2005 NEKDA Fall Meeting

October 20, 2005

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Scientists
Wood Drying

Impact of Airflow on Drying
Determine the impact of airflow on drying quality, drying time and energy consumption in SPF lumber.
Previous Research

Key references:

1. Culpepper L, 2000
5. Torgeson, 1940
Main Conclusions from Previous Research

Productivity:

Torgeson (1940):
- Airflow affects the drying rate above the FSP
- The impact of airflow on the drying rate increases with higher moisture contents

Figure 2—Effect of air velocity and moisture content on drying rate of sugar maple mixed sapwood and heartwood, dried in a 1.22-m (4-ft) wide stack at 54°C (130°F) and 76% RH (Torgeson 1940).
Productivity:

Salomon M. and McIntyre S., 1973

- For a given drying schedule increased airflow leads to shorter drying time

- By setting air velocity to 900 ft/min from the green state to 30% MC and 400 ft/min from 30% to the end of the drying cycle, it was possible to reduce drying time by 18% for western hemlock, 15% for spruce and 25% for Douglas fir.
Main Conclusions from Previous Research

Quality:

Salomon M. and McIntyre S., 1973

• Increasing airflow may lead to lower lumber quality

• However, with white spruce:
  – 900 ft/min for 20 h + 250 ft/min for 34 h as compared to 250 ft/min for 75 h

  – Drying degrade
  – Moisture content distribution = Comparable
Main Conclusions from Previous Research

Qualité:

Culpepper L., 2000

- Increased airflow makes for more uniform air distribution inside the kiln

(more uniform air flow will result in an improved final moisture content distribution)
Main Conclusions from Previous Research

Ventilation and energy:

Garrahan P., 1993

- Adjustable speed drives allow for significant reductions in energy consumption with no effect on productivity and quality
Do these conclusions have any economic significance for eastern softwood species?
• Drying simulation
  – Air velocity from 200 to 1400 ft/min
  – Black spruce, balsam fir and jack pine

• Determine how airflow affects drying time
Drytek 2.0

Percentage of drying time reduction, Black Spruce (Reference air velocity: 300 ft/min)

-20% -10% 0% 10% 20% 30% 40% 50%

0 200 400 600 800 1000 1200 1400

Air velocity (ft/min)

Drying time reduction (%)

- Same tendency observed with Balsam Fir and Jack Pine
• LUMBER, INITIAL MEASUREMENTS AND LOADING
  – Black spruce 2x4x8 (from: Bowater, Mistassini)
  – 216 boards/load. Measurement of initial mass (all boards)
  – 6 sample boards to monitor moisture content changes
  – 12 boards equipped with resistance probes to control phase changes in the drying schedule
  – Stickers (¾-inch thick) at 24-inch spacings. 3000-lb concrete dead load

Sample boards
Lab Tests (Procedures)

- Measurements during the drying process
  - Air velocity - Measured with a hot-wire anemometer on the exit side of the pile when the temperature inside the kiln was about 20°C
  - Sample boards moisture contents
  - Fan energy consumption
• Measurements after drying
  – Final mass of load (all boards)
  – Oven-dry moisture contents of 6 control boards and 12 boards equipped with resistance probes
  – Moisture content gradients - Measured from 12 boards equipped with resistance probes with resistance moisture meter (using Forintek spacer)
  – Moisture contents of all boards – Measured with resistance moisture meter
<table>
<thead>
<tr>
<th>Air velocity (ft/min)</th>
<th>Number of charges dried</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>1</td>
</tr>
<tr>
<td>600</td>
<td>2</td>
</tr>
<tr>
<td>900</td>
<td>3</td>
</tr>
<tr>
<td>1200</td>
<td>1</td>
</tr>
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Results

Drying time adjusted for 40 to 15% MC (actual):

1. Based on drying rates for the 6 sample boards

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For a given drying schedule driven by moisture content, increasing airflow leads to shorter drying times. Same conclusion as Salomon M. and McIntyre S., 1973.

Increasing airflow affects the drying rate above the FSP (25 to 30%) but has no effect below the FSP (25 à 30%). Same conclusion as Torgeson, 1940.
These results suggest potential productivity gains of about 2.0% (in terms of drying time) with black spruce for every 100 ft/min increase in air velocity, assuming that:

– The same drying schedule is used
– The initial moisture content is 40%
Results

Productivity:

• Gains are greater if the initial lumber moisture content is over 40%
• Gains are lower if the initial lumber moisture content is under 40%
• There is no significant gain if the initial lumber moisture content is below the FSP
## Final moisture content and deviation:

