

MOISTURE METER CORRECTION FACTORS FOR HIGH TEMPERATURE DIMENSION LUMBER

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SUMMARY

Exposure of softwood lumber to temperatures of 82° C or higher during kiln drying affects the electrical properties of that material. This, in turn, affects readings taken with a D.C. resistance moisture meter. This study was designed to develop a correction factor to account for this effect. The present correction factors were found to overestimate actual moisture content by 0.6 to 4.5 percent moisture content.

A new table of correction factors has been generated for both black spruce and jack pine. Implications of applying this new correction factor in industry are also discussed.

OBJECTIVES

The primary objective of this study was to develop new correction factors to be used on D.C. resistance moisture meter readings taken on high temperature dried material. The secondary objectives were to test the application of this correction factor on industrially dried material and recommend procedures for its application by industry or grading association personnel.

INTRODUCTION

The D.C. electrical resistance moisture meter is widely used in the Canadian lumber industry. Despite its limitations, it still provides the most convenient way to obtain an estimate of the moisture content (MC) of a large number of samples. Over the years, a major problem has been the absence of adequate correction factors. Since the meter scale is calibrated for one species at one temperature (normally Douglas-fir at 21° C), all meter readings have to be corrected for species and temperature effect.

BACKGROUND

Previous studies carried out at Forintek (Cech, 1975, Pfaff, 1984) have developed species and temperature correction factors for most commercially used Canadian species. When proper procedures are followed, these correction factors will give a good estimate of the true moisture content. A study carried out at the University of California (Breiner, 1985) showed a significant variation between MC determined by resistance meter vs. true (oven-dry) moisture content. They found that at a 95% confidence interval, the D.C. resistance meter could estimate true MC to within 3.8%. This shows the tremendous variation (or error) that is possible on any individual reading. This sort of variation was also noted in previous Forintek studies. From work in industry, we have noted that when following the recommended procedures and testing a large number of samples that the average meter MC for a group will give an accurate estimate of the average true MC.

The recommended procedures when using a D.C. resistance meter are as follows:

- 1) use a probe with two insulated pins and ensuring that the pins are driven into the wood parallel to the wood grain;

- 2) when testing wood that has a moisture gradient, the pins should be driven into the wood to a depth where the gradient MC corresponds to the average MC of the cross section (proper depth is typically 1/5 to 1/4 of board thickness);
- 3) determine wood temperature;
- 4) finally, apply the appropriate species and temperature correction factor.

Tests carried out under normal mill conditions by Forintek as well as industry and lumber association personnel have demonstrated the reliability of previously developed correction factors under most circumstances. In late 1985, it came to our attention that a number of mills with high temperature kilns were experiencing difficulty in meeting the target final MC without incurring serious degrade, normally associated with over drying. As a result, Forintek initiated an exploratory study (Garrahan, 1986) to determine the cause of the problem. In this study, it was found that, when using current correction factors on material dried at maximum dry bulb temperatures of 99° and 116° C, true moisture content is overestimated by 2.7% and 3.4% MC respectively.

Following the exploratory study described above, it was decided that a more intensive study was warranted to establish a specific correction factor for high temperature dried material. Until such a correction factor was developed, it was recommended to industry personnel and grading association inspectors that the results of our preliminary study be used as a guideline when testing material dried at high temperature. For the purpose of this report, and following accented practices, high temperature drying refers to kiln drying operations where the maximum dry bulb temperature reaches or exceeds 100° C for a significant portion of the kiln schedule.

MATERIALS AND METHODS

The application of high temperature drying in eastern Canada is restricted to the S-P-F species group. For this reason, material representing the three major species within this group, black spruce (*Picea mariana* (Mill.) B.S.P.), jack pine (*Pinus banksiana* Lamb.), and balsam fir (*Abies balsamea* (L.) Mill.) was obtained for the study from a northern Quebec sawmill. The material was cut from freshly felled logs and arrived at the laboratory shortly after sawing. All material received measured 51x102 mm (2x4-inch) nominal by 2.4 m (8 ft.) long.

