TECHNIQUES AND PROCEDURES FOR THE QUALITY DRYING OF OAK LUMBER

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INTRODUCTION

Oak has become increasing popular over the past decade as one of the major furniture and cabinet woods in the United States. At the Furniture Market in High Point, North Carolina for the past 10 years, oak has represented from 20 to 25 percent of the bedroom and dining room units. Furthermore, oak comprised over 63 percent of the total volume of hardwood lumber exported in 1987. With the increasing demand for oak, not only domestically but in Europe and the Far East as well, oak timber is being cut from even more diversified geographical areas then ever before. The lumber entering the commercial market is being made up of an increasing diverse mix of the various oak species. Some of these species do have different processing characteristics (especially drying rates) than others. All oaks are not the same!

THE OAKS

The U. S. Forest Service "Checklist" contains 58 native species of Quercus that are large enough to be considered as trees. This number does not consider the various hybrids and varieties. Botanically, the oaks are divided into two groups:the red oaks (Erythrobalanus) and the white oaks (Leucobalanus). Individual species of trees as well as the two groups can be determined by leaf, flower, and acorn characteristics. Of the 58 species of oaks, only about 20 species are commercially important. Of these 20, eight are designated as"select" based on the timber volume available, the form of the tree, and the quality of the wood. The select oaks are as follows:

Red Oaks	White Oaks
Cherrybark	Bur
Northern Red	Chinkapin
Shumard	Swamp Chestnut
	Swamp White
	White

The wood of the oaks can be classified only into the two major groups of red or white. Individual species can not be distinguished from each other by the wood alone. However, because of drying differences between oak grown on the lowland or wet sites and oak grown on the upland or drier sites, we should use four groupings for oak lumber:

Upland red oak	Upland white oak
Lowland red oak	Lowland white oak

Often the words "northern" or "Appalachian" are imprecisely used to denote upland red oak. Similarly, "Southern" is often used imprecisely when referring to lowland red oak. A fifth classification, bacterial infected, is becoming more common. Anaerobic bacteria can infect oaks in any of the four groups(although red oaks seem the most susceptible). This bacterial infected oak also presents a unique set of drying problems.

The major species contained in each of the four major oak groups are as follows:

Upland Red	Lowland Red
Black	* Cherrybark
Blackjack	Laurel
Pin	Nuttall
* Northern Red	* Shumard
Scarlet	Water
Southern Red	Willow

* Select red oaks

Upland White	Lowland White
* Bur	Overcup
Chestnut	* Swamp Chestnut
* Chinkapin	
Post	
* Swamp White	
* White	

* Select white oaks

THE IMPORTANCE OF THE PROPER DRYING OF OAK

Lumber prices for 5/4 oak are still over $1000 per MBF for FAS and almost $600 per MBF for No. 1 Common. The premium for kiln dry material can be over $300 per MBF. This makes kiln drying of oak an attractive operation. However, oak is our most difficult to dry hardwood. Extreme care must be exercised if quality lumber is to be produced.

Repeated studies throughout the Appalachians have shown that there is a great potential for value loss during the drying of oak. These losses result from staining, checking, splitting, and warp of oak lumber during drying. It is not uncommon for drying losses in oak to exceed 10 percent of the value of the lumber. For those operations with poorer drying practices, the losses can be significantly more.

Drying losses are insidious. They are hidden in low yields in the rough mill, high reject rates for panels and parts, and other machining, gluing, assembling, and finishing problems. Drying degrade of 10 percent may affect rough mill yield by as much as 5 percentage points. For example, a 50 percent actual rough mill yield could possibly have been 55 percent if the drying degrade had been reduced. Drying degrade is more expensive than many people assume.

We use the term "degrade", but drying losses are more than just loss in grade. They are the loss in lumber quality which can have significant impact on the subsequent processing of that material. Drying degrade is actually a loss in quality of the dried lumber because of drying defects and improper drying techniques.

