HEATING TIME SIMULATION FOR FROZEN AND UNFROZEN WOOD

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INTRODUCTION

The heating time simulation software LOGHEAT1 (Steinhagen et al.) was developed for peeler logs used in the veneer and plywood industry. These logs are heated in water in order to soften the wood for improved veneer cutting. Accurate estimates of heating times required to reach target temperatures at given depths are important, particularly when the logs are frozen during the winter and many hours of heating are needed just to thaw the ice. This simulation might also be used for poles that are heated and dried prior to being treated with salt preservatives, provided some limitations are taken into account.

This paper outlines the capabilities and limitations of the software LOGHEAT1 and discusses heating time data generated with it.

LOGHEAT1

LOGHEAT1, developed for an IBM-PC, uses a finite-difference approach to analyze heat transfer in the radial direction of a debarked, cylindrical log having a length of at least four diameters ("long log") and a maximum diameter of 25 inches. The log is assumed to be fully immersed in the agitated water bath which is maintained at a constant temperature. The input required includes indication of the wood species or specific gravity and moisture content (considered the main keys to the species effect), log diameter and length, initial log temperature--which is assumed to be uniform and may be above or below the freezing point--and bath temperature (Figure 1). The output table records the computed temperatures for each half-hour increment into the heating cycle; at each time level the temperatures are listed for half-inch increments along the log radius. Log energy consumption is also recorded.

Computations were compared with available experimental data (Steinhagen et al.). For a given temperature within a log, the discrepancy between measured and computed heating time was usually within the 10 percent target, which appears satisfactory from a practical point of view.

DISCUSSION OF HEATING TIME DATA

LOGHEAT1 was used to generate heating time data over a range in parametric values (Table 1).

The table values reflect the large effect of log diameter on heating time. Theoretically, if the log diameter is increased by a factor of two (e.g., from 10 inches to 20 inches), heating time will increase by a factor of four (squared relationship), for any constant ratio of core diameter to log diameter. This is not evident from the table values; as the core diameter was assumed to be constant, the ratio of core diameter to log diameter is different for each different log diameter. To give another example, temperature histories were computed for two logs (both were grand fir logs at 27°F initially, and were exposed to a water bath at 156°F); only the diameter was varied in these computations, using 12 inches and 24 inches. As a result, after 20 hours of heating the 12-inch log registered 119°F at a radial depth of 6 inches; the comparable temperature for the 24-inch log was only 39°F.

Frozen logs need much time to thaw so that their total heating time is significantly longer than that of nonfrozen logs. As an example, the center of a log reached a temperature close to 32°F after about 15 hours of heating (Figure 2, curve marked "6"); but it then took the ice another 15 hours to melt before the temperature rose again at the log center.

If the log's specific gravity is 0.3 instead of the assumed table base value of 0.4, heating time will be about five percent smaller than the table value, and conversely, five percent larger if the specific gravity is 0.5.

If the bath is nonagitated water, the heating time will be about 10 percent larger than the table value.

When the heating medium is air instead of water, considerably more heating time may be needed than that recommended by the table. This is due to a difference in the rate of heat transfer--5 to 50 Btu/hr-sqft-°F for forced air versus 50 to 2000 Btu/hr-sqft°F for agitated water, according to Kreith (1965)--which will affect the surface temperature history. The latter, in turn, affects the internal temperature history. In water, surface temperature rises almost immediately to the level of the bath temperature (Figure 2, curve marked "0"). In air, this rise occurs gradually over the whole range of moisture loss (Figure 3, curve marked "0"). It is for this reason that heating of poles in air followed by drying will take more time than suggested by the values of Table 1.

CONCLUSIONS

The computer software LOGHEAT1 simulates log heating in agitated water. Heating time estimates via LOGHEAT1 for nonfrozen as well as frozen logs are satisfactory; data are presented here over a range in parametric values. The log diameter has a considerable effect on heating time. Thawing also affects heating time significantly. Heating in air may be considerably slower than heating in water.

