Hand Held Moisture Meters

Charles Peterson

2008 WOODFLOORINGEDU.ORG

TABLE OF CONTENTS

MOISTURE AND WOOD

Moisture is responsible for over ninety percent of wood flooring problems. The correct use of hand held moisture measuring equipment is the best insurance to safe guard the successful long term installation of wood flooring.
The relationship between wood and moisture is the most important aspect of wood science relating to wood flooring. The moisture content of wood affects its dimensions, strength, adhesive bonding and fugal development.

TYPES OF METERS:

Hand held moisture meters are a convenient method to measure the moisture content of wood flooring, concrete and the air. Hand held moisture meters that are used for wood flooring measure the electrical properties of wood. The two main types of hand held moisture meters are resistance type and the dielectric type. Resistance type meters use penetrating electrodes that measure the resistance between the two pins. Dielectric-type moisture meters use surface electrodes to generate a radio frequency field into the wood. The meter measures the resulting difference in electrical field conditions.

ACCURACY:

Studies around the world indicate resistance meters provide approximately twice the accuracy of dielectric meters at this time. This is mainly due to the effects of varying density through out the wood flooring. Dielectric meter technology is advancing at a rapid rate but at this time dielectric meter readings are considered qualitative and not quantitative.

Resistance type moisture meter are generally accurate between ±1.5% to ±3.0%.

Dielectric moisture meter readings (corrected) are generally accurate between ±3.0% to ±6.0%.
(FWPRDC Project No. PN01.1306)

RESISTANCE MOISTURE METER:

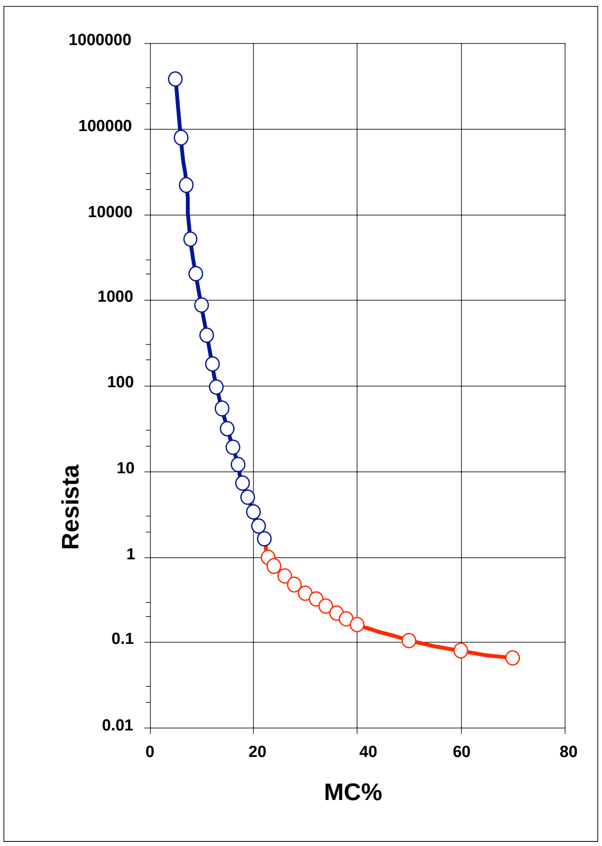
A resistance type moisture meter forces a current through the wood sample between the probes. It measures the voltage that develops and calculates the resistance. The results are displayed as moisture content instead of ohms.

Wood is a poor conductor of electricity. Water that is present in the wood flooring is considered a good conductor. As the moisture content of the wood sample increases, the resistance decreases.

RESISTANCE MOISTURE METER RANGE:

Wood flooring begins to shrink at the fiber saturation point because the cell lumens no longer contain free water and any further water removal comes from within the cell walls, thus causing a decrease in cell volume. The Fiber Saturation Point is generally between 25% to 30% MC. The electrical conductivity decreases after the free water no longer exists in the cell lumen. An abrupt increase in electrical resistance occurs at the fiber saturation point. Douglas fir has a resistance of 22,400 mega ohms at 7% moisture content and .46 megohms at 25% moisture content. One megohm is equal to one million ohms.

