Drying Stress: How to Deal With It

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As wood dries,
(below FSP, 30%MC),
it shrinks.

But remember, wood shrinks both
"as a material", and
as a "board".

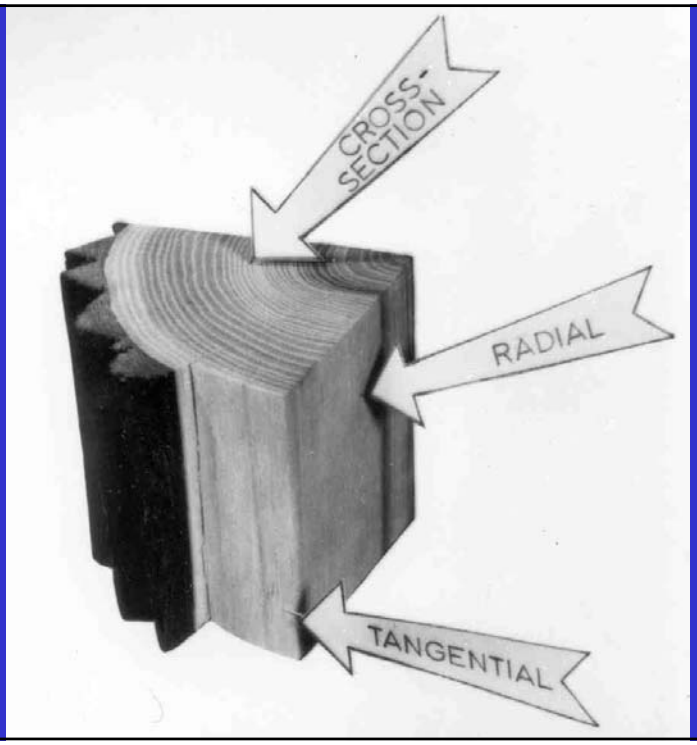
i.e.- when a "board" is at 40% MC, the "shell" is already below FSP, perhaps at 16% MC.

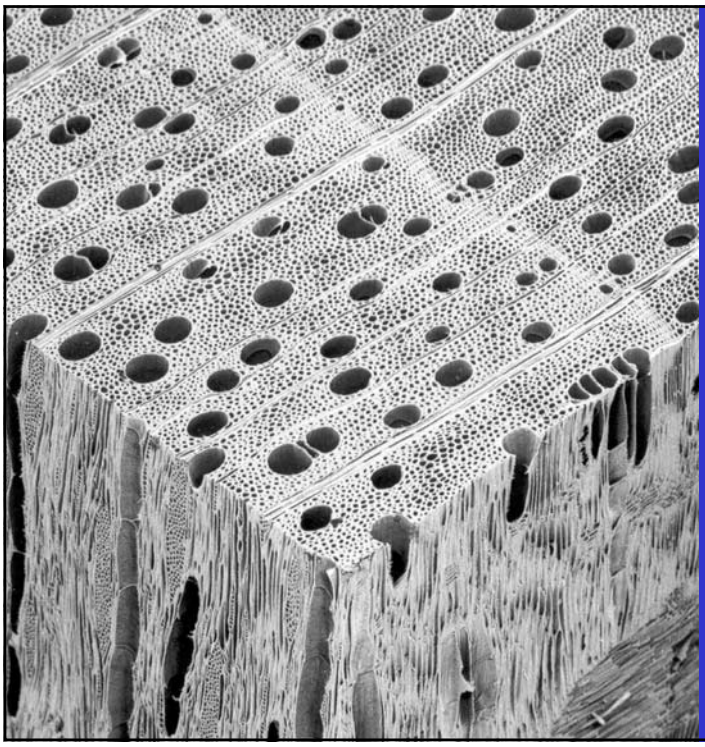
If shrinkage is “restrained”,
because the
“core” is still wet,
while the
“shell” is drying,
stresses develop.

So,
as wood dries it shrinks,
as wood shrinks,

stresses develop.

