EFFECT OF HIGH TEMPERATURE DRYING ON MOISTURE CONTENT DETERMINATION WITH ELECTRONIC METERS

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BACKGROUND

Knowledge of wood moisture content (MC) is vital to kiln operators and industry managers who must be sure that their lumber is sufficiently dry to meet grade rule or contractual standards. Accurate determination has become more important as many mills attempt to dry to higher average, but still within grade, moisture contents in efforts to reduce drying degrade.

Oven drying at 215°F, is usually considered the most accurate method for determining true moisture content (1,9). It is destructive and time consuming, however, and thus its practicality is limited. Electronic moisture meters, which produce immediate readings of wood moisture content, have come to be relied upon by industry as an indispensable quality control tool. They measure the electrical properties of wood and translate them into a moisture content reading (5). The predictable nature of these properties for specific moisture contents and species allows calibration and reproducible accuracy. The most common types of wood moisture meters are the hand-held conductivity/resistance and dielectric capacitive-admittance based meters manufactured by companies such as Delmhorst, Lignomat, and Wagner.

Conductance meters generally measure the electrical conductivity between two metal pin electrodes which are driven into the wood. Moisture content and gradients within and along boards are easily determined. In addition to moisture, conductivity can be significantly affected by chemical content, which varies between species, and temperature. To account for this specific species (2,5,8) and temperature (4,5,7) correction factors have been developed and published. Meter manufacturers, using microprocessor technology, have recently been incorporating these compensating factors directly into many of their meters.

Capacitive-admittance based meters measure the dielectric capacitive properties of wood. Similar to conductance meters, use of appropriate species correction factors is recommended. Dielectric meters use surface electrodes which do not physically penetrate the wood. Moisture readings are the resultant average of the region under the electrode, generally extending about 1 inch deep into the wood and over a 2-3 inch radius. Excellent discussion of these and other characteristics, benefits, and limitations of moisture meters have been published by James (5) and Skaar (9).

The conditions by which wood has been treated or dried can affect its hygroscopicity and electrical conductivity characteristics (1,5,9). Certain fire retardant and wood preservative chemicals increase hygroscopicity and electrical conductivity. Wood may attain higher moisture contents and meters may read even higher. Exposure to elevated temperature, such as with high-temperature kiln drying, has been found to reduce wood hygroscopicity (9). In such cases wood MC will equilibrate to lower equilibrium moisture content (EMC) conditions at comparable temperature and relative humidities.

Much lumber today, particularly softwood, is high-temperature kiln dried. Concerns have recently been expressed as to whether the published correction factors for moisture meters are accurate for material which has been high temperature kiln dried (12). Garrahan (3) reported that high-temperature drying (240°F dry bulb) resulted in an overestimation of true MC with a resistance meter in black spruce and jack pine by about 2-4%. Balsam fir, on the other hand, was not affected. Earlier work by Salamon (8), however, with mixed western species found that drying method had no effect on moisture meter accuracy. Milota and Quarles (6), investigating Douglas-fir and lodgepole pine, found that while high-temperature dried wood had somewhat lower moisture contents at similar conditions as conventionally dried wood, the effect on meter performance was minimal. They concluded that additional correction factors for lumber which has been high temperature dried are not necessary.

OBJECTIVES

The objective of this work was to determine whether high-temperature kiln drying affects the ability to reliably determine wood moisture content with resistance and capacitive-admittance electronic moisture meters.

METHODOLOGY

Freshly sawn red pine, eastern white pine, eastern hemlock, and Norway spruce 2"x4"x8' lumber was high temperature or conventional temperature kiln dried (11) to a target moisture content of 12%. Conventional drying utilized USDA Dry Kiln Operator's Manual schedule T10-B3, with a maximum temperature of 180°F. Total drying time was 12 days. High-temperature drying at 240°F dry bulb temperature was accomplished in 1 day.

Seventy five 1" thick x 2" wide x 4" long (longitudinal) clear straight-grained samples were prepared, fifteen from each of five boards, of each species from each drying method. Following procedures described in ASTM D-444 (1), three samples from each board were conditioned to target EMC conditions of 6, 10, 12, 15, 20% at 77°F in temperature and humidity controlled chambers. After the fifteen samples at each EMC condition were equilibrated for a sufficient period of time to eliminate moisture gradients, their moisture contents were determined with resistance and capacitive-admittance moisture meters, and then by oven drying.

