PRODUCING HARDBOARDS FROM RED OAK

U.S.D.A. FOREST SERVICE
RESEARCH PAPER
FPL 219
1973

U.S. Department of Agriculture
Forest Service
Forest Products Laboratory
Madison, Wis

ABSTRACT

To improve hardboards produced from red oak, extractives were removed, pulp yield reduced, resin content increased, and fiber pH adjusted. The methods were applied to both wet-formed and dry-formed, phenolic-bonded, high-density boards. Although a large portion of the extractives was removed by washing the pulp with hot water, board quality was not affected. A loss in all properties occurred when the pulp was washed with a 1 percent sodium hydroxide solution that removed a greater amount of the extractives than did the water. Lowering the pulp yield from 88 to 80 percent improved board strength, but adversely affected linear stability. Increasing resin content improved all properties for both types of boards. Dry-formed boards were greatly improved by adjusting the pH of the fiber prior to resin treatment.

PRODUCING HARDBOARDS FROM RED OAK

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INTRODUCTION

Hardboard production has been increasing at a substantial rate. Among the predominant hardwood species of the Nation oaks have not been used to any great extent in manufacturing hardboard because of the generally low strength and poor linear stability of the resultant boards. The work reported here was undertaken to establish means of overcoming the deficiencies to expand the use of oaks and maintain consumer satisfaction. Both dry-formed and wet-formed high-density hardboards were evaluated to determine if one forming process was more conducive than the other to successful utilization of the oaks.

EXPERIMENTAL PROCEDURE

Fiber Preparation

Red oak (Quercus rubra L.) chips (1/2 in. long) were fiberized at 175 pounds per square inch (p.s.i.) steam pressure in a 12-inch laboratory Asplund Defibrator under the following conditions: (1) Steamed 2 minutes, fiberized 1 minute, high pulp yield 88 percent, and (2) steamed 2 minutes, fiberized 3 minutes, low pulp yield 80 percent. The pulps were then reduced to an Asplund freeness of approximately 35 seconds in a 10-inch single disk refiner.

Washing Pulp

The fiber of each of the two pulp yields was divided into three portions. One portion was washed with water at 130° F; one, with a 1 percent sodium hydroxide solution; and one, left unwashed for reference purposes. Each washing treatment consisted of three cycles, 30-minute washings and 30 minutes of draining. The sodium hydroxide treated pulp was further washed with distilled water, which resulted in a pulp pH of 7.0 to 8.0.

Boardmaking

Wet-formed and dry-formed 1/8-inch high-density (1.0 specific gravity) hardboards were made from each of the six pulps.

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[1] *Maintained at Madison, Wis., in cooperation with the University of Wisconsin.*

Mats for the wet-formed boards were produced in a defibrator freeness tester (8-1/2-in. diameter) with 0, 1, or 2 percent of a water-soluble liquid phenolic resin of the type commonly used in board manufacture, with 0.75 percent rosin size, with 1 percent alum, and with sufficient sulfuric acid to reduce the pH of the pulp slurry to 4.5. All additions were based on the ovendry weight of the fiber.

Dry-formed mats were made in a 23- by 25-inch mold with each of the six pulps. In addition, one-half of each pulp was treated while still wet with a dilute sulfuric acid solution to reduce the pH to 4.5 before treating with either a 2 or a 4 percent water-soluble phenolic resin and 0.75 percent wax size.

All boards were hot-pressed at 385° F using a cycle typical for the particular process with a pressing time of 6 minutes for the wet-formed and of 2.5 minutes for the dry-formed boards.

Evaluations

Number and size of specimens cut from the hardboards for evaluating properties were the following: Five 2- by 4-1/2-inch for modulus of rupture; five 2- by 2-inch for internal bond; and ten 6- by 1/2-inch for dimensional stability. Modulus of rupture and internal bond were determined in accordance with ASTM D 1037.[2]

To eliminate errors in measurement due to compressing or crushing of the linear dimensional stability specimens, stainless steel balls, 1/8-inch in diameter, were embedded with epoxy adhesive in the ends of each specimen. These specimens were initially conditioned to equilibrium for 30 days at 50 percent relative humidity and 72° F. Two specimens of each configuration were then exposed to each of the following conditions: 65 percent relative humidity (R.H.), 80 percent R.H., 90 percent R.H., and immersion (water soaking) for 30 days, all at 80° F. Specimen length, thickness, and weight were recorded before and after each of these exposures.

Alcohol-benzene was used as an extractant on each pulp before and after washing. The extraction gives a measure of the resins, fats, waxes, and certain ether-insoluble components in pulps (table 1).

RESULTS

A summary of the data for board performance is in figures 1 through 10; the wet-formed and the dry-formed boards are shown separately because of the differences in the variables and the inherent differences between the two types of boards. The base line indicates the values obtained under usual boardmaking conditions (control conditions).

Washing Pulp

It was felt that some of the extractives in the pulp, for example the tannin-like substances that are prominent in the oaks, might act as a barrier to the curing of the resin. The data obtained, however, showed no improvement in properties due to the washing treatments although the alcohol-benzene solubility indicated that a large portion of the extractives was removed by the washings. The washing with hot water had little influence

[2] *American Society for Testing and Materials. Standard Methods of Evaluating the Properties of Wood-Base Fiber and Particle Panel Materials, D 1037. Philadelphia, Pa., 1972.*

on the properties of the wet–formed boards, but improved the effect of additional resin on strength properties of the dry–formed boards. Although washing with sodium hydroxide removed more of the extractives than did the washing with hot water, the board properties were adversely affected.

Adjusting pH of Pulp to 4.5

In the dry–formed boards, adjusting the pH for both unwashed pulps to 4.5 before resin treatment improved modulus of rupture, modulus of elasticity, and linear stability of all boards and the internal bond strength of those only from the high–yield pulp. With the washed pulps, adjusting the pH to 4.5 had an adverse effect on board strength, but had a favorable effect on linear movement.

