LOW TEMPERATURE DRYING SYSTEMS--
SOLAR, DEHUMIDIFIERS, AND PREDRYERS

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Low temperature kiln drying of lumber is an important drying technique for drying fine hardwoods as this technique will result in less drying degrade (or quality loss) than air drying or kiln drying, dries much more rapidly than air drying thereby saving inventory costs, and requires less capital investment than a standard kiln.

Low temperature drying is defined as a technique for drying lumber in an enclosed building with air temperatures below 130°F. In practice, most low temperature dryers operate between 80° to 100°F. All dryers have internal fans to circulate air through the lumber piles. Humidity is removed from the dryer by venting or by condensation.

There are three types of low temperature dryers:

-- solar-heated kilns
-- electric dehumidifier kilns
-- steam heated kilns (often called warehouse dryers or predryers)

It is a key point, however, that these three dryers all operate at low temperature and, therefore, produce excellent drying quality and reasonable drying times. The differences between them are primarily hardware differences and not fundamental differences in the process of drying.

General Characteristics

The most attractive features of low temperature drying are 1) low drying degrade [especially important for hard-to-dry species such as oak and beech (see Table 1) that can easily degrade with over a 10% value loss] and 2) the reduction of lumber inventory (and therefore lumber inventory carrying expense) compared to air drying. There are other important advantages and characteristics in reference to hardwood drying:

* usually quite economical for drying from green to 20% MC (Table 2)
* usually quite rapid, approximately normal kiln drying time from green to 20% MC
* species and thicknesses can be mixed without serious problems
* labor costs are low
* overall costs are low
* dry lumber is available on schedule (except for solar which is still dependent on the weather)
* capital costs are low
* moisture contents are more uniform than in air drying

In addition to these benefits, there are also secondary benefits that include:

* decreased kiln drying time and, therefore, increased kiln productivity due to improved MC uniformity
* increase yield of furniture parts due to decreased degrade
* increase in the proportion of longer furniture cuttings due to decreased degrade
* decrease in processing time for furniture cuttings due to decreased degrade

Brief Descriptions

A. Solar Heated Lumber Dryers

The typical solar heated dryer is a small green-house type structure with the roof and often one or more walls covered with a translucent material that allows sunlight into the structure. The sunlight is absorbed by black painted surfaces inside and converted to heat. This heat is used in turn to heat the air in the dryer, thereby lowering the relative humidity and also supplying the heat to evaporate moisture. It is possible to dry the lumber to 7% final moisture content.

The design of the solar lumber dryer has undergone only small changes since it was first proposed in the late 1950's, but in most cases the cost of a dryer has been the primary consideration. Therefore, dryers have usually been quite simple in design and operation. The Virginia Tech kiln[1] for small businesses is a four walled (2 x 4 framing, 4-inch batt insulation, and 3/8-inch plywood skins) structure with a roof at 45° angle sloped to the south. The roof covering is 2-layers of clear, weatherized plastic. (Corrugated fiberglass should perform just as well.) One of the key design features is the ratio of clear roof area to the lumber capacity: 1 sq. ft. to 10 bd. ft. for 1-inch oak. This ratio is increased for faster drying and decreased when slower drying is needed.

Until recently, there have probably never been more than half-a-dozen operating dryers in the United States. But with rising energy prices and rising lumber costs, the small wood using business has begun to utilize the solar lumber dryer as a do-it-yourself means of obtaining dry, stress-free lumber at a much lower cost than by purchasing it already dried.

An important point in the use of solar energy is that the amount of energy available per square foot of collector is low--the Virginia Tech kiln has 1 square foot of collector for approximately 120 bd. ft. of <u>annual</u> production. For an annual production of a million board feet, over 8,000 square feet of collector is needed. (As a point of reference, commercial collectors cost about $30/sq. ft.) With the availability of wood waste in the larger operations, usually a solar kiln is more

[1] Plans and operating instructions available at no cost from Gene Wengert, Dept. of Forest Products, 210E Cheatham Hall, Virginia Tech, Blacksburg, VA 24061.

practical for an annual production below 1,000,000 bd. ft. where steam and dehumidification would be too expensive.

As with any drying process, the rate of drying in a solar kiln is limited by the risk of degrade formation. Typically for oak, the drying rate is 2 to 2-1/2% moisture content loss per day. On sunny days, the rate may be 3-3/4% per day--the maximum possible for oak, especially when green, without excessive risk of degrade. Sample boards should be used to monitor the drying rate.

Stresses (or casehardening) are removed in a solar kiln every night when the relative humidity reaches 100%. It is important, therefore, to avoid adding supplemental heat at night.

The cost of materials for a solar kiln is approximately $0.50 per board foot capacity. The fan operating costs are approximately $6.00 per MBF.

B. Dehumidifier Dryers

Dehumidification is a drying method that uses an electric heat pump to reduce the relative humidity of air in the kiln, thereby drying the wood. A heat pump has the advantage of being quite energy efficient--it requires 1,000 Btu's to evaporate a pound (=1 pint= 0.03% MC/MBF) of water, but the dehumidifier, when water vapor is condensed, is able to recapture this heat and recycle it. The net effect is that a dehumidifier uses only about 50% of the energy of a normal, steam kiln. However, be aware that electricity may be 3 times the cost natural gas or wood waste generated steam.

