THE SEGREGATION OF REDWOOD LUMBER AFTER PARTIAL AIR DRYING

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Introduction

Redwood lumber is not an easy species to dry. In addition to having a low diffusivity or drying rate, it is very susceptible to the development of certain drying defects such as collapse, birdseye checking and honeycombing (small dormant buds) and sticker stain. The wood is also extremely variable in nature with the result that different boards exhibit vastly different initial moisture contents, specific gravities, growth rates and extractive contents. As a result some boards, sapwood for example, may readily be dried green from the saw, while other boards are so difficult to dry that they must be air dried for many months before being kiln dried. The length of air drying varies with thickness and ranges from several months to as much as two years. The final kiln drying times range from 5 to 15 days.

Present Segregation Practices

The large variation in drying rates between different boards has compelled the redwood industry to establish a system of lumber segregation at the green chain. The purpose being, obviously, to place boards of reasonably similar drying characteristics into the same sort. While practice varies throughout the industry at least two if not three drying sorts are normally made. These sorts, usually called light, medium and heavy, are based on a number of different factors including:

1. board weight
2. number and distribution of birdseye
3. size and number of water streaks and
4. growth rate, i.e., number of rings per inch

The light sort contains material which is easiest to dry such as the sapwood. The material that is heaviest (highest specific gravity and moisture content), or has large clusters of birdseye or water streaks is placed in the heavy sort. The medium sort contains boards that are intermediate in the above properties.

Generally some 65 percent of the boards are segregated into the heavy sort with the remaining boards being divided about equally between the other two sorts. In mills using only two sorts, the light and medium boards are grouped together. Regarding these practices, it is commonly believed that only a small fraction (10 to 20 percent) of the boards in the heavy sort should actually be classified as the very difficult to dry stock. The remaining 80 to 90 percent actually belong in the medium sort or in an entirely new sort that is somewhere between the medium and heavy sorts. If this is the case then the majority of the heavy sort boards are being dried according to a schedule representative of only 10-20 percent of the total board population. It would seem advantageous, therefore, to further segregate the heavy sort and thus improve the overall drying practice. Although logically sound, this further segregation is not presently practiced as the boards in the heavy are practically indistinguishable from each other.

Overall Purpose

This study is part of a cooperative project, between the California Redwood Association and the University of California Forest Products Laboratory, aimed at improving the drying practice for redwood lumber. This particular study was made to evaluate the feasibility of improving the segregation practice for lumber presently classified as heavy sort. That is, it was desired to devise a means of separating the 10-20 percent of "truly-hard-to-dry" boards from the other 80-90 percent.

Part 1. Variation in drying rate of present mill sorts

The project was started with an initial study which had two objectives, which were to determine:

1. If sufficient variation in drying rate actually exists within both heavy and medium sorts, as presently made, to warrant improved segregation
2. What factors might be employed to improve the segregation practice?

A 104 board sample of 1" x 6" x 8' B & Better of both green heavy and medium material already sorted on the green chain was obtained from Georgia-Pacific's mill at Fort Bragg.[1] The initial weight and moisture content, specific gravity and thickness was determined for each board in addition to metering each with a hand-held capacitance-type meter. The particular meter used had a 0 to 50 micro-amp output rather than a moisture content indication usually found with such meters.

After measuring and metering, the boards were stickered and dried under forced-air type conditions (dry and wet bulb temperatures of 90 and 80, respectively) in a 10,000 board foot experimental dry kiln located at our laboratory. The air velocity was set at 100 fpm. While drying, the boards were periodically weighed and remetered. Once dry, moisture sections were cut from each end of the boards and the board oven-dry weight calculated. Working in reverse it was thus possible to determine the approximate moisture content of the boards at each time of their weighings.

