SENSITIVITY OF IN-LINE DRY LUMBER MOISTURE METERS TO WET SPOTS IN HEM-FIR LUMBER

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Although several studies have reported on the influence of moisture gradients and wet regions on the performance of hand-held moisture meters (Mackay 1976, Dennis and Beall 1977, Pfaff 1978), very little has been reported which describes the influence of through thickness moisture content variability and wet regions on the performance of in-line dry lumber moisture meters. McLauchlan (1975) suggested that in-line meters should be used to identify lumber that was wetter than a predetermined target in order to monitor the drying operation, however no quantitative results were given with regard to sensitivity to gradients or wet regions. Breiner, Arganbright, and Pong (1987) reported on the general performance characteristics of two in-line moisture meters. Quarles and Breiner (1989) reported on the effect of density on the performance of the same in-line meters. The objective of this study was to determine the sensitivity of in-line dry lumber moisture meters to regions of high moisture content.

MATERIALS AND METHODS

Two dry lumber in-line moisture meters were used in this study. One was a low dual-frequency meter which operates at 312.5 Hz and 10 kHz, and the other was a high-frequency meter which operates at several MHz (the low dual-frequency meter was supplied by Weyerhaeuser Co., Tacoma, WA, and the high-frequency meter was a commercially available analog model manufactured by Wagner Electronic Products, Inc., Rogue River, OR). Measurements were made using a laboratory scale dry chain. A Rockwell AIM-65 microcomputer operated the dry chain and transferred data from both meters to a Compaq portable microcomputer which stored the information. The chain speed was ramped up to 80 ft/min prior to passing over each sensing head (both meters were tested with single heads). Meter readings were taken every 0.24 inches of board travel across the sensor heads. The maximum reading was used for analysis.

The sample material was 10-foot long, nominal 2 x 8 Hem-fir lumber. The lumber was purchased dry from a local lumber yard, and was equilibrated to 14% moisture content (MC, oven-dry basis) prior to testing. The wet spots were artificially generated by soaking the wet spot samples in water under a series of pressure-vacuum cycles.

Three wet spot sizes were used, each having a volume of 15 cubic inches. The three sizes were 1) 3/4 in. x 2 in. x 10 in., 2) 1/4 in. x 5 in. x 12 in., and 3) 1/4 in. x 3 in. x 20 in.

Slots were machined in the dry lumber to hold the wet spots and a precut "cap" made from the equilibrated Hem-fir lumber was fitted on top of the wet spot. The wet spots were wrapped in clear plastic wrap prior to being inserted into the milled slot. The wet spot and cap were held in place by wrapping the board with two thin strips of fiber-reinforced tape. The locations of the wet spots and the

associated identification numbers, and distances from the wet spots to the lumber surfaces are given in Table 1. Each 10-foot board was cut in half, with each 5-foot length serving as a replication for each wet spot size and location combination. The wet spot was centered over the sensing heads for each measurement.

The specific gravity (oven-dry mass, volume at 14% MC) was determined for each 5-foot sample by cutting a 6-inch piece from one end. The volume was determined by measuring the length, width and thickness using a vernier caliper. The specific gravity measurement was used to apply a density correction to both dry sample meter readings, and to determine the actual MC at test.

Two measurements were made for each wet spot size and location combination - one measurement with the wet spot in the otherwise dry board and one measurement with a dry spot (of the same dimension as the wet spot) in the board. Since the meters were not specifically calibrated for Hem-fir lumber, the difference between the maximum wet spot and density corrected dry spot reading was analyzed.

Table 1. The location of wet spots in the dry lumber samples.

| ID # | Wet Spot Size, in. | Location[1] with respect to | | Distance to | |
		Width	Thickness	Narrow Edge, in.	Wide Face, in.
1	3/4x2x10	C	C	2 1/2	3/8
2	3/4x2x10	L	C	1/2	3/8
3	3/4x2x10	T	C	1/2	3/8
4	1/4x5x12	C	D	1	1/4
5	1/4x5x12	C	U	1	1/4
6	1/4x3x20	C	D	2	1/4
7	1/4x3x20	C	U	2	1/4
8	1/4x3x20	L	D	1/2	1/4
9	1/4x3x20	T	D	1/2	1/4
10	1/4x3x20	L	U	1/2	1/4
11	1/4x3x20	T	U	1/2	1/4
12	NONE			CONTROL	
13	NONE			CONTROL	