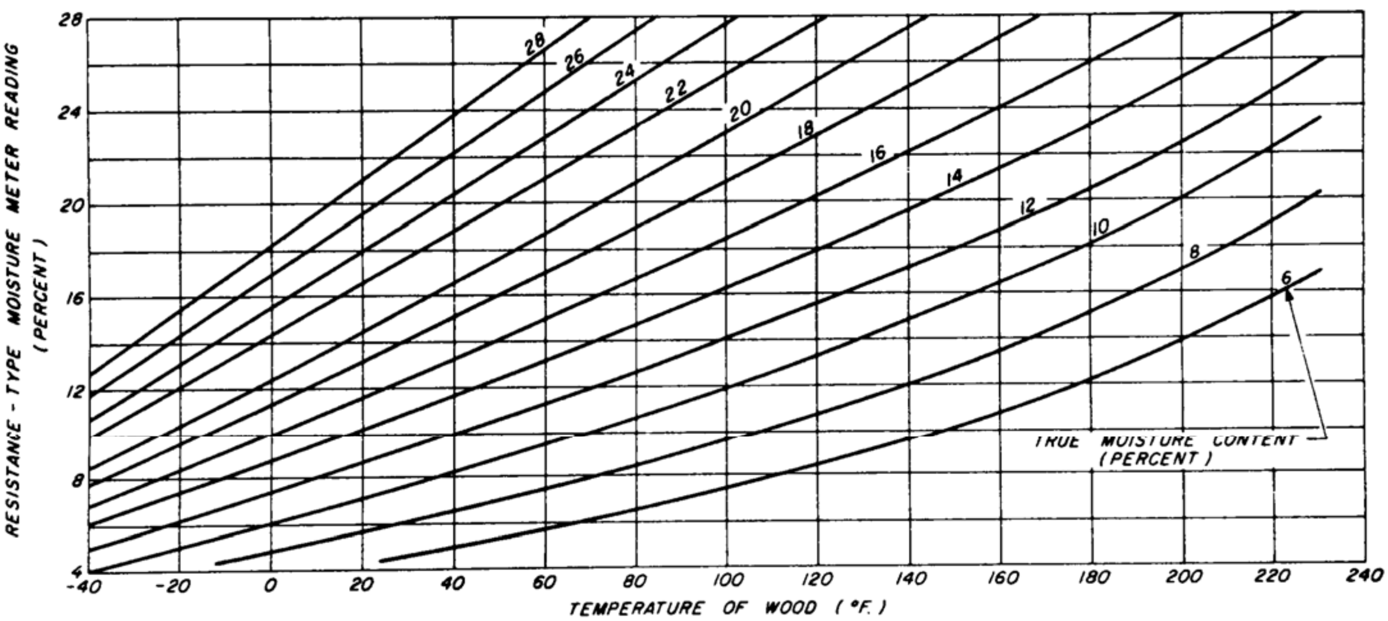
The resistance type moisture range is limited by the extremely low conductance of wood at low moisture content. The upper limit corresponds to the fiber saturation point of the wood. The conductance does not correlate well at higher moisture content scales. The range of moisture content that can be measured with reliability by resistance type meters is from 7% to about 27%.



Graph of standard resistance data (Edwards, 1974) against MC% for Douglas-Fir.

EFFECTS OF TEMPERATURE:

The temperature of the wood (not air temperature) significantly influences the readings on a resistance type meter.



Temperature corrections for use with resistance type moisture meters (James, 1988)

TEMPERATURE CORRECTION TABLE

			METER READINGS										
°C	°F		6	7	10	15	20	25	30	35	40	50	60
-20	0		9	11	15	22	*31*	*38*	*45*	*53*			
-10	20		8	10	14	20	28	*34*	*40*	*47*	*55*		
5	40		7	8	12	18	24	30	*36*	*42*	*48*		
15	60		6	7	11	16	21	27	*32*	*38*	*43*	*54*	
30	80		6	7	9	14	19	23	28	*33*	*38*	*47*	*55*
40	100		5	6	8	12	17	21	25	29	34	42	50
50	120		5	5	7	11	15	19	22	26	30	*38*	*44*
60	140		4	5	7	10	14	17	20	23	27	34	*40*
70	160		4	4	6	9	12	15	18	21	24	30	*36*
80	180		3	4	5	8	11	13	16	19	22	27	*33*
95	200		3	4	5	7	10	12	14	17	19	24	28
105	220		2	3	4	6	9	11	13	15	17	21	26

Moisture content values above the fiber saturation point are only qualitative. The temperature correction values shown in this chart have been rounded for easy reference.

