USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

# Introduction to Lumber Dry Kiln Operations – Week 1

**November 1, 2021**

Hosted Virtually by the Southwest Ecological Restoration Institutes Wood Utilization Team

Instructor: Patrick Rappold, Regional Wood Utilization Specialist, USDA Forest Service Wood Education & Resource Center

# Week 1 Agenda November 1, 2021

**12:00pm MST – 1:00pm MST**

- Orientation to the course.
- Importance of the lumber drying operation.
- Economics of the lumber drying operation.
- How wood cellular structure impacts warp, twist, and other drying defects.
- How lumber sawing accuracy impacts lumber quality.
- Importance of good air-dry yard practices.

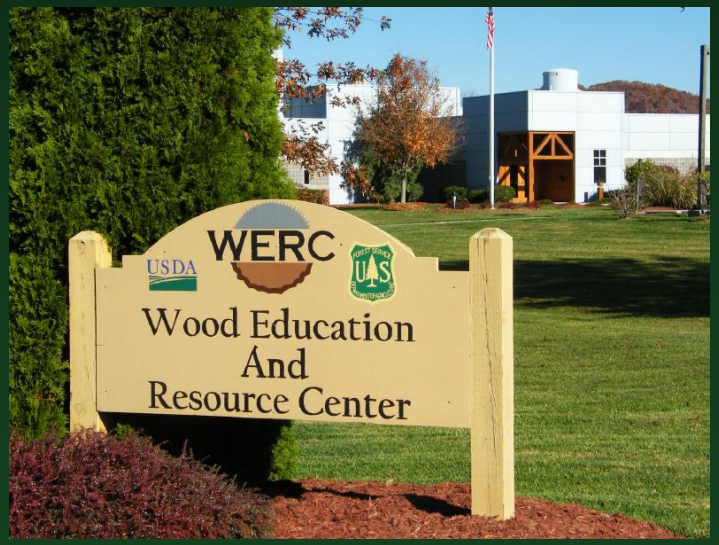
**1:00pm MST – 2:00pm MST**

- Tools and techniques for determining moisture content. Followed by calculation exercises.
- How to select and prepare lumber dry kiln sample boards.
- Determining moisture contents of the shell and the core of the sample boards.

# Instructor

**Patrick Rappold**
**USDA Forest Service**
**Regional Wood Utilization Specialist**
**626 E. Wisconsin Ave.**
**Milwaukee, WI 53202**
**patrick.rappold@usda.gov**
**Mobile: 414-477-9167**

# Wood Education & Resource Center




A 13 – acre campus in **Princeton, WV** that includes a training center, a maintenance building, and a rough mill.

The Wood Education and Resource Center (**WERC**) Forest Markets program has grown to become a virtual hub for technical assistance to forest products manufacturing.

Objective is to contribute to a more competitive, productive, and profitable forest products industry in the U.S.

Provides technical assistance nationally and financial assistance at the regional level.

Photographs taken pre-pandemic

# Non-Discrimination Statement

In accordance with Federal law and U.S. Department of Agriculture, the Forest Service is prohibited from discriminating on the basis of race, color, national origin, sex, age, or disability.

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USDA is an equal opportunity provider, employer, and lender.

# Discussion of Pricing and Costs

Refrain from discussing lumber costs and purchasing activities.

# Books and Materials

Dry Kiln Operator's Manual, USDA Forest Service Forest Products Laboratory – 1991 Edition https://www.fs.usda.gov/treesearch/pubs/7164

Air drying of Ponderosa Pine, USDA Forest Service Forest Products Laboratory https://ir.library.oregonstate.edu/concern/conference_proceedings_or_journals/7w62f942j?locale=en

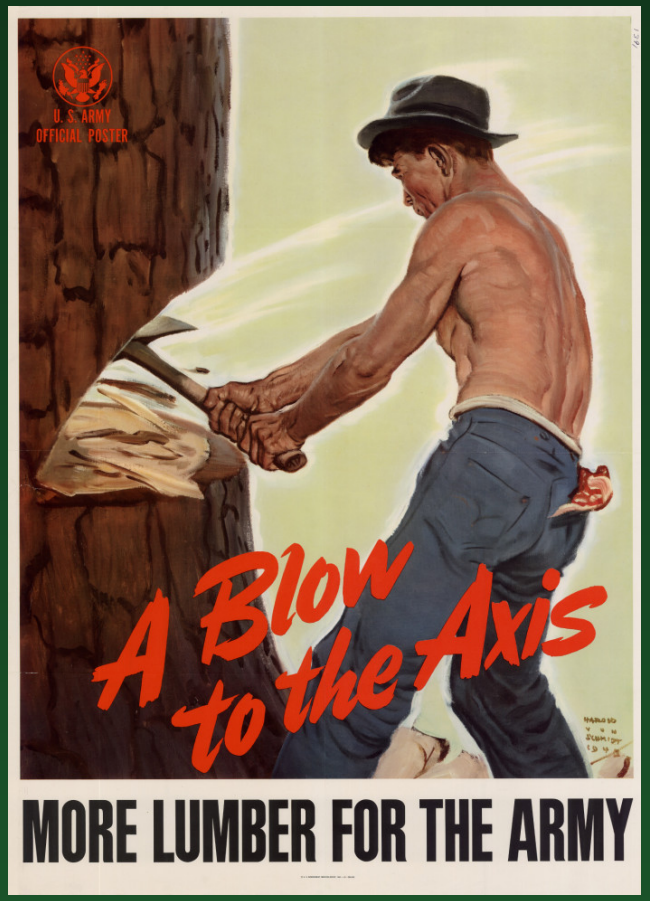
Air Drying of Lumber, USDA Forest Service Forest Products Laboratory https://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr117.pdf

Design Considerations for Lumber Pile Covers in Air-Dry Yards, University of New Hampshire Cooperative Extension https://scholars.unh.edu/cgi/viewcontent.cgi?article=2088&context=extension

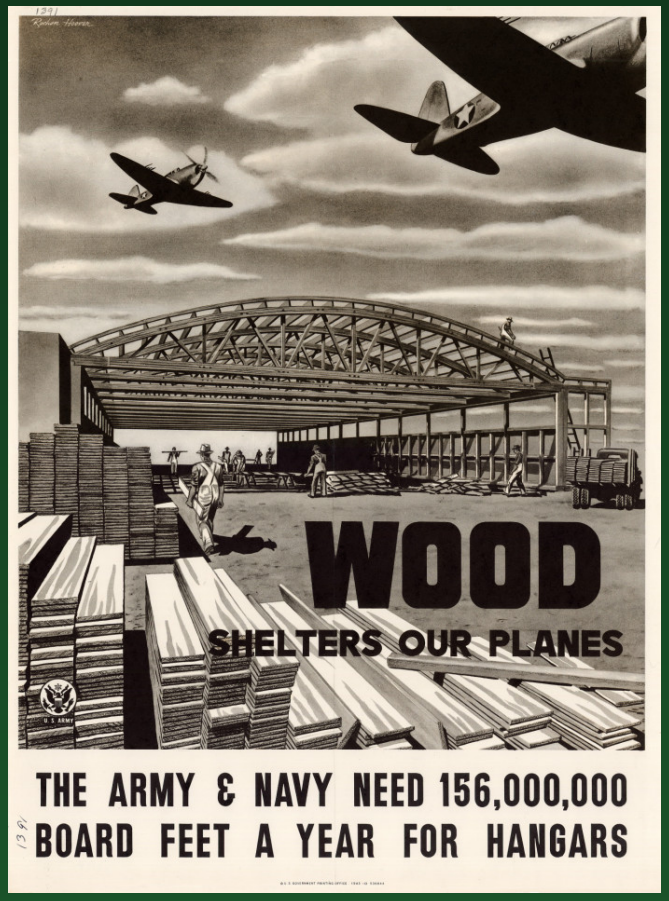
Wood handbook- Wood as an engineering material – 2021 Edition, USDA Forest Service Forest Products Laboratory https://www.fs.usda.gov/treesearch/pubs/62200

# Federal Interest in Forest Products

## Past – Wood was a Strategic Material




Source: University of North Texas Digital Archives
https://digital.library.unt.edu/ark:/67531/metadc420/




Source: University of North Texas Digital Archives
https://digital.library.unt.edu/ark:/67531/metadc390/

# Federal Interest in Forest Products

## Current – Conservation of Natural Resources

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## Current – Conservation of Natural Resources

Control of Invasive Insects

### Port of New Orleans Finds Invasive Insects in Wood on Deck of Foreign Vessel July 28, 2021

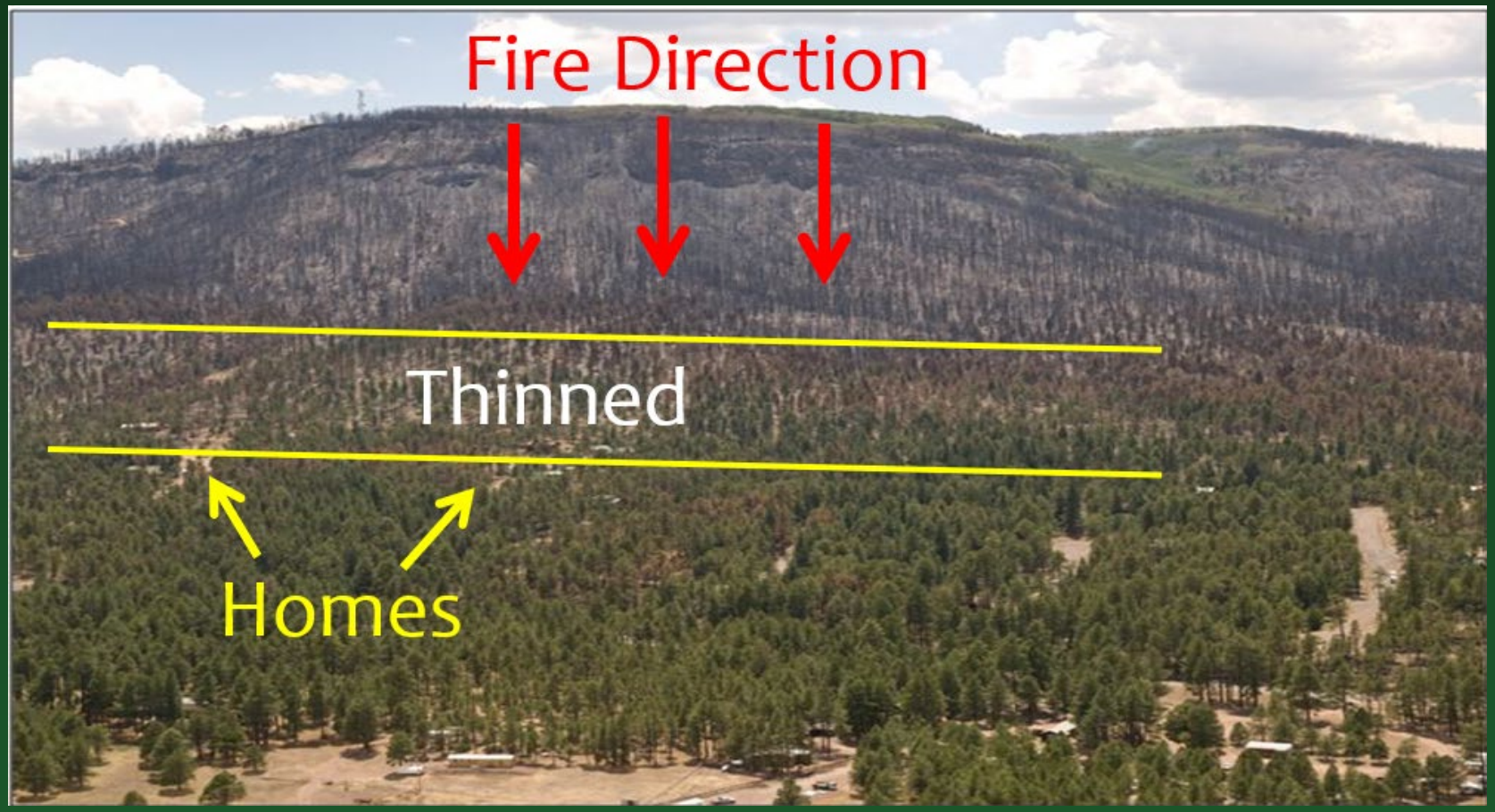
**Release Date:** July 28, 2021

**NEW ORLEANS** - U.S. Customs and Border Protection (CBP) agriculture specialists at the Port of New Orleans ordered the removal of a vessel du invasive insects found in the wood used to secure their previous cargo. The wood (henceforth referred to as "dunnage") on the ship named Pan Jasmine was found to be infested with five separate pests, two of which required action.

The Pan Jasmine arrived at the anchorage of Davant, down river from New Orleans at mile marker 54, on July 17. The ship had previously offloa a shipment of aluminum in Vera Cruz, Mexico, after coming from Paradip, India. The dunnage used to pack the aluminum had not been offloaded in Mexico and was left scattered on the deck of the Pan Jasmine, which is unusual. No reason was provided to CBP as to why the dunnage was refused discharge in Mexico, and this raised a red flag. An examination of the dunnage revealed burrowing holes and fresh sawdust near the holes, which indicates pests. After two examinations of the dunnage by CBP and USDA personnel, five separate pests were found and identified. Two of the pests discovered pose an agriculture threat to the U.S. They were positively identified by USDA entomologists as Cerambycidae and Myrmicinae. The Cerambycidae Family of Longhorned Beetles contains many non-native species that pose a serious threat to the environment. The larvae of invasive wood-boring beetles can feed on a wide variety of trees in the U.S., eventually killing them. The Myrmicinae queen ants are a concern because they

# Federal Interest in Forest Products
## Current – No Markets, No Management

**How Fuel Treatments Saved Homes from the 2011 Wallow Fire in Arizona**
**August 16, 2011 Report**



# Forest Restoration Economics

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Source: Ecological Restoration Institute