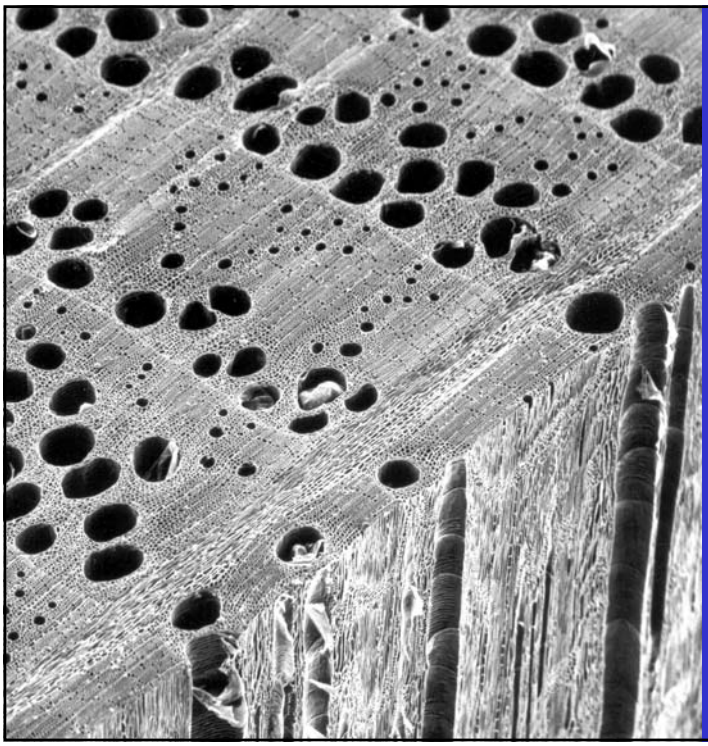
Wood Shrinkage Varies with Orientation, Density, and Species.





Hard Maple

Scanning Electron Micrograph
Courtesy of the SUNY ESF
N.C. Brown Center for
Ultrastructure Studies



Red Oak

Scanning Electron Micrograph
Courtesy of the SUNY ESF
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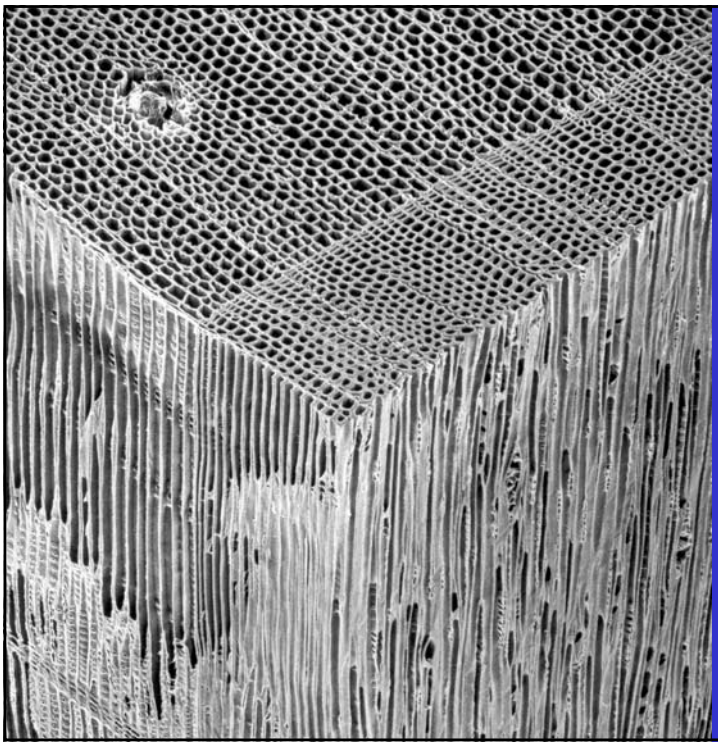

White Pine

Scanning Electron Micrograph
Courtesy of the SUNY ESF
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Several “rules” about wood shrinkage:

- Dense wood shrinks more, because there is more wood material.
  - Latewood shrinks more than earlywood.
  - Maple and oak shrink more than pine.
- Shrinkage varies varies with orientation;
  - Longitudinal vs. transverse
  - Tangential vs. Radial
    - T/R ratio ~ 2/1

