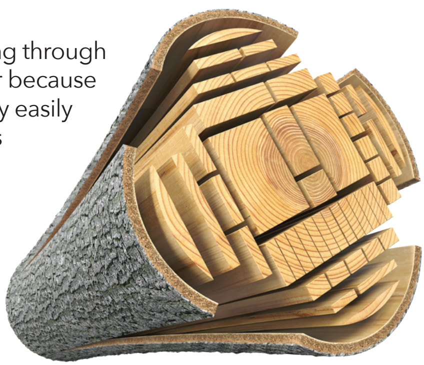
How Much Water is in Lumber?

Some species of wood are more than half water in terms of their weight when they're fresh cut. Moisture content in lumber is generally expressed as a percentage of the dry weight. For example, if a fresh cut board weighs five pounds per board foot, then weighs 3 pounds per board foot after it's been dried in an oven to 0% moisture content, that means it had two pounds of water in every board foot. Two pounds of water per board foot compared to the lumber's dry weight of three pounds per board foot is a ratio of 2:3 so the lumber has a moisture content of 2/3, or 67%. That's similar to oak, for example, which is usually about 68% moisture content when fresh cut.

It's really astounding how much water has to be removed from wood to make it suitable for finished products. Take the example of a truckload of oak. Fresh cut oak weighs about 5.4 pounds per board foot. So a truckload of 8,000 board feet weighs about 43,560 pounds—just under 22 tons. Once you remove enough water to get the oak down to a moisture content of 6%-8%, it weighs about 3.5 pounds per board foot. So that truckload now weighs 28,000 pounds, or about 14 tons. That means that to completely dry a truckload of 8,000 board feet of oak, you have to remove 15,560 pounds of water—almost eight tons! That's why choosing the right drying system and using the proper method are so important.

What is Free and Bound Water?

When trees are growing there is liquid water moving through the cells of the wood. This water is called free water because it exists in water form and can be removed relatively easily from the wood. Bound water is 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. Fiber saturation is generally reached when the moisture content gets to about 28%. At that 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.



The Difference Between Drying Hard and Softwoods

This is a commonly asked question, but the actual species of the wood is really more important to consider than just whether it's a hardwood or a softwood. The terms hardwood and softwood generally refer to whether the wood comes from a tree with leaves (hardwood) or a tree with needles (softwood). Some hardwoods are actually softer than many softwoods, so there's no general drying method that applies as a rule to all hardwoods or all softwoods.

Different species require drying at different temperatures and different speeds to produce the best results. Oak has to be dried slowly or it degrades badly. Pine needs to be dried at a fast rate or it stains and molds. That doesn't mean all hardwoods should be dried as slowly as oak, or that all softwoods can be dried as quickly as pine. There's a proper method that's been determined for nearly every species of lumber to produce the best results. Check with your Nyle representative for information on drying a particular species.

Does the Wood Stay Dry?

Wood is always trying to come into equilibrium with the air surrounding it, so its moisture content can change somewhat after it's been dried. In dry air, the wood gives up water to the air until it is dried, as it equalizes with the air. When the air is more humid, wood absorbs water from the air. Wood expands when it absorbs water, and shrinks when it gives up water.

In worst-case winter heated conditions in northern climates, wood may dry to a moisture content of 6% as it gives up water to the dry air. In the humidity of summers, it may pick up moisture to about 15-16%. If dried lumber is exposed to outdoor conditions long enough, it will eventually reach about 12% moisture content, which corresponds to the average annual equilibrium point in most geographic areas.

Can Drying Cause the Wood to Split or Check?

Wood does shrink as it dries, but the shrinkage doesn't start until the lumber is below fiber saturation, about 28% moisture content. If the outside surface is below 28% while the center of the board is still above fiber saturation, the outside will try to shrink while the center doesn't and if this continues until the surface becomes too dry in relation to the core, the lumber will split or check. Controlled drying in a kiln, especially when drying from the green state, reduces or eliminates splitting and checking. When lumber is air dried, however,there is no control over the drying process, and the weather can easily cause splitting and checking that results in losses.

Does the Thickness of Lumber Affect the Drying Rate?

Yes. The lumber industry generally refers to lumber thickness in terms of quarter inch multiples. Therefore, one inch thick lumber is referred to as 4/4, one and one-half inch lumber is 6/4, etc. Generally speaking, drying times are roughly proportional to the thickness. That is, 8/4 lumber usually takes a little more than twice as long to dry as 4/4.

