SOLAR KILN BASICS

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Why do we dry lumber?

• Removes excess water and reduces weight.
• Provide dimensional stability for end use conditions. (Controls shrinkage and swelling)
• Prevent degrade caused by uncontrolled drying.
• Reduce deterioration by fungi & bacteria.
• Improve machining properties.
• Permits gluing.
• Permits and enhances uses of finishes.
BRIEF LESSON ON DRYING THEORY
What is Wood?

Wood is an anisotropic, hygroscopic, naturally occurring organic material.
Anisotropic
Having different values of a given property in different directions (longitudinal, radial or tangential) through the material.
Hygroscopic

• Having the ability to absorb & desorb water until it’s in balance with conditions of surrounding air.
Wood-Moisture Relations

• Gains/loses moisture to achieve equilibrium with the air surrounding it.
  – Depends on RH and temp of surrounding air.
  – EMC (Equilibrium Moisture Content).

• MC of green wood varies greatly.
  – Mostly dependent upon species.
  – Variations may occur within the same species and within the same tree.

• MC in green wood does not vary much by season of the year.
Free Water and Bound Water

• Free water is liquid water contained in cell cavities.
  – Not held as tightly in wood; easy to remove.
  – Does not affect shrinkage.

• Bound water contained within cell walls.
  – Held more tightly; harder to remove.
  – Requires more energy.
  – Does affect shrinkage.
Fiber Saturation Point (FSP)

- Point at which cell wall are saturated but no free water remains.
  - Around 30% MC
  - Wood dries from the outside in which causes a moisture gradient within the board. The average MC may be 30% but the core may have 50% MC and the surface may have 10% MC.
Figure 12–2. Typical moisture gradient in lumber during drying at time increasing from $t_1$ to $t_3$. 
Fiber Saturation Point cont..

• More energy required below FSP.
  – Further below FSP, the more energy required

• Wood cells begin to shrink below FSP.
Equilibrium MC (EMC)

- The MC at which wood neither gains nor loses moisture when surrounded by air at a given RH and temp.
  - 80 F with RH of 75= 14.3 EMC
  - 70 F with RH of 55= 10.1 EMC
  - 70 F with RH of 25= 5.5 EMC

- Drying lumber requires controlling the “weather” inside of the kiln (temp and RH).
How Wood Dries

• Water moves from higher to lower zones of MC.
  – Wood dries from the outside in.
• The very surface of a board reaches EMC very quickly after drying starts.
• Capillary action causes free water to move.
• Differences in RH cause water vapor to move by diffusion.
• Differences in MC cause bound water to move by diffusion.
Factors That Influence Drying Rate

• RH
  – The lower the RH, the faster the drying.

• Temperature
  – Higher temp will increase drying rate.

• Airflow (at least in the early stages)

• Lumber thickness
  – Thicker lumber dries slower.
  – Not a 1:1 ratio (8/4 takes more than twice as long to dry as 4/4 of the same species).

• Properties of the wood.
Shrinkage of Wood

Shrinkage curves for wood Data from physical tests of six kinds of wood tested at State University of New York, College of Forestry, for the United Fruit Company
Drying Stresses

• Main cause of non-stain related drying defects.

• 2 types of stresses:
  – Hydrostatic tension
    • Forces that develop during capillary flow
    • Creates tension on cell walls and can cause collapse of cell walls.
  – Differential shrinkage
    • Caused by differential shrinkage between shell and core.
    • Cause defects such as warp, checking, splits, etc.
Heat Source

Area for stacked lumber
Penn State Extension

Fans
Area for baffle
Vents
Solar Kiln

Exterior walls with insulation

Solar collector to power the fans
• Optimum roof angle is typically equal to the latitude of your location.
  – Angle changes throughout the seasons
  – For winter optimization, increase angle by 10 degrees.

• Size of the collector will determine how much heat is created.
  – For 1” thick red oak use 1 sq ft of collector for every 10 BF.
  – To increase heat, have more area of collector.
  – Reduce heat, cover part of the collector.
How a Kiln Dries Lumber

• Air enters the kiln where it is heated up.
  – Increases the moisture holding capacity of air
• Fans circulate the heated air through the lumber.
• Air transfers heat to the lumber and picks up moisture.
• Moist air is vented.
Tips for Operating Solar Kilns

- Monitor drying rates of lumber
  - Kiln samples
  - Try to adhere to industry standards for loss rates
  - Adjust drying rates if needed

Safe Drying Rates for N. American Hardwoods

<table>
<thead>
<tr>
<th>Species</th>
<th>Maximum rate of MC loss per day (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-inch thick</td>
</tr>
<tr>
<td>Ash, white</td>
<td>10.4</td>
</tr>
<tr>
<td>Beech</td>
<td>4.5</td>
</tr>
<tr>
<td>Birch, yellow</td>
<td>6.1</td>
</tr>
<tr>
<td>Cherry</td>
<td>5.8</td>
</tr>
<tr>
<td>Elm, American</td>
<td>10.4</td>
</tr>
<tr>
<td>Maple, Soft (Sapwood)</td>
<td>13.8</td>
</tr>
<tr>
<td>Maple, Hard</td>
<td>6.5</td>
</tr>
<tr>
<td>Oak, Red Upland</td>
<td>3.0</td>
</tr>
<tr>
<td>Oak, Red Lowland</td>
<td>1.0 – 2.5</td>
</tr>
<tr>
<td>Oak, White Upland</td>
<td>2.5</td>
</tr>
<tr>
<td>Gum (Red Gum)</td>
<td>5.3</td>
</tr>
<tr>
<td>Tupelo (Black Gum)</td>
<td>10.9</td>
</tr>
<tr>
<td>Walnut</td>
<td>8.2</td>
</tr>
<tr>
<td>Yellow-poplar</td>
<td>13.8</td>
</tr>
</tbody>
</table>
Tips for Operating Solar Kilns

• To reduce drying rate:
  – Cover a portion of the collector
  – Shutting fans off when hot may cause an unsafe rise in temp
  – Partially close the vents
Tips for Operating Solar Kilns

• Temp will increase during daytime and decrease at night.
• As temps cool at night, RH increases.
• This heating/cooling cycle along with the increase in RH helps minimize drying stress.
• Fans should be turned off at night — Help with stress relief
• Data loggers can help track temp and RH.
Tips for Operating Solar Kilns

• A simple timer can be used to control when fans run and shut down.

• Humidistat can be used to turn off fans when there is very high humidity such as rainy days.

• As lumber gets drier, water is more difficult to remove so higher temps may be needed
  – Closing down the vents should help to increase temp.
Resources

- Dry Kiln Operator’s Manual

- Virginia Tech:
  [http://sbio.vt.edu/about/extension/vtsolar_kiln/](http://sbio.vt.edu/about/extension/vtsolar_kiln/)

- Woodweb Sawing and Drying Forum:
  [http://www.woodweb.com/cgi-bin/forums/sawdry.pl](http://www.woodweb.com/cgi-bin/forums/sawdry.pl)
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