A good "general rule" about tangential shrinkage

- Softwoods, such as white pine shrink about 5 - 6 % from green to 0% -
  - ~ 1 % / 5.5% MC change
- Hardwoods, such as maple and oak shrink about 8 % from green to 0% -
  - ~ 1 % / 4% MC change

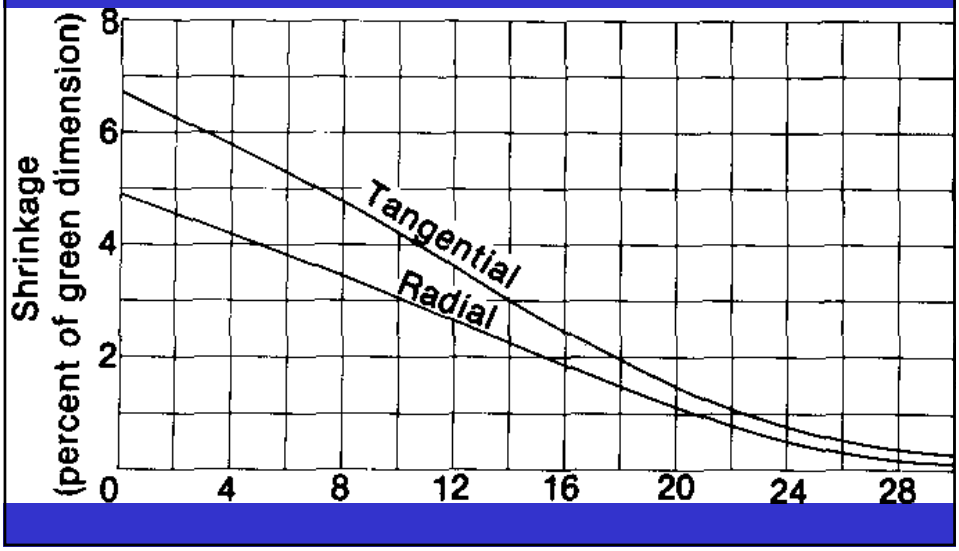
Longitudinal shrinkage of wood is very small, 0.1%

- Except for juvenile wood and reaction wood (compression and tension wood)

Longitudinal shrinkage of boards is very small.

- Except for -
  - boards with juvenile wood and reaction wood (compression and tension wood)
  - boards with sloped grain (which means there is a transverse component to the longitudinal orientation.

Wood Shrinkage



Strength and Stiffness
of wood depends primarily upon
Density and Moisture Content

Stiffness (bending // to grain)

	S.G.grn	Green	12%MC
		*1,000,000 psi	
White Pine	0.34	0.99	1.25
Hard Maple	0.56	1.55	1.83

*S.G.grn = dry weight (oven dry) / volume (green)

Strength (bending // to grain)

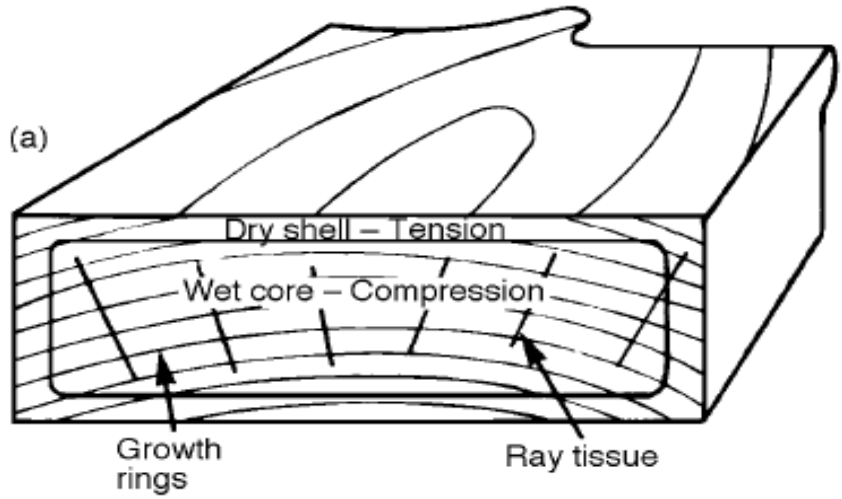
	S.G.grn	Green	12%MC
		psi	
White Pine	0.34	4,900	8,600
Hard Maple	0.56	9,400	15,800

