GUIDELINES FOR ON-SITE MEASUREMENT OF MOISTURE IN WOOD BUILDING MATERIALS

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PREFACE

The need for this document is driven by the concern for the durability of wood structures built under wet site conditions in certain parts of the country. Of particular concern at the present time are building sites in the lower mainland of British Columbia where it has been determined that greater care is needed in moisture management through the design and construction techniques used for building envelopes. As a result, there has been an increased interest in field measurement of moisture in wood-based building materials, including lumber, panels and other products. While there is considerable information on lumber from experience with kiln drying, there is little or no information on moisture content measurement in panels or engineered wood products which are dry from manufacture. There is limited information on fire retardant- and preservative-treated wood. Similarly, there are no widely accepted procedures for non-destructive measurement of moisture in non-wood materials. These areas require further research.

Builders, inspectors and engineers undertaking moisture measurements on site in many instances do not possess the necessary background for using or interpreting moisture meter readings from wood and wood-based products. Because judgement is also needed in their interpretation, this document has been prepared to provide both detailed instructions and background information to assist persons involved in these endeavours. Users may wish to consult with experienced practitioners in cases where there are questions concerning this information.

The objective of this report is to assist those not fully informed in wood moisture measurement technology and, in addition, to provide general guidance with respect to measuring moisture content in field conditions. Field measurements are more variable and complex than measurements in controlled laboratory or industrial conditions, and as a result there are no established practices addressing all aspects of this methodology. This report is not intended to conflict with methods or techniques used by the wood products industry.

PRÉFACE

Ce document a été conçu pour répondre aux préoccupations ayant trait à la durabilité des ouvrages en bois construits en chantier lors de temps humide dans certaines régions du pays. À l'heure actuelle, on s'inquiète particulièrement au sujet des bâtiments érigés dans les basses terres continentales de la Colombie-Britannique, où il a été déterminé qu'il faut apporter un plus grand soin à la gestion de l'humidité par l'entremise des techniques de conception et de construction de l'enveloppe des bâtiments. Il en résulte donc un plus grand intérêt pour les méthodes de mesure de l'humidité présente dans les matériaux de construction en bois ou ses dérivés, y compris le bois d'œuvre, les panneaux et les autres produits.

Nombreux sont les constructeurs, les inspecteurs et les ingénieurs qui n'ont pas les connaissances suffisantes pour interpréter les résultats des lectures d'humidité effectuées à pied d'œuvre sur le bois et sur ses dérivés. Parce qu'il faut une bonne dose de jugement pour interpréter les lectures, on a préparé le présent document dans l'optique de fournir tant les instructions détaillées que les informations documentaires pour aider les personnes qui œuvrent dans le domaine. Les utilisateurs ont avantage à consulter des praticiens expérimentés dans le cas où ces informations soulèvent des questions.

Le rapport a pour objectif de renseigner les personnes mal informées au sujet des appareils de mesure des taux d'humidité du bois et également de leur fournir des directives générales quant à la prise de lectures d'humidité sur le terrain. Les lectures d'humidité effectuées sur le terrain sont plus variables et plus complexes que celles prises en laboratoire ou en milieu industriels, et il n'existe pas de pratiques établies qui répondent à tous les aspects de la question. Les informations contenues dans le rapport ne se veulent aucunement conflictuelles avec les méthodes ou les techniques utilisées dans l'industrie du bois d'œuvre pour la production et le classement des différents produits.

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PART 1

SOME HISTORY ON WOOD, DRYING AND CONSTRUCTION PRACTICES

Some moisture in wood framing and other building products is normal. Lumber can absorb a great deal of moisture before the effects pose a potential risk to the wood and surrounding materials. Climatic conditions during construction, and construction practices themselves, provide circumstances that can result in excess moisture retention or accumulation. When excess moisture is retained over sustained periods, premature failure due to decay or other physical, biological or chemical effects can occur.

The main purpose of this document is to assist in understanding how moisture in wood products can be measured in the field. However, this purpose will be greatly facilitated by understanding how construction practices affect the moisture content attained by materials and their durability. Some of this information is contained herein, for context and interpretation purposes.

Code Requirements

The National Building Code of Canada (NBCC), and the provincial codes based on it specify that lumber be dry at the time of installation in buildings. The definition of "dry" lumber in the North American context is wood having a maximum moisture of 19% on a dry weight basis. This is a typical moisture content that air-dried lumber can also achieve in covered, outdoor storage. This requirement is derived from a long history of scientific research and experience involving good practice by the construction trade.

The justification for the 19% specification does not seem to be recorded. However, it has long been recognised in the lumber industry that once logs have been sawn into lumber, if drying conditions are poor or the lumber is close-piled, there is opportunity for fungal infection and staining ~~to~~ which may degrade its appearance and render it less marketable.

The following quotation was taken from an early edition of the Wood Handbook (1940 revision) [1] in a discussion of storage of lumber at yards (p 205)

> *"Lumber that has a moisture content higher than 20 percent is likely to become stained or decayed when piled solidly. On the other hand, lumber, even though at a moisture content of less than 20 percent, when not properly protected against the weather is apt to stain or decay."*

This was at a time when the majority of wood was air-dried and may well have become infected with decay fungi during the drying process. Today, we recognise that while existing decay may continue until the wood is dried below 20%, re-infection of kiln dried (normally sterile) wood by decay fungi will not occur unless the moisture content approaches the fibre saturation point (typically 28-30% MC) [2]. The 20% rule is now considered to provide a "reasonable margin of safety against fungal damage" [3].

While some may now recognize the physical effects in buildings caused by moisture gradients [4], it is likely that biological (durability) considerations were the primary basis for the current regulation concerning moisture in construction lumber.

Industry Drying Practices

Canadian softwood lumber producers use large, batch-loaded kilns to dry lumber under controlled conditions of temperature, relative humidity, and airflow. Variables such as species, initial moisture content, dimension, and other characteristics, affect drying times. Even after taking all of these variables into consideration, wood remains a complex material to dry. Natural variations in grain pattern, density, and the amount of sapwood/heartwood result in a certain amount of variability in the final moisture content. For these reasons, end users must expect and be prepared to accommodate for a certain amount of variability in the final MC.

Virtually all kilns in the softwood construction lumber industry are of the heat-and-vent (or conventional) variety. Very few mills use non-traditional systems such as dehumidification or vacuum drying for softwood dimension lumber. Heat-and-vent dryers used in the drying of dimension lumber are large chambers with forced air circulation systems and controlled ~~of~~ temperature and relative humidity systems. Drying schedules may employ maximum temperatures of 82 to 88° C. (180 to 190° F.) in conventional kilns ~~or~~ and up to 115°C. (240° F.) in high-temperature kilns. These temperatures are sufficient to kill all insects and any other organisms that might be present in the wood.

Computerised controls are used in most dry kilns to accurately monitor and control the drying conditions and to collect some data on the moisture content (MC) of the material in the process. There are no practical systems available to accurately measure the moisture content of wood in a dry kiln. Kiln operators have data/tools available to assist in determining the end point for drying, but, for the most part, accurate measurement of MC cannot be conducted until after the wood is removed from the kiln.

Moisture content sampling at the planer mill is the point in the process where the most accurate and greatest quantity of information can be gathered. Many of the larger softwood mills employ in-line moisture meters to monitor the MC of every piece of lumber processed. If well calibrated and maintained, such instruments can provide average estimates of the MC to within plus or minus one percent of the "true" MC. Spot checks with handheld moisture meters are also usually conducted at various points in the dressing (surfacing), grading, and packaging process. Mills rely on such information to verify conformance with MC specifications and provide feedback to the dry kiln operator. Sampling of final MC by the oven-dry method may provide accurate information on an individual board basis but it is impractical for obtaining an accurate picture of the condition of the entire load.

Historic versus Current Building Practices

In the past, construction practices were forgiving to either higher initial MC's or addition of moisture during the building process. Construction scheduling was slower and permitted gradual drying of the standing wood frame structure. Use of lumber subflooring permitted drainage of moisture that impinged on the partially completed structure and prevented ponding of water. Lumber wall sheathing, permeable to both air and vapour movement, resulted in rapid drying of excess moisture that was in the wall cavity.