Each species was divided into four groups and each group was designated for drying at one of four temperature levels. The four temperature levels are 82° , 93° , 104° and 116° C (180° , 200° , 220° and 240° F) and represent the maximum dry bulb temperature used in drying each group. The material from all three species designated for drying at a particular temperature was dried together in one of the laboratory's kilns using a typical industrial schedule.

Following kiln drying, the lumber was resawn into 25 mm thick by 76 mm wide boards, then planed to a thickness of 19 mm. The boards were then cross-cut to produce samples with final dimensions of 19x76x102 mm. Approximately 1500 samples were prepared for this study.

The samples were placed in temperature and humidity controlled chambers for conditioning at four different equilibrium moisture content (EMC) levels. The selected EMC's were 10%, 12.5%, 19% and 22.5%. Due to natural variation between species and the effect of exposure to high temperatures, not all samples equalized to precisely the target MC. In all cases, conditioning periods were at least 3 months. Samples from each species and in each conditioning chamber were monitored for weight loss or gain. Samples were only used once they had reached and remained at equilibrium for several weeks.

Groups consisting of 25 samples were formed for each combination of species, drying temperature and EMC. This accounted for 1200 samples, with the extras being reserved for monitoring the conditioning chambers and spares in the event of an accident. Once ready for testing, each group of 25 was sealed in a plastic bag and placed in a chamber where temperature was kept at 21° C (70° F). The bags of samples were stored in this chamber overnight to ensure that all material was tested at the same temperature. The 21° C temperature was chosen as this is the level at which there is no effect on meter reading resulting from the temperature of the wood at the time of testing. This was done solely to eliminate the effect of wood temperature at time of pinning as a variable.

A Delmhorst RC-1C, D.C. resistance moisture meter was used to measure MC on each sample. A two pin probe was used and readings were taken at a depth of 9.5 mm (mid thickness). Each sample was tested at two locations. Wood temperature was measured for each group to detect any minor variation from the target temperature. Following meter testing, each sample was weighed and oven dried to obtain an actual MC.

All meter readings were corrected for species and wood temperature effect using Forintek's previously developed correction factors (Pfaff, 1984). The data for each species and drying temperature were then plotted and analyzed to determine the extent of error at each temperature and detect any trends.

EXPERIMENTAL PLAN

The D.C. resistance moisture meter is accurate only within the range of 6% to 21% MC. Readings below 6% are not possible and those over 21% are inconsistent. The extent of the error is likely to be greater for readings well over 21% versus those closer to this level. The softwood lumber industry is generally interested in determining if the product they are testing meets the 19% MC limit set for kiln-dried construction lumber. The EMC levels used to condition samples for this study were chosen, keeping in mind the limitations of the meter and the requirements of the industry. It was expected that the four EMC's used would provide enough data within this range to confidently develop a relationship between maximum kiln temperature, meter reading and true MC.

It is assumed that Forintek's previously developed correction factors are accurate. Therefore, if drying temperature had no effect on meter reading, all corrected meter readings would give an accurate (within limitations of meter) estimate of the actual MC. By comparing corrected meter readings from material dried at different temperature levels to actual MC, it is possible to determine how this relationship differs from the existing correction factor.

The difference between the existing correction factor and the correction factor required for the test material then needs to be described. For example, at what point does drying temperature begin to affect meter readings and is the error consistent across the range of MC's. It is also important to find out if the required correction varies between species or if it is similar enough to allow a single correction factor for all species.

RESULTS AND DISCUSSION

The comparison between corrected meter readings and true MC showed a definite effect of drying temperature in all three species. Figures 1, 2 and 3 show that the effect of drying temperature is similar in all three species (i.e. the higher the drying temperature, the greater the error). The error associated with the drying temperature is the vertical distance between the regression line for each temperature and the base line. The base line is the line along which the corrected meter reading gives an exact estimate of the true MC.

The temperature effect on black spruce and jack pine is similar enough that the data was grouped to obtain a new set of regression lines that could be used on either species. A reasonably good fit for each drying temperature was obtained with variance ranging from 0.93 to 0.97.