DRYING SYSTEMS FOR OAK LUMBER

Air Drying. The air drying system involves exposing lumber to the outside environment. Air drying loss in value for oak lumber often exceeds 10 percent. For poorly operated yards, for thick lumber, or for harder to dry material, degrade costs may exceed $150 per MBF. Air dry degrade costs are typically in the range of $40 to $100 per MBF. Air drying operating costs for oak lumber based on a 6-month drying time are about $50 per MBF excluding stacking, handling,and degrade costs. For oak, degrade costs can far exceed the air dry operating costs.

When air drying must be used for oak (such as with thick,lowland oak), drying sheds should be used. These sheds are typically a roofed structure with louvre walls. They significantly improve drying quality, but also increase drying time. Still, the quality improvement is worth the increase in time.

Steam-Heated, Warehouse-Type Predryer. Lumber predryers typically operate in the range of 80 to 100 degrees F and 50 to 80 percent relative humidity. The predryer is usually a prefabricated metal building of 5000 to 15000 square feet with insulation in the walls and roof and along the perimeter of the concrete floor. The heating system is usually steam with the coils located along the walls. Overhead fans along the length of the building provide air circulation through the lumber stacks. Ridge fans provide for ventilation. Predryer capacity is usually scaled from 3 to 5 times that of the dry kiln capacity. Predryers offer substantial quality benefits over air drying especially for the hard-to-dry or check prone woods like oak.

If properly operated, predryers can have the lowest amount of drying degrade of any of the drying systems. Predried lumber is bright, clean, and of excellent quality as compared with air dried lumber. Drying degrade should be less than $15/MBF.

Predryer operating costs (excluding stacking, handling, and degrade costs) from green to 25 percent moisture content is about $43 per MBF.

Dehumidification Drying. A DH dryer uses an electrically operated heat pump to run a low temperature drying system. For oak, the dry bulb temperature is usually under 130 degrees. In some dryers, temperatures may reach 160 degrees.

For small operations, DH drying is especially attractive because it does not require a large boiler as does conventional dry kilns.

When properly operated, DH dryers (like predryers) can have as little drying degrade as any drying system. The lumber is bright, clean, and of excellent quality as compared with air dried lumber. Drying degrade should be less than $15/MBF.

Typical DH operating costs (excluding stacking, handling, and degrade) for 4/4 oak dried from green to 6 percent in approximately 36 days is about $72 per MBF.

Conventional Kiln Drying. Conventional kiln drying systems use drying temperatures up to 200 degrees F, usually in the range of 100 to 180 degrees. Conventional dry kilns are generally prefabricated aluminum or masonry construction. The kiln design may be either package or track. The dry kiln provides the mechanisms to control the temperature, relative humidity, and air velocity in the drying chamber. There is a vast research and industrial experience base of information regarding the kiln drying of oak lumber.

If properly maintained and operated, a dry kiln will provide good drying quality for most oaks. Drying degrade can be held to about $15 to $25 per MBF when kiln drying green-from-the-saw. For well predried material, degrade costs can be even less.

Typical kiln drying operating costs (excluding stacking, handling, and degrade) for 4/4 oak dried from green to 6 percent in approximately 35 days is about $79 per MBF.

DRYING SCHEDULES FOR OAK

The moisture content based drying schedules for oak are based on certain assumptions:

1. The kiln or dryer equipment is all functioning correctly: fans, steam lines, spray lines, baffles, and recording and control equipment.
2. The sample board method of moisture content determination is used and the schedule is controlled by the moisture content of the wettest half of the samples. The sample boards must be properly placed within the pile of lumber if the initial moisture content is greater than 25 percent.
3. Sample boards must be properly chosen to represent the fastest and slowest drying parts of the load.
4. The moisture content is based on the average for the piece, not just the shell or the core moisture.
5. The daily drying rate is monitored.
6. Sample boards are inspected for signs of checking, splitting, or warping.
7. Air flow through the lumber pile in the dry kiln must be 250 fpm and preferably 350 fpm.