A Delmhorst RDM-1S moisture meter was used for the resistance moisture meter determinations. The meter was set to the Douglas-fir species scale (the most commonly used "standard" species), 2-pin electrode, and 77°F wood temperature. The insulated pins were driven about 1/4" into the wood for each reading. Four readings were taken from each sample, two from each face, and averaged. The Wagner L-600 meter was used for the capacitive-admittance meter moisture measurements. Each sample was placed over a non-conductive surface and moisture content was measured on its top and bottom faces and averaged. The Wagner meter was also used with the Douglas-fir species scale.

RESULTS

Figures 1-4 and 5-8, respectively, show the relationship between moisture content determination with the Delmhorst and Wagner meters and oven drying of conventional and high-temperature dried wood. In accordance to ASTM D-444 (1) linear regression lines are presented for each set of data, along with r^2 correlation coefficients. The "normal" line on the graphs indicates a perfect correlation between moisture meter readings and oven-dry values, based upon the conductance characteristics of Douglas-fir. The excellent overall meter vs. oven dry MC relationships shown for these species illustrates the usefulness of moisture meters.

The correlation between the Delmhorst resistance meter and oven dry MC values was very good for each of the four species, red pine, white pine, eastern hemlock, and Norway spruce. r^2 coefficients ranged from 0.94 to 0.98. Differences due to high-temperature drying were quite small. In the 15-20% range, true MC of high-temperature dried red pine and white pine was over estimated by only amount 0.5%, which is within the realistic range of instrument accuracy. The degree to which data points and the regression line varied from the so called "normal" line indicates appropriate species correction factors. Interestingly, the results of this work for the most part confirms already published species correction factors.

As expected, hygroscopicity reduction due to high temperature drying was found in this study. Using red pine (Figure 1) as an example, at target EMCs of 10 and 20%, respectively, the high temperature dried material equilibrated to about 9 and 21% while the conventionally dried wood equilibrated to 11 and 22%. This did not, however, affect meter accuracy.

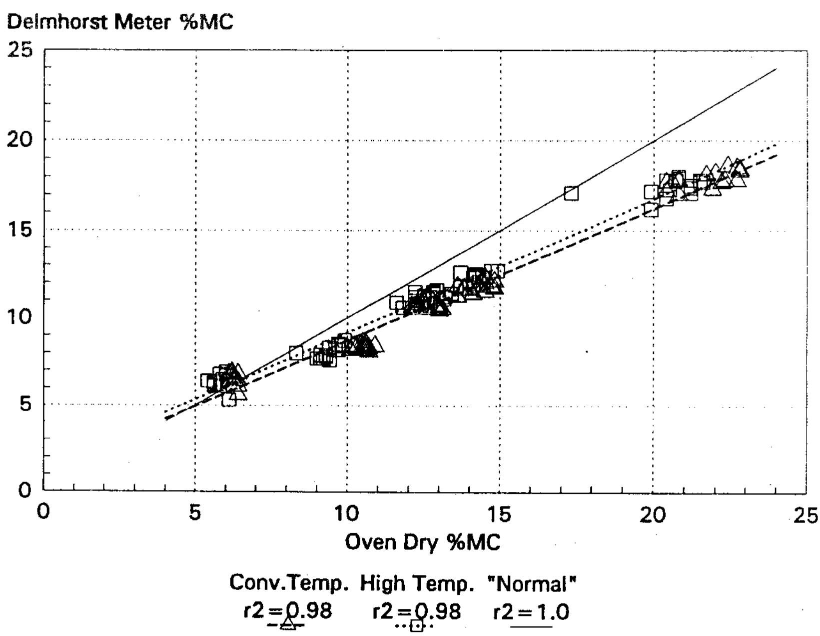

Figure 1. Data and regression lines for red pine tested with a resistance-type meter.