Results of the initial tests showed that there is indeed wide variation in drying rate in both heavy and medium material as presently sorted (Figure 1). As expected some boards in each sort were incorrectly segregated, i.e., a few medium sort boards had been placed in the heavy segregation and vice versa. The extremely wide range of drying times found in the heavy sort was the most significant finding. As it adds credence to the previously stated contention that perhaps those boards taking the longest periods to dry are the only really troublesome material.

The data on weight, moisture content, meter reading and the changes in these variables after various lengths of drying (relative to the initial or green values) were statistically correlated to total drying time in an attempt to establish which variables might be used in the making segregations. Specific gravity and thickness were also included. These regressions showed that it is highly unlikely that one can accurately predict the drying

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[1] The enthusiastic assistance and helpful advice of Louis Andreani and other personnel at Georgia-Pacific, at that time Boise Cascade, is gratefully acknowledged.

time of any given board within the heavy or medium sorts in the green condition (Table 1). Thus, knowledge of a board's initial weight, moisture content, specific gravity and thickness is not sufficient. This was not totally unexpected since a previous study by Resch and Ecklund (1964) reached the same conclusion in addition to showing that extractive content is the single most important factor controlling redwood's drying rate.

The regressions using the data taken after various lengths of drying (Table 2) revealed, however, that a natural segregation process occurs during drying. This is reflected by both the moisture content and meter reading data. The reasonable agreement between these two variables was indeed fortunate since the meter provides a relatively simple way of making any further desired segregation. This agreement was somewhat surprising since most moisture meters are not generally considered to be very accurate at moisture levels above the fiber saturation point (James 1963). Regression equations relating moisture content values to their corresponding meter micro-amp readings (Figure 2) were also made for both the heavy and medium sorts and correlation coefficients (R^2) between 0.670 and 0.822 established.

Table 1. Regression equations for prediction of drying time to 12% moisture content.

Sort		Equation	R^2
Medium		Time to 12% = $31.817 + 2.744\ (Wt_g) - 0.081\ (MC_g) - 77.977\ (\rho_g)^2 - 22.085\ (Thick_g)^2$	0.185
Heavy		Time to 12% = $11.938 + 2.4243\ (Wt_g) + .0440\ (MC_g) - 14.354\ (\rho_g)^2 - 18.436\ (Thick_g)^2$	0.267
Wt_g	=	Weight green	
MC_g	=	Moisture content green	
ρ_g	=	Density (oven dry weight - green volume)	
$Thick_g$	=	Thickness green	

The natural segregation occurring in heavy sort material during drying as indicated by the meter readings is shown in Figure 3. The medium sort showed a similar trend although the variation in values was not as great.

In summary, these results showed that sufficient variation in drying rate exists within both medium and heavy sorts to justify attempts at making a second sort after partial air drying. It was further found that an additional segregation of this nature could be done using a capacitance-type moisture meter. The nature of the material in the present sorts together with the proposed sorts made after partial air drying are shown in Figure 4.

Part 2. Drying characteristics of sorts made after partial air seasoning

A second study was, therefore, started having the following objectives:

1. To gain additional information as to the amount of material which might fall into each of the new sorts
2. To identify the drying characteristics of the new sorts in terms of using accelerated drying schedules and the amount of accompanying degrade.