The temperature corrections for reading of conductance-type moisture meters are based on the combined data from several investigators. Find the meter reading on vertical left margin, follow horizontally to vertical line corresponding to the temperature of the wood, and interpolate corrected reading from family of curves. Example: lf meter indicated 18 percent on wood at 120 °F, the corrected reading would be 14 percent. This chart is based on a calibration temperature of 70 °F. For other calibration temperatures near 70 °F, adequate corrections can be obtained simply by shifting the temperature scale so that the true calibration temperature coincides with 70 °F on the temperature scale.

Pin (electrode) Orientation to the Wood Grain

Currently most manufacturers recommend placing the pins parallel with the grain of the wood flooring. James (1988) notes that the effects of wood grain orientation is considered negligible for meter readings less than 15 % moisture content. Moisture contents above 20% may exhibit differences of up to 2% in moisture content.

Pin (electrode) Types

Insulated pins are covered by a tough insulating resin except at the tip. Insulated pin are useful in measuring moisture gradients. The average moisture content of a sample can be obtained by placing the pin one-fourth to one-fifth the thickness of the wood flooring.

Non-insulated pins will read the wettest layer of the wood flooring. This layer provides the path of least of resistance.

Density

Density itself has no significant effect on the resistance-type meter readings.

Extractives

Extractives such as water soluble electrolytes may affect resistance-type meter readings.

Calibration and Species corrections

Most resistance type meters use common building wood species such as Pine, Douglas-fir and Hemlock, for a calibration point. Corrections factors for other species involves conditioning a set of 75 sample boards to at least five ECM levels which are generally spaced between 7% and about 21%. Sap wood and heartwood should be put in separate groups. Meter readings are then taken once the boards are equalized. The boards are then oven-dried to determine the true moisture content and the results compared. Linear regression equations are used calculate species corrections.

Meter reading drift

Meter readings may start to drift lower after the pins are driven into the wood flooring with high moisture content.
Meter drift is less of a problem at lower moisture content levels. The best practice would be to take readings within the first 2-3 seconds of driving the pins into the wood flooring.

Wood preservatives, adhesives and coatings

Any chemicals or contaminates can affect the reliability of meter readings. Insulated pins can be utilized to help verify accuracy of readings. Penetrate the sample throughout its different layers. Compare readings of the wood sample with the surface coating, adhesives layer or ply's.

Static Electricity

In dry climates static charges may cause erratic meter readings. The effects of static charges can be minimized by having the pin inserted into the wood sample prior to applying power to the meter. Place your hand across the inserted pins to help discharge the static charges.

DIELECTRIC MOISTURE METERS

Dielectric meters are generally divided into two types. The first being the power-loss type which uses the relationship between moisture content and the dielectric loss factor of the wood. The second is the capacitance type, which uses the relationship between moisture content and the dielectric constant of the wood. Most pinless meters use the capacitance type method.

Power-loss type meters radiate an electric field into the wood sample. A low power oscillator radiates the field through the meters electrode. The power absorbed by the wood sample reduces the amplitude of the oscillation. The power loss factor is dependent on the moisture content of the wood sample. The meter converts the power loss to a moisture content reading.

Capacitance type moisture meters operate on the relationship between moisture content and dielectric constant of the wood cell. All capacitance type moisture meters are based on the same operating principle. They may differ in the frequency they employ or in their electrode design. The meter's oscillator provides a radio frequency wave (such as 125 KHZ) to the transmitter electrode. An alternating field is generated in the flooring sample and picked up by the receiver electrode. The meters circuits convert the signal to a moisture reading.

Capacitance type Moisture Meter Moisture Range

Capacitance type moisture meters are able to measure down to zero percent moisture content with diminished accuracy. Reading above thirty percent moisture content are also subject to diminished accuracy. About seven to thirty percent moisture content is considered the approximate useful range of capacitance type moisture meters.