# By-Product of Forest Restoration - Lumber


Source: Popular Woodworking

# Lumber Grade Yields Impact Economics

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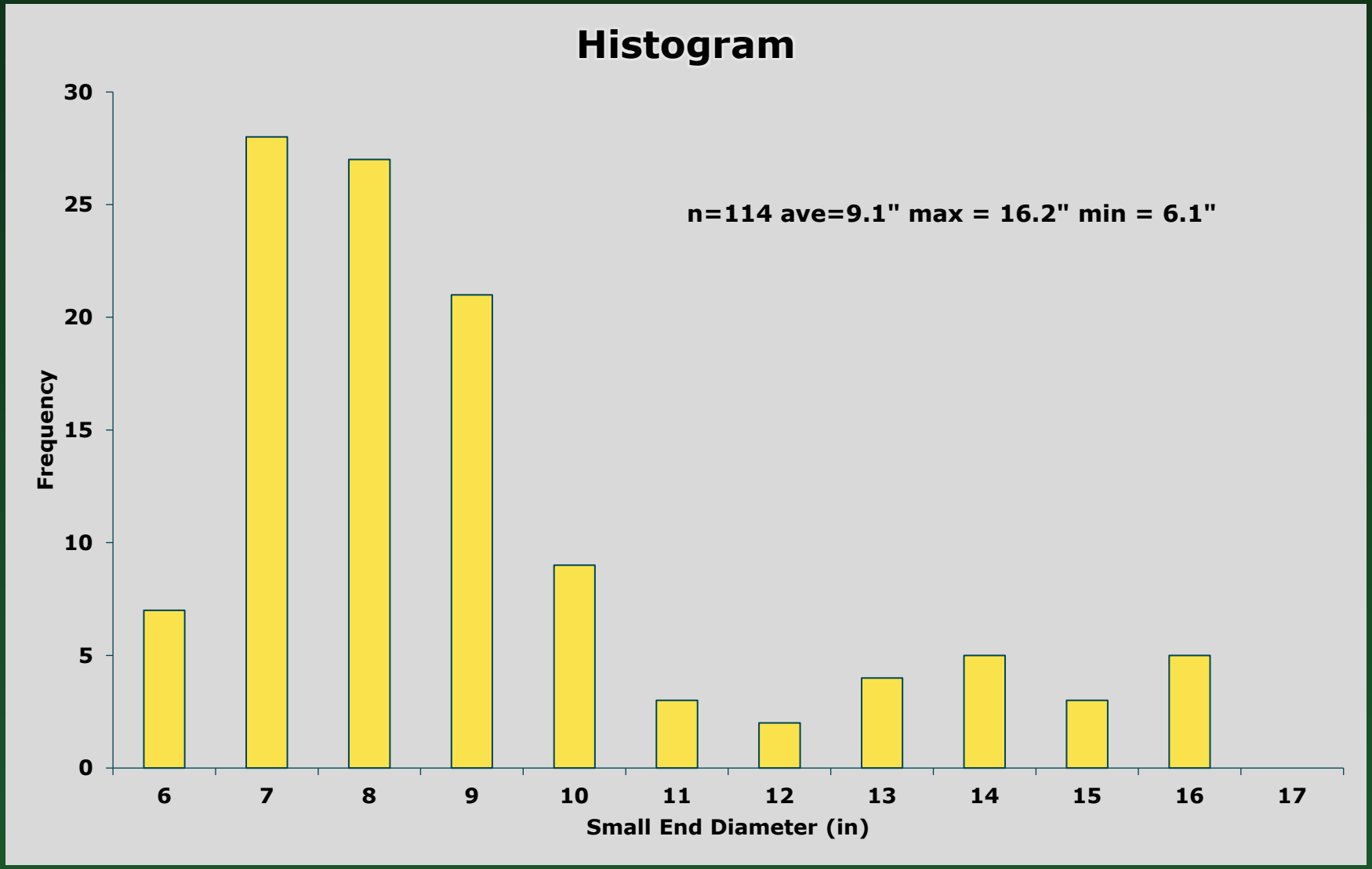
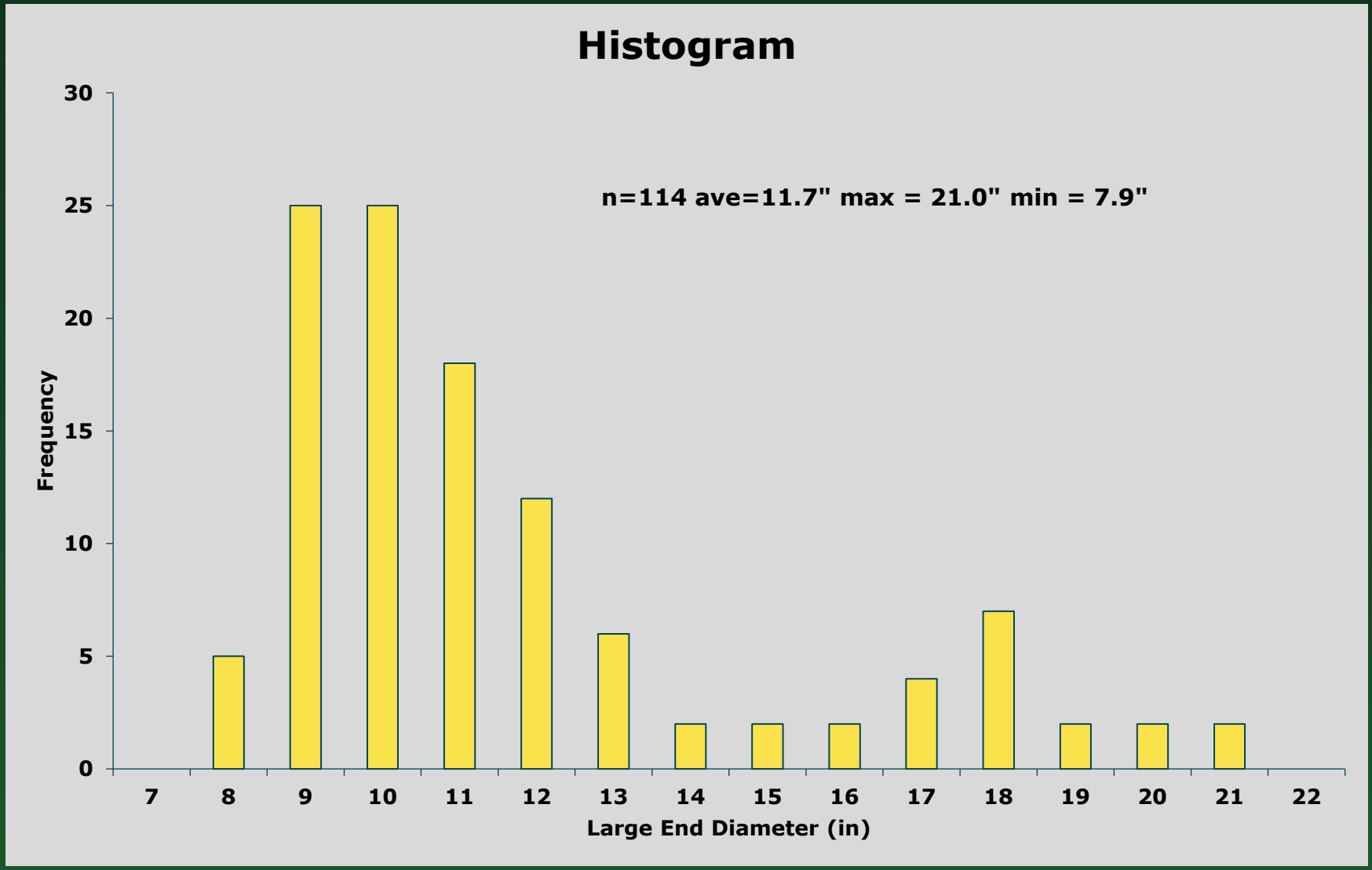
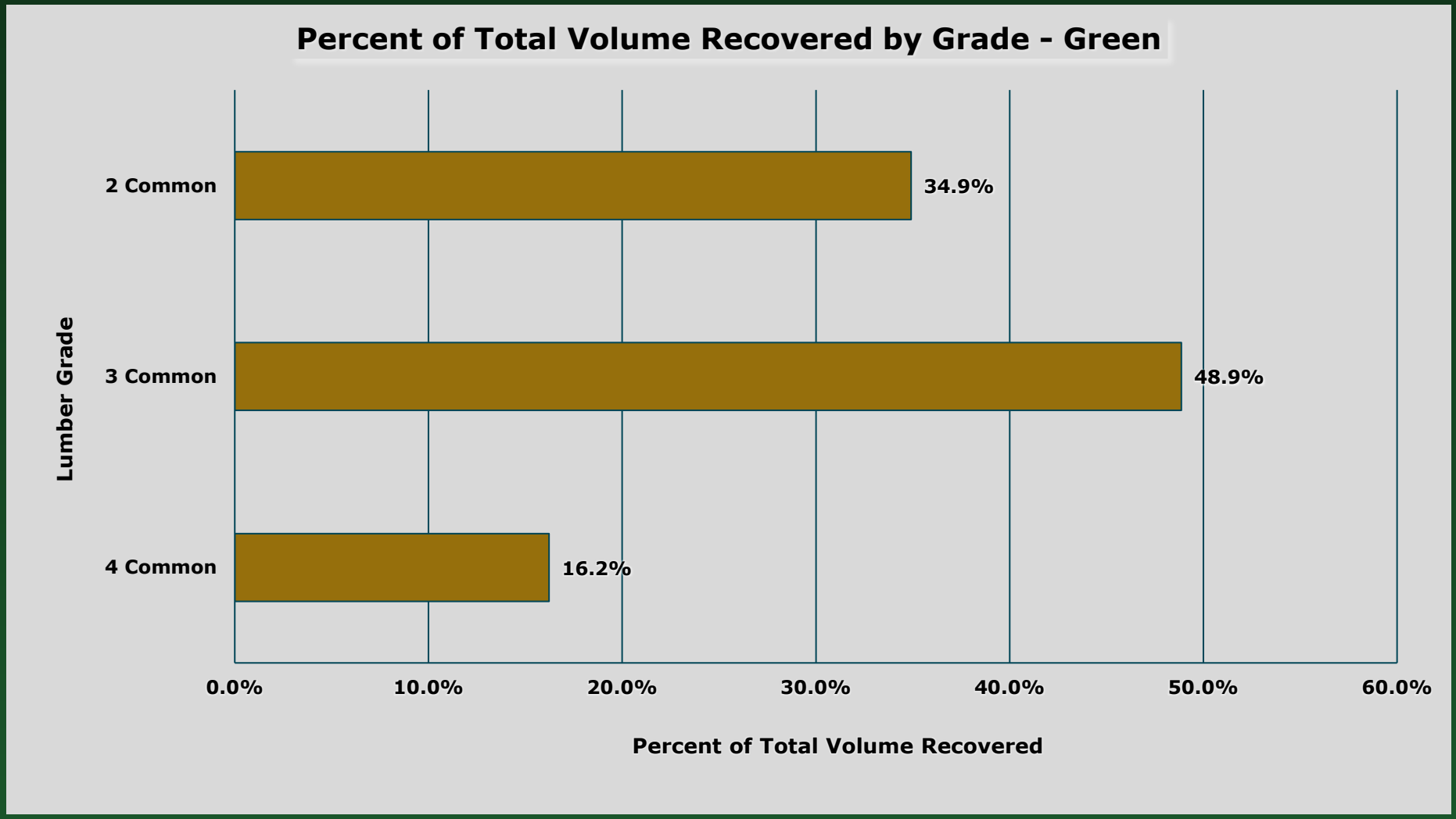


