FOR-132

University of Kentucky
College of Agriculture, Food and Environment
Cooperative Extension Service

A Start-Up Guide for Operators of Small Dry Kilns

A companion to *A Checklist for Operators of Small Dry Kilns* (FOR-131)

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Introduction

In *A Checklist for Operators of Small Dry Kilns* (FOR-131), I discussed various things to look over to prepare your dry kiln before you load it with lumber. Among the things I said to check for were the kiln baffles, controllers, fans, moisture meters and sensors, and so forth. Just having your equipment in good operating condition won't assure that you end up with well-dried lumber, though—the most important part of operational readiness takes place between your ears! With that in mind, in this manual I've tried to present step-by-step kiln operating procedures so you can keep everything well-organized and running properly.

Starting Up the Kiln

If all of your equipment checks out, if you have boards selected for moisture monitoring and a kiln schedule selected, now is the time to look over you're the rest of your lumber for existing drying problems (such as end or surface checks). End checking problems might have been caused by placing stickers too far from the ends of the boards during air-drying, or maybe the end coating you applied wasn't put on thickly enough. End checks, as well as surface checks, could also have been caused by the lumber being trucked without a tarp when it was green. These are just a few of the things to think about before the next load of lumber goes onto your air-drying yard. None of those problems can be fixed in the dry kiln, though the kiln operator often gets the blame.

If everything is as good as it can be, you're ready to load the lumber into the kiln! Here are some step-by-step directions that will help you get high-quality lumber; some steps I wrote out for sample boards may not be necessary if you are drying air-dried lumber using electronic moisture sensors.

If you haven't done it already, pick your sample boards (or the boards you will use with moisture sensors). If you aren't using moisture sensors, or if the lumber is too wet to use sensors reliably, you need sample boards. Some moisture variation is likely present even before you put the lumber into the kiln. Pay attention to the growth ring orientation and whether the boards were originally at the edge of a pack of lumber (where they might be drier) or the middle of the stack (wetter).

Moisture meters can be very useful to help locate dry and wet boards in your stack. Perhaps you have already appropriately used a moisture meter to examine the moisture variability in your lumber. Pinless meters in particular make quick work of this task.

Number your sample boards. Numbering each sample board with a marker will make your life a lot less confusing. You need to replace each board in the pocket you drew it from, and you should also keep track of the sample board moisture contents on a spreadsheet! If you are using moisture sensors, it's still a good idea to label the boards so you know which board your kiln controller is reading; make sure they correspond to the sequence on your control's display. See Figure 1.

Cut moisture wafers from the ends of your sample boards and calculate the ovendry weight and current moisture contents of your sample boards. Appendix A contains detailed instructions.

Moisture wafers are approximately one-inch thick cross-sections of wood taken from both ends of each sample board (Figure 2).

Keep moisture wafers in baggies if you can't weight them right away. They can lose moisture quickly in the open air, and that will affect the accuracy of your moisture content calculations. Weigh the wafers immediately after they are cut, oven dry them completely, calculate the moisture contents, and average these to obtain the moisture content of each sample board. Write both the dry and current weights on the sample boards with a marker and record them in a spreadsheet as well.

Figure 1. A sample board with markings to identify the species, board number, original wet weight, calculated oven-dry weight, and overall average moisture content based on moisture wafers.

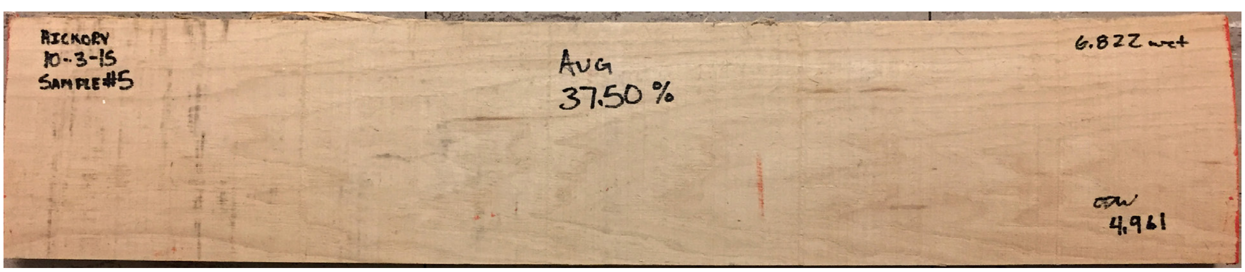
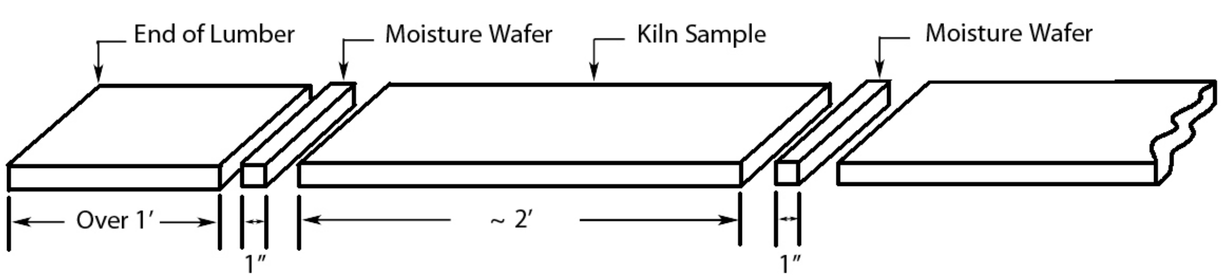


Figure 2. This diagram shows what moisture wafers and a kiln sample looks like.