LITERATURE CITED

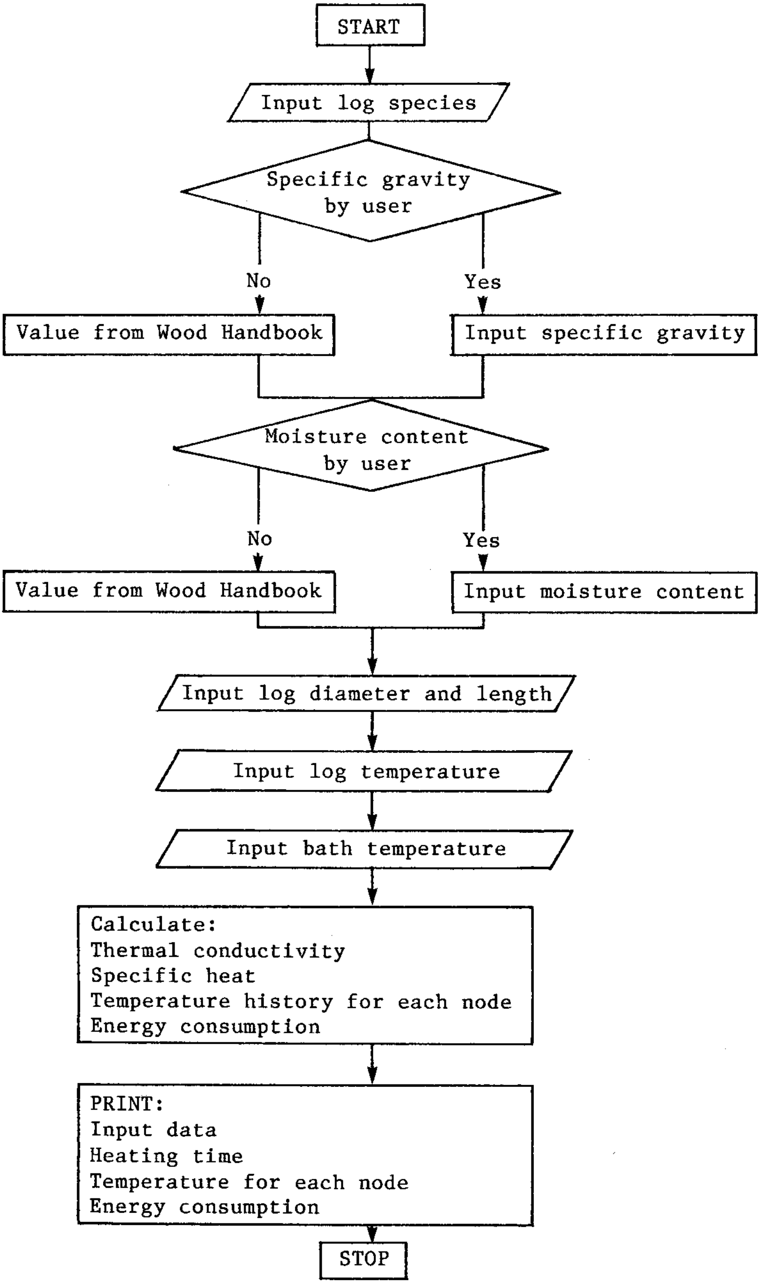
Kreith, F. 1965. Principles of Heat Transfer. International Textbook Company, Scranton, PA. Second edition.

Stanish, M.A., and F. Kayihan. 1984. Moisture transport in wood particles during drying. AIChE Symposium Series 80(239):9-20.

Steinhagen, H.P., H.W. Lee, and S.P. Loehnertz. Computer program LOGHEAT1. Submitted October 1986 for publication in the Forest Products Journal.

Table 1. Heating time estimates for "long" logs heated in agitated water. The logs' specific gravity based on dry weight and green volume is 0.4. T_i is the initial wood temperature, T_f the final temperature at a 5-inch core diameter, T^∞ the bath temperature, MC the wood moisture content based on dry weight, t the heating time, and D the log diameter.