In the wet–formed boards the pH had to be adjusted to 4.5 to effectively retain the resin and fix the size on the fiber. The pH adjustment apparently makes the resinous sub–stances in the pulps effective by possible cross–linking or by precipitating the desirable substances onto the fibers. Further investigation is indicated for pH adjustment to establish the optimum pH for use with this or other resin systems. Other recent work by Nelson [3] at this Laboratory has indicated that this optimum may vary with type of resin binder.

Pulp Yield

Lowering the pulp yield from 88 percent to 80 percent improved the bending strength and modulus, internal bond, and thickness swelling for both the wet– and dry–formed boards except for those made with sodium hydroxide–washed pulp. In these, however, linear dimensional movement was increased.

Resin Content

All properties were improved by adding resin. The wet–formed boards benefited very little when the resin content was increased from 1 percent to 2 percent. The dry–formed boards, however, exhibited substantial improvement of properties when the resin content was increased from 2 to 4 percent. The improvement in dimensional stability, both length and thickness, however, was not evident at 90 percent relative humidity, but was very much in evidence at the water–soak conditions.

Combination of Variables

The interactions of the variables in combination with one another offer improvements not possible when considering each variable separately. For example, increasing the resin to 4 percent in the dry–forrned boards increased the modulus of rupture very little, but effectively reduced dimensional movement. Combining the increase in resin with a pH adjustment to 4.5 provided a 50 percent increase in bending strength, and reduced the linear movement an additional 20 percent.

It is evident that adjusting the pH to about 4.5 provides an environment more compatible with the resin, and results in more efficient use of the resin.

Proceeding a step further with the modifications by reducing the yield to 80 percent in addition to the other changes improved the strength an additional 15 to 20 percent, but increased the linear movement almost 50 percent, an undesirable level.

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[3] *Nelson, Neil D. Effects of wood and pulp properties on medium-density, dry–formed hardboard. Forest Prod. J. 23(9) 72-80, 1973.*

When considering the wet-formed boards, no interactions of variables proved more beneficial to all properties than those encountered with boards formed under conventional conditions. This was because the pH is normally adjusted, thus taking advantage of the resin present.

CONCLUSIONS

Wet-formed high-density hardboards that meet commercial standards can be made from 100 percent red oak high-yield pulp by using 1 percent phenolic resin. The dimensional movement is somewhat higher than that for most boards, but this can be minimized by raising the resin content to 2 percent.

Dry-formed boards can be upgraded to meet commercial standards by reducing the pH to 4.5 for the particular resin system used in this study and by increasing the phenolic resin from 2 to 4 percent. Lowering pulp yield is beneficial for board strength, but undesirable for good linear stability. Washing oak pulp to remove some of the extractives does not improve board characteristics.

Trade or proprietary names are included for the benefit of the reader and do not imply any endorsement by the Forest Service, U.S. Department of Agriculture.

Table 1.--Extractives before and after washing treatments measured by alcohol-benzene solubility of pulps

Condition	Extractives at pulp yield of--	
	88 percent	80 percent
Before washing	17.5	25.5
After washing with hot water	6.8	10.5
After washing with sodium hydroxide	3.9	6.5

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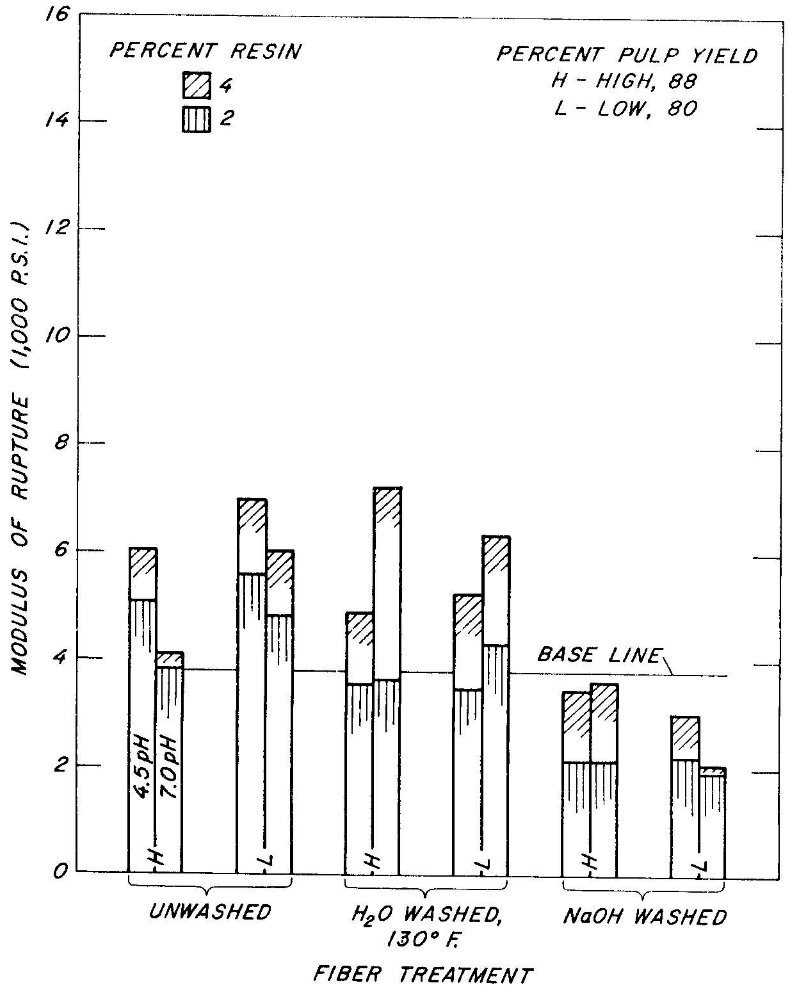

Figure 1.--Relationship of modulus of rupture to fiber treatment of dry-formed red oak hardboards. (Base line, control.)

