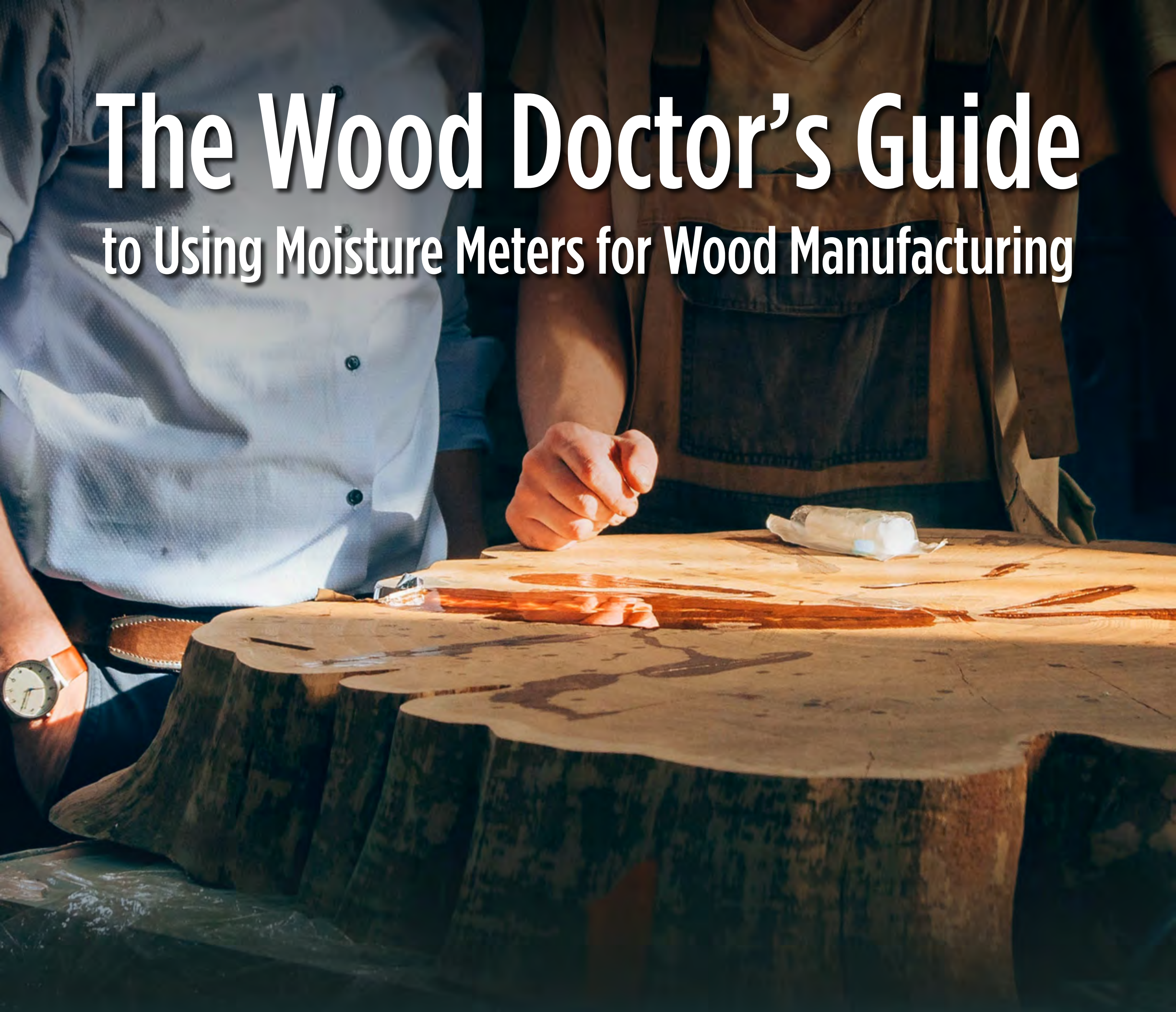
The Wood Doctor's Guide

to Using Moisture Meters for Wood Manufacturing



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Who is the Wood Doctor?

Gene Wengert, also known as "The Wood Doctor," is one of the most well-known and respected experts in the woodworking industry. He provides instruction in wood manufacturing and frequently helps businesses diagnose their manufacturing issues with wood products.

His woodworking career first began with the Forest Products Lab in Madison, Wisconsin. Later, he moved to work at Virginia Tech as an Extension faculty member specializing in wood products. Over the course of his long career, Gene has written eight books and more than 600 articles about the practical aspects of wood manufacturing.

Gene Wengert wrote a series of articles for Delmhorst on the subject of using moisture meters for wood manufacturing. Delmhorst has collected these articles into a single resource for your convenience.

Practical Uses for Moisuture Meters for Quality Improvement in Wood Manufacturing

Part 1: Moisture and Wood Interaction

Why MC?

Why do wood people worry so much about MC? In my 50 years in this wood manufacturing industry, I estimate that **75% of the manufacturing problems with wood are related to incorrect or changing moisture content (MC)**. If we can get MC under control, we can eliminate the majority of the problems with wood.

Why MC? When the MC changes, many wood properties change including the size and shape, glueability, and machinability. A key, practical concept is: **"Wood does not change size or shape (that is, shrink or swell, split or warp) in manufacturing or in-use except when its moisture content changes."**

The basic question is: "What makes the MC of wood change?" The answer is: **"Only the relative humidity (RH) makes the MC change; not temperature, phases of the moon, who won the election, or others factors."** MC changes when the humidity around the piece of wood changes… finishes may slow the speed of the change, but finishes cannot seal the wood or prevent MC changes.

