METHODS OF DETERMINING THE
MOISTURE CONTENT OF WOOD

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Despite the fact that wood, for many of its highest uses, must have the proper moisture content, no standard method for testing lumber or dimension stock for moisture content has been adopted by any of the standards associations. The method universally accepted in the wood-using industries, as if it were a standard, is the ovendrying method, or oven test, in which the moisture content is calculated from weight values obtained before and after drying a sample of the wood in an oven.

Other methods that have been used for the determination of the moisture content of wood are the distillation method, the electrical methods, relative-humidity methods, and chemical methods. Since the electrical methods are the subject of another report and the relative-humidity and chemical methods are generally not of practical importance in the wood-using industries, this report will be confined to the ovendrying method and the distillation method. The ovendrying method is useful if the wood contains few or no volatile extractives. The distillation method is useful for woods that do contain such extractives in the natural state or that have been impregnated with volatile chemicals. It also may be used for woods that do not contain such extractives. Both methods require that a sample be cut out of the wood to be tested.

Mode of Expression of Moisture Content

The moisture content of wood can be expressed in three different ways: (1) as an absolute amount of water in an absolute amount of wood, (2) as a per-

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pctage of the ovendry weight of the wood, or (3) as a percentage of the

total original weight of the wood plus water.

The mode of expression in general use by the woodworking industries for
the moisture content of wood in relation to its suitability for any particular
purpose is as a percentage of the ovendry weight of the wood. There are
several advantages in expressing the moisture content on the ovendry basis.
The moisture content of wood in equilibrium with a given temperature and
relative humidity is a definite value when expressed in this manner, re-
gardless of its specific gravity, but the relationship would have no consist-
ency if it were based on the total weight of the wood and water. In most
woods there is an approximately straight-line relationship between shrink-
age and the moisture content of wood below the fiber-saturation point when
moisture content is expressed as a percentage of the weight when ovendry.
There also are definite straight-line relationships between many strength
properties of wood and moisture content in the range below the fiber-
saturation point when this mode of expression is used. These relationships
are not so simple when moisture content is expressed as a percentage of the
total weight.

Figure 1 shows a graph suitable for converting percentage moisture con-
tent based on original-weight to percentage moisture content based on
weight when ovendry, and vice versa.

Ovendrying Method

The ovendrying method consists of selecting representative sample boards
or pieces from the material to be tested, cutting moisture sections from
each sample, weighing them, drying them in an oven to constant weight,
weighing them again, and calculating the moisture content.

Selection of Test Sample

The proper selection of representative sample boards or pieces from which
the moisture content sections are cut is exceedingly important. Extreme
accuracy in determining the moisture content of the sections is of little
value if a wide variation of moisture content exists throughout the pile or
load of lumber being tested and the selected pieces are not representative.
If there is a wide variation of moisture content, several pieces should be
selected in order to obtain a representative average value for the material
being tested. When a carload or kiln charge of lumber contains lumber from different sources or lots, a separate representative sample should be obtained for each lot, if the use involved requires that refinement, or the sample should be confined to the lot that is critical in determining kiln operation or any other operation involved.

Preparation of Moisture Sections

The method of cutting moisture sections from a piece selected for test is shown in figure 2. Wood dries much more rapidly at end-grain surfaces than at side-grain surfaces, and if a board has been allowed to dry without end coating for some time, the moisture content near the end of the board will be lower than in the center of the piece. The moisture content sections should be cut, therefore, at some distance from the ends of the pieces. When it is known definitely that the ends of the pieces have not been exposed to drying conditions for more than a few days, a minimum distance of 6 inches is suggested. Otherwise a minimum distance of 20 inches should be observed.

The sections should be approximately 1 inch thick. In dimension stock that is 1 inch square or less in cross-sectional dimensions, the section should be 2 inches or more along the grain to yield a piece having a volume of 2 or more cubic inches. To speed up ovendrying, such long moisture sections may be partially cross cut at one-half inch intervals. Sections less than 1 inch in thickness may lead to errors due to the very rapid drying at the end-grain surfaces during the sawing operation and handling subsequent to sawing. On thin sections the percentage of end-grain area is very high, and the error can be great. There are some advantages in using sections thinner than 1 inch, particularly for getting quick results and for using some of the self-calculating moisture content scales when operating a large battery of kilns. Whenever such thin sections are used, a special technique must be used in which the sections are cut rapidly on a sharp, cool-running bandsaw and are handled thereafter so that moisture loss has little chance to occur. An operator's technique in such operations should be checked frequently by making tests on sections of full thickness and applying proper correction factors to the values obtained with thin sections. The errors are likely to be greater, of course, with green or partially seasoned material. After the sections are cut, all loose splinters and sawdust should be removed, and the sections be weighed immediately. If it is necessary to cut a number of sections at a time, they should be protected from drying by wrapping them in aluminum foil with paper backing. The aluminum side should be placed next to the section. If it is known that the sections
are of approximately the same moisture content, they can be stacked end grain to end grain to protect each other; otherwise each section should be wrapped separately. A method of subdividing a section to check the distribution of the moisture between inner and outer zones of the boards is shown in figure 3.