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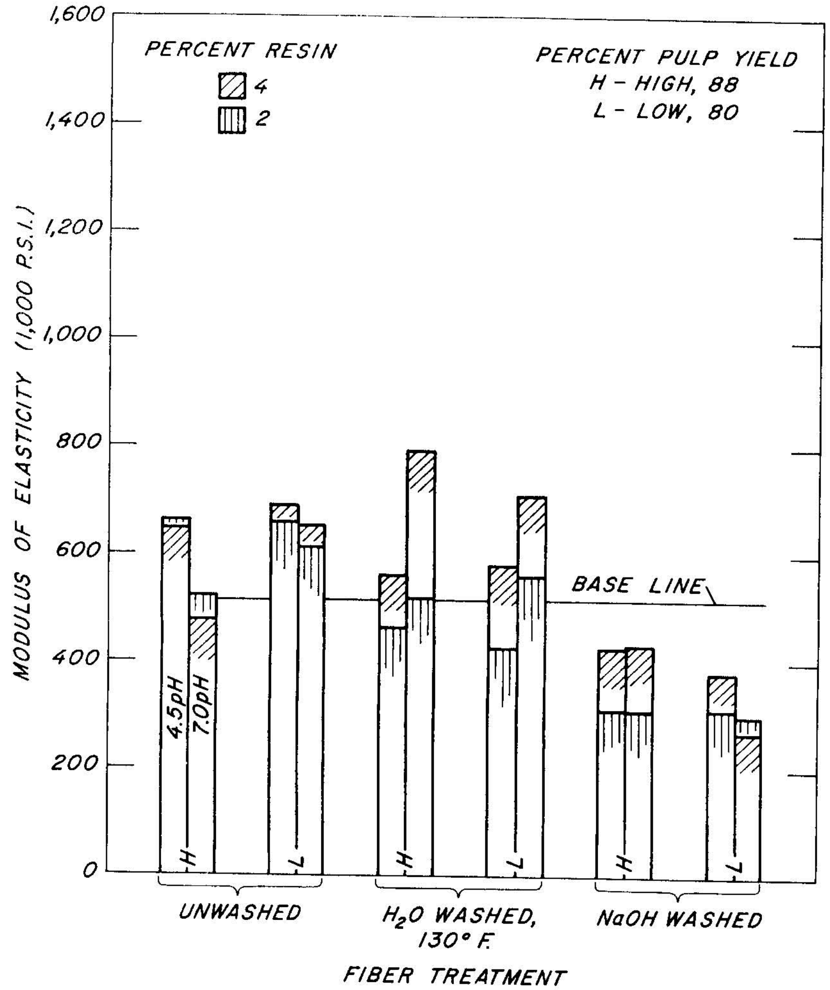

Figure 2.--Relationship of modulus of elasticity to fiber treatment of dry-formed red oak hardboards. (Base line, control.)

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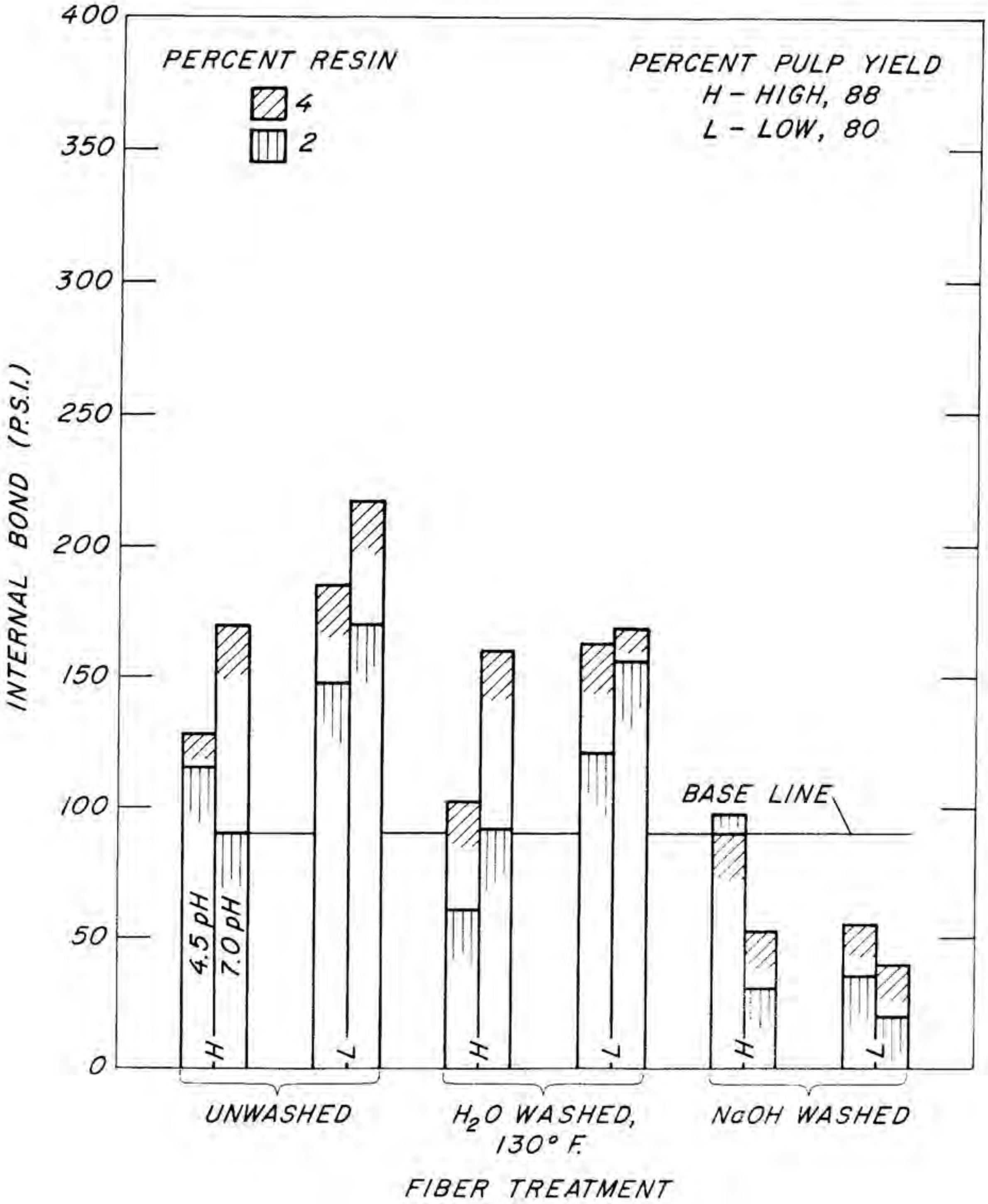