*S.G.grn = dry weight (oven dry) / volume (green)

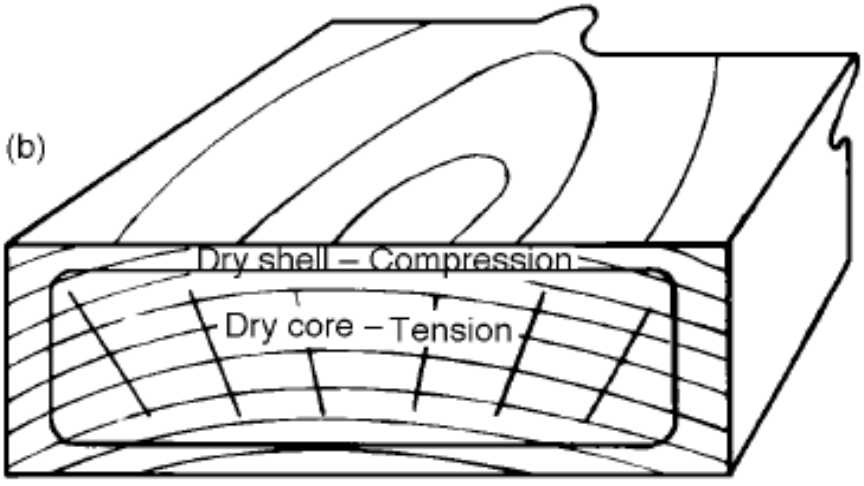
So,
as wood dries it shrinks,
as wood shrinks,

stresses develop.

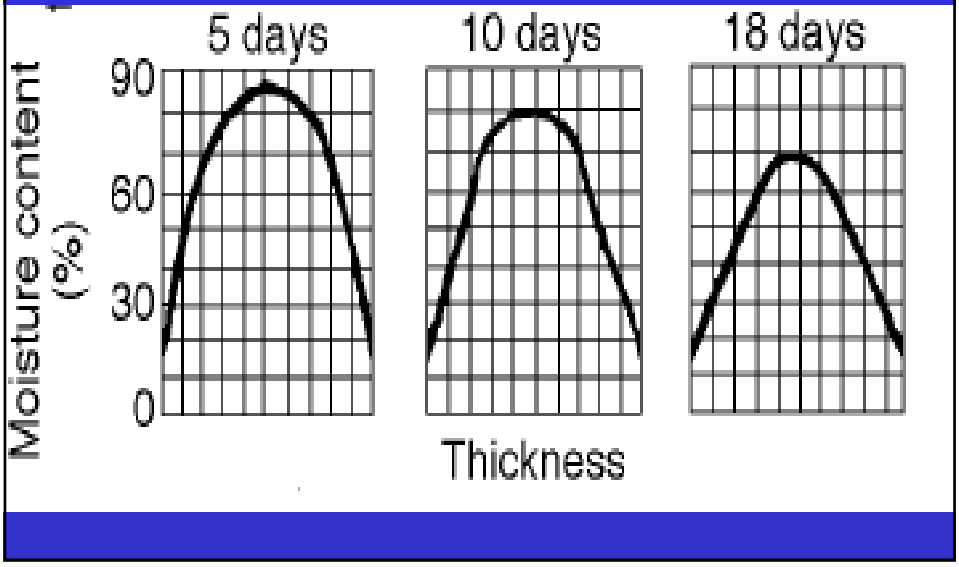
Development of Drying Stresses, Early in Drying