With the application of lath and plaster finish for the interior, a wet process, drying was needed before the final finish plaster coat was applied. This was commonly done after a longer period of time when sufficient drying and building settlement had occurred to allow any shrinkage cracks to be manifest and to be repaired before the final finish coat and paint were applied. These building practices are not now commonly employed in North America.

Dry rather than wet practices for interior finishes, use of plywood and OSB panels, and the use of power tools all provide for greater flexibility and ease of assembly, which in turn have resulted in much shorter construction times. Faster construction times are encouraged by the cost of money tied up in purchasing the land and materials for the building.

Recently, there has been increasing attention paid to construction moisture built in to wood framing. In 1991 CMHC published a report of a study they had commissioned Forintek to undertake to assess this issue across the country [5]. The moisture content of framing in wall studs and plates of over 515 houses under construction were assessed at 10 regional centres and at 4 different seasons of the year. In some parts of the country, S-GRN lumber was used predominately and high moisture levels were measured on site. When S-DRY lumber was used, moisture contents tended to be lower, but not always below 19%. At some sites, re-wetting had occurred during transport, storage and construction. Bottom wall plates were found to have higher moisture contents than wall studs because they were more vulnerable to absorbing rainfall due to their position.

The speed of construction has much to do with maintenance of a greater degree of affordability. This process leaves little room for accommodating circumstances such as wetting of materials. Thus, given these constraints and the need for producing durable structures, a rethinking in design and/or specification of materials may have to be done to produce assemblies that will meet all needs at an optimum cost.

Consequences of Drying -- Shrinkage

We have touched on building practices that were used in the past to deal with shrinkage-induced effects related to drying. It is worth pointing out that whether lumber framing conforms or does not conform to the regulation concerning moisture content in the NBCC, shrinkage effects still have to be accounted for in construction. The equilibrium moisture content (EMC) finally attained by lumber in the building may be 8% or lower depending on its location in the building and the climate.

The shrinkage of green lumber as it dries to its end point EMC can be as much as 4.5%. Dry lumber meeting the NBCC will experience significantly less shrinkage but it still can be expected to shrink in the order of 2%. Longitudinal shrinkage is much smaller being in the order of less than 0.1% for green lumber, and is normally ignored in calculations. A useful tool for estimating shrinkage for those with access to the Internet is the Canadian Wood Council tool DeltCALC found at www.CWC.ca/design/design_tools/.

The consequences of shrinkage are nail popping leading to loss in air tightness (and drywall plaster popping), differential settlement leading to drywall cracks, floor squeaks, and building height settlement leading to potential problems with plumbing. These problems are normally associated with the initial drying-out period as lumber dries to its EMC. Our current building practices can accommodate for these effects. Probably the most important concern is the need for more careful attention to installation of air barriers and vapour barriers. These help minimize energy loss and restrict movement of air and moisture in wall spaces.

Differential settlement leading to drywall cracking is minimized by use of drier wood, but minor defects may be repaired during the warranty period (typically one year). The use of air and vapour barriers helps to ensure that the consequences of cracking in the drywall are aesthetic rather than performance-reducing.

Floor squeaks as a result of nail popping of attachments are a nuisance but can be overcome by field gluing of floors, and to some extent, by using flooring screws. Building height shrinkage is overcome by accounting for it in the design of the plumbing runs. In summary, current building practices can overcome these deficiencies by design, resulting in functional, durable structures.

Key Points

- The building code requirement for use of lumber having moisture content of 19% or less at time of framing is based on long standing experience for average conditions
- Green lumber can be used but carries the risk of greater problems and requires particular attention to the wall system used and scheduling of construction
- Past building practices allowed greater opportunity for drying during construction
- Current building practices allow less opportunity for drying during construction and greater planning may be needed to produce assemblies that meet all needs at optimum cost
- Shrinkage of lumber is an expected consequence of drying. This is minimized by use of kiln-dried or air-dried lumber. Other related effects can all be designed around to minimize their effect on the quality and performance of the end product.

PART 2

MOISTURE CONTENT MEASUREMENT

In the lumber industry, moisture content (MC) is defined as the amount of water contained in a sample expressed as a percentage of the oven-dry weight of wood. There are a number of ways of evaluating the wood MC and the choice between them is mostly based on the level of accuracy required and whether or not a destructive test is an option. The two techniques commonly employed by the lumber industry to assess MC in solid wood are the oven-dry method and electrical moisture meters. Both methods are described in the following sections.

Oven-dry MC Determination

The oven-dry method is generally the standard against which other methods of assessing MC are judged, since it is the most reliable and reproducible in terms of precision and accuracy. This method measures the MC of a small specimen of wood, typically selected from a larger lumber sample. It is a simple test to conduct, but because it is destructive and time-consuming, it is generally used in laboratory studies on specimens chosen to represent specific samples. For field studies, rather than being used as the principle method of collecting MC data, it is typically used as the reference to calibrate other procedures (i.e. handheld moisture meters). This same procedure can be used to determine the moisture content of non-wood materials, provided that they do not have components that are volatile.

For information: to conduct an oven-dry test you will require:

- A sample drying oven capable of maintaining an even temperature of 102 to 105° C.
- A balance with a capacity of approximately 500g and an accuracy and readability to within 0.1 g.

The following steps are involved in conducting an oven-dry test:

1. The samples should be cut approximately 30 to 40 cm in from the end of the board in order to get a good approximation of the board average. The samples should be 2 to 3 cm. wide along the grain (see Figure 1).
2. Weigh the samples and record the weights directly on the samples and on a separate tally sheet. This is the "wet weight" of the sample.
3. Place the samples in an oven, pre-set at 102 to 105° C, for 18 to 24 hours. Larger blocks may take longer to dry. Toward the end of this time period, weigh one or two of the larger samples at several 1-hour intervals to assure they have reached a constant weight. Record the final weight as the "dry weight" of the sample.
4. Calculate the MC of the samples using the following equation:

$$\text{Moisture Content (\%)} = \frac{(\text{wet weight} - \text{dry weight})}{(\text{dry weight})} \times 100$$

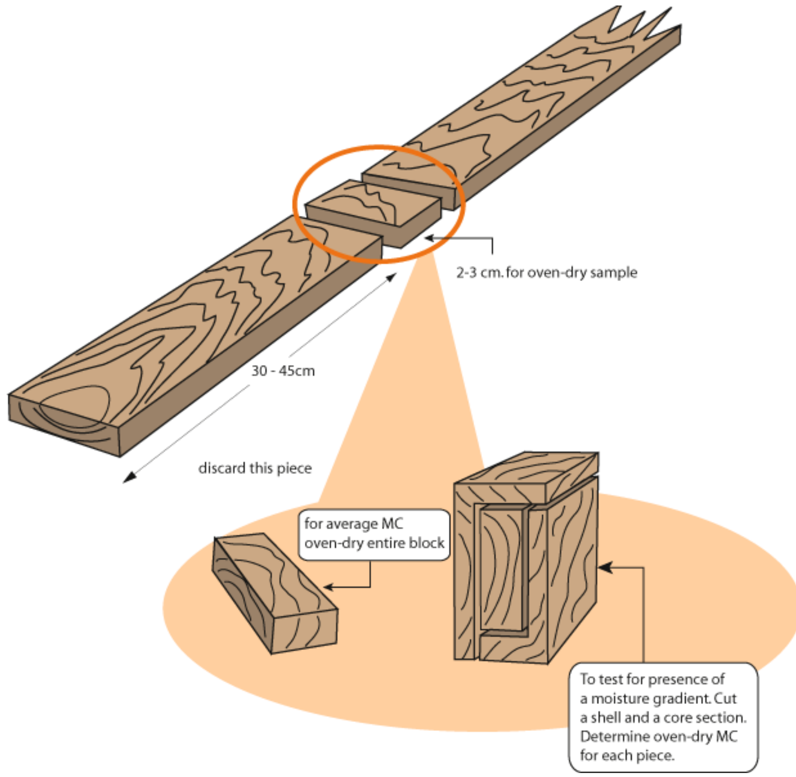

Figure 1: Preparation of specimens for moisture content determination by oven-dry method

The oven-dry method provides a measure of the average MC of the block of wood that is being tested. If there is a moisture gradient present it will not be detected by the sampling method described above. To test for a moisture gradient, the oven-dry sample can be cut to produce a shell and core sample as shown in Figure 1.