Remember to coat the ends of the sample boards to prevent moisture loss immediately after you cut the moisture wafers; use a specially designed coating compound that won't evaporate or melt in the hot kiln, because that will expose the end grain to rapid moisture loss. (The coating compound used on the ends of sample boards is different from the end coat designed to be used on the ends of the lumber.) Several companies sell effective end coating compounds for this purpose. The weights of the end coating will be negligible and won't affect your moisture calculations.

Some people use a microwave oven to hasten the drying of moisture wafers, but the wafers will often smoke ominously before the water is completely evaporated. If you stop drying at that point you will probably calculate an incorrect moisture content for your sample board, and it's hard to predict whether the difference will be significant or not. I find it's useful to start drying the wafers in a microwave oven, but I always move them to a regular oven heated to between 215° and 220°F to be sure I have a dry weight that I can trust. Be sure you get at least two successive readings that are the same weight.

Don't use moisture meters to measure the current moisture contents of your sample boards, particularly if the boards are fairly green; the readings won't be accurate at high moisture contents. Like sensors, pinless meter readings can also be affected by lumber density. The accuracy of pin-type meters will be influenced by pin orientation and placement (edges will be drier, for example, and moisture readings will be affected by the depth of the pin placement), species, and temperature. Any meter can be slightly incorrect due to meter calibration variations. Why not make the very best moisture determination you can?

Plan how you will position your moisture samples (sample boards or boards with embedded sensors) **in the stack of lumber.** Regardless of whether you are using sample boards or moisture sensors, you need to be able to check on those boards. You will be removing sample boards daily, for example, and even moisture sensors may need to be checked to be sure the pins and cables haven't become separated. Don't put boards someplace where you have to crawl over your lumber to get to them.

Putting labels or a line of fluorescent chalk on a long edge will make it easier to find the boards in the kiln.

Put your moisture samples in different locations. Airflow or kiln construction differences might cause some lumber to dry faster than the rest. Even if your lumber is perfectly homogeneous, different boards will dry at their own pace. You need a good idea of how your lumber is drying overall.

Take a look at Figure 3 to see an example of how sample boards can be embedded in a stack of lumber. Placing sample boards within a stack of lumber is important for green lumber because air-flow affects green lumber more than it affects dryer lumber. I have seen some kiln operators place air-dried sample boards on cantilevered sticks alongside the stack edges during kiln drying, but unless the lumber is already well air-dried this can cause sample boards to dry more quickly than the rest of the pack. I don't recommend this practice unless you're careful and understand the potential pitfalls.

Figure 3. One way to label sample boards and insert them into a stack of lumber. The stickers shown here are spaced two feet apart for 4/4 lumber. Note the Bright Orange Sample Sealer (B.O.S.S) used by this firm to coat the ends of their sample boards. (B.O.S.S. is sold by Anchorseal.)

Decide how much lumber you will put into the kiln. If you aren't running a dehumidification kiln, the size of the dry kiln will probably control how much lumber you place in the kiln. On the other hand, if you are running a DH kiln, the amount of lumber you can put into the kiln depends on the species, especially if the lumber isn't already well air-dried. Refer to the table for "Wood Groups" in your kiln manual.

Determine the MC of your lumber at its surface. You ought to know the surfaced moisture content so you don't start the kiln at a higher equilibrium moisture content (EMC), thereby moistening the lumber surface. That could create the potential for drying defects. The MC at the surface of your lumber will be affected by the EMC conditions in your air-drying yard or storage area, and you will probably find that the surface MC varies a little from board to board.

To measure the surface moisture content of some of your lumber, use a pin-type moisture meter with short non-insulated pins. Normally the moisture increases as you go deeper into the core of drying lumber, so only press the pins in as far as you need to in order to get decent contact with the lumber (about 1/16"). Remember, non-insulated pins will read the highest moisture content in contact with the pins, so keep the contacts as close to the surface as you can.

Load the kiln. Regardless of the type of kiln you use, be sure to allow room for air flow through your lumber, and use baffles across the top and sides of your lumber to make the air flow through (rather than around) your lumber. Don't load the packs of lumber too close to either a DH compressor or the walls, because that disrupts air flow. It's better to make the pack of lumber a little taller than to make it so wide that it's hard to get in and out of the kiln (and I've seen people do that)!

Decide which moisture sample(s) to use when you enter the kiln schedule. The starting kiln condition (the dry bulb and wet bulb temperatures [and by extension, the EMC]) in the schedule is determined from the moisture content of the sample boards. The documentation for the USDA schedules tell you to change kiln conditions according to the moisture content in the wettest half of all of your sample boards, but if you only have a small number of sample boards or sensors your sampling may not indicate the full extent of the moisture variability in your lumber. This is particularly true if the samples weren't chosen with deliberate care.

