CHAPTER 4 – Moisture Content and its Measurement

Moisture content (MC) is a measure of the amount of water found within a material at any given time. As discussed in Chapter 2, wood has an affinity for moisture and as a result the moisture content is influenced by the humidity of the air to which the wood is exposed as the wood takes up or loses bound water. MC is expressed as the percentage of the mass of the material that is contributed by the mass of contained water. For most materials the mass of the material is defined as the mass of the material substance plus the mass of the water, e.g. the "wet mass". However for wood, the MC is typically defined on the basis of the oven-dry (bone dry) mass of wood, which means the mass with all the moisture removed. The oven dry condition is defined by the American Society of Testing Materials (ASTM – Standard D2016) as the condition when wood reaches a constant mass in equilibrium with a constant oven temperature of 214 degrees Fahrenheit (101 C).

Moisture content on the oven-dry basis is the most commonly used definition of moisture content for wood. However, there is an exception to this rule in the wood energy field when wood is used as a combustion fuel. In this case the MC is defined on the basis of the wet mass. The procedure for the oven-dry and the wet basis are described below.

- Oven Dry Basis
  - Weigh the specimen in the initial condition, record the initial mass (M_i)
  - Oven dry the specimen at 214 ^{o}F until it stops losing weight, weight the specimen and record the oven dry mass (M_{od})
  - Calculate the MC as:

$$MC(\%) = \left(\frac{Mi - Mod}{Mod}\right) * 100$$

- Wet Basis
  - Weigh the specimen in the initial condition, record the initial mass (M_i)
  - Oven dry the specimen at 214 ^{o}F until it stops losing weight, weight the specimen and record the oven dry mass (M_{od})
  - Calculate the MC as:

$$MC(\%) = \left(\frac{Mi - Mod}{Mi}\right) * 100$$

Determining the oven-dry moisture content of even small specimens often requires drying the specimen in a calibrated oven for at least eight hours. An alternative procedure using a microwave oven can reduce the time to less than ½ hour. However, this method is tricky and the specimens can be over dried resulting in thermal degradation and even combustion, both which effect the mass. If care is taken and the recommended procedure described below is carefully followed reasonable results can be obtained.

- Keep samples less than 1-inch in length (in the direction of the grain)
- Use a microwave oven with a carousel tray so the specimens will be rotated through the energy field, resulting in more uniform drying
- Use a medium-low power setting on the microwave (about 20 - 40% power)
- Dry for about 10 minutes, remove the specimen and weigh it
- Continue to dry the specimen at the same power setting for 1 minute, remove and weigh
- If the specimen has reached constant mass it is oven dry, if it is still losing weight then continue drying in 2 minute increments until constant mass is achieved.

Moisture Meters

Moisture content can also be measured with electronic moisture meters. The amount of water in wood has a measurable effect on the electrical properties of wood, or how electrical currents flow through wood. For example, because water is a very good conductor of electricity the resistance of wet wood is lower than the resistance of drier wood. Moisture meters are instruments developed to take advantage of this relationship. A moisture meter is helpful to determine the moisture content of wood quickly (without oven drying) and it can also be used to monitor the moisture content of lumber as it dries, once the MC falls below the fiber saturation point (FSP). This is the stage of wood drying where the cell walls are saturated and the cells cavities are free from water. For most wood, the FSP is approximately 25-30% M.C., based on oven dry weight. Moisture meters cannot precisely or accurately measure MC above 25% or below 5%.

Two types of meters have been developed that are based on the good correlation between the electrical properties of wood and its moisture content below the FSP (Table 4-1). A resistance (or conductance) meter measures the electrical conductance between two contact electrodes (pins) that are imbedded into the wood. A dielectric (or capacitance) meter measures the dielectric constant of the wood in an electromagnetic field produced by a surface electrode. The dielectric constant is essentially a measure of the potential energy/unit volume stored in the material in the form of electric polarization when the material is in a given electric field (U. S. Forest Products Laboratory, 1974).

