Moisture Meters - Best Practices and Effective Use

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The Importance of Knowing Wood Moisture Content

The Importance of Moisture Content

- Minimizes shrinkage problems
- Increases strength and stiffness
- Improves fastener holding ability
- Is lighter weight
- Improved glue ability
- Readily stained, coated or pressure treated

Determination of Wood MC%

- Oven Drying; at 103^{o}C, 218^{o}F
  - Time Consuming
  - Destructive
  - Accurate?
- Moisture Meters
  - Fast
  - Non-Destructive
  - Accuracy?

When to Determination Wood MC%

- During air drying; prior to the kiln
- During pre-drying; prior to the kiln
- While kiln drying
- After kiln drying

What Can Wood Moisture Meters Tell Us?

- Moisture Gradients;
  - Shell to Core
  - End to End
- Wet Pockets in Lumber
- %MC Between Many Boards from a Kiln
  - Through a kiln pack
  - Through a kiln

%MC Knowledge from Meters is Important Because:

- Kiln, pre or other drying conditions could, unknowingly, vary
- Different species being dried
- Different thicknesses being dried
- Different %MC being dried
- Perhaps boards are being redried

Hand-Held Moisture Meters

- Resistance (ex., Delmhorst, Lignomat)
  - Utilizes pins for measurement
  - Insulated or uninsulated
- Electromagnetic Field (ex., Wagner)
  - Capacitive / Admittance – Dielectric


2-15 SP8 T3-C5
2-16 SP8 T3-C5
12 SP8 T3-C5
2-11 SP8 T3-C5
DELMHORST
RDM-2S


1-10 SP8 T3-C5
1-8 SP8 T3-C5
2-15 SP8 T3-C5
DIGITAL RECORDING
WAGNER

Correction Factors

- Species
- Temperature
- Pins
  - 2 vs. 4
  - Insulated vs. Uninsulated
- Treatments can effect chemistry of wood

Important Accuracy Issues

- Wood Species - Chemical differences between species affect electrical conductivity
- Temperature – higher temperature increase electrical conductivity
- Density – affects on electro-magnetic field and moisture relationships

Water Treatment - Resistance

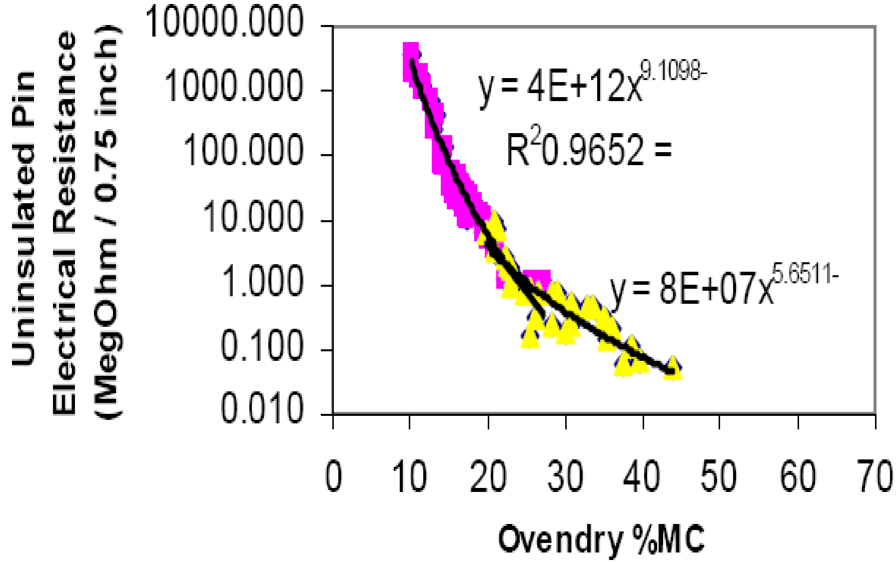


Table 1-11—Average electrical resistance along the grain, for selected species, as measured at 80°F between two pairs of needle electrodes 1-1/4 inches apart and driven to a depth of 5/16 inch

