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THERMAL TREATMENT OF CANADIAN LUMBER FOR PHYTOSANITATION

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Introduction and Overview

This paper and presentation are intended to provide a brief overview of the heat treatment of solid wood products both from the standpoint of the physics behind the process as well as the status of its application in the Canadian wood products industry. The specific objectives in preparing this presentation are:

1. To define what a thermal treatment is.
2. To describe how thermal treatment is achieved.
3. To show why this option is attractive to industry.

The Food and Agriculture Oranization (FAO) of the United Nations has issued International Standards for Phytosanitary Measures (ISPM's) to help control the transmission of forest (and other) pests from country to country or continent to continent. ISPM No. 15 "Guidelines for Regulating Wood Packaging Material in International Trade" lists heat treatment (HT) as an approved measure for wood packaging material. ISPM No. 5 defines heat treatment as:

> *"The process in which a commodity is heated until it reaches a minimum temperature for a minimum period of time according to an official technical specification."*

ISPM No. 15 states that:

> *"Wood packaging material should be heated in accordance with a specific time-temperature schedule that achieves a minimum wood core temperature of 56°C for a minimum of 30 minutes."*

The footnote for this line states that this combination of temperature and time was chosen "in consideration of the wide range of pests for which this combination is documented to be lethal and a commercially feasible treatment." Although these documents relate to wood packaging materials, heat treatment is now accepted by many countries as an effective phytosanitary measure for all solid wood products. For example, Canadian softwood lumber being shipped to Europe needs to be heat treated to the above standard in order to be marked or otherwise documented as being heat treated.

Development of HT Requirement

In the late 1980's the European Union identified the pinewood nematode (PWN)(Bursaphelenchus xylophilus), which was present in some North American softwoods, as a possible threat to their forests. As a result the Canadian lumber industry needed a way to ensure their product was phytosanitary safe. For the most part, kiln drying was accepted as an effective means of eliminating pests as the majority of kilns operated at temperatures of 70 to 80°C or higher. However, kiln drying has certain costs associated with it which are only recovered when the customer has requested the lumber in that condition.

In order to develop a lower cost alternative, Forintek and several other Canadian research facilities embarked on a project to identify the lowest temperature and shortest time combination that would eliminate the pinewood nematode and its vector the Monochamus beetle. The report on that work (Smith et al, 1991) identified 56° C for 30 minutes as an effective treatment. This temperature time combination was recommended after taking into consideration the most temperature resistant isolate of PWN and the worst case combination of wood species and moisture content. This report also lists heating times for a limited range of chamber operating temperatures, wood species, and lumber dimensions. Subsequent to the results of this work being reviewed and accepted by European authorities, a program was developed to identify, on a site specific basis, the chamber operating temperatures and times required to achieve a wood core temperature of 56° C for 30 minutes.

The study described above also investigated other technologies as possible treatments. Borate treatment, DDAC treatment, irradiation sterilization, and radio frequency were all investigated and eliminated as practical alternatives due to technical and/or economic considerations.

Wood Properties Affect on Heat Treatment Time

Questions have arisen over time as to the affect of wood properties on treatment time. Physical properties such as basic density and moisture content (MC) have long been known to have an affect; however, the significance of each of these is not well documented for Canadian species in this temperature range. Wood at a higher MC has less air present and wood cells being saturated with water make the material a better conductor of heat than wood cells filled with just air. On the other hand, more water present means more mass and therefore more energy is required to heat the piece. One of the factors limiting heating rate is the surface area in contact with the heated air stream.

Work conducted at the USDA Forest Products Laboratory has demonstrated that low MC material can be heat treated in a shorter time period than green material of the same species. In a report by Simpson (2002) treatment times for air dried slash pine was shown to be shorter than for green material of the same species. In another study by Simpson (2004) heat treatment times were documented for five hardwood species covering a range of wood density. Treatment times were different between species which raises the possibility that wood density has an impact on treatment time. An analytical method of predicting heating rate in wood is being developed by Forintek. Preliminary results confirm that both wood density and moisture content have an impact on heat treatment time. Both the U.S. and Canadian work has shown than wood thickness has by far the greatest impact on total treatment time. The results of our work and the U.S. reports listed above confirm that treatment time increases in relation to, and at a faster rate than, thickness. If lumber thickness doubles, heat treating time will more than double.

The U.S. and Canadian studies have also investigated the impact of heating conditions on heating rate. The results clearly show that when heat treating green lumber, the wet-bulb temperature has by far the greatest impact on treatment time. This is not surprising if we consider that a piece of wood that is well saturated with moisture will act very much like a wet-bulb sensor. Moisture evaporating from the surface will cause a cooling affect. On very green wood, the surface temperature will not rise above the wet-bulb temperature until some drying has taken place. Therefore, in order to achieve a short treatment time it is essential that the wet-bulb temperature be somewhat in excess of the target core temperature. Work conducted by Forintek (Garrahan and Savard, 2002) identified that treatment chambers operating at a wet-bulb temperature of 60° C or higher achieved the shortest heat treatment times (when targeting a core temperature of 56° C). It is not impossible to achieve a successful heat treatment when wet-bulb temperatures are lower than the target core temperature (assuming that the dry-bulb temperature is greater than the target core temperature) but treatment times will be greatly extended. The wood must either be partially dry at the time of treatment or some time must be given to dry the surface of the wood and allow the surface temperature to rise above the wet-bulb temperature.