The importance of MC means that a wood manufacturing facility needs to control the incoming lumber's MC and the facility's RH. Having this humidity match the customer's RH in their home or office (within 5% RH, if possible) means we will eliminate troublesome MC changes and therefore eliminate MC problems.

MC, RH, and EMC

The basic relationship between MC and RH, between 30˚F to 100˚F, is given below, with a third column for the equilibrium moisture content (EMC), which is a property of the air. EMC is useful in that it represents what moisture content the wood will be trying to achieve. Note that the interior of most homes and offices in North America runs between 6% to 9% EMC, wintertime to summertime respectively; the exterior (not subject to rain wetting) averages 12 % EMC or a bit higher.

RH	MC	EMC	Conditions
100%	28%	28%	Very wet; foggy
80%	16%	16%	Tropical island; coastal climate; humid
65%	12%	12%	Exterior in most of North America; interior in coastal areas
50%	9%	9%	Interior in summertime for most of North America
30%	6%	6%	Interior in wintertime for most of North America
0%	0%	0	Oven-Dry

If the wood's MC is not equal or very close to the EMC of the air, the MC will change. The rate depends on the wood's temperature, surface area to volume ratio, thickness, density, and permeability of the finish. A small piece can change MC substantially within a few hours, while larger pieces can take months before substantial change occurs throughout.

Measuring Plant Humidity

To measure humidity accurately requires a high-quality meter that costs more than $200. Consider the portable, handheld, digital Delmhorst HT-3000 thermo-hygrometer, which is designed for rugged use. It measures, in a few moments, both temperature and humidity at a location within a plant, in a storage facility, or in the customer's facility (The brass circular instruments are known to be inaccurate, especially after a few months of use).

> ***Special Hint:*** *Due to the long time it takes lumber to change MC in most situations, for six months after the lumber leaves the kiln, the core MC of lumber is almost always the same MC that the lumber had when it left the kiln. We would measure the core MCs with a pin meter using insulated needles; see more in Rx #7.*

Wood Movement

How much does wood move when the MC changes? In general, wood does not shrink or swell lengthwise when the MC changes. (Exceptions are compression wood, juvenile wood, and steep slope of grain, all of which are not common in furniture, cabinet, flooring and similar wood uses). On the other hand, the width of a flatsawn piece of lumber does change; a general rule of thumb is that fairly dry wood changes 1% in size with a 4% MC change. The width of quartersawn lumber is about 1% size change for 7% or 8% MC change. The precise movement varies from species to species.

Note that dried wood can regain about 1% MC, but little movement will occur; that is, there is a lag (hysteresis effect). This means we generally prefer to go on the dry side of the expected final MC in use; a little MC gain will not be worrisome. Using the table above, ***a target MC of 6.8% to 7.0% MC for hardwood lumber and interior wood products is ideal for most locations; softwoods are about 3% to 4% wetter due to loss of machinability if drier.*** Softwood shrinkage must be planned for.

If the wood is at the wrong MC when first put into use, it will adjust its moisture content to achieve equilibrium with its environment and therefore may warp, shrink or swell initially quite a bit. Let's consider a 10" wide panel of flatsawn Sitka spruce. The change in width (across the grain) will be 1% for a 4% MC change, or 1/4% for a 1% MC change. This is a width change of 0.025" for a 1% MC change, or just under 1/32".

For a precise calculation of movement, please look here (2010 Edition), starting on page 13-15 in the section entitled "Dimensional Changes in Wood."

Part 2: Selecting Kiln Samples to Test with Moisture Meters

Kiln Drying Basics

For kiln drying all hardwood, and some softwood, the basic kiln operation process is:

- ❒ Determine the moisture content (MC) of the wettest lumber in the kiln load at the start. The test pieces are called kiln samples.
- ❒ Determine the correct kiln conditions (temperature, humidity, and air speed) that are acceptable for this initial MC level.
- ❒ As the lumber dries, adjust kiln conditions as the wettest lumber dries, based on the MC of the kiln samples.

Step three is usually based on oven-dry moisture tests and weighing the samples. However, a moisture meter with remote probes (the probes remain in the wood during the drying cycle) can be used successfully in many operations. Delmhorst, who developed this system many decades ago, does have a manual system called KIL-MO-TROL available. Wires run from the probes in the lumber to an external switch-box. You can measure the shell and core MC at any time during the kiln cycle, and then change kiln conditions as required. Similar systems are available that are computer based, so the computer will determine the probes' MC and the control the kiln conditions.

A standard 50 MBF (1 MBF = 1,000 board feet) kiln typically holds 8,000 to 10,000 pieces of lumber. The kiln operator cannot measure the MC of every piece of incoming lumber to find the wettest pieces or check every piece near the end of a cycle to determine that the kiln drying process is completed. So, the operator uses kiln samples (KS), following four basic guidelines in the KS selection process. The wettest pieces are likely to be the:

- ❒ Thicker pieces;
- ❒ Heartwood pieces (for species with mainly heartwood);
- ❒ Quartersawn pieces (dry 15% slower than flatsawn); and
- ❒ Most recently sawn pieces.

These four criteria work very well for kiln drying lumber without any previous drying.

However, with air-dried or pre-dried lumber, there are two other considerations:

1. **Air-Dried Lumber:** The pieces in the bottom layers of a bottom stack.
2. **Pre-Dried Lumber:** The pieces in the top stacks in a downdraft predryer.