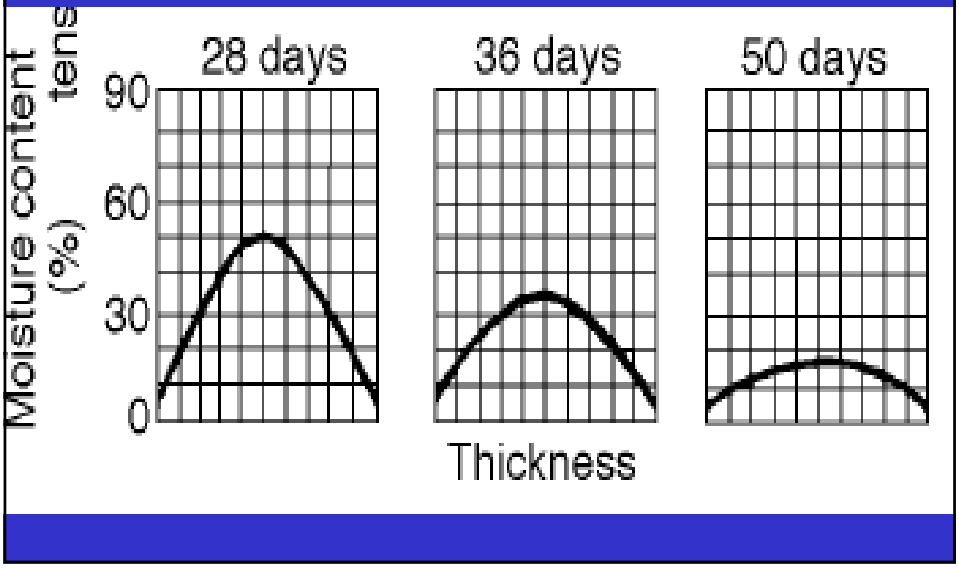
Development of Drying Stresses, Later in Drying