I think you ought to be conservative, especially when you are drying a species or thickness that is new to you; instead of using the average of the wettest half of your samples to decide when to change kiln conditions, use the very wettest moisture sample as the MC indicator.

Figure 4. An example of a kiln schedule.

Initial MC (%)	4/4 and 5/4 (T3-D2)		
	Dry-bulb temperature (°F)	Wet-bulb depression (°F)	Wet-bulb temperature (°F)
>50	110	4	106
50	110	5	105
40	110	8	102
35	110	14	96
30	120	30	90
25	130	40	90
20	140	45	95
15	160	45	115

Take a look at your kiln schedule to familiarize yourself with it. Here's an example of a kiln schedule for 4/4 and 5/4 northern red oak (from Drying Hardwood Lumber, with the rows for Equalization and Conditioning removed for simplicity)[1] (Figure 4):

Kiln schedules sometimes confuse people the first time they see one. All they're telling you is that you should change from one kiln setting to another when you have reached the next lower moisture content. Be sure you're looking at the row that matches up with the moisture content of your sample(s). If your wettest sample is at 32 percent MC, for example, you should be following the line parallel to 35 percent MC (110°dry bulb and 14° depression) until the moisture sample equals the MC in the next line (30% MC in this example). Continue to change kiln settings according to the schedule as your samples dry. (Keep an eye on the driest sample, because you will use that to tell you when to stop drying.)

Think about your start-up kiln settings. Earlier I told you to check the surface moisture content of your lumber. If you know this then you can avoid adding moisture to the surface of your lumber when you start the kiln; all you have to do is to make sure that the starting EMC is less than the lumber surface moisture content. This goes hand-in-hand with the starting conditions prescribed by your kiln schedule, so let's start by taking a look at that.

The way the kiln schedule is depicted in Figure 4 is typical for a lot of schedules–it lists different moisture contents, the dry bulb and dry bulb settings and the wet bulb depression. What's missing, though, is a column with the EMC values. That's easily remedied. Here's a copy of Figure 4 with values added for equilibrium moisture content from Table B in the Appendix (Figure 5):

1 Denig, Joseph; Wengert, Eugene M.; Simpson, William T. 2000. *Drying Hardwood Lumber*. Gen. Tech. Rep. FPL–GTR–118. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 138 p. http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr118.pdf

Figure 5. Figure 4, with values for the equilibrium moisture content added at each step (in italics).

Initial MC (%)	4/4 and 5/4 (T3-D2) Dry-bulb temperature (°F)	Wet-bulb depression (°F)	Wet-bulb temperature (°F)	*EMC (%)*
>50	110	4	106	*17.5*
50	110	5	105	*16.2*
40	110	8	102	*13.3*
35	110	14	96	*9.9*
30	120	30	90	*5.4*
25	130	40	90	*3.8*
20	140	45	95	*3.4*
15	160	45	115	*3.7*

According to the kiln schedule, lumber at 32 percent MC ought to follow the 35 percent MC row. That group of settings matches an EMC of 9.9 percent MC. Now would be the time to see if the starting EMC is higher or lower than the surface moisture content that you measured earlier. If the surface MC was 12 percent, starting the kiln at around 10 percent ought to be no problem.

What should you do if the starting EMC is higher than the surface moisture content of your lumber? This might happen with green lumber, for example. If your lumber was sawn and stacked but not really air-dried yet, the surface moisture content might be around 15 percent, for example, because that might be close to the EMC of the storage conditions. The prescribed starring kiln condition for lumber that's at 50 percent MC (+) would indicate an EMC of around 16 to 17 percent. Of course, depending on what your actual schedule indicates, this might be a little different. What you need to do is to start up the kiln at a similar dry bulb setting and at a wet bulb setting that is just a little less than the EMC of the surface of your lumber.

Here's an example: If you were 4/4 drying red oak and following the kiln schedule outlined above and your lumber was at 50 percent MC, the schedule calls for an EMC condition of 16.2 percent. If that's higher than the 15 percent surface moisture content you measured, you might decide to start the kiln at a slightly drier setting. Follow your instincts and decide what you're comfortable with. You might set the kiln to a dry bulb of 110°F and a wet bulb depression of 7°F for an EMC of 14.1, for example (see Appendix B for the EMC table). When your moisture samples reach 40 percent you change the schedule to a depression of 8°F for an EMC of 13.3.

Start the kiln. You don't have to start the kiln at the setting indicated by the schedule. Maybe your kiln takes a while to warm up, or perhaps your lumber is cold and you don't want to put it into a kiln at the scheduled temperature right away. You have options. You could start out at a lower dry bulb temperature as long as you pay attention to how you set your EMC condition, for example. Look for an EMC setting that would give you a similar EMC value and set your kiln accordingly. A lower temperature would slow down the drying a bit, but your lumber would be dried safely. As the lumber warms up, you could increase the dry bulb temperature while maintaining your desired EMC condition and advance your kiln settings according to the sample boards as you see fit.

Monitor the sample boards daily if possible. Tracking your moisture samples, whether via moisture probes or sample boards, is necessary because you need to know what the moisture content of your wettest lumber is–and you need to know when the lumber approaches your dry target MC too. Keep in mind that the sample that starts out the wettest might not be the wettest sample throughout drying, so you need to monitor all of the samples.

