# EFFECT OF SPECIFIC GRAVITY AND SPECIES ON A CAPACITANCE-TYPE MOISTURE METER

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## INTRODUCTION

Correct estimation of kiln-dry moisture content is important at the sawmill so products are dimensionally stable for secondary manufacturing. Recently, increased kiln drying of export lumber has increased claims for improper drying against US firms and focused more attention on accurate estimation of moisture content. Moisture content is usually inferred based on either the electrical resistance or the dielectric constant of the wood. Very few firms, at least in the Western US, use the oven-dry test method.

The Western Wood Products Association (WWPA) oversees grading of 35 percent the nation's softwood lumber. The grade often specifies a moisture content or an upper limit for moisture content. Several years ago the WWPA discontinued using the pin- or resistance-type moisture meter in favor of a nonpenetrating, dielectric-type moisture meter[1] for reinspection of lumber when a claim is raised. At that time the available species correction factors for this meter were based on a small number of samples of material from unknown locations. WWPA inspectors were reporting unexplainable irregularities in meter readings and both the manufacturer and WWPA saw a need to further investigate the effect of species on the meter readings.

The objective of this work was, first, to develop species correction factors for use by the WWPA inspectors and mills. And second, to determine if the correction factor for a given species can be estimated based on specific gravity. This latter objective, if true, would eliminate the need for extensive testing of every species.

## MATERIAL AND METHODS

Douglas-fir (*Pseudotsuga menziesii*) was used as an experimental control because moisture meters are factory-calibrated to not need a correction factor for this species. Several other softwood species, were chosen because of their commercial importance and range of specific gravity. These included lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), western red cedar (*Thuja plicata*), western larch (*Larix occidentallis*) and the hem-fir species group. White oak (a subgroup of *Quercus*) was chosen because its specific gravity is significantly higher than the softwoods and adds greater range to that variable.

Commercially, the true firs (*Abies* spp.) and western hemlock (*Tsuga heterophylla*) are sold together under the name hem-fir. The true firs are not separable based on anatomical properties and the true firs cannot reliably be separated from hemlock. For this reason, we used two hem-fir groupings. Group 1, from western Washington and Oregon, we believe is 100 percent

[1] Model L-600 manufactured by Wagner Electronic Products, Rogue River, OR

hemlock. Group 2, from California and the East side of the Cascades, we believe is 100 percent white fir (*A. concolor*). This is based on what the mills were cutting at the time of sampling.

Fresh, green, nominal 2" by 4", samples were obtained from the 23 locations listed in Table 1. Sampling occurred between November 11, 1991 and April 21, 1992. The samples ranged from 1' to 2' in length. Either 40 or 80 samples were selected from each mill. Mills were selected to obtain samples from a wide geographic range. There are noticeable differences in the specific gravity and drying behavior within a species, for example, Douglas-fir from the Coast range versus Cascade range and inland and ponderosa pine from the west or east side of the Cascades. It is unknown if these differences, with the exception of specific gravity, affect the dielectric moisture meters.

Samples were placed on stickers and dried to a constant weight at EMCs of 22, 18, 12, and 8% at 100°F in a laboratory dry kiln. Each sample was first conditioned from green, then moved sequentially to drier conditions. This process took approximately four months for the first condition and two months for the others. After reaching the first moisture content, approximately 22%, the samples were planed on both faces. This provided a consistent surface on which to place the meters. Otherwise it was felt that mill-to-mill and piece-to-piece variation in surface roughness would affect the results.

At each EMC, the samples were weighed, and four dielectric moisture meter readings were made on each sample, one on each wide face with each meter. Two model L-600 dielectric-type moisture meters were used. Each was calibrated by the manufacturer just prior to and just after the study period. Repeatability of the meters throughout the 1-year study was assured by reading a calibration standard every 30 minutes during testing. The meters' scales read from 6 to 30% moisture content. Readings outside this range were recorded as either high or low. Care was taken to maintain the samples at approximately 70°F during testing, although the readings should be independent of temperature for this meter. Marks were made on each face of the samples so placement of the meter on the sample was the same for the four EMC conditions. The meter was not pressed hard against the sample, rather it was just placed on the sample for greater repeatability. At the end of the experiment, each sample was ovendried at 220°F for 48 hours and weighed. Finally, the samples were cut to square the edges, oven dried again, and weighed. Length, width, and thickness measurements were made at this time.

## DATA ANALYSIS

Upon receiving the calibrated moisture meters from the manufacturer prior to the study, meter #1 read approximately 1.5% lower than meter #2 on the calibration standard. This difference remained constant throughout the study. The meters were again checked by the manufacturer at the end of the study. All of the data was adjusted, a 0.25% increase for meter #1 and a 0.75% decrease for meter #2. The remaining 0.50% difference encountered using the calibration standard at OSU was never accounted for.

The sample weight at each EMC condition and the oven-dry weight were used to gravimetrically obtain the dry-basis moisture content at each condition. Specific gravity was calculated based on dry weight and dry volume. These values were then adjusted to 12% moisture content according to ASTM D-2395-83.

