PROPERTIES OF WHITE PINE LUMBER DRIED BY RADIO-FREQUENCY/VACUUM PROCESS AND CONVENTIONAL KILN PROCESS

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ABSTRACT

A study was conducted to evaluate selected physical and mechanical properties of white pine lumber dried by a radio-frequency/vacuum drying process compared to lumber dried in a conventional kiln. Twenty-four 8/4 white pine boards 16 feet long were cut in half to provide end-matched, 8-ft long boards. One half of the boards was dried in a radio-frequency/vacuum (RFV) kiln and the other half in a conventional kiln. The RFV drying process produced white pine lumber with slightly, but significantly higher equilibrium moisture content, and lower compressive strength than lumber dried by a conventional process. No difference was detected for static bending, shear, hardness, or specific gravity.

Keywords: White pine, radio-frequency/vacuum, dielectric, kiln drying, EMC, specific gravity, static bending, shear, hardness, compression strength.

INTRODUCTION

Radio-frequency/vacuum (RFV) drying of wood has proven to be an effective way to reduce the drying time of certain species of wood, when compared to the time required in conventional drying of those species. For example, the RFV process lends itself to drying turning squares of white pine (*Pinus strobus*) and red oak (*Quercus* sp.). Such squares are, in fact, presently being effectively dried by the RFV process on a commercial scale.

Some information on the effect of RFV drying of red oak has recently been published (Harris and Taras 1984; Lee and Harris 1984; Wengert and Lamb 1982). Lee and Harris (1984) found that red oak dried by the RFV process had a somewhat lower equilibrium moisture content (EMC), lower specific gravity (SG), and lower compression strength than red oak lumber dried in a dehumidification kiln. However, no information on the effect of RFV drying on the physical and mechanical properties of white pine has been published. This study was undertaken to develop some basic information on the effect of RFV drying on the hygroscopicity, specific gravity, and selected mechanical properties of white pine.

MATERIALS AND METHODS

The wood used was 8/4 white pine boards 16 feet long. Twenty-four boards were cut in half and marked to provide 8-ft end-matched boards. One-half of each 16-ft board was dried in a RFV kiln and the other half was dried in a conventional forced-air kiln.

Conventional drying was accomplished in a 500 board foot capacity, forced-air kiln at Clemson University, using a T10-C4 white pine schedule, with a

TABLE 1. *Specific gravity and equilibrium moisture content (EMC) of white pine dried by conventional and radio-frequency/vacuum (RFV) processes.*

Drying process	Specific gravity	EMC**[1] %
Conventional	0.39 (0.03)[2]	8.75 (0.42)
RFV	0.39 (0.04)	9.30 (0.80)

** Significant difference between methods (0.01 level).
[1] EMC at 75 F and 50% relative humidity.
[2] Standard deviation shown in parentheses.

maximum temperature of 180 F (Rasmussen 1961). The kiln is a prefabricated aluminum paneled kiln equipped with electric resistance heating units, a hot water bath to generate steam for humidity control, and four fans that generate air velocities of 600 feet per minute and are reversed on a 6-hour time schedule. Drying time was 6 weeks from an initial moisture content of 146% to a target moisture content of 8%.

RFV drying was done by General Wood Processors, Inc. (GWP), Easley, S.C., by a schedule provided by GWP. This process has been described in more detail by Harris and Taras (1984). RFV drying took 54 hours. The temperature of the lumber ranged from 90 to 130 F, and the vacuum reached a maximum at 30 mm of mercury. The final moisture content was also approximately 8%.

After drying, end-matched boards were machined to produce clear test specimens according to the secondary methods of ASTM-D143 (1978). A total of 672 separate test specimens were prepared (336 pieces for RFV tests and 336 pieces for conventional drying), and these were broken down by properties evaluated as follows:

1. Compression parallel to the grain, 144 specimens (1 in. × 1 in. × 4 in.).
2. Static bending, 144 specimens (1 in. × 1 in. × 16 in.).
3. Shear parallel to the grain, 24 specimens.
4. Hardness, 24 specimens.
5. Equilibrium moisture content, 144 specimens.
6. Specific gravity, 144 specimens.