[1]C = wet spot centered

L = wet spot located toward the leading edge

T = wet spot located toward the trailing edge

D = wet spot located down, near meter sensing head
    (near the bottom surface of the board)

U = wet spot located up, away from meter sensing head
    (near the top surface of the board)

RESULTS AND DISCUSSION

The average equilibrium MC of the sample boards, as determined with the 6-inch specific gravity samples, was 14% with a standard deviation (s) of 0.83. The average specific gravity (volume at 14%) was 0.42 (s = 0.06). The average MC of the saturated wet spot material was 185% (s = 20.6). Using the average MC values, the wet spot increased the overall MC of the sample from 14% to approximately 23% (based on a 26-inch sample length, which is the average length of the sensing heads). Therefore, the in-line meters should yield an average MC difference of 9% if the total effect of the wet spot was measured.

The results for the low dual-frequency meter are given in Figure 1, and those for the high-frequency meter are given in Figure 2. These types of figures are commonly called box plots. For each box in the plots, the center horizontal line represents the median value, and the upper and lower horizontal lines represent the upper and lower quartile. Thus, the size of the box gives a visual representation of the data variability. A single horizontal line indicated that there was no difference in readings between the measurements (or replications in this case).

As seen in Figure 1, there were differences in readings between the three wet spot size categories and, within a given size category, between locations. The smallest MC difference was observed with the relatively thick wet spots (3/4 in. x 2 in. x 10 in.). There were only minor differences between the centered, and leading and trailing edge readings. Somewhat larger MC differences were observed with the 1/4 in. x 5 in. x 12 in. wet spot material. In this case, the MC difference was greatest when the wet spot was located in the "down" position, near the sensor head. The highest MC differences were observed with samples which used the 1/4 in. x 3 in. x 20 in. wet spot. As was the case with the other wet spot sizes, there were relatively minor differences between centered, and leading and trailing edge readings, and the MC difference was greatest when the wet spot was located in the "down" position. It should be noted that the maximum possible reading for the low dual-frequency meter was 24%. This was the wet spot reading obtained for combinations 6, 8 and 9. Therefore, the measured MC difference could very well have been larger for these combinations, possibly approaching the "actual" 9% MC difference between the dry lumber and that with the wet spots.
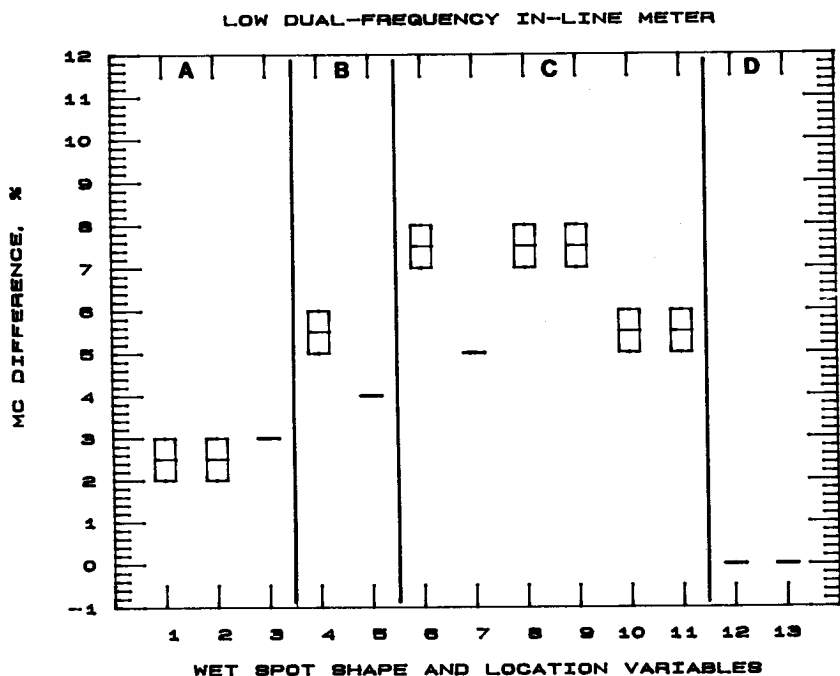

LOW DUAL-FREQUENCY IN-LINE METER

Figure 1. The MC difference (wet spot reading - density corrected dry spot reading) for each wet spot and location combination determined by the low dual-frequency dry lumber in-line meter. The identification number key is given in Table 1. The A, B, and C groupings represent the three different wet spot sizes. Group D are the control samples.