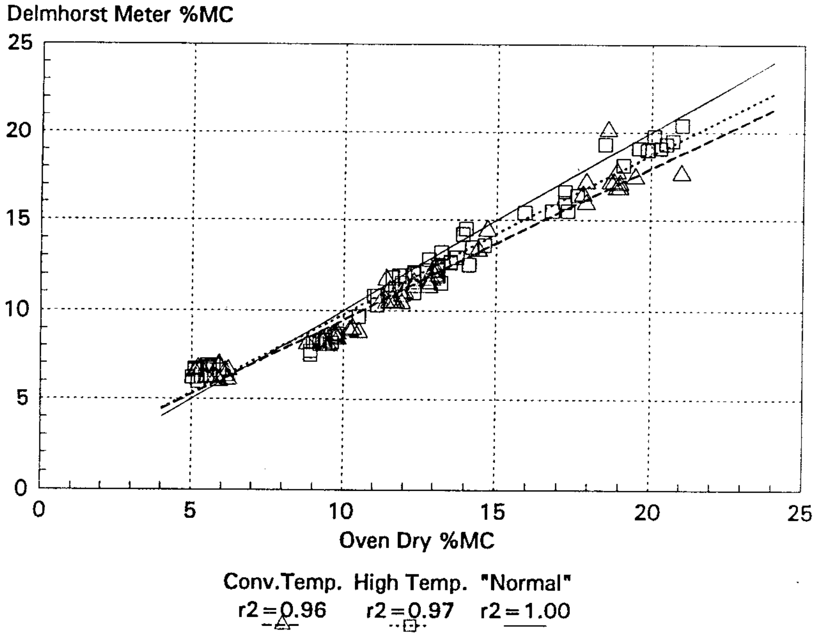

Figure 2. Data and regression lines for eastern white pine tested with a resistance-type meter.

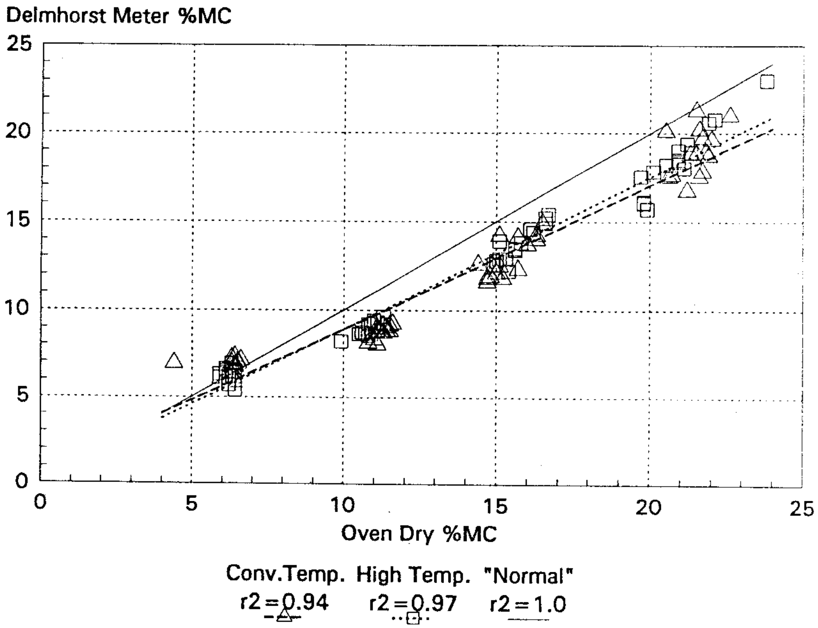

Figure 3. Data and regression lines for eastern hemlock tested with a resistance-type meter.

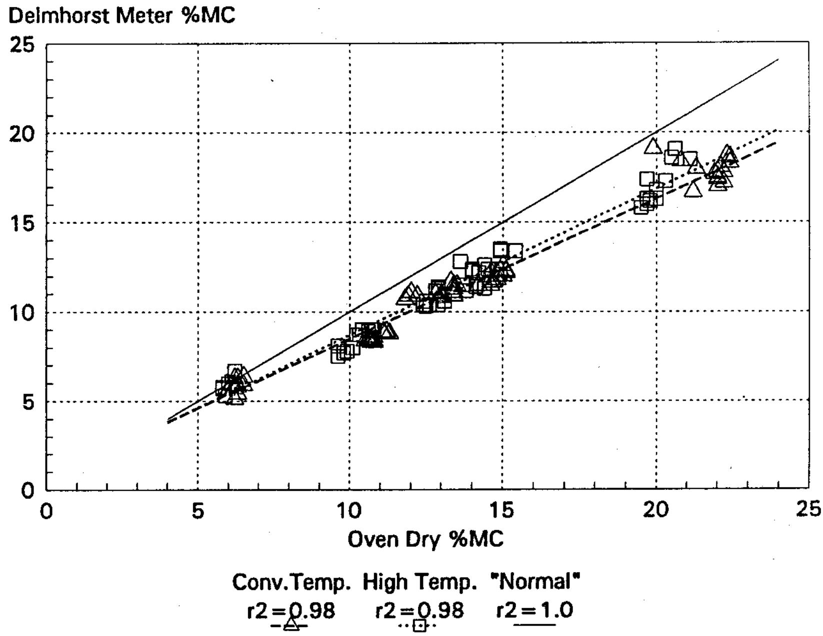

Figure 4. Data and regression lines for norway spruce tested with a resistance-type meter.and 21% while the conventionally dried wood equilibrated to 11 and 22%. This did not, however, affect meter accuracy.