Species	Electrical resistance (megohms) at different levels of moisture content (percent)																		
	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Softwoods																			
Cypress, southern	12,600	3,980	1,410	630	265	120	60	33	18.6	11.2	7.1	4.6	3.09	1.78	1.26	0.91	0.66	0.51	0.42
Douglas-fir (coast type)	22,400	4,780	1,660	630	265	120	60	33	18.6	11.2	7.1	4.6	3.09	2.14	1.51	1.10	0.79	0.60	0.46
Fir, California red	31,600	6,760	2,000	725	315	150	83	48	28.8	18.2	11.8	7.6	5.01	3.31	2.29	1.58	1.15	0.83	0.63
Fir, white	57,600	15,850	3,980	1,120	415	180	83	46	26.9	16.6	11.0	6.6	4.47	3.02	2.14	1.55	1.12	0.86	0.62
Hemlock, western	*22,900*	*5,620*	*2,040*	*850*	*400*	*185*	98	51	*28.2*	*16.2*	*10.0*	*6.0*	3.89	2.52	*1.58*	*1.05*	*0.72*	*0.51*	*0.37*
Larch, western	39,800	11,200	3,980	1,445	560	250	120	63	33.9	19.9	12.3	7.6	5.02	3.39	2.29	1.62	1.20	0.87	0.66
Pine, eastern white	20,900	5,620	2,090	850	405	200	102	58	33.1	19.9	12.3	7.9	5.01	3.31	2.19	1.51	1.05	0.74	0.52
Pine, longleaf	25,000	8,700	3,160	1,320	575	270	135	74	41.7	24.0	14.4	8.9	5.76	3.72	2.46	1.66	1.15	0.79	0.60
Pine, ponderosa	39,800	8,910	3,310	1,410	645	300	150	81	44.7	25.1	14.8	9.1	5.62	3.55	2.34	1.62	1.15	0.87	0.69
Pine, shortleaf	43,600	11,750	3,720	1,350	560	255	130	69	38.9	22.4	13.8	8.7	5.76	3.80	2.63	1.82	1.29	0.93	0.66
Pine, sugar	22,900	5,250	1,660	645	280	140	76	44	25.7	15.9	10.0	6.6	4.36	3.02	2.09	1.48	1.05	0.75	0.56
Redwood	22,400	4,680	1,550	615	250	100	45	22	12.6	7.2	4.7	3.2	2.29	1.74	1.32	1.05	0.85	0.71	0.60
Spruce, Sitka	22,400	5,890	2,140	830	365	165	83	44	25.1	15.5	9.8	6.3	4.27	3.02	2.14	1.58	1.17	0.91	0.71
Hardwoods																			
Ash, commercial white	12,000	2,190	690	250	105	55	28	14	8.3	5.0	3.2	2.0	1.32	0.89	0.63	0.50	0.44	0.40	0.40
Basswood	36,300	1,740	470	180	85	45	27	16	9.6	6.2	4.1	2.8	1.86	1.32	0.93	0.69	0.51	0.39	0.31
Birch	87,000	19,950	4,470	1,290	470	200	96	53	30.2	18.2	11.5	7.6	5.13	3.55	2.51	1.78	1.32	0.95	0.70
Elm, American	18,200	2,000	350	110	45	20	12	7	3.9	2.3	1.5	1.0	0.66	0.48	0.42	0.40	0.40	0.40	0.40
Hickory, true	—	31,600	2,190	340	115	50	21	11	6.3	3.7	2.3	1.5	1.00	0.71	0.52	0.44	0.40	0.40	0.40
Kahya[1]	44,600	16,200	6,310	2,750	1,260	630	340	180	105.0	60.2	35.5	21.9	14.10	9.33	6.16	4.17	2.82	1.99	1.44
Magnolia	43,700	12,600	5,010	2,040	910	435	205	105	56.2	29.5	16.2	9.1	5.25	3.09	1.86	1.17	0.74	0.50	0.32
Mahogany, American	20,900	6,760	2,290	870	380	180	85	43	22.4	12.3	7.2	4.4	2.69	1.66	1.07	0.72	0.49	0.35	0.26
Maple, sugar	72,400	13,800	3,160	690	250	105	53	29	16.6	10.2	6.8	4.5	3.16	2.24	1.62	1.23	0.98	0.75	0.60
Oak, commercial red[2]	14,400	4,790	1,590	630	265	125	63	32	18.2	11.3	7.3	4.6	3.02	2.09	1.45	0.95	0.80	0.63	0.50
Oak, commercial white	17,400	3,550	1,100	415	170	80	42	22	12.6	7.2	4.3	2.7	1.70	1.15	0.79	0.60	0.49	0.44	0.41
Shorea[3]	*2,890*	*690*	*220*	*80*	*35*	*15*	*9*	*5*	*2.8*	*1.7*	1.1	*0.7*	*0.45*	*0.30*	*0.21*	*0.16*	*0.12*	*0.09*	*0.07*
Sweetgum	38,000	6,460	2,090	815	345	160	81	45	25.7	15.1	9.3	6.0	3.98	2.63	1.78	1.26	0.87	0.63	0.46
Tupelo, black[2]	31,700	12,600	5,020	1,820	725	275	120	58	27.6	13.0	6.9	3.7	2.19	1.38	0.95	0.63	0.46	0.33	0.25
Walnut, black	51,300	9,770	2,630	890	355	155	78	41	22.4	12.9	7.8	4.9	3.16	2.14	1.48	1.02	0.72	0.51	0.38
Yellow-poplar[2]	24,000	8,320	3,170	1,260	525	250	140	76	43.7	25.2	14.5	8.7	5.76	3.81	2.64	1.91	1.39	1.10	0.85

[1]Known in the trade as "African mahogany."
[2]The values for this species were calculated from measurements on veneer.
[3]A Philippine hardwood, identified as tanguile or some similar species.