Temperature

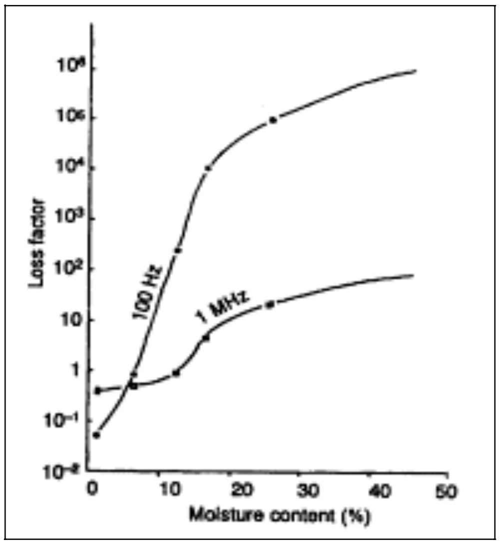
Temperature is not a factor throughout normal temperature ranges. The dielectric constant of wood becomes greater with an increase in temperature. Results are inaccurate at very high temperatures.

Grain orientation

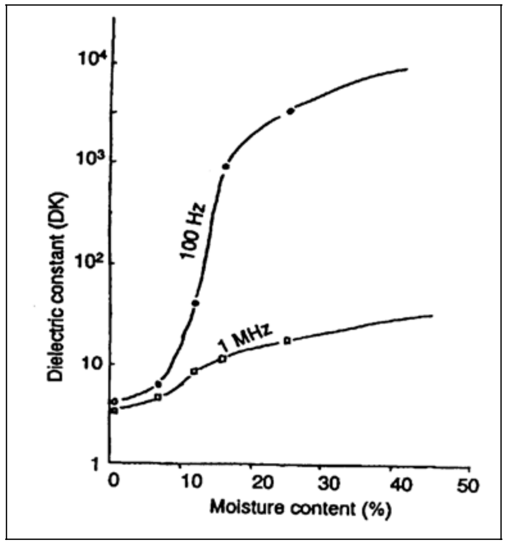
Grain orientation does not matter with capacitance meters that have circular electrodes. Capacitance meters the employ parallel electrodes are able measuring dual depths. Capacitance meters the employ parallel electrodes should have readings taken with the grain.

Calibration

Most dielectric type meters utilize Douglas-fir for a calibration point. Multiple linear regression equations are utilized used to calculate the species corrections.



Power Loss Type Meter



Capacitance Type Meter

Examples of (A) relationship between power-loss factor and MC% and (B) relationship between dielectric constant and MC%. (James, 1988).

The first graph depicts the differences in the Power Loss Factor to changes in moisture content using two different frequencies.

The second graph depicts difference in the dielectric constant to changes in moisture content using two different frequencies.

Thickness of Flooring

The signal penetration depth of should match that of the material being measure. Moisture readings are influenced by material near the surface of the flooring. Material below about 1/8" of the surface is taken into account to a lesser extent. Capacitance meters that employ parallel electrodes may be capable of measuring dual depths. For example three separate parallel electrodes may be utilized. The first and last electrode or the first and second electrode may be paired to obtain readings for different depths.

Density

The dielectric constant of wood increases nearly linearly with increasing density. There is a slight concave upward trend as the wood moisture content increases.

Hand pressure

Most meter manufacturers recommend applying a light hand pressure. Rough sawn boards may benefit from a slightly higher hand pressure (6lbs versus 3lbs). The firmer pressure may help compensate for any air gap between the sample and meter.

Initial Moisture Testing for Installing Wood Flooring over Wood Subflooring

It is essential moisture content readings are measured using a moisture meter capable of recording quantitative results. Also a hand held hygrometer should be used to check the moisture equilibrium of the installation materials and their environment. Although dielectric meter readings are considered only qualitative, they provide a quick and convenient method for a moisture content survey and help locate areas of concern. Hygrometer and dielectric readings also provide a way of corroborating the quantitative readings taken by a resistance type meter.

Moisture Survey

Using a hand held electronic hygrometer check the relative humidity and temperature of the room that the installation will take place. Readings should also be taken in areas that could have adverse effects at a later date (basements, crawlspaces). Electronic hygrometers take time to acclimatize, make sure that the temperature reading changes by no more that 0.2% over 5 minutes before you assume acclamation of the meter. The temperature should be within the normal limits of 60-80 degrees F. Relative Humidity will vary by region and season and it's recommended that installation should not take place if the relative humidity is out side the normal ranges.

The Equilibrium Moisture Content (ECM) of wood occurs when the moisture content of the wood is equal to the corresponding relative humidity reading and temperature for that moisture content. At the ECM point the wood is no longer gaining or losing moisture to the atmosphere. A calculator is available on www.woodflooringedu.org to convert the relative humidity and temperature readings into ECM readings. ECM readings should be calculated and compared to moisture meter readings on every project.