Table 4-1. Comparison of the attributes of resistance and dielectric moisture meters

Meter Characteristic	Resistance Meters	Dielectric Meters
Damage to wood	Yes, pin penetration makes holes	No, does not use pin penetration
Sensitive to wood temperature	Yes	No
Sensitive to species differences	Yes, moderately	Yes, very sensitive
Sensitive to density variation within species	No	Yes, very sensitive
Influenced by high surface moisture	Insulated pins – No Un-insulated – Yes	Yes
Influenced by low surface moisture	No	Yes
Influenced by surface roughness	No	Yes
Influenced by adjacent materials	No	Yes

When using either of these meter types it is necessary to apply correction factors. This is because electrical properties of wood are also influenced by variables other than the amount of water in the wood (such as temperature and wood density). All wood moisture meters are calibrated for Douglas-fir at 70^{o} F. Many meters will have built in settings for making these corrections. If the meter does not have the built in correction settings than manual adjustments must be made. Tables 4-2, 4-3, and 4-4 summarize, for a few select speices, the corrections needed for both types of meters. It is important to read the manufacturer's instructions on how to use the meter correctly. When used correctly, both types of meters provide an accuracy of plus or minus 1.5% points.

Table 4-2. Species corrections for resistant moisture meters*

Species	Meter Reading (% MC)												
	6	8	10	12	14	16	18	20	22	24	26	28	30
US Commercial													
Ash, White	-0.4	-0.4	-0.9	-1.2	-1.1	-1.5	-1.8	-2.1	-2.5	-2.9	-2.9	-2.9	-2.9
Cedar, Incense	0.2	0.3	0.5	0.6	0.7	0.8	0.8	1	1.2	1.3	1.3	1.3	1.3
Cherry	1	1	1.2	1.4	1.6	1.7	1.8	1.9	2	2.1	2.1	2.1	2.1
Fir, Douglas	0	0	0	0	0	0	0	0	0	0	0	0	0
Fir, White	0.9	0.9	0.6	..5	0.7	1	1	1	1	1.2	1.2	1.2	1.2
Hemlock	0.1	0.2	0.4	0.7	0.8	0.8	0.7	0.4	-0.2	-0.4	-0.4	-0.4	-0.4
Hickory	1.1	0.7	-0.3	-0.8	-1.4	-2	-2.4	-2.8	-3.2	-3.4	-3.4	-3.4	-3.4
Mahogany, Afr.	0.7	1.4	2	2.8	3.2	3.6	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Mahogany, Hond.	0.3	0.3	0.4	0.6	0.5	0.2	0	0.5	-1	-1.5	-1.5	-1.5	-1.5
Mahogany, Phil.	-1.2	-1.2	-1.9	-2.4	-2.8	-3.3	-3.7	-4.5	-5.2	-5.8	-5.8	-5.8	-5.8
Maple, Sugar	0.7	0.7	0.1	-0.2	-0.1	-0.2	0	0.2	0.5	1	1	1	1
Oak, Red	-0.4	0	0	0	0	0	0	0	-0.2	0	0	0	0
Oak, White	-0.1	-0.2	-0.4	-0.5	-0.5	-0.8	-1.1	-1.5	-1.8	-2	-2	-2	-2
Pine, Longleaf	0.2	0.6	0.8	1.2	1.5	1.6	1.5	1.3	1.1	1	1	1	1
Pine, Ponderosa	0.4	0.6	1	1.4	1.6	1.6	1.4	1.2	1.2	1.6	1.6	1.6	1.6
Pine, Sugar	0	0	0	0.2	0.8	0.8	0.9	1	0.9	0.8	0.8	0.8	0.8
Pine, White	0	0.2	0.3	0.7	1.1	1.2	1.3	1.1	1	1.5	1.5	1.5	1.5
Poplar, Yellow	0.1	0.6	0.7	1.2	1.6	1.6	1.6	1.7	2	1.7	1.7	1.7	1.7
Redwood	0	0	0	-0.2	-0.5	-0.8	-1	-1	-0.2	0	0	0	0
Spruce, Sitka	0	0.2	0.3	0.5	0.6	0.8	0.9	1	1.4	1.7	1.7	1.7	1.7
Walnut, Black	0.5	0.6	0.4	0.4	0.5	0.3	0.2	0	-0.2	-0.4	-0.4	-0.4	-0.4
Western US													
CA Black Oak	-0.1	-0.2	-0.4	-0.5	-0.7	-0.8	-1	-1.2	-1.3	-1.5	-1.6	-2	-2
OR White Oak	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.4	-1.4	-1	-1.4
Tanoak	-0.9	-1.2	-1.6	-1.9	-2.3	-2.6	-2.9	-3.3	-3.6	-4	-4.3	-5	-5
Pacific Madrone	-0.1	-0.3	-0.5	-0.8	-1	-1.2	-1.5	-1.7	-1.9	-2.2	-2.4	-3	-2.9
Chinkapin	1	1	1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2
Red Alder	0.9	1	1.1	1.1	1.2	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.8
Hawaii													
Koa	0.1	0.3	1	1.1	1.1	1.5	1.9	2.6	3.1	3.5	4.1	4.8	5.2
E. robusta	-0.4	-1	-1.3	-1.8	-1.8	-2.7	-3	-4	-4.3	-5	-5	-6	-7.5
E. saligna	-0.3	-0.2	-0.7	-0.6	-0.5	-1	-1.5	-2.1	-2.9	-3.1	-3.9	-4.8	-5.9
silk-oak	-1.8	-2	-2.5	-3.4	-3.8	-4.8	-5.6	-7.1	-8.3	-9	-10	-11	-12