Drying Methods

Air Drying

Air drying refers to drying that takes place using the natural wind and sun. Lumber is stacked on stickers and placed in a manner that allows the prevailing winds to blow through the pile and dry it. The drying is strictly dependent upon the weather, which can dry lumber too fast and cause checks and damage, or dry it too slowly, which is expensive. For lumber that is to be used in furniture or some other finished product which requires a 6–8% moisture content, air drying by itself can't do the whole job. It's often used as a first step, with the lumber being placed in a kiln for final drying. Air drying poses real problems with damage and degrade. And it's 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

Rain and direct sun can severely damage wood while air drying. Instead of air drying lumber, some people put lumber under a roof or shed to protect it from the elements. This enhances quality somewhat over air drying, but it extends the drying time. It also requires an investment in sheds and it still doesn't allow much control over factors like humidity, air flow, and temperatures.

Forced Air Drying or Fan/Shed Drying

This is shed drying as described above, except fans are used to force air through the lumber rather than relying upon the 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.

Pre-Drying

Pre-drying is used to remove most of the free water from lumber before it is placed in a kiln for final drying. In a pre-dryer, lumber is stacked in a building where heat and humidity are controlled. The temperature is usually kept around 90-100°F (35°C). The lumber is dried to 20- 30% moisture content, and then placed in a kiln for final drying. Though pre-dryers cost about the same to build as kilns when you compare costs on the basis of your annual production, they require extra handling of the lumber, and they actually cost more to run than dry kilns. They are usually only used in combination with dry kilns that are old or inefficient and cannot be used to dry green lumber.

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. The different types are defined by the manner in which the temperature and humidity are controlled. The three most common types of kilns are Conventional, Dehumidification, and Solar.

Different Types of Kiln Drying

Solar Kilns

There are several types of solar kilns, but they all generally rely on some type of solar collector to provide the heat energy that evaporates the water in the lumber. Unlike solar heating for an office or home, in lumber drying it's not possible to reduce the heat requirement to the point where solar heating can be competitive. When you've got a certain amount of water to remove from a certain amount of wood, you need a certain amount of total heat to do it, and that heat requirement can't be changed.

Drying times in a solar kiln are dependent upon the weather, and thus unpredictable. In hot climates they can degrade lumber due to excessive drying. In colder climates they are unreliable and slow. Solar kilns often use electric-powered fans to circulate air through the lumber, but the cost of running these fans is high—and because of the long drying times, you've got to run the fans for a long time, making solar drying quite expensive. The electricity for running the fans in a solar kiln is usually more than would be used running a DH kiln, as the drying time is longer.

Conventional Kilns

A conventional kiln uses heat provided by either steam or hot water coils or a furnace to heat the kiln chamber and remove water from the wood. The water removed from the wood is turned into water vapor by evaporation, and then exhausted from the kiln with the heated air. This process takes a great deal of heat and requires constant heating of air, so these systems are not as energy efficient as dehumidification kilns. To remove one pound of water from the lumber, a conventional kiln has to draw in about 400 cubic feet (or 12 cubic meters) of air, heat the air, and then exhaust it with the evaporated water. Between heating these large quantities of air and heating the water to evaporate it, conventional kilns have a very high heat requirement. They can provide a very good quality of lumber if a good method of kiln control is provided, but their energy consumption is much higher than that of a dehumidification kiln.

Vacuum Kilns

The temperature at which water boils is determined by atmospheric pressure. The higher up a mountain you go, the less pressure the atmosphere exerts, so water boils at a lower temperature up the mountain than at its base. Vacuum kilns take advantage of this fact to achieve drying times that are usually only a fraction of the time required for conventional or dehumidification kilns. A major drawback of vacuum kilns, however, is that the chambers are small, so the kilns cannot dry large quantities at any one time. It is necessary to provide heat to the lumber continuously in a vacuum kiln. To do this, some systems use electric blankets in contact with each piece of lumber, while some use heat coils or microwaves. All of these systems are extremely expensive to run when compared to dehumidification or conventional kilns.

Operating costs are usually three to four times higher than costs for dehumidification kilns. Initial/ capital costs, as well as handling costs, are much higher because of the smaller loads. Uneven drying is also a problem in vacuum kilns. When compared on the basis of cost per thousand board feet of annual production, the costs for a vacuum system are much higher than dehumidification. Vacuum drying can often be justified when drying thicker hardwoods.