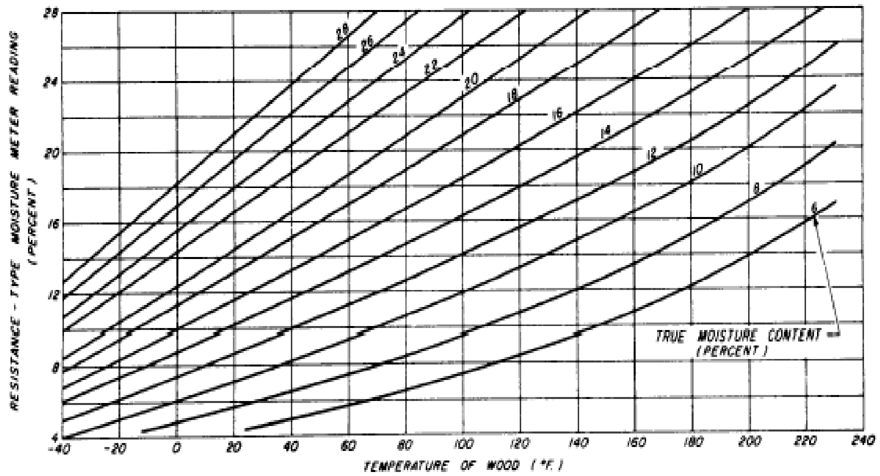


Figure 5— Temperature corrections for reading of conductance-type moisture meters, based on combined data from several investigators. Find meter reading on vertical left margin, follow horizontally to vertical line corresponding to the temperature of the wood, and interpolate corrected reading from family of curves. Example: If meter indicated 18 percent on wood at 120 °F, the corrected reading would be 14 percent. This chart is based on a calibration temperature of 70 °F. For other calibration temperatures near 70 °F, adequate corrections can reobtained simply by shifting the temperature scale so that the true calibration temperature coincides with 70 °F on the temperature scale. (M 70476 F)

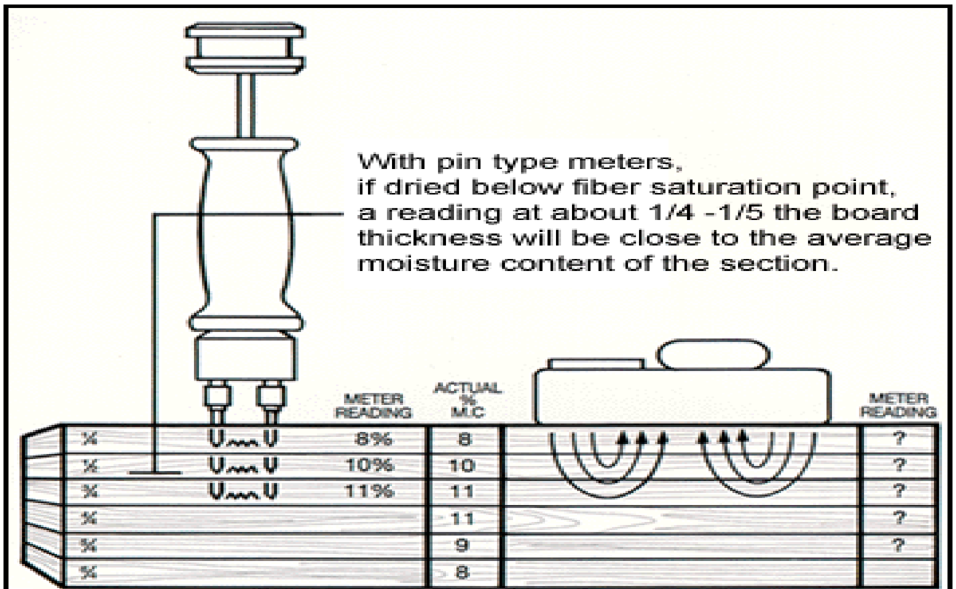


FIGURE I

PIN TYPE METERS VS. SURFACE TYPE METERS.
(HYPOTHETICAL DRAWING OF 6/4 BOARD WITH
VARYING LEVELS OF MOISTURE.

Species Correction Factors

- USDA Data;
  - Dry Kiln Operator's Manual
  - Using uninsulated pins
- Proprietary Species Factors

Several examples of Moisture Meter Accuracy in Practical Use:

- Eastern red cedar
- White Oak
- Pressure-Treated Pine

Eastern red cedar -

- Extractives in eastern red cedar appeared to be causing incorrect %MC values during oven-drying.

