PRACTICAL ASPECTS OF MEASURING MOISTURE IN BUILDINGS

Lew Harriman
Mason-Grant Consulting - www.MasonGrant.com
Portsmouth, NH

Is the building still wet... or is it dry? And where is it wet? And if that masonry block is "dry enough" that you can reinstall gypsum board... how dry would that be, exactly? Sooner or later, all investigations of chronic or catastrophic water damage need quantitative moisture measurements to provide a firm foundation for conclusions and recommendations.

Any quantitative moisture measurement is useful to some extent. But it's helpful to recognize that with state-of-the-art, modest-cost meters, there are practical aspects of the building environment which limit the utility of raw moisture content readings. To increase their value, one also wants know the:

- Precise location of the measurement
- Operator's skill
- Type and brand of the meter
- Scale used to record the measurement

Building owners, their insurance carriers and even many investigators are not always aware of these factors. But a full understanding of the context of the measurement is essential when assessing the current condition of water-related problems in buildings, and is therefore very helpful in balancing risks with costs.

11% WME, measured on the dry side

15% WME, measured across the visible edge

19% WME, measured on the moldy side

23% WME, measured in the moldy area

Figure 1.
Moisture content and therefore mold growth can vary significantly over short distances

THE PRECISE LOCATION IS MEANINGFUL

Figure 1 shows an informal mold-growth test conducted in the unconditioned basement of the author's 230-year-old colonial home in Portsmouth, NH. A short test wall section, consisting of fir 2" x 4" studs covered by paper-faced gypsum board, was stored standing on its end. The upper end leaned against the dry basement wall, and the lower end rested on the hard-packed earthen floor. Over several months, moisture from the earth slowly wicked upwards through the gypsum board, eventually providing enough moisture for mold to grow on the untreated paper face of the gypsum board, at the lower end of the test wall section. Many months later, mold also succeeded in growing on the surface of a fir stud, where was in direct contact with the earth floor.

There are two useful points illustrated by figure 1. First, note the significant difference between moisture measurements taken less than 1/2 an inch apart. On the left, or "dry side" of the visible mold growth line, the moisture meter reads 11%. Then, just 1/2 an inch to the right and straddling the visible mold growth line, the meter reads 15%. Move another 1/2 inch to the right and the meter reads 19%. Another movement of 1/2 inch to the right provides a moisture reading of 23%.

Such large differences over very short distances illustrate why knowing the exact location of the measurement is important for understanding its true importance. For example, if a report stated that "the exterior wall moisture content was found to be 16%", a prudent decision-maker would want to know exactly where the measurement, or measurements, were taken. Was the moisture content consistently 16% both up and down and across that entire wall? How many readings were taken to reach the conclusion that the moisture content was 16%? Was the 16% number a maximum?.. or an average? If the 16% was an average, what was the maximum and where was that maximum reading taken?

A second point illustrated by figure 1 is that mold growth rates can also be highly variable over short distances. In this test, there is no visible growth at 11% but prolific growth at 19%, less than two inches away. And this variation happened in gypsum board, which is a uniform material that transports any internal moisture rather quickly. With rapid moisture transport in the material, this sharp edge of mold growth might not be the usual expectation. One could expect that over several months, the moisture content of the gypsum board (and therefore the potential for mold growth) would be more uniform along the length of the board. But that's not always the case, as shown here. The sharp differences in mold growth come from those sharp differences in moisture content. So again, in reaching conclusions about the potential for mold growth, the exact location of the moisture measurement can be important when making decisions about mold-sensitive material.

Figure 2 shows one way to comprehensively record the entire "moisture geography", at a reasonable cost of time and effort. The first photo shows the overall context of the measurements. We can see the area of concern along with it's position with respect to the building as a whole. The second photo is taken close enough to read the moisture content values written on the strips of masking tape, but still far enough away to show the increase in moisture content as the readings approach the window frame.