Dehumidification Kilns

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. So it is more energy efficient and its operating cost is usually lower. This is true even though a dehumidification kiln uses electric energy to run the fans, the blower that draws the air over the dehumidification coil, and the refrigeration compressor; while a conventional system burns less expensive fuel such as gas or wood. 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 small, so it comes out ahead of a conventional system that may use cheaper fuel, but needs a lot more of that fuel to do the same job.

In a dehumidification kiln, heated air, (usually starting at a heat of about 85°F or 29°C) 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 60°F (15°C). 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 as 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 160°F (72°C). 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 very popular with beginning lumber dryers. They are also popular with experienced operators who want a system that requires minimum attention to get zero defect drying. Dehumidification is usually the least expensive to run and to install by a wide margin. Drying times with a Nyle XDH kiln are about the same as conventional kilns.

Facts on Dehumidification Kilns

Air Dehumidification Kilns More Expensive to Run?

They are actually a good deal less expensive. First, a dehumidification kiln is much more energy efficient, so that reduces operating costs dramatically compared to a conventional kiln. Additionally, with a conventional kiln you have to amortize the higher cost of the boiler, you have to pay additional taxes and insurance, and you have higher handling and labor costs for your operation. When you add it all up, dehumidification kilns are usually much more economical.

To make your own detailed cost comparisons, give us a call. We will help you do a complete operating cost analysis based on your local electric rates and other fuel costs.

Which Kiln is Faster?

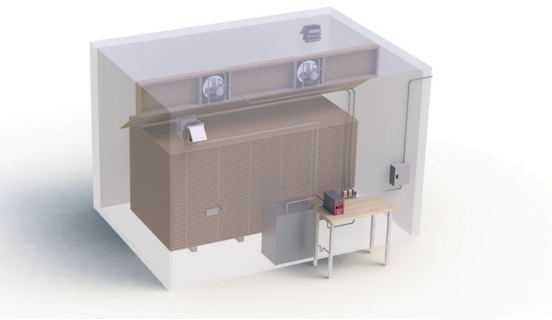
For hardwoods, and high grade softwoods, a properly sized dehumidifier will dry as fast as a conventional kiln. If you have a low temperature dehumidifier that has a maximum drying temperature of 120°F, the drying time will be the same going from green down to 30% moisture content. From 30% MC down, the temperature makes a difference, with a 120°F (50°C) kiln taking about 2½ times longer for this part of the cycle.

What is the Nyle XDH System?

The Nyle XDH System is a unique self regulating feature patented by Nyle. It increases the operating efficiency of the system and allows the dehumidification system to operate to temperatures as high as 160°F (72°C). No other dehumidification system sold in North America has this feature, or can operate over the wide temperature range that Nyle XDH systems handle. The XDH system constantly monitors the air temperature leaving the cooling coil and modulates the airflow over the coil to maximize the system's water removal. That makes the dehumidification cycle operate at optimum efficiency, and it minimizes electricity use. The modulating function also carefully controls the temperature of the refrigerant returning to the compressor, preventing overloading or overheating and prolonging the life of the refrigeration system. The XDH System is provided as standard equipment on all Nyle systems of 3 hp and larger.

How Important is Airflow?

The airflow in the kiln chamber is very important. The velocity of the air over the wood affects the drying rate and provides even drying. You should discuss air velocity with your kiln manufacturer to be sure that the air velocity in the kiln will be adequate for the species and thickness of the lumber you are drying and the type of kiln you are using. Generally, wetter lumber requires a higher velocity of air through the lumber. If the air is only blowing through 4 or 8 feet of lumber, the airflow requirements are less.



Should the Fans Reverse?

Fans usually reverse in larger kilns. This prevents uneven drying by forcing the air to enter the lumber pile first from one direction and 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 12 feet (3.5 meters) deep in the direction of airflow should have reversing fans. If the lumber stack is less than 12 feet thick, reversing the fans will not make any significant difference in the drying.

What Type of Heating Systems to Use for Warm-up?

It is only necessary to heat the kiln to about 85°F (29°C) to start the dehumidification process. Once started, the process feeds itself by recycling the heat recovered from the air. Initial warm-up can be done with nearly any type of heating system. Usually, small kilns or single kiln chambers use electric heat, because the additional money required for a more traditional type of heating system doesn't make economic sense when the heat is only used for a few hours a month. When larger kilns are used or more chambers are added, it may make sense to install a gas, oil or wood boiler to provide heat through steam coils. This is an economic decision based upon local energy costs, weather, type of lumber being dried, etc. Nyle can provide operating cost estimates to help with this decision. However, in most cases, electric heat provides the most economic choice for initial warm-up.

