FOREST PRODUCTS LABORATORY † FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

SPECIAL METHODS OF SEASONING WOOD

HIGH-FREQUENCY DIELECTRIC HEATING

Large amounts of heat are needed to dry wood rapidly. Heat is needed to evaporate the water and to keep the temperature of the wood high enough for rapid movement of moisture from inside the wood to the surface. In modern dry kilns, heat is carried from steam coils or other heating units to the wood by air. Much of the heat is lost by radiation and leakage. To avoid drying defects in most hardwoods and some softwoods, temperature and relative humidity conditions must be kept mild or moderate, except during the final stages of drying. Because these woods must be dried more slowly than other woods, the heat losses are larger.

When it was found that a high-frequency dielectric field could change electrical energy into heat inside a solid, it was logical to attempt to dry wood by this method. Abramenko apparently first used it to dry wood in 1934, but others began tests about the same time. First work in this country apparently was done by Stephen and Holmquest in 1936. Because the method appears to have limited uses, little work has been done on high-frequency drying at the Forest Products Laboratory. This report on the work of others, therefore, has been written to answer general questions on the method. A number of references are given at the end of this report. A considerably larger number are given in Kozlik's bibliography.[1]

Dielectric heating requires a generating apparatus capable of setting up an electric field that will oscillate at a high frequency between condenser plates or electrodes. Wood placed in a powerful electric field oscillating at more than 1 million cycles per second is heated quickly throughout to a temperature above the boiling point of water. If wood were very permeable, with no resistance to the movement of free water or vapor, it could be dried rapidly. In general, however, wood is not very permeable. It varies considerably in its structural characteristics. Some species have fairly permeable sapwood, but others have a tight structure. Moisture does not move freely, either as a liquid or as a vapor, through these "tight" woods. Moisture movement may be so impeded that high internal pressures and temperatures well above the boiling point of water are built up.

In permeable woods, the temperature levels off slightly above the boiling point as long as free water exists. When only bound water (the water held within the walls of the wood cells) remains, the temperature rises. If these high temperatures are prolonged, they weaken the wood and lower its resistance to pressure. This may cause local explosions or split the wood wide open.

---

[1] Kozlik, C. J. Bibliography of Special Seasoning Methods. Oregon Forest Research Center, Corvallis, Oreg.

† Maintained at Madison 5, Wisconsin in cooperation with the University of Wisconsin

Pratt and Dean proposed two methods of using high-frequency heat to dry wood. In the first, the temperature is kept above the boiling point of water. This converts the moisture within the wood to steam that can be rapidly driven off. In the second, only enough heat is supplied to maintain a temperature gradient within the wood when the surface is kept cool by air circulation. By the "boiling" method, European beech, which is easier to dry than American beech, was dried in an hour or so without much degrade. Green oak, however, was badly degraded by bursting, and air-dried oak surface checked severely. Other tests showed the method might be satisfactory for European poplar, sycamore, and a few exotic woods. Elm, Douglas-fir, Scotch pine, Sitka spruce, western redcedar, and a number of exotic hardwoods, however, were not tolerant to the process. The "temperature gradient" method was developed with beech, then tried for oak. Although a very low temperature and a small temperature gradient were used, there was some fine checking. The tests showed that drying time might be cut to one-third or one-fifth of the time required for kiln drying.

Apart from technical difficulties, high-frequency heating is generally too expensive to use for drying wood in this country. In Russia, however, the prospect of low-cost electric power led to further investigation. One report says many high-frequency drying plants are in use there. A technician's handbook by Birjukov describes cost factors and "economic efficiency" of the method. Netushil has stated, however, that even in Russia costs limit the use of this method to special cases, such as the drying of large, high-quality structural parts or partial drying of ties, piles, and building materials before they are treated with preservatives.

The main costs are for high-frequency generators, power tube replacement, and electricity. A minimum estimate of these costs follows. It is based on drying green beech, birch, or maple sapwood from a moisture content of 70 percent to one of 8 percent. The wood is assumed to have an ovendry weight of 35 pounds per cubic foot. About 10,000 board feet are to be dried per 24 hours.

To bring the lumber to drying temperature and to remove the calculated 764 pounds of water per hour requires 263 kilowatts. Thus, a generator with a minimum output of about 270 kilowatts would be needed. Because a generator is only about 50 percent efficient and because a certain amount of heat would be lost, the power line would have to deliver at least 600 kilowatts to the generator. At 1 cent per kilowatt hour, power would cost $144 per 24-hour day or $14.40 per 1,000 board feet of lumber.