Table 1. Species and mills from which the wood was obtained. The number of samples from each mill is shown.

| MILL | LOCATION | SPECIES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | DF | LP | RC | ES | WH | WF | LA | WO |
| 1 | Bonners Ferry, ID | 40 | 40 | | | | | | |
| 2 | Lewiston, ID | | | 40 | | | | | |
| 3 | Forest Grove, OR | | | 40 | | | | | |
| 4 | Anderson, CA | 40 | | | | | | | |
| 5 | Snoqualimie, WA | | | | | 80 | | | |
| 6 | Port Gamble, WA | 40 | | | | | | | |
| 7 | Riddle, OR | | | 40 | | | | | |
| 8 | Willits, CA | 40 | | | | | | | |
| 9 | Saratoga, WY | | 40 | | 40 | | | | |
| 10 | Molala, OR | | | | | 40 | | | |
| 11 | Colville, WA | | | 40 | | | 40 | | |
| 12 | Quincy, CA | | | | | | 40 | | |
| 13 | Standard, CA | | | | | | 40 | | |
| 14 | Warrenton, OR | | | | | 40 | | | |
| 15 | Deer Lodge, MT | | 40 | | 40 | | | | |
| 16 | St. Maries, ID | | | | | | 40 | 80 | |
| 17 | Elgin, OR | | | | 40 | | | | |
| 18 | Fortine, MT | | 40 | | 40 | | | | |
| 19 | Cayuta, NY | | | | | | | | 40 |
| 20 | Galway, NY | | | | | | | | 40 |
| 21 | Moyie Springs, ID | | | | | | | 40 | |
| 22 | Kettle Falls, WA | | | | | | | 40 | |
| 23 | Montezuma, IN | | | | | | | | 40 |

The moisture meter readings from each face of a sample were averaged for each meter and used in regression analyses. The independent variable in these analyses was the gravimetrically-determined moisture content and the dependent variable was the meter reading. Several simple linear regressions were done to show the effect of mill, meter, and species. Correction factors were determined based on a regression which included the data from all mills and both meters.

Slope and intercept of the regression lines for each species were then regressed against specific gravity to determine if the specific gravity of a species can be used to estimate correction factors. Slope or intercept were the dependent variables and specific gravity was the independent variable.

A multiple regression was done using the model

$$CF = \beta_0 + \beta_1 * MM + \beta_2 * SG + \beta_3 * SG * MM + \varepsilon \qquad (1)$$

to provide a CF-SG relationship that accounts for the changing moisture content. CF is the correction factor and MM is the moisture meter reading. The moisture meter reading was obtained by adding the correction factor to the true moisture content.

## RESULTS AND DISCUSSION

### Specific gravity

The specific gravity of the samples at 12% moisture content by mill and species are shown in Table 2. The experimental values are comparable to those published in the Wood Handbook with the exception of lodgepole pine. For this species the experimentally-determined specific gravity was 0.03 higher than the published value. Statistically, there were differences between the experimentally-determined values and the published values and between the experimentally-determined values for lumber from mills within the study; however, a sample taken over a one- or two-day period should not be taken as indicative of the mill's total production. Nor is a sample from four mills indicative of the species average. This is especially true for the white oak because of the large differences in specific gravity between species within the group. Specific gravity was determined in this study because of its effect on moisture meter readings, not to make comparisons between regions.

The two hem-fir species had similar specific gravities which matched the specific gravity for white fir (0.38). The western hemlock had a lower than expected specific gravity (SG=0.45, Wood Handbook). This may be because the source was second and third growth timber.

Table 2. Specific gravity by species and mill. Experimental values are adjusted to 12% moisture content. WH indicates the Wood Handbook value at 12%. Where multiple species may be in a group, a high and low value are given.

| SPECIES | MILL | SG | SPECIES | MILL | SG |
|---|---|---|---|---|---|
| Douglas-fir<br>0.49 ± 0.009<br>WH - 0.48/0.50 | 1 | 0.49 | White fir<br>0.38 ± 0.008<br>WH - 0.38/0.45 | 11 | 0.38 |
| | 4 | 0.46 | | 12 | 0.37 |
| | 6 | 0.47 | | 13 | 0.39 |
| | 8 | 0.50 | | 16 | 0.40 |
| Lodgepole pine<br>0.44 ± 0.008<br>WH - 0.41 | 1 | 0.44 | Western larch<br>0.54 ± 0.013<br>WH - 0.52 | 16 | 0.55 |
| | 9 | 0.43 | | 21 | 0.53 |
| | 15 | 0.42 | | 22 | 0.53 |
| | 18 | 0.47 | | - | - |
| Western red cedar<br>0.33 ± 0.006<br>WH - 0.32 | 2 | 0.34 | Engelmann spruce<br>0.37 ± 0.006<br>WH - 0.37 | 9 | 0.39 |
| | 3 | 0.31 | | 15 | 0.36 |
| | 7 | 0.34 | | 17 | 0.39 |
| | 11 | 0.32 | | 18 | 0.35 |
| Western hemlock<br>0.38 ± 0.006<br>WH - 0.38/0.45 | 5 | 0.36 | White oak<br>0.66 ± 0.014<br>WH - 0.66/0.72 | 19 | 0.60 |
| | 10 | 0.39 | | 20 | 0.71 |
| | 14 | 0.41 | | 23 | 0.68 |

## Corrections

Moisture meter data and regression lines by species and mill are shown in Figure 1. Some differences are noted between mills. For example, for Douglas-fir at 15% moisture content, the regression lines indicate meter readings of 13.7% for mill 4 and 17.2% for mill #6. These differences cannot be explained based on specific gravity since the wood from these mills had similar specific gravity. However, it was later discovered that logs at mill #6 are ponded in salt water. This explains the points (squares in Figure 1) which are well above the data cluster. For western hemlock, wood from mill 5 had the lowest specific gravity and the lowest predicted values for the regression line. Despite these differences, general conclusions about differences between mills cannot drawn.

In Figure 2, the data and regression lines are plotted by species. The data from mill #6 is not included in this analysis. Confidence intervals (95%) are also shown. The correction factors in Table 3 were obtained from the regression lines shown. Table 3 also shows the slope and intercept of the lines in Figure 2.