Development of Generic Heat Treatment Schedules

As part of the process to develop the HT option for the Canadian industry a considerable amount of industrial testing and demonstration work was conducted. This was necessary in order to convince the European authorities that a methodology could be developed to monitor and verify attainment of the 56/30 standard. Several reports were issued with the results of testing under industrial conditions (Smith et al, 1991 and Mackay et al, 1993). From this work a site-specific certification procedure was developed. This site-specific program was the only option available to Canadian softwood producers wishing to export to the European Union for approximately a 10 year period. The procedure involved having a third party conduct tests on the treatment chamber and develop a heat treatment schedule specific for that chamber and the type of material present during testing. Several hundred chambers originally built to as dry kilns have been certified in this manner over the past decade.

In recent years, concerns over transmission of insects and others pests have become more global. As a result a much larger portion of the Canadian lumber industry is now either directly or indirectly impacted by requirements to prove that the wood is safe from a phytosanitary standpoint. In 2002 Forintek was asked by the Canadian Food Inspection Agency (CFIA) and the Canadian Forest Service (CFS) to investigate the possibility of developing a more streamlined approach to certifying treatment chambers. Mills that had participated in the "site specific" program were contacted to seek their permission to use the results of the testing on their chamber(s) in developing a new approach. The result was that heat treatment schedules from 64 chambers became available for assessment. The objective of the review was to identify common factors between treatment schedules and identify an approach that would be safe to apply on any industrial kiln used as a heat treatment chamber.

The report on this analysis (Garrahan and Savard, 2002) outlines the development of a generic approach to describing a heat treatment schedule. Figure 1 shows the relationship between wood temperature, dry-bulb temperature, and wet-bulb temperature during a typical heating phase. As mentioned previously, the temperature of wet wood approaches and follows the wet-bulb temperature more closely than the dry-bulb temperature. Therefore, the schedules resulting from this analysis are based primarily on achieving a wet-bulb temperature of 60° C for some minimum period of time, depending on the wood thickness. The generic schedules for Canadian softwood lumber up to 130 mm thick are listed in table 1 and other can be found in the CFIA document PI-07. These schedules list a minimum total treatment time, the portion of the schedule where the wet-bulb must meet or exceed 60° C and the final wet-bulb temperature that needs to be attained.

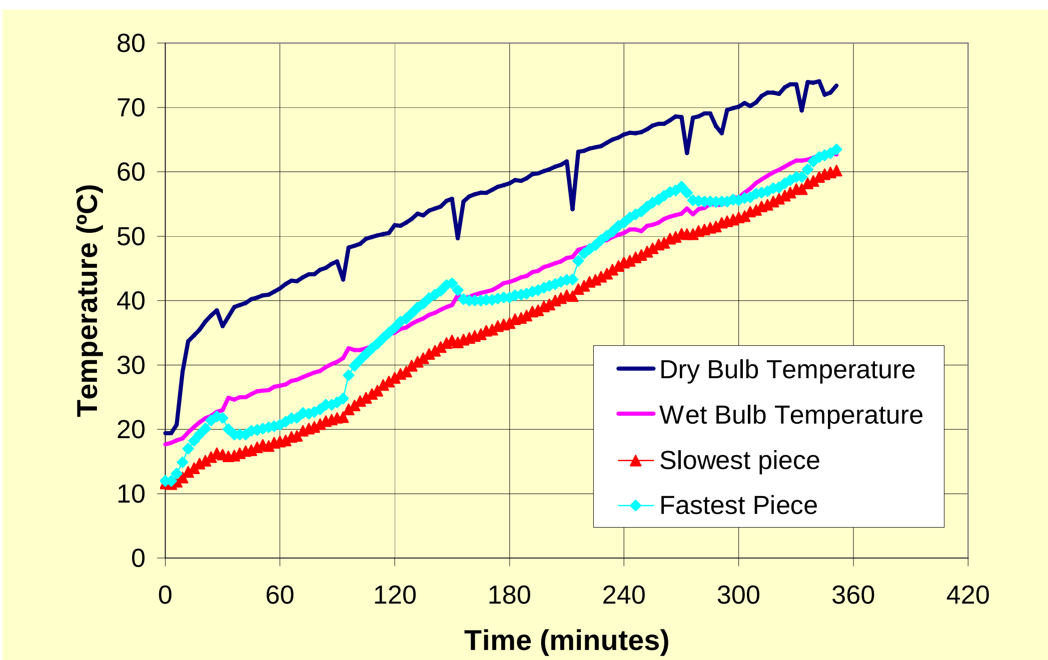

Figure 1. Sample heating rate in 2-inch softwood lumber as compared to dry and wet-bulb temperatures.

Table 1. Generic heat treatment schedules for Canadian softwood lumber from report by Garrahan and Savard (2002).