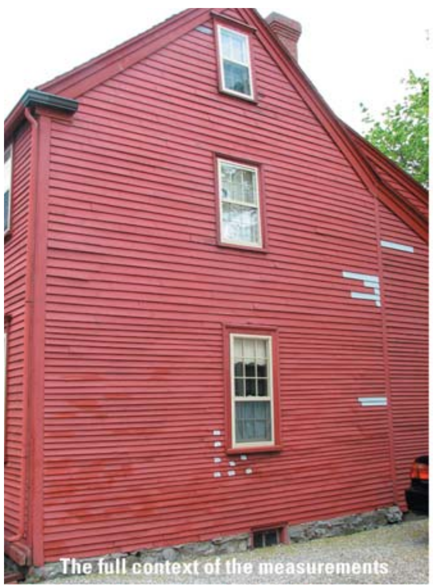

Figure 2.
It is usually helpful to document the exact location and full context of moisture values

The Operator's Skill

Figure 3 shows an example of the importance of the operator's skill. The meter shown is a "non-penetrating" type. It does not use pins to penetrate the material. Instead, it measures moisture by the change in an electrical field projected immediately behind the meter.

Inside that electrical field is both the moist material and the thin air gap between the back of the meter and the

Figure 3. *A technician's skill can significantly influence the meter reading*

moist material. The electrical properties of that thin air layer are very different than the properties of the moist material.

So as shown in figure 3, if the operator does not press the meter down evenly to ensure the air gap is of uniform thickness, the reading shown on the meter will be higher or lower the next time the technician makes a measurement, even though the true moisture content of the material may not have changed.

A similar issue applies to resistance-based, or "pin-type" meters. Two pins are pressed into the wet material and the resistance between those pins is converted to a moisture content reading. But the electrical resistance of air is much higher than the resistance of solid materials. So when there is any tiny air gap between a pin and the material—if the operator does not seat the pins firmly, or if the pins wobble in the material while the reading is being taken—two meter readings taken in the exact same location can be different, even when there is no actual change in moisture content.

Any error introduced by these particular meter characteristics will always understate the moisture content. With both pin-type and "non-penetrating" meters, any small air gap will produce readings below (drier) than the true moisture content of the material.

Given the limitations of current state of the art, moderate-cost meters, these are problems which can only be minimized by the skill of the operator and the consistency of his or her work habits. There is no simple way to cross-check the operator's technique from written reports after the fact. To reduce the uncertainty caused by these issues, it's useful to know (and to document) exactly who took the readings.

Document the Meter Type, Its Manufacturer, and Measurement Scale

In the moderate-cost range ($100 to $500), there are two principal types of moisture meters in common use: resistance, or "pin-type" meters, and capacitance/impedance, or "non-penetrating" meters. (There are several other types of meters beyond that price range which are not in common use, but those will be discussed in some other article)

When analyzing moisture measurements in a written report, it's useful to keep in mind that meters from different manufacturers usually show different values for the same moisture content, even if they use the same measurement principle and are taken in precisely the same location.

Figure 4 shows an example of this fact. The gypsum board being measured by these resistance meters is essentially saturated. So the reading will be simply "maxed-out"—the true moisture content is going to be out of scale for all of the meters. Meter one indicates that fact by showing an upwards-facing arrow at the 44% maximum value on its pre-printed scale. Meter two maxes-out at 37%. Meter three pegs its scale at "40%", while meter four suggests the moisture content is "over 100%." In fact, most resistance-based meters are not very accurate when wood moisture content is more than about 35%. So in this situation the true moisture content is not reliably reported by any of these instruments. Correctly reported, the moisture content is simply "more than 35% on a softwood lumber scale".

Figure 4.
Meters from different manufacturers show different values for "saturated" moisture content

Figure 5 shows a similar example. In this case the meters are used to read a much lower moisture content in gypsum board—a moisture content which is in the usual range of interest for making decisions about whether gypsum board is "dry enough" for further work. The meters show values from a low of 13% to a high of 19%, in exactly the same location (The pin positions do not vary by more than 1/8th of an inch).

There are two obvious implications of these meter characteristics. First, the prudent investigator keeps in mind that any reading above 30% really only indicates that the material is "pretty darn wet". Distinctions such as 34% vs. 46% moisture content read from meters made by different manufacturers do not reliably indicate a meaningful difference in moisture content. Secondly, if the type, manufacturer and model number are not recorded along with the moisture readings it will be difficult to compare readings taken on different days to each other, even if the readings are taken in precisely the same location.