Table 3. Species correction factors. The slope and intercept (from Fig. 3) describe the regression line from which the correction factors were calculated. DF=Douglas-fir, LP=lodgepole pine, ES=Engelmann spruce, WH=western hemlock, WL=western larch, WF=white fir, and WO=white oak. A small correction for Douglas-fir appears in the study but should not be applied in practice.

| Species | DF | LP | WRC | ES | WH | WL | WF | WO |
|---|---|---|---|---|---|---|---|---|
| Slope | 0.9704 | 1.0344 | 0.9751 | 0.9336 | 0.9901 | 0.9816 | 1.0408 | 1.3982 |
| Intercept | 0.0631 | -2.035 | -4.202 | -2.437 | -2.821 | 1.686 | -2.5512 | 0.2456 |
| $r^2$ | 0.89 | 0.88 | 0.80 | 0.82 | 0.78 | 0.79 | 0.77 | 0.87 |
| Meter | Correction | | | | | | | |
| 6 | 0.1 | 1.8 | 4.5 | 3.0 | 2.9 | -1.6 | 2.2 | -1.9 |
| 7 | 0.1 | 1.7 | 4.5 | 3.1 | 2.9 | -1.6 | 2.2 | -2.2 |
| 8 | 0.2 | 1.7 | 4.5 | 3.2 | 2.9 | -1.6 | 2.1 | -2.5 |
| 9 | 0.2 | 1.7 | 4.5 | 3.3 | 2.9 | -1.5 | 2.1 | -2.7 |
| 10 | 0.2 | 1.6 | 4.6 | 3.3 | 2.9 | -1.5 | 2.1 | -3.0 |
| 11 | 0.3 | 1.6 | 4.6 | 3.4 | 3.0 | -1.5 | 2.0 | -3.3 |
| 12 | 0.3 | 1.6 | 4.6 | 3.5 | 3.0 | -1.5 | 2.0 | -3.6 |
| 13 | 0.3 | 1.5 | 4.6 | 3.5 | 3.0 | -1.5 | 1.9 | -3.9 |
| 14 | 0.4 | 1.5 | 4.7 | 3.6 | 3.0 | -1.5 | 1.9 | -4.2 |
| 15 | 0.4 | 1.5 | 4.7 | 3.7 | 3.0 | -1.4 | 1.9 | -4.4 |
| 16 | 0.4 | 1.4 | 4.7 | 3.7 | 3.0 | -1.4 | 1.8 | -4.7 |
| 17 | 0.5 | 1.4 | 4.7 | 3.8 | 3.0 | -1.4 | 1.8 | -5.0 |
| 18 | 0.5 | 1.4 | 4.8 | 3.9 | 3.0 | -1.4 | 1.7 | -5.3 |
| 19 | 0.5 | 1.3 | 4.8 | 4.0 | 3.0 | -1.4 | 1.7 | -5.6 |
| 20 | 0.5 | 1.3 | 4.8 | 4.0 | 3.0 | -1.3 | 1.7 | -5.9 |
| 21 | 0.6 | 1.3 | 4.8 | 4.1 | 3.1 | -1.3 | 1.6 | -6.2 |
| 22 | 0.6 | 1.2 | 4.9 | 4.2 | 3.1 | -1.3 | 1.6 | -6.4 |
| 23 | 0.6 | 1.2 | 4.9 | 4.2 | 3.1 | -1.3 | 1.5 | -6.7 |
| 24 | 0.7 | 1.2 | 4.9 | 4.3 | 3.1 | -1.3 | 1.5 | -7.0 |
| 25 | 0.7 | 1.1 | 4.9 | 4.4 | 3.1 | -1.2 | 1.5 | -7.3 |
| 26 | 0.7 | 1.1 | 5.0 | 4.5 | 3.1 | -1.2 | 1.4 | -7.6 |
| 27 | 0.8 | 1.1 | 5.0 | 4.5 | 3.1 | -1.2 | 1.4 | -7.9 |
| 28 | 0.8 | 1.0 | 5.0 | 4.6 | 3.1 | -1.2 | 1.4 | -8.1 |
| 29 | 0.8 | 1.0 | 5.0 | 4.7 | 3.1 | -1.2 | 1.3 | -8.4 |
| 30 | 0.9 | 1.0 | 5.1 | 4.7 | 3.1 | -1.2 | 1.3 | -8.7 |