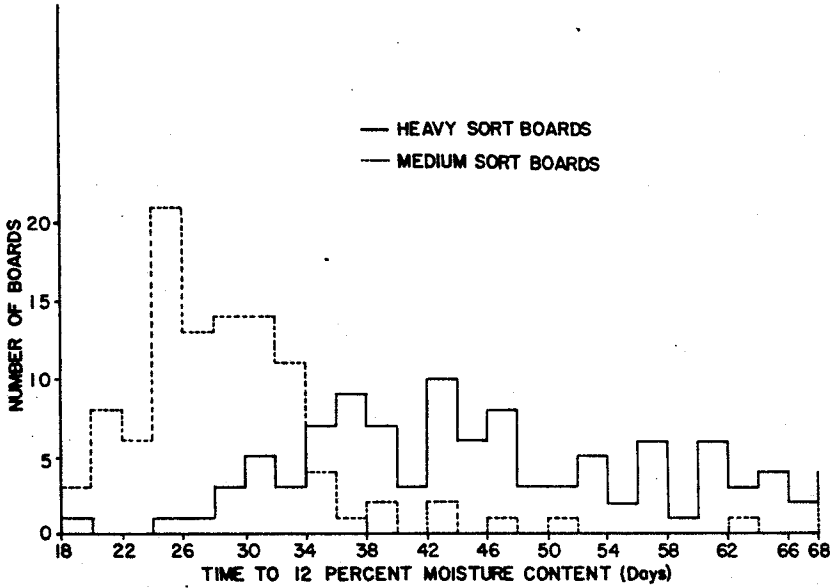

Figure 1. Variation in drying time to 12 percent moisture content for heavy and medium sort lumber.

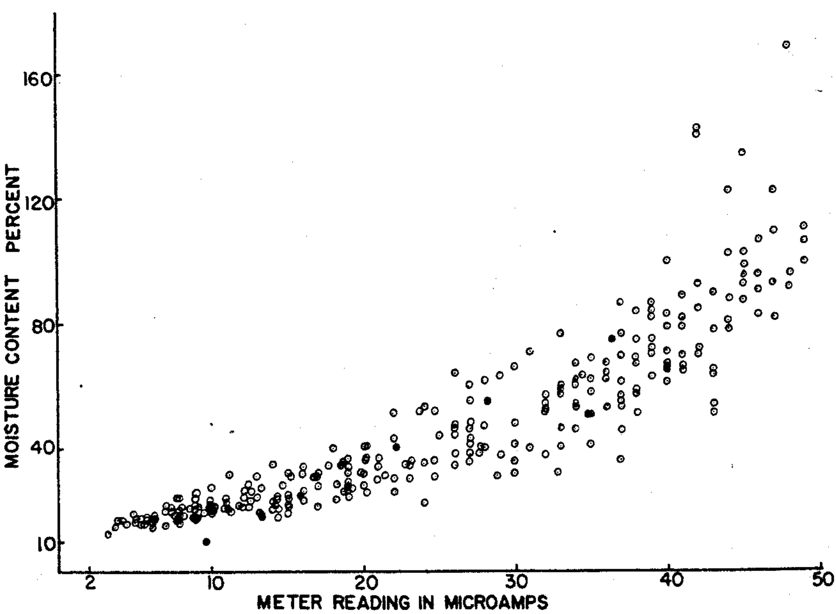

Figure 2. Relationship between moisture content and meter reading values (in microamps) for medium sort boards.

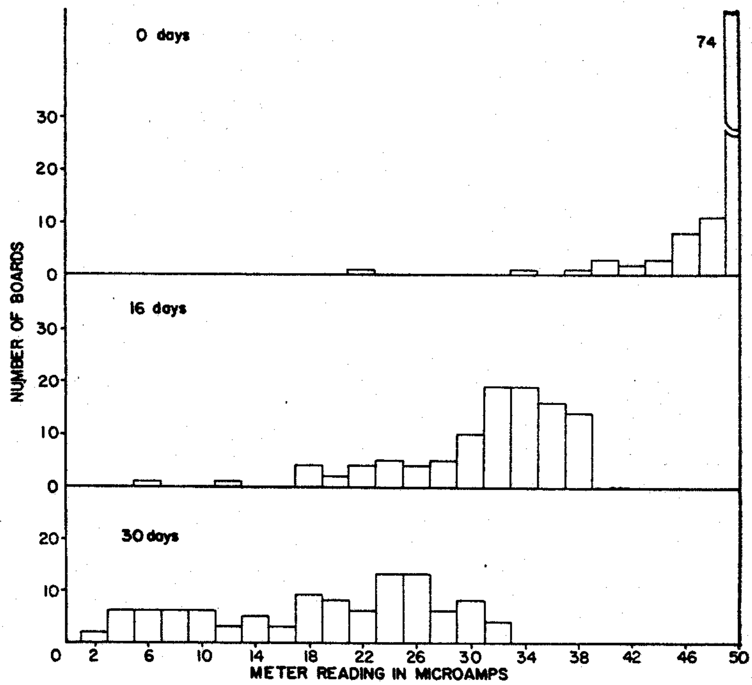

Figure 3. Change in meter reading values with increasing drying time for heavy sort boards, illustrating natural segregation process.