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 120°F (approx. 50°C), then the lumber has to be get above that temperature again before the pitch starts to run. Some high-speed sanding equipment used by major furniture manufacturers heats the wood to 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. This can be done even if the dehumidifier is not rated to operate at that temperature, because during pitch setting you are not removing water with the dehumidifier, you're just applying heat.

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. A tree that grows on the side of a hill or mountain may have stresses from that.

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. Nyle recommends people do a stress test at the end of a load to know the status of the lumber.

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 planned on 4 sides, the stressed wood will be lost.

Selecting a Kiln

What Size System Do I Need?

The first step is to 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 500,000 board feet of oak per year: Fresh off the saw oak takes about 28-30 days to dry, so you'll be able to do 12 loads in a year. Each load will need to be 42,000 board feet to give you the 500,000 board feet you need for the year. That means you could build a single 40-45,000 board foot chamber or two 20-25,000 board foot kilns. For more specific information, see the Capacity Chart on pages 10.

It is not a good idea to mix species, thicknesses, or moisture contents 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 moisture content will equalize in the load. Therefore, if you're going to be drying several species and thicknesses of lumber during the year, it's better to use smaller chambers rather than one large one, so you can keep each species and thickness in its own kiln. If you are drying air dried lumber, and it is all below 25% moisture content, you can mix species without trouble.

It generally does not cost much more to have two smaller kilns rather than one large one, and the benefits of flexibility, loading times, and control of the drying processes will favor multiple smaller chambers over a single large one. If you are only drying one species and thickness of lumber in a month, a single kiln would be appropriate. Please contact Nyle to talk about different sizing options.

Where Should the Drying Unit Be?

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. Small systems that operate at lower temperatures often have the compressor inside the kiln chamber. Nyle can custom design a system based on your specific requirements.

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 25,000 board feet (60m^3) are wood frame chambers. A wood frame is fairly easy to insulate properly, and is basically built like a well insulated garage. At Nyle, we provide you with technical drawings and expert advice on kiln chamber construction.

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. Proper insulation is just as critical in hot climates as it is in cold climates.

Nyle can help with the design of your kiln, or provide a complete turnkey system, building and all, or give you any degree of assistance in between. We're the experts in lumber drying, and we are ready to give you experienced advice not only in the design of your kiln structure, but in the layout of your yard and operating as well. Some manufacturers provide complete kiln chambers.

Capacity Chart?

This chart can be used to compare drying times, annual production, and electric cost for drying a load. Remember, a Nyle kiln is an investment, and should be looked at as such. The return on the investment 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 a majority of applications.

Different types of wood are dried at different rates; we have grouped similar drying woods in this chart to reflect that. As some woods, such as softwoods, need to be dried fast in order to avoid mold and stain, while some hardwoods, such as Oak have to be dried slowly to avoid checks and honeycomb.

Group 1–Pine, Fir, Cedar, Poplar, Aspen (softwoods and fast drying hardwoods)

Group 2–Cherry, Birch, Maple, Ash, Beech, Walnut, Elm (medium drying hardwoods)

Group 3–Oak (Red and White), Rock Elm (slow drying hardwoods)

This chart is based on 10¢/kWh electricity, 50°F outside temperature, building sized for the load size listed and as a separate building. This chart assumes electric pre-heat. The drying times are based on drying 4/4 (1", 25mm) lumber. Thicker lumber will take longer to dry, and has to be dried slower.

MBF= 1000 Board Feet (2.36m³)

			Moisture Content Green to 7%		Moisture Content 30% to 7%	
Model	Wood Group	Load Size BF	Annual Production BF	Drying Days	Annual Production BF	Drying Days
L200	1	1,500	43,000	12	180,000	3
	2	3,000	48,000	22	135,000	8
	3	4,000	40,000	35	88,000	16
HT 8	1	3,000	135,000	8	360,000	3
	2	8,000	320,000	22	264,000	8
	3	12,000	144,000	30	312,000	14
HT 18	1	10,000	400,000	9	1,200,000	3
	2	20,000	400,000	18	1,040,000	7
	3	30,000	360,000	28	900,000	12

Nyle Dry Kilns - Drying Chart

Dry Bulb °F		Wet Bulb Depression °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

Notes

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