CALIBRATION OF MOISTURE METERS FOR SOUTHERN HARDWOODS

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ABSTRACT

Correction factors for resistance- and capacitance-type moisture meters were determined for 13 southern commercial hardwood species. The correction factors can be used with most resistance-type and the Wanger L-612 capacitance-type moisture meters in the range from 6 to 26 percent moisture content.

Much of the hardwood lumber that is kiln-dried is destined for indoor utilization in secondary forest products. It is essential that such lumber be properly kiln-dried to minimize problems such as warp and starved glue joints. The use of moisture meters to determine wood moisture content (MC) is favored by the industry because they are fast, inexpensive, nondestructive, and relatively simple to use. A primary barrier to proper utilization of moisture meters is the need for species-specific correction factors. The manufacturer typically provides these factors for some traditional commercially valuable species. For other species, a correction factor must be developed.

Species correction factors have previously been established by Milota (1996) and Salamon (1972) for several western hardwood and softwood species, respectively. Previous research has also established moisture meter correction factors for northern hardwoods (Wengert and Bois 1997), dahurian larch (*Larix dahurica*) (Milota and Gupta 1996), jelutong (*Dyera costulata*) (Milota 1991), baldcypress (*Taxodium distichum*) (Wu 1997), and Pacific yew (*Taxus brevifolia*) (Simpson and Loehnertz 1994), and four topical wood species (Simpson 1994). Other studies have investigated proper use and calibration of moisture meters (ASTM 1992, James 1988).

Numerous investigations have examined the influence of wood density and temperature on the performance of various moisture meters. Specifically, specific gravity was used as a predictor of species correction factors for a capacitance-type moisture meter (Milota 1994). Quarles and Breiner (1989) developed multiple-regression techniques to determine the relationship between readings from a given meter and MC and density. They found that the incorporation of density significantly improved the model for the high-frequency in-line and resistance handheld moisture meters but not for the low dual-frequency in-line or power-loss handheld moisture meters. Similar findings were reported by Quarles and Milota (1991). The influence of kiln temperature on the performance of handheld moisture meters seems to be minimal (Milota and Quarles 1990).

The two types of portable electric meters in widespread use today are resistance types and dielectric (or capacitance) types. Wengert and Bois (1997) found that both meter types performed quite well, with the readings seldom being more than 2 percent MC different from the ovendry MC. Wilson (1999) found that in industrial conditions, in timber stored under shelter, a capacitance-type meter performed better than three resistance-type meters.

Correction factors are not currently available for many southern hardwood species. For example, correction factors for several of the species included in this study were not included with instructional materials received with the resistance meter from the Delmhorst Instrument Co. (Anonymous 1993). Therefore, the objective of this study was to determine the species correction factor for 13 southern hardwood species using a dielectric- and resistance type meter.

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*Forest Products Society Member.

Forest Prod. J. 52(7/8):59-62.

TABLE 1. — Specific gravity value by species.

Wood species	Scientific name	Specific gravity (12% MC)	
		USDA Wood Handbook (1999)	This study
Ash	*Fraxinus americana* L.	0.60	0.51 (0.06)[a]
Cedar	*Juniperus virginia* L.	0.47	0.40 (0.02)
Cherry	*Prunus serotina* Ehrh.	0.50	0.59 (0.03)
Elm	*Ulmus americana* L.	0.50	0.52 (0.03)
Hackberry	*Celtis occidentalis* L.	0.53	0.47 (0.06)
Maple	*Acer saccharinum* L.	0.47	0.44 (0.08)
Pecan	*Carya illinoensis* (Wang.) Koch.	0.66	0.66 (0.05)
Red oak	*Quercus falcata* Michx.	0.59	0.64 (0.03)
Sap gum	*Liquidambar styraciflua* L.	0.52	0.50 (0.02)
Sycamore	*Platanus occidentalis* L.	0.49	0.53 (0.04)
White oak	*Quercus alba* L.	0.68	0.69 (0.05)
Willow	*Salix nigra* Marsh.	0.39	0.40 (0.01)
Yellow-poplar	*Lirodendron tulipifera* L.	0.42	0.47 (0.02)

[a] Values in parentheses are standard deviations.