Finding the Wettest Lumber

Even using these additional criteria in air drying and predrying, the operator has perhaps a hundred pieces that could be used. The question is: "How can the wettest pieces be quickly located?"

The practical answer to this question is to use a moisture meter with a probe that can reach inside the lumber pack. Delmhorst has such a probe, Model 42-E/B, that has two needles at the one end of the probe and a handle at the other end; I call this a "T-probe" because it looks like a large letter "T."

The probe is inserted into the lumber pile in the space between the stickers; the distance it is inserted to determines which piece will be measured for MC. Then, the handle is turned, which drives the needles into the lumber piece selected, and a MC reading is obtained.

The reason that this works is that as lumber dries, the surface dries before the core. So, the surface may read 20% MC while the core is still 40% MC. On a wetter piece, however, the surface will read more than 25% MC. So, the pieces within a stack of lumber can be probed easily and quickly; the wettest readings represent the wettest lumber. The wettest pieces are, with the help of a forklift that lifts the pack open, retrieved and used for making the kiln samples.

Note that because the pins on the T-probe only penetrate perhaps one-quarter of an inch, the MC reading is not the average MC of the lumber. That is, we use the readings, using the probe, to select the samples, but not to run the kiln or give the actual average MC. The true sample MC needs to be calculated using the standard techniques.

When using the 42-E/B probe, try to drive the needles the same depth every time; that is, turn the handle the same amount every time. As we are not using the precise MC readings from the meter, we do not need to worry about species corrections or temperature corrections.

Overall, using this T-probe technique, along with proper kiln operating techniques, a kiln operator should never hear any complaints about "wet lumber."

> ***Special Note:*** *The "T-probe" can also be used to measure the surface MC by driving the needles into the wood only 1/8". Species and temperature corrections should be made so the MC readings are accurate. This 1/8" reading is the surface MC.*

One key rule for running a kiln is “Never use a kiln condition that will add moisture back to the lumber.” This rule applies to the initial warming and to the main part of the kiln schedule (higher humidity can be used for equalizing and conditioning at the end of a cycle). There are several reasons for this rule, but the key one is that checks, cracks, and cupping will increase when the EMC is higher than the surface MC.

In addition, if EMC is greater than surface MC, the lumber will not dry as quickly as desired. So, we need to know the surface MC so that the kiln’s EMC during warming and the initial humidity settings in the schedule must never be higher than the surface MC. When starting the kiln, usually the EMC is 1% or 2% drier than the surface MC.

Part 3: Measuring MC When Unloading a Kiln

Over the last few decades, the processors and users of kiln-dried (KD) lumber have become more and more conscious of the importance of achieving the correct final moisture content (MC). These users appreciate that incorrect MC does affect the quality of their product. Stated another way: “Lumber at the correct MC is worth more — often lots more — money.”

Determine Final MC Targets

- **Softwoods.** In the past, the softwood kiln operator may have been told that after drying, 95% of the pieces of lumber need to be under 19% MC, or perhaps nothing over 15% MC and nothing under 9% MC. Today, specifications for softwoods are even tighter, especially for 1” boards. As a result, the quality is, indeed, improved.
- **Hardwoods.** In the past, the hardwood kiln operator was often told that the final MC should be “6 to 8% MC.” Today, many hardwood operations are demanding an average of 6.8% to 7.2% MC with very few, if any, pieces of lumber over 8.0% MC. There is a definite trend of requiring tighter specifications for final MCs to achieve higher-quality final products.

We must appreciate that no matter how good a kiln operator is and no matter how good the equipment is, there will be some variability in the final MC when kiln drying is complete. Plus, no two pieces of wood behave the same.

So, the two key related questions for every kiln operator and manager are: "What is the desired average final MC?" and "How much spread or variability around the average is acceptable?" For softwoods, it is the grading association that usually specifies the answer to this question; for hardwoods, the user of the lumber should specify, but usually does not. Here's the problem: Without a precise answer, the kiln operator is "in the dark."

Two follow-up questions for the kiln operator or manager include: "Is the final MC of a specific load right on target?" And, if not, "What can the kiln operator do to improve the final MC values to hit the target?

Measuring Final MC

The kiln operator has perhaps four to 12 kiln samples in the kiln that were used to check the MC at the end of drying. However, there are perhaps 10,000 pieces of lumber in the kiln. How do we find out the MC of all 10,000 pieces? Unless we have an in-line moisture meter at the unstacker, we cannot measure every piece, so we must carefully sample and make a reliable estimate. To be most useful for improving the drying process in the future, these final MC measurements should be taken right when we unload the kiln. To help identify kiln equipment issues, in addition to the MC value, each reading should be related to the location of that piece of lumber in the kiln.

Sampling

As just stated, here is no way we can measure the MC of every piece of lumber when we unload the kiln. So, we must rely on statistical sampling to estimate the MC values in the entire kiln. For reliable estimates, we need about 30 MC, randomly taken, readings.

We do not want to use more than one piece of lumber that is exposed to the 4x4 spacing, as we know that the higher air flow will dry lumber in these locations drier than much of the rest of the load. We also want the 30 readings to come from at least 15 different locations, preferably 15 different packs. We want the locations to represent a cross section of the kiln — that is, left side, right side, middle, edge packs, center packs, bottom packs, and top packs — and so on. Such randomness gives more confidence in the estimates.

Using a meter with a memory speeds up data collection: Make sure that no bogus readings (readings that are way out of line) are included in the data set. Make sure that the temperature (of the lumber, not air temperature) and species corrections are made. Make sure that readings are taken with one decimal point; that is 10.3% or 6.8% MC.