Figure 3.--Relationship of internal bond to fiber treatment of dry-formed red oak hardboards, (Base line, control.)

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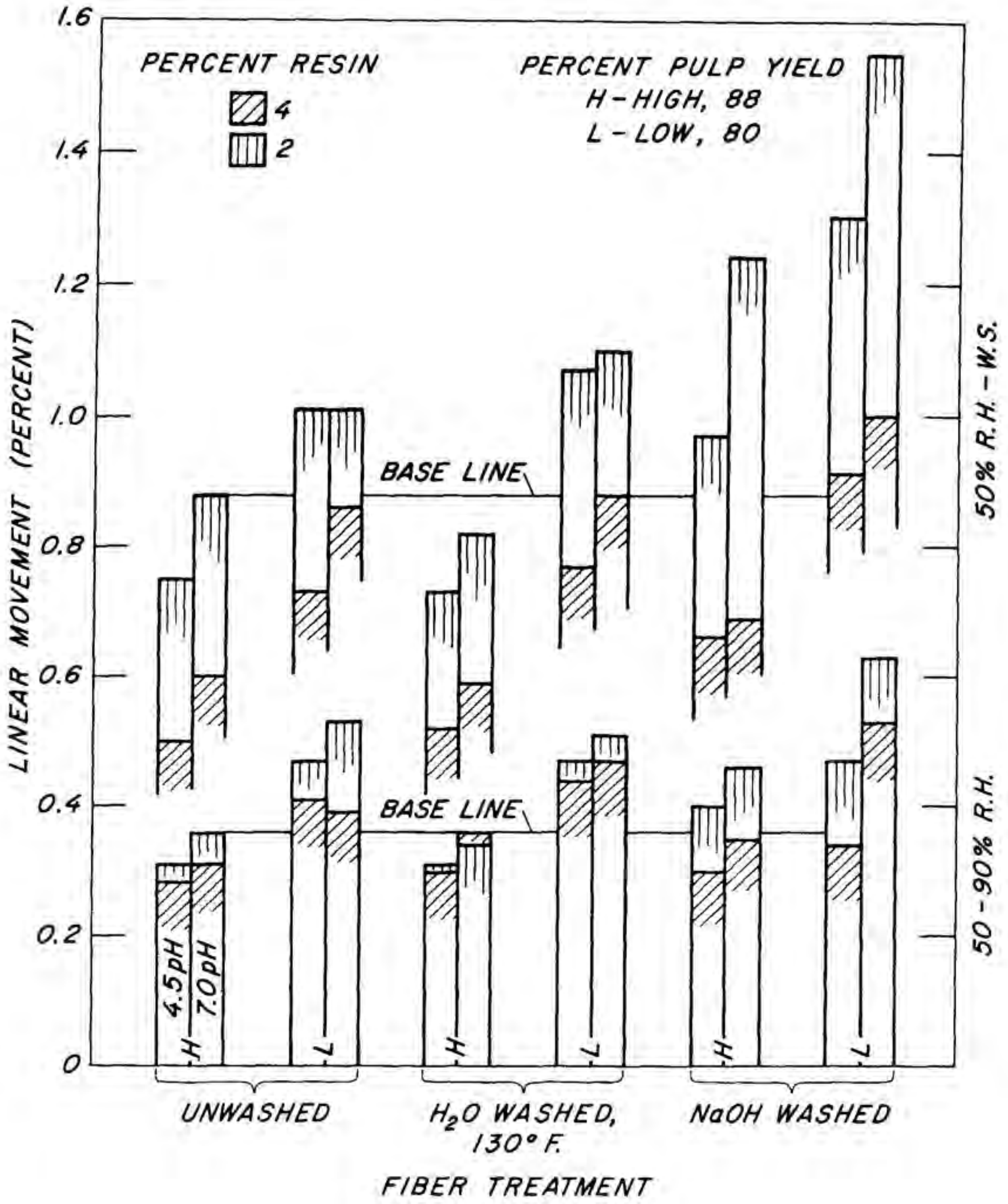

Figure 4.--Relationship of linear movement to fiber treatment of dry-formed red oak hardboards. (R.H., relative humidity; W.S., water soak; and base line, control.)

