PERFORMANCE OF AN IN-KILN MOISTURE METER
- PRELIMINARY RESULTS -

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INTRODUCTION

In-kiln measurement of lumber moisture content is required for implementing moisture content-based schedules and for determining the end-point of drying. Determining end-point is particularly important since over drying results in significant degrade losses.

Several methods are available for remote monitoring of the moisture content of lumber while it is in the kiln. These include resistance type moisture meters, temperature drop across the load (TDAL), and capacitive admittance type moisture meters. The capacitance admittance type in-kiln moisture meter, whose performance is addressed is this paper, measures the capacitive admittance of the load of lumber to an audio frequency signal which is carried by a coax cable to an aluminum strip inserted into the load.

PREVIOUS STUDIES

Extensive studies on the operational characteristics of two in-kiln meters were carried out at the USDA Forest Products Laboratory (1,2,3) in the early 1980's. The meters used in that study were an Irvington Moore Kiln Scan and a Winkle Meter supplied by Weyerhaeuser Company. The meters were modified so that the form (sine, square, and rectangular), amplitude, and frequency of the output signal could be modified. The signals produced by the unmodified meters were 10 Khz sine waves. The parameters that were investigated included signal form, signal frequency, signal amplitude, probe shape, temperature, ground configurations, kiln type (masonry or metal), and moisture distribution in the load.

Several of the findings of James and Boone (3) apply to the application of the tested meters as used in normal mill operations.

1. Meter readings were predominantly affected by the tier of lumber in direct contact with the probe strip.

2. The surface moisture content of the lumber in contact with the probe had the predominant effect.

3. While the meter responded to the composite moisture content of the tier in contact with the probe, the wettest pieces in the tier had the predominant effect.

4. The structure of the kiln (masonry or metal) affected meter readings. All factors being constant, the meter readings in a metal kiln were greater than that in a masonry kiln.

5. Rapid increases in humidity caused large transient readings.

OBJECTIVES

The objectives of this study were to:

1. Investigate the accuracy of an in-kiln capacitive admittance meter, with accuracy being defined as the degree of correlation between lumber moisture content and meter reading.

2. Investigate the resolution of the in-kiln meter, with resolution being defined as the change in meter reading for a given change in moisture content. Graphical data reported by James and Boone (1,2) suggested that the resolution of the in-kiln meters used in their studies was low in the range below 20%.

3. Further investigate whether the in-kiln meter reading is influenced by the presence of high moisture in tiers below that in contact with the probe strip.

METHODS

The material used in this study was 2 by 4 white fir [*Abies concolor* (Gord. and Glend) Lindl.]. The material was tested at nominal moisture contents of 30%, 18% 12% and 8%. To achieve each moisture content except 30% the lumber was held in the kiln at a dry bulb temperature of 160° F and the appropriate wet bulb depression to achieve the desired equilibrium moisture content. It was held at that condition until the meter reading was constant for at least 8 hours. For the 30% readings, the lumber was heated to 160° F and the humidity was held as high as possible to minimize the moisture lost during the period of testing.

The meter used was a four channel Wagner Model 778 Kiln Alert. Only two of the channels were utilized. The mechanical switch used to indicate which probe reading was displayed was replaced by an electronic switch which could be set by an external computer. A desk top computer was used to set the switch and subsequently read the level of the voltage signal being input to the digital display. The signal was processed though a 12 bit analog to digital converter. The desk top computer read and logged readings from both probes every 20 seconds. It should be noted that the meter display does not read in moisture content, but rather on an unitless 0-30 scale.

Typically, 8-foot probe strips are used in production kilns. In this study, however, the load was 2 feet wide and consequently the strips were 2 feet long. To compensate for any reduction in meter reading caused by using the shorter strip, the meter was operated at a sensitivity setting of 10, the maximum gain setting.

In order to closely monitor the moisture content of the load, the test material was limited to six tiers, each being 4 feet long and 2 feet wide, and containing seven 2 by 4's. The tiers were stacked end to end, three high on top of a 10 tier high 8-foot long "dummy" load. Stickers were 3/4 inch thick. In all tests the probe strip was placed on top of the middle tier in the 3-tier stack. The dummy load was made up of dried 2 by 4's. All tests were carried out in a 1000 board foot aluminum and steel kiln.

Normally, the meter output would be coupled to ground through the load of lumber, the kiln truck and finally the track to earth ground. Since the moisture content of the dummy load was not controlled it was felt that a path to ground that did not include the dummy load was necessary. As a result, grounding was implemented by attaching 0.064 inch thick aluminum plates to the underside of the

stickers located under the bottom test tiers. These plates were the width and length of the stickers. During testing the plates were grounded to the meter console's chassis, which was grounded.

The test procedure was carried out 12 times at each nominal moisture content level. The test tiers were repositioned after each test so that each of the six tiers was tested while positioned under each of the two sensors strips. The procedure for testing is outlined below.