With the pin meter used on KD lumber that normally will not have significant moisture gradients, we obtain the average MC of a piece of lumber by using insulated, 1/2" needles (I like the shorter needles as they are not so prone to bending especially with dense species. However, with lumber that has a MC gradient, which is more common with softwood lumber as we do not equalize the final MC like we do with hardwoods, use the 1" needles.) The needles are driven into the edge of the lumber at a point about 1/4 of the lumber's thickness from the top or bottom of a piece. This 1/4 depth procedure is used because we want the average MC and not just the core value. (We also drive the insulated needles 1/4 deep when measuring from the face.)

When taking the MC readings, also note where the lumber was located in the kiln. In this way, we can often find out that the top dries more slowly than the bottom, the back left corner is slow drying, and so on. Generally, we will make such conclusions after analyzing six loads of lumber and not just one or two.

I encourage the kiln operator to take the readings rather than relying on a forklift driver or other person. Yes, this does take time, but the information obtained is worth it for sure.

When crawling around the lumber stacks, safety is certainly an issue — be careful.

Calculations

First, all 30 readings are averaged (add all 30 and divide the sum by 30); use one decimal point, such as 7.1% MC. Any deviation between the actual average and the target average final MC should be noted and explained with the idea that the next load can be better. Some meters have a button to push to get the average MC automatically and instantly — a big time saver and no chance of calculation errors. Note this advice from the voice of experience: "Remember to zero the memory before starting a new batch of measurements."

In addition, note any trends in final MC related to location. A drawing of the kiln with deviation of the actual MC at each location from the load's average MC (written on the drawing) can give a good picture.

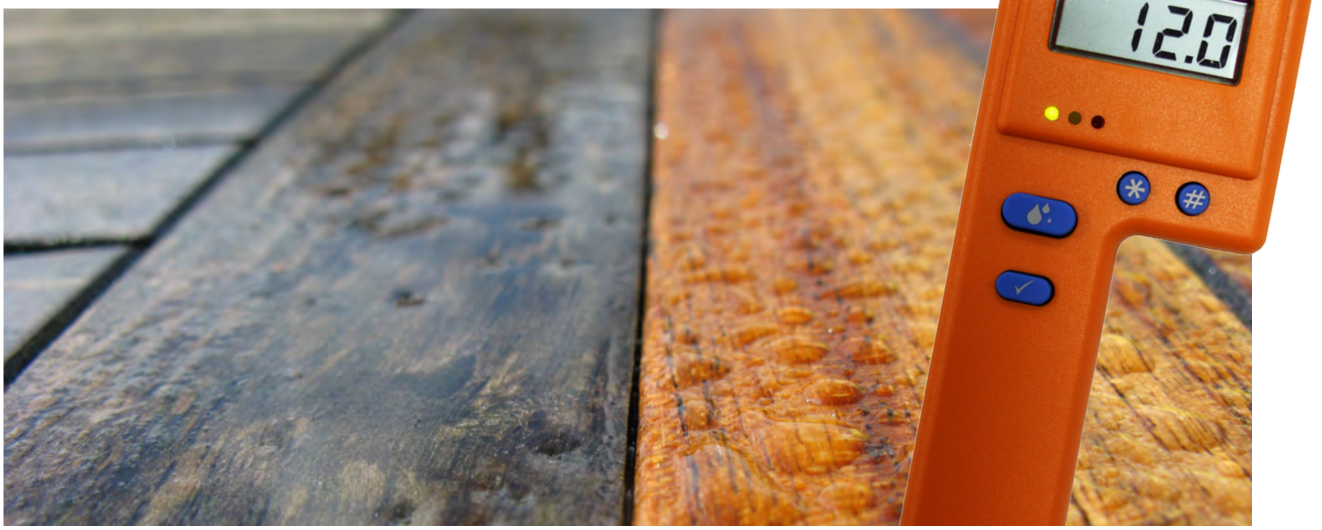
Some meters also can automatically calculate the Standard Deviation (SD), which is a measure of the variability of the final MC. Otherwise, the MC data will have to be entered into a calculator or computer to get the SD. An excellent hardwood kiln drying operation will have SD < 0.3; an average operation will have SD < 0.5. Softwood dimension operations will target SD < 1.5; softwood boards, 0.5 is excellent.

The average MC can be adjusted and the SD can be reduced by controlling the EMC in the kiln at or near the end of the kiln cycle and by adjusting the time for equalization. The more uniform the MC of the lumber when a kiln is loaded, the better the final MC uniformity.

When air drying or predrying prior to kiln drying, the MC uniformity in incoming lumber can often be improved. Some ideas are:

- ❒ Use longer air drying or predrying time.
- ❒ Rearrange packs after a few months so that the bottom packs of lumber are now on the top, and the top ones are on the bottom.
- ❒ Improve the rain drainage system in air drying.
- ❒ Spread the piles out in air drying.
- ❒ Use different predrying times for different species and thicknesses.
- ❒ Use plenum baffles in the predryer.

Overall, remember that the objective in measuring final MC is to improve drying quality and not to “point fingers.”



Part 4: Sampling Incoming Lumber with Moisture Meters

Always check the moisture content (MC) of incoming lumber. It is critically important for a wood products manufacturing operation to have lumber that is at the correct moisture content. Failure to achieve this goal often means a loss in quality and, potentially, repairs or replacements of defective products — flooring, cabinets, furniture, guitars, millwork, drumsticks and more. Rx #1 in this series gives suggested target MCs; fine tune these for a specific customer.

