Research & Development Summary

Value to Wood

RDS 2009-07-E

# High Temperature Drying Strategies for Value-added Wood Products

The Canada and Quebec softwood lumber industries focus heavily on producing lumber for the North American housing construction market. This dependence makes our lumber industry highly vulnerable during periods of negative economic growth. It is thus important to develop new value-added products and new markets for softwood lumber, which is traditionally sold as a commodity. Standards of quality in manufacturing these products are much more restrictive than the standards governing lumber production. Moreover, since value-added products are generally manufactured and used with moisture contents much lower than lumber, the wood tends to warp more when drying. Drying processes and strategies must thus be adapted to reflect these new difficulties and requirements. High-temperature drying offers several advantages in this regard. Warping is better controlled by plasticizing wood by means of temperature and mechanical restraint, and drying time is at least half that of medium-temperature processes. The process is also more energy-efficient.

*Figure 1: Load of spruce stands in experimental kiln.*

## Objectives

The ultimate objective of this project was to develop high-temperature (HT) drying strategies for value-added products from secondary species or species traditionally used for lumber. Two complementary approaches were used to define drying strategies: laboratory tests and the development of a mathematical simulation model for high-temperature drying. The specific objectives were to:

- use a laboratory kiln to test high-temperature drying strategies for white spruce, balsam fir and trembling aspen;
- adapt an existing drying model (DRYTEK) to high-temperature drying and to validate the model for white spruce wood.

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# Methodology

## Laboratory Tests

Three laboratory drying tests were done on 2x4 studs (50 mm x 100 mm), 8 ft. (2.44 m) long, for each of the three species chosen for the study, varying strategies from one test and one species to another. The effect of lumber presorting (for balsam fir and trembling aspen) was also studied. In all cases, 160 lb/ft2 (8 kN/m2) of top loading was used. *Table 1* shows a typical HT drying schedule used in this study for unsorted spruce, as well as for fir and poplar of mixed sapwood/normal heartwood. *Table 2* shows a medium-temperature/high-temperature (MT/HT) hybrid drying schedule, tested for fir and poplar containing heartwood pieces with wet pockets (wetwood). Drying was monitored by periodically weighing six control boards laid at the end of the stack (*Figure 1*). The target moisture content (MC) was 8%.

*Table 1: Typical HT drying schedule used for spruce, fir and poplar, containing mixed sapwood/normal heartwood.*

| Drying step | Time (h) | MC (%) | Tdb (ºC) | Twb (ºC) | EMC (%) |
|---|---|---|---|---|---|
| Pre-heating | 4 | | 99 | 98 | 17.2 |
| Pre-steaming | 6-10 | | 95 | 95 | -- |
| Drying HT 1 | | > 30 | 105 | 94 | 6.8 |
| Drying HT 2 | | 30-8 | 115 | 90 | 3.5 |
| Cooling | 2 | | 115 -190 | | -- |
| Equalizing | 15 | | 90 | 77.5 | 6.8 |
| Conditioning | 4 | | 90 | 84 | 11.0 |
| Cooling | 3 | | 40 | | |

*Table 2: Hybrid MT/HT drying schedule used for fir and poplar, containing mixed sapwood/wetwood.*

| Drying step | Time (h) | MC (%) | Tdb (ºC) | Twb (ºC) | EMC (%) |
|---|---|---|---|---|---|
| Pre- heating | 4 | | 60 | 59 | 21.8 |
| Drying MT 1 | | 100-50 | 60 | 52 | 1.2 |
| Drying MT 2 | | 50-40 | 63 | 52 | 7.8 |
| Drying MT 3 | | 40-30 | 66 | 52 | 6.3 |
| Steaming | 6 | | 95 | 95 | -- |
| Drying HT 1 | | 30-20 | 105 | 94 | 6.8 |
| Drying HT 2 | | 20-8 | 115 | 90 | 3.5 |
| Cooling | 2 | | 115-90 | | -- |
| Equalizing | 15 | | 90 | 77,5 | 6.8 |
| Conditioning | 4 | | 90 | 84 | 11.0 |
| Cooling | 3 | | 40 | | |

## Drying Simulation

DRYTEK software — jointly developed by Laval University and FPInnovations - Forintek to simulate medium-temperature drying of four commercial species of softwood from eastern Canada — was adapted to simulate HT drying. An equation was then added to the existing mathematical model to simulate changing wood pressure and a series of laboratory experiments were conducted to evaluate the physical parameters of the HT drying model. Finally, drying tests were performed on white spruce wood at temperatures of 105ºC and 115ºC to validate the model (*Figure 2*).