Temperature		Moisture content (%) at various relative humidity values																		
(°C	(°F))	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%
–1.1	(30)	1.4	2.6	3.7	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.4	13.5	14.9	16.5	18.5	21.0	24.3
4.4	(40)	1.4	2.6	3.7	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.3	13.5	14.9	16.5	18.5	21.0	24.3
10.0	(50)	1.4	2.6	3.6	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.3	11.2	12.3	13.4	14.8	16.4	18.4	20.9	24.3
15.6	(60)	1.3	2.5	3.6	4.6	5.4	6.2	7.0	7.8	8.6	9.4	10.2	11.1	12.1	13.3	14.6	16.2	18.2	20.7	24.1
21.1	(70)	1.3	2.5	3.5	4.5	5.4	6.2	6.9	7.7	8.5	9.2	10.1	11.0	12.0	13.1	14.4	16.0	17.9	20.5	23.9
26.7	(80)	1.3	2.4	3.5	4.4	5.3	6.1	6.8	7.6	8.3	9.1	9.9	10.8	11.7	12.9	14.2	15.7	17.7	20.2	23.6
32.2	(90)	1.2	2.3	3.4	4.3	5.1	5.9	6.7	7.4	8.1	8.9	9.7	10.5	11.5	12.6	13.9	15.4	17.3	19.8	23.3
37.8	(100)	1.2	2.3	3.3	4.2	5.0	5.8	6.5	7.2	7.9	8.7	9.5	10.3	11.2	12.3	13.6	15.1	17.0	19.5	22.9

Forrest Product Lab ECM chart

Building materials are continually absorbing and desorbing moisture in relation to the surrounding air moisture and temperature. Its important prior to installation that the sub floor and hardwood finish are in moisture equilibrium with the environment. Take multiple moisture content measurements on the subflooring material (at least 3 per 100sq feet, The NWFA recommends a minimum of 20 per 1000 square feet). Optional hammer probes are available from most manufactures and can be used to get deeper into the material and floor joists often harbor moisture especially in new construction. Record your results. Moisture content reading of joists, framing, trim and ECM readings will help validate subfloor moisture meter readings.

Use your pin moisture meter to measure your wood flooring material. Take multiple measurements and average the results. The NWFA recommends measuring the moisture content of 40 boards for every 1000 square feet (Do not just measure the ends of the boards that are on the top of the pile). The boards should be selected provide the most accuracy survey of the moisture content. When using a pin meter it is important that you push the pins in as close to their full length to ensure good, consistent contact with the wood fibers. Using an insulated pin allows you to penetrate to whatever depth is appropriate for that thickness of wood.

Use calibration charts supplied by you meter manufacture to adjust the readings for your sub floor and hardwood finish. Some meters have built in species correction factor that may be utilized.

The APA evaluated the equilibrium moisture content of structural panels. The results indicated that the moisture content of plywood and OSB at a given relative humidity is lower than the published values for solid wood. The APA data below is based on an absorption cycle at a temperature of approximately 70°F. (APA Form No. TT-028A December 2006)

Use the EMC chart below to calculate the appropriate moisture content of the sub floor and wood finish and then check against the actual reading you have recorded.

Relative Humidity	Moisture Content (%)		
	Solid Wood[1]	Plywood	OSB
10	2.5	1.2	0.8
20	4.5	2.8	1.0
30	6.2	4.6	2.0
40	7.7	5.8	3.6
50	9.2	7.0	5.2
60	11.0	8.4	6.3
70	13.1	11.1	8.9
80	16.0	15.3	13.1
90	20.5	19.4	17.2

[1]From Wood Handbook by U.S. Forest Products Laboratory

The NWFA recommends maximum difference between the sub floor moisture content and finished wood moisture content of 4% for strip flooring and 2% for plank flooring.

CONCRETE MOISTURE TESTING

Concrete must cure a minimum of thirty day prior to moisture testing.

Dielectric Moisture Meters:

Dielectric meter readings are considered qualitative and not quantitative. They are useful in determining areas higher moisture levels to aid in determining the placement of quantitative moisture testing equipment.

ASTM F 2170 – 02 RELATIVE HUMIDITY TESTING IN CONCRETE

(Available at ASTM.ORG)

Relative humidity testing provides quantitative determination of the percent equilibrium relative humidity in concrete. The test method requires the forming of a hole in the concrete to facilitate the insertion of a relative humidity probe. The results of the testing indicate the moisture condition of the concrete at that time and cannot predict conditions from external moisture influences. Relative humidity testing performed at proper depth of the concrete slab will indicate the potential concrete moisture equilibrium after floor coving is installed.

