THE EFFECT OF BROWN STAIN ON DRYING CHARACTERISTICS OF SUGAR PINE--PRELIMINARY OBSERVATIONS

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Introduction

Brown stain is a well known problem to those drying sugar pine lumber. This discoloration which occurs during kiln drying varies in color from yellow to a dark brown. While it is usually limited to a board's surface or the outer few hundreds of an inch it can occur across the entire thickness in severe development. In sugar pine the stain develops in both heart- and sapwood; however, it often fades with time in the latter. Although the stain is usually associated with the drying of green material it can occur with partially air dried lumber. It is also a frequent problem with lumber that has been rewetted by rain or fog.

Early studies on brown stain by the Western Pine Association established that the length of time between felling a log and its sawing was an important factor determining brown stain severity and that the amount of stained material increased as log storage time increased (Rasmussen, 1952). Later studies revealed that the length of solid piling after sawing and before sticking was an even more important factor (Stout, 1950). The amount of stained material again increasing as the length of solid piling increased. Since stain will develop during kiln drying on any material which has been exposed to air for some time, partially dried logs, logs containing shake or splits and areas around knots are particularly susceptible.

The pattern of stain development quickly taught kiln operators to avoid using kiln conditions of high dry or wet bulb temperatures or any conditions which might lead to condensation on lumber. Operators were thus advised to keep initial dry bulb temperatures below 130°F, to use as large a wet bulb depression as possible without causing checking and to keep the wet bulb temperature below 120°F throughout drying (Knight, 1959; Rasmussen, 1961). Such conditions naturally lengthened drying time and in spite of these precautions stain continued to be a problem at times.

The losses due to brown stain in sugar pine were significantly reduced when the Western Pine Association, through laboratory and field tests, found that dipping in buffered aqueous solutions of sodium azide could prevent brown stain (Stutz, 1959 and 1961). Later research in Canada, on Eastern white pine, showed that dipping in sodium fluoride solutions was also effective (Cech, 1966; Catterick & Gillies, 1966).

Sugar pine brown stain is now known to be enzymatically initiated and is dependent upon a complex combination of moisture content, temperature and length of exposure to air (presumably oxygen) (Stutz, 1959). The stain probably occurs from an oxidative polymerization of certain water soluble extractives such as tannins and phlobaphenes which accumulate in the surface layer of the boards during drying (Millett, 1952).

Purpose

The results presented in this paper were obtained from a portion of a study designed to test the effect of conditioning for stress relief on brown stain development in sugar pine.

Materials and Procedures

Eight 5/4-inch thick by 10-inch by 10-foot sugar pine boards were selected from sinker stock at a cooperating mill. Four boards were dipped in a commercial chlorinated phenol solution for blue stain control; the remaining four boards were not dipped.

Following shipment to our Laboratory each 10-foot board was cut into six 19.5-inch-long samples. Two one-inch-long wafers were also cut in order to calculate each board's initial moisture content (Figure 1). The six samples from each board were then distributed at random into 3 experimental kiln charges; each kiln charge thus had two samples from each board. The ends of each sample board were carefully sealed to prevent excessive drying from the ends. The sample material was solid piled in plastic bags and stored in a cold room (35°F).

Each kiln run was carried out in an experimental micro-kiln using the schedule described in Table 1. Air velocity at the entering air side was 100 feet per min. No fan reversal was used due to the extremely short length of air travel across the load. Each board was weighed at regular intervals during drying to obtain drying curves.

After each kiln run, the two sets of specimens (eight samples each) were conditioned using one of the following three conditioning treatments: (1) No conditioning, (2) Cooling for six hours followed by conditioning at 130°F wet bulb for six hours, (3) Conditioning at 160°F wet bulb for six hours immediately after drying.

Table 1. Kiln schedule.

Time (hrs)	Dry Bulb Temperature (°F)	Wet Bulb Depression (°F)	EMC (%)
0-12	115	5	16.2
13-24	120	10	12.1
25-36	125	15	9.7
37-48	130	20	8.0
49-60	135	25	6.8
61-70	140	30	5.8
73-84	145	35	5.0
85-96	150	40	4.2
97-108	155	45	3.6
109-finish	160	50	3.2

The order in which the material from each kiln charge was allocated for conditioning is given in Table 2. The two sets of specimens not conditioned were used as control material. Conditioning treatment 3 was selected as being representative of current commercial practice for sodium azide-dipped lumber, while treatment 2 was chosen to provide a lower temperature which might be more appropriate for non-dipped lumber. Conditioning temperatures were obtained by closing the heating coils and adjusting the wet bulb to the desired temperature.

After conditioning, two moisture content wafers and a one-inch-long case-hardening specimen were cut from both the conditioned and non-conditioned boards (Figure 1).