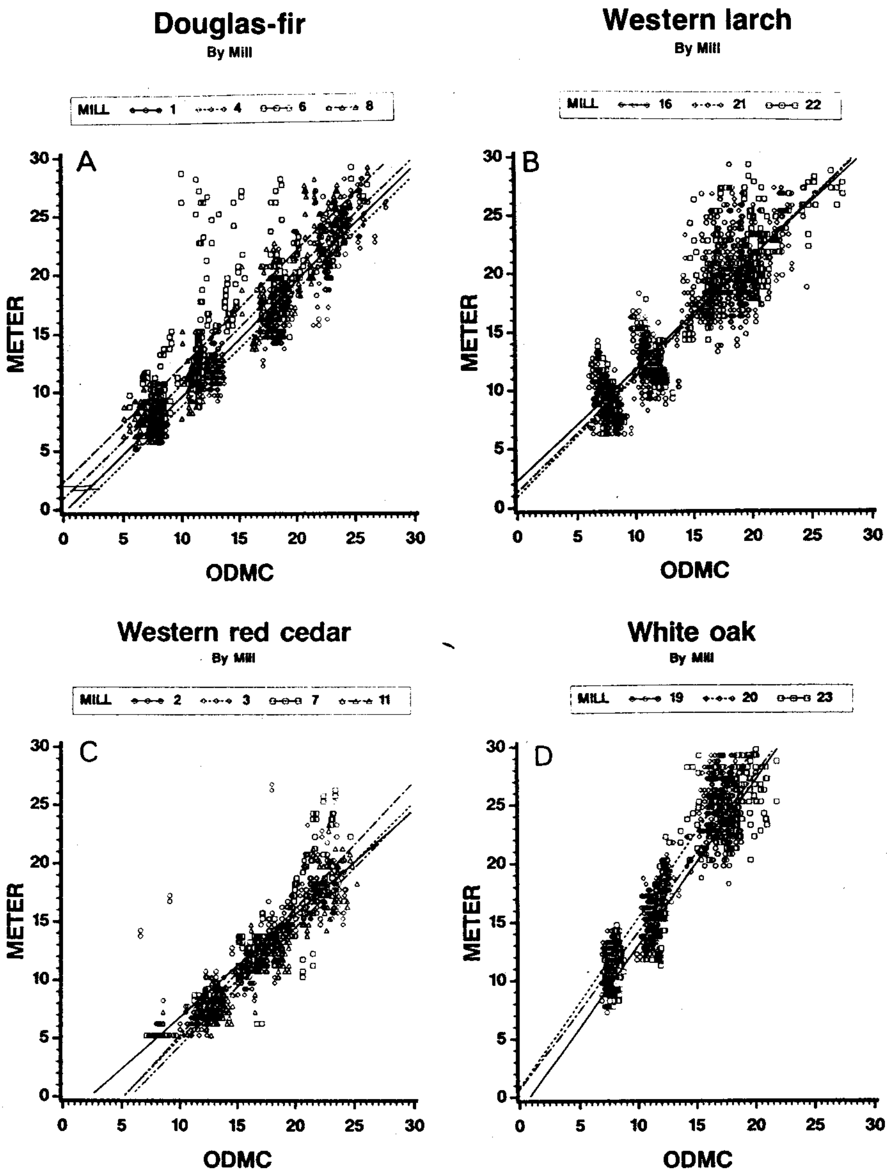


Figure 1. Moisture meter data by species and mill. Mill numbers correspond to Table 1. Lines are the least squares best fit for that mill.

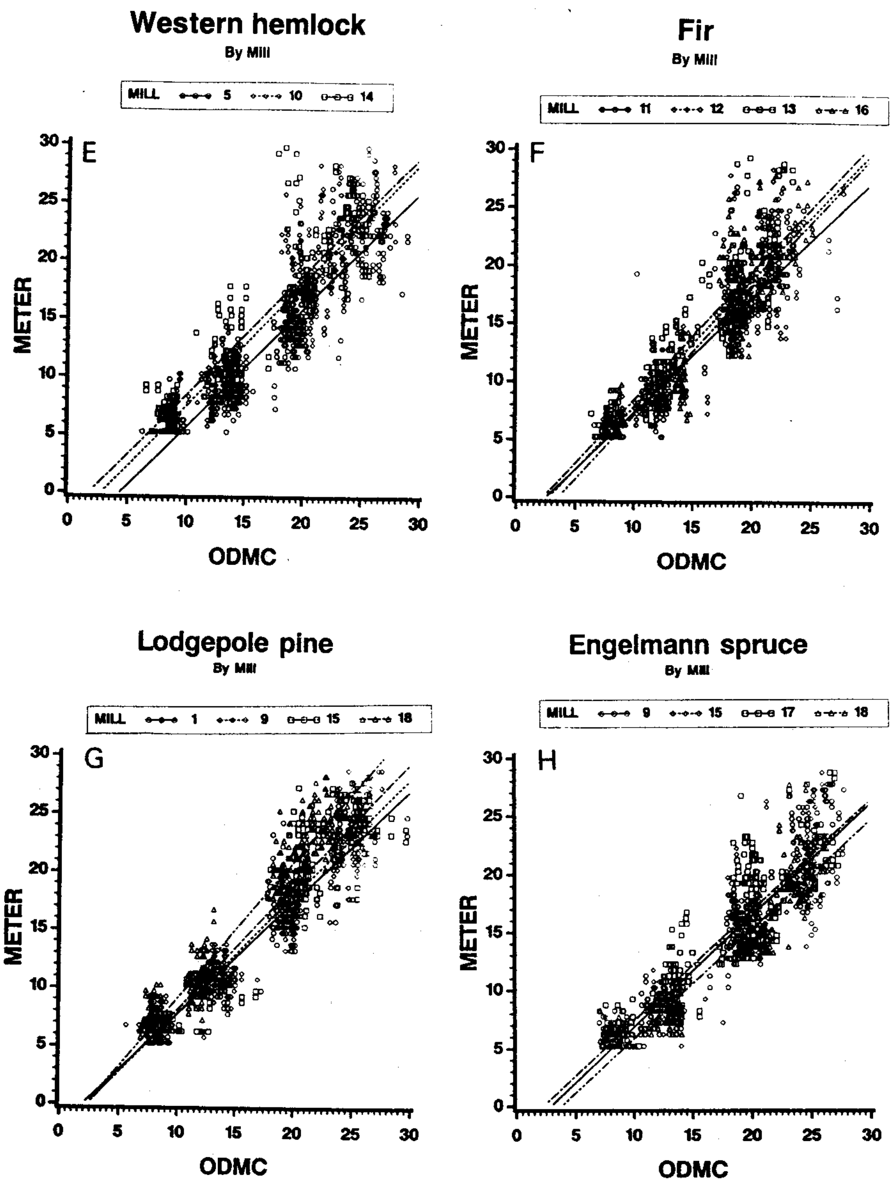


Figure 1. (continued). Moisture meter data by species and mill. Mill numbers correspond to Table 1. Lines are the least squares best fit for that mill.