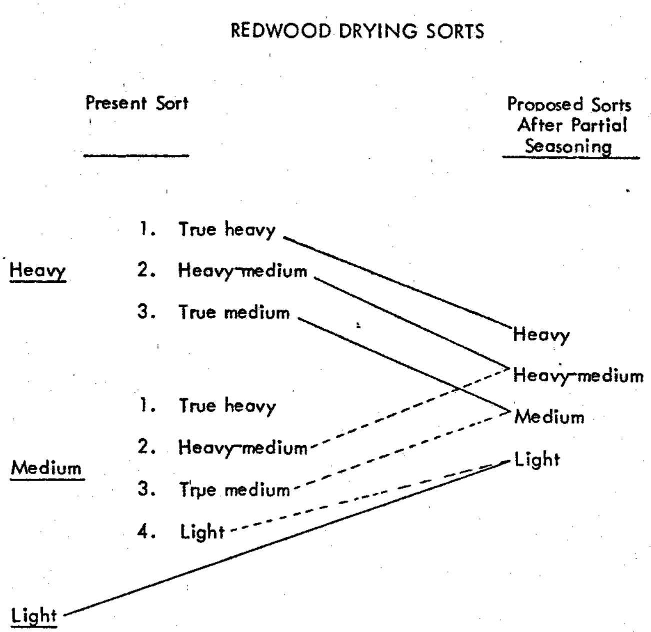

Figure 4. Identification of present drying sorts and types of material each contains together with proposed sorts after partial drying.

Table 2. Correlation coefficients from equations of drying time to 12% moisture content versus indicated test variables.

Sort	Test Variable	Correlation Coefficient (R^2) for data obtained after drying time in days of:					
		0	9	16	23	30	37
Heavy	Weight	0.224	0.419	0.472	0.455	0.360	0.229
	Change in weight[1]	-	0.099	0.853	0.021	0.001	0.028
	Meter reading	0.063	0.197	0.388	0.599	0.749	0.805
	Change in meter reading	-	0.125	0.318	0.549	0.665	0.743
	Moisture content	0.142	0.449	0.640	0.748	0.827	0.844
	Change in moisture content	-	0.053	0.027	0.009	0.000	0.014
Medium	Weight	0.162	0.238	0.227	0.160	0.140	0.098
	Change in weight	-	0.004	0.020	0.060	0.081	0.107
	Meter reading	0.066	0.209	0.333	0.424	0.429	0.390
	Change in meter reading	-	0.184	0.202	0.297	0.188	0.076
	Moisture content	0.090	0.298	0.429	0.416	0.537	0.381
	Change in moisture content	-	0.000	0.005	0.025	0.040	0.058

[1] All changes in weight, moisture content or meter reading reflect change from value at 0 days of drying.

Material for this study was again provided by Georgia-Pacific's mill in Fort Bragg, California and was 1" x 8" - 10 to 14' Clear and Better. Five units (168 boards/unit) of heavy sort placed on the air yard in September and left for 104 days were used in addition to 3 units of medium air dried for 74 days after placement in October.

The units were broken down and every other board metered at mid-length with the hand held capacitance meter.[2] A total of 736 boards were metered and 497 selected for kiln drying. Boards were classified into the new drying sorts on the basis of the meter readings (Table 3). Material for drying was selected so that boards having meter values uniformly distributed throughout the entire range of a given class were obtained.

