THE GENERAL DRYING CHARACTERISTICS OF YOUNG-GROWTH REDWOOD DIMENSION LUMBER

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Introduction

Lumber from small diameter young-growth logs generally has different properties than that produced from large diameter old-growth logs and drying characteristics are no exception. Typical differences include greater quantities of boards containing pith, mixed amounts of heartwood and sapwood, and "abnormal" wood such as juvenile and compression wood. As a general rule the utilization of small logs leads to the development of more lower and less upper grade lumber.

There has been extensive past research on the drying characteristics of redwood [Sequoia sempervirens (D. Don) Endl.] lumber, however, it has dealt almost exclusively with lumber sawn from old growth, large diameter trees. Until very recently there has been very limited experience with young growth material.

It was this lack of available information which prompted the research described here. The study was initiated after discussion with the California Redwood Association and visits to five of its member mills. Although there was no consensus of opinion as to exact drying needs or future products, it was clear that information on both air drying and kiln drying was needed. In particular, there was no agreement as to whether or how much heavy drying sort (the slowest, most difficult to dry) material is found in young-growth lumber. While most individuals felt that young-growth lumber was easier to dry, little data could be found to confirm this or to show exactly how different it is from old-growth lumber. In addition, ever-increasing raw material/inventory costs puts greater emphasis on the kiln drying of green off the saw material rather than kiln drying following partial air seasoning which was the usual past practice.

Acknowledgements

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Objectives

The overall objective of the study was to establish the general drying characteristics of young growth redwood. The specific objectives were to determine:

1. the number and types of drying sorts or segregations needed to minimize drying times.

2. the approximate percentage of material which will be found in each sort.
3. the general air drying times and characteristics of each sort and
4. the kiln drying times and characteristics of each sort.

No attempt was made to include degrade analysis other than in a general sense because it was felt that degrade cannot be quantified using small sample sizes (Comstock and Kerns, 1971; Jamison and Bassett 1977).

Test Material

Experimental material was obtained from two mills, one located at the northern end and one at the southern end of the commercial growing range of redwood. This was done in an attempt to obtain as representative a sample as possible.

Approximately 2000 board feet was obtained from each mill consisting of three grades, Select and Better, Construction Heart and Construction Common (Anon, 1979). Each grade contained 110 boards--8 feet in length. One-half of each grade (55 pieces) was made up of 2x4's and the other half 2x6's.

The material was pulled either directly from the green chain or from fresh solid units, sawn within three days. Young-growth material was distinguished from old-growth by growth rate. Eight rings per inch or less was used as the criterion.

All material was solid piled, wrapped in polyethylene sheeting, and shipped to the U.C. Forest Products Laboratory.

Segregation into Drying Sorts

Each board was weighed and labeled numerically upon receiving the material, immediately dipped in a commercial fungicide, extra strength solution, for 3 to 5 seconds, then segregated by weight. Weight segregations were based on Manson's (1949) weight per bd ft approach, i.e., the light sort weighing less than 3.5 lbs, medium less than 5.0 lbs and heavy, any board above 5.0 lbs per bd ft. All material was again wrapped in polyethylene sheeting until needed.

Experimental Design

The material was ultimately subdivided into five kiln drying charges and two air drying units (Figure 1). Three of the kiln drying runs contained lumber of all three grades, while the other two kiln charges only used Select and Better material. The two air drying units were made up of Construction Heart and Construction Common; no Select and Better was air dried. The rationale behind this design will be given in the results and discussion.

Air and Kiln Drying Procedures

The air drying material was thoroughly mixed and placed on 3/4 inch thick stickers. A total of 4 stickers were used in each tier, one flush with each end and one at a point 30 inches from each end. One, 5-foot wide package was made covered with a 4'x8' sheet of exterior grade plywood and placed on a large asphalt working area outside the laboratory. The stack was placed between two existing dummy air drying units with its length being parallel to the direction of prevailing wind direction. The lumber was not end coated. The units were set out in April and left in the yard until the middle of September at which point all boards were air dry.

Individual drying curves were obtained for each board by periodically breaking down the units and reweighing each board on an electronic platform balance to the nearest 0.05 lb. Once the material was air dry, the air dry moisture content was estimated by taking two electric resistant moisture meter readings at points 2 feet from each end. These two values were averaged and this value was used as the board value. With this moisture content value and the corresponding board weight, each board's oven-dry weight could be calculated. Initial board moisture content and the moisture content at each weighing time could then be calculated. These data were placed on computer cards and subsequent data processing was done by computer.

The material designated for kiln drying was wrapped in polyethylene until needed to prevent predrying as described previously. This permitted comparison of kiln runs made at different times. The boards were stuck into a 3 foot wide unit, using 3/4 inch thick stickers with a sticker on each end and another 30 inches from each end. Drying was carried out in a 1000 bd ft kiln using an air velocity of 350 fpm with a 6 hour fan reversal. The schedules used are shown in Figure 2 and were obtained from Manson (1971). Schedule changes were made on the basis of 8 sample boards, 4 of which were 2x4's (2 fast drying and 2 slow drying) and 4 - 2x6's (2 fast drying and 2 slow drying). The samples were chosen based on their initial board weight, percent heartwood or sapwood, grain orientation, and growth rate. They were prepared following procedures described by Rasmussen (1961). The samples were located within the unit, 4 on each side. Schedule changes were made on the basis of the calculated average moisture content of the 4 slowest drying sample boards. The initial moisture content and calculated sample oven-dry weight were determined from 1 inch long sections cut from each end of the 30 inch sample boards.