*Figure 2: Experimental setup for validation tests: a) lumber stack into kiln; b) sensors to measure wood pressure and temperature.*

# Results and Discussion

*Figure 3* shows typical drying curves for HT-dried white spruce wood. It will first be noted that drying time is about twice that of commodity lumber. The pre-steaming and equalizing steps largely account for this difference. It should also be noted that, despite the significant variation of the initial moisture content, the six control boards are close to the target moisture content at the end of the schedule (*Table 3*). Presorting thus is not necessary when the target moisture content is less than 10% – provided, of course, the load contains no pieces with wetwood. However, *Table 3* shows fairly significant downgrading of studs after drying, which was mainly due to twist. This is likely the result of a high number of large knots in some pieces.

*Figure 4* compares average HT drying curves for fir and poplar mixed sapwood/normal heartwood with hybrid MT/HT drying curves for mixed sapwood/wetwood from the same two species. Once heartwood with wet pockets is separated from sapwood and normal heartwood, HT drying is highly suitable for these two species, which can then achieve the target moisture content of 8% to 9% in about five days. The variation in final moisture content and the percentage of downgrading are then highly acceptable (*Table 3*). However, separate drying of mixed sapwood/wetwood, using a hybrid MT/HT drying schedule, doubles drying time. This made it possible to minimize the range of final moisture contents, but somewhat at the expense of downgrading. A very low proportion of pieces was affected by collapse, as opposed to unsorted dry loads.

*Table 3: Distribution of moisture content before and after drying and percentage of downgrading (stud to utility stud) for spruce (SP), fir with normal heartwood (FINH), poplar with normal heartwood (PONH), fir with wetwood (FIW) and poplar with wetwood (POW) (value in parentheses = standard deviation).*

| Species | IMC (%) | FMC (%) | Proportion from 6% to 10% | Down-grading (%) |
|---|---|---|---|---|
| SP | 53.8 (35.8) | 8.0 (1.4) | 96 | 18 |
| FINH | 85.1 (27.7) | 9.1 (1.1) | 90 | 3 |
| PONH | 83.2 (9.7) | 7.7 (1.1) | 92 | 5 |
| FIW | 114.0 (24.8) | 9.2 (1.4) | 91 | 23 |
| POW | 90.5 (16.7) | 7.6 (1.0) | 97 | 10 |