A household-type microwave oven can be used to dry samples and save time in obtaining results; however, there are some precautions to be taken. To prevent overheating and burning, the sample will have to be dried using several short bursts at a low power setting in the microwave oven. Turnaround time for the test can be reduced to about 1 hour but will require constant supervision.

Types of Moisture Meters

There are two general categories of moisture meters based on the electrical properties being assessed, i.e., DC-resistance and dielectric meters. Both systems are widely used in the lumber manufacturing industry. Under good conditions, both types of meters have similar levels of accuracy and the choice between the two depends on the type and location of the test to be conducted. Each meter is affected by different attributes of the wood and these must be taken into account in order to obtain a good estimate of the moisture condition.

Figure 2 shows two different moisture meters, one based on dielectric properties and the other on DC-resistance. The application of each meter type is discussed in the following sections.

(a) (b)

Figure 2: D.C. Resistance moisture meter (on left) and dielectric moisture meter (on right)

This document is not intended to replace operating instructions that are provided with all of the widely used instruments for measuring moisture. Aside from general care and maintenance of the meter, special attention should be given to calibration. All meters are provided with some means of verifying their calibration. A spot check on calibration should be carried out, following the manufacturer's instructions, before conducting a moisture check on a building or wall system.

With both of the meter types discussed below, it is important to sample MC only in clear sound areas of wood. The relationships between the electrical property being used and the MC of the wood are all based on readings in clear wood. Wood characteristics such as knots, pitch pockets, and incipient decay may affect the density or extractive content of the wood, and alter the property being measured. Ions from corrosion of fasteners can also distort the readings.

Dielectric-based Moisture Meters

Dielectric moisture meters describe a broad range of instruments that rely on the relationship between a dielectric property and the MC of the wood. This can include measurements of the dielectric constant, radio frequency (RF) power loss, and capacitance. The relationships are only strong below the fibre saturation point. The working range of most of these meters is from 25 to 30% down to approximately 5 to 6% MC. The specific technologies of each manufacturer are not fully revealed which makes it difficult to make broad statements on this class of meter.

Dielectric moisture meters have a sensor which is brought into direct contact with the sample to be tested. The RF field emitted penetrates the wood and the response is measured by the meter. Manufacturers claim penetration of the RF field of 25 mm or more into the wood. On this basis, the meters should be able to provide a good estimate of the average MC of the cross-section of wood up to 50 mm thick. Both wood density and moisture level affect the meter reading. A correction is required to compensate for differences in density between species. These meters are only minimally affected by wood temperature and this is generally not a concern for testing at ambient conditions. Species correction factors for these meters are supplied by the manufacturers.

Dielectric meters are affected by moisture gradients. They tend to be more heavily influenced by surface moisture and less affected by core moisture. As an example, this type of meter will not work well for a board that may be well dried through most of its cross-section but has been re-wetted on the surface from recent exposure to moisture. In this instance the meter will over-estimate the average MC. This may be a common problem at building sites where partially framed structures are exposed to rain or melting snow.

There are probably only limited circumstances where a dielectric-type meter can be used in inspecting lumber at a building site. This may include an inspection of a delivery of wrapped lumber or a test on studs well protected from the weather. They may also be effective when testing vertical members that have been well protected from the weather. Meter readings on sill plates and other horizontal members may not be as accurate due to the effect of the backing material and a greater tendency for such pieces to have severe moisture gradients. This type of meter could be useful to sample a large number of pieces very quickly and identify potential problem areas that can then be further assessed by oven-dry testing or using a DC-resistance meter.

DC-resistance Meters

DC-resistance is another electrical property of wood that varies with its MC. Again, the relationship is only strongly correlated within a range of 5 to 25% MC. Above that range the meter will still provide results but these should be considered as only a rough approximation of the MC. Within the range mentioned above and when used in accordance with recommended procedures, the meter is accurate to within plus or minus 1 to 2% MC of the oven-dry MC. Readings will be more accurate at the lower end of the MC range and less accurate as the wood approaches 25% MC. Readings above 25% will be less accurate but are still a useful indicator that the wood is at an elevated MC.

Meter readings are obtained by inserting a pair of pins into the wood and measuring the resistance to flow of a DC current. It is important to note that the line joining the tips of the pins should be aligned along the grain of the wood. The pins are generally insulated along their length with only the tips exposed. For testing of wood frame construction, insulated pins should be used and care taken to replace them when the insulation becomes worn. The meter readings represent the MC estimate for a narrow band of wood between the tips of the pins. This must be kept in consideration when using the meter and interpreting the results. The effect of moisture gradient and pinning depth are discussed in the following sections. The DC-resistance of wood is affected by a number of additional factors. The principal factors are wood temperature and species, both of which are also discussed in the following sections.

Adjusting for Temperature

When moisture meter readings are taken out-of-doors, or in unfinished buildings, the effects of temperature variation play an important role in accuracy. The temperature of the wood, as well as the air, needs to be considered. The electrical resistance of wood decreases as its temperature increases. The decreasing resistance has the effect of producing a higher MC estimate using the moisture meter; this must then be compensated for. Over the range of –30 to 50° C., the average effect of temperature, results in elevating the meter reading by approximately 1.1% MC for every 10 C° rise in wood temperature. This effect is independent of species and is compensated for before applying the species correction. In many meters the temperature and species correction is applied internally.

It is important that the actual wood temperature be considered when applying a temperature correction, particularly in cases where the air and wood temperatures vary widely with time or location in the building. In some circumstances, it may be possible to estimate the wood temperature to within a few degrees; however, in many instances a good estimate will not be possible. A thermocouple temperature probe is the most convenient way of obtaining an accurate wood temperature. Figure 3 shows a handheld meter with a thermocouple probe sized to fit in the hole left by the moisture meter probe. It is usually only necessary to take temperature readings on a few boards and apply the average temperature to all readings.

Care should be taken when testing boards in a wall system, as there may be wide variations in temperature between pieces. For example, vertical pieces exposed to the sun on one wall may be quite different from sill plates on an opposite wall. In such instances it will be necessary to take temperature readings from more locations, or over a longer period of time.

Figure 3: Hand-held digital thermometer fitted with thermocouple probe to measure internal wood temperature

Adjusting for Species

Differences in wood density, structure, and extractive content (naturally occurring chemical constituents of wood) between species result in variations in electrical resistance. Various studies have been conducted to quantify the effect of species for all commercial species from North America as well as most other regions of the world. Table 1 demonstrates this effect for small clear wood specimens of several Canadian species at two MC levels and a fixed wood temperature of 20° C. *Note: These effects may vary slightly, depending on the moisture gradients (drying, wetting) and distribution in full-sized lumber.*

Table 1: Example of effect of wood species on meter reading*.

Species	Meter Reading Corresponding to a True MC of:	
	12%	15%
Douglas-fir	11.5	14
Jack Pine	9	11.5
Western Hemlock	10	12
White Spruce	9	11

* *Taken from "Moisture Content Correction Table for the Resistance-Type Moisture Meter", Forintek Canada Corp. Special Publication SP511E, 1984*.

To obtain the most accurate estimate of MC, the species of every piece of wood tested would have to be known. As most construction lumber is sold in species groupings, and it is difficult to differentiate species within these groupings, correcting for the species is not always practical. Inspecting the grade stamp will identify the species grouping and also the general area of the country from which the material originated.

Sources of Temperature and Species Correction Factors

When dealing with a species group there is the potential to over or under-estimate the MC by up to 6% by applying the wrong species correction. There are several alternatives in deciding which correction factor to apply to readings from a species grouping.

1. For the best level of accuracy possible with a DC-resistance meter, it would be necessary to identify the species of each board and to measure its internal temperature. When the species can be determined, the most appropriate correction factor can be applied to each reading. Forintek has developed temperature and species correction factors for all major Canadian wood species for the Delmhorst DC-resistance moisture meter. These are available in a booklet entitled "Moisture Content Correction Tables for the Resistance-Type Moisture Meter", publication number SP511E [6]. Most meter manufacturers also supply correction factors but the accuracy and relevance to the species you are working with should be verified by comparison against oven-dry tests. However, as noted above, the species for each board is not generally known, or easily established in the field by untrained personnel.