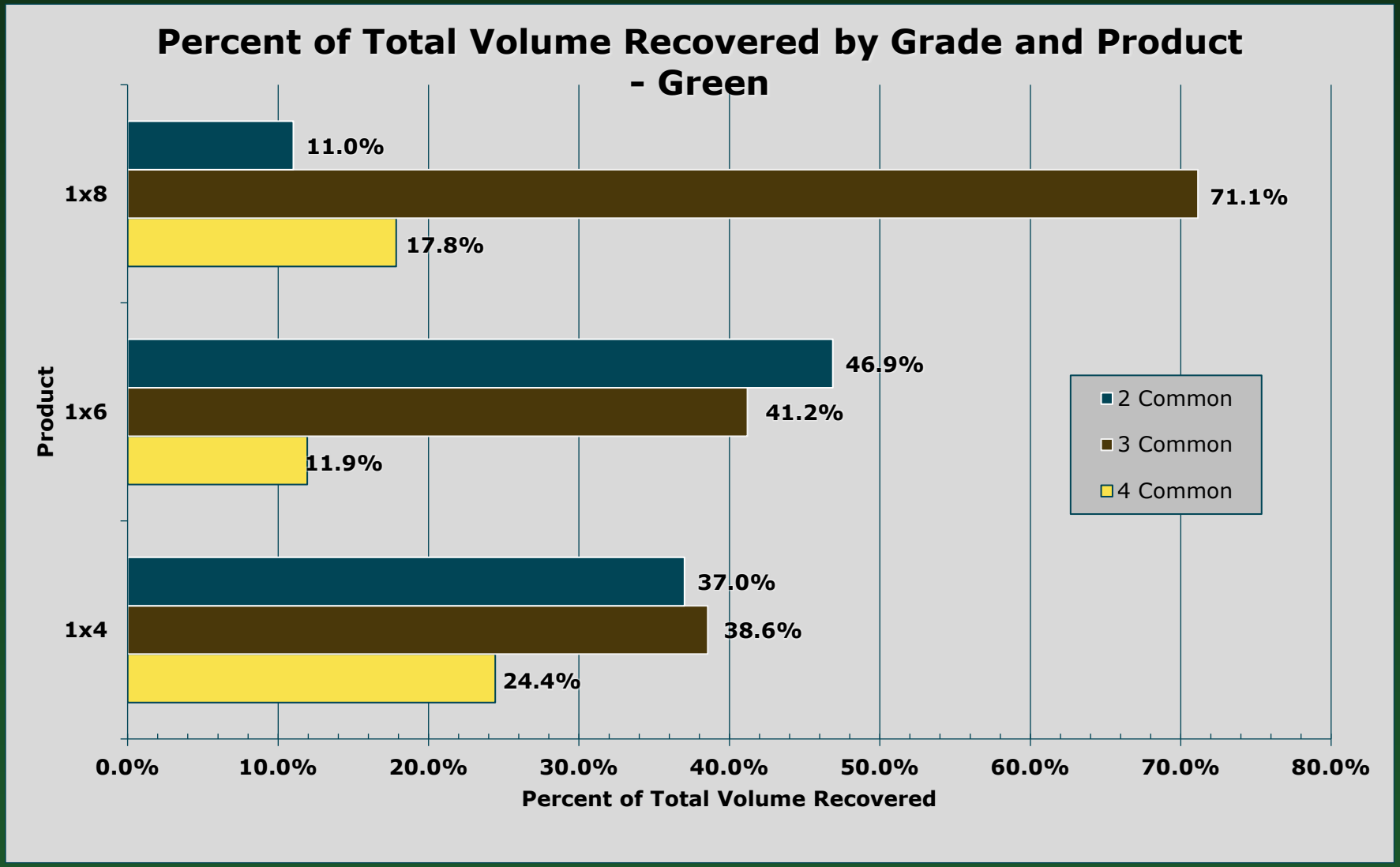
# Lumber Grade Yields Impact Economics

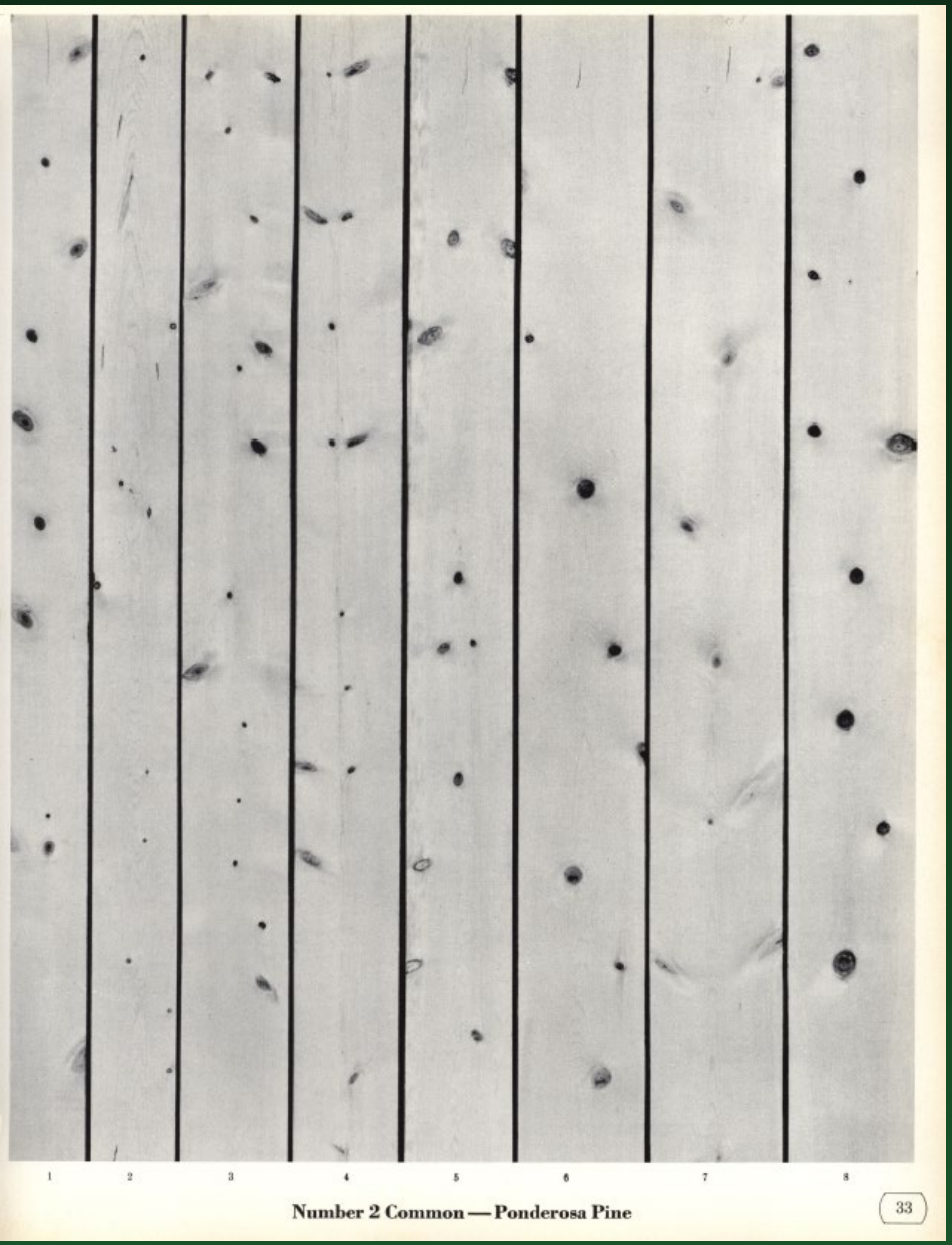


# Lumber Grade Yields Impact Economics



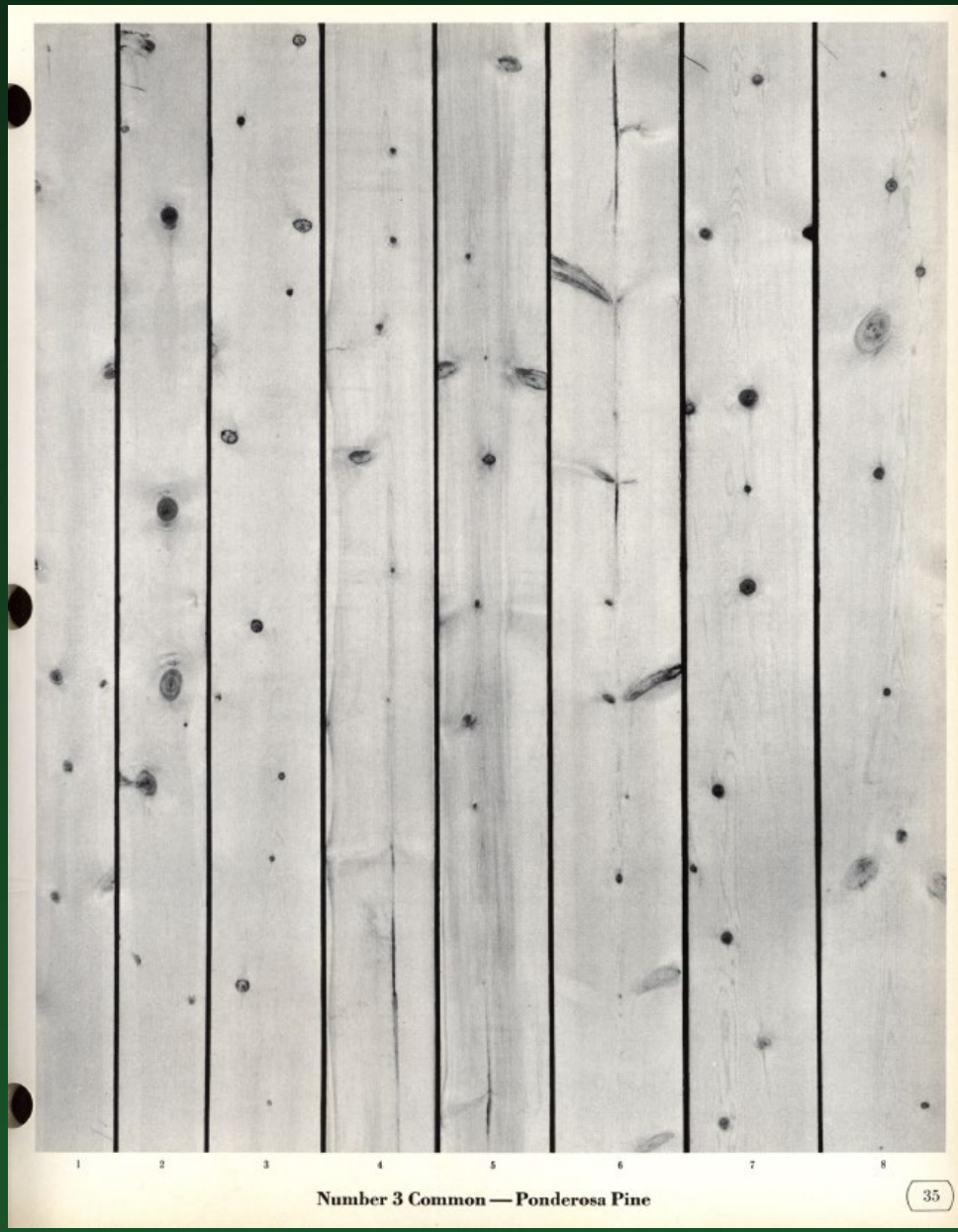
# Lumber Grade Yields Impact Economics





Number 2 Common — Ponderosa Pine

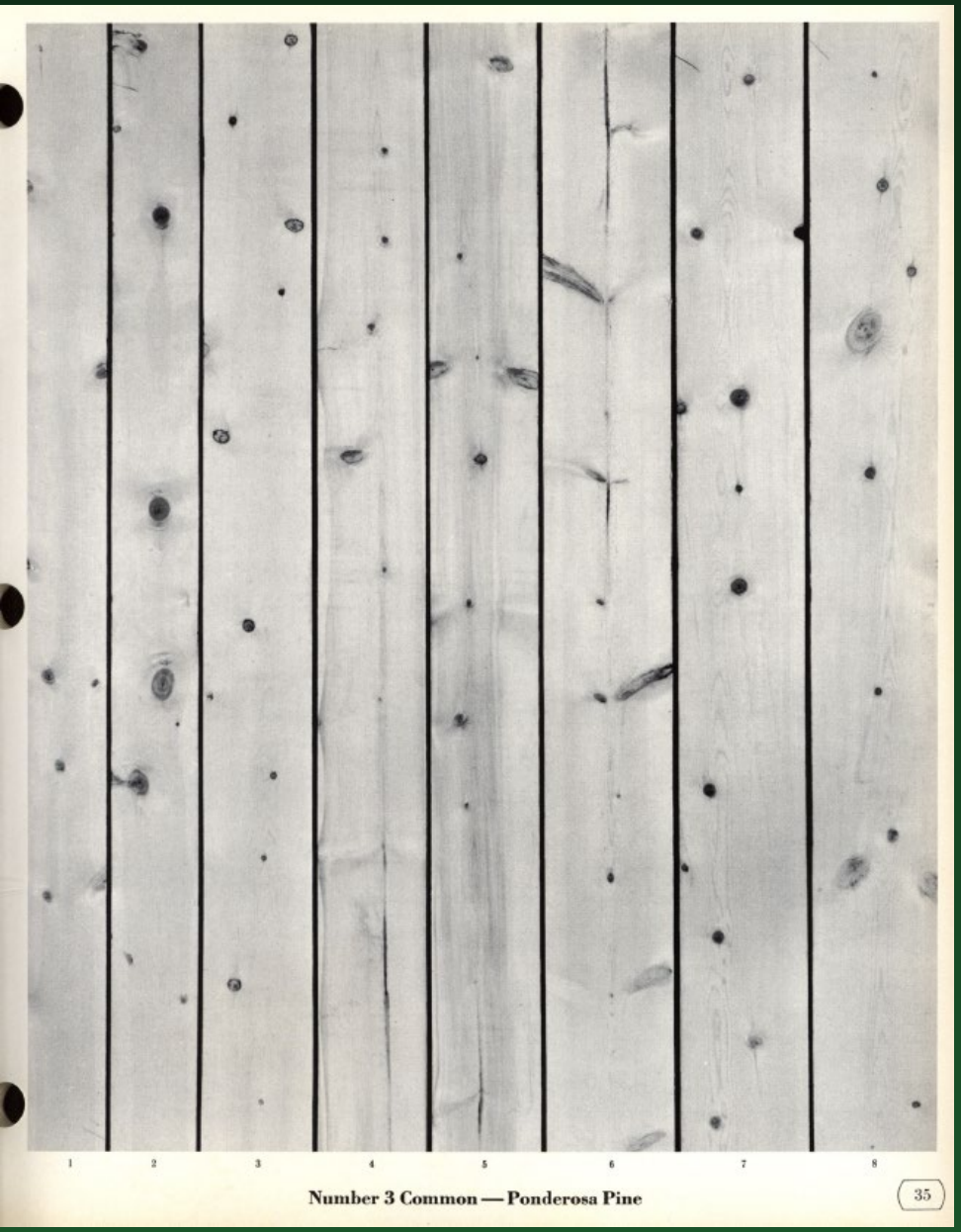
33



Number 3 Common — Ponderosa Pine

35

Source: https://archive.org/details/PonderosaPineThePickOThePinesItsPropertiesUsesAndGrades



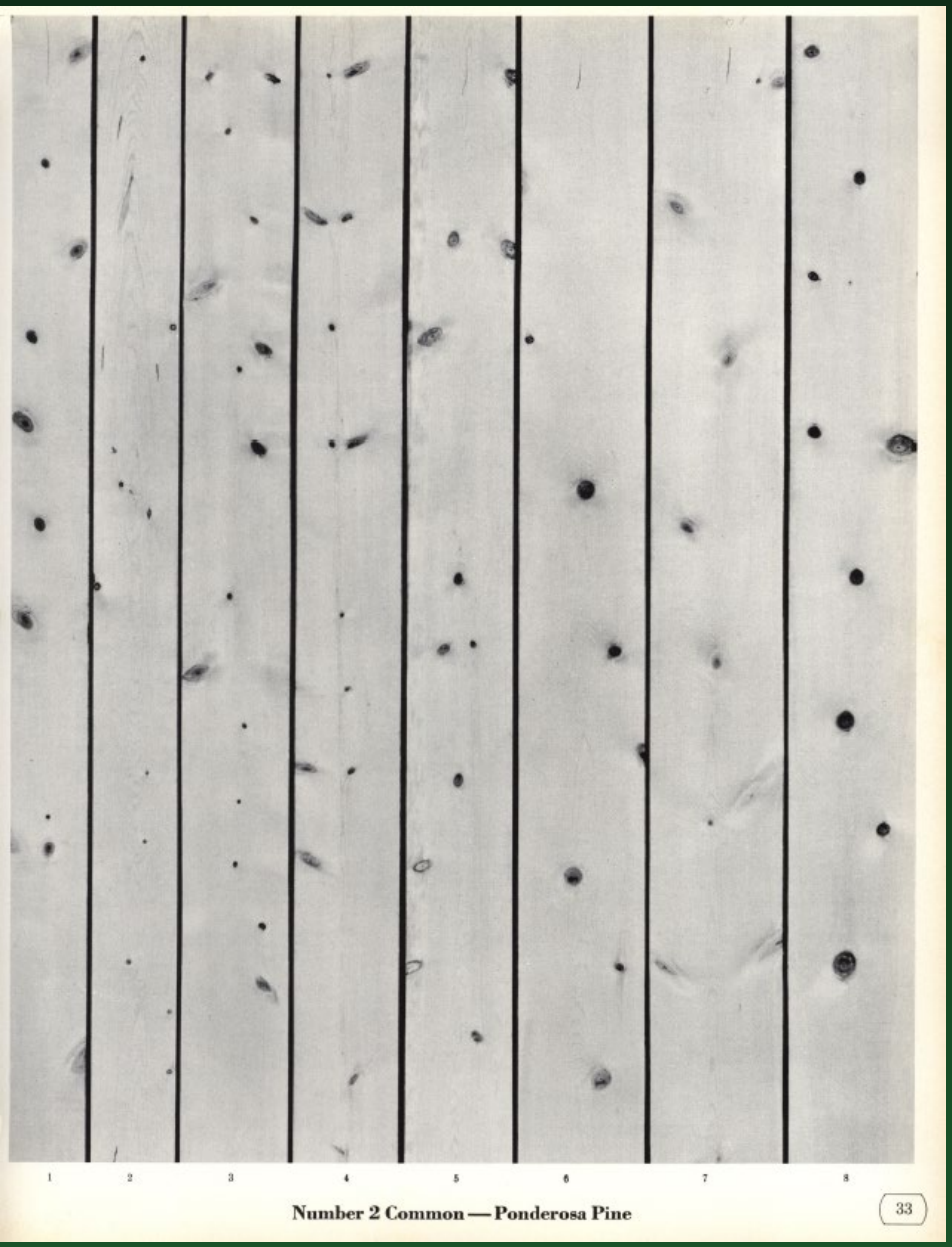

Number 3 Common — Ponderosa Pine

35


Number 4 Common — Ponderosa Pine

37

Source: https://archive.org/details/PonderosaPineThePickOThePinesItsPropertiesUsesAndGrades




Number 2 Common — Ponderosa Pine




Number 4 Common — Ponderosa Pine



Source: https://archive.org/details/PonderosaPineThePickOThePinesItsPropertiesUsesAndGrades

# Lumber Recovery From Small-Diameter Ponderosa Pine From Flagstaff, Arizona

Eini C. Lowell
David W. Green

A study published in 2000 by USDA Forest Service researchers found the same distribution of grade yield

**Table 6**–Lumber grade recovery from logs sawn for appearance grade products.

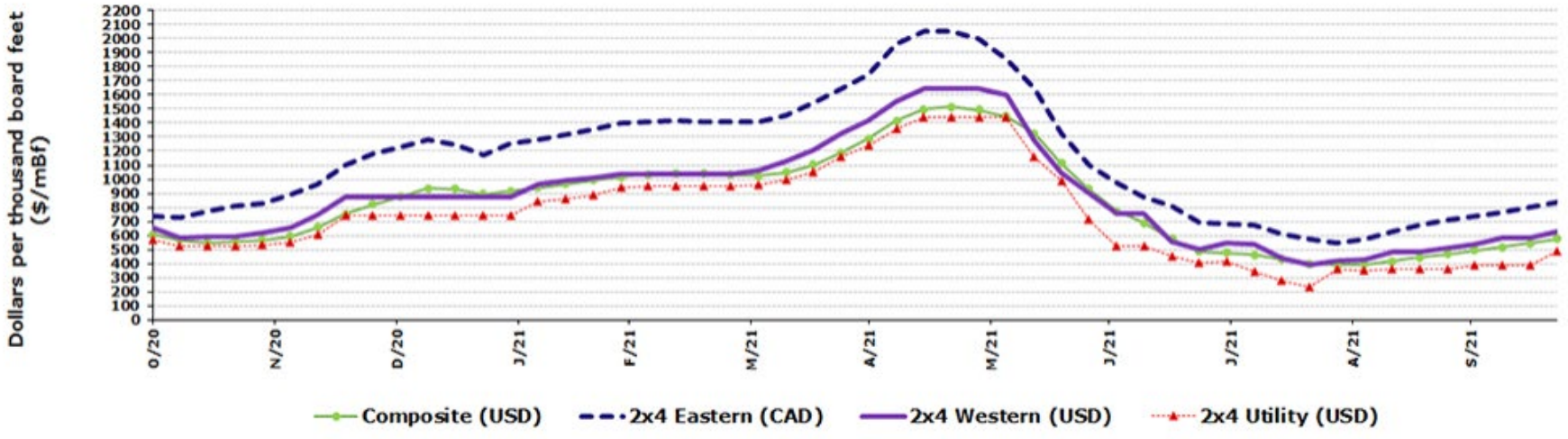
| Board grade | Lumber volume |
|---|---|
| | *Percent* |
| #1 Common | 3 |
| #2 Common | 22 |
| #3 Common | 66 |
| #4 Common | 7 |
| Moulding | <1 |
| 3 Clear | <1 |
| 1 Shop | 1 |
| 2 Shop | 1 |

USDA Forest Service Proceedings RMRS-P-22.2001

Report available at:
https://www.fs.usda.gov/treesearch/pubs/5706

# Why Dry Lumber?

Add value to the lumber




**Note:** Eastern spruce-pine-fir 2x4 #2 and better, Random Lengths composite prices and western spruce-pine-fir 2x4 #2 and better, kiln dried

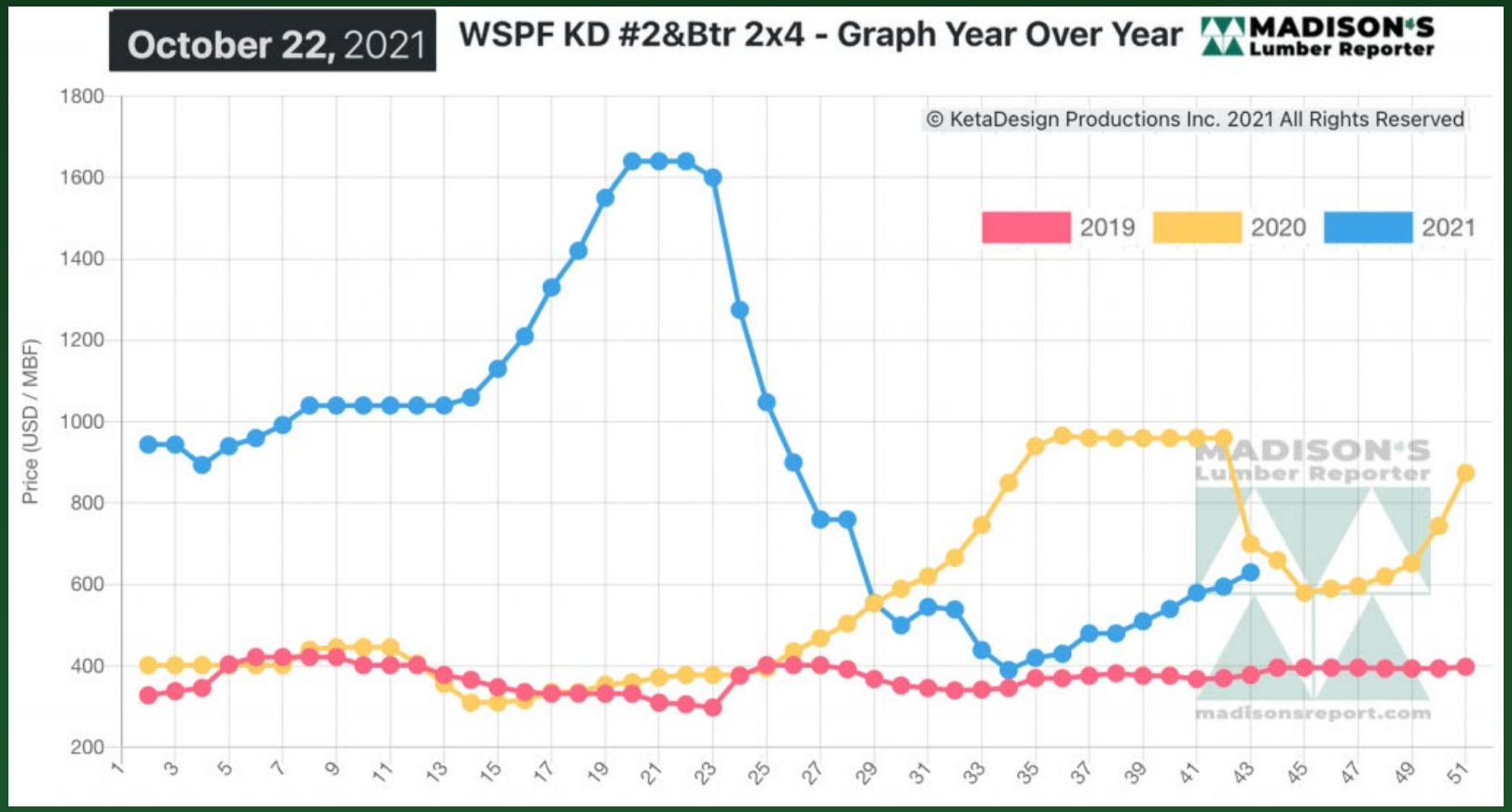
**Sources:** 1) Random Lengths, used with publisher's permission

