MOISTURE TESTING

The determination of moisture content is an essential part of quality control within the flooring installation process. Flooring installers must know the ambient conditions in the space, the moisture content of the wood flooring, and the moisture content of the substrate. Hand-held thermo-hygrometers and electronic moisture meters should be a critical part of every flooring contractor's toolbox. Moisture content (MC) from 5-30% may be determined using various moisture meters developed for this purpose.

PART I
Temperature/Relative Humidity

The moisture content in wood is directly affected by temperature and humidity.

A. In order to understand why temperature and humidity affect wood, it is important to understand the relationship between temperature and humidity.
   1. Temperature is simply a measurement that indicates how hot or cold something is. In the United States we use the Fahrenheit (°F) scale. The majority of the rest of the world uses the Celsius (°C) scale.
   2. Humidity is the amount of water vapor in the air. This air/water vapor mixture, when measured as the actual moisture in a given volume of air (or grains/ft3) is the absolute humidity ($H_{absolute}$). In regular usage, however, we use the term relative humidity (RH), which is the ratio of the amount of moisture the air is holding in comparison to the total amount of moisture the air can hold at the same temperature. No matter how the property of humidity is expressed, the values are very much temperature dependent.
   3. Heating the air will increase its ability to hold moisture; therefore, for the same physical amount of water, the relative humidity decreases (absolute humidity remains the same).
   4. Cooling the air will decrease its ability to hold moisture; therefore, for the same physical amount of water, the relative humidity increases (absolute humidity remains the same).
   5. Humidity is important because wood products exchange water molecules from the surrounding air based upon the amount of moisture in the air.

B. Test the temperature and relative humidity in the room(s) where the flooring is being installed.

C. **Hygrometers:** Instruments used for measuring the amount of water vapor in the air. There are a few types of these instruments, but in modern times, we employ digital thermo-hygrometers. These tools typically can read temperature, relative humidity, and oftentimes properties like absolute humidity and dew point as well. Many of today's thermo-hygrometers are wireless, have data logging, and even have remote capabilities.

D. **Data Loggers:** An electronic device that records and stores data over time or in relation to location, either with a built-in instrument or sensor or via external instruments and sensors. These instruments are oftentimes left on the jobsite in order to monitor the conditions in the space prior to, during, and after wood flooring installation.

E. The "EMC of Wood at Various Temperature and Relative Humidity Readings" table in the Acclimation/Conditioning chapter, provided by USDA Forest Products Lab, indicates a reasonable representation of the predicted Moisture Content (MC) of wood at any given combination of temperature and relative humidity. Use the values in this table to approximate the average MC of the wood based on the temperature and humidity readings in the facility. You also can use this chart to determine approximate change in moisture content based on a seasonal change in conditions within the facility.

PART II

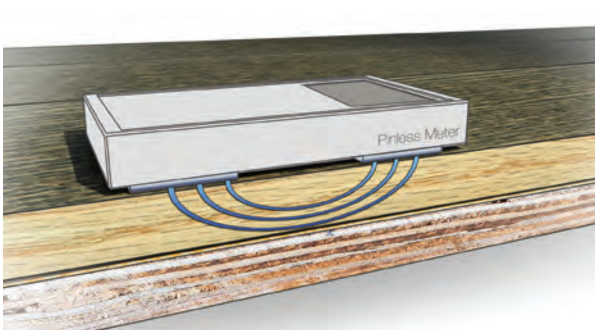
Moisture Testing Wood

A. **Oven Dry Method** (Laboratory Test)

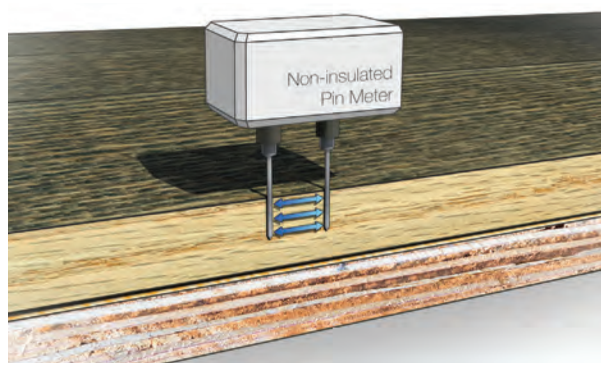
1. The moisture content (MC) of wood is measured as the weight of the water in the wood expressed as a percentage of the weight of the wood itself. The weight of the wood itself is obtained when the wood is dried to a point where all of the moisture is removed. This is referred to as oven-dried. Weight, shrinkage, strength, and other properties depend in part on the moisture content of wood.
2. Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials (Oven Dry Method – ASTM D4442):
   a. This method is generally accepted for basic laboratory work and as a standard for calibrating other test methods. This is because the oven-dry test method is the most precise test method to determine gravimetric moisture content.
   b. This test method requires weighing the piece of wood with moisture, removing the moisture by fully drying it in an oven (215°F-220°F or 102°C-105°C) and then reweighing. The equation for determining moisture content is as follows:

$$\frac{\text{(weight of wood with water – oven-dry weight of wood)}}{\text{oven-dry weight of wood}} \times 100 = \text{MC (\%)}$$