Table 2. Conditioning schedules.

Conditioning Treatment No.	Specimen Sets from Kiln Runs	Conditions		
		Cooling	Wet bulb	Time
1	1 and 3	None	None	None
2	1 and 2	6 hr	130°F	6 hr
3	2 and 3	None	160°F	6 hr

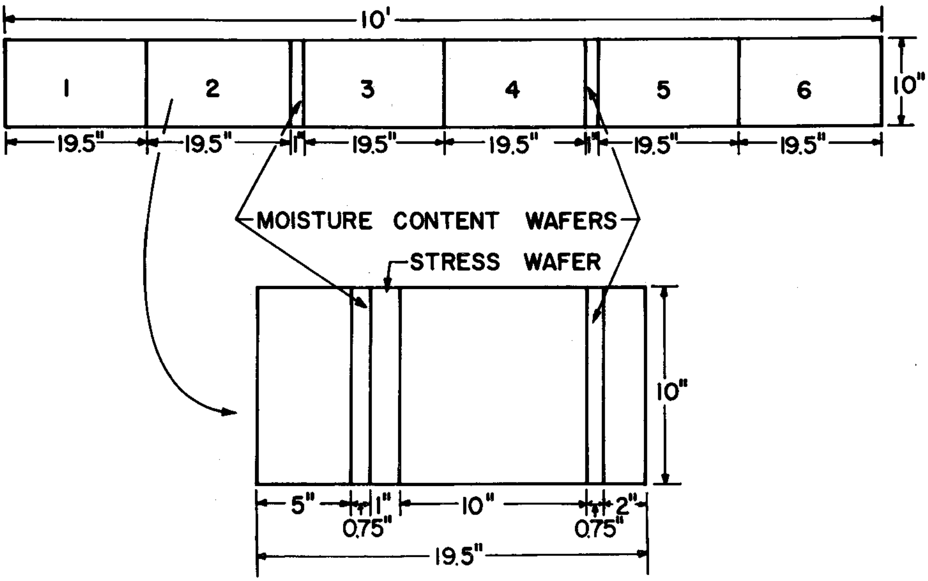


Figure 1. Sample location.

Results and Discussion

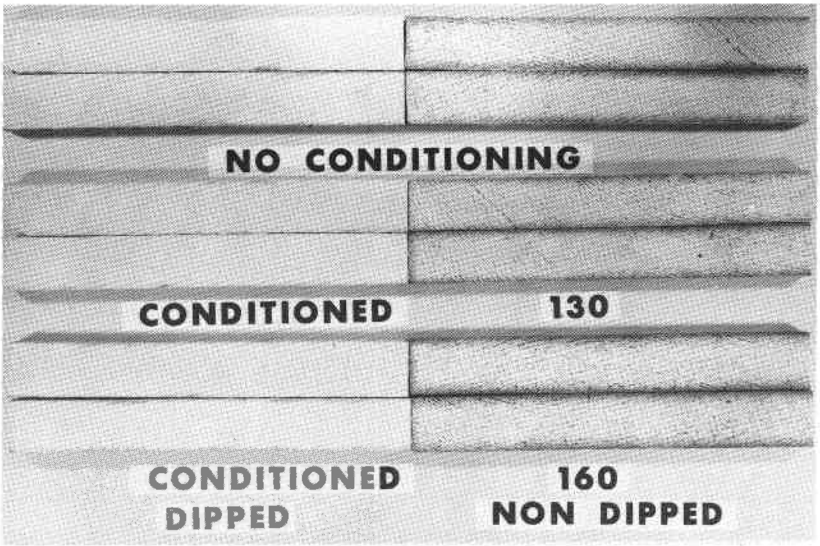
Stain Development

A significant difference in brown stain development was observed between the boards dipped for blue stain control and those not dipped. Dipped boards showed slight staining or no stain while non-dipped boards were always severely brown-stained. The partial control of brown stain by chlorinated phenol solutions has been shown before (Stutz, 1959). Typical examples of surfaced boards and an end grain view are given in Figures 2 and 3, respectively.

No apparent difference in the intensity of stain was noted between the non-conditioned and conditioned boards, regardless of the conditioning treatment used. There appeared to be slightly less stain in the lumber dried in the first kiln charge than in the second and third charges, due, probably, to the longer periods of solid piling in charges 2 and 3.

Drying Rate

The development of brown stain was found to affect the drying rate of the boards. Non-dipped boards, which had heavy brown stain, dried at a much slower rate than the dipped, non-stained boards. This is clearly shown in Figure 4 where the drying curves for a dipped and non-dipped board are plotted. The time required to dry to a moisture content of 15 percent for these two boards was 5 days 20 hours and 8 days 18 hours for the dipped and non-dipped boards respectively.



igure 2. Surfaced boards showing differences in brown stain development between dipped and non-dipped boards.