Species	Maximum Thickness (mm)	Minimum Total Treatment Time (min.)	Time with wet-bulb temp. over 60°C. (min.)	Final wet-bulb temperature (°C.)
All softwood	51	386	123	63
All softwood	76	440	200	66
All softwood	102	657	394	67

These schedules reflect the actual conditions achieved during industrial heat treatment processes. They are flexible in that the total treatment time must be extended if the wet-bulb temperature does not reach 60°C within the allotted time. For example, on 51mm material, if the chamber did not reach a wet bulb temperature of 60°C until 450 minutes into the process, the total treatment time would become 573 minutes (450 minutes to reach 60°C plus 123 minutes over 60° C). This schedule became the template for developing all of the wet-bulb-based schedules listed in the CFIA document "The Technical Heat Treatment Guidelines and Operating Conditions Manual" (PI-07). Other schedules based on dry-bulb temperature alone are listed in PI-07. These were developed through discussions between the lumber grading agencies, industry representative and CFIA and then validated by tests conducted under industrial conditions by Forintek. Table 2 provides the details for the low-temperature, dry-bulb treatment option known as "Option C" within the CFIA's document PI-07.

Table 2. Low dry-bulb temperature heat treatment schedule for Canadian Softwood species. As listed in the CFIA document PI-07.

Lumber Thickness (mm)	**Dry-bulb temperature run time with temperature over 52°C**	**Minimum time at the end of the treatment with Dry-bulb temperature over 60°C**
Up to 28mm	8 hours	4 hours
Up to 60mm	18 hours	6 hours
Up to 85mm	45 hours	15 hours
Up to 110mm	72 hours	24 hours

There are a number of other generic options developed to cover hardwood species (Garrahan and Savard, 2003) as well as hardwood or softwood schedules for material up to 205mm thick based on results of U.S. testing (Simpson, 2003). The generic schedule option is available to all industry providing they demonstrate that they meet certain operating requirements and register into the CFIA program. A number of industry associations (i.e. lumber grading associations) provide technical and administrative support to the industry to facilitate registration for their members. The site-specific chamber certification process is still available; however, the generic schedule option is cheaper and easier for most companies to meet the requirements. Companies handling large volumes of material may still benefit from the site-specific procedure as it will result in the shortest treatment time possible.

Practical Aspects of Heat Treating

Heat treating in a large-scale, industrial kiln is considerably different than heat treating in small-scale laboratory kilns. As a result a simple comparison of laboratory heating times with industrial heating times is not valid. The dynamics of heating a large load of lumber are more complex than a small chamber where heating conditions can be assumed to be uniform over time as well as throughout the treatment chamber. In an industrial kiln, the large volume of wood will rapidly absorb heat at the start of the process and therefore prevent the kiln air from heating up as rapidly as it would in a small, test kiln. The ratio of heating capacity to kiln volume will be much larger in a small scale kiln than in an industrial kiln. Another factor to consider in a large scale kiln is the variation in conditions across the load. As air flows through the load, it gives up heat to the lumber and its temperature is reduced. This results in a temperature drop across the load which needs to be considered in determining the "worst-case" heating conditions in the chamber. It is the "worst-case" heating conditions that will invariably determine the total treatment time.

For the most part, treatment chambers used to heat treat wood products were built originally, and in most cases are still used primarily to dry lumber. There are many shapes, sizes, equipment types, and equipment configurations found in lumber dry kilns. Not all dry kilns are necessarily good heat treatment facilities. The following is a brief list of operating features that make a dry kiln better suited for use as a heat treating facility:

- **High and uniform air flow –** this helps reduce temperature drop across the load and improves heat transfer to the wood.
- **Uniform temperature distribution –** helps provide even heating along length and from top to bottom in the kiln.
- **Well sealed –** helps retain moisture escaping from the wood and thereby helps maintain a higher wet-bulb temperature
- **Large heating capacity –** typically need a faster heating rate than most kilns are designed for.
- **Humidification system –** ability to add humidity to the kiln air and achieve the desired wet-bulb temperature sooner.

It is not imperative that heat treatment chambers have all of the capacities listed above. Kilns that do have most of the above characteristics would also be ones that are more likely to benefit from the site-specific approach described earlier. Any kiln that can reach the prescribed conditions in the generic schedules in the minimum listed time will likely be able to attain an even shorter treatment time if tested following the site specific procedure.

Future Developments

Forintek continues to work with industry and government to help develop more technical information on the subject of heat treatment of solid-wood products. At present we have a research project in place to help extend the range of generic schedules available to industry. A heat transfer model has been adapted to estimate wood heating time over a wide range of possible temperature and humidity conditions. Testing to develop a database on wood heating rates and help validate the model is on-going. Future possible additions include schedules specific to low moisture content softwood species (i.e. insect killed timber) and denser tropical species.

As various international markets adopt the new heat treating standards, Canadian producers must be prepared to demonstrate that their solid-wood products are safe from a phytosanitary standpoint. A combination of both scientific and industrial testing is necessary in order to validate the process and defend it in other jurisdictions. Although 56°/30 is the accepted standard for most wood products, certain markets main demand a different standard. Again, this highlights the need to have sound technical information on wood heating properties and expected treatment times.

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