If you are using sample boards, use the calculated dry weights together with the current weight of each board to determine the current moisture contents. (See Appendix C for an example of how to do this.) The math is easy to incorporate into a spreadsheet.

At some point you may notice that one sample is reliably drier than the rest. You might have an EMC set to something like 3 or 4 percent MC, but if you continue to dry at that setting your lumber will overdry and your customers will complain that it doesn't machine well. You need to stop the driest samples from getting too dry but at the same time you want to continue drying the wettest samples. This process of getting all the lumber close to a moisture content target is called "equalization." It's impractical to get all of the lumber to one single moisture content, so it's usual to set a small range of moisture contents that buyers find acceptable; a range of 7±1 percent moisture content (6–8%) is pretty common for hardwood. If no further work is done to adjust the moisture content of lumber in the kiln, a kiln operator should match his final EMC condition to that 1 percent-below-the-target MC. In other words, if the target range is 7±1% MC, when the driest sample reaches 6 percent the operator should change the kiln conditions to 6 percent EMC to prevent further drying. The wetter lumber will continue to dry, and the entire load can be removed when the wettest sample reaches 8 percent MC.

Equalizing your load of lumber is important. I heard of one small company that sold a stack of lumber to a customer who set one board on his table saw overnight. When he went to work on it the next day, he found that there was rust on his table saw! Obviously, that kiln operator was having some problems. Either he didn't do a good job of selecting appropriate sample boards or he pulled his lumber out of the kiln too early.

Sometimes an additional procedure (called "conditioning") is used to remove drying stresses before the lumber is pulled from the kiln. Drying stresses could be important to your customer; drying stresses, for example, might mean that the lumber tends to pinch when it's run through a table saw. Conditioning adds a little bit of moisture back to the lumber surface before it's removed from the kiln. This increases the overall moisture content by about 1 percent, so during equalization (i.e., before conditioning) the lumber gets dried to 2 percent (not 1%) below the target MC. When moisture is added during conditioning the driest wood is pushed back up into the target MC range.

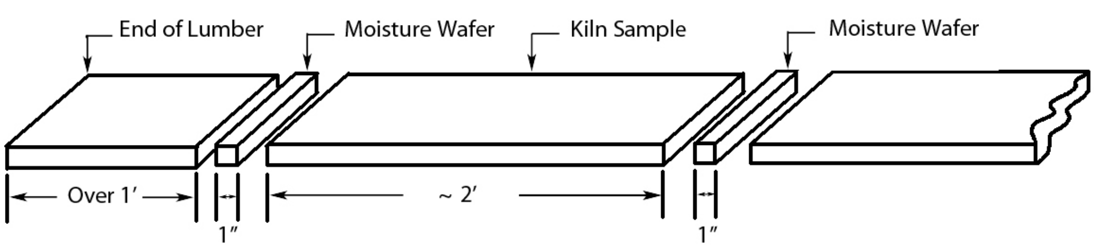
Not every kiln runs a conditioning cycle before unloading the kiln. Usually it's the bigger kilns that do that; they heat their kilns with steam and just have to bleed off a little of that steam into the interior of the kiln. The combination of heat and moisture is very effective in reducing drying stresses. Smaller kilns, including most DH kilns, don't have steam available. An accessory is available that meters a very fine mist into the kiln which acts similarly to the steam, but companies sometimes choose to forego that and finish drying at the end of the equalization cycle. The thinking is that the day-night cycling of temperature and humidity during prolonged air-drying sufficiently relieves drying stress.

Appendix A: Determining the Initial Moisture Content and Calculated Ovendry Weight of Sample Boards

Moisture wafers, also called moisture sections, are used to determine the overall moisture content of your sample boards. In turn, these sample boards are used to help you determine the entry point in your kiln schedule that you should use to initiate kiln drying. Once the current moisture content of each sample board is known, you can calculate the expected ovendry weight. By comparing the calculated ovendry weight with the actual weight on a daily basis, you can monitor the moisture contents of each of your sample boards. This enables you to change kiln conditions according to the kiln schedule you chose to use.

If you've never estimated the current weight of a sample board before, here's an example.

To begin with, take a one-inch-thick piece from each end of each sample board, as shown in the figure below. Cut your sample board as far from the ends as practical to avoid potentially drier lumber, and make the sample boards as long as practical in case you need to recheck the sample board at a later time.



Cut moisture wafers, then put a moisture-proof coating like B.O.S.S. (by Anchorseal) on the ends of the sample boards. Weigh each wafer to within an accuracy of 0.1 grams and write the weights on each one with a black magic marker. As soon as possible after you cut the wafers, weigh the large remainder of your sample board–you'll need a larger scale, but this board doesn't need to be weighed to the same level of accuracy. After you weigh each sample board, coat the ends with B.O.S.S. or a similar product.

Dry the wafers in an oven set at a minimum of 215°F and weigh them periodically until the weight doesn't change; this might take anywhere from one to several hours, depending on the moisture content of the lumber. Using the original and the ovendry weights from your moisture wafers, calculate the current moisture content for each sample board.