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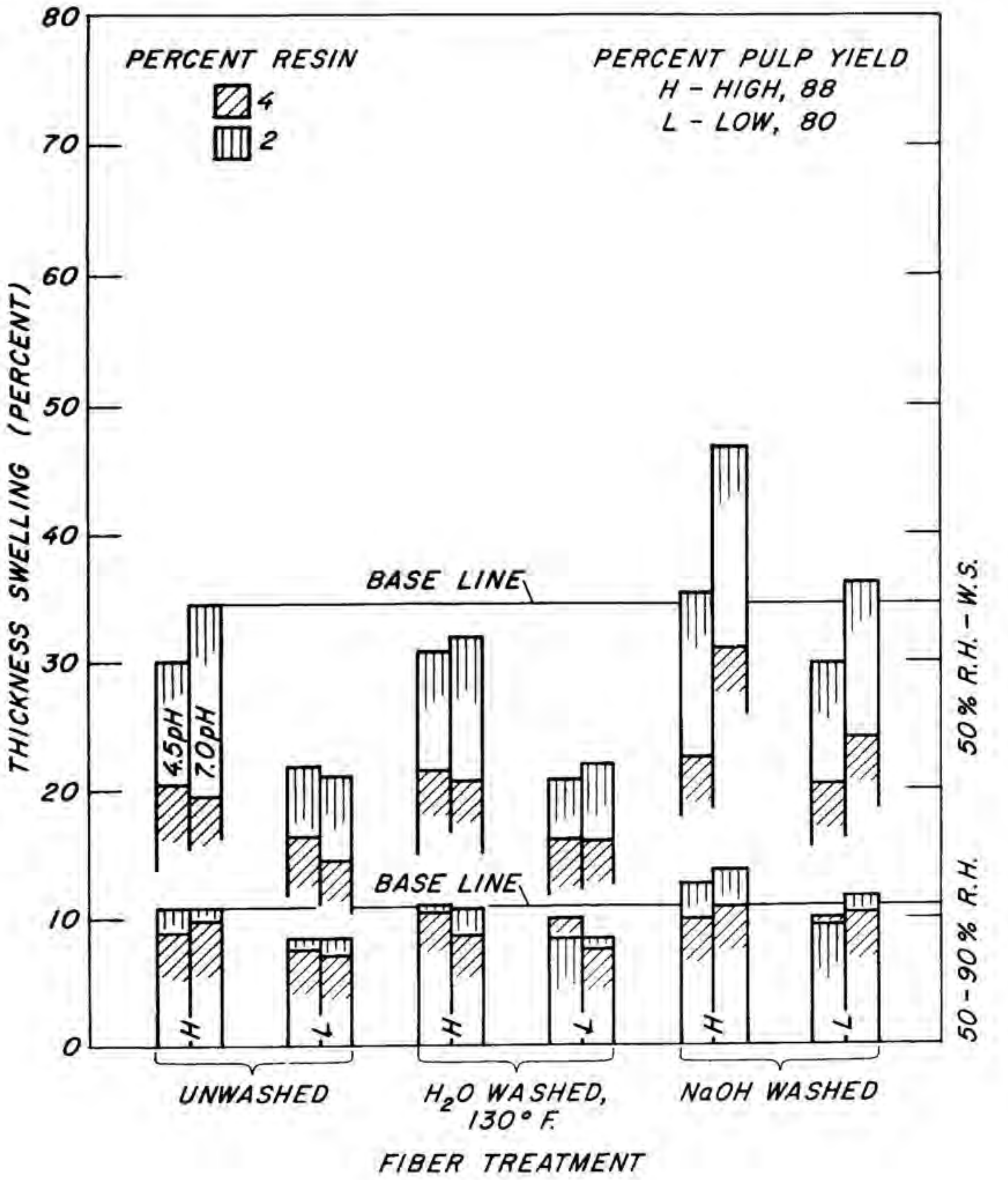

Figure 5.--Relationship of thickness swelling to fiber treatment of dry-formed red oak hardboards. (R.H., relative humidity; W.S., water soak; and base line, control.)

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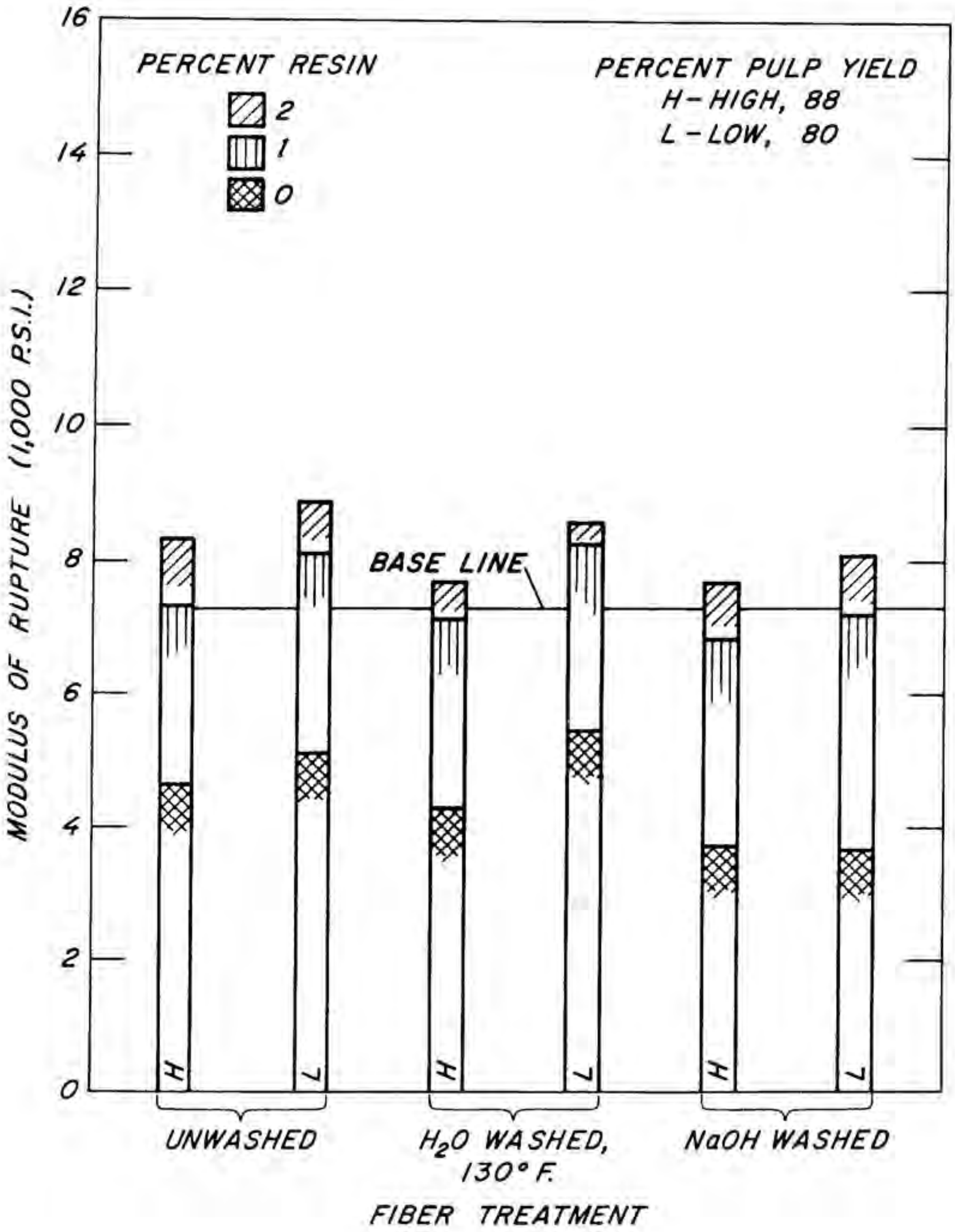