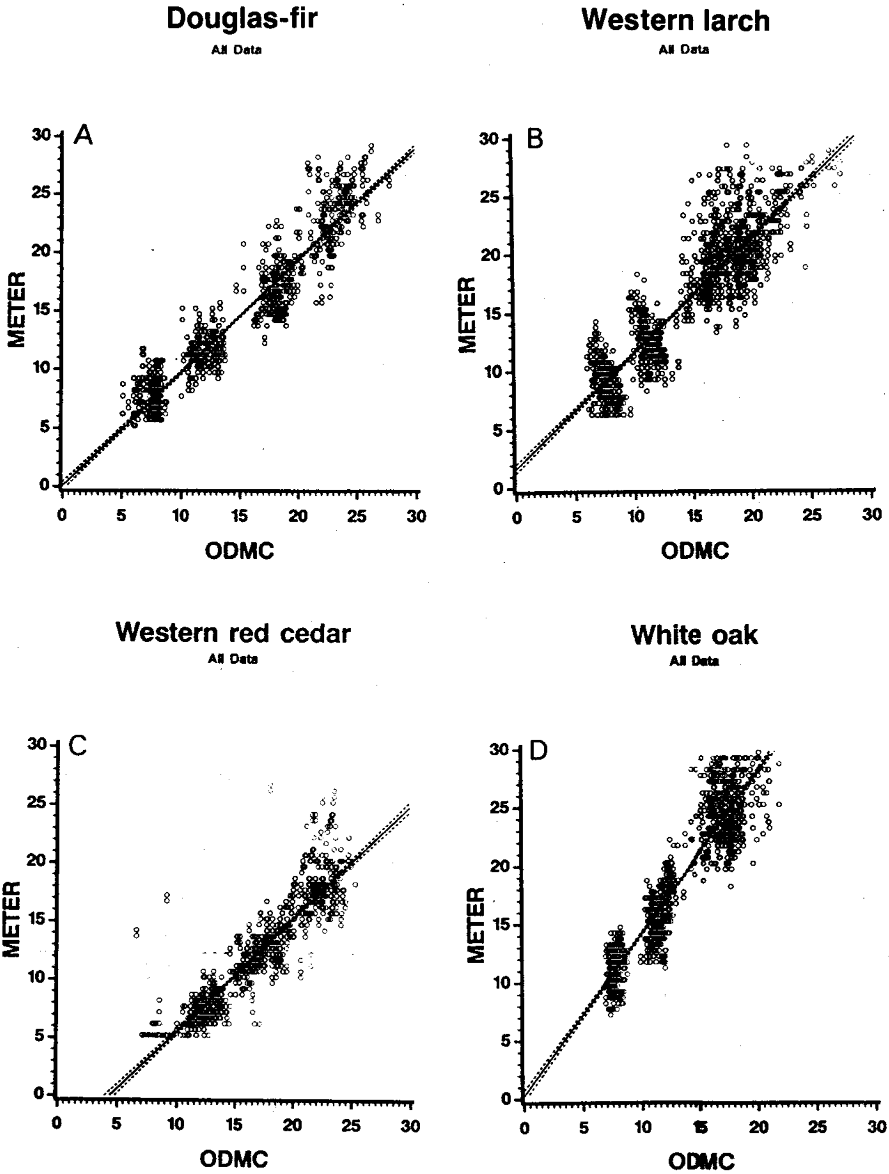


Figure 2. Moisture meter data by species. Data from all mills and both meters are combined. Lines are the least squares best fit for the data and are used for correction factors in Table 3. Mill 6 was deleted for Douglas-fir.