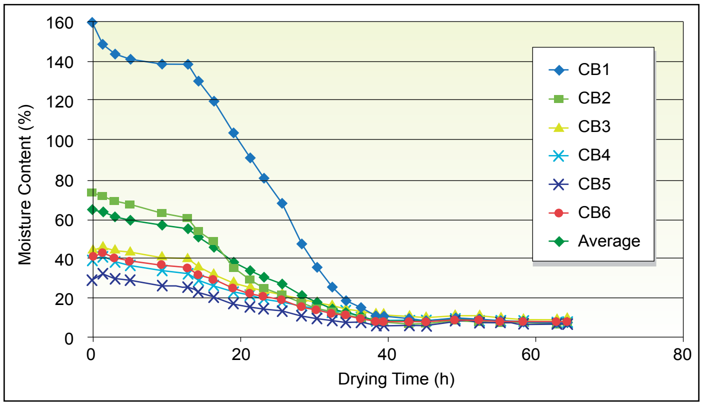


*Figure 3: Typical HT drying curves for white spruce wood.*

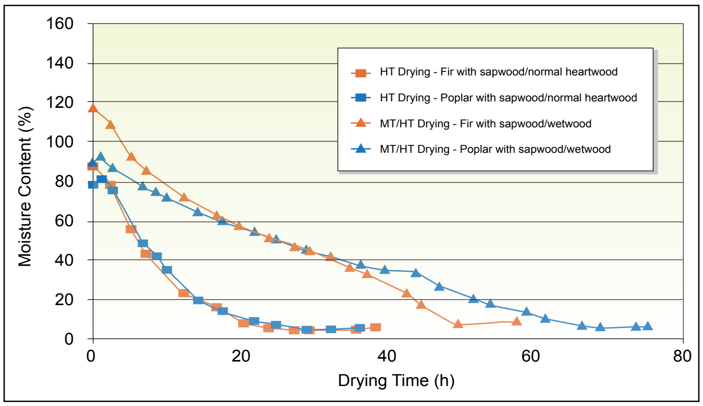


*Figure 4: Average HT drying curves for balsam fir and trembling aspen with mixed sapwood/normal heartwood, and average MT/HT drying curves for mixed sapwood/wetwood from the same species.*

*Figure 5* compares the results for simulated HT drying of white spruce wood with the experimental results obtained from the validation test at 115°C. The simulation results are in very good agreement with the experimental data for both sapwood and heartwood. The results obtained at 105°C were also very similar. For the moisture content profiles, the consistency between the experimental data and the simulated values was very good for heartwood. For the high moisture contents of sapwood, however, DRYTEK tends to predict profiles that are too flat. For wood pressure profiles, simulated values proved to be very close to experimental values. The pressure at the centre of a piece of wood when drying began could reach nearly one atmosphere (80 to 100 kPa) at a drying temperature of 115°C, and about 35 kPa at 105°C. The effect of pressure must thus be considered when calculating the driving force of water movement in wood at high temperatures, at least for moisture contents above 30% to 40%.

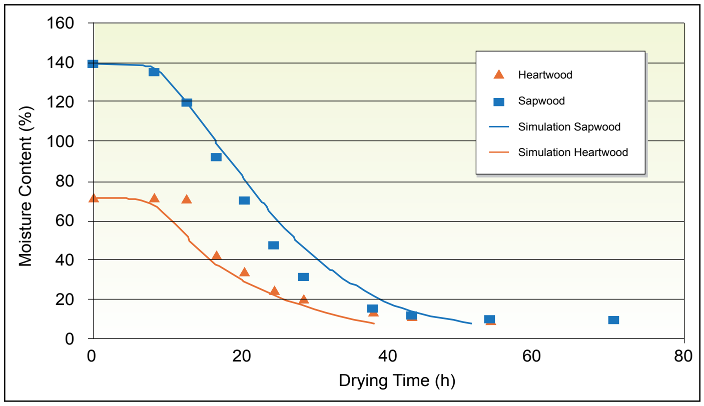


*Figure 5: Average experimental and simulated drying curves at 115 °C.*

## Potential Benefits of Study

This study provides industry with very useful data for any plan to convert from drying lumber to drying value-added products. High-temperature drying has some impact on the mechanical resistance of wood, however, this constraint does not affect several applications of value-added products, even for structural purposes. If the drying strategy is appropriate and adapted to load characteristics (top loading, presorting, pre-surfacing, hybrid schedule, and so on), high-temperature drying can quickly yield a product of excellent quality, as this study shows. As for the drying schedule as such, a simulation tool, such as DRYTEK, can greatly facilitate the planning of projects in this regard.

## Conclusions

This project showed that 2x4 studs of white spruce, intended for value-added products, can be dried to a target moisture content of 8% in fewer than three days. Balsam fir and trembling aspen studs, containing sapwood or normal heartwood, can be properly dried in five days. Fir and poplar studs, containing heartwood with wet pockets, must be dried using a hybrid process (medium-temperature/high-temperature). Drying time then varies from eight to ten days. In all cases, the drying strategy necessarily involves at least 150 lb./ft.2 of stack restraint, an equalizing period of at least 15 hours, and four to five hours of conditioning when the drying cycle is completed. The drying model developed for the high-temperature drying simulation can constitute a very useful tool for the development of appropriate drying schedules or the optimization of existing schedules.

## Acknowledgments

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