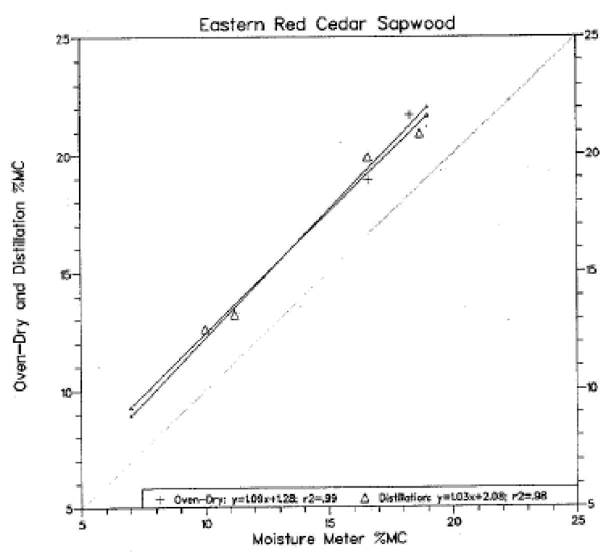


Figure 1.—Relationship between moisture meter, ovendrying, and distillation methods of determining MC in eastern redcedar sapwood.

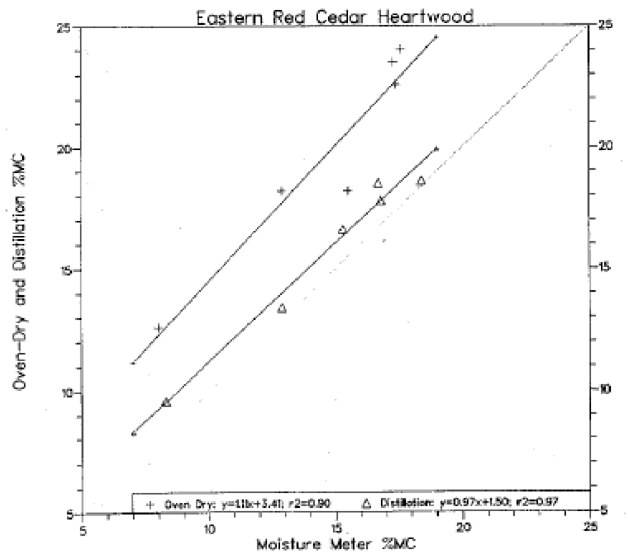


Figure 2.—Relationship between moisture meter, ovendrying, and distillation methods of determining MC in eastern redcedar heartwood.

TABLE 1. – *Eastern redcedar moisture content analysis.*

	A section				B section		
Sample no.	Moisture meter	OD-MM[a]	Ovendry	OD-TD[b]	Moisture meter	TD-MM[c]	Toluene distillation
Heartwood							
1-H	38.4		80.6	12.0	26.8		68.6
2-H	37.5		69.9	1.5	34.0		68.4
6-H	8.0	4.6	12.6	3.0	8.3	1.0	9.6
7-H	15.5	2.7	18.2	1.6	15.3	1.3	16.6
8-H	12.9	5.3	18.2	4.8	12.9	0.5	13.4
11-H	17.3	6.2	23.5	4.9	18.4	0.2	18.6
12-H	17.4	5.2	22.6	4.8	16.8	1.0	17.8
13-H	17.6	6.4	24.0	5.5	16.7	1.8	18.5
Average difference		**5.1**		**4.8**		**1.0**	
Sapwood							
3-S	16.6	2.3	18.9	-1.0	16.6	3.3	19.9
4-S	18.3	3.4	21.7	0.8	18.7	2.2	20.9
5-S	10.1	2.5	12.6	0.0	10.0	2.6	12.6
9-S	>60		83.9	1.5	46.6		83.3
10-S	11.2	2.1	13.3	0.1	11.2	2.0	13.2
Average difference		**2.6**		**0.3**		**2.5**	

[a] OD-MM = Ovendry – moisture meter value.
[b] OD-TD = Ovendry – toluene distillation value.
[c] TD-MM = Toluene distillation – moisture meter value.

Eastern Red Cedar

- True %MC of heartwood and sapwood was determined using toluene solvent distillation.
- It was proved that due to evaporation of heartwood extractives oven drying did not accurately determine %MC.
- The resistance moisture meter accuracy was comparable to oven-drying with e.r.cedar sapwood.
- The resistance moisture meter accuracy was much better than oven-drying with e.r.cedar heartwood

8/4 inch White Oak

- A furniture company was concerned because their white oak appeared to be too wet
  - Wagner Meter – 10.7% MC
    - Range – 8.5 – 13%

8/4 inch White Oak

- Wagner Meter – 10.7% MC
  - Range – 8.5 – 13%
- …so we checked the wood with a resistance meter, and then oven dried samples as well…
- Delmhorst Meter – 7.9% MC
  - Range – 6.3 – 8.8%

8/4 inch White Oak

- Oven Dry – 6.8% MC (18 specimens)
  - Range – 6.1-7.4%
- Wagner Meter – 10.7% MC
  - Range – 8.5 – 13%
- Delmhorst Meter – 7.9% MC
  - Range – 6.3 – 8.8%