2. While in most cases it will not be possible to identify the exact species of every board, some information may be available on proportion of species in a given load. If it is known that there is one predominant species in a load, then it is recommended that the correction for that species be applied to all readings rather than using an "average" correction as described in the following option. Information on the predominant species may be available from the supplier or someone on site that has experience in species identification. As an example, pine is generally easy to distinguish from spruce and fir because of the pinkish to reddish tinge of the heartwood. If a load is seen to be mostly pine and has a grade stamp from a Western Canadian mill, it would be advised to use the lodgepole pine correction factor.

3. When the individual species can not be determined, then a combined or "average" correction factor for the species grouping should be applied. Combined correction factors have been developed for the three main species groupings in Canada and are listed in Appendix I of this report. By applying a combined correction factor an additional source of potential error is introduced. The total error is generally less than 2% MC but in some cases it can be as high as 4% MC.

Moisture Gradient and Sampling Depth

When construction lumber is removed from the dry kiln, it has a predictable moisture gradient with a lower moisture content in the shell than in the core. Tests have shown that, after a reasonable period of time out of the kiln, the average moisture content for the cross-section of a board having such a moisture gradient can be approximated by measuring the moisture content at $1/5^{th}$ of the board's thickness. For 2-inch dimension lumber machined to 1.5-inches thick, it is recommended that the insulated pins of the moisture meter be inserted to a depth of 5/16-inch (8mm). *Note: it is important that the pins be insulated to get readings at specific depths.*

This pinning depth should be appropriate for all recently manufactured lumber and material being inspected directly from wrapped lumber packages. It is not appropriate for lumber that has been exposed to conditions that have caused it to regain moisture. Figure 4 shows a comparison of lumber with a normal post-drying MC gradient versus material that has been re-wetted.

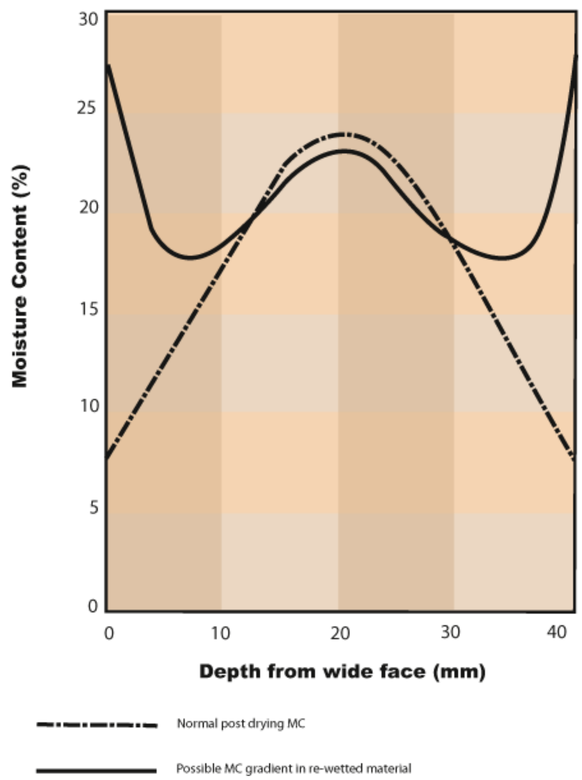

Figure 4: Typical moisture gradients in cross-section of 2-inch thick dimensional lumber

The presence of an atypical moisture gradient can be detected by taking readings at several depths. If the readings are steadily increasing from surface to core, the 5/16-inch pinning depth is appropriate. When an atypical MC gradient exists, it is recommended that readings be taken at two different depths and averaged. The first reading should be taken at approximately ¼-inch (6mm) and the second in the geometric centre of the piece, ¾-inch (19mm).

When the face of a stud is not accessible, it may be necessary to sample a board's moisture content from its edge. There are no accepted practices for pinning depth from the edge. In such cases, it is suggested that one reading be taken at ¼-inch depth (6 mm) and a second reading at about 1-inch depth (25 mm). Care should be taken to keep the pins parallel to the wood grain and as close as possible to the mid-thickness of the board.

Wet Pockets

Several Canadian species are prone to a condition referred to as "wet pockets", which prevent the establishment of a normal moisture gradient. The main softwood species that are affected are balsam fir, alpine fir, hemlock, and white pine. The problem is due to a bacterial infection in the living tree which does not affect wood strength or colour but does affect its permeability. The permeability is reduced to the point where, wet pocket zones in a board may take 3 or 4 times as long to dry as normal wood. The infection is usually not widespread in a tree and therefore typically affects only portions of a board.

The objective in drying construction lumber is to reduce the overall MC to 19% or less. This can be achieved without necessarily drying all of the wet pocket zones in every board. After a normal drying cycle, it is possible to find localized areas in a board cross-section that may have MC's as high as 30 to 50% MC while the rest of the wood is well below the target MC (see Figure 5).

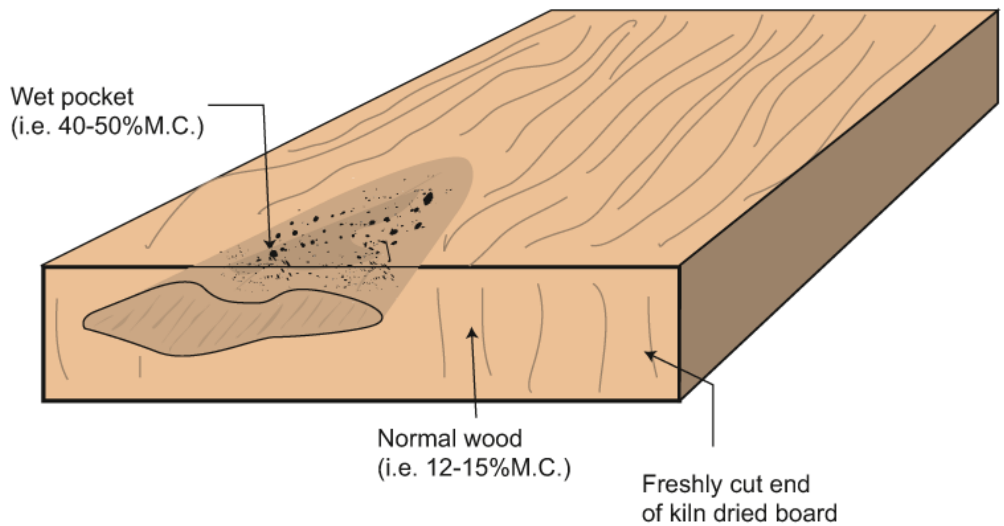

Figure 5: Typical wet pocket in cross-section of a board from a species such as balsam fir or western hemlock.

When testing wood that potentially contains wet pockets, care must be taken to avoid obtaining misleading results. If you are using a dielectric meter, the readings will not be as heavily influenced by wet pockets as they may be when using a DC-resistance meter. If you obtain a high reading on a single board, take at least two further readings at other locations on the same board. If you are using a DC-resistance meter and obtain a meter reading that is significantly higher than neighbouring boards, two further meter readings should be taken.

It is recommended that the board be tested 1 to 2-feet (300 to 600 mm) further along its length and, if possible, on the opposite side. If the average of the three readings is below the target or, if two of the three readings are below the target then the piece can be considered adequately dry. Small wet pockets are not a concern as they will eventually dissipate into the rest of the board and dry out. Furthermore, fungi will not be able to gain access to the wet wood because the wood surfaces will be dry.

MEASURING MOISTURE CONTENT OF OTHER WOOD-BASED BUILDING MATERIALS

Oriented Strand Board [OSB]

OSB panels are produced by laying up parallel and cross mats of wood strands having a wafer-like appearance. The adhesive used is either applied in powder form or sprayed in liquid form as the strands are tumbled prior to lay-up in mats. Lower density aspen and poplar are preferred for this product because these strands can more easily be made to conform to each other under heat and pressure. The high temperatures and pressures used also result in some densification of the material. Industrial wax is applied to the wafers to allow better uniform adhesion of powdered adhesives to the wafer surfaces. This also imparts some water repellency to the finished product.

Due to the densification and the addition of wax and adhesive, the bulk density of OSB is higher than that of wood or plywood. The moisture content (dry weight basis) is about 3-4 % lower than for solid wood of the same species at the same conditions.

Some limited testing was conducted at Forintek to develop a correction factor for OSB. This test was limited to sampling material from one supplier. The tests were all conducted at room temperature with samples equalized at three different MC levels. Existing temperature correction data for solid wood was used to develop corrections at other temperatures. Table A-4 provides a summary of the combined correction for the product and temperature effects.

