Understanding Vacuum Drying Technologies for Commercial Lumber Production Applications

Scott Lyon
Forest Products Specialist

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Learning Objectives

- History of vacuum drying
- Comparing drying methods
- How vacuum drying works
- Advantages and disadvantages
- Research findings

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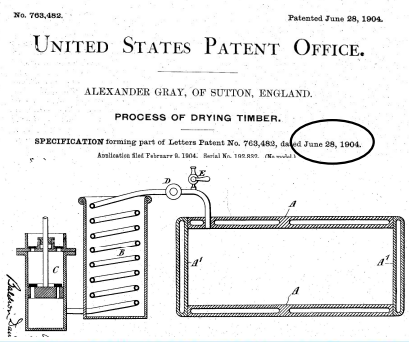

No. 763,482. Patented June 28, 1904.

UNITED STATES PATENT OFFICE.

ALEXANDER GRAY, OF SUTTON, ENGLAND.

PROCESS OF DRYING TIMBER.

SPECIFICATION forming part of Letters Patent No. 763,482, dated June 28, 1904.

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Early Vacuum Kilns

- Promised a lot
- Problems:
  - Too low heat
  - Poor controls
  - Incomplete understanding of the process and how to control it
  - Large moisture distributions

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Why the renewed interest in vacuum drying?

Word on the street is that:

- Faster drying rates
- Decrease in kiln cost
- Better quality lumber
- Lower operating costs
- Ability to dry small loads

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Three basic requirements for drying

- Energy (heat) source
- A mechanism to transfer the heat from the source to wood
- A means to remove water

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Conventional Drying

- The heat source (steam) is passed through heat exchangers to heat the air.
- Fans circulate the warm air through the kiln and heats the lumber by convection
- Lumber releases moisture that is vented from the kiln drying the lumber

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Vacuum Drying

- Ambient pressure is lowered which creates total pressure differences inside the wood
- Water boils and changes into water vapor during vacuum drying.
- Under the total pressure difference, water vapor is removed from the wood.
- Under the pressure difference, most moisture moves in the longitudinal direction.

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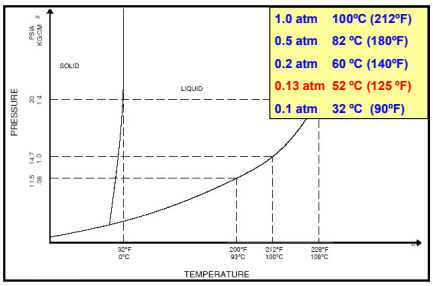
Vacuum Drying



Espinoza 2005

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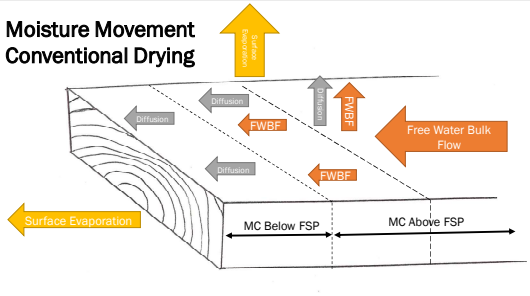
Moisture Movement Conventional Drying



Water is removed by two mechanisms bulk flow and diffusion

Adapted from Chen 1997

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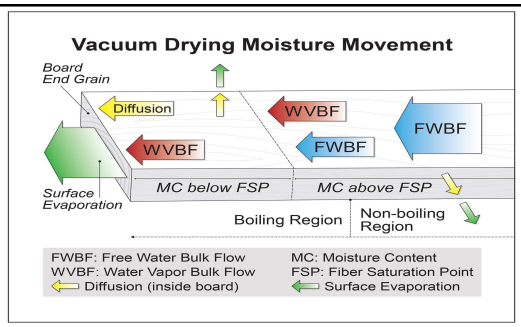

Adapted from Chen 1997

During vacuum drying, total pressure difference rather than diffusion is the primary driving force. A boiling front exists inside the wood.

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Drying times

	Conventional	Vacuum
	Green Condition	Dependent on Technology
Red Oak 4/4	25-35 days	3-9 days
Hard Maple 4/4	10-12	1-7
Ash 4/4	10-12	1-7
Black Walnut 4/4	12	1-7
Hard Maple 8/4	30-35	5-12

Bond and Brenes 2017

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Heating Methods and Technology Types

1. Conduction by direct contact hot plate or electric blanket
2. Convection using cycles of hot air (cyclic systems)
3. Convection using superheated steam
4. Radio frequency (RF) or dielectric heat

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What's needed for Vacuum Drying?