2) Madison's Lumber Reporter, used with permission granted by the publisher

Source: https://www.nrcan.gc.ca/our-natural-resources/domestic-and-international-markets/current-lumber-pulp-panel-prices/13309

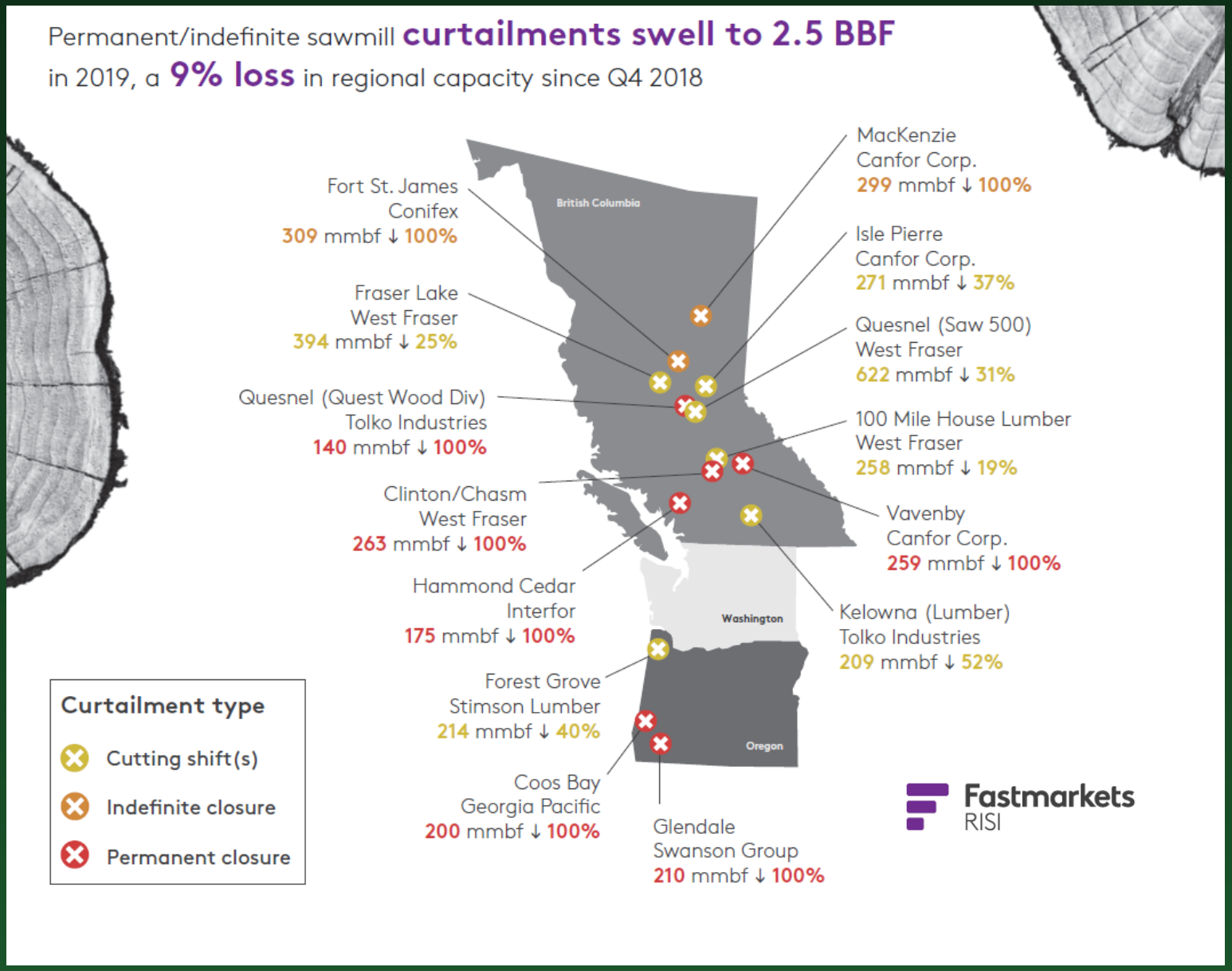
# Why Dry Lumber?

Add value to the lumber




Source: https://madisonsreport.com/

# Permanent curtailments rise: British Columbia and Pacific Northwest



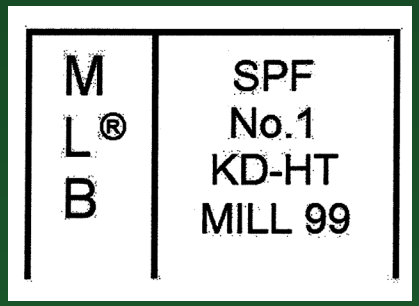

Source: https://insights.risiinfo.com/permanent-sawmill-curtailments-british-columbia-pacific-northwest-september-2019/index.html September 2019

# Why Dry Lumber?

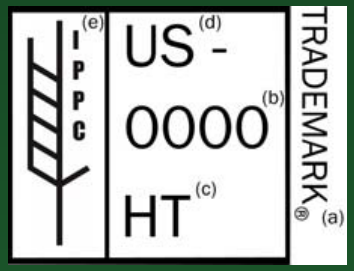
Adhere to Phytosanitation Standards

Kiln Drying (KD) as defined by International Standards for Phytosanitary Measures (ISPMs)

- Definition - A process in which wood is dried in a closed chamber using heat and/or humidity control to achieve a required moisture content [ISPM No 15, 2002].
- Goal – to reduce the amount of moisture to a percentage that is not likely to support pests, regardless of temperature.



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**KAIBAB LUMBER COMPANY, Fredonia, AZ 1960**
**Source: Arizona has trees : an analysis of forest products potential in Arizona**
**https://azmemory.azlibrary.gov/digital/collection/statepubs/id/15149/**

# Wood Structure and Lumber Drying

Gymnosperm

Angiosperm



Images Source: Wood Handbook: Wood as an Engineering Material, 2021

# Anisotropic – Different Properties in Different Directions

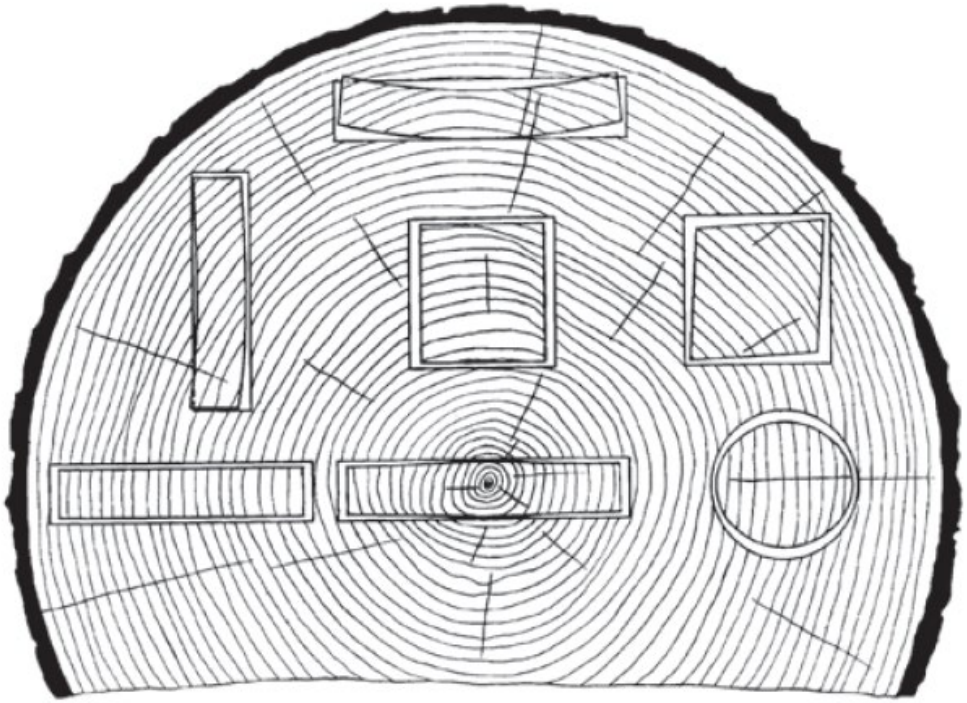
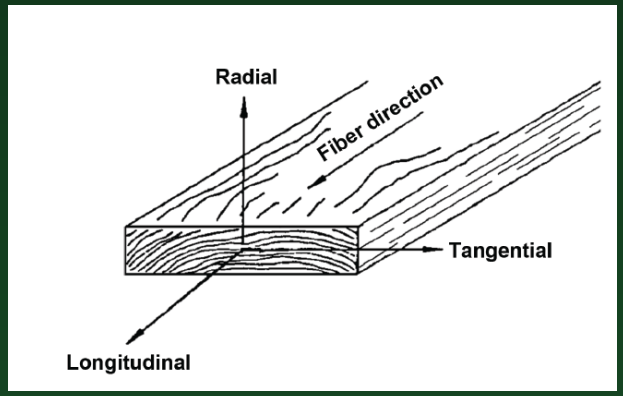


Figure 4–4. Characteristic shrinkage and distortion of flat, square, and round pieces as affected by direction of growth rings. Tangential shrinkage is about twice as great as radial.



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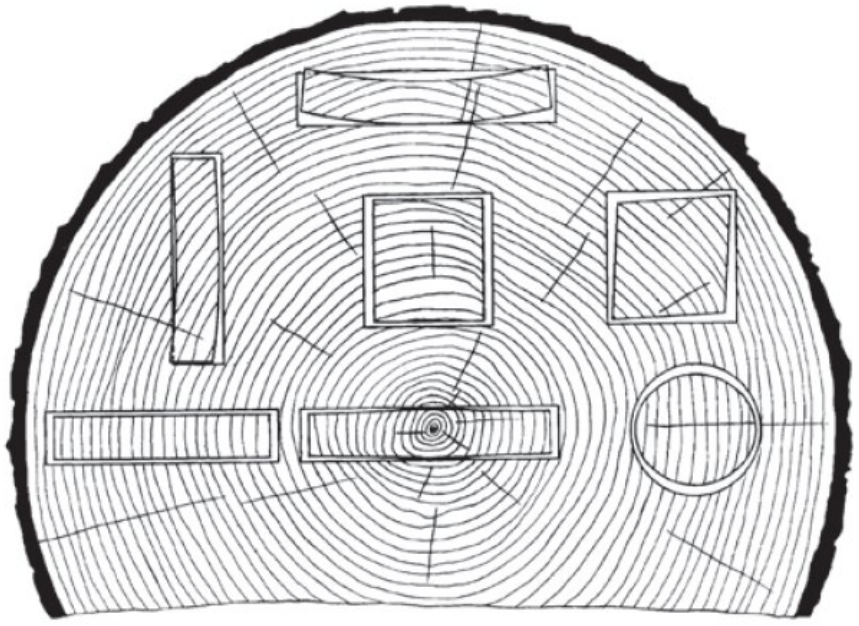

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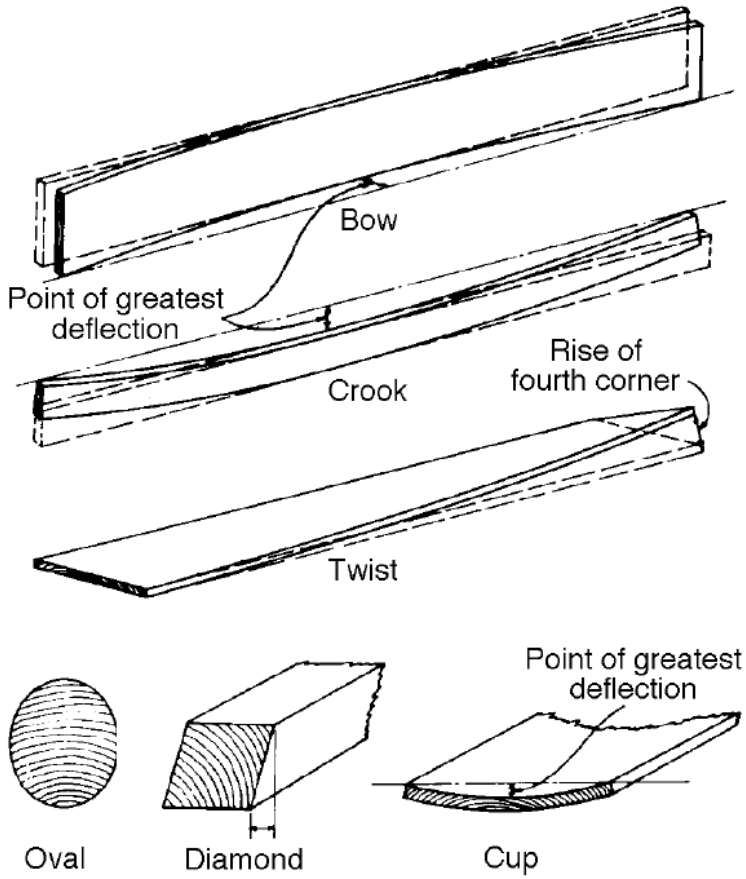


Figure 53—Various types of warp in lumber.



Images Source: https://www.wood-database.com/

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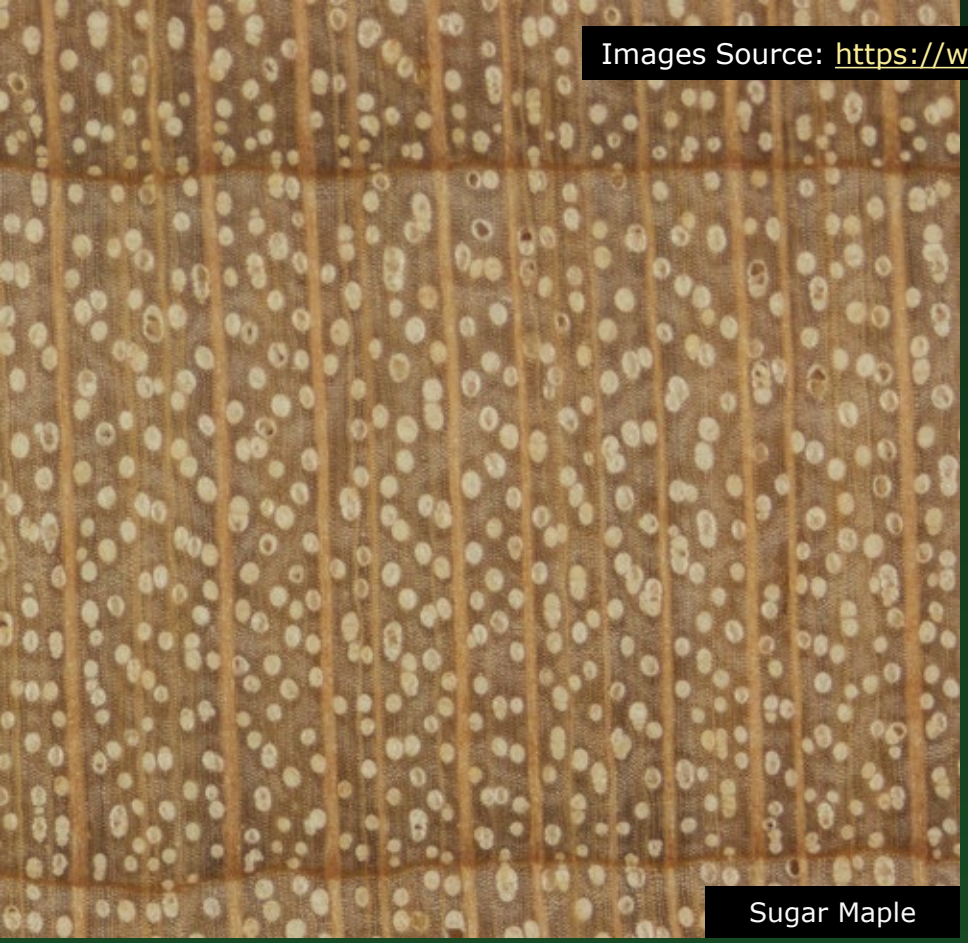
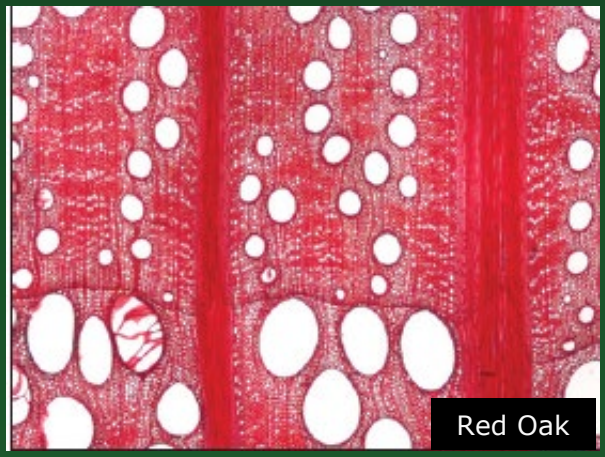