1. The test material was stacked on top of the dummy load in the kiln and heated to 160° F. The load was held at this temperature throughout the testing period except when test material was removed for weighing.

2. After a given measurement, the test tiers were removed for weighing, and then returned to the kiln. The load was then heated until the desired temperature and humidity were reached. After reaching set point an additional 15 minutes elapsed before data collection began. Readings were logged by the desk top computer for 15 minutes at a rate of three readings per minute. These 45 readings were averaged in order to minimize the effect of transient fluctuations on the meter reading.

3. At the end of the 15-minute data collection period the kiln was opened and all six tiers were weighed. Each tier was weighed as a group, and therefore only tier moisture contents were determined. After all tests were run each tier was oven dried.

4. At the 12% moisture content level only, meter readings were taken to determine if the presence of an aluminum plate simulating the presence of moisture, could be detected. These tests were run with and without the grounding in place to ascertain if grounding had a notable effect.

RESULTS

The relationship between the moisture content of the tier in contact with the probe and meter readings for probe strips 1 and 2 are given in Figures 1 and 2 respectively. Results obtained from combining probe strips 1 and 2 combined are given in Figure 3. Readings for both probes showed a high degree of correlation with actual tier moisture content. The coefficient of determination (R^2) for probes 1 and 2 was 0.99 and 0.96 respectively, and 0.97 for the combined readings. Prediction intervals for probes 1 and 2 were ±1.9 and 3.0 respectively, and ±2.5 for all readings combined. An analysis of variance was conducted since it appeared that the variability in Probe 2 was greater than that in Probe 1. This was especially true at high moisture contents. Results of the analysis of variance showed that there was no between-probe difference (p-value = 0.80). The deviation between meter readings and actual tier moisture content diminished as moisture content dropped. It should be noted that at in spite of the high humidity at the 30% moisture content level, condensation or the presence of liquid water on the probe strip did not occur. Though the meter was tested over a moisture content range from 8-30% moisture content, the meter is typically used as an end point detector in the range below 20% moisture content. When readings at the nominal 30% level were excluded from the analysis, R^2 was 0.98 and the prediction interval was ±1.5. Under these test conditions the meter's minimum reading was at approximately 7%
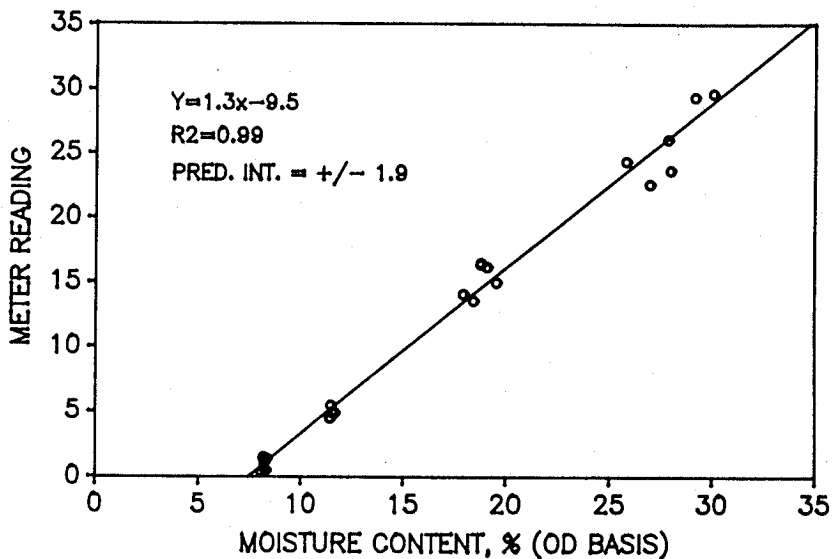
Figure 1. Correlation between tier moisture content and in-kiln meter readings for probe 1.
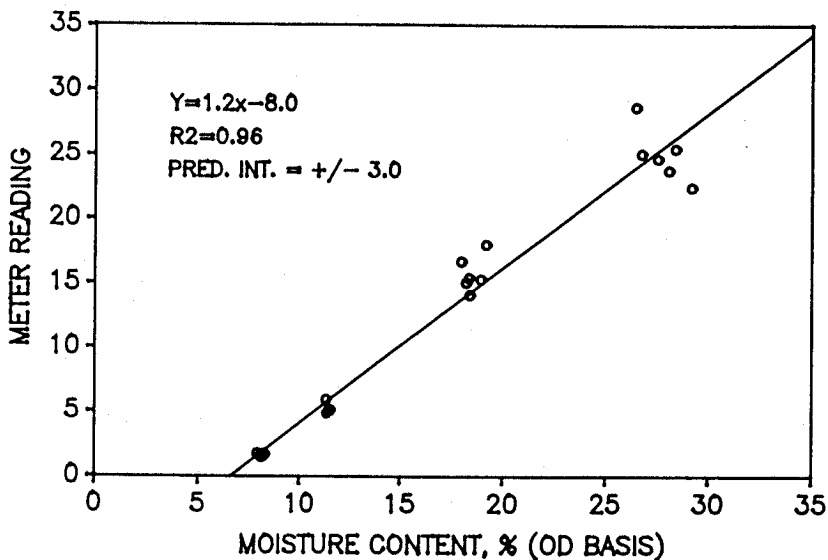