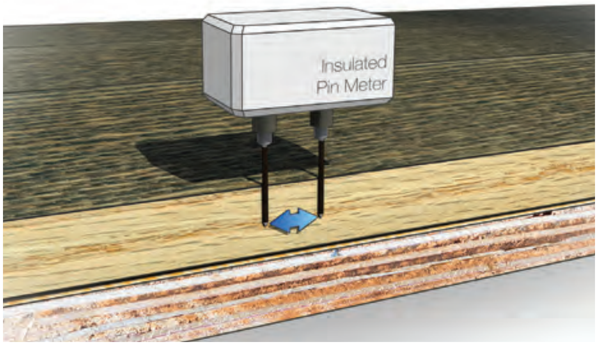
B. **Moisture Meters:** There are two main types of meters: pinless meters (dielectric) and pin-type meters (electrical resistance). Both types of meters will give generally reliable readings from as low as 5% MC, up to the fiber saturation point (FSP) of the species being tested.



1. **Pinless Meters**
   a. The pinless, dielectric types are also referred to as non-invasive, non-destructive, scanning, or surface meters.
   b. Signal penetration for these types of meters can be from ¼" up to 1 ½".
   c. These meter readings are dependent on material density and specific gravity.
   d. The meter can be moved across the surface to test multiple areas for moisture in a wood block or plank.
   e. Some of these types of meters can be sensitive to surface moisture, but relatively unaffected by temperature (check with the meter manufacturer).
   f. Measurements can also be taken through coatings without damage to the surface. However, some coatings with metallic components may affect the accuracy of the readings.
2. **Pin-Type Meters**
   a. The pin-type meters measure the electrical resistance across opposing sets of pins, which are pushed into the wood.
   b. Placement of the pins in relation to grain orientation is manufacturer and meter specific. This depends on the international standard to which the meter is calibrated. Check with your meter manufacturer for proper use.
   c. These types of meters force an electrical current through the wood sample between the probes. Because wood is a poor conductor of electricity and water is a good conductor of electricity, wood with higher MC has a lower resistance. The results are displayed as a number that represents a moisture content percentage.
   d. Pin-type meters are available with either insulated or non-insulated pins:



      i. Non-insulated pins will read as deep as they are inserted and will report the highest value of resistance through the entire depth of the pins.



ii. Insulated pins are typically available in many different lengths, from 1"-3", and are normally used with a slide hammer extension. Insulated pins only measure the resistance at the uninsulated tips of the pins, allowing one to evaluate the moisture gradients through the sample of flooring, subflooring, or the entire flooring system.

C. Moisture Meter Reading Variables

1. **Species Correction**
   a. Most meter manufacturers calibrate their meters to pine/Douglas fir/hemlock.
   b. Species correction is a meter manufacturer-specified, user-adjusted setting that is made to the moisture meter to compensate for either varying electrical properties (for pin-type meters) or densities (for pinless meters) of the species under test, as compared to the species of the reference calibration.
   c. Some meters have a species correction adjustment built in, while others include conversion charts to account for species correction.
   d. Making these adjustments allows for a more-accurate assessment of the moisture within the wood being tested.
2. **Calibration**
   a. Calibration ensures the meter is giving accurate readings.
   b. Calibration is usually considered the responsibility of the manufacturer, and the user accepts the calibration data supplied with the meter. The accuracy of calibration, especially in regard to sampling and specimen control, is usually unknown to the user.
   c. ASTM D4444 is the standard test method for laboratory standardization and calibration of handheld moisture meters.
   d. Some meters can be checked for calibration internally or by use of a calibration block supplied by the manufacturer.
   e. Check with the meter manufacturer to determine if, when, and how to get your meter properly calibrated. Many meter manufacturers will provide a calibration certificate, which verifies National Institute of Standards and Technology (NIST) traceability and that the meter is operating properly.
3. **Meter Drift**
   a. Meter drift is the decrease (or increase) in true moisture content over a specified elapsed time.
   b. Record readings from your meter within the first 2-3 seconds to ensure accuracy.
4. **Temperature Correction**
   a. The temperature of the wood will significantly influence the readings of a pin-type meter.
   b. Temperature correction is the adjustment that is made to the moisture meter reading to compensate for the phenomena that the electric conductance of wood increases as the temperature increases, and vice-versa. This adjustment, whether manual or automatic, allows for accurate measurements of moisture content even at extreme temperatures (e.g., less than 50°F and greater than 90°F).
   c. Use the following chart to determine the temperature correction based on the surface temperature of the wood being tested.