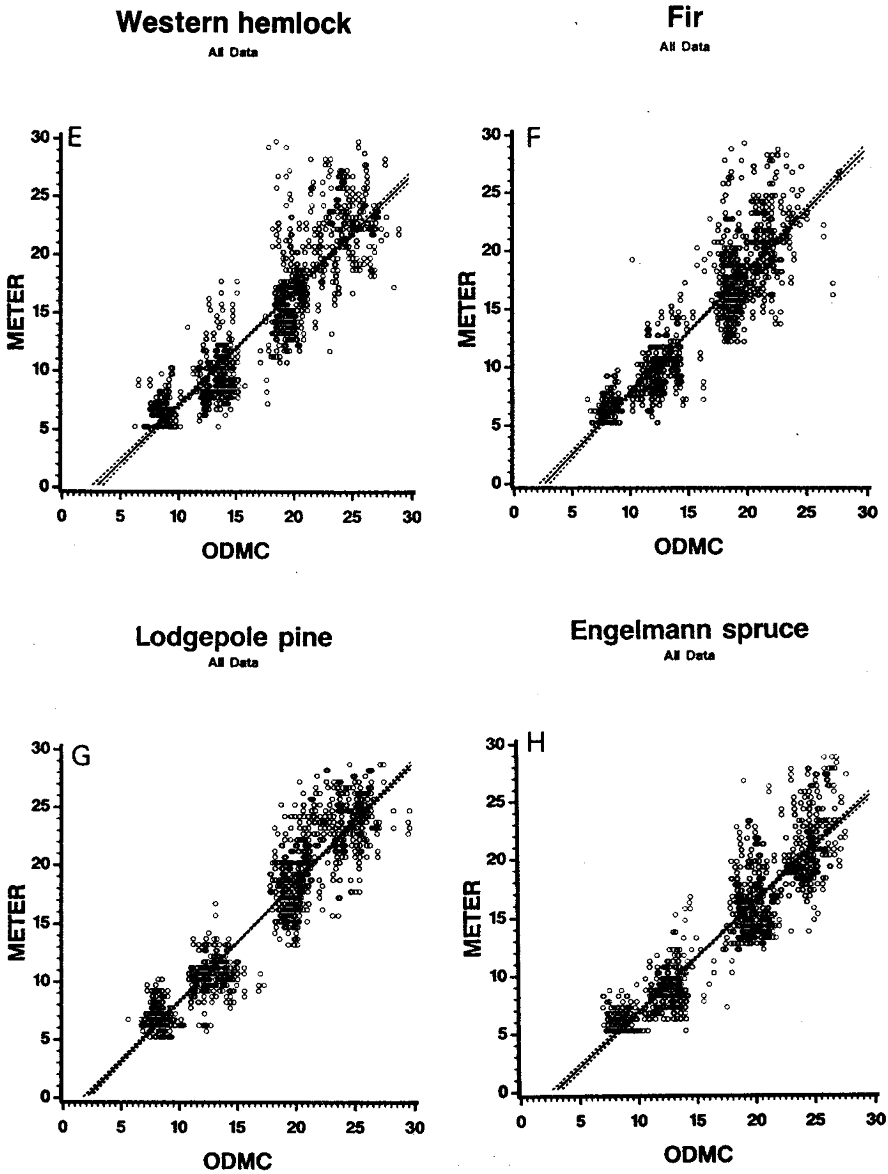


Figure 2. (continued). Moisture meter data by species. Data from all mills and both meters are combined. Lines are the least squares best fit for the data and are used for correction factors in Table 3.

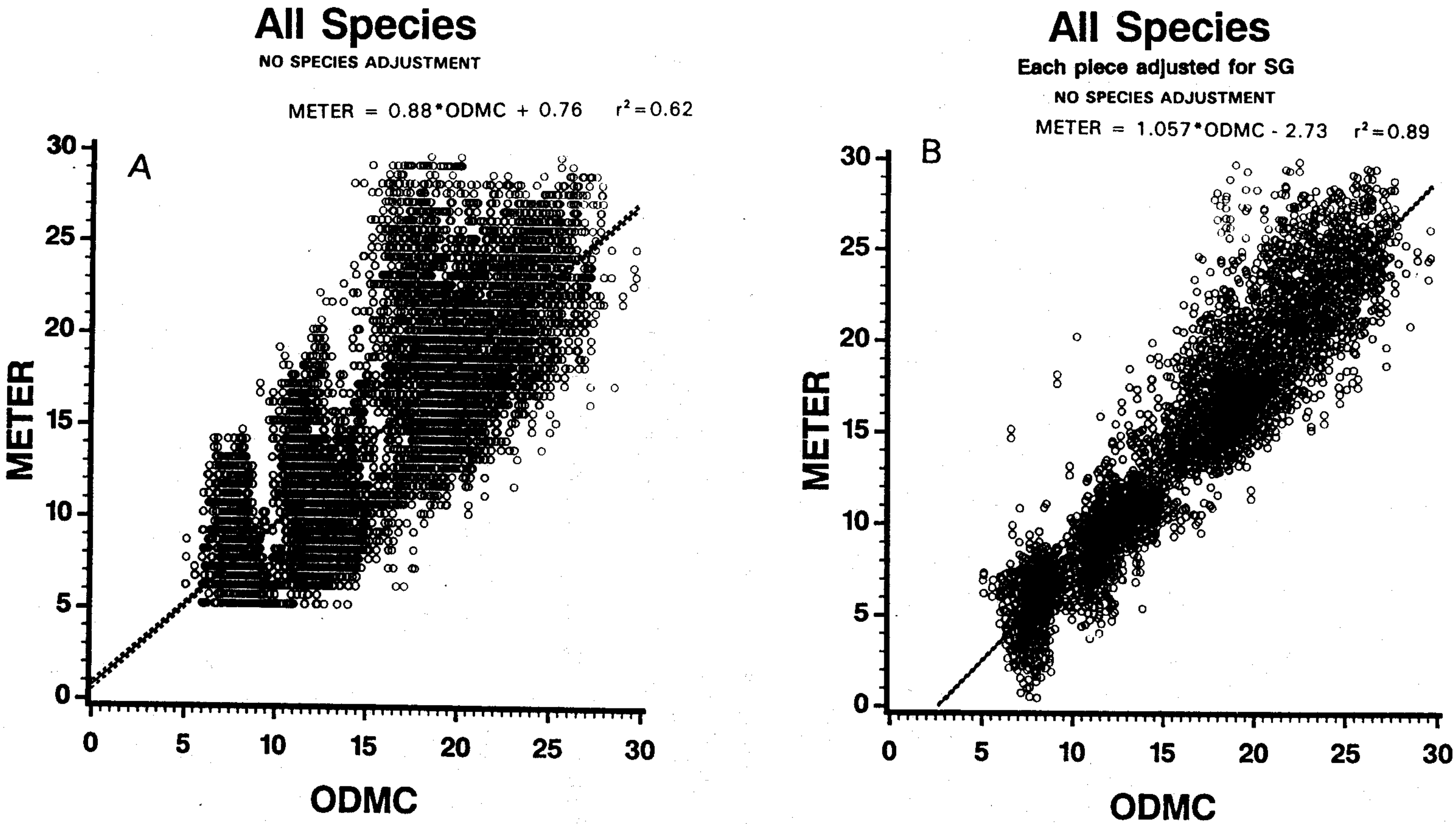


Figure 3. Moisture meter readings versus gravimetrically-determined moisture content. A - raw data. B - corrected for specific gravity.

### Douglas-fir

The correction factors for Douglas-fir should be zero throughout the 6 to 30 percent moisture content range. As shown in Table 3 the correction factors are positive ranging from 0.1% at low moisture contents to 0.9% at high moisture contents. However, the mill-to-mill variability displayed in Figure 1a (for mills 1, 4, and 8) suggests that this difference may be due to the source of the wood. At moisture contents below about 10%, the confidence band includes the line y=x. Based on this, no changes are suggested to the meter calibration.