* add or subtract the species appropriate, tabulated value from the meter reading; e.g. if measuring incense cedar and the meter reading is 20%, add 1% point to get the corrected MC of 21%

Table 4-3. Temperature corrections for resistant moisture meters*

Wood Temp (F)	Meter Readings (% MC)												
	6	8	10	12	14	16	18	20	22	24	26	28	30
0	3	4.5	5	5.8	6.5	7.8	9.3	11	11.8	12.8	13.8	14.8	15
20	2	3.5	4	4.3	4.8	5.8	7.3	8.0	8.3	8.8	9.3	9.8	10
40	1	1.5	2	2.3	2.8	3.3	2.8	4.0	4.3	4.8	5.3	5.8	6
60	0	0.5	1	1.0	1.0	1.0	1.0	1.0	1.3	1.8	2.0	2.0	2
80	0	-0.5	-1	-1.0	-1.0	-1.0	-1.0	-1	-1.3	-1.8	-2.0	-2.0	-2
100	-1	-1.5	-2	-2.3	-2.8	-3.0	-3.0	-3	-3.3	-3.8	-4.3	-4.8	-5
120	-1	-2.5	-3	-3.3	-3.8	-4.3	-4.8	-5	-5.3	-5.8	-6.3	-7.3	-8
140	-2	-2.5	-3	-4.0	-4.5	-5.3	-5.8	-6	-6.8	-7.5	-8.8	-9.5	-10
160	-2	-3.5	-4	-4.8	-5.5	-6.8	-7.5	-8	-8.8	-9.5	-11	-11	-12
180	-3	-3.8	-5	-5.8	-6.5	-7.8	-8.5	-9	-10	-11	-13	-13	-14
200	-3	-3.8	-5	-6.5	-7.5	-8.8	-9.5	-10	-11	-12	-14	-15	-16
220	-4	-5.3	-6	-7.3	-8.0	-9.8	-10	-11	-12	-13	-15	-16	-16

* If the wood temperature is less than 70°F, then add to the meter reading the tabulated value for the actual wood temperature. If the wood temperature is greater than 70°F, then subtract the appropriate value. For example, if the meter reading (already corrected for species) is 16% MC and the wood temperature is 160 °F, then subtract 6.7 to get the corrected MC of 9.3%