TEMPERATURE CORRECTION

SURFACE TEMPERATURE		METER READINGS										
°F	°C	6	7	10	15	20	25	30	35	40	50	60
0	-17.8	9	11	15	22	31	38	45	53			
20	-6.7	8	10	14	20	28	34	40	47	55		
40	4.4	7	8	12	18	24	30	36	42	48		
60	15.6	6	7	11	16	21	27	32	38	43	54	
80	26.7	6	7	9	14	19	23	28	33	38	47	55
100	37.8	5	6	8	12	17	21	25	29	34	42	50
120	48.9	5	5	7	11	15	19	22	26	30	38	44
140	60	4	5	7	10	14	17	20	23	27	34	40
160	71.1	4	4	6	9	12	15	18	21	24	30	36

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.

5. The materials within the **depth of signal penetration** can influence the readings the meter is taking. Substrate composition, adhesives, and engineered flooring core and backing components (different species or composite materials) all can have different densities, specific gravities (pinless), or electrical resistances (pin-type), which will alter the end reading. For example, a ¾" deep scan over a ½" engineered floor is also scanning the core, the flooring adhesive, and the surface of the substrate. Check with the meter manufacturer for testing protocol, accuracy, and appropriate species correction values when testing any engineered wood flooring product.

6. **Skill of the Operator:** Although moisture meters are normally very simple to operate, there are many user-errors that can affect the accuracy and reliability of the readings.
   a. Are the batteries in the meter fresh? A weak battery can affect the readings the meter is giving you.
   b. Follow all of the meter manufacturer instructions on proper use of the tool.
   c. Wood flooring material selection should be taken into account to achieve the real objectives of the moisture measurements.

PART III
Moisture Testing Wood Subfloors

At the time of installation, it is important to know the moisture content of not only the wood flooring, but of the substrate as well.

A. Due to the variability in wood subflooring materials, such as the different species of woods used in the production of wood subfloors, and the non-wood resins and adhesives used within them, it is difficult to get an accurate moisture reading of this material. Check with the moisture meter manufacturer for proper settings, testing methods, and correction values when testing wood subfloor materials.

B. When in doubt, check the moisture content of other properly conditioned wood materials (2x4s, newel posts, wood beams, etc.) within the structure in order to get an idea of where the EMC is in comparison to where it should be, and then compare this value with the EMC chart as a baseline for testing the subfloor.

C. After calibrating your meter to the subfloor material being tested, take MC readings in a minimum of 20 test locations for up to the first 1,000 square feet, and an additional 4 readings per 100 square feet thereafter, and average the results. Testing locations should be representative of the entire project and include a minimum of three tests per room receiving wood. Pay special attention to exterior walls and plumbing. Elevated readings should be addressed prior to delivery and installation of any wood flooring. In general, more readings will result in a more-accurate average. Record, date, photograph, and document all results.

D. The MC of the subfloor should coincide with the expected in-use (e.g., normal living) conditions of the facility, based on the EMC chart. Anything outside of this range would be considered unusually high.

E. In hot and humid climates, and during the humid season, the subflooring should not exceed 13% moisture content (MC). In regions where equilibrium moisture content (EMC) within the facility can sustain these higher MC levels, additional precautions should be implemented through the flooring product selection and the acclimation/conditioning process (see Acclimation/Conditioning chapter for more information).

F. Any unusually high MC readings must be identified, documented, and addressed in order to establish the size and magnitude of the problem area. Installation should not proceed until the origin of the moisture has been identified and remedied.
   1. IMPORTANT: Never install a wood floor over a known moisture condition. A known moisture condition is one that you are aware of, and could pose future damage to the flooring, the building, or the occupants. It is compulsory practice to always test for moisture regardless of conditions so that any unknown conditions can become known conditions, which then can be handled appropriately.
   2. The traditional standard for protecting wood and wood products from rot or decay is to keep the moisture content below 19 percent. Studies have shown, however, that mold growth can occur on wood at moisture content levels above 15 percent, and corrosion of metal fasteners can occur when moisture content exceeds 18 percent. Reaching these moisture content levels does not mean rot, decay, mold growth, or corrosion will occur, but does raise a potential concern. In all cases, it is important that the installer consult with all involved parties including the manufacturer and customer.