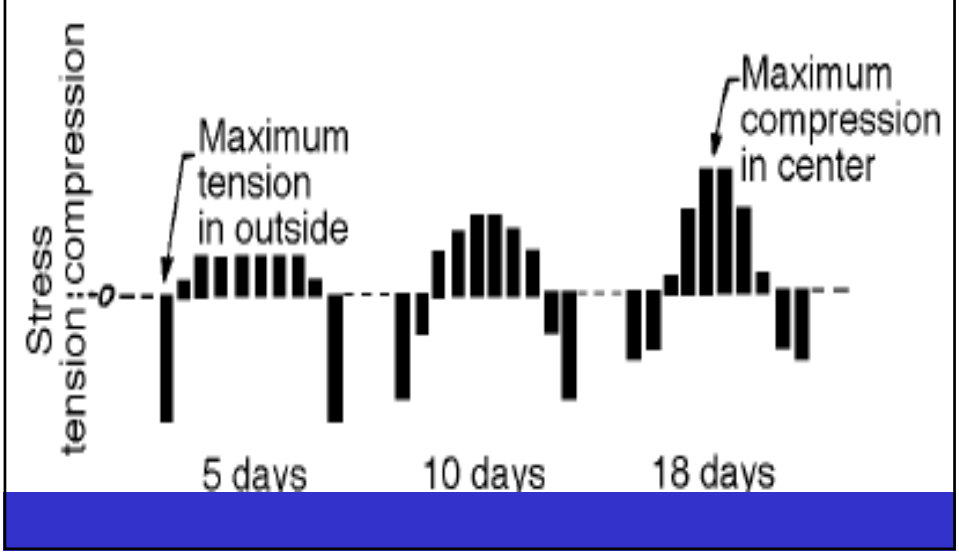
Moisture Gradient during Drying



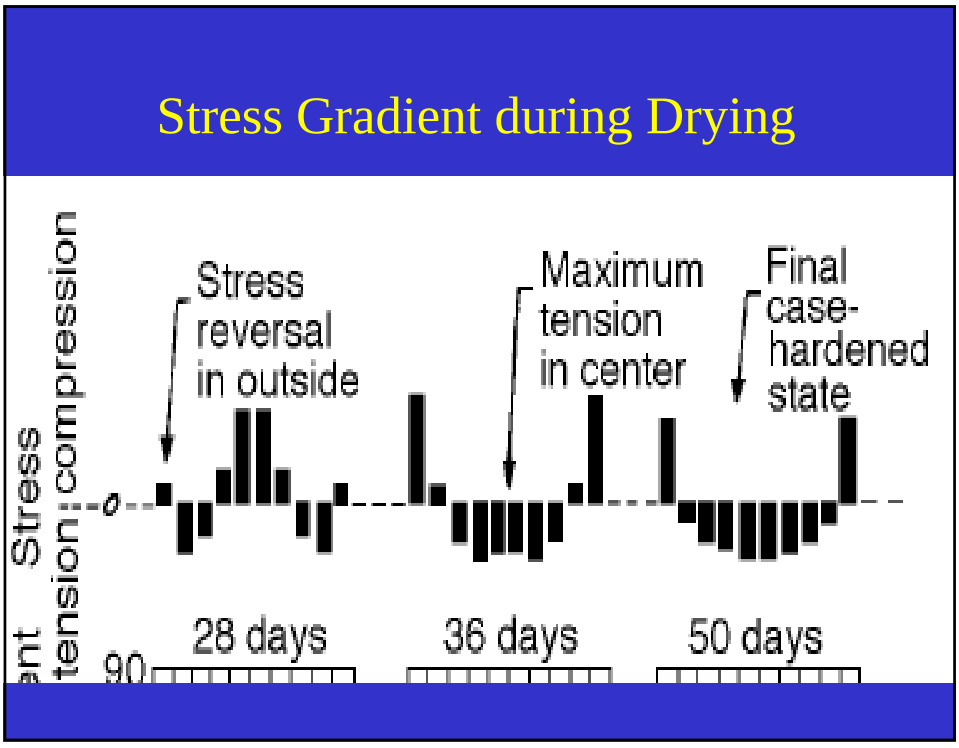
Moisture Gradient during Drying



Stress Gradient during Drying



Stress Gradient during Drying



During “Stress Relief”,

- Moisture is added to the “shell” to cause it to try to swell against the core, relieving the stresses.

Stress Relief Conditioning

- High EMC (+4% hdwds) and Temperature
  - Adds moisture –
    - ACHIEVE ***DESIRED EMC*** QUICKLY!
    - AVOID OVERHEAT!
      - Cool kiln first
      - Reheat with spray
      - Low pressure steam
      - Water spray
      - Etc.
  - High temperature moves moisture faster
  - High temperature means wood is not as strong so stresses relieve more readily.

Equalization— Bringing the pieces of lumber in a kiln charge to nearly uniform moisture content. See Treatment, equalization.

Treatment, equalization—A controlled temperature and relative humidity condition used in a dry kiln at the end of drying to stop the drying of the driest boards while allowing the wettest boards to continue drying, thus reducing the moisture range between boards.

Table 7-32—Kiln sample moisture content and equilibrium moisture content values for equalizing and conditioning a charge of lumber

Desired final average) moisture content (percent)	Equalizing moisture content values (percent)			Conditioning equilibrium moisture content values (percent)	
	Moisture content of driest sample at start	Equilibrium moisture content conditions in kiln	Moisture content of wettest sample at end	Softwoods	Hardwoods
5	3	3	5	8	9
6	4	4	6	9	10
7	5	5	7	10	11
8	6	6	8	11	12
9	7	7	9	12	13
10	8	8	10	13	14
11	9	9	11	14	15

Table 7.23—Traditional wet-bulb temperatures for equalizing hardwoods

Final MC[a] (%)	Equalizing EMC (%)	Wet-bulb temperature at various dry-bulb temperatures (°F)						
		140	150	160	170	180	190	200
5 (6)	3	92	101	110	120	130	140	150
6 (7)	4	99	108	118	127	137	147	157
7 (8)	5	105	115	125	135	145	156	167
8 (9)	6	111	121	131	141	152	163	174

[a]Final MC values in parentheses are for faster drying when the highest quality drying is not required.