Table 4-4. Species corrections for dielectric moisture meters*

Species	Meter Reading (% MC)												
	6	8	10	12	14	16	18	20	22	24	26	28	30
US Commercial													
Ash, White	-1.5	-1.5	-2.0	-2.0	-2.5	-2.5	-2.0	-3.0	-3..5	-3..5	-4.0	-4.0	-4.5
Cedar, Incense	+3.0	+3.0	+3.0	+3.0	+3.5	+3.5	+3.5	+3.5	+3.5	+3.5	+3.5	+3.5	+3.5
Cherry	+0.5	+0.5	+0.5	0	0	0	0	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0
Douglas-fir	0	0	0	0	0	0	0	0	0	0	0	0	0
Fir, White	+2.5	+2.5	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0
Hickory	-3.5	-4.0	-4.5	-5.0	-5.5	-5.5	-6.0	-6.5	-7.0	-7.5	-7.5	-8.0	-8.5
Mahogany,Afr.	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0
Mahogany,Phil.	+3.5	+4.0	+4.0	+4.0	+4.0	+4.0	+4.0	+4.0	+4.5	+4.5	+4.5	+4.5	+4.5
Maple, Sugar	-2.0	-2.5	-2.5	-3.0	-3.0	-3.5	-3.5	-4.0	-4.0	-4.5	-5.0	-5.0	-5.5
Oak, Red	-2.0	-2.5	-2.5	-3.0	-3.0	-3.5	-3.5	-4.0	-4.0	-4.5	-5.0	-5.0	-5.5
Oak, White	-2.5	-3.0	-3.0	-3.5	-4.0	-4.0	-4.5	-5.0	-5.0	-5.5	-6.0	-6.0	-6.5
Pine, Longleaf	-1.0	-1.5	-1.5	-2.0	-2.0	-2.5	-2.5	-3.0	-3.0	-3.5	-3.5	-4.0	-4.0
Pine, Ponderosa	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5
Pine, White	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.0	+3.5
Poplar, Yellow	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0	+2.0
Redwood	+3.5	+3.5	+3.5	+3.5	+4.0	+4.0	+4.0	+4.0	+4.0	+4.0	+4.0	+4.0	+4.5
Spruce, Sitka	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5
Walnut, Black	-0.5	-0.5	-1.0	-1.0	-1.0	-1.5	-1.5	-1.5	-2.0	-2.0	-2.0	-2.5	-2.5
Western US													
CA Black Oak	-3.0	-3.0	-2.0	-2.0	-1.5	-1.0	-1.0	-0.5	0	+0.5	+0.5	+1.0	+1.5
OR White Oak	-5.0	-5.0	-5.0	-4.0	-4.0	-4.0	-3.5	-3.5	-3.0	-3.0	-2.5	-2.0	-2.0
Tanoak	-1.0	-1.0	-1.5	-1.5	-2.0	-2.0	-2.5	-2.5	-3.0	-3.0	-3.0	-3.5	-3.5
Pacific Madrone	-1.0	-1.0	-1.5	-1.5	-2.0	-2.0	-2.5	-2.5	-3.0	-3.0	-3.0	-3.5	-3.5
Chinkapin	+2.5	+2.0	+2.0	+1.5	+1.0	+1.0	+0.5	+0.5	0	0	-0.5	-1.0	-1.0
Red Alder	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.5	+2.0	+2.0	+2.0	+2.0

* add or subtract the species appropriate, tabulated value from the meter reading; e.g. if measuring incense cedar and the meter reading is 20%, add 3.5% point to get the corrected MC of 23.5%

Moisture Meter Procedures

The following general procedures are recommended when any moisture meter is being used.

- Make measurements at least 2 ft. from the lumber ends and 2 in. from knots and lumber sides. These zones respond faster to humidity changes and often bias the measurements.
- At least three measurements per board are required to get a reliable average measurement for the board.
- Apply correction factors provided by the meter manufacturer.

In addition, the following the meter-specific procedures listed below are considered best practices.

- Resistance Meter
    - Change the meter settings (if possible) to reflect the species being measured and temperature of the wood
    - Use insulated pins if surface moisture is present. The wettest area between the electrodes, in this case the surface, has the lowest electrical resistance and will be the area measured if the pins are not insulated.
    - Drive the pins into the wood so that an imaginary line between the pins is parallel to the direction of the grain
    - Driving the pins to a depth of 1/4 of the thickness of the piece of wood being measured. This will yield the best overall average for the piece.
    - Make corrections to the measured reading if using a meter that does not have built in temperature and species corrections. First make the species correction, than make the temperature correction.
- Dielectric Meter
    - Change the meter settings (if possible) to reflect the species being measured
    - Clear the area beneath the wood being measured. The electromagnetic energy zone being measured extends about 2-1/2 inches from the electrode plate of the meter and contact with other materials will influence the measurement