G. Another key variable of the moisture content of wood subfloors involves what is going on below the subfloor.
   1. When the space below the subfloor is controlled and conditioned to the same temperature and RH as above the floor, the moisture content through the thickness of the subfloor material should be the same.

2. When conditions below the subfloor are unconditioned, the moisture content will vary through the thickness of the subfloor system. This difference may affect the installed wood flooring and can result in damage.
3. Do not install a wood floor over an unconditioned space without addressing the moisture situation as detailed in the Underlayments: Moisture Control chapter.

PART IV
Moisture Testing Concrete Subfloors

It is extremely important to test for moisture on every flooring job. Even when the adhesive manufacturer states "no moisture testing is required," it is still in your best interest to moisture test, and document the results. Doing so will minimize the risk of failure, it will meet the flooring manufacturer's warranty requirements, it will fulfill your contractual obligation as the flooring professional, and it will minimize your liability if a failure does occur. In cases where there is not an effective vapor retarder in place directly below the slab, the results of any type of moisture test are likely to increase as moisture from the ground will enter and raise the moisture level in the concrete once it is covered.

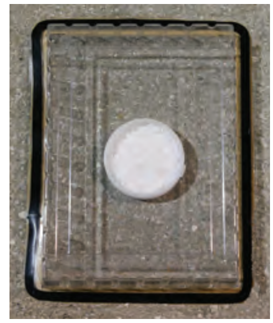
A. All concrete moisture tests indicate a condition of the concrete floor slab at the time of the test under the ambient conditions of the test, and may not predict future conditions of the floor slab. These tests do not indicate a permanent condition of the substrate. This is especially true if an effective moisture vapor retarder is not present or has been compromised by damage or by improper installation.

B. Conduct tests to give you the ability to know when to start or not start a job, and to determine what products and systems will be necessary in order to install the floor. All concrete slabs, regardless of age, will exhibit changes in moisture over time.

C. As concrete moves through its initial drying period, regular testing of moisture content to evaluate the drying condition of the slab may begin 30 days after placement.

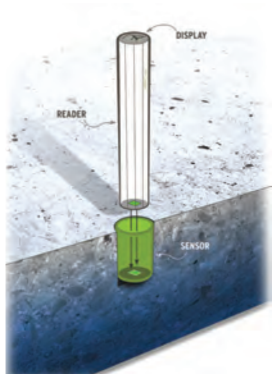
D. Appropriate moisture testing, specified by the flooring and/or adhesive manufacturer, is the only way to identify if moisture levels in the slab are adequate for the systems being used.

E. All tests should be performed as dictated by the ASTM standard.



1. **ASTM 1869 Calcium Chloride:** A calcium chloride moisture test is a standard test method for measuring the moisture vapor emission rate (MVER) of a concrete subfloor using anhydrous calcium chloride. The results of this test give quantifiable values.
   a. Results are shown as pounds of water over a 24-hour period, per 1,000 square feet.
   b. Ambient conditions must be 65°-85°F and 40-60% relative humidity for a minimum of 48 hours prior to conducting the test.
   c. Each prepared area must be 20"x 20," clean, and free of all foreign substances.
   d. Lightly grind the area to produce a surface profile equal to a concrete surface profile (CSP) 1-2, a minimum of 24 hours prior to testing.
   e. Weigh the calcium chloride in its container.
   f. Place the opened calcium chloride container on the prepared area and immediately cover it with a transparent cover to create an airtight seal.
   g. Let the covered container sit for 60-72 hours undisturbed.
   h. Remove the transparent cover and calculate as directed by the calcium chloride test kit manufacturer.
   i. Place three kits in the first 1,000 square feet and one per every 1,000 square feet thereafter.
   j. Record the data.
   k. Concrete slabs with a calcium chloride MVER reading of greater than 3 lbs/ 1,000 square feet/24 hour are strongly recommended to wait for further drying of the slab, or install/apply a minimum class 1 impermeable vapor retarding membrane over the slab according to the adhesive manufacturer's instructions, prior to installation.