NOTE: Even when the kiln MC is perfect, the storage of lumber between the kiln and the user can be a source of moisture change. Storage of lumber at the wrong relative humidity can, in a few weeks, begin to increase or decrease the lumber's MC above or below acceptable levels. Heated storage at the correct relative humidity, or even wrapping all six sides of a pack in plastic wrap, can stop any moisture changes in storage.

Two MC Factors

We have two concerns when evaluating the MC of incoming lumber: the average (or mean MC) and the variability of the MC around the average. To be clear, if the average is 7.0% MC, a reasonable target for many operations, but with pieces ranging from 4.0 to 10.0% MC, the variability is likely "way too high.

- ❒ **Average.** The average MC of a set of data is the sum of the MC readings divided by the number of readings. Many moisture meters have a memory and can do the calculation of average MC with the push of a button. A computer, iPhone app, or pocket calculator can do this as well. As stated in Rx #1, 6.8% to 7.2% MC is a reasonable target for many hardwood operations; 10.0% MC for softwood boards.
- ❒ **Variability.** There are several ways to measure variability of MC data, but the most common is to calculate the Standard Deviation (SD). SD is sometimes given as the lower case Greek character sigma. Some moisture meters can do the SD calculations with the push of a button; a computer, iPhone app, or pocket calculator can also give the answer, but there is always the chance of an entry error. A well-run hardwood and 1" softwood kiln operation should target <0.5. The best hardwood drying operations will target <0.3.

MC Estimates

It is ideal if we can measure every piece of lumber with a so-called "in-line moisture meter." Such devices are quite expensive, but are certainly worth it for large manufacturing operations. For most operations, the average MC and SD, if taken from about 30 randomly chosen samples from a load, allow a fairly accurate estimate of the total population of lumber, even though only 30 pieces were measured. (It is much like the estimates made of the voters' choices in an election—random samples of 1,000 people can predict the outcome quite accurately.)

Variation (Specifically)

- About 67% of the pieces of lumber will have MCs between [average MC - (1 x SD)] to [average MC + (1 x SD)].
- About 90% of the pieces will have MCs between [average MC - (1.64 x SD)] to [average MC + (1.64 x SD)].
- About 95% of the pieces will have MCs between [average MC - (2 x SD)] to [average MC + (2 x SD)].
- About 99.9% of the pieces will have MCs between [average MC - (3 x SD)] to [average MC + (3 x SD)].

Here's an example: Assume the average is 7.2% MC and the SD = 0.5. Assume that a 50MBF kiln has 10,000 pieces of lumber. Using the formulae above, we estimate:

- There will be 67% or 6,700 pieces of lumber between 6.7% MC to 7.7% MC.
- There will be 90% or 9,000 pieces between 6.4% MC to 8.0% MC. Therefore, 500 will be wetter and 500 will be drier than these limits.
- There will be 95% or 9,500 pieces between 6.2% MC to 8.2% MC. Therefore, 250 will be drier and 250 wetter than these limits.
- There will be 99.9% or 9,990 pieces between 5.7% MC to 8.7% MC. Therefore, five pieces will be wetter and five pieces drier than these limits.

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Obviously, it is up to the individual manufacturing operation to determine whether the spread in the example is okay or needs to be tightened. I suggest that 0.3 SD is often better, as then 9,500 pieces would be between 6.6% MC to 7.8% MC, with 245 between 6.2% MC and 6.6% MC and 245 between 7.8% and 8.2% MC. This is much better from a MC point of view.

Measuring 30 samples from a load can be a bit time-consuming, but using a pinless meter makes the job much quicker.

Acceptance Sampling

A second question when evaluating incoming lumber is whether to accept the lumber as having the correct average MC or rejecting it. Indeed, there are rules for this acceptance sampling. For example, if taking 30 readings and after the first 25 everything looks perfect, it is a good guess that this lumber is OK.

Unfortunately, the precise acceptance sampling technique requires someone, perhaps from a Community College or Extension Business Office, to work with you to set the exact procedure... the last thing we want is to reject a load that is actually OK.

I have seen some operations that buy KD lumber using a pin-type moisture meter on incoming lumber before the lumber is even unloaded from the trucks. They use insulated, 1/2" long needles that are driven in the edge of the lumber at a point about 1/4 of the lumber's thickness from the top or bottom of a piece. They measure 10 pieces and if one is over 8.0% MC, they measure 10 more. If the second sample has one over 8.0% MC, they reject the load. You would fine tune these numbers for your operation (note that 1" needles are also available, but with KD lumber that has a very small gradient, the shorter needles will work fine and will be less likely to break or bend).

- **Benefit.** I had one client that manufactured interior doors. They typically had about 300 recalls mainly in the wintertime. They put in a MC sampling standard for incoming lumber and the next winter they had three recalls!
- **Redrying.** If a load of lumber is a little bit wet, the entire load can be stickered and can be dried in a day or two to improve the final MC values.

With an in-line meter, only the wet pieces would need to be redried. Accumulate the wet pieces and when enough for a kiln load is accumulated, then put it into the kiln for a day or two.

In either case, use a kiln setting of about 130˚F and about 6.0% EMC. Precise instructions are on page 95 of Drying Hardwood Lumber, which is available online.

Part 5: Monitoring Moisture Content in Wood Production

There should be no doubt that the moisture content (MC) of the wood used in manufacturing of furniture, cabinets, flooring, and so on is super critical for producing products that perform well in service. As stated in Rx #1, the MC of lumber, of parts, and of the final product should match the expected MC of the product when it is put into use.