Plywood

Plywood panels are laid up with parallel and cross veneers of rotary peeled veneers from logs. After drying, sorting and grading, liquid beads of adhesive are deposited on each sheet or width of veneer on their way to the lay-up station. The pressure and temperature used by the presses in the production of plywood are lower than those used for production of OSB resulting in less densification. The adhesive forms a mostly discontinuous thin film that alters the liquid permeability of the product somewhat. The moisture reading obtained with a resistance-type meter is based on the most conductive path of the veneer into which the pins have been inserted. At high moisture levels, because of the possibility of liquid paths in the more open structure of veneers compared with solid wood, somewhat higher than average readings may be obtained.

Because of the added mass of adhesive and slight densification, the bulk density of plywood is higher than wood from which it was derived. Consequently, at specific environmental conditions, the equilibrium moisture content of plywood will be about 2% less (dry weight basis) than would be achieved by the parent material based on oven drying determinations. More accurate readings can be obtained if care is taken to insert the pins from a resistance-type meter into the same layer of veneer. Grain direction has a small effect and it is advisable to take the average of parallel and cross readings.

The species of veneers used in the core may not be the same as that used on the faces. Consequently one is limited to using species and temperature corrections based on broad species groupings such as are provided in the Appendix.

Treated Lumber

Copper Chrome Arsenate (CCA) treated wood is the most commonly available treated wood used in construction. This wood is dried and then pressure treated in a water-borne solution of chemical. Consequently, the presence of an S-DRY stamp on pressure treated lumber is not indicative of the moisture content after treatment. The material is stored at ambient temperatures or heated for a short time and the chemical becomes fixed to the fibre in the wood and protects the treated portions from decay. The treatment adds water to the wood, but this is not normally considered to be a problem for exterior uses. For use in a building, kiln drying after treatment (KDAT) should be specified.

Loading of the chemical tends to be restricted to the shell and sapwood of each piece of lumber. However, this level of protection has been shown to be sufficient for above ground applications. For high risk exposure conditions, such as experienced by preserved wood foundations, higher treatment levels are required.

The moisture content of CCA-treated wood, when used in more severe conditions in the building envelope can be evaluated using the same procedures as for untreated wood. No special correction need be made for measurement in the treated portion of the lumber.

Borate treated lumber and sheathing has recently been introduced into the market in Canada. This is also a water-borne treatment, but it is intended only for applications protected from rain. All borate treated wood should be specified as KDAT. The treatment will also prevent decay and be instrumental in reducing the risk of mould growth. At the current time, little is known about the effect of the treatment on the moisture meter correction coefficients.

Fire-retardant-treated wood will be either coated or pressure treated with chemicals. In Canada, the majority of fire-retardant-treated wood used in construction is strictly surface coated. The interior of surface-coated wood is essentially unaffected and therefore the method of moisture measurement is unchanged from that for untreated wood. It is important to ensure that insulated pins in good condition are used to avoid any electrical contact with the fire retardant. In pressure-treated material, the presence of fire retardant within the wood will affect its resistivity and therefore a separate correction factor is required. At present, there is insufficient information to suggest how to interpret moisture meter readings in this situation. If moisture content data on such material is required, cutting small samples for an oven-dry determination is recommended.

Key Points

- Moisture meters provide good estimates of the actual moisture content of wood
- DC-resistance meters are the most practical and versatile for testing of construction lumber that is in place.
- DC-resistance meter readings must be corrected for the effect of wood temperature and species, in order to get the most accurate predictions of MC.
- Proper pinning depth is important to ensure a good estimate of the average MC for the cross-section.
- Care must be taken to ensure that reading are obtained from sound, clear wood and special precautions taken when dealing with species prone to wet pockets.

- Meters can be used on composite products such as Plywood and OSB. For solid wood treated with preservatives or fire-retardants, however, there is limited information available on how to interpret readings.

PART 3

FACTORS TO CONSIDER WHEN ASSESSING THE MOISTURE CONTENT IN LUMBER FRAMING

Sampling of Wood Framing

This section will address the subject of sampling to assess the moisture status of the lumber framing in a building under construction. In part we will also attempt to provide guidance on how to assess the condition of particular portions of the structure.

Consideration of Moisture Distribution

The description of use of DC-resistance handheld moisture meters described in Part 2 gives the operator guidance on obtaining and interpreting a reliable moisture content value at a particular point. Dielectric (RF-based) meters can be used to make quick assessments but are not the recommended means for a detailed evaluation of a wood structure. In deciding when and where to assess the moisture contents, it is necessary to understand the causes and likely distributions and accumulation of moisture.

The potential for introduction of construction moisture by rain, snow or contact with wet concrete means that whatever the moisture content distribution of the individual pieces of lumber before construction, the quantity and distribution of moisture at time of construction may be radically altered. Bottom wall plates and the bottom end of wood studs are most vulnerable to soaking up and retaining water. Panel subflooring does not drain so retention of precipitation by ponding is common on floors that are exposed to rain or snow. Bottom plates in direct contact with water can absorb moisture rapidly. Concrete floor toppings will also add to the moisture load.

When moisture meter readings indicate that a piece of lumber exceeds the desired upper level, it is important to determine if the moisture content is generally high or if this represents a small portion of the material. In other words, is the high moisture content due to a small wet pocket typical for that species, or is it a significant re-wetted portion that was in contact with liquid water?

Wall Studs and Plates

To assess the general moisture content of a stud in a wall, two sampling locations with a moisture meter are recommended. Readings taken at a level of about 300 mm and at mid height, approximately 1200 mm, should give a fairly good estimate of the basic moisture content of the vertical members in that elevation of the building, at that storey level (see Figure 6).

Note: Although a pinning depth of about 5/16" is recommended in normal conditions, it is best to check the core moisture content as well. If the shell and core moisture contents of the cross section are similar this might indicate that the piece had uniform moisture on delivery to the site. If the surface is relatively dry and the core is wet (above 25% MC), this may indicate that high MC lumber was used and that it is in the process of drying; if the shell is wet and the core is drier, re-wetting is more likely. The question will be to determine whether the levels are permissible.

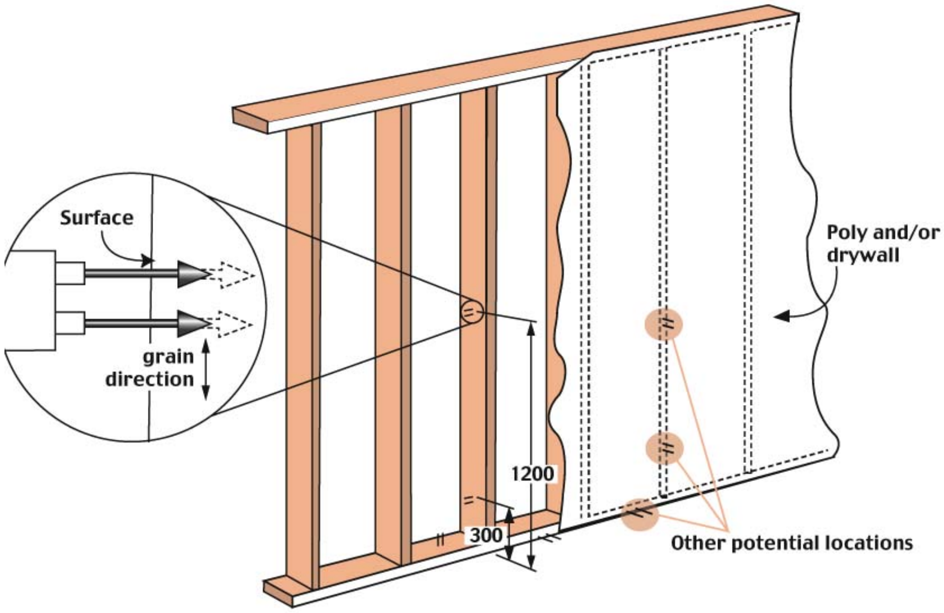

Figure 6: Suggested approximate locations for meter measurements to obtain average moisture contents in studs and wall plates

Interior wall studs are more likely to be representative of the lumber as it was delivered to the site and then dried somewhat in place. Since they are usually only enclosed with gypsum wallboard and this permits ready drying, the moisture content of interior studs is less critical to durability. Exterior wall studs and plates are the more critical elements to evaluate, since they are generally more exposed to the weather and are constructed to be resistant to moisture flow. Consequently, obtaining the moisture content of one or two interior wall studs of the same size as those in the exterior walls may give the assessor an idea about whether there was excess moisture in the lumber to start with.