2. **ASTM 2170 Relative Humidity:** Relative humidity moisture testing is the standard test method for determining relative humidity in concrete floor slabs using in-situ probes. The results of this test give quantifiable values and may be used to test lightweight concrete and gypsum-based underlayments.



    a. This method predicts what the equalized relative humidity will be through the entire thickness of the slab once it is covered with flooring material.
    b. Normal living conditions should be maintained for 48 hours prior to testing.
    c. Calibration of reusable probes should be checked before every job, or if not used for 30 days.
    d. To perform the test, drill a hole in the slab at the following thickness:
        i. If the slab is drying from top only (e.g. slab on-grade or in fluted metal decking), drill holes to 40% of the slab thickness.
        ii. If the slab is drying from top and bottom (e.g., suspended slab), drill holes to 20% of the slab thickness.
    e. The hole diameter is determined by the manufacturer's sleeve size.
    f. Tests should be placed within 3 feet of each exterior wall.
    g. Conduct three tests for the first 1,000 square feet and one for every 1,000 square feet thereafter.
    h. Insert the sleeve, cap it, and allow it to acclimate for a minimum of 24 hours.
    i. The meter reading must not drift more than 1% relative humidity over a five-minute period. When leapfrogging reusable probes, allow at least 1 hour to achieve a true 1% drift in 5 minutes. (Leapfrogging is when reusable probes are being used. An example would be a project where you have 50 holes drilled, lined and capped. However you only own 10 probes. When those ten probes are removed from the first 10 hole liners, allowed to acclimate with the ambient conditions, and then placed in the next ten liners, it is referred to as "leapfrogging.")
    j. Record the data.
    k. Always follow manufacturer guidelines for testing procedure.
    l. Concrete slabs with a RH reading of more than 80% are strongly recommended to wait for further drying of the slab, or install/apply a class 1 impermeable vapor retarding membrane according to the adhesive manufacturer's instructions, prior to installation.

3. **ASTM F2659 Electrical Moisture Meter:** Nondestructive electrical moisture meters are the standard guide for preliminary evaluation of the comparative moisture condition of concrete, gypsum cement, and other floor slabs and screeds. It is a nondestructive testing method. These tests should be used to evaluate the surface of the concrete and to determine where to place other quantifiable tests. These tests provide useful information, but should not be used on their own to determine whether a floor should or should not be installed unless otherwise directed by the flooring manufacturer.

    a. To ensure accuracy, the meter should be calibrated before every project or if not used for 30 days.
    b. The interior environment of the jobsite should be 65°-85°F and 40-60% relative humidity for at least 48 hours prior to testing.
    c. The temperature of the floor slab is to be tested and reported within 8" of each test area.
    d. Eight tests should be conducted for the first 1,000 square feet and 5 additional tests should be conducted for each additional 1,000 square feet with 3-5 tests per test site. Be sure to record the highest reading. Each test area should be within a one-foot-by-one-foot area.
    e. This test shows a moisture condition in the upper one-inch of the slab.
    f. It is very useful for mapping areas for further qualitative tests.
    g. There are three types of electrical moisture meters: impedance, capacitance, and field charge detecting.

4. Other tests that are not as common, but still in use, include:
   a. **ASTM D4944 Calcium Carbide Gas Pressure Test:** This test method includes quantifiable test procedures for determining moisture in building and other materials.

      i. This test involves taking samples of the concrete and pulverizing them into a fine-grained material. The test material is then weighed.
      ii. This material is then placed into a testing chamber with an attached pressure gauge, along with two steel balls and a calcium carbide reagent.
      iii. The testing chamber is sealed closed, and then shaken vigorously for 2-5 minutes. This breaks up the calcium carbide that, when coming into contact with the water in the concrete, creates a highly flammable and explosive acetylene gas.
      iv. When the pressure gauge dial needle stops moving, the final pressure reading shows the percentage of water content in the dry mass of concrete.
      v. Concrete slabs with a reading of more than 2.5% requires use of a class I vapor retarder. A reading of more than 4% may not be acceptable for the wood flooring to be installed.

   b. **ASTM D4263 Plastic Sheet Method:** The plastic sheet test method is used to indicate the presence of capillary moisture in concrete. This test can provide useful information, but should NOT be used to determine whether a floor should or should not be installed.

      i. To conduct this test, tape an 18″ x 18″ sheet of 4 millimeter poly to clean concrete.
      ii. You should conduct one test area per 500 square feet.
      iii. Allow the test to sit for 16 hours.
      iv. After 16 hours have passed, lift the plastic.
      v. If a darkened area is visible, moisture is present.
      vi. If there is not a dark area, it does not mean moisture is not present. More conclusive tests should always be conducted.