8/4 inch White Oak

- Wagner Meter – 10.7% MC
  - Range – 8.5 – 13%
  - Specific Gravity Average = 0.79;

    book value = 0.68
- Delmhorst Meter – 7.9% MC
  - Range – 6.3 – 8.8%
- Oven Dry – 6.8% MC (18 specimens)
  - Range – 6.1-7.4%

8/4 inch White Oak

- In this case :
- Because the white oak density was greater than normal (book value), the Wagner electromagnetic meter tended to overestimate true % MC.
- Because the Delmhorst resistance meter is not affected by density it more accurately predicted true % MC.
- Which is the better meter???
  – Both meter technologies are good. However each has differing limitations and benefits. Take advantage of the benefits, understand and account for the limitations.

Pressure-Treated Wood

Several Experiments with Pressure-Treated Southern Pine Methodology …

- 2 x 4 or 2 x 6 inch Southern Pine Sapwood
- End matched specimen replicates
- Five Replicates
- Full-cell treatment
- Water treatment was proved as a control
- End-sealing to dry as full-size boards

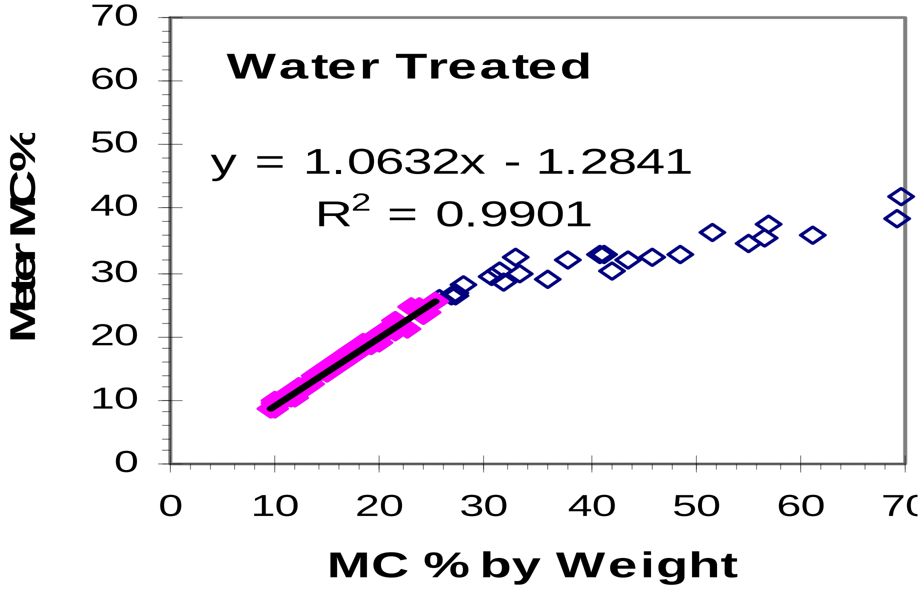
Methodology – continued

- Controlled drying
- Regularly weigh and check MC w/ meter
- Two readings each side w/ Delmhorst
- One reading each side w/ Wagner
- Plot against MC by weight
- Created equations and correction tables

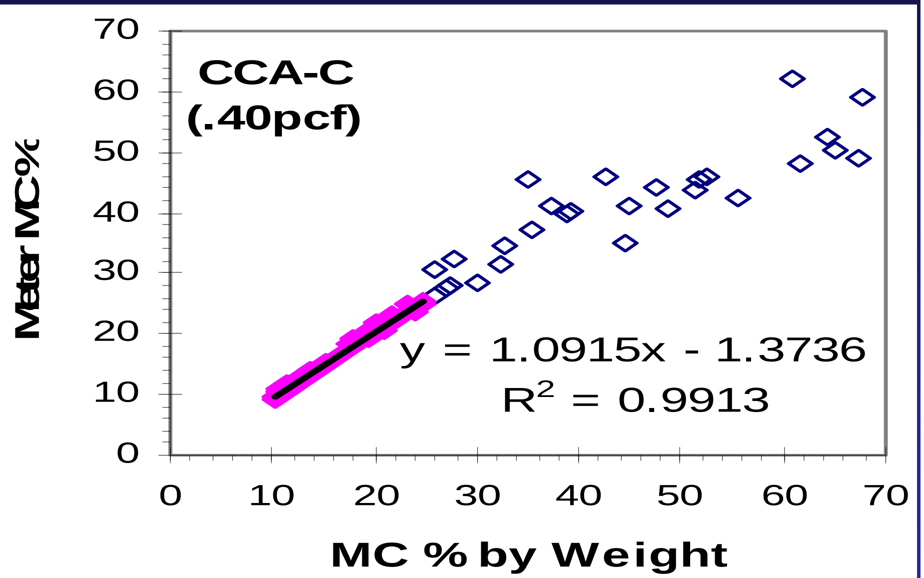
Species Correction Factors

- In 1983, Delmhorst Instrument, in conjunction with the southern pine industry, developed a species correction factor for Southern Pine.
- It utilized a 2-pin insulated probe with pins driven in about 3/8 of an inch.
- It assumed the average MC was at that point, due to the MC gradient while drying