Although the data for balsam fir shows a similar trend to the other two species (Figure 3), the magnitude of the error is not as great. This difference may be the result of a lower wood temperature during drying due to the higher MC in this species. The test material for this study was dried together and the balsam fir did not reach the same final MC as the spruce and pine. This would be typical of a mill operating with only a small percentage of balsam fir in their lumber mix. It is likely that if the balsam fir was dried to a lower MC and wood temperatures were, as a result, higher, that the temperature effect would be more similar to the spruce and pine data.

From the combined data on spruce and pine, it is apparent that there is a temperature effect and that this effect is significant on material dried at temperatures as low as 82° C (180° F). Figures 1-3 show an increase in the error as drying temperature increased from 82° to 116° C (180° to 240° F). In order to develop a mathematical description of the data, a regression on the magnitude of the error was carried out. This repositioned the lines slightly as shown in Figure 4. In each case, the repositioned line is still within the 95% confidence interval for the original line. This was done to allow computer generation of temperature effect at various drying temperatures and at all MC's within the working range of the meter. Table 1 shows a summary of this data for black spruce and jack pine. Using these data, a new set of correction factors was generated for both of these species. A revised table for balsam fir will be produced once some further tests have been completed.

Table 1. Correction for High Temperature Dried Material.

Max. Drying Temperature (°F) (°C)		Corrected Meter Reading				
		8	12	16	20	24
160	71	--	--	--	--	--
180	82	-0.5	-0.7	-0.8	-1.0	-1.2
200	93	-0.8	-1.1	-1.4	-1.7	-2.0
220	104	-1.1	-1.5	-2.0	-2.5	-2.9
240	116	-1.3	-1.9	-2.5	-3.1	-3.7

The measured effect of drying temperature on meter readings for this study is similar to the estimate made in a preliminary study of this problem (Garrahan, 1986). At 116° C, the error ranges from 1.2% to 4.6% MC. At 82° C, the error is much less and ranges from 0.5% to 1.4% MC. From previous data, there is no significant effect at drying temperatures below 82° C.

CONCLUSIONS AND DISCUSSION

Drying temperature does have a significant effect on D.C. resistance moisture meter readings. The magnitude and direction of the error is such that the use of existing correction factors requires wood to be over-dried. This over-drying has resulted in unnecessarily long drying times and increased degrade losses. As existing correction factors are adequate for most applications, it is recommended that the information in this report be released as an addendum to Forintek's publication No. SP511F (Pfaff, 1984).

A more difficult aspect of this work is governing the application of these correction factors. It is relatively easy to determine at the mill site, if lumber has been dried at high temperature. Most mills have either conventional or high temperature kilns. The problem will arise once the lumber has been shipped to a distributor or end user. A possible solution would be the inclusion in the grade stamp of the maximum drying temperature used.

In order to apply a correction factor for high temperature drying, we recommend that the lumber be exposed to the maximum dry bulb temperature for at least 8 hours. The schedule up to this point should also be in line with the final temperature settings (i.e. no sudden increase from 71° C to 115° C).

ADDITIONAL WORK

As mentioned in this report, the results on high temperature effect on balsam fir were inconclusive. Since the completion of this report, further tests have been carried out to study this aspect.

Test material was obtained from a mill which uses a high temperature kiln to dry a lumber mix with 90-100% balsam fir. Small samples were cut from this material and conditioned to 15% moisture content (MC) as described for other material in this report. This material was then tested with a moisture meter and the results compared to oven-dry MC's.

The results confirmed our observations made during the main study. Exposure to high temperatures (up to 116° C) does not have any effect on DC resistance moisture meter readings taken on balsam fir. The scope and nature of this study does not provide any insight into why balsam fir behaves differently in this respect than black spruce or jack pine.

This does pose a problem to mills drying at high temperatures who also have a significant proportion of balsam fir in their lumber mix. Due to the impracticality of having a different rule for each species, we suggest that all concerned parties agree on a compromise that neither severely disadvantages any party or drastically effects the accuracy of the results.