Table 7.24—Traditional wet-bulb temperatures for conditioning hardwoods

Final MC (%)	Conditioning EMC (%)	Wet-bulb temperature at various dry-bulb temperatures (°F)					
		140	150	160	170	180	190
6	10	126	136	147	157	168	178
7	11	128	138	149	159	170	180
8	12	130	140	151	161	172	182
9	13	132	142	152	163	173	183

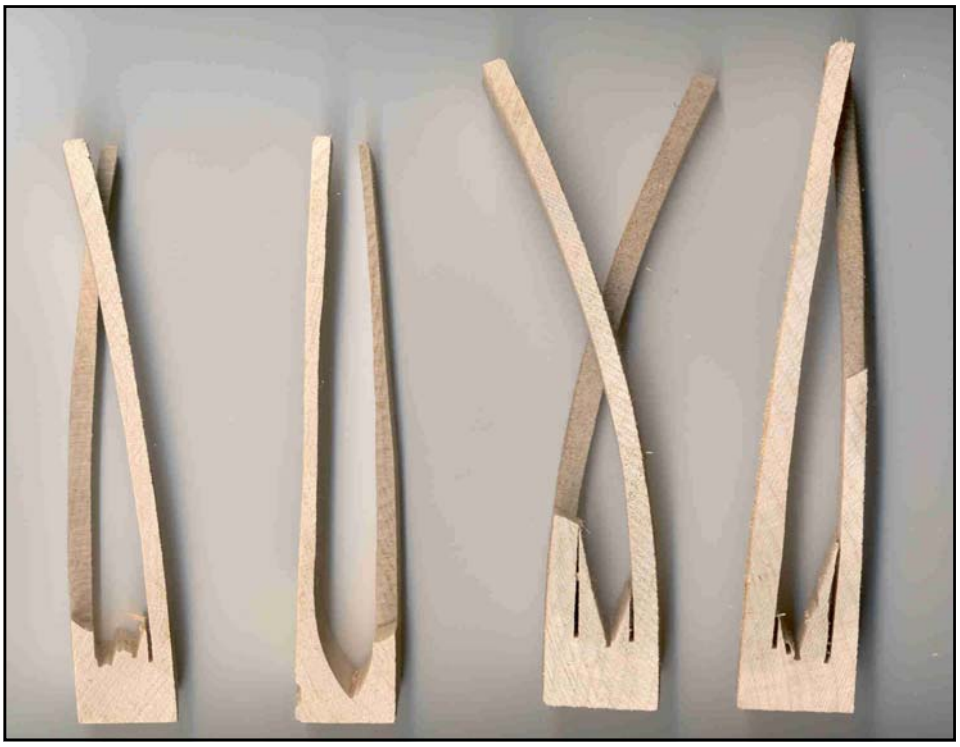
Conditioning treatment—A controlled high temperature-high relative humidity condition used in a dry kiln after the final stage of drying to bring about a uniform moisture distribution in the boards and to relieve drying stresses.

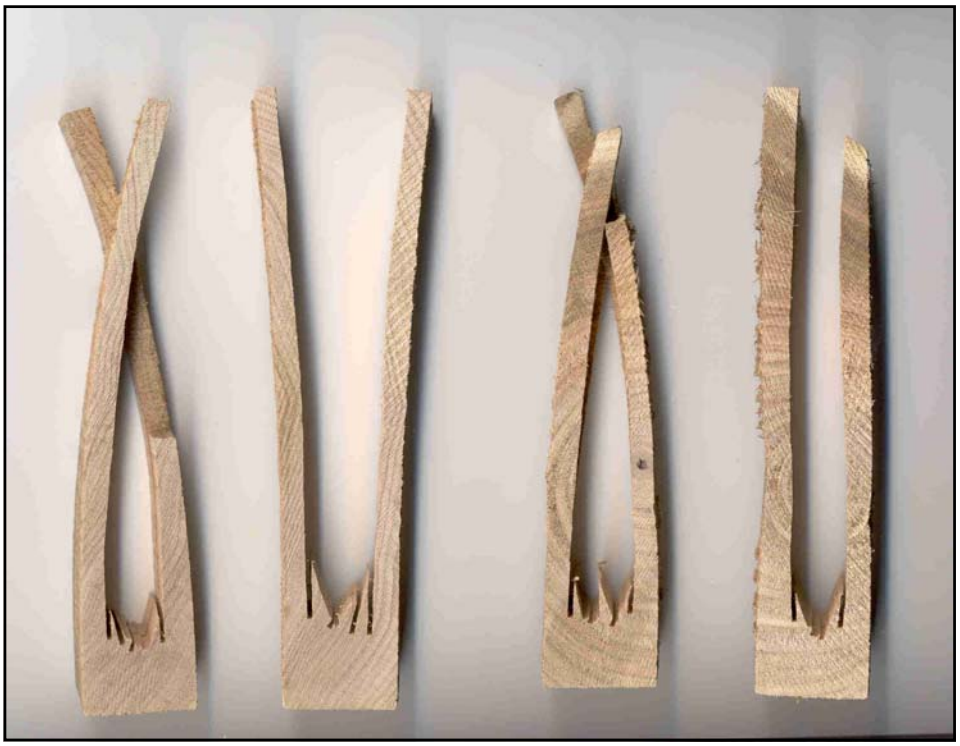
Stress, drying—An internal force, exerted by either of two adjacent parts of a piece of wood upon the other during drying, caused by uneven drying and shrinkage, and influenced by set.