The distribution of the material in the different sorts is given in Table 4. Of the material originally sorted at the mill as being heavy, approximately 54 percent was resorted as heavy-medium with 30 percent as medium. As hoped, the smallest portion, 15 percent, was placed in the heavy sort. All of this material, thought to be the most difficult to dry was placed on the air yard again for additional air seasoning. Thus, some 84 percent of the heavy was felt to be able to withstand accelerated drying. In the medium sort, some 12 percent was changed to a heavy classification and 26 percent reclassified as light. The vast majority, however, remained as medium. After metering the boards were solid piled and transported to our laboratory for immediate kiln drying.

Drying was carried out in a 10,000 bd ft kiln using the time schedules given in Table 5; these schedules were provided by the cooperating mill. As indicated, the heavy-medium material was dried in 15 days, the medium in 10 days, and the light in 5 days. At the time of this study material being sorted in a normal fashion and kiln dried for equivalent periods of time, i.e., heavy 15 days, medium 10 days would have been left on the air yard an average of 129 and 104 days, respectively.

The total drying time per M bd ft for regular mill sort material and that for material resorted after partial air drying is given in Table 6. Total drying time for regular mill sort material was determined by simply summing the average air and kiln drying periods. Drying times in days/M bd ft for the material segregated after air drying were calculated as follows:

Table 3. Identification of hand meter values and corresponding moisture contents used in establishing partially air dried sorts.

	Original Sort			
	Heavy		Medium	
New Sorts	Meter reading (μ amps)	Corresponding moisture content	Meter reading (μ amps)	Corresponding moisture content
Heavy	≥ 40	≥ 107%	---	---
Heavy-medium	26.0 to 39.9	43 to 107%	≥ 42	≥ 88.4
Medium	≤ 25.9	≤ 43%	24.0 to 41.9	44.7 to 88.4
Light	---	---	≤ 23.9	≤ 44.7

[2] The calibration reading was set at 15 micro-amps.

Table 4. Breakdown of mill sorted material into new sorts and amount selected for kiln drying.

Type of Sort	# of boards in original mill sort		# of boards in sort of metering		% of each meter sort		# boards selected for drying		% distribution of boards selected for drying	
	H	M	H	M	H	M	H	M	H	M
Heavy	490	-	77	0	15.72	0	0	0	0	0
Heavy-medium	-	-	265	29	54.08	11.78	151	29	52.61	13.81
Medium	-	246	148	154	30.20	62.60	136	131	47.39	62.38
Light	-	-	0	63	0	25.60	0	50	0	23.81
			490	246			287	210		

Total number of boards metered = 736

Total number of boards selected for drying = 497

Table 5. Schedules used in drying 4/4 B & Better redwood sorted after partial air drying.

Day	Drying Sort: Heavy-medium		Medium		Light	
	Dry bulb	bulb	Dry bulb	bulb	Dry bulb	Wet bulb
0	120	110	120	100	130	100
1	120	105	125	100	140	110
2	120	105	130	100	150 12 hrs	115
					160	120
3	120	100	140	110	170	120
4	120	100	145	115	160 12 hrs	134
					170	160
5	125	100	150	115	out	
6	126	100	160	120		
7	130	100	160 12 hrs	120		
			170 12 hrs	120		
8	130	100	170 12 hrs	120		
			160 12 hrs	134		
9	140	110	170	160		
10	150	120	out			
11	160	120				
12	160 12 hrs	120				
	170 12 hrs	120				
	160 12 hrs	134				
14	170 12 hrs	160				
15	out					

$$\text{Drying time (days/M bd ft)} = \left(\begin{array}{c}\text{fraction of a M bd ft}\\ \text{in each sort}\end{array}\right)\left(\begin{array}{c}\text{length of air}\\ \text{drying for that sort}\end{array}\right) + \left(\begin{array}{c}\text{fraction of a M bd ft}\\ \text{in each sort}\end{array}\right)\left(\begin{array}{c}\text{length of}\\ \text{kiln time used}\end{array}\right)$$

Total drying time for a M bd ft of heavy stock resegregated after partial air drying was slightly over 121 days as compared to 144 days for heavy material not resorted. This amounts to a reduction in total drying time of 15.7 percent. Medium stock, after a second segregation, dried in 83.3 days as compared to 109 when not resorted. This represents a saving of 23.6 percent. It is obvious from these figures that significant total savings in total drying time can be achieved by using a second segregation.