TABLE 2. — Regression results on meter readings.

Species	Resistance meter MC_{OD} (%) = $a + b\ MC_{Meter}$ (%)			Capacitance meter MC_{OD} (%) = $a + b\ MC_{Meter}$ (%)		
	a	b	r^2	a	b	r^2
Ash	-0.543	1.1756	0.97	1.435	1.1125	0.87
Cedar	0.9688	0.9128	0.98	3.732	0.5911	0.90
Cherry	0.303	1.0297	0.96	4.637	0.8740	0.95
Elm	0.449	1.1573	0.92	2.928	1.0143	0.91
Hackberry	1.153	1.1397	0.94	2.931	0.9196	0.91
Maple	-0.311	1.0733	0.95	1.972	0.8755	0.78
Pecan	0.635	0.9979	0.96	2.149	1.2252	0.95
Red oak	1.273	1.1428	0.82	4.932	1.0871	0.80
Sap gum	0.667	0.9257	0.98	4.126	0.7601	0.96
Sycamore	2.138	0.9658	0.92	0.775	1.0443	0.97
White oak	0.822	1.1591	0.97	4.538	1.0952	0.85
Willow	1.248	1.2598	0.97	-0.013	1.3335	0.93
Yellow-poplar	1.315	0.7723	0.86	4.042	0.7208	0.87

TABLE 3. — Correction table for various species of wood (resistance-type meter).

Species	Meter reading								
	8%	10%	12%	14%	16%	18%	20%	22%	24%
Ash	-0.73	-0.88	-1.03	-1.33	-1.63	-1.93	-2.23	-2.53	-2.82
Cedar	-0.30	-0.20	-0.11	0.09	0.28	0.47	0.66	0.85	1.04
Cherry	-0.52	-0.55	-0.58	-0.63	-0.69	-0.75	-0.80	-0.86	-0.91
Elm	-1.47	-1.61	-1.74	-2.02	-2.29	-2.56	-2.83	-3.10	-3.37
Hackberry	-1.99	-2.11	-2.23	-2.48	-2.72	-2.96	-3.21	-3.45	-3.70
Maple	-0.25	-0.32	-0.39	-0.53	-0.66	-0.80	-0.93	-1.07	-1.21
Pecan	-0.62	-0.62	-0.62	-0.61	-0.61	-0.60	-0.60	-0.59	-0.59
Red oak	-2.10	-2.22	-2.34	-2.59	-2.83	-3.08	-3.32	-3.57	-3.82
Sap gum	-0.08	0.00	0.08	0.24	0.40	0.56	0.72	0.88	1.04
Sycamore	-1.92	-1.89	-1.85	-1.78	-1.71	-1.64	-1.57	-1.50	-1.43
White oak	-1.81	-1.94	-2.08	-2.35	-2.63	-2.90	-3.18	-3.45	-3.73
Willow	-2.64	-2.84	-3.05	-3.46	-3.87	-4.28	-4.69	-5.11	-5.52
Yellow-poplar	0.68	0.98	1.28	1.88	2.47	3.07	3.67	4.27	4.86

EXPERIMENTAL

Four 2.4-m-long, 127-mm-wide, 25-mm-thick (8-ft. by 5-in. by 1-in.) boards of 17 different species were obtained from two sawmills (**Table 1**). The mills were Fred Netterville Lumber Co. in Woodville, MS and Marionneaux Lumber Co., Inc. in Livonia, LA. The boards had been air-dried to about 30 percent MC. They were randomly selected in an order to obtain variability in the samples. The boards were planed on both faces, from which 20 clear pieces, each measuring 203 by 127 by 23 mm (8 by 5 by 0.92 in.), were cut for each species.

The test samples were stacked on a kiln cart and placed in a kiln at 100°F first at 90 percent relative humidity (RH), then 80, 65, and 45 percent RH, until equilibrium was reached at each condition. These conditions correspond to wood equilibrium MC of approximately 20, 15, 11, and 8 percent. At each of the four conditions, the samples were removed from the kiln and allowed to cool. They were covered with plastic film when not being handled or conditioned. One moisture measurement was made with each of two meters on each wide face of each sample, and the samples were weighed. At the end of the experiment, each sample was ovendried at 220°F for 48 hours and weighed. The sample volume was determined by the immersion method described in ASTM D 2395-83 (1993). The ovendry weight and volume were used to calculate specific gravity of each sample.