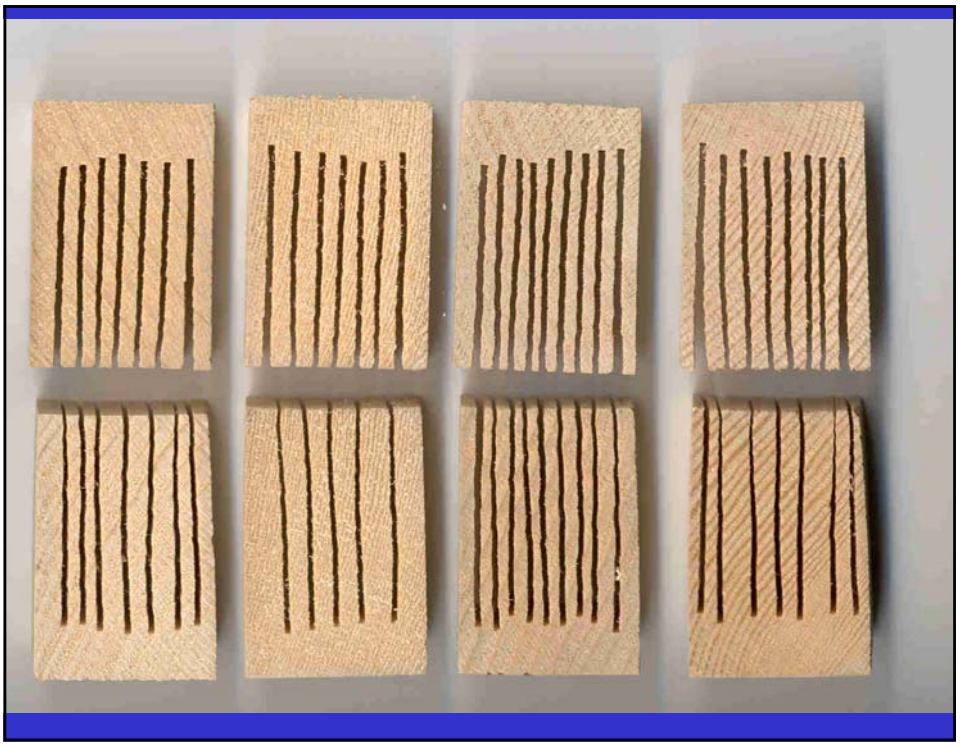
Tensile—Stress in the outer layers of wood during the early stages of drying when the layers are trying to shrink but are restrained by the still-wet interior region; also, the stress in the interior layers later in drying as they try to shrink and are restrained by the set outer shell.

Compressive—Stress found in the interior region of wood during the early stages of drying, caused by the shrinking of the outer shell; also, stress in the outer layers later in drying caused by the shrinking of the interior.

Stresses, relief of—The result of a conditioning treatment, following the final stage of drying, which causes a redistribution of moisture and a relief of the sets.







Thank you!