

# HARDWOOD KILN SCHEDULES

with emphasis on oak

# KILN SCHEDULES

## NINE DRYING PRINCIPLES

pp. 72-72 in *DRYING HARDWOOD LUMBER*

# KILN SCHEDULES

### 1. MC Basis

Wettest half (many use the wettest)  
10-12 samples

# KILN SCHEDULES

### 2. MC is Average (not shell or core)

# KILN SCHEDULES

### 3. Visual inspection

# KILN SCHEDULES

### 4. Use Drying Rate (% MC loss per day) (see page 99, *Drying Hardwood Lumber*)

## KILN SCHEDULES

**5. Precise temperatures**

## KILN SCHEDULES

**6. Conservative Schedules**

## KILN SCHEDULES

**7. Final MC must be precise**  
(include decimal; not a range)

## KILN SCHEDULES

**8. Equalize**

## KILN SCHEDULES

**9. Condition (Stress relief)**

## KILN SCHEDULES

**Four Stages**

<u>Stage</u>	<u>Moisture Content</u>	<u>Major defect risk</u>
I	Green to 2/3 green	Formation of surface and end checks; stain; warp

Note: "Green" is the MC in the living tree, not the MC when the lumber is receive

# KILN SCHEDULES

**Stage I**    **MC:** Green to 2/3 green  
**Risk:** Formation of surface and end checks; stain; warp

**Drying Conditions Required:**  
 -- Cool temperatures (maximize wood strength; brighter colors)  
 -- High RH (avoid too much shrinkage stress),  
     but not too high (staining and warp)  
 -- Modest air flow (avoid rapid drying and high shell to core stress); higher air flow for white woods

# KILN SCHEDULES

-----4/4 + 5/4 RED OAK-----

Sample Stage	MC (%)	Dry-Bulb (F)	Wet-Bulb (F)	EMC (%)	RH (%)
Over 50% Stage 1		110	106	17.5	87

Note: DB is maximum

# KILN SCHEDULES

-----4/4 + 5/4 RED OAK-----

Sample Stage	MC (%)	Dry-Bulb (F)	Wet-Bulb (F)	EMC (%)	RH (%)
Over 50% Stage 1		110	106	17.5	87

-----4/4 + 5/4 WHITE OAK-----

Sample Stage	MC (%)	Dry-Bulb (F)	Wet-Bulb (F)	EMC (%)	RH (%)
Over 40% Stage 1		110	106	17.5	87

# KILN SCHEDULES

## Four Stages

Stage	Moisture Content	Major defect risk
I	Green to 2/3 green	Formation of surface and end checks; stain; warp
II	2/3 green to 30% MC	Aggravation of surface checks and end checks

Note: "Green" is the MC in the living tree, not the MC when the lumber is receive

# KILN SCHEDULES

**Stage II**    **MC:** 2/3 green to 30% MC  
**Risk:** Aggravation of surface checks and end checks

**Drying Conditions Required:**  
 -- Cool temperatures (maximize wood strength)  
 -- Fairly High RH (avoid too much shrinkage stress),  
     but avoid too high (staining and warp)...can drop RH slightly;  
     avoid rewetting  
 -- Modest air flow (avoid rapid drying and high shell to core stress)  
 -- Constant drying rate (fairly constant) to avoid different colors

# KILN SCHEDULES

-----4/4 + 5/4 RED OAK-----

Sample Stage	MC (%)	Dry-Bulb (F)	Wet-Bulb (F)	EMC (%)	RH (%)	Stage
Over 50%		110	106	17.5	87	Stage 1
50% - 40%		110	105	16.2	84	Stage 2
40% - 35%		110	102	13.3	75	Stage 2
35% - 30%		110	96	13.3	60	Stage 2

## KILN SCHEDULES

-----4/4 + 5/4 RED OAK-----					
Sample MC (%)	Dry-Bulb (F)	Wet-Bulb (F)	EMC (%)	RH (%)	Stage (%)
Over 50%	110	106	17.5	87	Stage 1
50% - 40%	110	105	16.2	84	Stage 2
40% - 35%	110	102	13.3	75	Stage 2
35% - 30%	110	96	9.9	60	Stage 2

  

-----4/4 + 5/4 WHITE OAK-----					
Sample MC (%)	Dry-Bulb (F)	Wet-Bulb (F)	EMC (%)	RH (%)	Stage (%)
Over 40%	110	106	17.5	87	Stage 1
40% - 35%	110	105	16.2	84	Stage 2
35% - 30%	110	102	13.3	75	Stage 2

## KILN SCHEDULES

### Four Stages

Stage	Moisture Content	Major defect risk
I	Green to 2/3 green	Formation of surface and end checks; stain; warp
II	2/3 green to 30% MC	Aggravation of surface checks and end checks
III	30% MC to final	Conversion of checks to honeycomb; cupping; over-drying

Note: "Green" is the MC in the living tree, not the MC when the lumber is receive

## KILN SCHEDULES

**Stage III MC:** 30% MC to final  
**Risk:** Conversion of checks to honeycomb; Cupping; Over-drying

**Drying Conditions Required:**  
 -- WARM TO HOT temperatures (maximize wood strength)  
 -- Fairly low RH (fast drying), but avoid too low (warp) and rewetting  
 -- Low air flow