- Required a pressure vessel
  - Limits sizes
- Low heat requirements
- Vacuum pump
- Temperature is control through wood core or condense water

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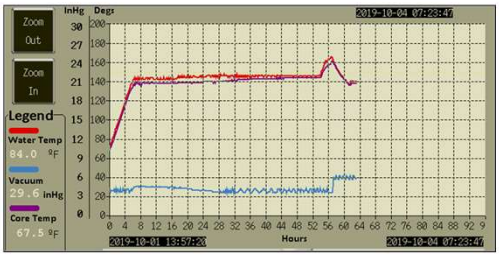

Drying is control by assume MC, by implied internal temp and vacuum level

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Conductive Heating

- Heat transfer is by direct contact with a hot surface
  - Electric blankets
    - Issues with heating uniformly
  - Platens filled with hot water
    - Efficient and uniform heating
    - Labor intensive

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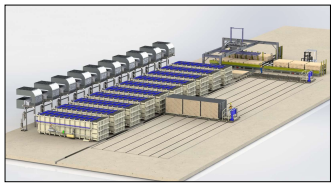
Conductive Heating Kiln

- Use of robotics to overcome labor and loading



https://www.vacutherm.com/home/vacupress-drying-centers/

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Cyclic/Convection Vacuum Drying

- Lumber is heated using convectional methods
  - Lumber is stickered
  - After heating phase, a vacuum is drawn causing drying
  - When the wood temperature drops, the heating cycle is repeated



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Superheated Steam Vacuum Drying

- Superheated steam is used under low-pressure conditions and forced through courses of lumber

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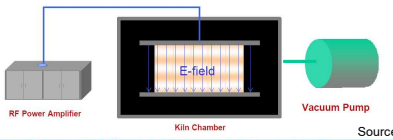
Radio Frequency Drying

- Heating occurs by using an alternating electromagnetic field causing polar water molecules in the wood to shift when changes fields.
  - The rapid shifts causes the wood to heat up.



Source: www.heatwave.com

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Vacuum Drying Advantages

- Much shorter drying times
- Lower drying temperatures
  - Wood retains original color
  - Stronger wood
- Quality at least as conventional drying
- No Volatile Organic Compounds (VOC) emissions
- Energy efficient

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Advantages Continued

- More uniform final moisture content
- Much easier to mix species and thickness
- Just-in-time inventory
- Use less valuable space

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Disadvantages

- High cost of energy and equipment
- Vessel capacity
- Each system is different
- Risk of over-drying
- Dependent on permeability (white oak)
- Equalization and conditioning capabilities (M.C. variations among boards and residual stresses)
- Complex technical operational skills
- Loading and unloading challenges

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Preferred Applications

- High valued species
- Timbers, large sections of lumber and logs
  - Live edge slabs
- Decorative and thick veneer
- Difficult to dry species
- Smaller scale

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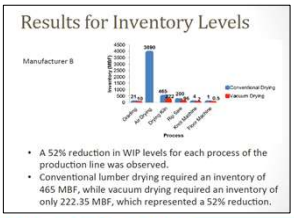
Where are we going?

- How can vacuum drying be used in the large-scale operations?
  - Increase flexibility
  - Decrease lead times
  - Reduce amount of inventory



Bond and Brenes 2017

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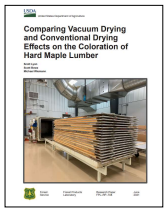
Recent Findings

- Flat lumber
- Case hardening varied between charges
- Tight moisture content
- Color comparison



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Color Comparison Study

Five #1 grade hard maple logs 8 ft 6 in. diameters of 14 to 16 in. at the small end were chosen for the study.

Harvested September 16, 2019, in Langlade County, WI

Logs were not end-coated and were sawn on October 3, 2019.

Seven to nine boards were selected from each of the five logs based on the following criteria: all sapwood, clear, and free from discoloration.

Dried to 7% MC

In total, 206 board feet of lumber were used in the study.

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Drying Times

- Samples in the vacuum kiln were dried in 58 hours using a vacuum of 10 cm Hg with a hold of 140 ° F for 8 hours, and the charge was completed when wood core temperature of 160° F was reached.
- Samples in the conventional steam kiln were dried in 288 hours using the T1-C5 schedule.

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Color Comparison Study

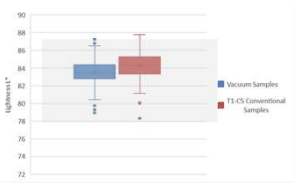
The eight readings taken by the spectrometer for each variable were averaged for each sample board.

The 40 paired sample averages were compared

Smith and Montoney (2000) determined that customers preferred a white color for hard maple with the following spectrophotometer data ranges of color values: L* = 79 to 88; a* = 3 to 7; b* = 14 to 19. These data were used for comparison purposes in this study

Table 2—Average L*a*b* values for surfaced wood samples from each drying schedule and *P* values for *t*-test: paired two sample for means

Drying schedule	L*	a*	b*
Vacuum	83.51	4.43	17.01
T1-C5 (conventional)	84.25	4.24	16.75
P(T ≤ *t*) one-tail	0.00	0.004	0.002



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Color Comparison Study Summary

- In summary, there was no visual difference in color between the two drying methods, although the vacuum kiln did produce tighter variances in color measures compared with the conventional kiln.
- Drying times were nearly five times faster in the vacuum kiln. However, loading and unloading a vacuum kiln is significantly more labor intensive.
- The results have demonstrated that vacuum drying can produce industry acceptable white hard maple as compared to a known white hard maple conventional kiln schedule.

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Thank You and Questions

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SCOTT LYON
Forest Products Specialist
Division of Forestry

2984 Shawano Ave.
Green Bay, WI 54313

(920) 360-3722
Scott.Lyon@wisconsin.gov

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