REFERENCES

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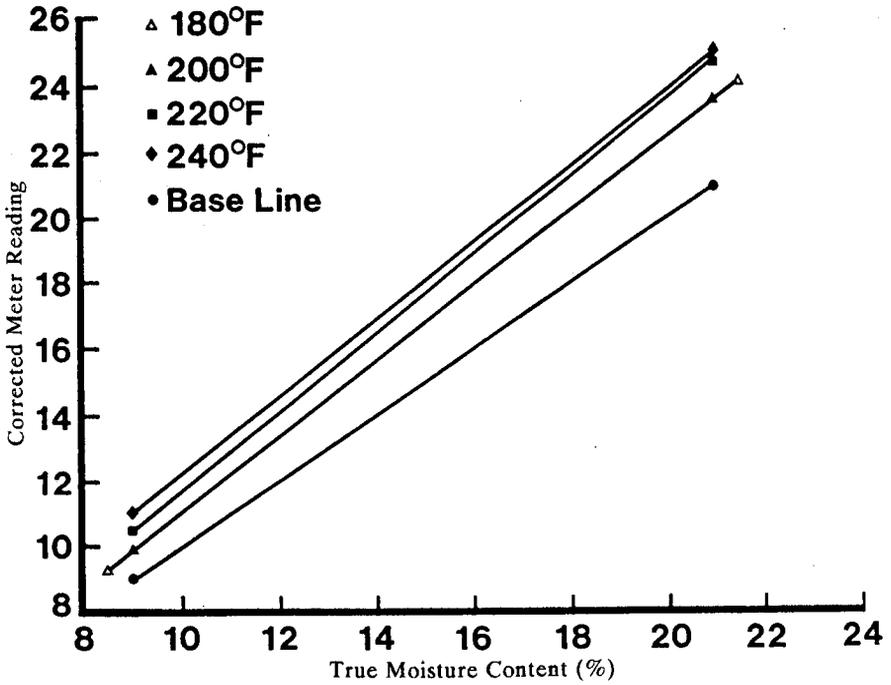


Figure 1. Temperature effect on meter readings - jack pine.

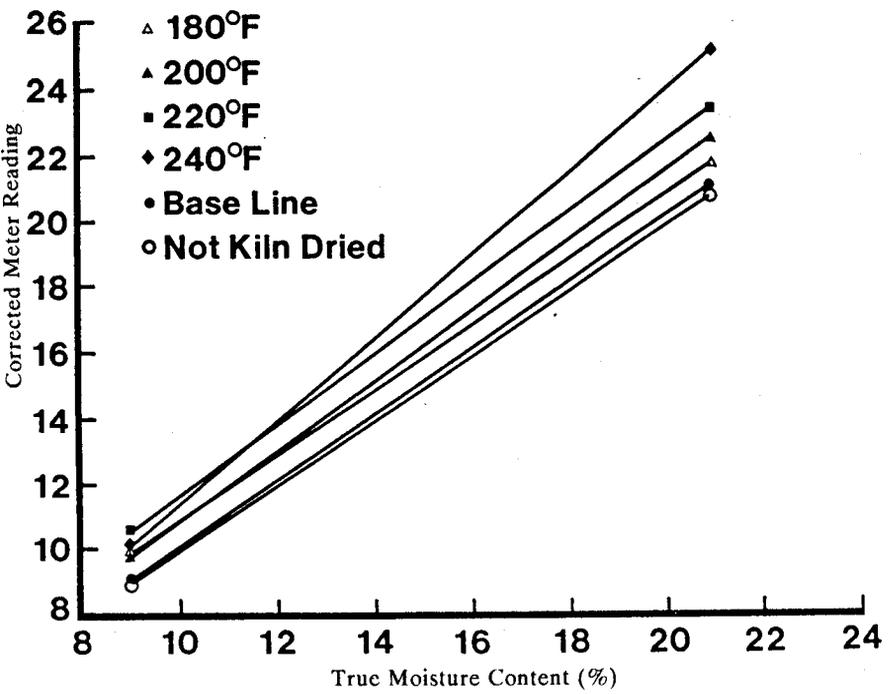


Figure 2. Temperature effect on meter readings - black spruce.