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The results for the high-frequency meter (Figure 2) were similar to those observed for the dual low-frequency meter. The MC differences were always greater when the wet spot was closest to the bottom surface ("down" position) versus the top surface ("up" position). In addition, there were again only minor differences between the centered, and leading and trailing edge readings for a given wet spot size. The high-frequency meter was not restricted to a 24% maximum MC, and therefore the MC differences for combinations 6, 8, and 9 were greater than those obtained with the dual low-frequency meter.
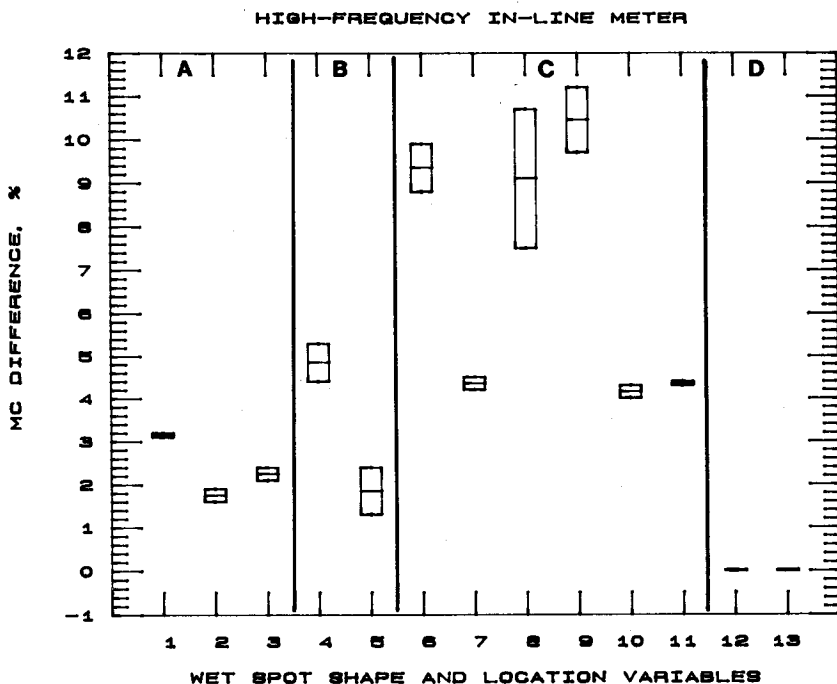

HIGH—FREQUENCY IN—LINE METER

Figure 2. The MC difference (wet spot reading - density corrected dry spot reading) for each wet spot size and location combination determined by the high-frequency dry lumber in-line meter. The identification number key is given in Table 1. The A, B, and C groupings represent the three different wet spot sizes. Group D are the control samples.

Multiple regression techniques were used to investigate the relationship between the wet spot size and location with respect to thickness, and the respective MC difference reading for each meter. Independent variables included the wet spot length and surface area (parallel to the sensor head) expressed as a fraction of the meter length and surface area, and indices which indicated the relative location of the wet spot with respect to thickness and overall geometry. Preliminary results from this analysis were promising. As might be expected from the results observed in Figures 1 and 2, the relationship between the MC difference and wet spot fractional surface area, location with respect to thickness, and overall geometry was very good, with coefficients of determination (R^2) of approximately 0.9 obtained for both meters. These results provide additional evidence that the surface area and relative location of the wet spot with respect to the sensing head will determine how well a given wet spot will be detected by dry lumber in-line moisture meters.

CONCLUSIONS

1) The sensitivity of in-line meters was dependent on a) the wet spot geometry, and b) the distance between the sensing head and wet spot.

2) The in-line meter readings did not depend on the location of the wet spot along the width of the lumber.

3) Both in-line meters were able to accurately detect the actual increase in moisture content caused by the wet spot only when it was located near the bottom surface.

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