Figure 6.--Relationship of modulus of rupture to fiber treatment of wet-formed red oak hardboards, (Base line, control.)

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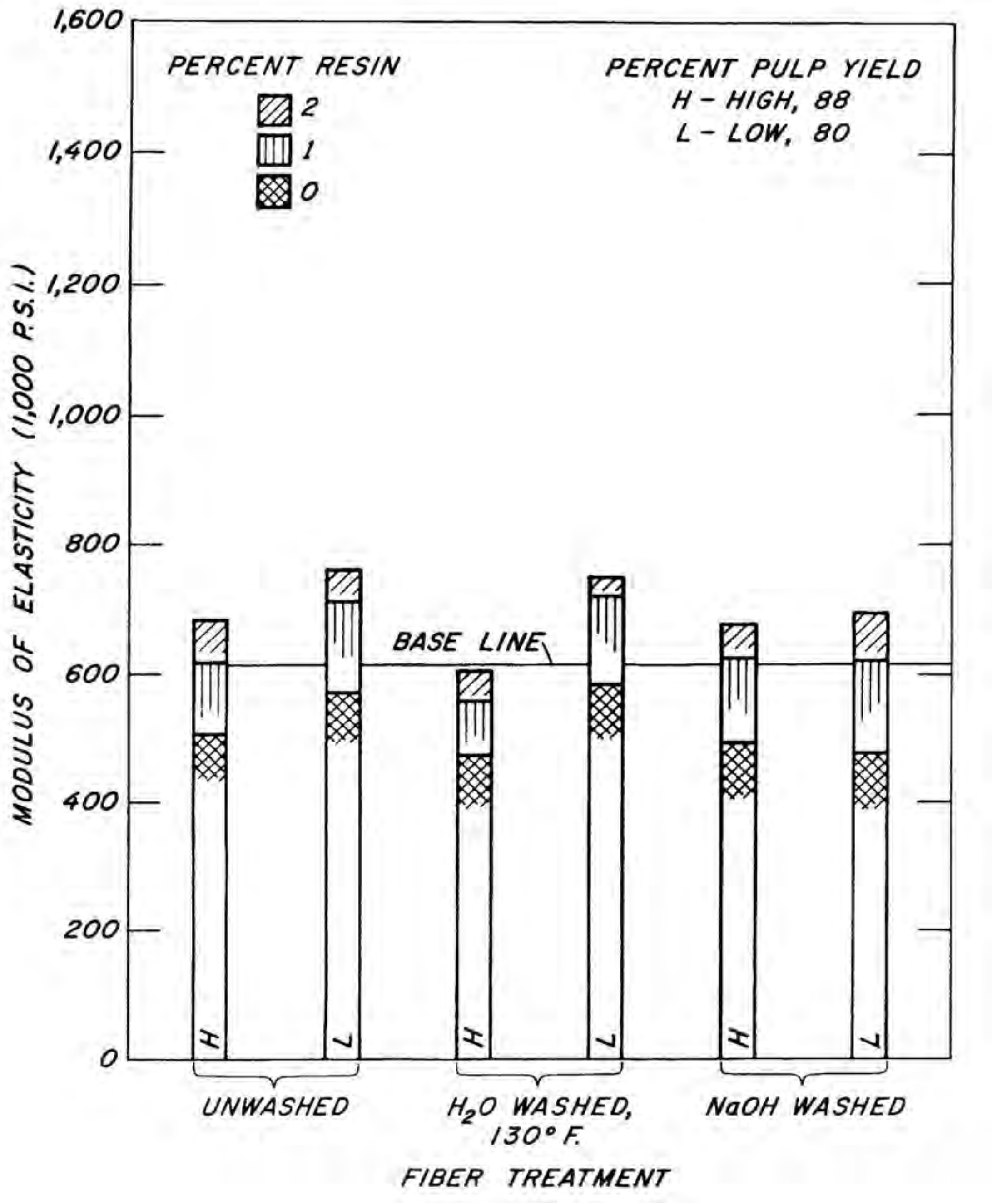

Figure 7.--Relationship of modulus of elasticity to fiber treatment of wet-formed red oak hardboards. (Base line, control.)