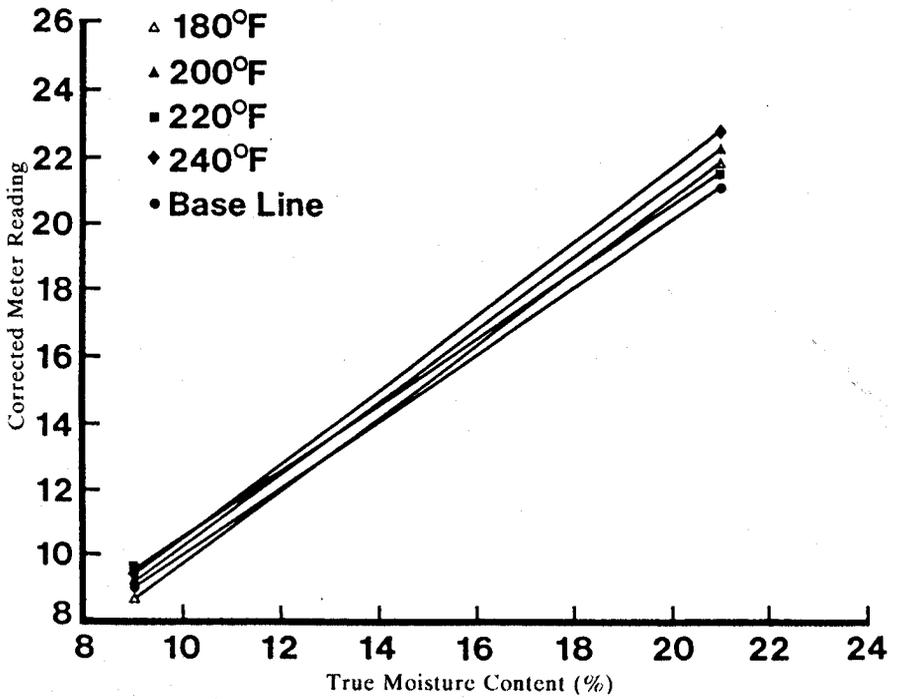


Figure 3. Temperature effect on meter readings - balsam fir.

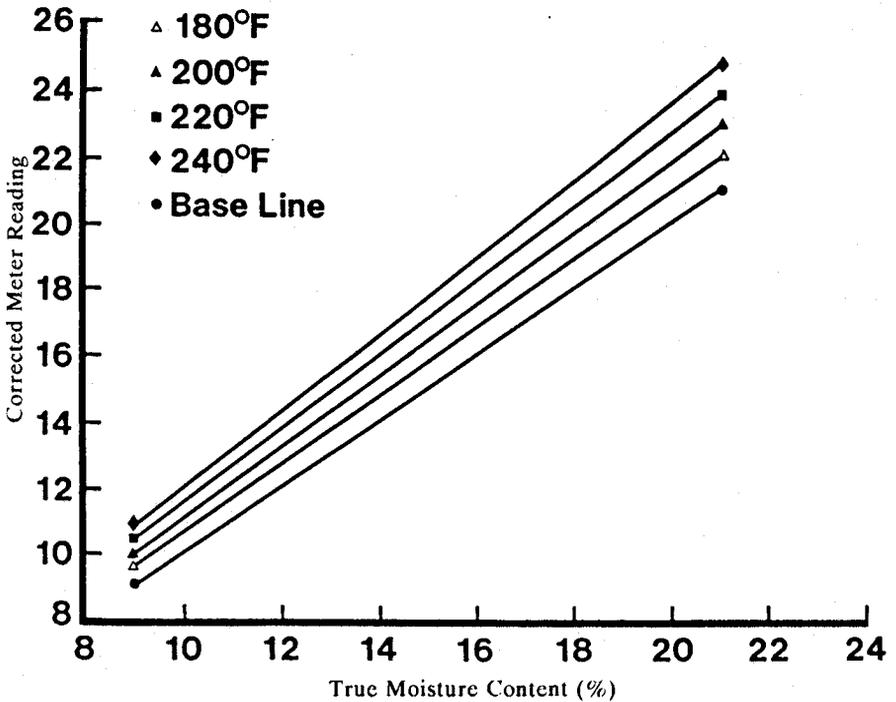


Figure 4. Adjusted temperature effect on black spruce and jack pine.