No correction factors are necessary for Douglas-fir.

### Comparison to manufacturer's correction factors

The manufacture's correction factors for white oak, western red cedar, and Engelmann spruce agreed well with the correction factors determined in this study. Only approximate agreement would be expected given the variation between mills. The new correction factors are calculated based on a linear relationship whereas the old correction factors are nonlinear with respect to moisture content. This also may contribute to some of the differences.

There is good agreement between the manufacture's corrections for hemfir and this study's corrections for western hemlock and poor agreement for white fir. Hem-fir is an unpredictable mixture of species and, based on the results of this study, the species themselves have different correction factors. Therefore, the species mix in the manufacturer's original sample could contribute to the discrepancy. Similar results may be expected in the field and suspicious readings should be verified by an oven-dry test.

### Specific gravity as a predictor of correction factors

The effect of specific gravity on the experimental results is great. In Figure 3a, the moisture meter readings are plotted against true moisture content for all eight species. Each point was then adjusted for specific gravity such that:

$$\textit{Meter Reading}_{corrected} = \textit{Meter Reading} + (SG - 0.45)*27.7 \quad (2)$$

The corrected points were then replotted in Figure 3b. This is similar to what the data would look like if there had been no variation in specific gravity (every piece at 0.45). The coefficient, 27.7, was obtained from a multiple regression of CF = f(MM,SG). Despite eight species being represented on the plot, $r^2=0.89$ for the relationship between meter reading and gravimetrically-determined moisture content. In practice, as individual meter readings are taken, the specific gravity of the sample is not known. Therefore, a species-averaged specific gravity must be used for correction factors.

The slope and intercept of the regression lines in Figure 2 increased with specific gravity, but when regressed against specific gravity, the correlation is not strong ($r^2=0.38$ and $r^2=0.67$, respectively). Thus, other factors influence the intercept besides the amount of wood substance present in the field of measurement of the meter. The amount of water in a piece increases with specific gravity at a given moisture content. However, within the softwoods, the specific gravity appeared to have minimal influence on the slope. Specific gravity is not a good indicator of the slope or intercept individually.

Table 4. Correction factor table as a function of wood specific gravity at 12% moisture content. This Table can be used as an approximation if a correction factor table is not available for a given species. Add the value in the table to the meter reading to estimate the true moisture content.