Placement of saw, scales, and oven close together in a sheltered place is helpful in obtaining accurate moisture content determinations. If it is necessary to cut the sample boards at a cut-off saw located some distance from a place in which an accurate scale can be maintained and used, large pieces should be cut from the boards and the pieces taken to the weighing room where the sections can be cut from the pieces with a convenient bandsaw, after a section at least 1 inch long has been cut from each piece and discarded.

Weighing the Sections

Each section should be weighed to an accuracy of one-half of one percent of its weight as soon as possible after it has been cut from the sample board. An accurate scale is necessary in order to get results within this percentage of accuracy. Weights should be obtained in grams, instead of grains or ounces, so that calculations will be simplified by the decimal system. A triple-beam balance is a convenient type of balance to use in kiln-drying work. The one shown in figure 4 is sensitive to 0.01 gram and has auxiliary weights making its capacity more than 1,000 grams. Any torsion balance sensitive to 0.1 gram or less should be suitable. A torsion balance with auxiliary weights and double rider sensitive to 0.01 gram is shown in figure 5. A type of balance (not illustrated) known as the Harvard trip scale, which is sensitive to 0.1 gram, is also suitable for weighing moisture sections. The triple-beam balance and the Harvard trip scale have knife-edge balances that must be kept free of dirt and corrosion to remain accurate. The accuracy and sensitivity of a scale should be checked at least every year against standard weights.

When sections are weighed, it is desirable to mark the weight on each section and also to give each section an identifying mark and to keep a separate record on tabulation paper or a form made specially for the purpose.

Ovendrying the Sections

After they are weighed, the sections should be placed in an oven maintained at a temperature of 214° to 221° F. (101° to 105° C.). Drying of each
section should be continued until it reaches a constant weight, within the
limits of accuracy of one-half of 1 percent. To test for constant weight,
weigh a few sections and replace them in the oven for 4 hours of additional
drying. If these sections have lost no further weight, the entire group of
sections can be assumed to be at constant weight. An electric oven, such
as the one shown in figure 6, equipped with a temperature-regulating de-
vice and a thermometer, is convenient for this operation. Where large
numbers of sections must be dried at the same time, a large oven equipped
for forced circulation of air is desirable. It is also possible to use a large
oven heated with steam at low pressure, if it can be made to maintain sat-
sfactorily the required temperature. The oven should have some vents to
allow the evaporated moisture to escape. The sections should be open
piled in the oven to allow free access of air to each. Excessive tempera-
tures or excessive periods of drying should be avoided because they cause
distillation or oxidation of the wood and erroneous results will be obtained.
Ordinarily, in the case of low-density woods, 12 hours of ovendrying may
be sufficient, but high-density wood may require 48 hours of ovendrying or
more. Newly cut sections should not be placed in the oven with sections
that are dried and ready to be weighed, for the dry sections will temporarily
absorb moisture from the fresh sections.

Weighing the Ovendry Moisture Section

It is essential that each section be weighed immediately after it is removed
from the oven, unless the dry section is stored in a desiccator while await-
ing weighing.

Calculating the Moisture Content

The moisture content of the wood is calculated by dividing the weight of
the water removed by the ovendry weight of the section and multiplying the
quotient by 100. The weight of the water equals the original weight minus
the ovendry weight of the section. Combining both statements into an alge-
braic expression:

\[
\text{Moisture content} = \frac{\text{original weight} - \text{ovendry weight}}{\text{ovendry weight}} \times 100. \\
\text{(percent)}
\]

An example of a moisture content calculation is as follows:

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A 1-inch section of kiln-dried black walnut lumber weighed 56.5 grams. After ovendrying, the section weighed 52.5 grams.

Moisture content = \( \frac{56.5 - 52.5}{52.5} \times 100 \)

\[ = \frac{4.0}{52.5} \times 100 \]

\[ = 0.076 \times 100 \]

\[ = 7.6 \text{ percent.} \]

It is sometimes convenient for slide-rule calculation to use an equivalent method of calculation by the following formula:

\[ \text{Moisture content} = \left( \frac{\text{original weight}}{\text{ovendry weight}} - 1 \right) \times 100 \]

Following through with the values used in the foregoing example:

\[ \text{Moisture content} = \left( \frac{56.5}{52.5} - 1 \right) \times 100 \]

\[ = (1.076 - 1) \times 100 \]

\[ = 0.076 \times 100 \]

\[ = 7.6 \text{ percent.} \]

**Distillation Method**

The distillation method consists of selecting a representative sample board or piece from the material to be tested, cutting a moisture section from the piece, dividing the moisture section into small chips, thoroughly mixing the chips and selecting a representative sample of them, weighing the sample of the chips, distilling the water from the pieces along with a liquid that is immiscible with water, catching the water in a trap and measuring its volume, and calculating the moisture content. The time required for the whole operation is less than 2 hours.

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Selection of Test Sample and Cutting of Sections

The procedure for selecting the test sample and cutting the sections is the same as for the ovendrying method.