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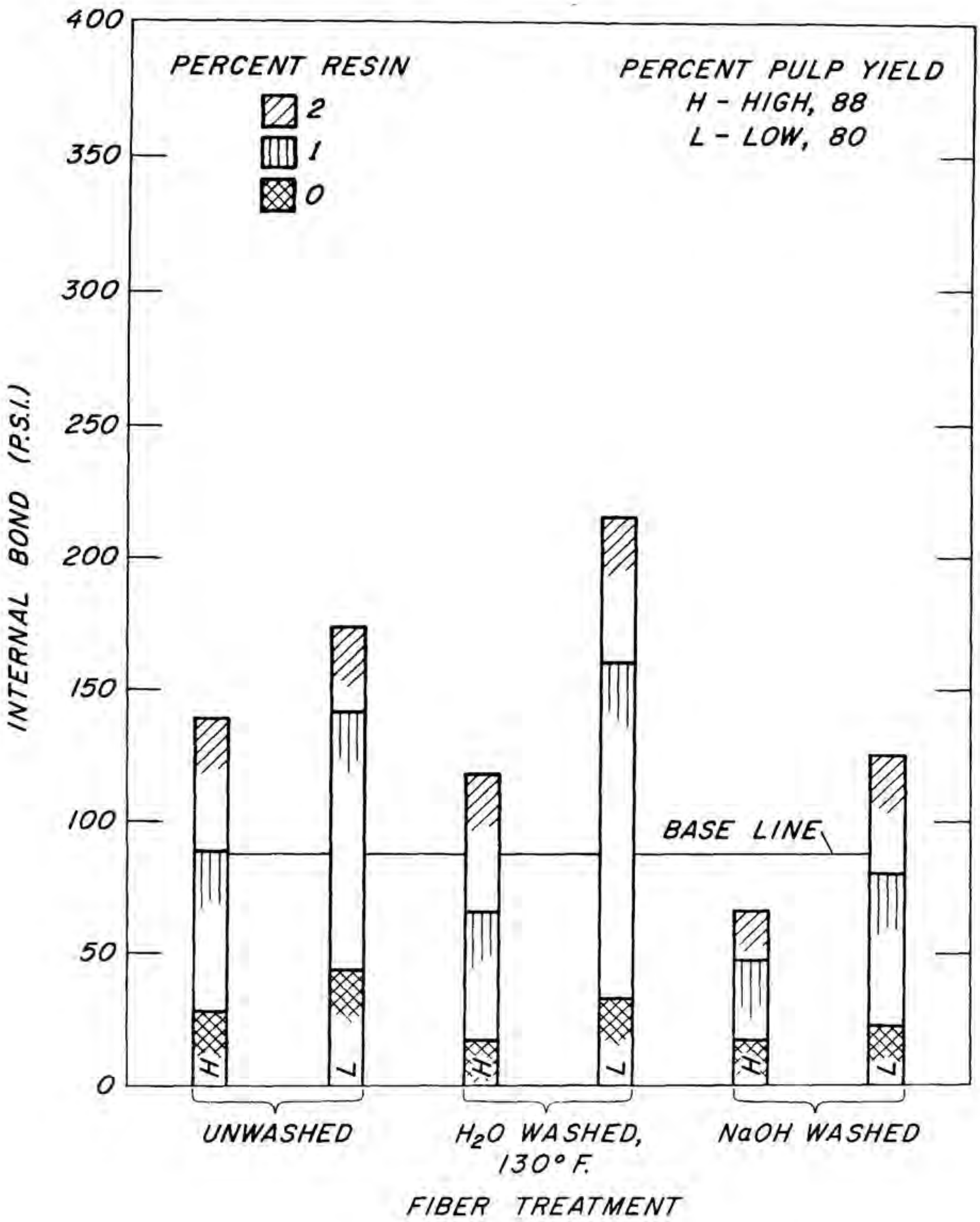

Figure 8.—Relationship of internal bond to fiber treatment of wet-formed red oak hardboards. (Base line, control.)

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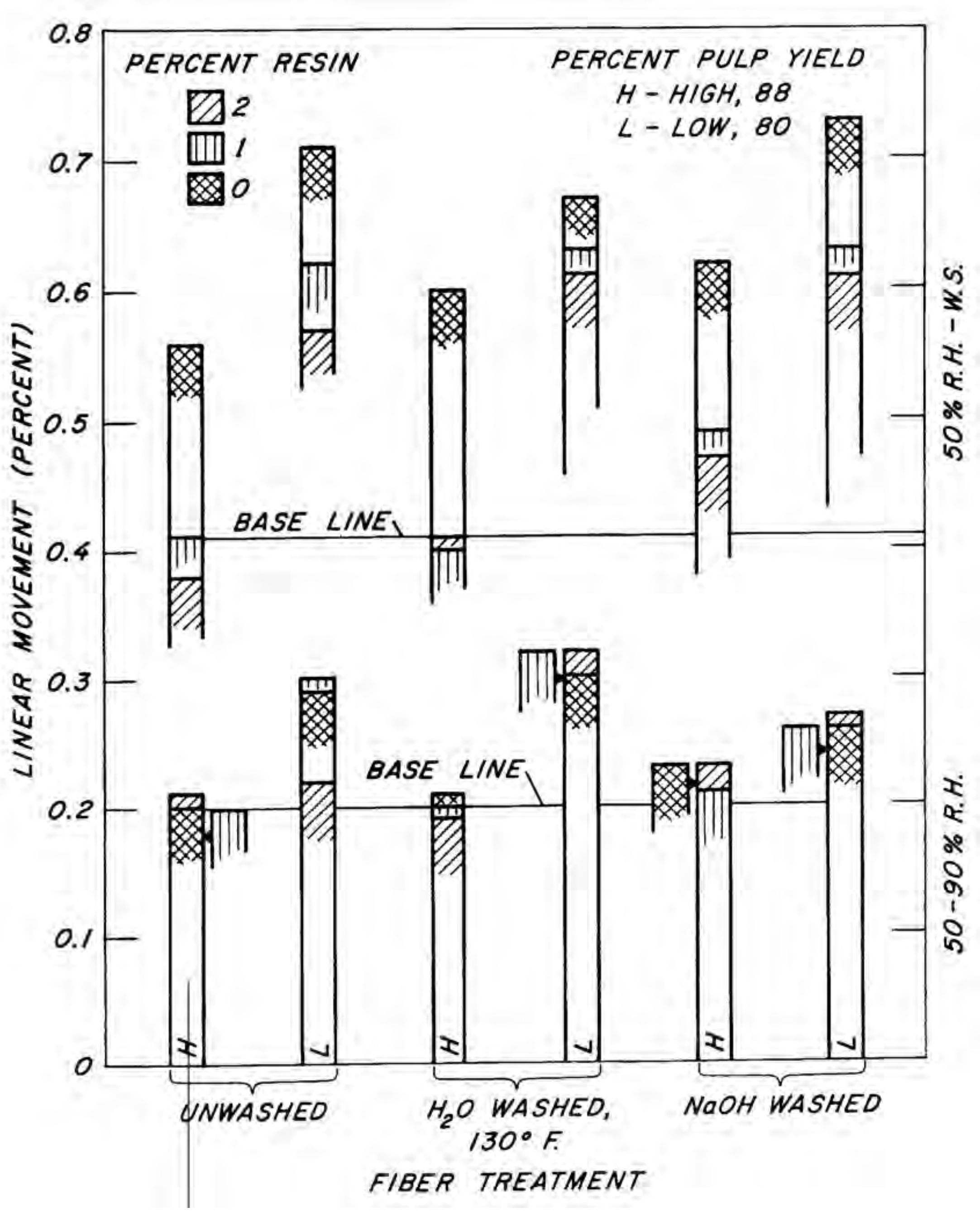