| | Specific Gravity | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Meter | 0.32 | 0.34 | 0.36 | 0.38 | 0.40 | 0.42 | 0.44 | 0.46 | 0.48 | 0.50 | 0.52 | 0.54 | 0.56 | 0.58 | 0.60 | 0.62 | 0.64 | 0.66 |
| 6 | 4.1 | 3.7 | 3.3 | 2.9 | 2.5 | 2.1 | 1.8 | 1.4 | 1.0 | 0.6 | 0.2 | -0.2 | -0.6 | -1.0 | -1.4 | -1.8 | -2.2 | -2.6 |
| 7 | 4.2 | 3.8 | 3.3 | 2.9 | 2.5 | 2.1 | 1.7 | 1.3 | 0.9 | 0.5 | 0.1 | -0.3 | -0.7 | -1.1 | -1.5 | -1.9 | -2.3 | -2.7 |
| 8 | 4.2 | 3.8 | 3.4 | 3.0 | 2.5 | 2.1 | 1.7 | 1.3 | 0.9 | 0.5 | 0.0 | -0.4 | -0.8 | -1.2 | -1.6 | -2.0 | -2.5 | -2.9 |
| 9 | 4.3 | 3.8 | 3.4 | 3.0 | 2.5 | 2.1 | 1.7 | 1.3 | 0.8 | 0.4 | -0.0 | -0.5 | -0.9 | -1.3 | -1.7 | -2.2 | -2.6 | -3.0 |
| 10 | 4.3 | 3.9 | 3.4 | 3.0 | 2.5 | 2.1 | 1.7 | 1.2 | 0.8 | 0.3 | -0.1 | -0.5 | -1.0 | -1.4 | -1.9 | -2.3 | -2.8 | -3.2 |
| 11 | 4.4 | 3.9 | 3.5 | 3.0 | 2.5 | 2.1 | 1.6 | 1.2 | 0.7 | 0.3 | -0.2 | -0.6 | -1.1 | -1.5 | -2.0 | -2.4 | -2.9 | -3.4 |
| 12 | 4.4 | 3.9 | 3.5 | 3.0 | 2.5 | 2.1 | 1.6 | 1.1 | 0.7 | 0.2 | -0.3 | -0.7 | -1.2 | -1.7 | -2.1 | -2.6 | -3.1 | -3.5 |
| 13 | 4.5 | 4.0 | 3.5 | 3.0 | 2.5 | 2.1 | 1.6 | 1.1 | 0.6 | 0.2 | -0.3 | -0.8 | -1.3 | -1.8 | -2.2 | -2.7 | -3.2 | -3.7 |
| 14 | 4.5 | 4.0 | 3.5 | 3.0 | 2.5 | 2.1 | 1.6 | 1.1 | 0.6 | 0.1 | -0.4 | -0.9 | -1.4 | -1.9 | -2.4 | -2.9 | -3.3 | -3.8 |
| 15 | 4.6 | 4.1 | 3.6 | 3.1 | 2.5 | 2.0 | 1.5 | 1.0 | 0.5 | 0.0 | -0.5 | -1.0 | -1.5 | -2.0 | -2.5 | -3.0 | -3.5 | -4.0 |
| 16 | 4.6 | 4.1 | 3.6 | 3.1 | 2.5 | 2.0 | 1.5 | 1.0 | 0.5 | -0.0 | -0.5 | -1.1 | -1.6 | -2.1 | -2.6 | -3.1 | -3.6 | -4.2 |
| 17 | 4.7 | 4.1 | 3.6 | 3.1 | 2.5 | 2.0 | 1.5 | 1.0 | 0.4 | -0.1 | -0.6 | -1.1 | -1.7 | -2.2 | -2.7 | -3.3 | -3.8 | -4.3 |
| 18 | 4.7 | 4.2 | 3.6 | 3.1 | 2.5 | 2.0 | 1.5 | 0.9 | 0.4 | -0.2 | -0.7 | -1.2 | -1.8 | -2.3 | -2.9 | -3.4 | -3.9 | -4.5 |
| 19 | 4.8 | 4.2 | 3.7 | 3.1 | 2.6 | 2.0 | 1.4 | 0.9 | 0.3 | -0.2 | -0.8 | -1.3 | -1.9 | -2.4 | -3.0 | -3.5 | -4.1 | -4.6 |
| 20 | 4.8 | 4.2 | 3.7 | 3.1 | 2.6 | 2.0 | 1.4 | 0.9 | 0.3 | -0.3 | -0.8 | -1.4 | -2.0 | -2.5 | -3.1 | -3.7 | -4.2 | -4.8 |
| 21 | 4.9 | 4.3 | 3.7 | 3.1 | 2.6 | 2.0 | 1.4 | 0.8 | 0.2 | -0.3 | -0.9 | -1.5 | -2.1 | -2.6 | -3.2 | -3.8 | -4.4 | -5.0 |
| 22 | 4.9 | 4.3 | 3.7 | 3.1 | 2.6 | 2.0 | 1.4 | 0.8 | 0.2 | -0.4 | -1.0 | -1.6 | -2.2 | -2.8 | -3.3 | -3.9 | -4.5 | -5.1 |
| 23 | 5.0 | 4.4 | 3.8 | 3.2 | 2.6 | 2.0 | 1.3 | 0.7 | 0.1 | -0.5 | -1.1 | -1.7 | -2.3 | -2.9 | -3.5 | -4.1 | -4.7 | -5.3 |
| 24 | 5.0 | 4.4 | 3.8 | 3.2 | 2.6 | 1.9 | 1.3 | 0.7 | 0.1 | -0.5 | -1.1 | -1.7 | -2.4 | -3.0 | -3.6 | -4.2 | -4.8 | -5.4 |
| 25 | 5.1 | 4.4 | 3.8 | 3.2 | 2.6 | 1.9 | 1.3 | 0.7 | 0.0 | -0.6 | -1.2 | -1.8 | -2.5 | -3.1 | -3.7 | -4.3 | -5.0 | -5.6 |
| 26 | 5.1 | 4.5 | 3.8 | 3.2 | 2.6 | 1.9 | 1.3 | 0.6 | -0.0 | -0.6 | -1.3 | -1.9 | -2.6 | -3.2 | -3.8 | -4.5 | -5.1 | -5.8 |
| 27 | 5.2 | 4.5 | 3.9 | 3.2 | 2.6 | 1.9 | 1.3 | 0.6 | -0.0 | -0.7 | -1.4 | -2.0 | -2.7 | -3.3 | -4.0 | -4.6 | -5.3 | -5.9 |
| 28 | 5.2 | 4.6 | 3.9 | 3.2 | 2.6 | 1.9 | 1.2 | 0.6 | -0.1 | -0.8 | -1.4 | -2.1 | -2.8 | -3.4 | -4.1 | -4.8 | -5.4 | -6.1 |
| 29 | 5.3 | 4.6 | 3.9 | 3.2 | 2.6 | 1.9 | 1.2 | 0.5 | -0.1 | -0.8 | -1.5 | -2.2 | -2.9 | -3.5 | -4.2 | -4.9 | -5.6 | -6.2 |
| 30 | 5.3 | 4.6 | 3.9 | 3.3 | 2.6 | 1.9 | 1.2 | 0.5 | -0.2 | -0.9 | -1.6 | -2.3 | -3.0 | -3.6 | -4.3 | -5.0 | -5.7 | -6.4 |

Multiple regression using equation 1 gave $\beta_0=8.77$, $\beta_1=0.249$, $\beta_2=-15.86$, and $\beta_3=-0.620$ with $r^2=0.95$. Thus, the model accounts for 95% of the variation in the data and it is likely that correction factors can be estimated based on the specific gravity of the species. However, it would be good to test this hypothesis on more species, particularly those with correction factors that are large or very dependent on moisture content.

In Table 4, correction factors predicted by Equation 1 are presented. For species without a published set of corrections, determine the average specific gravity at 12% (from Wood Handbook) and read the corrections from the table vertically as a function of moisture content.

## CONCLUSIONS

The L-600 moisture meter works well with no correction on Douglas-fir. Given the mill-to-mill variability observed in this study, changing the meter's electronics or using correction factors to account for the new data is not necessary.

For western red cedar and Engelmann spruce the agreement between the current data and the manufacturer's correction factors is good. If the sample size in this study is substantially larger than that upon which the original correction factors are based, then using the correction factors from this study is advised.

Hem-fir is a mix of several species and within this study the results varied. The manufacturer's correction factors are between the two sets of data in this study. Therefore, there is no basis for changing them. Problems in the field can be expected, however, as the specific gravity changes due to a changing species mix in hem-fir.

The species correction factors can be estimated based on the average specific gravity of the species using equation 1; however, more species should be tested for verification. Within a species, a 0.036 variation in specific gravity is likely to result in a 1% variation in the moisture meter reading.

## REFERENCES

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