Chipping, Sampling, and Weighing

Each moisture section should be split separately into little chips having cross-sectional dimensions about 1/16 inch square. All the chips for a particular section should be thoroughly mixed together under conditions such that the moisture content is not materially changed during the mixing. A bunch of chips weighing about 25 grams should be taken from the mixing vessel and immediately weighed to an accuracy of one-half of 1 percent of its weight. Any scales mentioned as satisfactory within this degree of accuracy for the ovendrying method can be used. The sample should then be placed in the distillation apparatus.

Distillation

An apparatus suitable for this test is shown in figure 7. A similar apparatus, the Bidwell-Sterling apparatus, is identical in principle, gives somewhat more accurate results when the moisture content is low, and does not have ground-glass connections. It can be purchased under that name from laboratory equipment supply houses. It consists of an Erlenmeyer flask of 250-milliliter capacity, a combination delivery tube and trap, and a water-cooled Liebig condenser, all connected with tightly fitting cork stoppers. When it is used in atmospheres of very high humidity, a drying tube should be used at the top of the condenser. Toluene is the liquid generally used for making the distillation, but as it is inflammable, due care must be observed in its use. Another chemical, tetrachloroethylene, which is non-inflammable, has been suggested for this test, but it requires a considerably modified apparatus and has not come into wide use. 3

Before it is used in the test, the liquid should be shaken with a small quantity of water to make sure that it will not absorb any traces of water during the test.

The distillation is run by adding 150 milliliters of the water-saturated liquid to the chips and connecting the apparatus. The cold water for the condenser is turned on. The flask is then heated by a hot plate so that the liquid goes up into the condenser, condenses, runs back into and fills the trap, then drips rapidly back into the distillation flask. The water collects at the bottom of the trap and does not get a chance to run back into the distillation flask. Distillation should be continued until no more water collects in the trap for 15 minutes. Any droplets of water clinging to the inside wall of the condenser should be dislodged with a long wire. Distillation usually takes about 1 hour. The hot plate then is turned off, and somewhat later the cold water is turned off. The oven-dry weight of the wood usually is not determined.

Measuring the Water

The bottom of the trap is graduated in cubic centimeters so that the volume of water collected can be observed. In the metric system, the weight in grams of a given volume of water is equivalent to its volume in cubic centimeters. The number of cubic centimeters of water observed can thus be changed to grams directly without any calculations.

Calculation of Moisture Content

Even though the oven-dry weight of the wood is usually not determined the moisture content is calculated as a percentage of the oven-dry weight of the wood by the following formula:

\[
\text{Moisture content} = \frac{\text{cubic centimeters water}}{\text{grams of chips} - \text{cubic centimeters water}} \times 100.
\]

For example, 25.8 grams chips gave 2.3 cubic centimeters of water.

\[
\text{Moisture content} = \frac{2.3}{25.8 - 2.3} \times 100
\]

\[
= \frac{2.3}{23.5} \times 100
\]

\[
= 0.098 \times 100
\]

\[
= 9.8 \text{ percent.}
\]
Ovendrying of Chips to Correct for High Content of Volatile Extractives

Since the strength- and shrinkage-moisture content relationships of wood and water are true regardless of the amount of volatile extractives present, the ovendry weight of the chips should be determined if there is an exceedingly large amount of volatile extractives present, to get at the true moisture content value. The formula for calculating the moisture content in that case is:

\[
\text{Moisture content} = \frac{\text{cubic centimeters water}}{\text{ovendry weight of chips}} \times 100
\]

The chips should be collected and rinsed with clean liquid before they are ovendried. If an inflammable liquid is used, it should be evaporated from the chips in a ventilated room before the chips are placed in an oven. A weighing vessel for which the tare weight is accurately known should be used to hold the chips during ovendrying and weighing. As stated previously, the ovendrying of the chips is not generally required.

Disconnecting and Cleaning Apparatus

When the apparatus is cooled almost to room temperature, it can be disconnected. All the liquid from the flask and the trap can be poured into the bottle in which the supply of toluene or other liquid is kept. Any water in the trap will go to the bottom, and, of course, care should be exercised to keep this water out of the distilling flask when another determination is started. The trap should be thoroughly cleaned and dried in an oven. It is also desirable to keep the inside of the condenser clean so that no droplets of water will cling to its walls during a determination. The same apparatus can be used for a number of determinations in series by having a few extra traps. When the apparatus is used frequently, the supply of water to the condenser can be left on continuously.
Figure 1. -- Relation of moisture content based on weight when oven-dry and moisture content based on original weight.

ZM 55221 F
Figure 2. --Method of cutting moisture sections from boards.

ZM 68006 F
Figure 3. -- Method of cutting section for determination of shell and core moisture distribution.
Figure 4. -- Triple-beam type balance with auxiliary weights.

ZM 68007 F
Figure 5. -- Pan-type balance with double beam and auxiliary weights.

ZM 68009 F
Figure 6. --Electrical oven with automatic temperature control.

ZM 8911 F
Figure 7. -- Apparatus for determining moisture content by the distillation method.

ZM 68005 F