Getting the correct MC means proper kiln drying (KD), proper storage after KD, proper MC when processing of the lumber begins, proper MC during manufacturing, and proper MC in storage and shipment.

There are three important elements of monitoring MC in production:

- ❒ **Knowing the correct target MC to within 0.2% MC** (and not just "6 to 8% MC," which is too general to be useful). SPECIAL NOTE: If, indeed, we manufacture furniture, cabinets, etc. that is designed to be used between 30% RH and 50% RH (6.0% to 9.0% MC), we should include a written notice to that effect when the product is shipped. If we don't tell the consumer or installer, who will?
- ❒ **Maintaining plant EMC as close as possible to the target EMC.** See Rx #1 for a definition of equilibrium moisture content (EMC) and its relationship to relative humidity. A handheld RH meter that can be carried around to check humidity in various locations in the plant is Delmhorst's HT- 4000F. This meter can also be used to check other sensors in the plant. Due to wood dust issues and aging, most cheap sensors (under $100) lose their calibration within a year or less.
- ❒ **Measuring the MC while manufacturing.** As a general rule, wood can tolerate a 1% swing in MC without serious problems, especially if the change is a gain in MC. If the change is done slowly over several months, like the change from summer to winter, a 2% MC change will seldom cause any problems. So, it is important to measure the MC of wood pieces during manufacturing to make sure that they are still correct. This is most often done with a pinless meter.

When doing these checks during manufacturing, we are looking for any prior errors in measuring MC or for changes in MC during prior manufacturing. Essentially, we have MC checks that tell us "Continue" or "Stop." Here is the basic question: "Why put time and money into wood at the wrong MC and that will likely result in future problems?"

Testing for Moisture Issues

One good test for moisture issues is to look at the top piece of wood in a stack for warp. We assume that initially the panel or other product was flat, so warp means a MC change—100% certainty. The top surface of the warped piece lost or gained moisture when exposed to the plant's EMC, and then shrank (lost MC) or swelled (gained MC). However, the core and reverse side were not exposed to the plant's EMC, so they do not change MC. To prove this, we can use a moisture meter with short pins that are pushed about 1/16" into the top surface and then into the bottom surfaces. Differences in MC, top to bottom, will cause warp.

Appreciate that there will be natural variation in moisture content. For example, if the target is 7.0% MC and we hit that target, we will find more than two-thirds of the measured values will be between 6.7% MC and 7.3% MC. This is normal variation for a very good drying operation.

So, in the plant during manufacturing, the pin meter should be used to make sure that no readings are over 7.9% MC if the target is 7.0% MC. Actually, maybe two out of 100 could be 8.0% MC, but no wetter. If we know that there are no samples wetter than this, we can be fairly certain that we will not have a MC issue in the future (unless the customer has exceptionally dry or wet conditions).

To monitor the in-plant MC, we need to take three readings once an hour at a particular manufacturing station. If two or three of these readings are more than 7.6% MC (when the target is 7.0% MC), then we have a strong suspicion that the lumber either was wetter than we thought or it has picked up moisture in the manufacturing process. Subsequently, using insulated needles to see the MC at different depths will confirm if it is wet lumber (the core MC will be higher with wet lumber) or if the wood is picking up moisture in manufacturing (in this case, the surface will be wetter than the core).

QC people could use the three MC readings every hour in a more sophisticated program to study long term trends in the average MC and the variations. They can also relate defects in the field to the MC at the time of manufacturing. One powerful tool they have is to make a graph of MC (vertical axis) and time (horizontal axis). The MC on this graph is the average MC of the three samples. As we know, a picture is worth a thousand words.

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> ***Special Note #1:*** *Wrapping a finished product in plastic or encapsulating in a plastic bag will assure that the MC will not change for a year or more — that is, no moisture can get into or out of the bag. Because heat alone does not cause wood to shrink, swell, warp, or crack, we are concerned only about the relative humidity.*

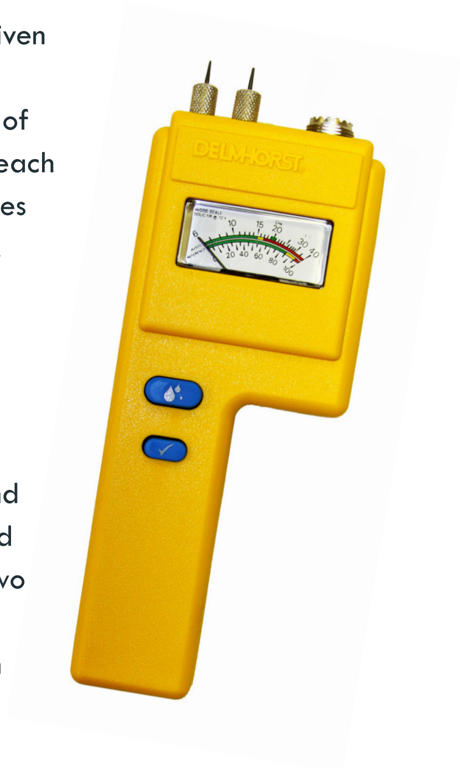
> ***Special Note #2:*** *It is possible to test the performance of a wood product when it will be used in an abnormally drier or abnormally more humid environment. We can build a very small room with a safe heater and humidifier or dehumidifier and create a different humidity or EMC environment than the plant's. Add heat to 95˚F; heat allows any serious problems to show up in a few days.*

Part 6: Moisture Meter Choices

There are two types of moisture meters used with lumber. One uses pins or needles that are inserted into the piece of wood being tested; the other does not have pins but has a plate that must be in good contact the wood. Which meter is best? There are two answers:

- ❒ It depends on what information you are looking for, such as moisture gradients; and
- ❒ The meter must be one that your employees will use.