## KILN SCHEDULES

-----4/4 + 5/4 RED OAK-----					
Sample MC (%)	Dry-Bulb (F)	Wet-Bulb (F)	EMC (%)	RH (%)	Stage (%)
Over 50%	110	106	17.5	87	Stage 1
50% - 40%	110	105	16.2	84	Stage 2
40% - 35%	110	102	13.3	75	Stage 2
35% - 30%	110	96	9.9	60	Stage 2
30% - 25%	120	90	5.4	31	Stage 3
25% - 20%	130	90	3.8	21	Stage 3
20% - 15%	140	90	2.6	14	Stage 3

## KILN SCHEDULES

-----4/4 + 5/4 WHITE OAK-----					
Sample MC (%)	Dry-Bulb (F)	Wet-Bulb (F)	EMC (%)	RH (%)	Stage (%)
Over 40%	110	106	17.5	87	Stage 1
40% - 35%	110	105	16.2	84	Stage 2
35% - 30%	110	102	13.3	75	Stage 2
30% - 25%	120	106	10.0	62	Stage 3
25% - 20%	130	100	2.0	10	Stage 3
20% - 15%	140	90	2.6	14	Stage 3
15% - end	180	130	3.3	26	Stage 3

## KILN SCHEDULES

### Four Stages

Stage	Moisture Content	Major defect risk
I	Green to 2/3 green	Formation of surface and end checks; stain; warp
II	2/3 green to 30% MC	Aggravation of surface checks and end checks
III	30% MC to final	Conversion of checks to honeycomb; cupping; over-drying
IV	Final	Unequal final MC; drying stress (casehardening)

Note: "Green" is the MC in the living tree, not the MC when the lumber is receive

## KILN SCHEDULES

-----4/4 + 5/4 WHITE OAK-----					
Sample MC (%)	Dry-Bulb (F)	Wet-Bulb (F)	EMC (%)	RH (%)	Stage
Over 40%	110	106	17.5	87	Stage 1
40% - 35%	110	105	16.2	84	Stage 2
35% - 30%	110	102	13.3	75	Stage 2
30% - 25%	120	106	10.0	62	Stage 3
25% - 20%	130	100	2.0	10	Stage 3
20% - 15%	140	90	2.6	14	Stage 3
15% - end	180	130	3.3	26	Stage 3
Equalization	180	135	4.0		Stage 4

## KILN SCHEDULES

**Problems with the 1950s schedule--**  
 due to different equipment  
 due to poorer resource  
 due to changing customer requirements/needs

## KILN SCHEDULES

**Problems with the 1950s schedule--**  
 due to different equipment  
 due to poorer resource  
 due to changing customer requirements/needs

- 180 F dry-bulb too hot
- 50 F depression; EMC too low
- 80 F Wet-bulb is hard to get
- Equalization EMC is too low

## KILN SCHEDULES

**The perfect schedule for 4/4 + 5/4 red oak**  
 T4-D2 Modified to T3-D2 with cooler DB, max 35 F depression

-----4/4 + 5/4 Red Oak-----			
Sample MC (%)	Dry-Bulb (F)	Wet-Bulb (F)	EMC (%)
Over 50%	105	101	17.5
50% - 40%	110	105	16.2
40% - 35%	110	102	13.3
35% - 30%	110	96	9.9
30% - 25%	120	90	5.4
25% - 20%	130	95	4.8
20% - 15%	140	105	5.0
15% - end	160	125	5.0
No equalization			

## KILN SCHEDULES

QUESTIONS ??

## KILN SCHEDULES

KILN START-UP

## KILN SCHEDULES

GREEN MC

## KILN SCHEDULES

GREEN MC --

Go right into the schedule

Avoid rewetting or condensation

## KILN SCHEDULES

PARTLY AIR-DRIED,  
FULLY AIR-DRIED,  
and PREDRIED

KEY: Avoid rewetting

## KILN SCHEDULES

**Step 1.** Bring dry-bulb temperature up to value prescribed by schedule

**Step 2.** Set the kiln EMC 1 or 2 percentage points below the average surface MC.

## KILN SCHEDULES

QUESTIONS ??

## KILN SCHEDULES

EQUALIZING

## KILN SCHEDULES

### WHY EQUALIZE?

- to avoid over drying
- to avoid under drying
- to achieve uniform final MC
  - \* piece to piece
  - \* within a piece

## KILN SCHEDULES

### HOW TO EQUALIZE?

Set EMC in kiln to the lowest final MC desired...

usually  $EMC = target\ MC - 2$

## KILN SCHEDULES

Hotter is better--faster & more uniform

Usually 170 F

## KILN SCHEDULES

Hold this until wettest reaches the target MC.

So, all pieces should be between target MC and (target -2) MC.

Typically, 5.0% MC to 7.0% MC

## KILN SCHEDULES

### QUESTIONS ??

## KILN SCHEDULES

### CONDITIONING

(Also called stress relief or removing casehardening)

## KILN SCHEDULES

Rapid addition of moisture to the surface at high temperatures

EMC = target MC + 4  
-- usually 11% EMC  
-- usually 180 F

## KILN SCHEDULES

Special technique:

Cooling the lumber's surface prior to conditioning

## KILN SCHEDULES

MEASURING STRESS DURING THE PROCESS:

Heat prong for 20 seconds in microwave and then read results about two minutes later.

## KILN SCHEDULES

QUESTIONS ??