For this example, let's say that moisture wafer #1 weighs 125 grams, and moisture wafer #2 weighs 163 grams. After drying, the weights are 80.5 grams and 104.2 grams. The weight of the remaining sample board is 3,810 grams.

a) Using the original and the final dry weights, determine the moisture contents of each of the wafers. Use equation [1] to determine moisture content:

$$\text{Moisture Content} = \frac{(\text{Original Wood Weight - Ovendry Wood Weight})}{\text{Ovendry Wood Weight}} \times 100\% \qquad [1]$$

Here's how to use that formula to determine the moisture content of the two wafers in this example:

$$\text{Moisture Content of Wafer \#1} = \frac{(125 \text{ grams} - 80.5 \text{ grams})}{80.5 \text{ grams}} \times 100\% = 55.3\%$$

$$\text{Moisture Content of Wafer \#2} = \frac{(163 \text{ grams} - 104.2 \text{ grams})}{104.2 \text{ grams}} \times 100\% = 56.4\%$$

b) Once the weights of the two moisture wafers are known, average the results to determine the overall moisture content of the remaining part of your sample board. Since the moisture contents for the moisture wafers in this example are calculated to be 55.3 percent and 56.4 percent, the average MC is

$$\text{Average Moisture Content} = \frac{(55.3\% + 56.4\%)}{2} = 55.8\%$$

You can use 55.8 percent moisture content to estimate the ovendry weight of the larger sample board from which these pieces were cut. You will need to refer back to your notes to find the weight of the sample board that remained after you cut the moisture wafers.

Use equation [2] to calculate the expected ovendry weight of your sample board:

$$\text{Ovendry Weight of Sample Board} = \frac{\text{Original Weight of Sample Board}}{\left(1 + \frac{\text{Average MC of Moisture Wafers (\%)}}{100}\right)} \qquad [2]$$

c) Since the original weight of the sample board was 3810 grams, the ovendry weight can be estimated from the previous equation:

$$\text{Ovendry Weight of Sample Board} = \frac{3810 \text{ grams}}{\left(1 + \frac{55.8\%}{100}\right)} = 2445 \text{ grams}$$

You can now use this predicted weight (2445 grams) in your daily moisture content estimates as your lumber dries in the kiln.

The calculations can be easily done with a calculator, but most people just put the formula on a spreadsheet. I've included the calculations in Appendix C along with an example of how to calculate the moisture content of your sample board from moisture wafers.

Appendix B: EMC Tables

These tables show values for relative humidity (RH) and equilibrium moisture content (EMC) at different kiln conditions, specified by dry-bulb temperature (DB) and wet-bulb temperature (WB). (This version has been copied from the USDA *Dry Kiln Operator's Manual,* Agriculture Handbook 188, edited by William T. Simpson, revised 1991.)

Table 1-6—Relative humidity and equilibrium moisture content at various dry-bulb temperatures and wet-bulb depressions below 212°F.

Dry-bulb temper-ature (°F)	Relative humidity[1] and equilibrium moisture content[2] (%) at various wet-bulb depression temperatures (°F)																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
30	89	78	67	57	46	36	27	17	6	—	—	—	—	—	—	—	—	—
	—	15.9	12.9	10.8	9.0	7.4	5.7	3.9	1.6	—	—	—	—	—	—	—	—	—
35	90	81	72	63	54	45	37	28	19	11	3	—	—	—	—	—	—	—
	—	16.8	13.9	11.9	10.3	8.8	7.4	6.0	4.5	2.9	0.8	—	—	—	—	—	—	—
40	92	83	75	68	60	52	45	37	29	22	15	8	—	—	—	—	—	—
	—	17.6	14.8	12.9	11.2	9.9	8.6	7.4	6.2	5.0	3.5	1.9	—	—	—	—	—	—
45	93	85	78	72	64	58	51	44	37	31	25	19	12	6	—	—	—	—
	—	18.3	15.6	13.7	12.0	10.7	9.5	8.5	7.5	6.5	5.3	4.2	2.9	1.5	—	—	—	—
50	93	86	80	74	68	62	56	50	44	38	32	27	21	16	10	5	—	—
	—	19.0	16.3	14.4	12.7	11.5	10.3	9.4	8.5	7.6	6.7	5.7	4.8	3.9	2.8	1.5	—	—
55	94	88	82	76	70	65	60	54	49	44	39	34	28	24	19	14	9	5
	—	19.5	16.9	15.1	13.4	12.2	11.0	10.1	9.3	8.4	7.6	6.8	6.0	5.3	4.5	3.6	2.5	1.3
60	94	89	83	78	73	68	63	58	53	48	43	39	34	30	26	21	17	13
	—	19.9	17.4	15.6	13.9	12.7	11.6	10.7	9.9	9.1	8.3	7.6	6.9	6.3	5.6	4.9	4.1	3.2
65	95	90	84	80	75	70	66	61	56	52	48	44	39	36	32	27	24	20
	—	20.3	17.8	16.1	14.4	13.3	12.1	11.2	10.4	9.7	8.9	8.3	7.7	7.1	6.5	5.8	5.2	4.5
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25
	—	20.6	18.2	16.5	14.9	13.7	12.5	11.6	10.9	10.1	9.4	8.8	8.3	7.7	7.2	6.6	6.0	5.5
75	95	91	86	82	78	74	70	66	62	58	54	51	47	44	41	37	34	31
	—	20.9	18.5	16.8	15.2	14.0	12.9	12.0	11.2	10.5	9.8	9.3	8.7	8.2	7.7	7.2	6.7	6.2
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35
	—	21.0	18.7	17.0	15.5	14.3	13.2	12.3	11.5	10.9	10.1	9.7	9.1	8.6	8.1	7.7	7.2	6.8
85	96	92	88	84	80	76	73	70	66	63	59	56	53	50	47	44	41	38
	—	21.2	18.8	17.2	15.7	14.5	13.5	12.5	11.8	11.2	10.5	10.0	9.5	9.0	8.5	8.1	7.6	7.2
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41
	—	21.3	18.9	17.3	15.9	14.7	13.7	12.8	12.0	11.4	10.7	10.2	9.7	9.3	8.8	8.4	8.0	7.6
95	96	92	89	85	82	79	75	72	69	66	63	60	57	55	52	49	46	44
	—	21.3	19.0	17.4	16.1	14.9	13.9	12.9	12.2	11.6	11.0	10.5	10.0	9.5	9.1	8.7	8.2	7.9