The Wagner meter also quite accurately predicted oven dry moisture content. The r^2 coefficients ranged from 0.84 to 0.96. There are substantially no differences shown due to drying method for red pine, white pine, or Norway spruce. With hemlock high-temperature drying resulted in an under estimated true MC of about 1%. This is the opposite of that found with the resistance meter and probably not particularly significant. The relatively broad spread of data points from the regression line, and somewhat reduced r^2 values with the white pine and eastern hemlock (Figures 6 and 7) was caused by specific gravity variability. Due to the fundamental dielectric properties of moist wood capacitive-admittance moisture meters will generally somewhat underestimate true moisture content with low, and overestimate with high, specific gravity wood. Of course this becomes less of an issue when many values are taken and averaged.

SUMMARY

This project was initiated to investigate whether high-temperature drying substantially affects the accuracy of current species correction factors for use with moisture meters. Results show small differences between high-temperature and conventional temperature drying methods. Correction factors found for the four species in this study are very similar to values published by USDA, Forintek, and moisture meter manufacturers. The data supports maintaining the status quo and discounts the need to make modifications due to drying method.

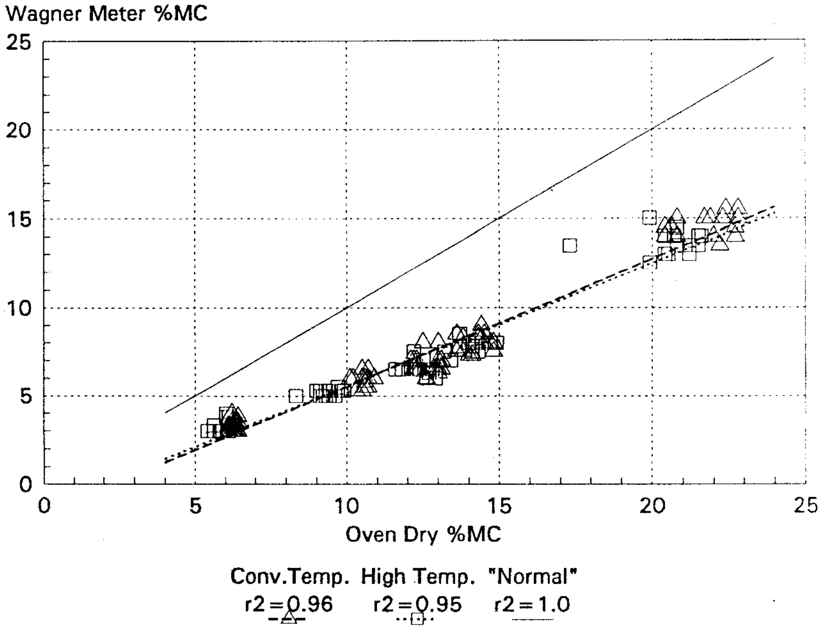

Figure 5. Data and regression lines for red pine tested with a capacitance-type meter.