The generator would cost about $100,000. Three power tubes, such as type 862A with a service life of about 5,000 hours, would cost $1,500 each. Total cost of investment and upkeep spread over 10 years would amount to $55 per working day or $5.50 per 1,000 board feet of lumber. This is based on three hundred 24-hour working days a year. Total cost for power, equipment, and maintenance is then about $20 per 1,000 board feet. This figure does not include cost of housing, lumber-handling equipment, labor, or the salary of a skilled operator.

The drying of green sapwood of softwoods, such as white fir, ponderosa pine, and western white pine would cost more, at least $26 per 1,000 board feet. The reason for the higher cost is the greater amount of water present in the softwoods. In this estimate the weight of the ovendry wood was assumed to be 23 pounds per cubic foot and its moisture content when green 160 percent.

In view of the above, high-frequency dielectric heating does not appear practical for the general drying of wood. Under some conditions, however, it could be used to dry special items that would absorb the extra cost. A company in New England, for example, used the method to dry turning squares of birch and maple. The drying unit, which cost about $23, 500, held a charge of about 1, 500 board feet. The 1-1/2-inch squares were given a drying period of 7 hours in each of three chambers. In only the third chamber was dielectric heating used. The wood was removed from the unit after the 21-hour cycle and then dried in the air under a porous canvas cover.

References

(1) Abramenko, S. N.
1934. The drying of wood by electric currents of high-frequency. Woodworking, U. S. S. R. 10: 65-68. (See also Holztechnic 15: 165-168, 221, 1935.)

(2) Bandi, C.
1959. High frequency drying. Timber of Canada 20(10), 46 et ref. (Also reprinted in Northeastern Logger 8(10): 8-9, 35.)

(3) Billig, K.
1950. High-frequency currents for timber processing. Timber News 58(2129): 114, 117-8, March. (Reprinted from Civ. Engin. & Pub. Works Rev.)

(4) Birjukov, U. A.
1950. Kiln seasoning of timber in an R. F. electrical field. Goslesbumizdat. Leningrad-Moscow, 1950, 102 pp., 1 dgm. (Forestry Abs. 14(1): 110, 1953.)

(5) Fessel, F.
1956. Practice of wood drying in the high-frequency electric condenser field in different countries. Holz als Roh und Werkstoff 14(2): 41-47. (Also Translation No. 95 by Forest Products Laboratory, Canada, 1956.)

(6) Hunger, J.
1960. High-frequency drying of wood. Holzforschung und Holzverwertung 12 (4), 68-70. (Translation No. 423, U. S. Forest Products Laboratory, 1961.)

(7) Ishaq, S. M.
1947. High-frequency drying of wood. Cosgrove's Mag., Oct. 1947; South. Lbrmn., Dec. 15, 1947.

(8) Miller, D. G.
1948. Application of dielectric heating to the seasoning of wood. Forest Products Research Society Proc. 2: 235-41.

(9) Netushil, A. V.
1947. Drying of wood with the aid of high-frequency current. Vestnik Ishenerov i Tehnikov 4: 141-48, April; also Engin. Digest 9(10): 343-46, 1948. Abs. Wood (Chicago) 4(3): 40, March 1949.

(10) Pratt, G. H., and Dean, A. R.
1951. Report on an investigation into the drying of timber by the application of radio-frequency heating. Forest Products Research Lab. (Great Britain) report, Oct. 1951, 36 pp., illus. Abs. Jour. FPRS 3(4): 78; see also Wood (London), Feb. 1949.

(11) Shinohara, U., Otori, S., and Iwata, K.
1952. On the drying mechanism of radio-frequency heating. Mem. Faculty Engin., Nagoya (Japan) Univ. 4(1).

(12) Siemens-Schuckertwerke Akt.-Ges.
1936. Method for drying bodies containing moisture, particularly for drying wood by means of alternating electric fields. Ger. patent 663,455, appl. July 28, 1936, issued Aug. 8, 1938.

(13) Stephen, J. L., and Holmquest, H. J.
1936. Drying lumber with high-frequency electric fields. Wood Products 41(10): 10-12 and 41(11): 15, 19.

(14) Villiere, A.
1956. Seasoning of lumber by high-frequency currents. Rev. Bois Appl. 11(1): 26-31. (Translation No. 103 by Forest Products Laboratory, Canada, 1956.)

(15) Vodoz, J.
1957. The behavior of wood during drying by radio-frequency heating. (In German) Holz als Roh-u. Werkstoff 15(8): 327-340.

(16) ______
1958. Seasoning by high-frequency (R. F.) current. Timber Tech. 66(2233): 535-538.

(17) Wood, H. P.
1951. Apparatus for drying wood. U.S. patent 2,543,618, Feb. 27, 1951. (See also U.S. patent 2,567,983, and Northeastern Wood Util. Counc. Wood Note 13, Nov. 1950.)

J. M. McMillen
W. L. James
Forest Products Laboratory
Madison 5, Wisconsin
Revised February 1961