Table 1-6—Relative humidity and equilibrium moisture content at various dry-bulb temperatures and wet-bulb depressions below 212°F—continued

Dry-bulb temper-ature (°F)	Relative humidity[1] and equilibrium moisture content[2] (%) at various wet-bulb depression temperatures (°F)																		
	19	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**32**	**34**	**36**	**38**	**40**	**45**	**50**
30	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
35	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
40	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
45	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
55	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
60	9	5	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	2.3	*1.3*	*0.2*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
65	16	13	8	6	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	3.8	*3.0*	*2.3*	*1.4*	*0.4*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
70	22	19	15	12	9	6	3	—	—	—	—	—	—	—	—	—	—	—	—
	4.9	*4.3*	*3.7*	*2.9*	*2.3*	*1.5*	*0.7*	—	—	—	—	—	—	—	—	—	—	—	—
75	28	24	21	18	15	12	10	7	4	1	—	—	—	—	—	—	—	—	—
	5.6	*5.1*	*4.7*	*4.1*	*3.5*	*2.9*	*2.3*	*1.7*	*0.9*	*0.2*	—	—	—	—	—	—	—	—	—
80	32	29	26	23	20	18	15	12	10	7	5	3	—	—	—	—	—	—	—
	6.3	*5.8*	*5.4*	*5.0*	*4.5*	*4.0*	*3.5*	*3.0*	*2.4*	*1.8*	*1.1*	*0.3*	—	—	—	—	—	—	—
85	36	33	30	28	25	23	20	18	15	13	11	9	4	—	—	—	—	—	—
	6.7	*6.3*	*6.0*	*5.6*	*5.2*	*4.8*	*4.3*	*3.9*	*3.4*	*3.0*	*2.4*	*1.7*	*0.9*	—	—	—	—	—	—
90	39	36	34	31	29	26	24	22	19	17	15	13	9	5	1	—	—	—	—
	7.2	*6.8*	*6.5*	*6.1*	*5.7*	*5.3*	*4.9*	*4.6*	*4.2*	*3.8*	*3.3*	*2.8*	*2.1*	*1.3*	*0.4*	—	—	—	—
95	42	39	37	34	32	30	28	26	23	22	20	17	14	10	6	2	—	—	—
	7.5	*7.1*	*6.8*	*6.4*	*6.1*	*5.7*	*5.3*	*5.1*	*4.8*	*4.4*	*4.0*	*3.6*	*3.0*	*2.3*	*1.5*	*0.6*	—	—	—

Table 1-6—Relative humidity and equilibrium moisture content at various dry-bulb temperatures and wet-bulb depressions below 212°F—continued