<table>
<thead>
<tr>
<th>Air velocity (ft/min)</th>
<th>Average MC (%)</th>
<th>Std. deviation (%)</th>
<th>Average gradient (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>14.4</td>
<td>3.7</td>
<td>4.2</td>
</tr>
<tr>
<td>900</td>
<td>14.3</td>
<td>4.0</td>
<td>4.3</td>
</tr>
</tbody>
</table>

Note: Gradient = Difference in MC measured at 3/8- and ¾-inch depths (on boards with final average MCs between 10 and 16%)
**Results**

**Quality:**

- Increasing airflow has no negative impact on moisture content distribution and moisture content gradients through board thickness.
Specific electric consumption:

- Air velocity (ft/min)
- Specific consumption (kWh/kg of water evaporated)
What will be the financial impact of increasing airflow, assuming 2% productivity gains for every 100-ft/min increase in air velocity?
Assumption: Changes to baffles and/or fan blade angle
To achieve a 100 ft/min increase of airflow

- Species: Black spruce (2x4)
- Kiln capacity: 250 MBf
- Initial MC: 40%; final MC 15% (actual)
- Number of drying hours per year: 8000
- Reference air speed: 300 ft/min on exit side
- Fixed calorific consumption
Financial Impact of Increasing Airflow

Assumption: Changes to baffles and/or fan blade angle
To achieve a 100 ft/min increase of airflow

- 2% reduction in drying time for every 100 ft/min increase in air velocity
- Price differential between green and dry lumber:
  $45/MBf Stud grade Year 2004 (Source: L’Indéc)

100 ft/min increase in air velocity (through adjustment of baffles and/or fan blade angle) = Low $ modification
Assumption: Changes to baffles and/or fan blade angle To achieve a 100 ft/min increase of airflow

• Increasing air speed by 100 ft/min in this scenario will have the effect of increasing:
  – Annual drying capacity by 742 MBf (3 kiln loads)
  – Annual revenue by approximately:
    • $33,000 for $45/MBf dry/green differential
Financial Impact of Increasing Airflow

Additionnal revenue – Additional cost = ADDITIONNAL PROFIT

Additional revenue ($/MBf)

Price differential between dry and green lumber ($/MBf)

- Augmentation de 500 pi/min
- Augmentation de 400 pi/min
- Augmentation de 300 pi/min
- Augmentation de 200 pi/min
- Augmentation de 100 pi/min
Performance Benchmark for SPF Kilns (Preliminary)

Graph showing the ratio of installed power to MBf versus air velocity. The graph compares single and double pass kilns. The best performances recorded are highlighted.

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Suggestions for Future Research

Factors affecting airflow performance

- Motor not running at maximum current
- Equipment geometry (building, venturi)
- Fan efficiency (model, diameter, etc.)
- Ventilation system configuration (line-shaft or cross-shaft)
- Motor efficiency and speed drive
- Load configuration (single pass or double pass)
- Loading method
- Etc.
Future Research

Models for airflow optimization

Model of Forintek’s experimental kiln with Fluent software

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Future Research

Models for airflow optimization

ROOF DESIGN (30° Baffle)

ROOF DESIGN (45° Baffle)

Éric Bibeau, UBC

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Suggested Future Research

Other

• **Species:** Balsam fir and jack pine
• **Drying process:** high or low temperature?
• **Etc.**
Key Points

• The air must flow through the wood pile
  • Ensure good piling and stacking practices
  • Ensure adequate baffle adjustment

• The fan blade angle should be adjusted in relation to available power

• The first 100 ft/min increase is the easiest to achieve (technically and financially)
Key Points

• The use of a variable speed drive is recommended to:
  • Reduce power consumption, below the FSP level
  • Optimize motor and fan performance, above the FSP level (power management)

• The overall performance of the motor/speed drive system decreases when it operates below the motor’s nominal speed
Key Points

• Make sure that the system can provide sufficient heat
  – For a given volume of lumber, heat energy requirements are constant
  – If the drying time is shorter, the system needs to supply more heat per unit of time

• Remember that air speed affects the TDAL
Technical Team

- Vincent Lavoie: Project Leader
- Dany Normand: Project Leader
- Carl Tremblay: Scientist
- Guy Labrecque: Technologist
- Simon Paradis-Boies: Technologist
- Francis Tanguay: Technologist
- Yves Lavoie: Technologist
- Lichang Wang: PhD Student – University of Beijing

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Acknowledgements

- Bowater, Canfor, Domtar
- Participating mill personnel
- Pierre Angers, Hydro-Québec
- Yves Fortin and Maurice Defo, Université Laval
- Séchoirs MEC
- Marc Savard, Forintek

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Added Value to the
Wood Products Industry

Un partenaire de
progrès technologique pour
l'industrie des produits du bois

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