A Delmhorst model RC-1E moisture meter was used for the resistance-type

TABLE 4. — Correction table for various species of wood (capacitance-type meter).

Species	Meter reading 8%	10%	12%	14%	16%	18%	20%	22%	24%
Ash	-2.10	-2.20	-2.30	-2.50	-2.71	-2.91	-3.11	-3.31	-3.51
Cedar	-0.78	-0.08	0.61	1.99	3.37	4.76	6.14	7.52	8.91
Cherry	-4.09	-3.94	-3.79	-3.49	-3.20	-2.90	-2.60	-2.30	-2.00
Elm	-3.00	-3.01	-3.03	-3.06	-3.08	-3.11	-3.14	-3.17	-3.19
Hackberry	-2.49	-2.40	-2.31	-2.14	-1.96	-1.79	-1.62	-1.44	-1.27
Maple	-2.25	-2.25	-2.25	-2.25	-2.25	-2.25	-2.25	-2.25	-2.25
Pecan	-3.22	-3.40	-3.58	-3.95	-4.32	-4.69	-5.05	-5.42	-5.79
Red oak	-5.18	-5.27	-5.35	-5.51	-5.68	-5.84	-6.01	-6.17	-6.34
Sap gum	-2.90	-2.59	-2.27	-1.64	-1.01	-0.38	0.26	0.89	1.52
Sycamore	-1.08	-1.12	-1.16	-1.25	-1.33	-1.42	-1.50	-1.59	-1.67
White oak	-4.84	-4.93	-5.01	-5.19	-5.36	-5.53	-5.71	-5.88	-6.05
Willow	-1.99	-2.24	-2.49	-2.99	-3.49	-3.99	-4.49	-4.99	-5.49
Yellow-poplar	-2.50	-2.11	-1.72	-0.94	-0.17	0.61	1.39	2.17	2.94

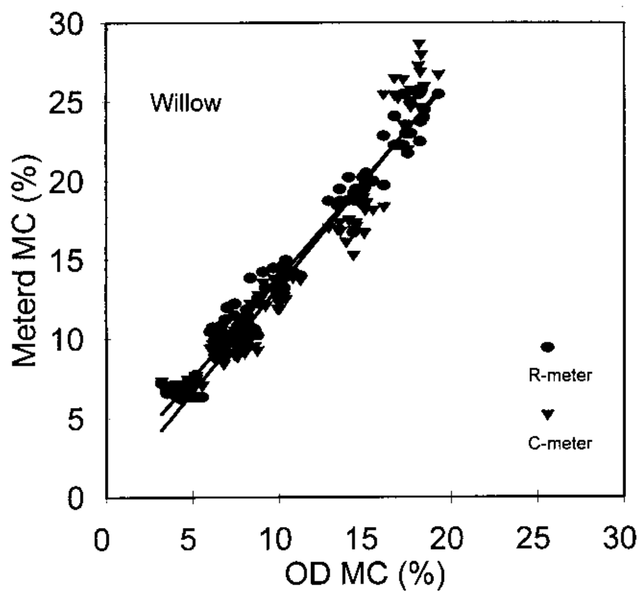

Figure 1.— Meter reading versus MC for the resistance- and capacitance-type meters for willow wood.

meter. Insulated pins were positioned parallel to the grain at a depth of 12.7 mm (0.5 in.) and readings were immediately taken upon complete insertion of the pins into the sample. A Wagner model L-612 moisture meter was used for the capacitance-type meter. It was placed at the center of the sample, parallel to the grain. During the study, the resistance meter was checked against a known resistance block, and the capacitance meter was calibrated against a capacitance plate. The calibration equipment for both meters was provided by the respective meter manufacturers. The correction factors were determined by linear regression, with the meter reading as the dependent variable and true MC as the independent variable.

Results

The results of the regression analysis are shown in **Table 2**. Because none of the slopes of the regression equations for the various species are equal to 1, it is evident that the correction factor varies with MC. In general, the coefficient of determination (r^2) shows a good fit for the different species when using both the resistance and capacitance meters.