Sugar Maple

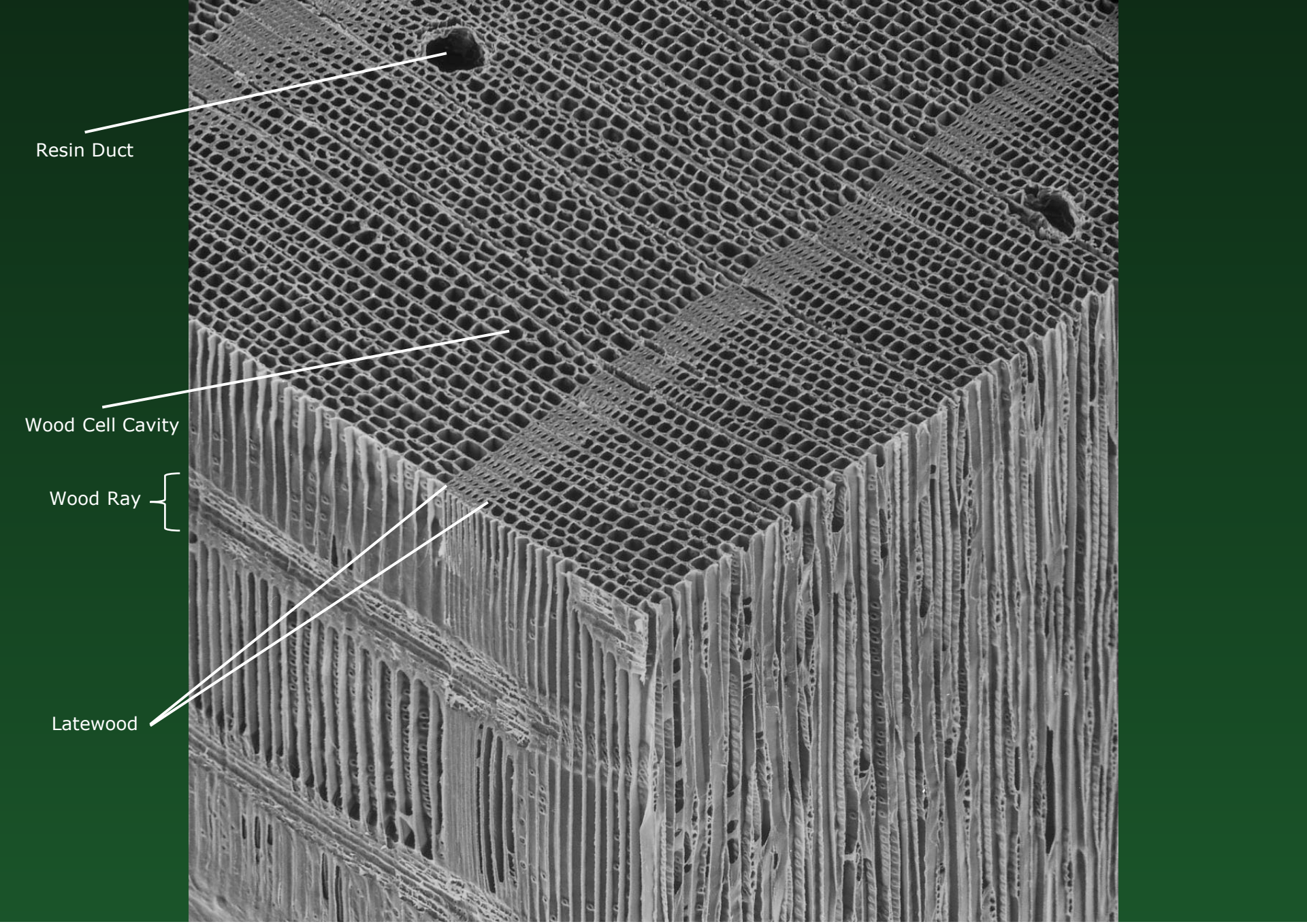
Southern Red Oak

Sugar Maple



Red Oak


Images Source: https://www.wood-database.com/




**Ponderosa pine Cross Section**, N.C. Brown Center for Ultrastructure Studies, Syracuse, NY, Softwood Image Gallery – NC Brown Center for Ultrastructure Studies (wordpress.com)

# A Wood Cell Cavity and the 3 Layers of the Wood Cell Wall

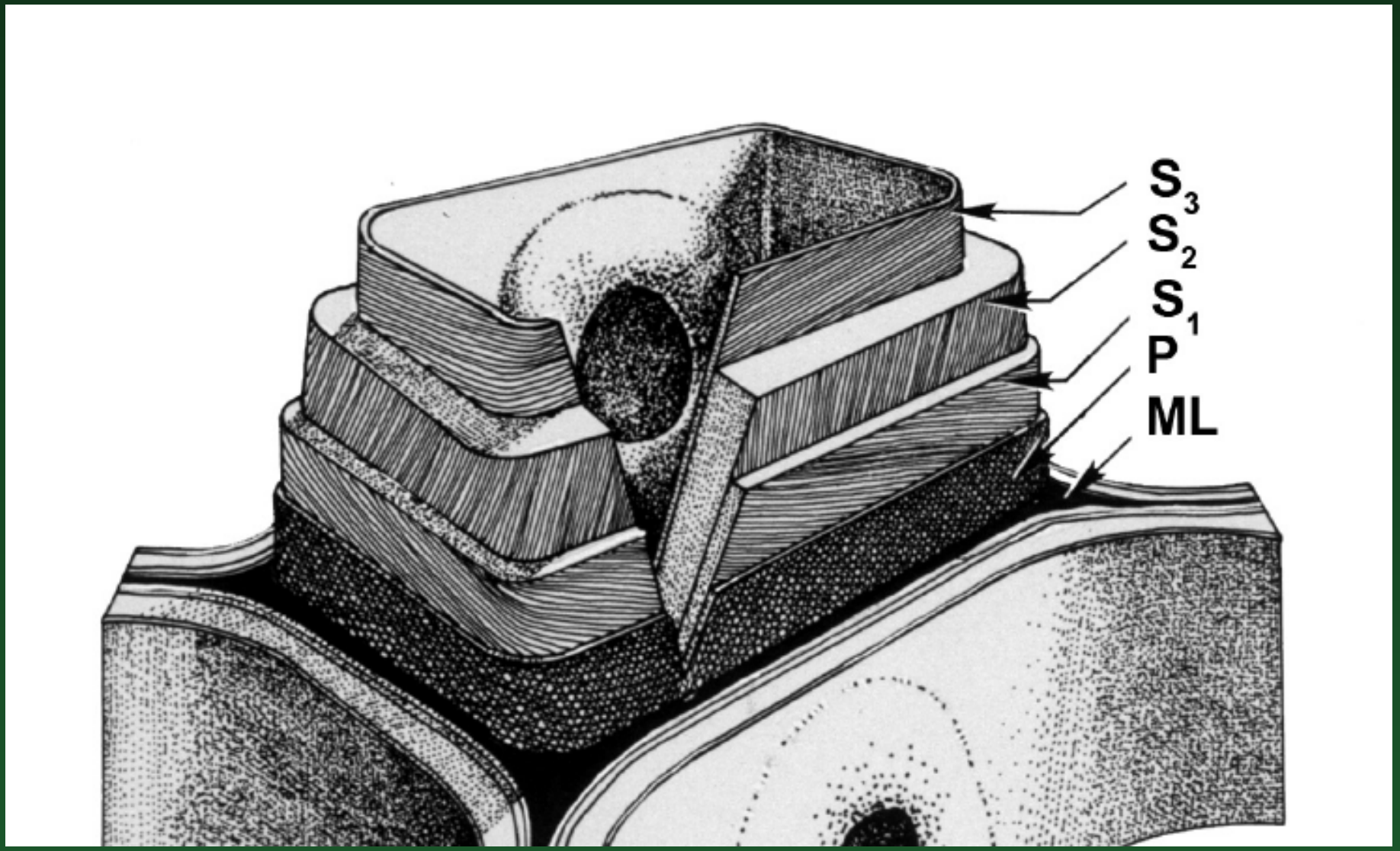
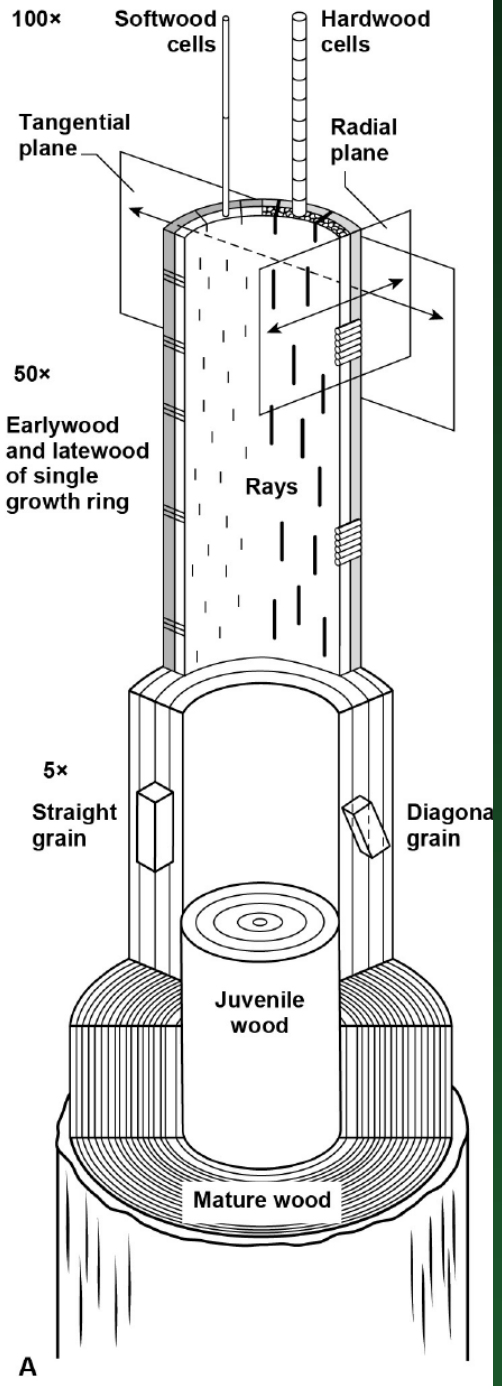
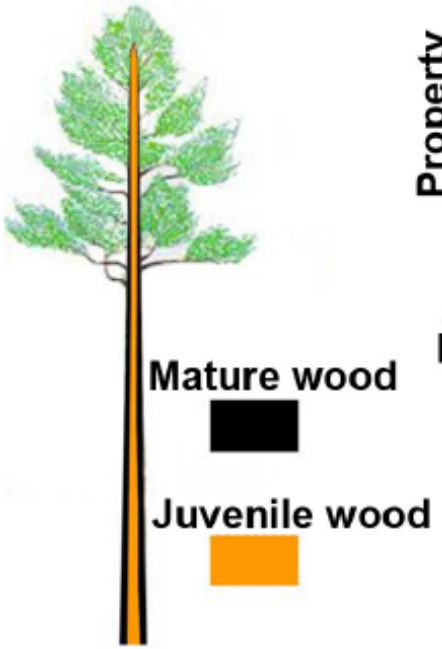
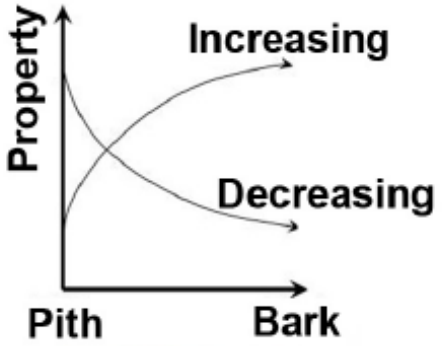



Image Source: Wood Handbook: Wood as an Engineering Material, 2021

# Juvenile Wood




| Properties that generally increase |
|---|
| Specific gravity |
| Cell length |
| Strength |
| Cell wall thickness |
| Transverse shrinkage |
| Percent latewood |

| Properties that generally decrease |
|---|
| Fibril angle |
| Longitudinal shrinkage |
| Moisture content |
| Spiral grain |

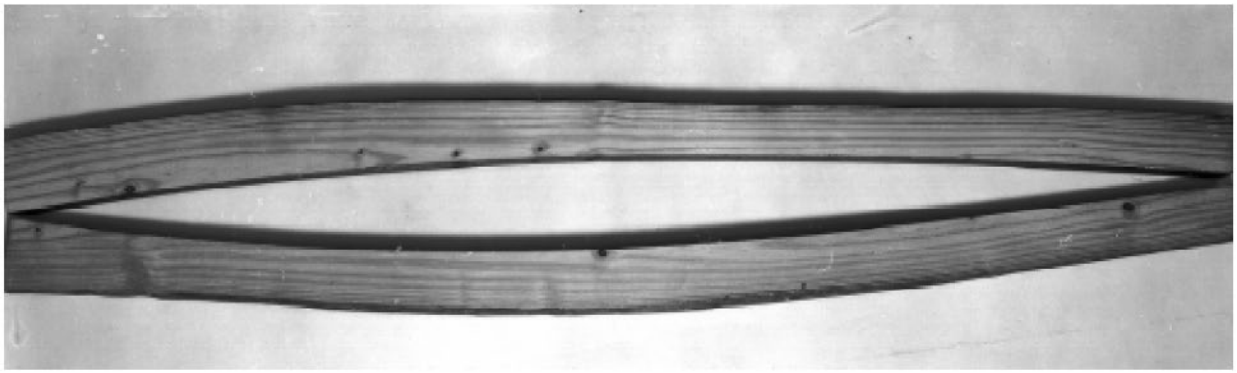


Figure 9—When the board was ripped in two, each piece crooked because of longitudinal shrinkage of juvenile wood in the center of the board.