Figure 2. Correlation between tier moisture content and in-kiln meter readings for probe 2.
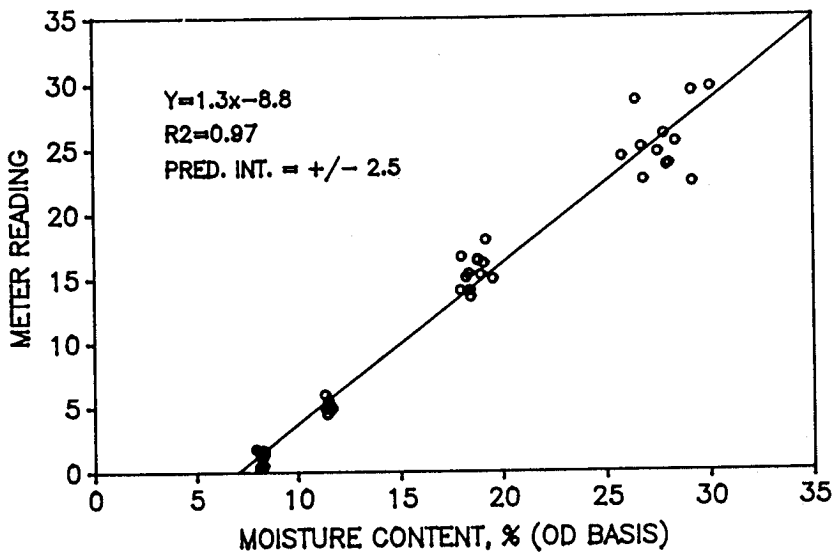
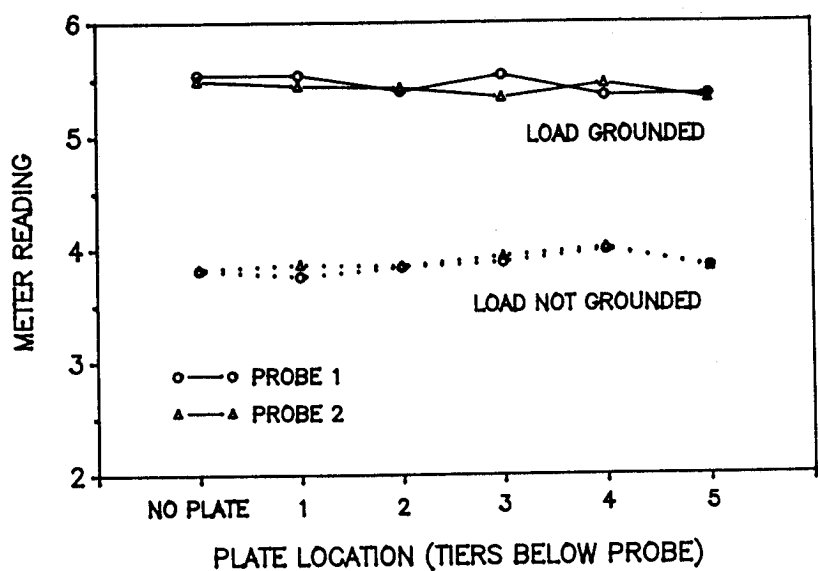Figure 3. Correlation between tier moisture content and in-kiln meter readings from both probes combined.

Figure 4. Effect of grounding and aluminum plate inserted on tiers below the tier in contact with probe strip.

moisture content (i.e. the meter reading was zero when the tier moisture content was 7%).

Figure 4 shows the effect of placing a 0.064 inch by 12 inch by 24 inch long aluminum plates on tiers below that in contact with the sensor strips, and the effect of removing the grounding (previously described). The function of the plates were to simulate the presence of moisture. The data suggests that the meter could not detect the presence of the plate as close as one tier below that in contact with the sensor strip. This finding is in agreement with that of James and Boone (2). However, additional studies utilizing green lumber, rather than aluminum would be necessary to definitively establish the effect of moisture in adjacent tiers on the meter reading. Figure 4 indicates that under the test conditions used, readings taken without proper grounding were notably lower than those taken with proper grounding in place.

SUMMARY

1. Readings from an capacitive admittance in-kiln moisture meter showed a high degree of correlation (R^2 = 0.97) with lumber moisture content.

2. Over the range of 8-30% moisture content, 95% prediction intervals indicated that at a given moisture content, meter readings would vary ±2.5. Over the range of 8-20% moisture content, the range in which the meter is generally used, the variation was ±1.5.

3. Under conditions used in this study, readings were not affected by a 12 inch wide aluminum plate placed one tier below the tier in direct contact with the probe.

4. Under conditions used in this study, grounding the load had a notable impact on meter readings.

REFERENCES

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