Pin Meters



With the pin meter, the electrical resistance between the pins, which are driven into the wood, is measured. The resistance value is then converted into an estimated moisture content (MC). The theory is that the electrical resistance of wood is affected primarily by the amount of water in the wood. However, each species has a slightly different inherent resistance, so the name of the species being tested must be known and then the MC reading adjusted for species. (Traditionally, American-made moisture meters have their basic calibration based on Douglas-fir; non-American meters have used many different standards).

Furthermore, temperature also has a slight effect; for every 20˚F wood is warmer than room temperature, 1% MC is subtracted from the reading; and for every 20˚F cooler it is, 1% MC is added. I did a test on several hundred pieces of kiln-dried lumber at room temperature of various species using two common USA-made pin-type meters and the results were typically within 0.5% MC of the oven-dry MC that I subsequently measured (see details on page 130 of Drying Hardwood Lumber).

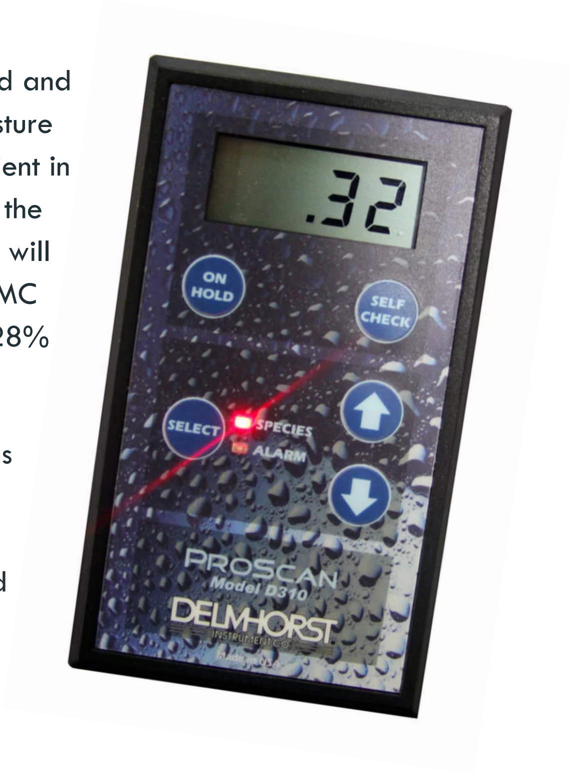
If the pins used are insulated along their length except for the tip, then the MC reading obtained will be the MC in the vicinity of the tip. It is possible with this pin meter, therefore, to obtain the MC at different depths. That is, the MC gradient within a piece of wood can be measured.

The practical range for pin meters is 6.5% MC to 28% MC. Some meters may provide MC values outside this range, but the reliability of such readings is poor. This uncertainty at low MCs is due to the extremely high electrical resistance wood has at low MCs; the uncertainty at high MCs is due to the small resistance changes above 28% MC.

Perhaps the greatest concerns with using pin meters are the time it takes to drive the needles into the wood and the two small holes that the pins leave. Furthermore, the MC measured is only the MC in the vicinity of the pins, which leaves most of the piece of the lumber unmeasured… though this is seldom a problem with properly dried lumber.

Some pin meters require the pin to run along the grain; others, across the grain. Most pin meters suggest that the reading be taken immediately after the reading button is pushed.

Pin-Less Meters



With the pin-less meter, a dielectric factor in the wood is measured and the results are converted to an estimated MC value. Although moisture is the greatest factor influencing the value of the dielectric coefficient in wood, the density of wood is also important. Therefore, even with the same species, if there is a density variation within the wood, there will be a similar variation in the indicated MC—even though the true MC does not vary. The practical range for these meters is 5% MC to 28% MC.

The main advantage of the pin-less meters is their speed (readings are almost instantaneous); so, every piece of wood in a load can be measured for MC quickly. Furthermore, these meters can scan an entire piece (end to end and side to side) if the meter is moved across the lumber's surface. The readings are not influenced much by temperature.

One drawback is that gradient readings cannot be taken. The meter also responds slightly more heavily to the MC on the surface closest to the meter. Because of the density issue mentioned above, whenever high MC readings are seen with the pin-less meter, it would be prudent to double check the MCs with a pin-type meter to assure that the MC is actually high.

In tests on hundreds of kiln dried lumber samples at room temperature, the MC readings were typically within 0.75% MC (See page 130 in Drying Hardwood Lumber).

It should be noted that pinless meters are designed for materials of a certain thickness. Also, the piece being tested should have an air gap on the other side.

Which Meter Is Best?

Both types of meters have several strong features and limitations that a user must be aware of. The best meter is actually both of them used together, as the weakness of one is a strong point of the other. I like the pin-less meter for its ability to scan large areas and many pieces quickly and the lack of temperature sensitivity. I like the pin meter for its gradient ability and small species effect. I like “Made in America” moisture meters for rapid repair/replacement, if needed, plus calibration accuracy for American wood species.

Once you have chosen the type of meter, then consider what special features you want, such as a memory, ability to attach a probe for selecting kiln samples, attachment of a probe with insulated needles, automatic calculation of average MC and the standard deviation; easy species adjustment and easy temperature adjustment. You may also want a lighted dial. The needs of your quality control people should also be considered.

In all cases, the manufacturer’s instructions must be followed if accurate readings will be obtained. Several key items are mentioned above, but check the instruction manual for details. Also, fresh batteries must be used always; keep a readily available supply.