Images Sources: Wood Handbook: Wood as an Engineering Material, 2021
Air Drying Lumber, 1999

# Anisotropic – Different Properties in Different Directions

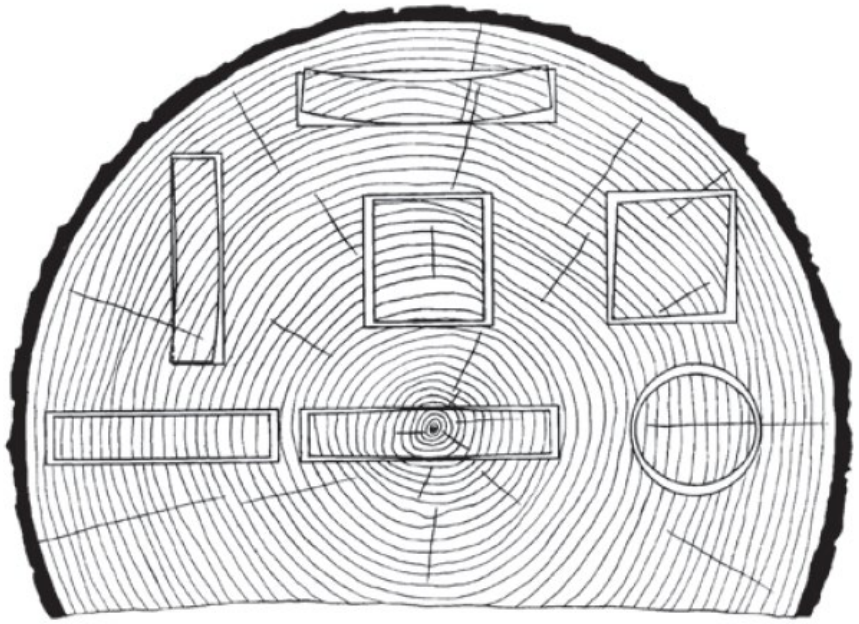


**Figure 4–4. Characteristic shrinkage and distortion of flat, square, and round pieces as affected by direction of growth rings. Tangential shrinkage is about twice as great as radial.**

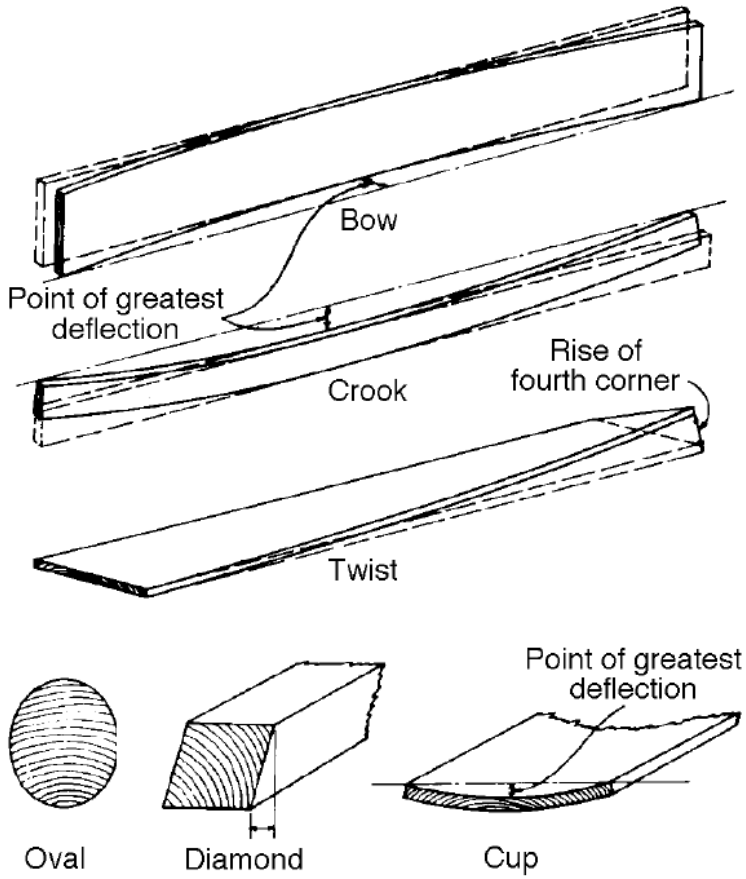
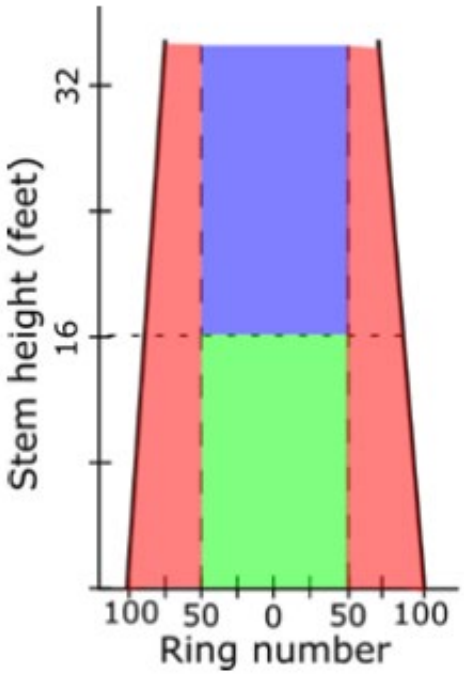



**Figure 53—Various types of warp in lumber.**

Images Sources: Wood Handbook: Wood as an Engineering Material, 2021 & Air Drying Lumber, 1999

**Northern Arizona University – Ecological Restoration Institute**

# Fact Sheet: Wood Properties of Southwestern Ponderosa Pine: Implications for Utilization of Forest Restoration Byproducts




| Type | Description | Recommended products |
|---|---|---|
| Mature wood | Highest density<br>Highest stiffness | Dimensional lumber;<br>Structural engineered products |
| Upper juvenile wood | Low in density<br>Good uniformity | Oriented strand board;<br>Low-grade lumber |
| Lower juvenile wood | Low in density<br>Low uniformity | Bioenergy;<br>Heating;<br>Low-grade lumber |

Vaughan, D., D. Auty, and K. Mackes. 2020. Wood Properties of Southwestern Ponderosa Pine: Implications for Utilization of Forest Restoration Byproducts. ERI Fact Sheet. Ecological Restoration Institute, Northern Arizona University. 2p. https://cdm17192.contentdm.oclc.org/digital/collection/p17192coll1/id/1046/rec/5

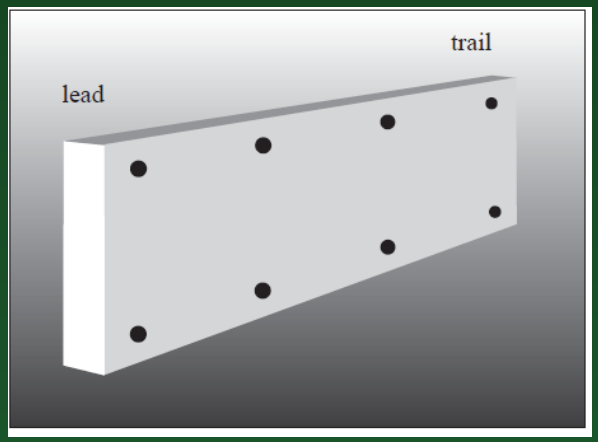
# Compensating for Juvenile Wood

- Minimize lumber thickness variation
- Practice proper lumber stickering techniques
- Use weighted covers when possible

# Monitoring Lumber Thickness Variation

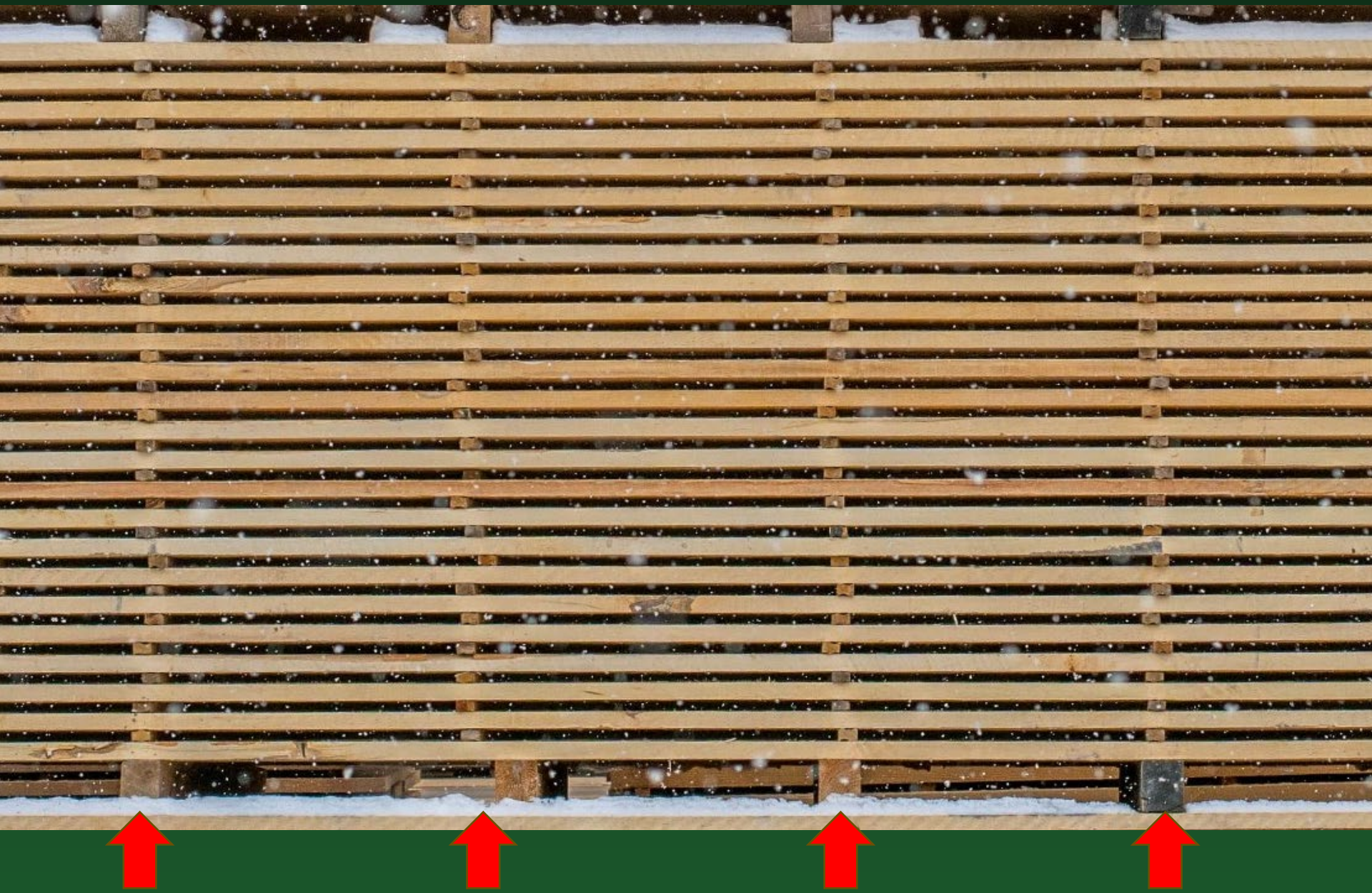
- Regularly monitor lumber thickness using digital calipers
- Variations in lumber thickness decreases lumber volume yields and can cause drying defects

Oregon State University Extension publication EM 8731, Lumber Size Control
http://owic.oregonstate.edu/sites/default/files/pubs/EM8730.pdf




# Practice Proper Lumber Stickering Techniques

1. Use dry stickers that are uniform in thickness. Planed/surfaced stickers would be ideal
2. Stickers should be aligned vertically
3. Use box piling techniques
4. Use adequate supports under the lumber piles




2008800
Hard Maple

# Box Piling – Support the Ends and the Sides

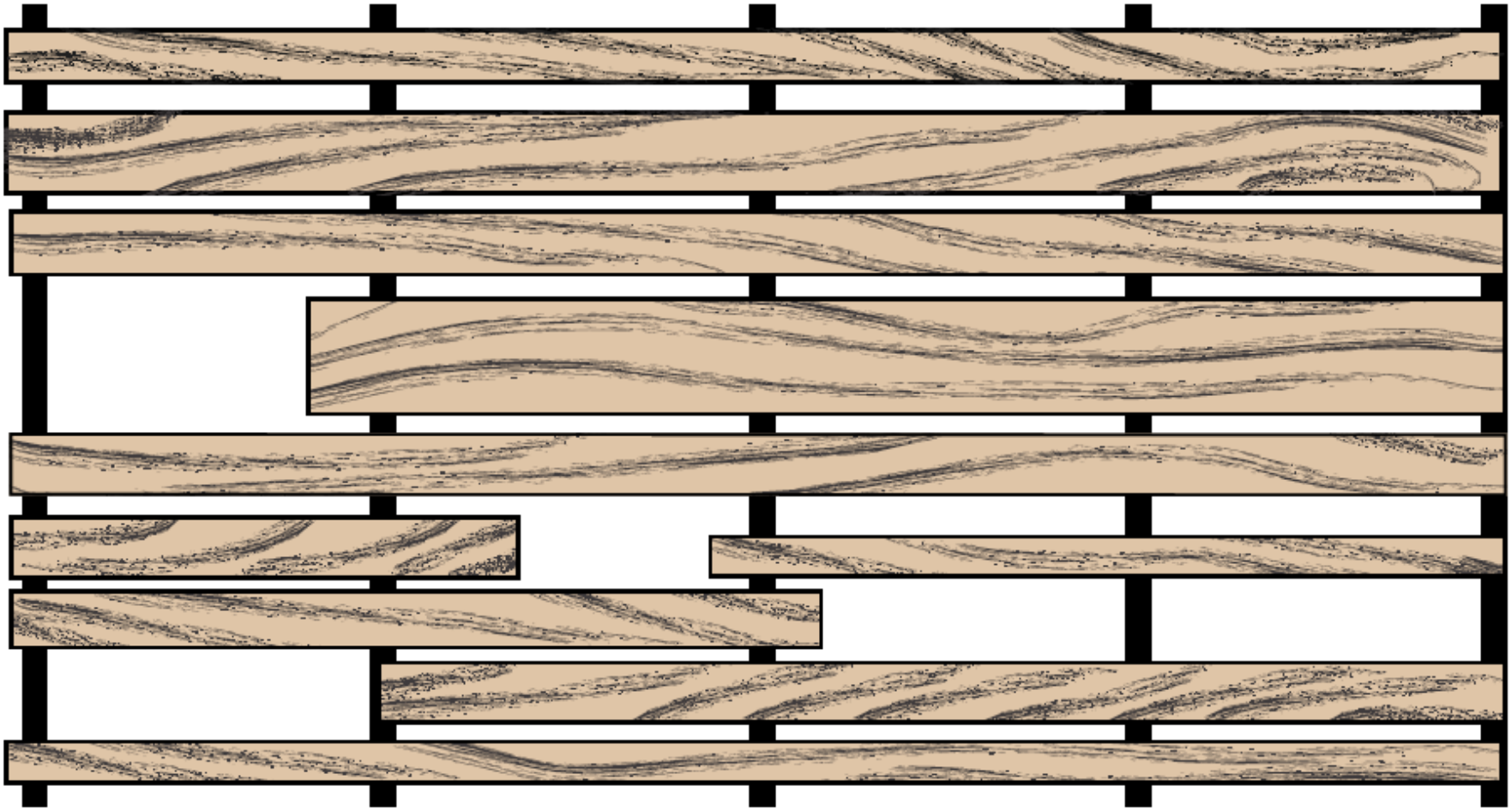


Image Source: Manufacturing and Marketing Eastern Hardwood Lumber Produced by **Thin Kerf Band Mills**
https://mdc.itap.purdue.edu/item.asp?Item_Number=FNR-435