After drying had been completed, the lumber of each sort was end-color coded and then returned to the mill where it was surfaced (S4S) and resawn into bevel siding. Each piece was then carefully inspected on both faces for the presence of collapse. The total number of pieces in each sort containing collapse, regardless of size or severity, was tallied (Table 7). Only collapse was evaluated, as this is the most common defect in kiln dried redwood.

Twenty-six of the 497 total boards contained some collapse on either their outside faces (external collapse) or on an inside face (internal collapse).

Table 6. Comparison of total drying time per M bd ft for regular drying sorts and sorts made after partial air drying.

Type of material	Length of air drying (days)	Length of kiln drying (days)	Fractional contribution of the sort to total drying time (days)	Total drying time (days)
M bd ft of heavy-sorted after partial air drying into:				
Heavy	129	15	22.64	121.42 days
Heavy-medium	104	15	64.35	
Medium	104	10	34.43	
M bd ft regular mill run heavy	129	15		144 days
M bd ft of medium-sorted after partial air drying into:				
Heavy-medium	74	15	10.48	83.28 days
Medium	74	10	52.58	
Light	74	5	20.22	
M bd ft regular mill run medium	99	10		109 days

Table 7. Number of boards degraded by collapse as seen after surfacing and resawing.

Type of material	# boards containing collapse	Percent of sort degraded
Heavy dried as heavy-medium	12	7.94
Heavy dried as medium	1	0.74
Medium dried as heavy-medium	5	17.24
Medium dried as medium	7	5.34
Medium dried as light	1	2.00
Total	26	

Total percentage of boards containing collapse = 26/497 = 5.23%.

Between the different sorts the medium dried as heavy-medium proportionally suffered the greatest amount of degrade. The heavy dried as heavy-medium was the next most severely degraded sort. Very surprisingly the heavy placed in the medium, which was felt to most likely have the greatest losses, in fact had the least amount of degrade. The percentage of boards being degraded, approximately 5 percent, is appreciably greater than the 1 to 2 percent encountered in normal mill practice. Much of this difference is probably attributable to the closer inspection procedures used in this study which are, of course, impossible on a normal dry chain grading system. It should be further emphasized that a board was tallied even though the degrade was insufficient to actually affect the grade or yield. Mill personnel assisting in the inspection felt that the degrade was not unusually high.

Summary and Conclusions

1. This study indicates that it is probably impossible to improve present green chain segregation practices regardless of the technology used. This is extremely unfortunate as existing heavy and medium sorts exhibit considerable variation in drying rate.
2. Natural segregation, however, occurs within both heavy and medium stock as they are air dried.
3. It appears that it is possible to resort redwood lumber after partial air drying using a capacitance-type moisture meter.
4. A second segregation of this nature would not only correct the errors made in the original sort but would permit separating the small amount of extremely difficult to dry stock from the remainder, which could then be dried more rapidly.
5. Such a practice, however, would necessitate creating one additional drying sort termed here as "heavy-medium".
6. An evaluation of the drying times for material resorted after partial air drying showed savings in total drying of 15.7 percent for heavy sort material and 24 percent for medium.
7. The amount of degrade, 5 percent, resulting from the faster drying was higher than normal industry practice (1-2 percent). Much of this difference, however, is felt to be due to the more careful inspection procedures used in the degrade evaluation.
8. Although apparently technically feasible, the real success of this approach can only be ascertained when the actual economics are known. This is due to the large rehandling costs involved in making a second segregation.

Literature Cited

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