Dry-bulb temper-ature (°F)	Relative humidity[1] and equilibrium moisture content[2] (%) at various wet-bulb depression temperature (°F)																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46
	—	21.3	19.0	17.5	16.1	15.0	13.9	13.1	12.4	11.8	11.2	10.6	10.1	9.6	9.2	8.9	8.5	8.1
105	96	93	90	87	83	80	77	74	71	69	66	63	60	58	55	53	50	48
	—	21.4	19.0	17.5	16.2	15.1	14.0	13.3	12.6	11.9	11.3	10.8	10.3	9.8	9.4	9.0	8.7	8.3
110	97	93	90	87	84	81	78	75	73	70	67	65	62	60	57	55	52	50
	—	21.4	19.0	17.5	16.2	15.1	14.1	13.3	12.6	12.0	11.4	10.8	10.4	9.9	9.5	9.2	8.8	8.4
115	97	93	90	88	85	82	79	76	74	71	68	66	63	61	58	56	54	52
	—	21.4	19.0	17.5	16.2	15.1	14.1	13.4	12.7	12.1	11.5	10.9	10.4	10.0	9.6	9.3	8.9	8.6
120	97	94	91	88	85	82	80	77	74	72	69	67	65	62	60	58	55	53
	—	21.3	19.0	17.4	16.2	15.1	14.1	13.4	12.7	12.1	11.5	11.0	10.5	10.0	9.7	9.4	9.0	8.7
125	97	94	91	88	86	83	80	77	75	73	70	68	65	63	61	59	57	55
	—	21.2	18.9	17.3	16.1	15.0	14.0	13.4	12.7	12.1	11.5	11.0	10.5	10.0	9.7	9.4	9.0	8.7
130	97	94	91	89	86	83	81	78	76	73	71	69	67	64	62	60	58	56
	—	21.0	18.8	17.2	16.0	14.9	14.0	13.4	12.7	12.1	11.5	11.0	10.5	10.0	9.7	9.4	9.0	8.7
140	97	95	92	89	87	84	82	79	77	75	73	70	68	66	64	62	60	58
	—	20.7	18.6	16.9	15.8	14.8	13.8	13.2	12.5	11.9	11.4	10.9	10.4	10.0	9.6	9.4	9.0	8.7
150	98	95	92	90	87	85	82	80	78	76	74	72	70	68	66	64	62	60
	—	20.2	18.4	16.6	15.4	14.8	13.7	13.0	12.4	11.8	10.2	10.8	10.3	9.9	9.5	9.2	8.9	8.6
160	98	95	93	90	88	86	83	81	79	77	75	73	71	69	67	65	64	62
	—	19.8	18.1	16.2	15.2	14.2	13.4	12.7	12.1	11.5	11.0	10.6	10.1	9.7	9.4	9.1	8.8	8.5
170	98	95	93	91	89	86	84	82	80	78	76	74	72	70	69	67	65	63
	—	19.4	17.7	15.8	14.8	13.9	13.2	12.4	11.8	11.3	10.8	10.4	9.9	9.6	9.2	9.0	8.6	8.4
180	98	96	94	91	89	87	85	83	81	79	77	75	73	72	70	68	67	65
	—	18.9	17.3	15.5	14.5	13.7	12.9	12.2	11.6	11.1	10.6	10.1	9.7	9.4	9.0	8.8	8.4	8.1
190	98	96	94	92	90	88	85	84	82	80	78	76	75	73	71	69	68	66
	—	18.5	16.9	15.2	14.2	13.4	12.7	12.0	11.4	10.9	10.5	10.0	9.6	9.2	8.9	8.6	8.2	7.9
200	98	96	94	92	90	88	86	84	82	80	79	77	75	74	72	70	69	67
	—	18.1	16.4	14.9	14.0	13.2	12.4	11.8	11.2	10.8	10.3	9.8	9.4	9.1	8.8	8.4	8.1	7.7
210	98	96	94	92	90	88	86	85	83	81	79	78	76	75	73	71	70	68
	—	17.7	16.0	14.6	13.8	13.0	12.2	11.7	11.1	10.6	10.0	9.7	9.2	9.0	8.7	8.3	8.0	7.6

Table 1-6—Relative humidity and equilibrium moisture content at various dry-bulb temperatures and wet-bulb depressions below 212°F—concluded