# Box Piling – Support the Ends and the Sides

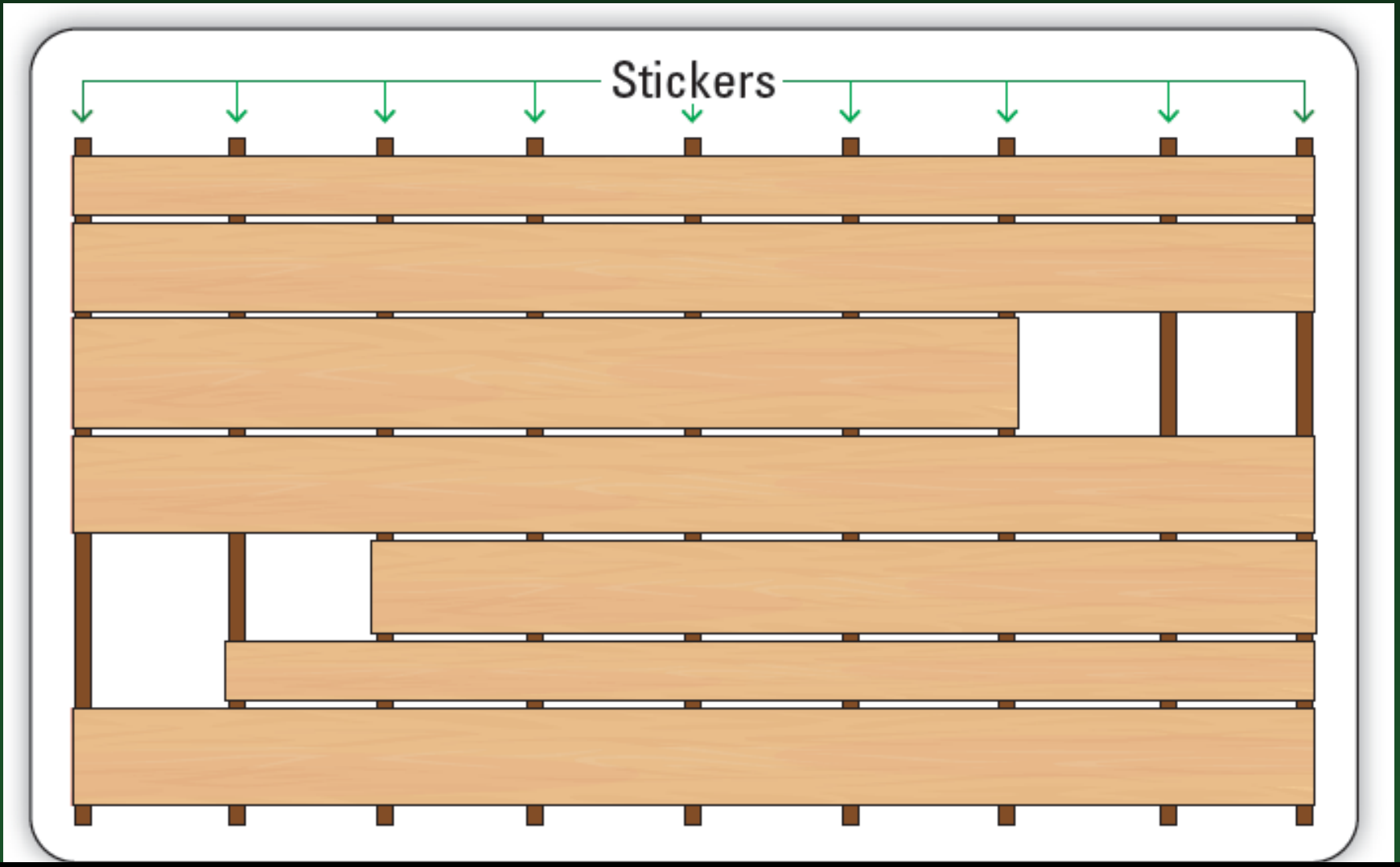
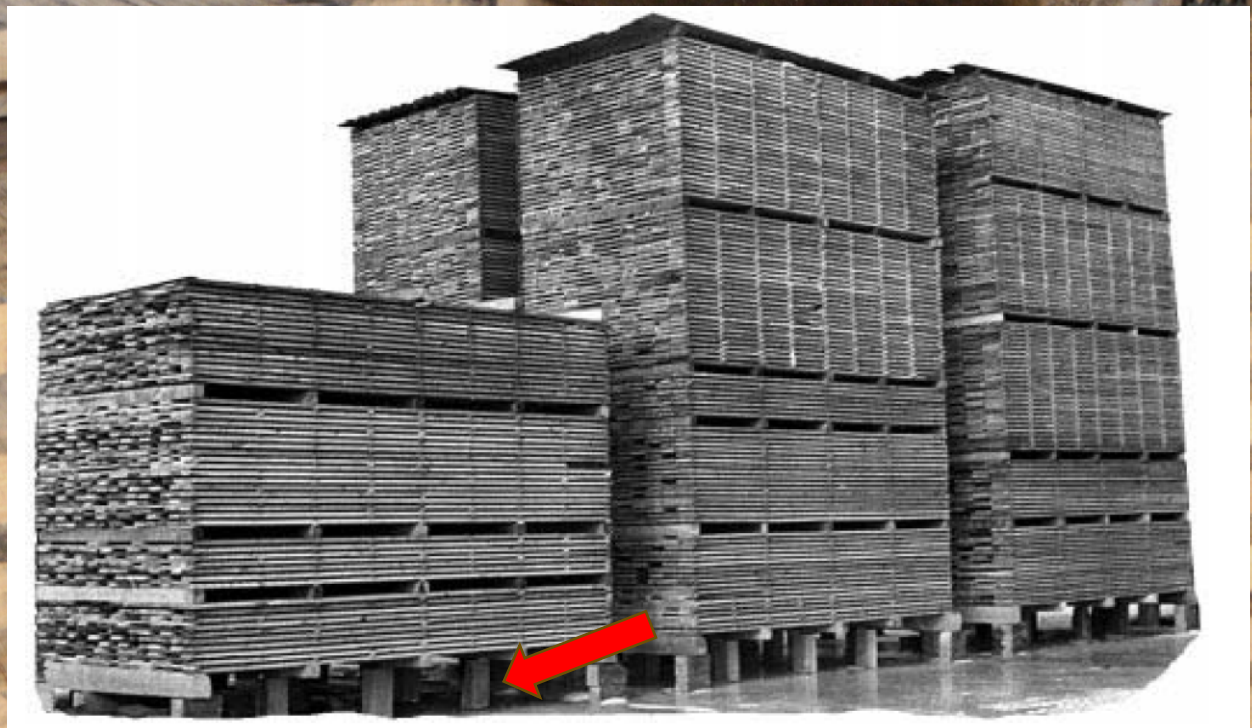



Image Source: Air Drying Lumber, Wisconsin Department of Natural Resources
https://widnr.widen.net/view/pdf/fdrca8oy8r/Air-Drying-Lumber.pdf?t.download=true&u=ustuql

Use railroad ties to support the bottom of the piles, not pallet cants




A lack of air circulation in the lower courses of the piles
Keep weeds out of your air-dry yards

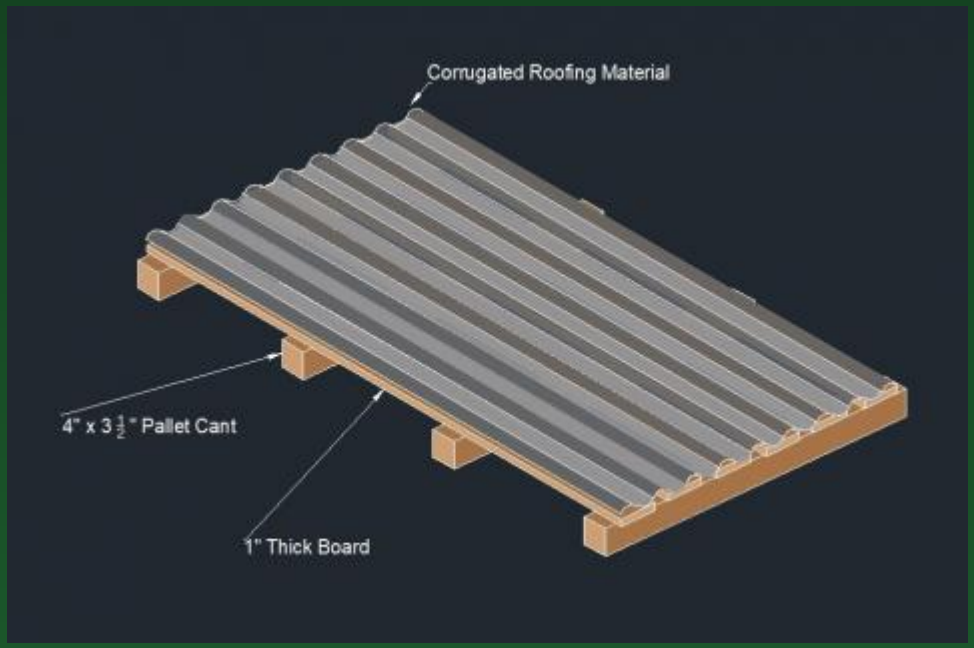
# Review - Compensating for Juvenile Wood

- ✓ Minimize lumber thickness variation
- ✓ Practice proper lumber stickering techniques
  - ➢ Use dry stickers that are uniform in thickness. Planed/surfaced stickers would be ideal
  - ➢ Stickers should be aligned vertically
  - ➢ Use box piling techniques
  - ➢ Use adequate supports under the lumber piles – Use steel tracks or rail ties and replace every two or three years
- ✓ Use weighted covers when possible. If lumber discoloration and the weather are not a problem, strap your lumber piles together with banding.

Image Source: Andrew Fast, University of New Hampshire Extension

# Design Considerations for Lumber Pile Covers in Air-Dry Yards

- New publication from the University of New Hampshire Extension and the USDA Forest Service Wood Education & Resource Center




Extension

MAKING LIFE BETTER IN NEW HAMPSHIRE

**Design Considerations for Lumber Pile Covers in Air-Dry Yards**

When air-drying green lumber a specified period of time or holding green inventory long enough for loss of value to occur, it is recommended to place "pile covers" on the lumber packs, to minimize lumber defects and discoloration resulting from exposure to the elements. While there are ample resources providing instructions on constructing pile covers, few address the trade-offs of material selection. This publication presents design and operational considerations for all sizes of lumber producers who are planning to invest time and money in fabricating pile covers. Employee safety and wellbeing should always be the first consideration of any sawmill management team. Any recommendations in this publication should first be verified that they adhere to federal and state occupational health regulations.

Degrade or loss of value of lumber stored in air-dry yards typically range from $21 – $54 per thousand board foot (MBF) and can easily reach $150 per MBF in poorly operated air-dry yards (Wengert 2006). Use of pile covers on stickered lumber, such as the ones shown in Figure 1, help to protect the top courses of lumber from undesirable discoloring and staining associated with sunlight and precipitation (Rietz 1970). Lumber

*Figure 1. Pile covers in an air-dry yard help preserve the quality and value of the lumber by protecting the lumber from the elements. Photo source: Coos Forest Products.*

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University of New Hampshire Cooperative Extension
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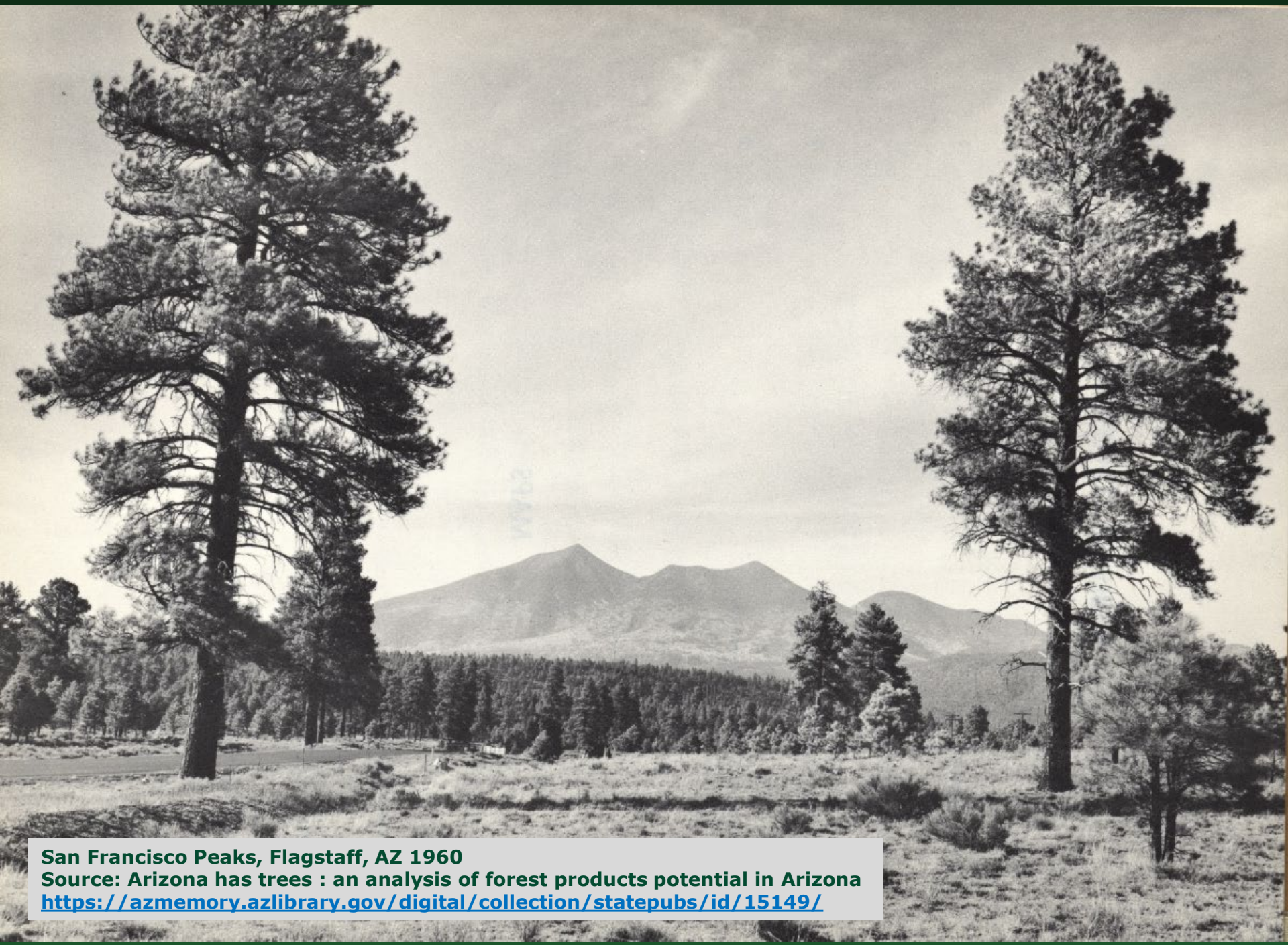
**UNH Extension Forest Industry Information**
bit.ly/UNHExtension-Forest-Industry

https://extension.unh.edu/resource/design-considerations-lumber-pile-covers-air-dry-yards

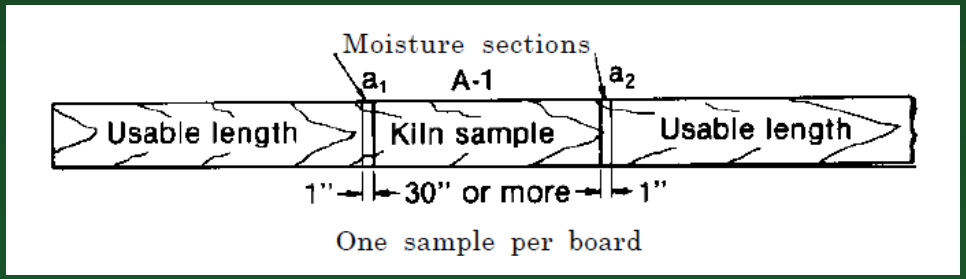


San Francisco Peaks, Flagstaff, AZ 1960
Source: Arizona has trees : an analysis of forest products potential in Arizona
https://azmemory.azlibrary.gov/digital/collection/statepubs/id/15149/

# Selecting and Preparing Sample Boards

Purpose of Sample Boards

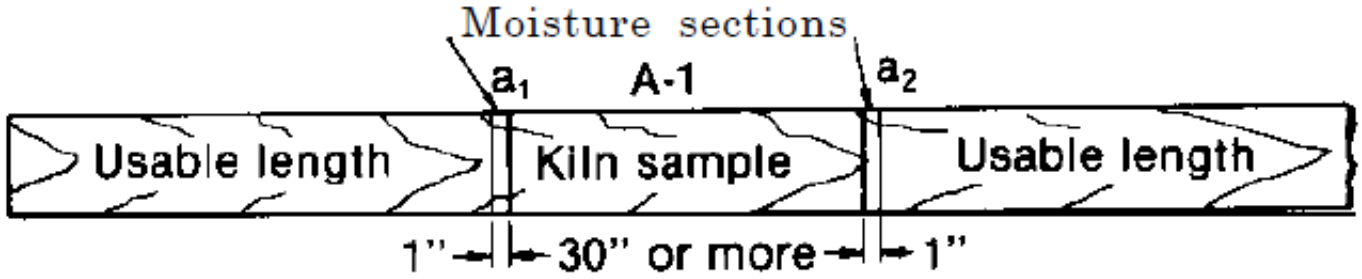
1. Monitor moisture content of lumber in the dry kiln
2. Monitor for drying stresses
3. Monitor shell and core moisture contents





RDM3
MC: 7.4%
DELMHORST

# Sample Boards Need to Be End Sealed




One sample per board

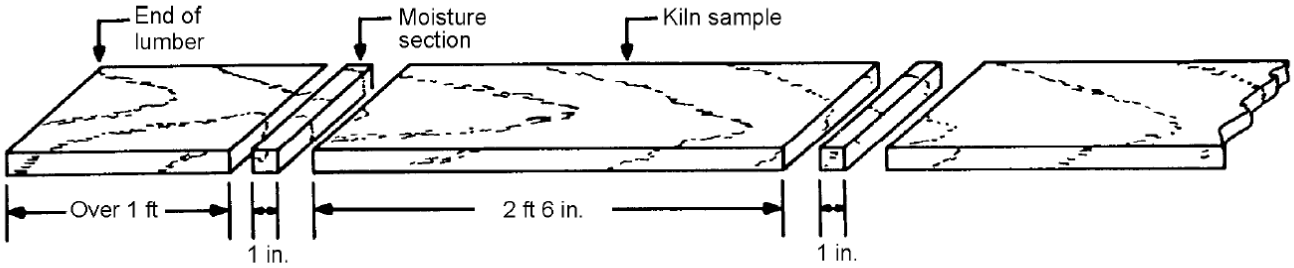



**Figure 7.4—Method of cutting and numbering kiln samples and MC sections. 1 in. = 25 mm; 1 ft = 0.3 m.**


Image Source: Conway-Cleveland Corp.
https://www.conwaycleveland.com/nelsonite/duroseal