Next it's useful to keep in mind that none of the above readings could be even remotely close to correct percentages of gypsum board moisture content. These numbers in the 11 to 35% range are far too high.

Figure 5.
Different meters also show different values in the range of mold-risky moisture contents

Corrected Values for % Moisture in Aspen OSB	Softwood Moisture Meter Readings (Moisture as a percent of dry weight) 8%	12%	16%	20%	24%	Surface Temperature (°F)
	10	14	18	22	26	14°
	8	13	17	21	25	32°
	8	12	15	19	23	50°
	7	11	14	18	22	68°
	6	10	13	17	20	86°

Courtesy of Forintek - Canada

Table 1.

Corrections for moisture content readings taken in aspen-based Oriented Strand Board (OSB).

As it leaves the factory, dry gypsum board has a moisture content of about 0.4% by weight. Later, if gypsum board becomes soaking wet and is crumbling apart, it's moisture content is still not likely to be more than 1.8%. Most gypsum board simply cannot hold more than about 2% of its weight in water. So the percent moisture content readings on the meters in figures 1 through 4 cannot be correct for gypsum board—although the readings are still useful for making comparisons on the same material.

The experienced investigator recognizes that the scale shown on most pin-type meters is calibrated for softwood lumber; usually Douglas fir. So in the case of the readings above, one should record the fact that the readings taken in the gypsum board are based on the Wood Moisture Equivalent, or the "WME" scale.

It's also useful to keep in mind that the electrical characteristics of lumber are different than the electrical properties of the same wood when it's chopped up, compressed and baked into engineered wood products. For example, the softwood lumber calibration does not apply directly to OSB (Oriented Strand Board), even though the OSB is made of softwood. A correction must be made to account for the increased electrical resistance of glue, and of the air spaces between the wood chips at low moisture contents. In addition, higher temperatures reduce the electrical resistance of both lumber and OSB (the opposite of what happens in metals, in which warmer temperatures raise electrical resistance).

Correction factors for Aspen OSB were developed by the Canadian Wood Council and the Canadian Mortgage and Housing Corporation in 2001. Those are shown in table 1. In general terms, unadjusted softwood-scale measurements overestimate the true moisture content of Aspen OSB at ambient and high temperatures, while they underestimate moisture content as the temperature goes below freezing.

There's another complication when reporting the moisture content of gypsum board, masonry block, brick and concrete. Capacitance or impedance-based meters are often used for these materials, and many such meters have only "relative" scales, rather than percent moisture content by weight. In other words, the meters may display values from 0 to 100 or perhaps 0 to 200. But these do not refer to percent moisture content by weight. Instead, they are simply non-absolute indicators of "higher or "lower" moisture content. Also, different manufacturers use different non-penetrating measurement technologies. And each manufacturer uses different "relative scale" values for the same moisture content. As a result, it's simply impossible to know whether there is any truly higher or lower moisture content indicated by a relative reading of 73 from one manufacturer compared to a relative reading of 122 from a different manufacturer.

To summarize, when reporting moisture measurements in buildings the most useful documentation will show the exact location of the measurement, in it's fullest "geographic" context. It's also important to record the manufacturer and model name of the instrument, along with which of it's possible scales are being used, as well as the date, time and the name of the person who took the measurements.

This information—admittedly not always included in most reports today—will enhance the value of any investigator's conclusions and recommendations, and will provide a firmer foundation for decisions made by owners and insurance companies with respect to moisture problems in buildings.

Lew Harriman is Director of Research & Consulting for Mason-Grant in Portsmouth, NH. (www.MasonGrant.com) He was the lead author for the ASHRAE Humidity Control Design Guide and the recent report to the California Energy Commission titled "A California Builder's Guide to Reducing Mold Risk." He is a member of ASHRAE Technical Committee 1.12 (Moisture Management in Buildings), and can be reached by phone at (603) 431-0635 or by eMail at LewHarriman@MasonGrant.com