The specimens used for the compression test were also used for specific gravity and equilibrium moisture content (EMC) determinations.

Prior to testing, all specimens were conditioned to an EMC at 75 F and 50% relative humidity. EMC was recorded for each specimen and specific gravity was calculated based on oven-dry weight and on volume at the prescribed temperature and relative humidity.

RESULTS AND DISCUSSION

The average specific gravity of the white pine samples was 0.39 for both drying methods (Table 1). Harris and Taras (1983) found no shrinkage difference in white pine when dried by RFV and conventional means. Since specific gravity is a measure of cell-wall substance, it follows that equal shrinkage rates would produce samples of equal specific gravity. By contrast, a reduced shrinkage rate has been reported for red oak dried by the RFV process (Harris and Taras 1984); and as a result, the specific gravity of red oak dried by the RFV process has been reported

TABLE 2. *Comparison of bending, shear, and hardness properties of white pine dried by conventional (CON) and radio-frequency/vacuum drying (RFV). Numbers in parentheses are standard deviations.*

	CON	RFV
Bending properties:		
MOE (1,000 psi)	1,532 (181)	1,525 (220)
MOR (psi)	12,454 (1,165)	13,130 (3,689)
FSPL (psi)	7,485 (801)	7,287 (938)
Shear parallel to grain:		
Max. stress (psi)	1,333 (207)	1,375 (182)
Hardness:		
Side (lb)	539 (67)	531 (87)
End (lb)	740 (77)	752 (72)
Compressive strength (psi)*	6,613 (703)	6,314 (640)

* Significant difference between methods (0.05 level).

as less than the specific gravity of conventionally dried red oak (Lee and Harris 1984).

The average EMC from RFV dried samples was greater than that from conventionally dried samples at 75 F and 50% relative humidity (Table 1). Average EMC values were: RFV, 9.30% and conventional, 8.75%. The difference of 0.55% is significant at the 0.01 level. Thus, the white pine lumber dried by the conventional process is slightly drier than that dried by the RFV process under the same temperature and relative humidity conditions. This could be a result of the drying temperatures. The maximum temperature in RFV drying was 130 F, while the maximum temperature in conventional drying was 180 F. An increased drying temperature has the effect of reducing the hygroscopicity of wood at a given relative humidity (Skaar 1972). In a previous study, it was reported that red oak lumber dried in a dehumidification kiln had an EMC of 9.4%, which was higher than that of red oak (8.8%) dried by a RFV process (Lee and Harris 1984). However, the highest temperature in the dehumidification process was only 140 F with the oak vs. 180 F for the white pine. The elevated temperature in the kiln drying of pine could account for the differences in these results.

The white pine dried by conventional drying had a significantly higher compressive strength than the white pine dried by the RFV system (Table 2). The average compressive strength figures for the conventional and RFV material were 6,613 and 6,314 psi, respectively. With the specific gravity of the wood dried by each method the same, a probable explanation for this difference in compressive strength is the difference in moisture content resulting from the higher EMC of the wood dried by the RFV process. If the compressive strength (C_1) of the RFV dried material is used as a base, and the compound interest formula, as discussed in Panshin and de Zeeuw (1980) is used, with a difference in moisture content, n, of 0.55%, and a rate of change, r, of 6%, the formula:

$$C_2 = C_1(1 + r)^n$$

would project a compressive strength (C_2) for the wood dried by the conventional process, of

$$C_2 = 6{,}314(1 + 0.06)^{0.55} = 6{,}520 \text{ psi},$$

which is only 1.4% different from the measured value of 6,613 psi.

The properties of bending, shear, and hardness are presented in Table 2. A *t* test was used to compare the values of the matched pairs. Neither static bending, shear, nor hardness showed a significant difference between lumber dried by conventional and RFV processes. This agrees with data reported by Lee and Harris (1984) for red oak.

In summary, the RFV drying process produced white pine lumber with slightly but significantly higher equilibrium moisture content, and lower compressive strength than lumber dried by a conventional process. White pine lumber dried by RFV and conventional processes showed no significant difference in static bending, shear, hardness, or specific gravity.

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