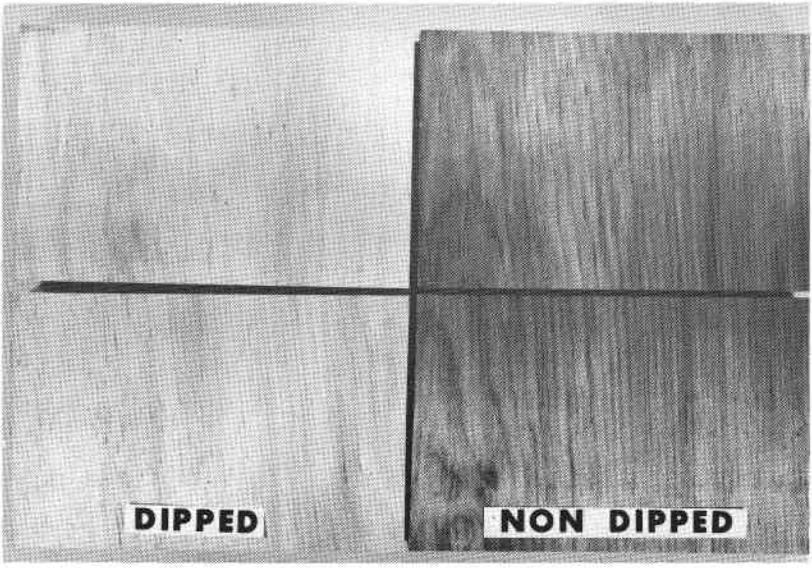


Figure 3. End grain view of stain development.

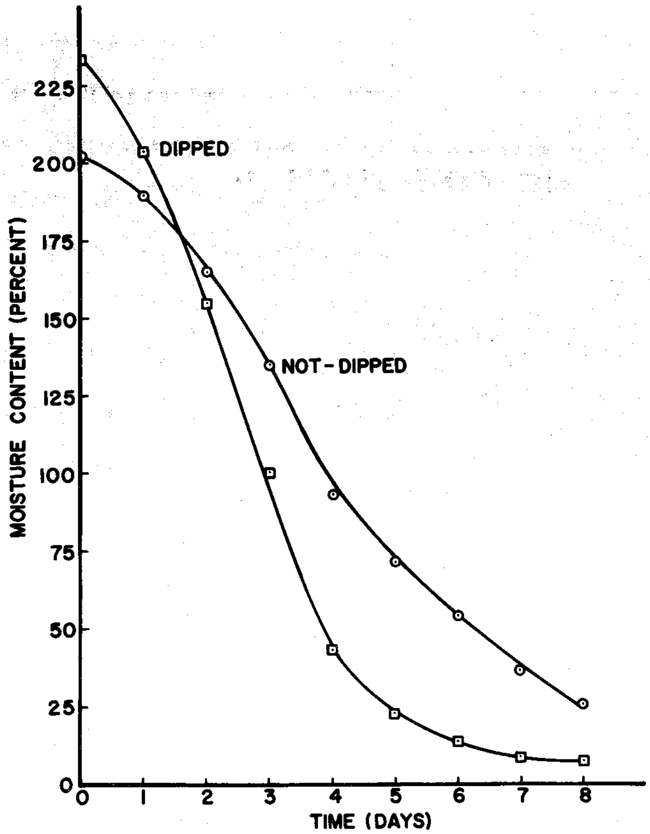


Figure 4. Drying curves

The rather wide variation in initial moisture contents made a direct comparison between all of the non-stained and stained boards impossible. Manson (1951), however, describes a procedure for calculating a "drying rate factor" which has the advantage of removing variability in moisture content thus permitting one to compare the drying behavior of boards with different moisture contents. The drying rate factor is calculated as follows:

$$\text{Drying Rate Factor} = \frac{\dfrac{\text{Initial Moisture Content - Final Moisture Content}}{\text{Total Drying Time (Days or hours)}}}{\dfrac{\text{Initial Moisture Content + Final Moisture Content}}{2}}$$

The drying rate factor for all brown-stained boards for the first 8 days of drying was 0.1914 compared to 0.2240 for the non-stained boards. On a percentage basis the brown-stained boards dried 14.6 percent more slowly. It is apparent that such an effect could significantly

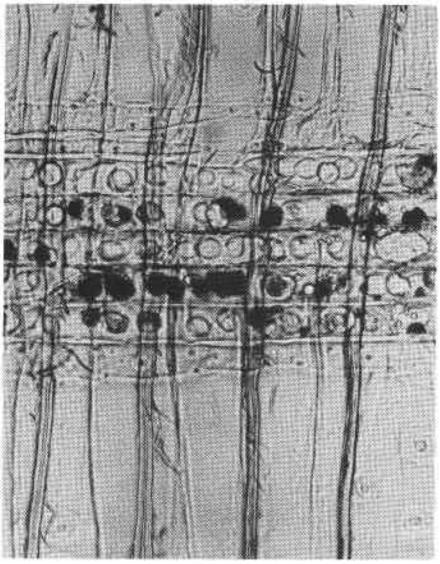


Figure 5. Radial section illustrating deposition of resinous substances in brown-stained areas.