The dehumidifier kiln building is often a well insulated, wood frame building. The cost for a homemade-building is about $1.00 per board foot capacity. The compressor or heat pump will cost an additional $1.00 per board foot and should be sized according to the following guidelines:

slow drying woods (4/4 oak, beech)	0.7 hp/MBF kiln capacity
medium drying woods (4/4 maple, birch)	0.9 hp/MBF kiln capacity
fast drying woods (4/4 pine, basswood)	1.1 hp/MBF kiln capacity

Electrical consumption is about 500 to 700 KWH/MBF for oak from green to 7% moisture. If complete drying stress relief is required, a standard steam relief method would be necessary.

The dehumidifier provides a small scale method of drying wood at a reasonable cost. As a general guideline, the dehumidifier may be most practical at production rates below 50 MBF per month. Above that level, the generation steam in a wood waste or natural gas boiler is possibly more economical. Overall, the dehumidifier is most economical above 25% moisture content, although it can dry to 7% moisture.

C. Steam Dryers

The steam predryer or warehouse dryer was developed 25 years ago by Mr. J. Imrie, but it is only recently that this dryer has attracted widespread industry interest as a means of reducing the inventory costs of air drying.

The predryer is typically a Butler-type building 5,000 to 20,000 square feet with insulated walls and roof. Heat is provided to maintain 80°F or so. Fans along the length of the building provide circulation of air through the lumber piles. Ridge or gable fans exhaust excessive moisture. Humidification is provided by the moisture coming from lumber itself. Humidity is usually kept between 60 to 80% RH; the correct level is determined by the correct, safe drying rate for the species being dried. Because of the high humidity, the lumber is usually dried only to 20% before moving it into a regular dryer for final drying. Drying times are 2 to 4 weeks for 4/4 lumber.

This dryer uses approximately the same amount of energy as a standard kiln, but operating costs are less because of reduced labor and reduced capital.

D. Solarized Predryers and Standard Kilns

With the high price of energy, the potential for solarizing (or retrofitting) a large dryer should be examined. Here are two examples that illustrate that the average low daily intensity of solar radiation makes the use of solar energy in a high energy demand dryer impractical at this time.

Example 1: A lumber predryer holds 3/4 million BF. The roof area is 90' x 220', or about 20,000 sq. ft. Each day an average of 20 million Btu's of solar energy will be collected. In order to reduce the MC of the lumber in the predryer by 1% MC, approximately 40 million Btu's is needed. In other words, solar heat will dry at a rate of 1/2% MC loss per day. On a yearly basis, the roof will collect 7.2 billion Btu's which is worth about \$16,000 of natural gas or \$50,000 of fuel oil. However, the collectors will typically cost \$30/ft.^{2} or \$600,000 for the roof.

Example 2: A small 20 MBF kiln has a roof area of 720 square feet. The roof can provide 3/4 million Btu's of solar heat per day. The dryer requires about 4 to 6 million Btu's per day for a reasonable drying rate (or a completely solar-powered kiln would require collector 5 to 8 times as large as the roof).

TABLE 1 -- Comparison Drying Quality for Eight Major Drying Systems for Drying 1-Inch Hardwoods to 7%MC

System	Oak, Beech	Hickory, Pecan Hard Maple	Ash, Basswood Yellow-Poplar Gum, Soft Maple
AD-NT	F-P	OK	OK
AD-HT	F-P	F-P	OK
LT	VG	VG	VG
LT-NT	VG	VG	VG
LT-HT	OK	VG	VG
NT	OK	VG	VG
NT-HT	OK	VG	VG
HT	NS	NS	F-P

Abreviations: AD = Air Drying, LT = Low Temperature, NT = Normal Temperature, HT = High Temperature, F-P = Fair to Poor, VG = Very Good, OK = Okay, NS = Not Suggested

TABLE 2 -- A comparison of low temperature drying with air drying and normal temperature drying from green to 25% MC, considering an annual production of 10MM bfm dried to 7%.

	AIR DRYING	LOW TEMPERATURE DRYER		NORMAL TEMPERATURE
		(Steam)	(Dehumidifier)	(Steam)
Time	3-6 months	4 weeks	3-4 weeks	3 weeks
Cost, Capital	$0.02/BF	.50	2.00	2.50
Operating	$.24-.65/%MC/MBF	.38	.48	.65
Degrade	$30-40/MBF	8.00	8.00	12.00
Energy Use	0 Btu/MBF	3.5 Million	1.7 Million (350 KWH/MBF)	3.5 Million
Boiler Hp, minimum[1/]	50	200	45	200
Capacity (Million BF)	Yard - 5 Kiln - 0.2	P.D. - 0.9 Kiln - 0.15	DH - 0.9 Kiln - 0.15	Kiln - 0.9

[1/] Includes hp for kiln to dry to 7%MC.