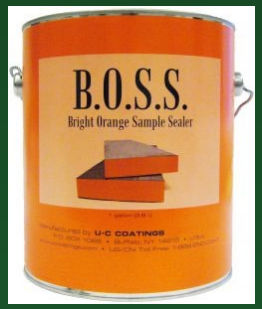



Image Source: UC Coatings
https://uccoatings.com/products/b-o-s-s/


FESTOOL

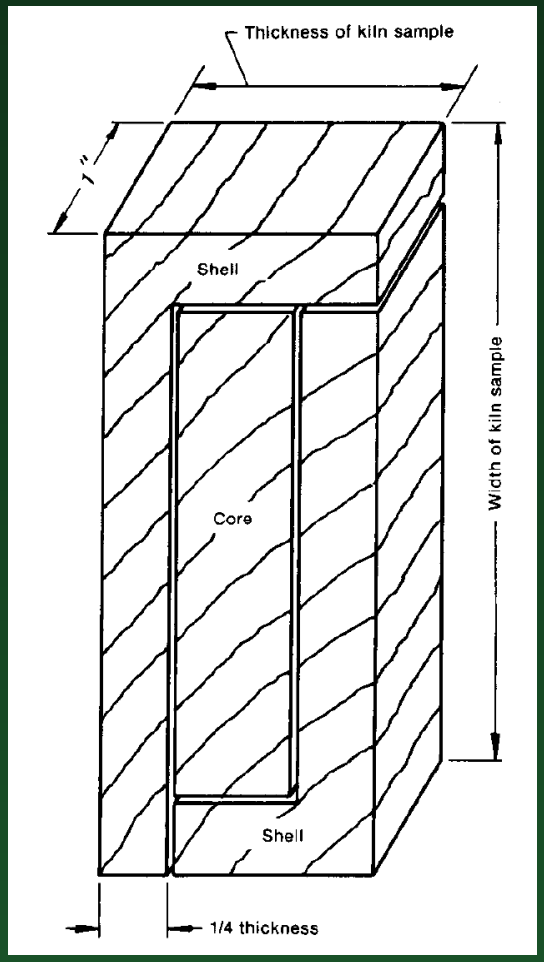

5

# Sample Board Preparation

https://www.youtube.com/watch?v=6VZn2tczE7Y


A&D EK-12Ki
Max 12000g d=1g
NET
ZERO
107g
ON:OFF
SAMPLE
PRINT
MODE
→0/T←
RE-ZERO


ON:OFF
SAMPLE
PRINT
MODE
→0/T←
RE-ZERO




Images Sources: Wood Handbook: Wood as an Engineering Material, 2021
Air Drying Lumber, 1999

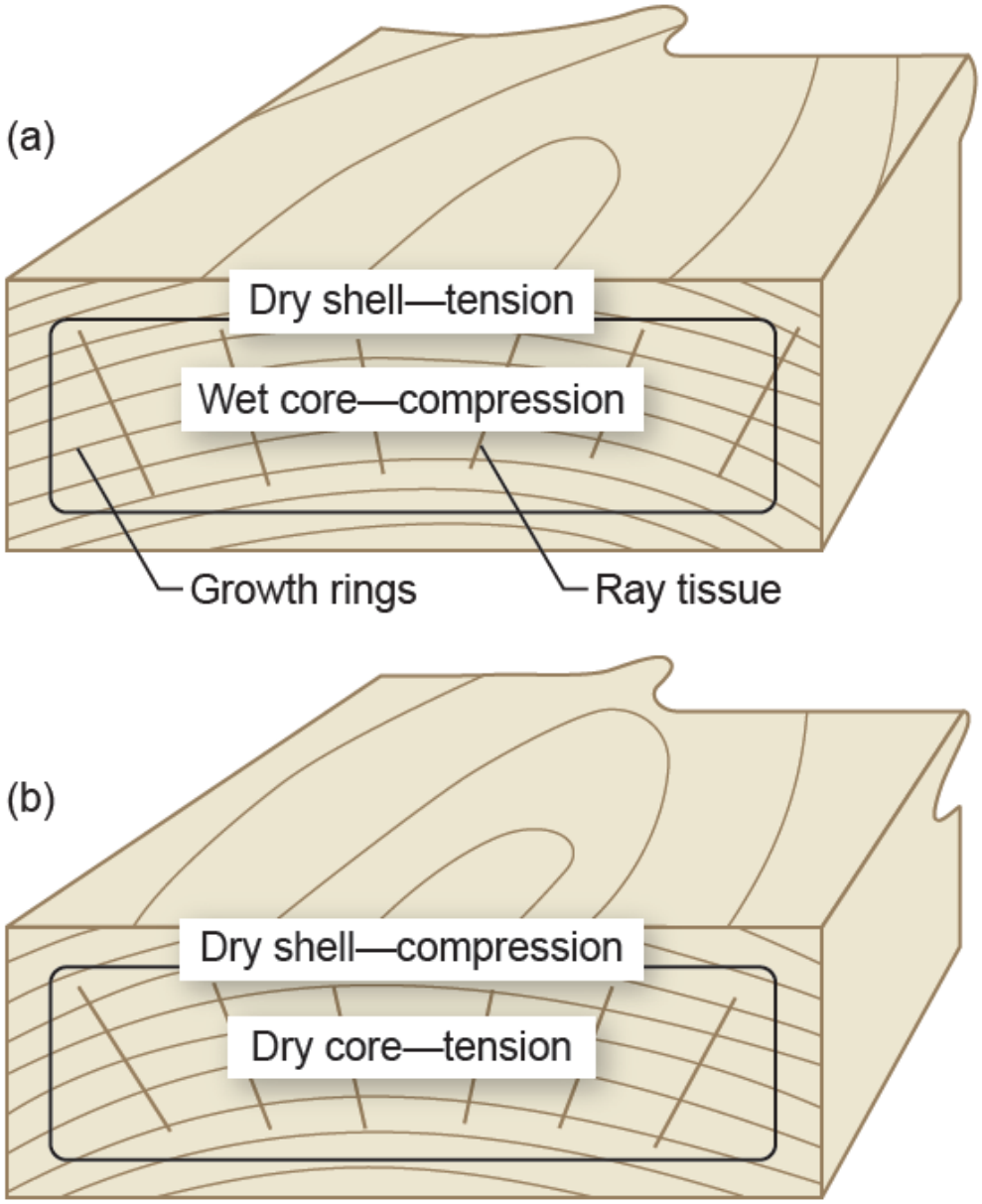



**Figure 13–3. End view of board showing development of drying stresses (a) early and (b) later in drying.**

# How Many Samples Are Needed?

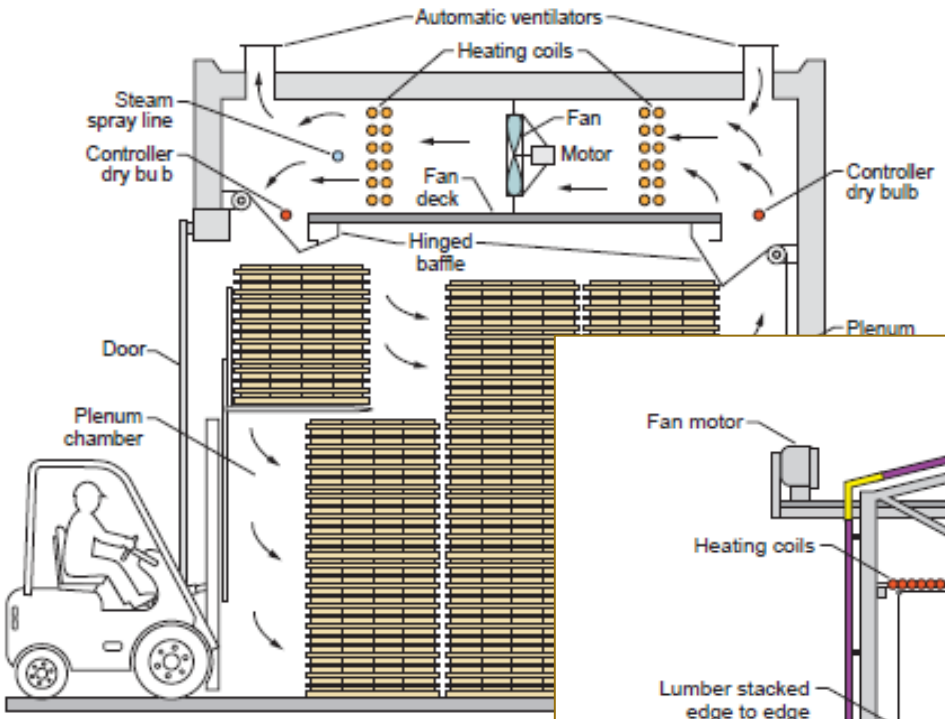



Figure 13–6. Package-loaded kiln with fans connected

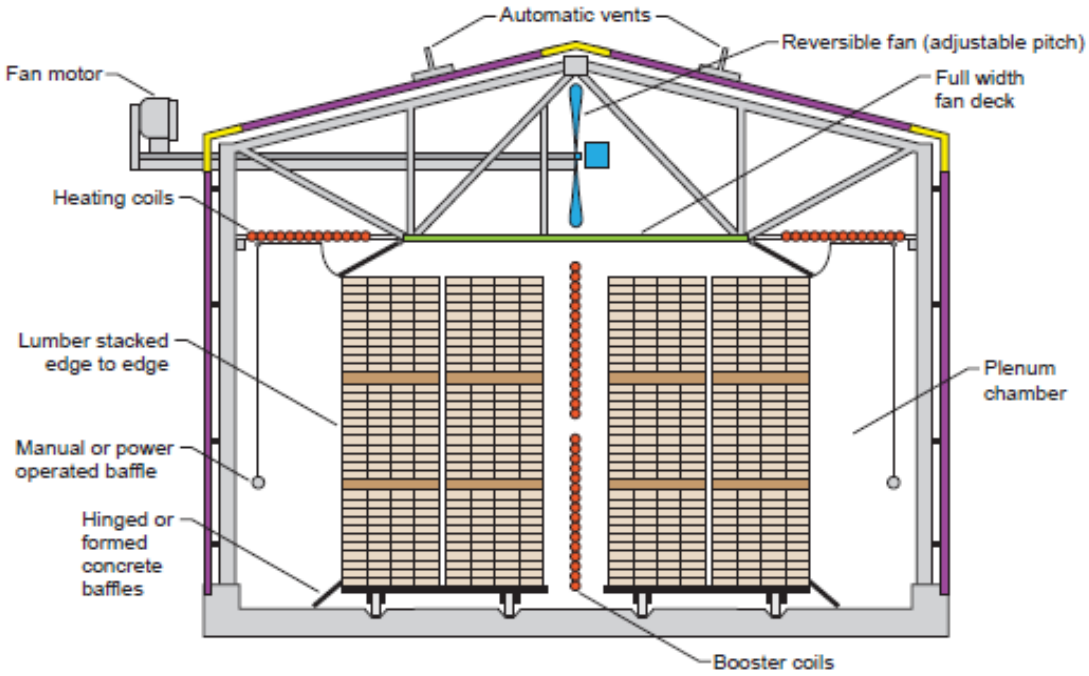
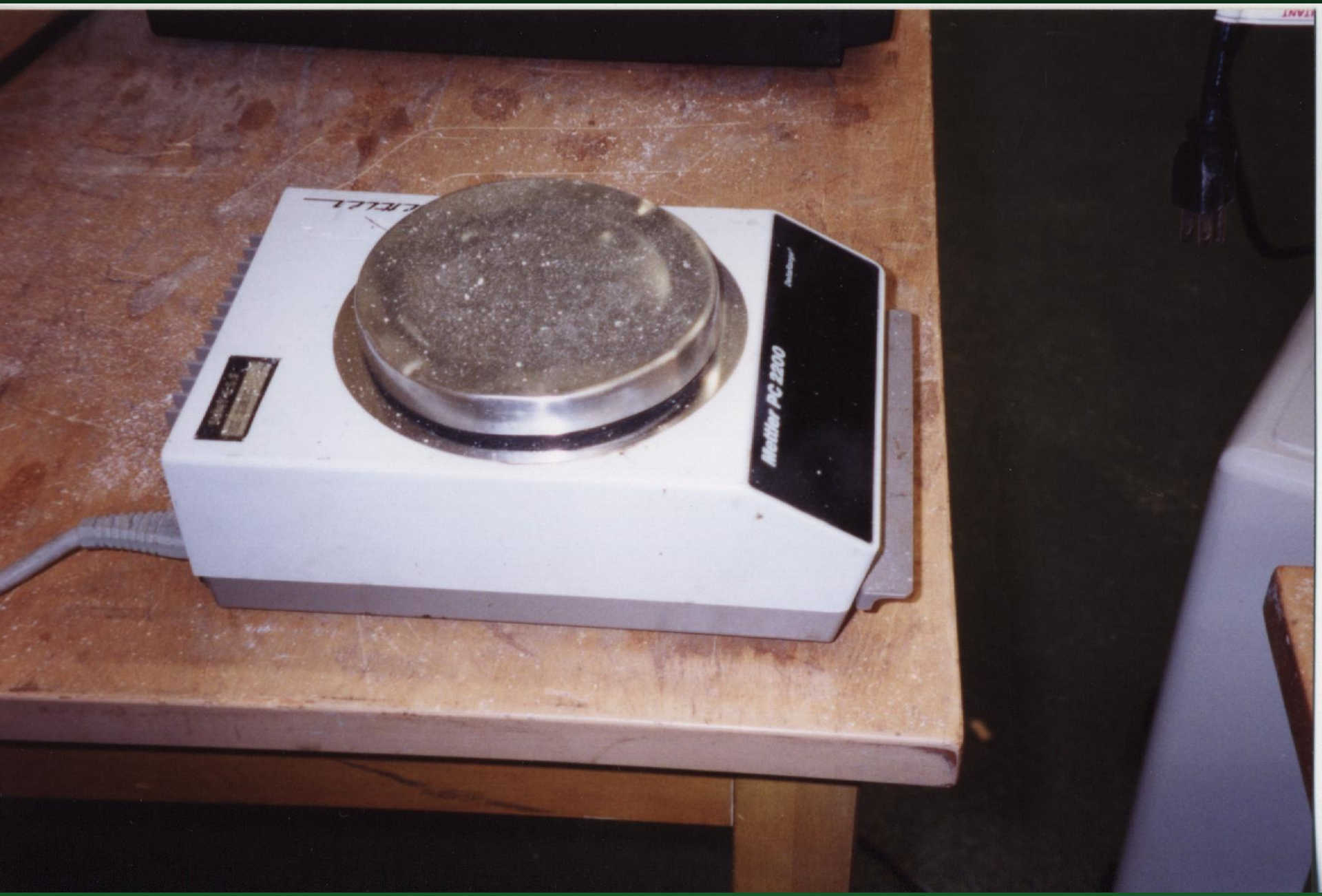



Figure 13–5. Lineshaft, double-track, compartment kiln with alternately opposing fans. Vents are over fan shaft between fans. Vent on high pressure side of fans becomes fresh air inlet when direction of circulation is reversed.

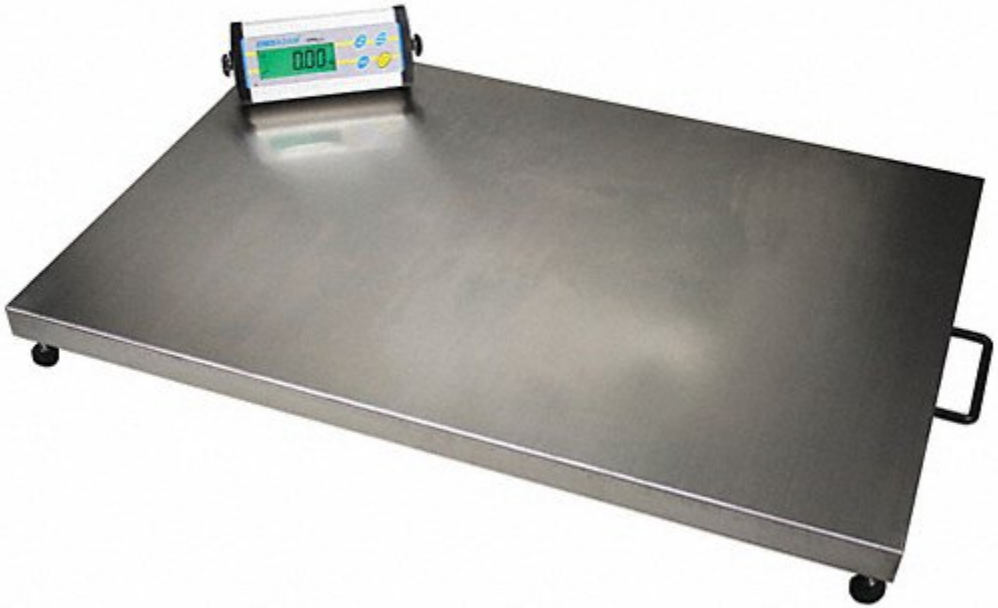
Images Sources: Wood Handbook: Wood as an Engineering Material, 2021
Air Drying Lumber, 1999


Heidolph PC 2200

# What about large material?


Image Source: North Carolina State University Wood Products Extension


doron
2200CW
0.00
doron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# Work in Teams When in Hot Kilns


Canadian News

## Flooring company fined after worker dies in wood-drying kiln

By Robert Dalheim  January 23, 2020 | 10:29 am CST

**TORONTO -** A Canadian flooring manufacturer has been fined $225,000 after a worker was killed on the job in late 2017.

The worker was killed at Satin Finish Hardwood Flooring's Toronto manufacturing facility after being trapped in a wood-drying kiln. He suffered severe heat injuries.