The kiln schedules we have traditionally used for oak were good for "the good old oak of the past." Today's oak is just not the same. It is from more non-select species, from more lowland species, has more bacterial infection, and generally from smaller and younger trees. As a result of all this, the oak of today is much more prone to checking. A second consideration is that the new hardwood kilns of today are more powerful with respect to rapid input of heat energy, rapid change in humidity, and air velocity.

Therefore, the following suggestions are made regarding the schedules for the kiln drying of today's oak.

1. The dry bulb temperature should not exceed 160 degrees F.
2. The wet bulb depression should not exceed 45 degrees F, and 40 degrees would be even better.
3. In order to control checking, the initial dry bulb temperature should be 5 to 10 degrees lower than the traditional schedules.
4. For especially difficult material, prone to checking, the initial wet bulb depression should be lowered to 3 degrees rather than 4 degrees. The air velocity may have to be reduced to 250 fpm rather than 350.

5. When the lumber has pre-existing checks (from the air dry yard or predryer), dry bulb temperature should be lowered as mentioned above and each schedule change delayed by 10 percent moisture content.

The following tables show some examples of oak schedules for steam dry kilns and dehumidification dryers.

Schedule for drying 4/4 and 5/4 upland red oak in a steam dry kiln.

Moisture Content	Dry Bulb	Wet Bulb	Depression
percent	degree F	degree F	degree F
Above 50	110	106	4
50 to 40	110	105	5
40 to 35	110	102	8
35 to 30	110	96	14
30 to 25	120	90	30
25 to 20	130	90	40
20 to 15	140	95	45
Below 15	160	115	45
	(Then equalizing and conditioning)		

For extra protection against checking, lower the dry bulb by 5 or 10 degrees keeping the depression the same.

Schedule for drying 4/4 and 5/4 upland red oak in a dehumidification dryer.

Moisture Content	Dry Bulb	Wet Bulb	Relative Humidity
percent	degree F	degree F	percent
Above 50	90	86	87 *
50 to 40	90	85	84 *
40 to 35	95	88	75 *
35 to 30	100	87	60 *
30 to 25	110	82	31
25 to 20	120	82	21
20 to 15	130	90	19
Below 15	140	90	26
	(Then equalizing and conditioning)		

* Because of the lower temperatures and usually lower air velocities, the relative humidity can usually be lowered to achieve an acceptable drying rate.

DRYING RATE

For each species, there is a maximum safe drying rate. If this drying rate is exceeded, drying degrade will increase. Listed below are some drying rates for oak. These are maximum daily rates, not averages over several days.

Maximum Daily Safe Drying Rates For Oak

Species	4/4	6/4	8/4
Upland Red	3.8	2.2	1.5
Upland White	2.5	1.4	1.0
Lowland Red and White	1 to 3 *	? **	? **

* There is too much variation in the lowland oaks to give one general number for the safe drying rate. The same is true for bacterial infected oak.

** For lowland oaks and bacterial infected oaks, thicknesses over 5/4 are very difficult to kiln dry green from the saw. They should be air dried first, preferably in a drying shed.

SUMMARY OF DRYING DEFECTS IN OAK LUMBER

The following are defects that occur because of drying the lumber too fast at the beginning stages of drying. Drying too fast can be caused by too high a temperature, too low a relative humidity, or high an air velocity.

- Surface Checks
- End Checks
- Internal Checks (Including Honeycomb)
- Splits and Cracks
- Collapse

The following defects are caused by drying too slowly usually at too high a relative humidity.

- Fungal or Blue Stain
- Chemical Stain or Graying
- Warp (Especially Cup)
- Mold and Mildew

The following defects are caused by poor stacking and stickering.

- Warp (Especially Bow)
- Uneven Drying

The following defects are caused by operational errors.

- Lumber Too Wet or Too Dry
- Case hardening or Drying Stresses