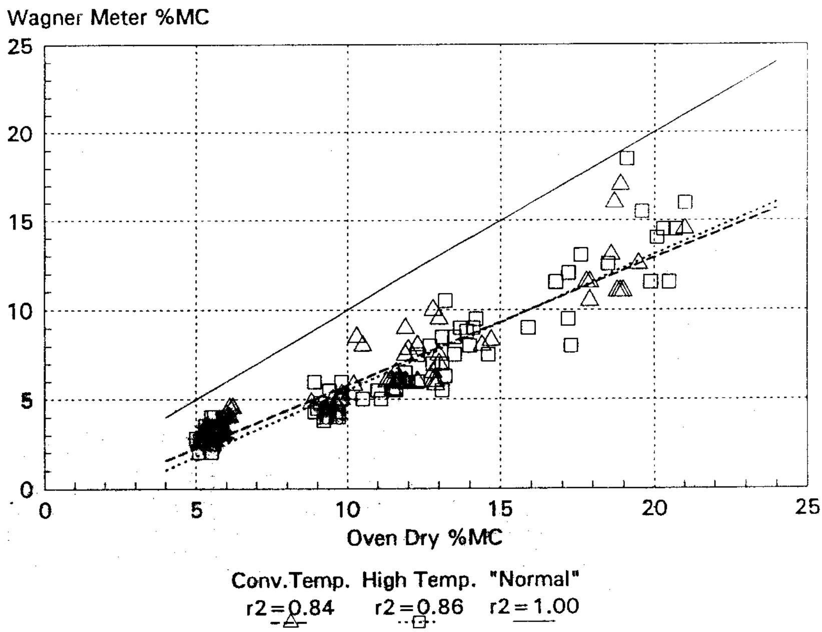

Figure 6. Data and regression lines for eastern white pine tested with a capacitance-type meter.

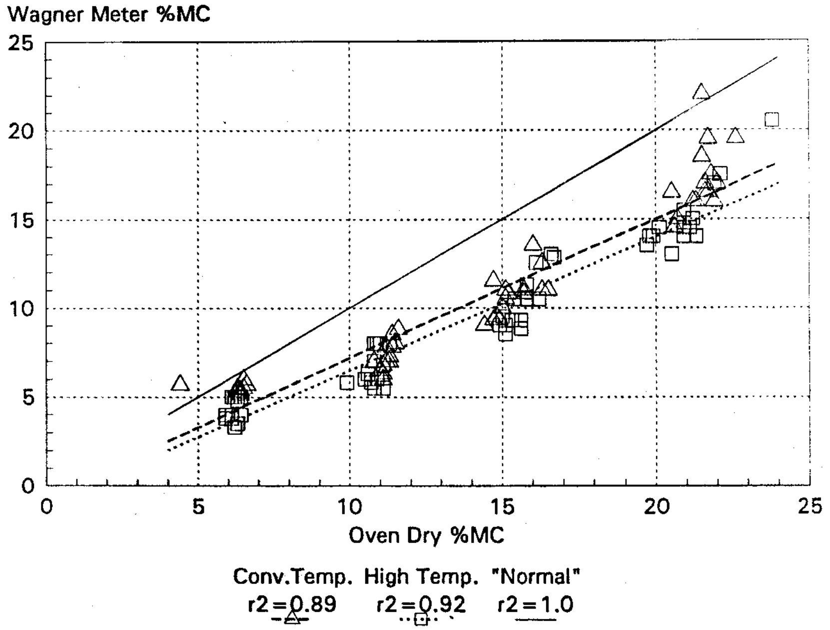

Figure 7. Data and regression lines for eastern hemlock tested with a capacitance-type meter.

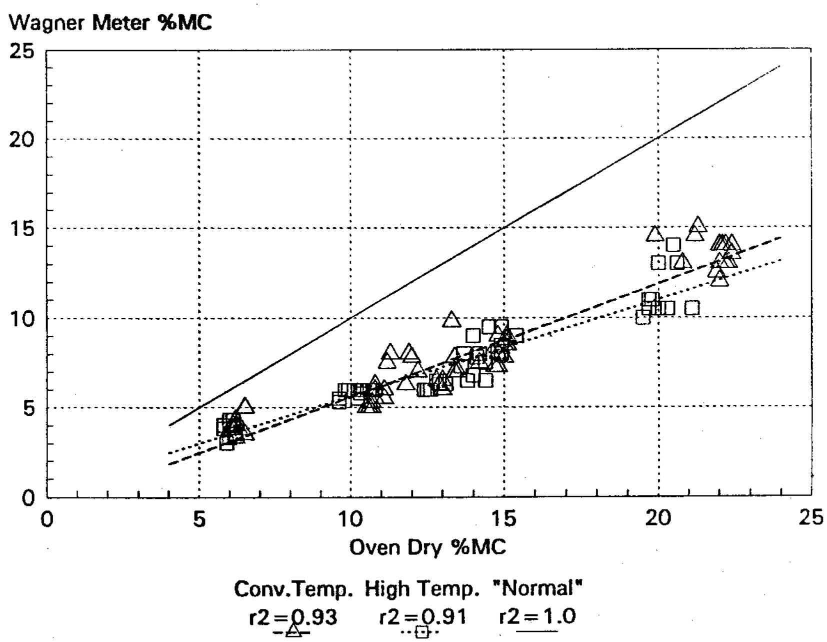

Figure 8. Data and regression lines for norway spruce tested with a capacitance-type meter.

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