The bottom plates are likely to be the wettest of the framing lumber in the building and should be checked more rigorously. These pieces should be checked for core and shell moisture content and at several points along their length, as described in Part 2. Headers, rim joists, built up columns or other assemblies with a large mass of wood are slow to dry when wetted. Areas where drying is inhibited by impermeable flashing or peel and stick membrane should also be checked.

While it is not the goal of this manual to provide guidance on the absolute maximum permissible moisture content of framing lumber, it is unlikely that high moisture conditions in interior wall framing at time of installation will lead to conditions leading to decay. The major consequence of tolerating higher moisture levels in the interior load bearing members is that more settlement and shrinkage of the interior will take place relative to the exterior shell of the building. This is not expected to be a significant effect although the total shrinkage of the whole building must be accounted for in the design of the plumbing and sewage distribution system.

If the intent of the measurements is to assess whether it is acceptable to proceed with the construction, it is recommended that a minimum of 4 studs be evaluated in each wall elevation. As far as the number of storeys that should be assessed, it is generally likely that the bottom storey will be the wettest even though it will have been constructed first. A lessor degree of *ad hoc* evaluation may be sufficient to determine where attention should be focussed with regard to detailed MC measurements in the building.

In summary, when it is found that higher than desirable moisture levels have been detected, adequate sampling is required to provide a solid basis for a decision to delay construction or undertake some additional measures. It is recommended that, for the studs in any particular wall with moisture readings at two depths at each location, measured at two heights, and for four studs in the wall, a total of 16 readings be obtained. The same level of sampling should be done for the bottom wall plates. This information should give the builder and assessor sufficient information to form an opinion on the degree of additional drying that may be required before proceeding.

The decision as to the frequency of sampling required beyond that noted above is a matter of judgement. The builder and assessor can only make decisions of this nature, at the time of inspection. It may well be decided that significant portions of the framing can be closed in and to only leave unfinished those sections which require longer natural or induced drying.

Grade Stamps

Examine the grade stamps to see whether the lumber is marked as S-DRY or S-GRN. At the time of grade stamping surfaced lumber "S-DRY", the moisture content should not exceed 19%. For vertical members at least, unless they have been soaked by rain or held in contact with wet ground, it is also likely that they will have a more uniform MC and require less probing. S-GRN (surfaced green) lumber on the other hand may be substantially wetter and may be more variable in MC.

The other important information on grade stamps is the species group. The most common groups are -- **S-P-F**, which is a mixture of spruces, pines and true firs, **Hem-Fir (N)**, which is a mixture of western hemlock and amabilis fir, and **D Fir-L (N)**, is a mixture of Douglas fir and larch.
***Note:* When a species grouping or species combination has the same name both in Canada and the US, the Canadian species grouping will include a "N" and this is identified in the Grade Stamp.**

External Factors to Consider

The National Building Code of Canada and all similar model codes are clear on the requirement that the wood be dry at the time of installation. This is normally taken to mean the time at which the framing stage is completed and the vapour barrier and interior finishes are applied. The issue of high moisture content in construction lumber is not new. Wood frame construction, as practised since this country came into being, has always had to accommodate for these conditions. Given the variability in climatic conditions across the country and the large seasonal changes we experience, it is difficult to put forward a general rule on what degree of wetness might be tolerable over time. Judgement is needed, particularly with respect to the type of construction, the scheduling and degree of protection provided. Some factors that builders and inspectors may consider when they encounter framing that exceeds code requirements are discussed below.

Climatic Factors

The climatic conditions are extremely important. Conditions in most of the country will often favour the maintenance of or promote drying toward an acceptable moisture level. Unfortunately, because unfavourable conditions - either being too wet, or too humid, or too cold can occur in all locations, the builder must exercise caution. Knowing the moisture contents of the materials used in the construction is part of the solution. Undertaking construction practices that minimise the risk is another part of the solution. In some cases, intermittent delays and some adjustment to construction scheduling can meet the intent of the code on this issue.

Type of Wall System

Some completed wall systems are more amenable to drying than others. Partially completed walls will be more amenable to drying and this should be taken advantage of when possible. Most wall systems built in Canadian climates are built with a vapour barrier located over the interior surface of the framing, just behind the interior gypsum board lining. Therefore the majority of drying of moisture after the installation of the vapour barrier can only take place toward the exterior.

Advantage should be taken of all conditions that could provide drying to the interior before the vapour barrier is installed. The polyethylene vapour barrier also serves to protect the gypsum board from moisture in the wall. The paper faces are particularly vulnerable to supporting mould growth when exposed to high humidity. Drainage capability behind the main weather barrier and the choice of materials used affects the ability of a wall to dry out. This must be left to the builders and designers to consider for each type of system they employ.

Orientation

The orientation of walls affects their drying rate. North facing walls and walls that are shaded from the sun by other buildings can be expected to dry more slowly. These walls are of particular concern and may have to be treated differently compared with east or south facing walls that receive more solar energy. In other areas, walls more exposed to wind-driven rain may require special consideration.

The builder and inspectors must also keep in mind that loading of exterior cladding by rainwater can contribute to, or reduce the ability of the backup wall to dry out. Stucco cladding is a wet process and, until it has set, cured and been finished properly, it may reduce the ability of the inner wall to dry to the outside. A solar driven moisture wave front toward the interior of the wall is not unusual, but the effect can be minimised by use of a ventilated cavity. Sequencing of construction in addition to location and orientation is critical when assessing the moisture content that can be safely retained in the framing.

Indoor Climate

It is not expected that interior conditions in northern climates will have much effect on exterior wall performance when the vapour barrier is well installed and air movement is minimised. However, if these construction details are not properly addressed, the moisture content of the lumber framing becomes more critical. The level of seasonal moisture storage may be safe for a building with a ~~low~~ lesser initial moisture content. Should the initial moisture content be high at time of closing, the addition of further moisture might prevent drying in a timely fashion.

When interior operating vapour pressures are expected to be high, the specific site circumstances, the particular wall designs involved, and all other matters noted above must be accounted for in assessing the safety of moisture loading in excess of code requirements. Air conditioning in the summer in northern and moderate climates in Canada can do much to reverse the flow of moisture in a wall. Here, it almost goes without saying, its makeup and design will affect the tolerance of the wall to these conditions.

Key Points

- Bottom plates are likely to be the wettest of the framing lumber in the building and should be checked more rigorously.
- For vertical members, meter readings should be taken at various heights and depths to assess average MC and moisture distribution.
- There is no hard and fast rule to recommend at what moisture content lumber and other materials in the standing frame may be protected against deterioration.
- The local climatic conditions, particularly wind-driven rain, can affect the likelihood of drying in a reasonable timeframe.
- The type of wall, its materials and design, ultimately affect the decision as to what must be done in cases where excess moisture exists.
- The orientation of walls in relation to solar gain, and in relation of the prevailing direction of wind-driven rain, plays a major role and should be accounted for in design and predictions on time required before closing.
- The indoor environment and whether or not it is air-conditioned must also be considered.

PART 4

HEADING OFF MOISTURE PROBLEMS BEFORE THEY START

Designers and builders can take steps to minimise construction complications due to moisture. Some ideas are presented below for doing this. Many are simple to implement, while some may be more difficult and costly. Here are some options.

Use of Kiln Dried Lumber

The framing situation is always enhanced in cases where the moisture content of the lumber does not exceed approximately 20%, either at the time it has been delivered to the building site, or in later stages. Most often this is achieved by kiln drying. If it is not the intent of the builder to schedule the construction in such a way that will allow drying of the framing prior to final closing of the structure, use of kiln-dried lumber is recommended.

By specifying kiln-dried lumber, one limits the number of pieces that may warp during framing. It must be recognized that all grades of framing lumber permit a certain degree of warp. This is dependent upon the grade of lumber purchased – the lower the grade, the greater the degree of warp. Use of straighter lumber reduces the possibility of costly call-backs to the builder. Use of kiln-dried lumber also eliminates the potential for carry-over of fungal infection from the standing tree or log stage.