The correction factors for the various species are shown for the resistance-type and capacitance-type meters in **Tables 3** and **4**, respectively. As expected, the two meters yielded different correction factors. A previous study reported that a capacitance-type meter performed better than the three pin meters combined. It was more accurate, and quicker and easier to use (Wilson 1999).

In general, the experimental values obtained from this study agree with published results. The correction factors for the resistance-type meter are slightly greater than those provided by the manufacturer, particularly for higher density species such as white oak and red oak. A possible explanation is the slightly higher specific gravity of the white oak and red oak specimens used in this study as compared to other published values (**Table 1**).

Graphs of meter readings versus ovendry MC of selected species are illustrated in **Figures 1** through **3**, for willow, cherry, and sycamore. The data from the resistance-type and capacitance-type meters are shown for the selected species. It appears that the meters are more accurate at lower MC levels since the data points are tighter (less variability) at the lower MC values. This is especially noticeable with the capacitance meter.

Application

Moisture meters should be used whenever the operator desires an estimation of the MC of wood. In instances in which the actual MC, rather than an esti-

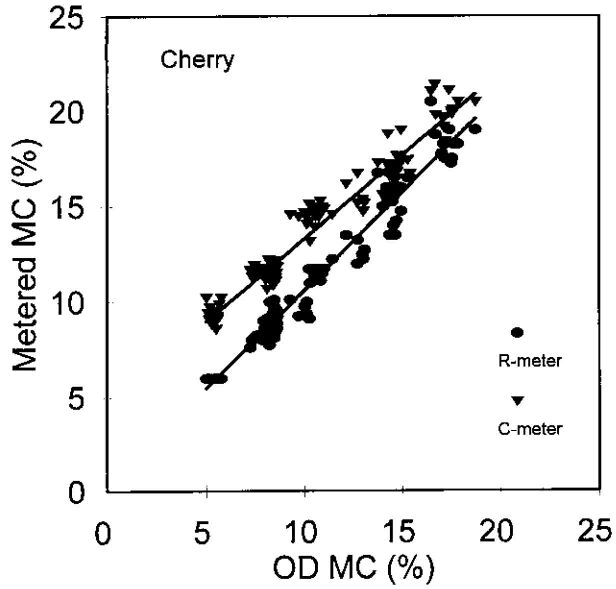

Figure 2. — Meter reading versus MC for the resistance- and capacitance-type meters for cherry wood.

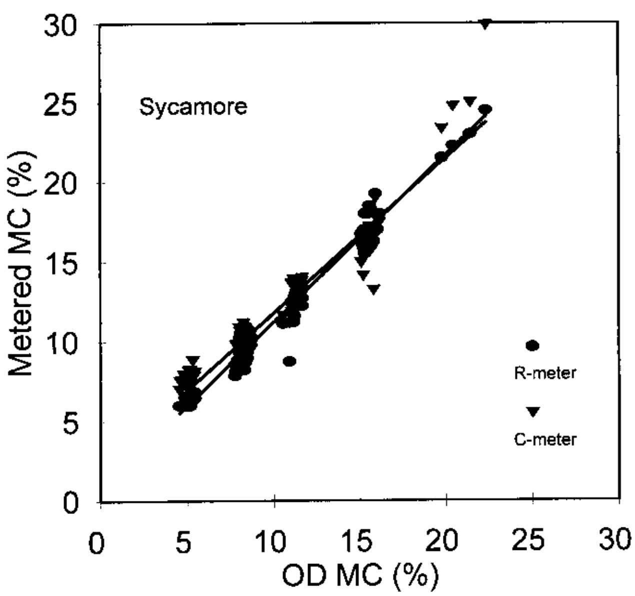

Figure 3. — Meter reading versus MC for the resistance- and capacitance-type meters for sycamore wood.

mation, is needed, the ovendry method of MC determination is recommended. Properly used meters may be within ± 3 percent of the actual piece MC if several samples are measured, and the accuracy of the meter may vary with wood source (Milota and Quarles 1990).

The correction factors presented in this study are best applied in practice when using the same models of moisture meters as used for this study. A user should follow the manufacturer's instructions for properly using a meter, including adjusting for temperature, if necessary.

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