T_i (°F)	T_f (°F)	T_∞ (°F)	MC (%)	t (hrs)		
				D_1 (10 in.)	D_2 (15 in.)	D_3 (20 in.)
0	100	160	100	9	23	43
			150	10	27	50
		200	100	6	18	34
			150	7	21	39
	140	160	100	15	36	66
			150	17	41	75
		200	100	9	24	44
			150	11	27	50
50	100	160	100	4	11	22
			150	4	12	24
		200	100	3	9	17
			150	3	10	19
	140	160	100	10	25	46
			150	11	27	50
		200	100	5	15	28
			150	6	16	31



NOTE: Recycle through 12 and 13 until care temperature is 10 degrees less than bath temperature.

Figure 1. Flow chart, LOGHEAT1

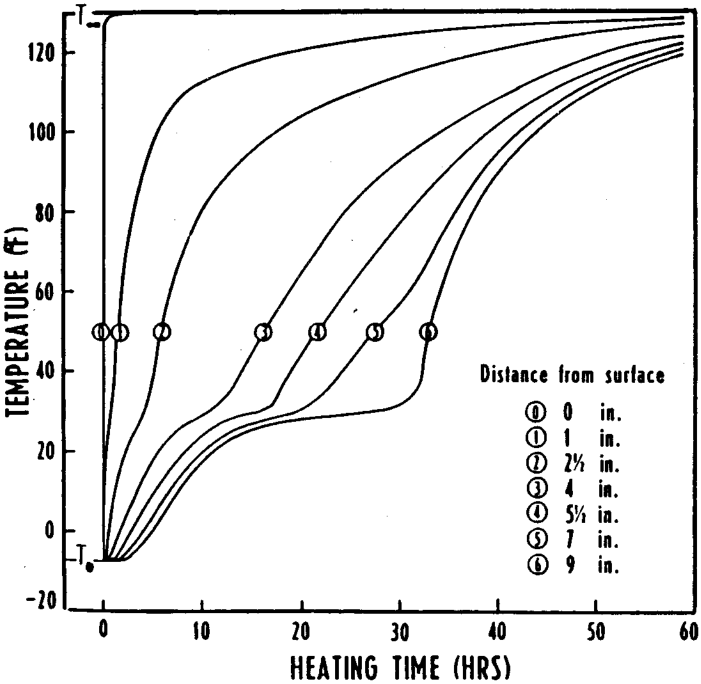


Figure 2. Transient temperature distribution in a "long" log heated in agitated water. Specific gravity was 0.32, moisture content 97%, log diameter 18 inches, log length 103 inches, initial log temperature (T_0) -8°F, bath temperature (T_∞) 130°F.

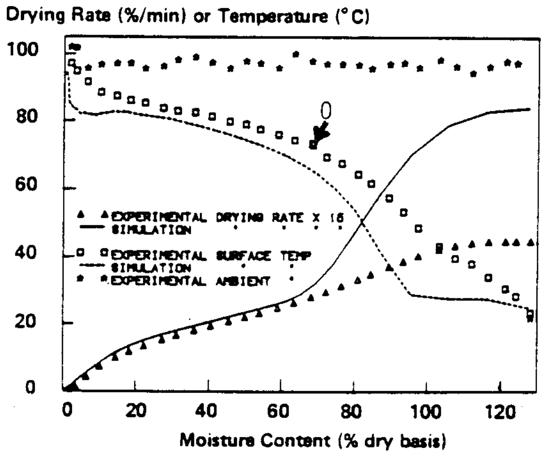


Figure 3. Small wood block (0.1 cubic inch) with one-dimensional (tangential) moisture movement. Wood species was Douglas-fir, initial moisture content 128%, air temperature 203°F, air velocity 37 FPM.

Source: Stanish and Kayihan, 1984