Protect Materials on Site

Not enough attention/emphasis is currently being given to storage of materials on site. Provision of a simple platform or series of platforms that can keep materials from contact with the ground on site is a prudent practise. Some engineered wood materials cannot tolerate extended exposure to moisture or direct contact with soil and water, and should be treated more carefully than sawn lumber. Packaged lumber materials or materials that have been dried and have been provided with nominal protection (wrappers) from moisture should continue to retain these coverings till needed, and recovered when the materials are not needed.

Install Roofing Membrane Early

Until the roof has been erected, the entire structure is vulnerable to wetting by rain or snow. However, even after the roof sheathing has been applied, it is still possible for moisture to enter the structure through joints between panels.

In recent years, it has been the practise to install roofing paper or eaves protection only at the bottom edges of roofs and over the overhangs. This protection is provided as a backup to roof shingles in the region of the roof where ice damming is more likely to happen. Additional roofing paper (if any) is usually applied only when the roofing trades are ready to apply the shingles. In the past, roofing paper was applied over the entire roof. Sometimes roofing paper was applied over the roof well in advance of applying the finished roofing, whether wood shingles, asphalt shingles, or metal roof tiles were used. At the time, this was needed because lumber boards were commonly used and they could not be counted on to shed rain.

If application of the finished roofing cannot be scheduled soon after erection of the roof sheathing, then consideration should be given to applying a roofing paper membrane over the entire roof immediately after, or as part of, the installation of the structural roof sheathing.

One additional advantage of this practice is that the dark asphalt roofing paper will absorb more heat from the diffused and direct solar energy and it can speed drying by improving the convection of naturally heated air from inside the partially completed structure.

Sheathing Panel Orientation

In some parts of the country, sheathing panels are applied horizontally across the studs. This is done for different reasons; e.g., for improved continuity and stiffness between studs, or to provide a gap to permit indoor humidity to escape outward.

A consequence of applying panels horizontally is that the horizontal butt joist between panels must be spaced (2 mm) to allow for expansion. This 2-mm space also satisfies the NBCC requirement for a gap permitting indoor humidity to escape. Some builders have been leaving more substantial gaps between the panels thinking that this would allow the structure to dry more quickly. While this may assist some wall types some of the time, with horizontal gaps all around the building every 1200 mm of building height, any water that runs down the outer side of the sheathing may be intercepted by these gaps. Some of this moisture could be directed into the wall interior.

Builders who orient the structural sheathing in a vertical orientation and use a moderately thicker sheathing to avoid buckling between studs find that they provide a continuous surface that can better shed rain and prevent excess water from entering the uncompleted structure. In areas of high wind-driven precipitation, this may be a more important consideration than preventing condensation from indoor humidity.

Install Sheathing Membrane Early

Early application of sheathing membranes to the partially completed structure will help shed rainfall. Since scaffolding for installation of the cladding is not erected until that segment of construction is scheduled, the only practical early application of sheathing paper is when the wall is first built before it is tilted into position. Doing this requires thorough planning and a rethinking of what individual trades are required to do. If the cladding will be applied on to vertical batten strips, it might be convenient to plan to have both the sheathing membrane and batten strips applied to the wall panels at this early stage. The walls will thus provide good protection for the interior of the structure immediately after being erected.

Although it may not be immediately obvious, some sheathing membranes applied to the partially completed frame can assist in absorbing both diffuse and direct solar energy. Heating the structural shell and the air inside provides higher drying ability for air inside the still-leaky structure. Even without direct sunlight, energy can be gained to improve drying at no cost.

Cover Window and Door Openings

Openings for windows and doors that are to be installed later are often left unprotected for some time. The length of time before windows can be installed depends on scheduling and potential delays. Openings are also left to provide natural lighting for the workmen inside. To enable natural lighting to be provided yet shield openings and prevent entry of rain and snow, translucent sheathing membranes can be used to cover these opening. These are best applied when the walls are first constructed, and can be applied whether or not sheathing membranes for the rest of the wall are installed at that time.

Install Cladding Late

Most claddings applied to the exterior of a wall will slow drying to the outside. If heating the interior is being done during the finishing stages in the interior, the thermal gradient can drive moisture to the cooler outer face. Providing that the sheathing membranes are applied to protect the exterior from rain, the rate at which moisture can escape to the outside is considerably improved. Leaving the installation of the cladding to a later stage in construction can be beneficial to drying.

Sequence Concrete Topping Pour

Buildings in which concrete topping will be poured on to the wood floors are more prone to retaining moisture. The bottom wall plates, particularly if double wall plates are used for the walls, are likely to retain moisture longer if they have been severely wetted by rain, or have not been permitted to dry prior to pouring of the concrete. Where possible, the sides of wall plates should be protected with a membrane prior to pouring the concrete. Alternatively the 50mm adjacent to the wall plates can be blocked out for later pour. In principle, early sequencing of pours are preferable to allow much of the construction moisture to dissipate before the dry materials and finishing materials are installed. (Note: bearing walls will require sheathing or bracing before the concrete is poured.) Some builders choose to use treated wood for the bottom wall plates when concrete topping is applied to provide them protection against decay caused by excessive retention of water.

Install Vapour Barrier Late

Installation of batt insulation and leaving the vapour barrier off can permit the water in studs to dissipate more rapidly if the climate is such that direct and diffused solar energy can drive the moisture inward. It is noted that during nights, sheathing papers can be cooled below ambient temperatures by radiation to the night sky and become condensing planes for moisture from inside and out. Temporary wetting is likely, but it brings the moisture forward for more ready removal when daylight returns. In such cases, accelerating the removal of moisture to both the interior and exterior of a wall is beneficial.

Dehumidification Using Heating and Ventilation Equipment

When a smaller building, such as a house, can be enclosed quite rapidly, it may be possible to have some of the ventilation equipment installed early. In some parts of the country, limited power is supplied to houses under construction to permit use of power tools. This limited power can be used for operation of heat recovery ventilators. Providing that the partially completed building is reasonably tight, this type of equipment can be run to help dehumidify the structure.

Use can also be made of powerful industrial dehumidification equipment that is sometimes used in rehabilitation of flooded buildings. The cost of doing so is high, but that expense can only be judged in the context of the importance of the structure and the seriousness of the need for rapid drying. Propane and natural gas heaters produce water of combustion and may not be effective in drying.

Once the building shell has been completed and the heating system has been installed, heating the interior space can be done to force drying. This should only be done with care and consideration of the type of cladding used and the season of the year. Monitoring of the moisture content at different layers in the building shell may be necessary to ensure that sufficient moisture is removed instead of just redistributed.

Key Points

- Use kiln-dried lumber for faster construction and fewer shrinkage and warping surprises.
- Protect materials on site from rain and from ground contact.
- Install roof membrane early, for rain protection of the entire structure below.
- Install sheathing membrane early, to shed rainfall.
- Cover window and door openings with a translucent membrane, to keep out rain but still admit daylight for workers.
- Install cladding late, as it can impede drying of lumber and other components that got wet during construction.
- Pour concrete topping early and/or use treated wood in bottom plates, to avoid problems with trapped moisture in the plates, and to reduce the moisture load.
- Install vapour barrier late, so it doesn't impede drying of lumber and other components that got wet during construction.
- Install HRV equipment to speed up drying at an early stage once the building is closed in. Heating the building at an early stage can also be beneficial.

CONCLUSIONS

Construction under difficult weather conditions may lead to higher than desirable moisture in lumber framing and other building materials, particularly in wet climates. Unless protected from such moisture, the lumber and other wood products may become too wet to permit timely final closing. To close a structure in these circumstances does not meet the intent of the building code, and can lead to degradation of the structure if wet conditions are sustained. In such cases, monitoring the moisture content of materials in a building helps the builder and inspectors assess the condition of the moisture sensitive materials being used. While a builder can be passive in this process and wait for the structure to dry to acceptable levels, it is far to his advantage to assume that conditions may not be favourable, and proactively plan his construction methods and sequencing to minimise the uptake of moisture by sensitive materials so there is no delay in getting the building to market.

In interpreting on-site moisture content readings, the user should consider both the accuracy of the measurements and the sensitivity of the end use application. Given the all the potential source of error that affect moisture meter readings in wood frame construction discussed in this report, the accuracy will typically be within 1 to 4% of the true moisture content for individual measurements. Considering average moisture contents for wall sections may be a more appropriate means of assessing moisture loads. In many applications, a tolerance of 1 to 4% may be acceptable given that the lumber is expected to dry over a period of a few months. More sensitive applications will require greater attention to the factors that affect the accuracy of MC estimates obtained using moisture meters.