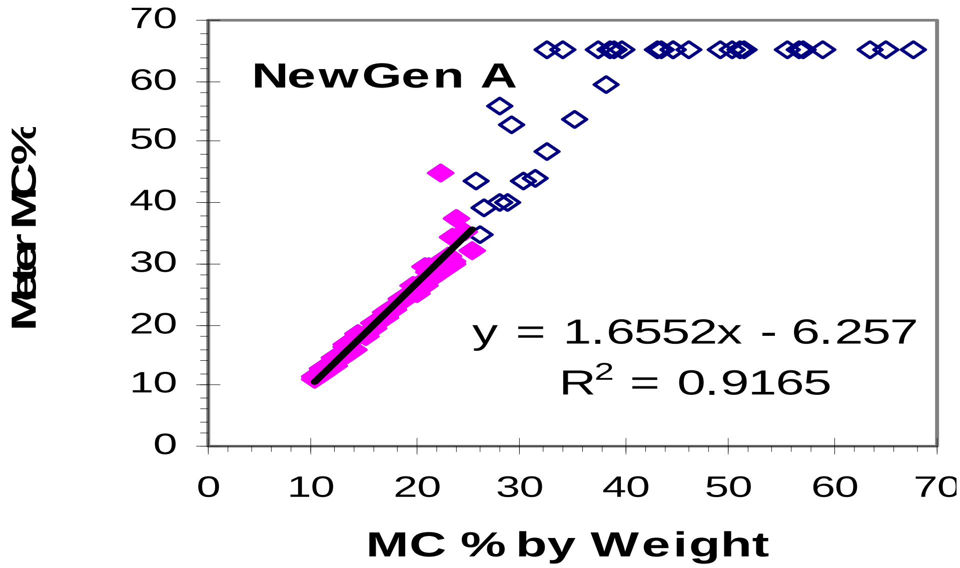
Delmhorst – Water Treated



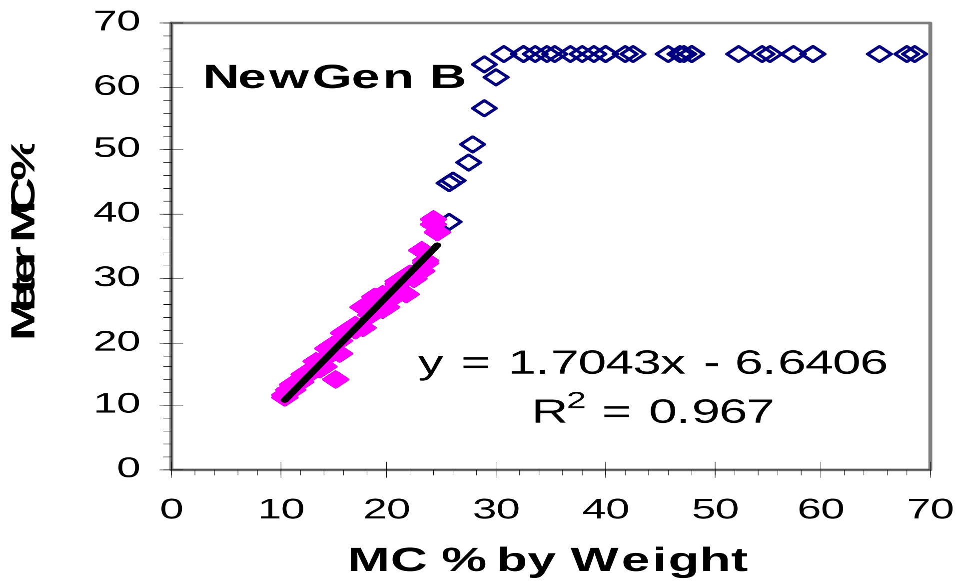
Delmhorst – CCA-C



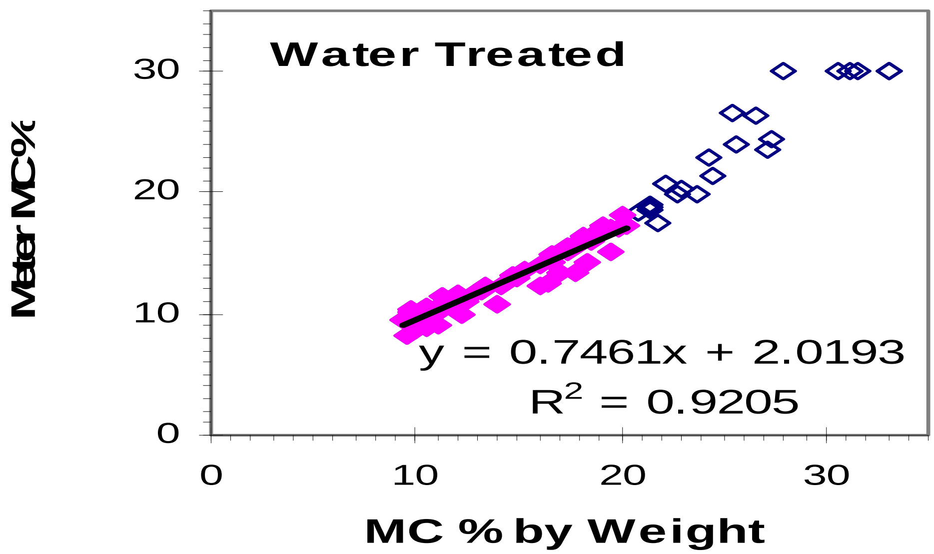
Delmhorst – NewGen A



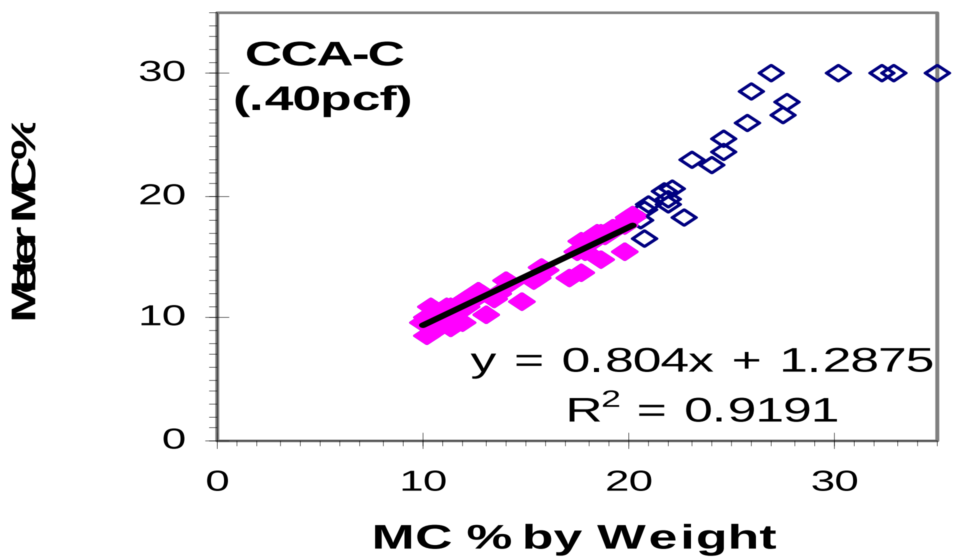
Delmhorst – NewGen B



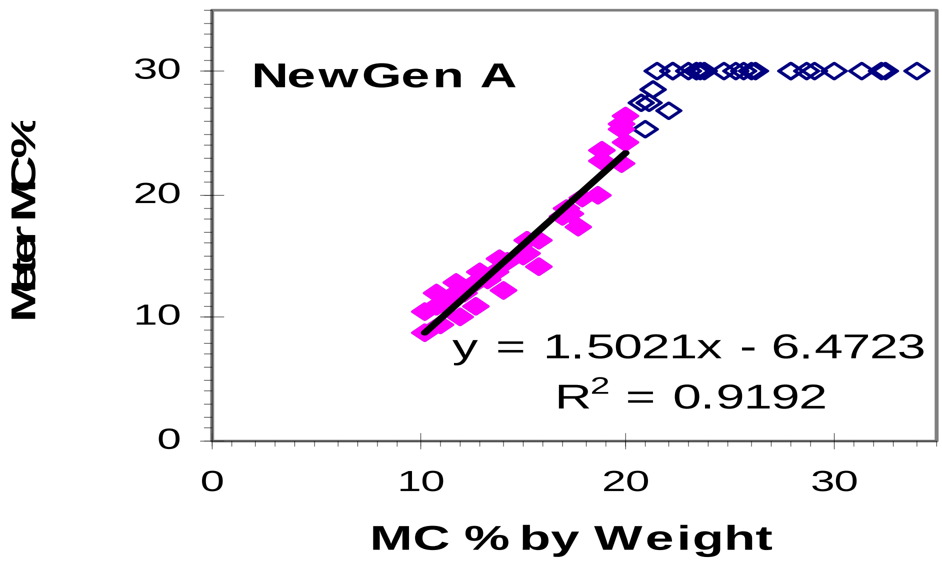
Wagner – Water



Wagner – CCA-C



Wagner – NewGen A



Wagner – NewGen B

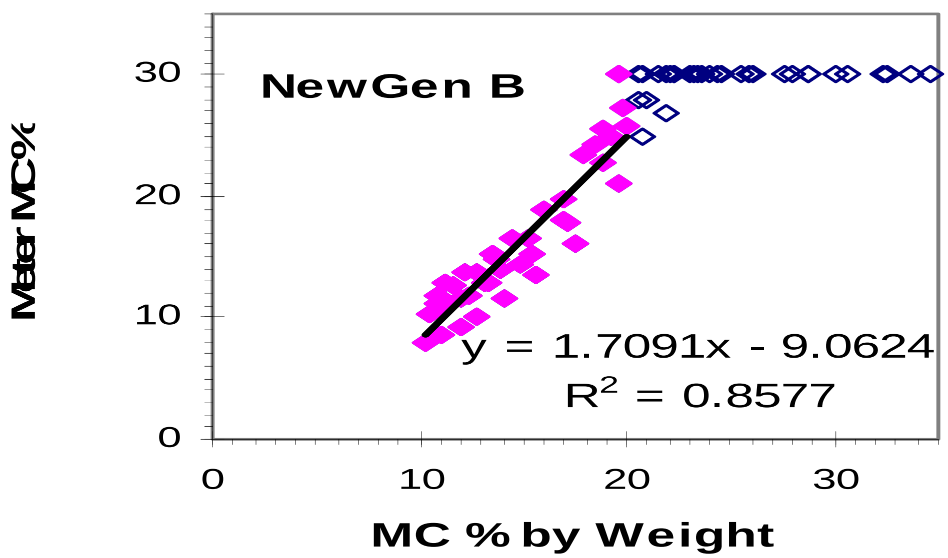


Table 1. Preservative Treated Southern Pine - 3.8 cm (1.5 in) thick Lumber: Delmhorst RDM Resistance Meter v. Actual %MC, using Insulated Pins, 0.95 cm (3/8 in) Penetration

	% MC by oven dry (Actual %MC)				
	12	15	20	22	25
Treatment	%MC meter values				
Water - 1	11.5	14.7	20.0	22.1	25.3
Water - 2	11.8	14.9	20.1	22.2	25.8
Water - 3	11.6	14.6	19.8	21.8	24.9
Water - 4	11.0	14.3	19.7	21.9	25.1
Water - 5	10.8	14.1	19.5	21.6	24.9
Freshly Cut	11.8	14.8	19.8	21.8	24.7
CCA-C, 0.40 - 1	11.7	15.0	20.5	22.6	25.9
CCA-C, 0.40 - 2	10.6	13.9	19.4	21.7	25.0