Advantages Over Calcium Chloride

Calcium Chloride testing is more sensitive to fluctuations in ambient air humidity and temperature above the slab than Relative humidity testing. Calcium Chloride testing measures vapor emission. The test method measures the evaporation rate at the surface of the concrete and not the amount of free water in the concrete. Evaporation rate will vary due to temperature and humidity conditions within the building.

Calcium Chloride testing requires cleaning a 20-inch-by-20-inch square at each test site to bare concrete.

Calcium Chloride testing requires twenty-four hour waiting period after cleaning before the test kit can be placed.

Calcium Chloride results must be measured with an exact time period and not more (60 to 72 hours).

Calcium Chloride testing only measures moisture vapor emissions from the very top ½” concretes surface.

Calcium Chloride testing will not indicate the potential concrete moisture equilibrium after floor coving is installed.

Humidity Probe must incorporate a temperature sensor. The external diameter of the probe must be less than approximately 0.75 in.

Hole Liners must be composed of plastic or non-corroding metal tubes. The inside diameter of the hole liner must not more than 0.04 of an inch greater than the probe's external diameter. The liner must have sufficient length to seal the hole to the desired depth. The liner must have seal around to concrete.

Hole Diameter must not be exceed 0.04 of an inch larger than the external diameter of the hole liner.

Hole Depth

A concrete slab drying from the top (vapor retarder in place on bottom) requires a hole depth of 40% of the slab thickness. A four inch thick slab would require a hole with a depth 1 ½".

A concrete slab drying from the top and bottom requires a hole depth of 20% of the slab thickness. A four inch thick slab would require a hole with a depth of ¾".

Hole Condition

The holes must be void of all drilled dust from the holes. The use of a HEPA filter vacuum and brush is recommended.

Environmental Conditions

The area to be tested and the concrete slab must be at normal ambient living conditions for at least forty-eight hours prior to testing (60-80 deg F).

Number of Tests Required

Three tests for the first 1000 square feet and at least one additional test for each additional 1000 square feet.

Test Locations

Locations must be selected to provide the accurate mapping of the moisture distribution across the entire concrete slab. Areas of potential high moisture are of vital concern. There must be test locations within three feet of all exterior walls for concrete slabs built on-grade and below.

Acclimation Time

Test holes must equilibrate for seventy-two hour prior to taking relative humidity measurements. Test liner must be sealed or have relative humidity probe installed during that period. The ASTM time requirement may be changed to twenty-four hours.

Humidity Probe Data Recording

The probe must reach temperature equilibrium before measuring relative humidity. The probe must be at the same temperature as the concrete before reading. The meter reading must not drift more than 1 % relative humidity over five minutes. Record the relative humidity to the nearest percent and the temperature to the nearest degree. Record the location and depth of the probe (depth to the nearest .04 of an inch). The relative humidity and air temperature above the concrete slab must also be recorded.

Probe Calibration

Probes should be calibrated at least one a year. Probes must be from a manufacturer with a NIST-traceable calibration. Certificate must state the range of calibration and the accuracy over that range. Probes must be calibrated at least 95 % relative humidity and lower relative humidity levels. Probes should be calibrated within thirty days of testing. The ASTM may be changed to: "Humidity probes should be purchased with a NIST traceable certificate which should be renewed annually. It is recommended that probes are checked against a know standard such as a set aside unused NIST calibrated probe on a month basis."

RELATIVE HUMIDITY "HOOD" METHOD ASTM F2420
(Available at ASTM.ORG)

Relative humidity hood testing provides quantitative determination of the percent relative humidity in above the surface of the concrete. The method measures the amount of free water in the concrete. Calcium chloride testing only measures how much vapor is being driven off the surface. An insulated hood is sealed on top of the surface of a concrete slab. An impermeable chamber is created above the surface of the floor slab. A humidity probe is inserted to measure the relative humidity (RH), temperature, and dew point within the air pocket. Readings from the hood method tends to be 5 percent lower than with the sleeve method.

Hood

Made from a thermal insulation type impermeable material insulation material (a maximum insulation-value of 1.0 W/ (m2·K). The hood's air chamber must have a minimum area of between thirty to forty square inches. The chamber must have a minimum depth of 0.25 of an inch.