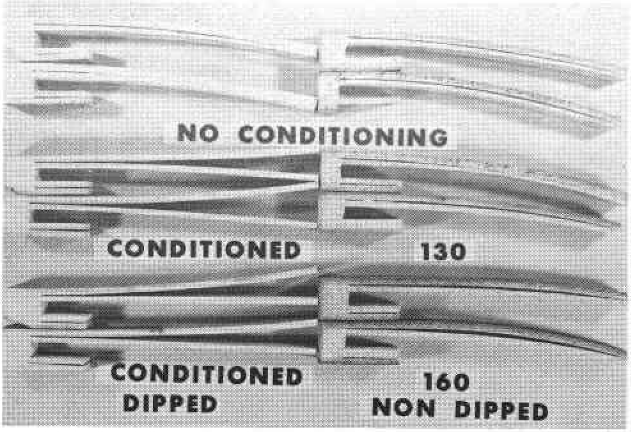


Figure 6. Casehardening development after various conditioning treatments.

influence the final moisture content, i.e., drying uniformity. The limited number of sample boards used in this study should, however, be emphasized. The effect that varying intensities of stain have on drying rate is unknown. It would appear, however, that the retardation of drying due to the brown stain would increase as stain intensity increases.

In an attempt to determine why brown stain affects drying, a microscopic examination of the brown-stained material was made. Brown-stained areas were observed to have a large number of dark resinous accumulations in the ray cells (Figure 5). The cell walls from brown-stained areas also had a darker yellow color than did cell walls from non-stained areas. As expected, the concentration of accumulations was greatest near the board surface.

The resinous material most likely occlude not only the pit pores but the cell walls of the wood, thus impeding moisture diffusion. An analogous situation occurs in other species where the naturally occurring extractives have been shown to significantly affect moisture movement (Resch and Ecklund, 1964).

Stress Relief

Typical internal stress specimens are shown in Figure 6. The control, or non-conditioned samples, showed severe casehardening. Similarly, the non-dipped (stained) boards which were conditioned also showed severe casehardening.

The poorer response of the brown-stained boards to the conditioning treatment substantiates the observations on drying rate, i.e., that brown stain retards moisture movement. In this case, moisture movement into the board is slowed rather than a movement outward.

Conclusions

1. Dipping for blue stain control is at least partially effective in reducing the occurrence of brown stain.

2. The development of brown stain during kiln drying decreases drying rate.

3. The retardation of moisture movement is apparently caused by the deposition of dark resinous substances on the internal surfaces of wood.

4. Brown stain does not become more severe as a result of conditioning at the conditions studied.

Literature Cited

Catterick, J. W. and Gillies, G. B. 1966. Production control of brown stain. For. Prod. J. 16(11):16.

Cech, M. Y. 1966. Brown stain in white pine. For. Prod. J. 16(11): 23-27.

Knight, E. 1959. The elimination of sugar pine brown stain. Proc. 11th Annual Meeting Western Dry Kiln Clubs, Eureka, California, May 7, pp. 25-30.

Manson, B. C. 1951. Drying rate and drying rate factor. California Redwood Association Res. Project Index 3.20432, Interim Report A.

Millett, M. A. 1952. Chemical brown stain in sugar pine. For. Prod. J. 2(5):232-236.

Rasmussen, C. A. 1952 (rev.). Age of logs as related to kiln brown stain of sugar pine. Western Pine Assoc. Res. Note No. 4.5112.

Rasmussen, C. A. 1961. Dry kiln operator's manual. USDA Agric. Handbook No. 188.

Stout, A. W. 1950. Storage factors and the occurrence of chemical brown stain in sugar pine. Western Pine Assoc. Res. Note No. 4.5113.

Stutz, R. E. 1959. Control of brown stain in sugar pine with sodium azide. For. Prod. J. 9(12):459-463.

Stutz, R. E., Koch, P. and Oldham, M. L. 1961. Control of brown stain in eastern white pine. For. Prod. J. 11(6):258-260.

Resch, H. and Ecklund, B. A. 1964. A statistical analysis of the variability in the drying rate of redwood. For. Prod. J. 14(9): 430-434.