Figure 9.--Relationship of linear movement to fiber treatment of wet-formed red oak hardboards. (R.H., relative humidity; W.S., water soak; and base line, control.)

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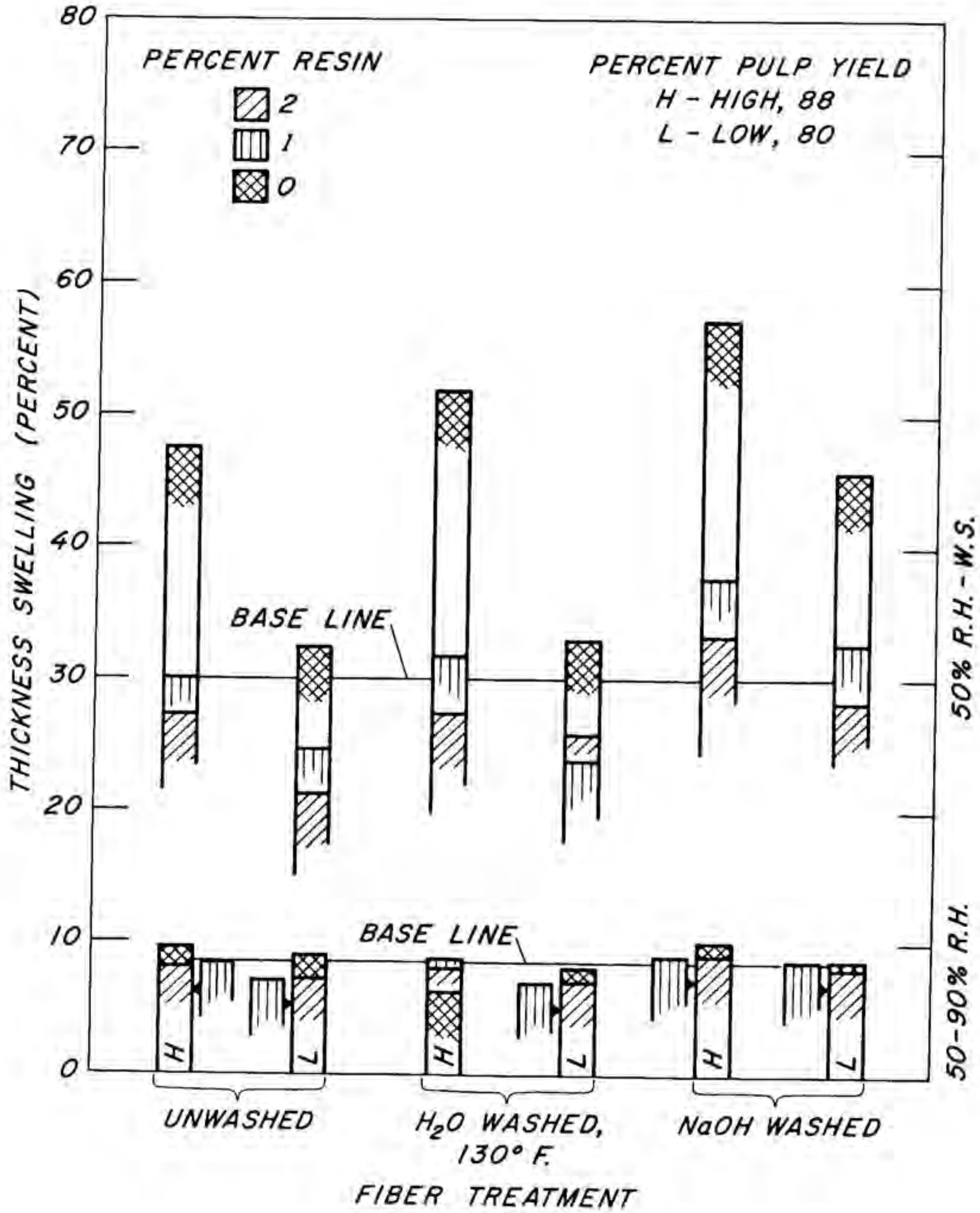

Figure 10.--Relationship of thickness swelling to fiber treatment of wet-formed red oak hardboards. (R.H., relative humidity; W.S., water soak; and base line, control.)

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