Humidity Probe must incorporate a temperature sensor. The external diameter of the probe must be less than approximately 0.75 in.

Concrete Slab Condition

Test must be placed over clean bare concrete.

Environmental Conditions

The area to be tested and the concrete slab must be at normal ambient living conditions for at least forty-eight hours prior to testing.

Number of Tests Required

Three tests for the first 1000 square feet and at least one additional test for each additional 1000 square feet.

Test Locations

Locations must be selected to provide the accurate mapping of the moisture distribution across the entire concrete slab. Areas of potential high moisture are of vital concern. There must be test locations within three feet of all exterior walls for concrete slabs built on-grade and below.

Acclimation Time

Hood chamber must equilibrate for seventy-two hour prior to taking relative humidity measurements. Hood must be sealed to the concrete.

Humidity Probe Data Recording

The probe must reach temperature equilibrium before measuring relative humidity. The probe must be at the same temperature as the concrete before reading. The meter reading must not drift more than 1 % relative humidity over five minutes. Record the relative humidity to the nearest percent and the temperature to the nearest degree. Record the location and depth of the probe (depth to the nearest .04 of an inch). The slab temperature, relative humidity air temperature above the concrete slab and due point must also be recorded.

Probe Calibration

Probes should be calibrated at least one a year. Probes must be from a manufacturer with a NIST-traceable calibration. Certificate must state the range of calibration and the accuracy over that range. Probes must be calibrated at least 95 % relative humidity and lower relative humidity levels. Probes should be calibrated within thirty days of testing. The ASTM may be changed to: “Humidity probes should be purchased with a NIST traceable certificate which should be renewed annually. It is recommended that probes are checked against a know standard such as a set aside unused NIST calibrated probe on a month basis."

GLOSSARY

Capacitance is a measure of the amount of electric charge stored (or separated) for a given electric potential.

Dew point temperature is the temperature at which air becomes saturated when cooled with no further addition of moisture or change of pressure. Condensation can occur when moist air is cooled to its dew point and below.

Dielectric is a non-conducting substance

Equilibrium Moisture Content (ECM) of wood occurs when the moisture content of the wood is equal to the corresponding relative humidity reading and temperature for that moisture content. At the ECM point, the wood is no longer gaining or losing moisture to the atmosphere.

Electrical resistance is a measure of the degree to which an object opposes an electric current through it. Its reciprocal quantity is electrical conductance

In situ is a Latin phrase meaning in the place.

Ohm is the electric resistance between two points of a conductor when a constant potential difference of 1 volt, applied to these points, produces in the conductor a current of 1 ampere

Radio frequency (**RF**) is a frequency or rate of oscillation within the range of about 3 Hz to 300 GHz. This range corresponds to frequency of alternating current electrical signals used to produce and detect radio waves.

Relative humidity, n—ratio of the amount of water vapor actually in the air compared to the amount of water vapor required for saturation at that particular temperature and pressure, expressed as a percentage.

REFERENCES

Forest Products Laboratory, Madison, WI
FPL-GTR-6
FPL-GTR-113
FPL-GTR-76
FPL-GTR-85
FPL-RN-0260

Forest & Wood Products Research & Development Corporation
FWPRDC Project No. PN01.1306

Technical Research Center of Finland. Accuracy & Functionality of Hand Wood Moisture Meters

Australian Standard AS/NZS 1080.1. (1997) Timber-Methods of Test. Method 1: Moisture Content

American Society for Testing and Materials. 1968.
Methods of measuring moisture content of wood.
ASTM Standards
F 2170 – 02
F 2420 – 05
D 4442 - 92
D 4444-92
F 1869-04

Jamroz W. (1994) Accuracy of moisture content measurements. May 5, 1993 Madison,

NWFA Installation Guidelines. March 2007

Skaar C. (1988) Wood-water relations

The Engineered Wood Association APA TT-028A Moisture Related Dimensional Stability

New Temperature Correction Factors for the Portable Resistance-Type Moisture Meter
PORTABLE RESISTANCE-TYPE MOISTURE METER
Frank Pfaff and Peter Garrahan Forintek Canada Corporation

Canadian Wood Their Properties and Uses. Mullins and McKnight

Understanding Wood. Hoadley

Concrete Floors and Moisture. Howard Kanare