REFERENCES

[1] Wood Handbook: Basic Information on Wood as a Material of Construction with Data for its Use in Design and Specifications. Prepared by the Forest Products Laboratory, Forest Service, United States Department of Agriculture, [Slightly Revised 1940], Washington, DC.

[2] Wood Handbook: Wood as an Engineering Material. [1999] Forest Products Society Madison WI.

[3] Zabel, R.A. and J.J. Morrell. Wood Microbiology: Decay and its Prevention. Academic Press. San Diego CA.

[4] Archer, J. 1994. Dry Lumber Makes Big Difference in Performance. Home BUILDER, November/December, p19.

[5] Garrahan, P., J. Meil, and D.M. Onysko. 1991. Moisture in Framing Lumber: Field Measurement, Acceptability and Use Surveys. Forintek Canada Corp., report prepared for Canada Mortgage and Housing Corporation.

[6] Pfaff, F. and P. Garrahan. 1984. Moisture Content Correction Tables for the Resistance-Type Moisture Meter, Eastern Species". Forintek Canada Corp. Special Publication No. SP511E (English) and SP511F (French), 1984.

[7] Pfaff, F. and P. Garrahan. 1985. Moisture Content Correction Tables for the Resistance-Type Moisture Meter, Western Canadian Species". Forintek Canada Corp. Research report.

APPENDIX

Combined Corrections for Species Groupings

Table A-1. Combined correction factor for the Spruce Pine Fir (S-P-F) species grouping

Wood Temp. ºC	METER READING 7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
-40	16	17	19	21	23	25	27	28	30															
-35	15	17	18	20	22	24	26	27	29															
-30	14	16	18	19	21	23	25	26	28	30														
-25	14	15	17	19	20	22	24	25	27	29	30													
-20	13	15	16	18	20	21	23	24	26	28	29													
-15	12	14	16	17	19	20	22	24	25	27	28	30												
-10	12	13	15	16	18	20	21	23	24	26	27	29	30											
-5	11	13	14	16	17	19	20	22	23	25	26	28	29											
0	11	12	14	15	17	18	20	21	23	24	25	27	28	30										
5	10	12	13	15	16	17	19	20	22	23	25	26	27	29	30									
10	10	11	13	14	15	17	18	20	21	22	24	25	27	28	29									
15	9	11	12	13	15	16	17	19	20	22	23	24	26	27	28	30								
20	9	10	12	13	14	16	17	18	19	21	22	23	25	26	27	29	30							
25	9	10	11	12	14	15	16	17	19	20	21	23	24	25	26	28	29	30						
30	8	9	11	12	13	14	16	17	18	19	21	22	23	24	26	27	28	29						
35	8	9	10	11	13	14	15	16	17	19	20	21	22	23	25	26	27	28	30					
40	7	9	10	11	12	13	14	16	17	18	19	20	22	23	24	25	26	27	29	30				
45	7	8	9	11	12	13	14	15	16	17	19	20	21	22	23	24	25	27	28	29	30			
50	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22	23	25	26	27	28	29	30		

Notes:
1. This table represents an average correction for Canadian S-P-F based on the nine predominant species from this group from across the country.
2. See notes in text with regard to implications regarding meter accuracy when using these tables.
3. Data compiled from Forintek Publication "Moisture Content Correction Factors for the Resistance-Type Moisture Meter, Eastern Species" publication number SP511E [6] and "Moisture Content Correction Tables for the Resistance-Type Moisture Meter, Western Canadian Species [7].

Table A-2. Combined correction factor for the Western Hemlock and Amabilis Fir (Hem-Fir) species grouping

Wood Temp.	**METER READING**																							
ºC	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
-40	15	16	18	20	21	23	25	26	28	30														
-35	14	16	17	19	20	22	24	25	27	29	30													
-30	13	15	16	18	20	21	23	24	26	28	29													
-25	13	14	16	17	19	20	22	23	25	27	28	30												
-20	12	14	15	17	18	20	21	23	24	26	27	29	30											
-15	12	13	15	16	17	19	20	22	23	25	26	28	29											
-10	11	13	14	15	17	18	20	21	22	24	25	27	28	29										
-5	11	12	13	15	16	18	19	20	22	23	24	26	27	28	30									
0	10	12	13	14	16	17	18	20	21	22	24	25	26	28	29	30								
5	10	11	12	14	15	16	18	19	20	21	23	24	25	27	28	29	30							
10	9	11	12	13	14	16	17	18	19	21	22	23	24	26	27	28	30							
15	9	10	11	13	14	15	16	18	19	20	21	22	24	25	26	27	29	30						
20	9	10	11	12	13	14	16	17	18	19	20	22	23	24	25	26	28	29	30					
25	8	9	10	12	13	14	15	16	17	19	20	21	22	23	24	26	27	28	29	30				
30	8	9	10	11	12	13	15	16	17	18	19	20	21	22	24	25	26	27	28	29	30			
35	7	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24	25	26	27	28	29			
40	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	30		
45	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	26	27	28	29	30	
50	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Notes:
1. This table represents an average correction for Hem-fir (N) based on Western hemlock and amabilis fir.
2. See notes in text with regard to implications regarding meter accuracy when using these tables.
3. Data compiled from Forintek Publications “Moisture Content Correction Factors for the Resistance-Type Moisture Meter, Eastern Species” publication number SP511E [6] and Moisture Content Correction Tables for the Resistance-Type Moisture Meter, Western Canadian Species [7].

Table A-3. Combined correction factor for the Douglas Fir - Larch (D Fir-L) species grouping

Wood Temp.	**METER READING**																							
ºC.	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
-40	14	16	17	19	21	22	24	26	27	29														
-35	13	15	17	18	20	21	23	25	26	28	30													
-30	13	14	16	17	19	21	22	24	25	27	29	30												
-25	12	14	15	17	18	20	21	23	24	26	28	29												
-20	11	13	14	16	18	19	21	22	24	25	27	28	30											
-15	11	12	14	15	17	18	20	21	23	24	26	27	29	30										
-10	10	12	13	15	16	18	19	20	22	23	25	26	28	29	30									
-5	10	11	13	14	15	17	18	20	21	22	24	25	27	28	29									
0	9	11	12	13	15	16	18	19	20	22	23	24	26	27	28	30								
5	9	10	12	13	14	16	17	18	20	21	22	23	25	26	27	29	30							
10	9	10	11	12	14	15	16	18	19	20	21	23	24	25	26	28	29	30						
15	8	9	11	12	13	14	16	17	18	19	21	22	23	24	26	27	28	29						
20	8	9	10	11	13	14	15	16	17	19	20	21	22	23	25	26	27	28	30					
25	7	9	10	11	12	13	14	16	17	18	19	20	21	23	24	25	26	27	29	30				
30	7	8	9	10	12	13	14	15	16	17	18	20	21	22	23	24	25	26	28	29	30			
35	7	8	9	10	11	12	13	14	16	17	18	19	20	21	22	23	24	26	27	28	29	30		
40	6	7	8	10	11	12	13	14	15	16	17	18	19	20	22	23	24	25	26	27	28	29	30	
45	6	7	8	9	10	11	12	13	14	15	17	18	19	20	21	22	23	24	25	26	27	28	29	30
50	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29

Notes:
1. This table represents an average correction for D fir-L based on interior and coastal Douglas-fir, and western larch.
2. See notes in text with regard to implications regarding meter accuracy when using these tables.
3. Data compiled from Forintek Publications “Moisture Content Correction Factors for the Resistance-Type Moisture Meter, Eastern Species” publication number SP511E [6] and Moisture Content Correction Tables for the Resistance-Type Moisture Meter, Western Canadian Species [7].

Table A-4. Combined correction for species (product) and temperature effects for Aspen oriented strand board.

OSB (Oriented Strand Board)

Temperature (°C.)	Meter Reading				
	8	**12**	**16**	**20**	**24**
-10	10	14	18	22	26
0	8	13	17	21	25
10	8	12	15	19	23
20	7	11	14	18	22
30	6	10	13	17	20

Notes: This table is based on limited tests conducted at three MC levels But at only one temperature. The temperature correction for solid Wood has been applied to obtain the above chart.