NewGen A - 1	13.6	18.6	26.8	30.2	35.1
NewGen A - 2	14.2	18.8	26.3	29.4	38.4
NewGen B - 1	13.8	18.9	27.4	30.9	36.0
NewGen B - 2	12.8	17.4	25.1	28.2	32.8

Table 2. Preservative Treated Southern Pine - 3.8 cm (1.5 in) thick Lumber: Wagner Electromagnetic Field Meter v. Actual %MC

	% MC by oven dry (Actual %MC)				
	12	15	20	22	25
Treatment	%MC meter values				
Water - 1	11.0	13.2	16.9		
Water - 2	11.2	14.1	18.9	20.8	23.7
Water - 3	11.8	14.0	17.8	19.4	
CCA-C, 0.40 - 1	10.9	13.3	17.4		
NewGen A - 1	11.6	16.1	23.6		
NewGen A - 2	12.6	17.2	23.2	27.8	
NewGen B - 1	11.4	16.6	25.1		
NewGen B - 2	11.4	14.9	20.7	23.1	

Summary

- Moisture meters can be used to accurately predict %MC in pressure-treated wood.
- However appropriate correction factors must be used.
- Accuracy
  - 5-12%; ~ +/- 0.5%
  - 12-18%; ~ +/- 1%
  - 20-30%; ~ +/- 2%
  - > 30%; ~ qualitative +/- 2-10%
- Results will likely be affected by treatment gradients.
- It is suggested that multiple data readings be utilized.

Care During Use is Important

- Keep meter dry and clean
  - moisture and contaminants can increase conductivity.
- Keep pins tight.
  - Loose pins are more likely to break and give bad readings.
- Drive pins parallel to grain
- Be cautious of surface wetness

Care During Use, continued…

- Appropriate species and temperature correction factors must be used.
- Be cautious of density variation with electromagnetic meters.
- Consider moisture gradients.
- Multiple data readings should be used. Do not make conclusions with limited data.
- Keep meter in calibration
- Keep batteries fresh.

Conclusions and Recommendations

- Moisture meters are effective, important, and indispensable tools.
- They can accurately predict %MC, including with pressure-treated wood.
- Appropriate correction factors must be used.
- Be sure to understand and take into account limitations of a particular meter technology.
- Base important conclusions and take action only with multiple data readings.