Part 7: Diagnosing Customer Issues

Every so often, but hopefully not too often, a customer has a complaint. Frequently, moisture content (MC) is the potential issue. So, let's discuss how to use a moisture meter on many types of finished products to obtain the necessary MC information.

Complaint: Wet Lumber

The best defense against shipping wet lumber or wet products is to measure the MC of the lumber or wood product just prior to shipping. This can be done with a pin- or pin-less meter.

Once wood is shipped, the core MC will be slow to change. So, measuring the core will almost always give us the MC when the lumber left the dry kiln. To get the core MC, use a pin-type meter with insulated needles that leave only the tips exposed. Drive the tips into the core (1/2 the thickness). Do not let the nuts holding the needles touch the lumber's surface. Washers on the pins come with the meter to prevent this; make sure they are still in place.

Complaint: Product Got Wet in Storage

If lumber or a manufactured wood product gained moisture during storage or shipment, then it will, for a short time after storage, have a higher shell MC than the core MC. Use insulated needles and take MC readings approximately every 1/8" in depth from the surface to the core.

Complaint: Over-Dry Lumber

When checking for over-dry lumber (over-dried hardwoods often are MC < 6.0% MC; softwoods are < 10% MC), it might be necessary to use a pin-less meter, as pin meters do not work well under 6.5% MC. The pin-less meter will give an average MC. Also, check the core MC with a pin meter using insulated needles, as the core is usually the MC when the lumber left the kiln.

Complaint: Checks or Cracks Opening after Finishing

Dry wood is twice as strong as wet wood, so it will take a lot of MC loss (over 12% MC change) to create enough shrinkage and resulting stress to initiate a new check or crack with dry wood. This applies to lumber, cut-stock and wood parts, and veneer.

Therefore, virtually all checks and cracks found in manufactured products are the result of old checks from the lumber or veneer reopening when the wood is exposed to a dry environment, such as normal, wintertime, interior, or home humidities. Many times, when we split open the crack or check and look inside, we will see small spots of finish inside the crack indicating the crack was present prior to finishing.

Here is a key: If the wood was very wet when the product was manufactured and then dried out after shipping, will a MC measurement taken on the dry material indicate that the wood was wet? Answer: "No!" The only way we know that the wood was wet when the product was manufactured is to take a moisture reading BEFORE the issue develops. Readings taken after the issue will always be dry readings. Even though the pin-less meter is designed for a specific thickness of wood, a pin-less meter will still come close enough to indicate a potential problem. For precise values, use a pin meter.

Complaint: Lumber or Product Warped AFTER Manufacturing

The 100% rule is that wood does not change size or shape unless its MC changes. So, when wood warps, we know there is a MC change. Readings after the warp occurs will be low MCs. So, we need to make sure that we have MC readings prior to the occurrence of warp.

When a wood product warps, we know for certain that the wood's MC did not match the environment's equilibrium moisture content (EMC). Was the wood at the wrong MC; or, was the environment too wet or too dry? Sometimes, we can tell by measuring the MC gradient, as described above, using insulated needles. Special note: Completely wrapping lumber or a manufactured product in plastic wrap will prevent any moisture change, as water cannot get in or out of the package, no matter what the temperature or outside conditions.

Complaint: Lumber or Wood Product Shrank or Swelled After Installation

Wood does not shrink or swell unless its MC changes. So, if we measure the MC now after changing size AND measure the amount of shrinkage or swelling precisely, we can easily estimate what the MC was before it shrank or swelled. The MC we need is the average for the piece, not shell or core alone; with a pin meter, drive the needles to 25% of the thickness; for a pin-less meter, the MC reading is the average.

Complaint: Open Glue Joints

In the majority of cases, the individual pieces of wood were cut with straight edges, but then were allowed to “sit around” for an hour or longer before they were assembled and glued together. During this waiting period, if the piece’s MC was a little higher than the plant’s EMC, the ends of the pieces lost MC and shrank around 0.01”. This small size change means a tiny gap exists at the ends when the panel was assembled; a gap of over 0.006” is the beginning of a weak glue joint.

A little more shrinkage after gluing—in the dry plant, finishing oven, or consumer’s home—means the shrinkage stress will likely open the joint. The solution is to make sure the MC of wood is within 2% of the plant’s EMC. Measure these values every three hours using accurate equipment. Rapid assembly after preparing the flat surfaces is also important. (A good glue joint is actually one to one-and-a-half times stronger than the wood itself. So, a good glue joint should never fail.)

Complaint: Brittle Wood with Machining Defects

Softwoods under 10.5% MC and hardwoods much under 6.5% MC behave in a brittle manner. Chip out and splitting are two machining defects that are often seen. The key to prevention is to avoid over-drying the wood. MC checks prior to processing are essential. As sometimes the MC is under 6.5% MC, moisture should be measured with a pin-less meter. Once over-dried, the wood’s brittleness cannot be easily reduced just by increasing the MC to more normal levels.

Rx is from The Wood Doctor, Gene Wengert, President, The Wood Doctor’s Rx LLC.

The Delmhorst team would like to thank The Wood Doctor for letting us share his hard-earned, practical wisdom with you.

Need Help Finding the Right Wood Manufacturing Moisture Meter?

If you need a high-quality wood moisture meter and in-kiln monitoring system to use for your wood manufacturing needs, Delmhorst Instrument Company has a large variety of wood moisture testing tools that you can benefit from. Contact us today for help choosing the best wood moisture meter for your needs!

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