Dry-bulb temper-ature (°F)	Relative humidity[1] and equilibrium moisture content [2] (%) at various wet-bulb depression temperatures (°F)																		
	19	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	45	50
100	44	41	39	37	35	33	30	28	26	24	22	21	17	13	10	7	4	—	—
	7.8	*7.4*	*7.0*	*6.7*	*6.4*	*6.1*	*5.7*	*5.4*	*5.2*	*4.9*	*4.6*	*4.2*	*3.6*	*3.1*	*2.4*	*1.6*	*0.7*	—	—
105	46	44	42	40	37	35	34	31	29	28	26	24	20	17	14	11	8	—	—
	7.9	*7.6*	*7.3*	*6.9*	*6.7*	*6.4*	*6.1*	*5.7*	*5.4*	*5.2*	*4.8*	*4.6*	*4.2*	*3.6*	*3.1*	*2.4*	*1.8*	—	—
110	48	46	44	42	40	38	36	34	32	30	28	26	23	20	17	14	11	4	—
	8.1	*7.7*	*7.5*	*7.2*	*6.8*	*6.6*	*6.3*	*6.0*	*5.7*	*5.4*	*5.2*	*4.8*	*4.5*	*4.0*	*3.5*	*3.0*	*2.5*	*1.1*	—
115	50	48	45	43	41	40	38	36	34	32	31	29	26	23	20	17	14	8	2
	8.2	*7.8*	*7.6*	*7.3*	*7.0*	*6.7*	*6.5*	*6.2*	*5.9*	*5.6*	*5.4*	*5.2*	*4.7*	*4.3*	*3.9*	*3.4*	*2.9*	*1.7*	*0.4*
120	51	49	47	45	43	41	40	38	36	34	33	31	28	25	22	19	17	10	5
	8.3	*7.9*	*7.7*	*7.4*	*7.2*	*6.8*	*6.6*	*6.3*	*6.1*	*5.8*	*5.6*	*5.4*	*5.0*	*4.6*	*4.2*	*3.7*	*3.3*	*2.3*	*1.1*
125	53	51	48	47	45	43	41	39	38	36	35	33	30	27	24	22	19	13	8
	8.3	*8.0*	*7.7*	*7.5*	*7.2*	*7.0*	*6.7*	*6.5*	*6.2*	*6.0*	*5.8*	*5.5*	*5.2*	*4.8*	*4.4*	*4.0*	*3.6*	*2.7*	*1.6*
130	54	52	50	48	47	45	43	41	40	38	37	35	32	29	26	24	21	15	10
	8.3	*8.0*	*7.8*	*7.6*	*7.3*	*7.0*	*6.8*	*6.6*	*6.4*	*6.1*	*5.9*	*5.6*	*5.3*	*4.9*	*4.6*	*4.2*	*3.8*	*3.0*	*2.0*
140	56	54	53	51	49	47	46	44	43	41	40	38	35	32	30	27	25	19	14
	8.4	*8.0*	*7.8*	*7.6*	*7.3*	*7.1*	*6.9*	*6.6*	*6.4*	*6.2*	*6.0*	*5.8*	*5.4*	*5.1*	*4.8*	*4.4*	*4.1*	*3.4*	*2.6*
150	58	57	55	53	51	49	48	46	45	43	42	41	38	36	33	30	28	23	8
	8.3	*8.0*	*7.8*	*7.5*	*7.3*	*7.1*	*6.9*	*6.7*	*6.4*	*6.2*	*6.0*	*5.8*	*5.4*	*5.2*	*4.9*	*4.5*	*4.2*	*3.6*	*2.9*
160	60	58	57	55	53	52	50	49	47	46	44	43	41	38	35	33	31	25	21
	8.2	*7.9*	*7.7*	*7.4*	*7.2*	*7.0*	*6.8*	*6.7*	*6.4*	*6.2*	*6.0*	*5.8*	*5.5*	*5.2*	*4.9*	*4.6*	*4.3*	*3.7*	*3.2*
170	62	60	59	57	55	53	52	51	49	48	47	45	43	40	38	35	33	28	24
	8.0	*7.8*	*7.6*	*7.3*	*7.2*	*6.9*	*6.7*	*6.6*	*6.4*	*6.2*	*6.0*	*5.7*	*5.5*	*5.2*	*4.9*	*4.6*	*4.4*	*3.7*	*3.2*
180	63	62	60	58	57	55	54	52	51	50	48	47	45	42	40	38	35	30	26
	7.8	*7.6*	*7.4*	*7.2*	*7.0*	*6.8*	*6.5*	*6.4*	*6.2*	*6.0*	*5.8*	*5.7*	*5.4*	*5.2*	*4.8*	*4.6*	*4.4*	*3.8*	*3.3*
190	65	63	62	60	58	57	56	54	53	51	50	49	46	44	42	39	37	32	28
	7.7	*7.4*	*7.2*	*7.0*	*6.8*	*6.6*	*6.4*	*6.2*	*6.0*	*5.9*	*5.7*	*5.5*	*5.3*	*5.0*	*4.8*	*4.5*	*4.4*	*3.8*	*3.3*
200	66	64	63	61	60	58	57	55	54	53	52	51	48	46	43	51	39	34	30
	7.5	*7.2*	*7.0*	*6.9*	*6.6*	*6.4*	*6.2*	*6.0*	*5.9*	*5.7*	*5.6*	*5.4*	*5.2*	*4.9*	*4.7*	*4.5*	*4.3*	*3.8*	*3.3*
210	67	65	64	63	61	60	59	57	56	54	53	52	50	47	45	43	41	36	32
	7.4	*7.1*	*6.9*	*6.8*	*6.5*	*6.3*	*6.1*	*5.9*	*5.8*	*5.5*	*5.4*	*5.3*	*5.1*	*4.8*	*4.6*	*4.4*	*4.2*	*3.7*	*3.8*

[1]Relative humidity values not italic.
[2]Equilibrium moisture content values italic.

APPENDIX C: Determining the Daily Moisture Content of Your Sample Boards

Let's pretend that your lumber has been in the kiln for a while, and the weight of this same sample board is now 3200 grams instead of 3810 grams. How can you determine the current moisture content?

From Equation [1] above:

$$\text{Moisture Content} = \frac{(\text{Original Wood Weight - Ovendry Wood Weight})}{\text{Ovendry Wood Weight}} \times 100\% \qquad [1]$$

Substituting into Equation 1 yields the current moisture content of that sample board:

$$\text{Moisture Content} = \frac{(3200 \text{ grams} - 2445 \text{ grams})}{2445 \text{ grams}} \times 100\% = 30.9\%$$

Redo these calculations daily to track the moisture content of each of your sample boards.

When you added the B.O.S.S. to the ends of your sample boards you added a small amount of weight, but you don't have to worry about having affected the moisture content determination. Since sample boards are a lot heavier than the moisture wafers, you have to weight them on larger balances. Usually my mid-range balance has sufficient capacity, even for 4/4 green hickory sample boards, but thicker boards will require a larger capacity balance. My two larger balances read to the nearest 1 gram or 5 grams, depending on the size of the balance; to get the best accuracy I weigh sample boards that are less than 5000 grams on my mid-size balance and heavier sample boards on my largest balance. Compared to the larger weight of the sample board, the small weight addition won't noticeably affect your moisture content calculations.

Issued 8-2018