The charge was dried until the moisture content of all eight sample boards had reached the final desired value. The moisture content of each board within the unit was then estimated by averaging resistance moisture meter readings at points 2 feet in from each end. The boards were also inspected for the presence of obvious drying degrade but the actual amount of falldown was not determined.

Results and Discussion

Drying Segregations

As noted before, drying rate segregations were based upon measured weight per board foot as determined upon green boards. All of the material was found to be of either the light or medium sort; no heavy sort material was found (Table 1). This is a major difference from old-growth material where up to 35 percent or more of a mill run could be in the heavy segregation.

The data in Table 1 must be viewed in light of the differences in moisture content between heart- and sapwood boards. When heavy heartwood sinker material is excluded sapwood lumber generally has a higher moisture content than does heartwood and hence is heavier on a per board foot basis. This is confirmed by the data, since the all heartwood Construction Heart specimen material always had, with one exception, the highest percentage of light material. The highest percentages of medium classified material were found to occur in the Select and Better and Construction Common grades, which permit sapwood material.

When averaged over both lumber sizes, all three grades and the two mill samples used, approximately 28 percent of the material was classified as being medium sort with the remaining 72 percent as light. In light of the differences between the two mills it appears that one can expect that young-growth redwood will contain between 25 to 33 percent medium sort lumber and 67 to 75 percent light with little or no heavy sort lumber.

Air Drying Tests

As previously noted only Construction Heart and Construction Common lumber was used in these tests. The exact composition of the material used is summarized in Table 2. It can be seen that roughly 68 percent of the air dry stock had been classified as light with the remainder as medium; a total of 198 boards was used. In terms of size there were roughly an equal number of 2x4's and 2x6's.

The average and standard deviation of initial moisture content by mill, grade and board width are given in Table 3. As expected, due to its higher sapwood content, the Construction Common material generally had a higher average initial moisture content than did the Construction Heart boards. The average initial moisture contents ranged from a low of 76.6 percent for 2x4 Construction Heart (Mill 1) to a high of 107.9 percent for a 2x6 Construction Common (Mill 1). As was also seen in the kiln drying test sample boards, considerable variation between boards existed as is shown by the values of the standard deviation. The range in initial moisture contents between individual boards was from 19.8 to 187.6 percent.

The individual drying curves of each board were used to calculate average drying times to an average final moisture content of 19 percent (Table 4). It is obvious that there was considerable variation in drying time. The Construction Common from Mill 1 required 66 days as opposed to 47.5 days for the same grade from the other mill. This difference is largely due to the fact that the amount of light and medium drying sort material was not the same, as is also noted in Table 4. The Mill 1 Construction Common, the slowest drying stock, had the highest percentage of medium material, 54.8 percent. The remaining three classes of material which had roughly the same total drying time had more or less equal amounts of light and medium sort material.

In many cases young-growth material would probably be placed upon the air yard without any segregation. Under this situation, one would ask how long will it take to reach some average final moisture content? Because of the inherent variability in drying rate, it is more logical to ask, how long will it take for some specified portion or percentage of the material to reach a desired final moisture content? That is, it simply takes too long and is too expensive to wait for all the stock to reach the desired end point and one should accept the fact that some allowable portion will not yet be completely air dry.

All of the data was, therefore, combined and cumulative frequency distributions made for the drying times to 30 and 19 percent final moisture contents. These final moisture contents were selected since 30 percent would be a reasonable value to dry to if the sole purpose was to reduce shipping costs, while 19 percent corresponds to the American Lumber Standards. The data obtained are summarized in Table 5. The total drying times to 30 and 19 percent when each and every piece is at this moisture content or less were 97 and 133 days, respectively. If, on the other hand, one is willing to accept that 10 percent of the material is still above the target moisture content, the necessary times are reduced to 66 days for the 30 percent target moisture content and 74 days for the 19 percent target. This represents savings in total drying time of 32 and 44 percent, respectively. The drying times needed to bring other varying amounts (by 10 percent classes) of the total stock to these final moisture contents are also given in Table 5. The time for any desired proportion can also be obtained from Figures 3 and 4 which were used to develop the data in Table 5.

In this same vein, it may be desired to partial air dry simply to reduce shipping weights. To give some indication of the weight change versus time, weight per 1000 bd ft at different air drying times was determined and is shown in Figure 5. Under the particular drying conditions which existed during this test, it is quite obvious that the largest change in weight occurred within the first 29 days and from that point on the rate of weight loss slowed appreciably. Twenty-nine days represents approximately 40 percent of the total air drying time. It should be emphasized that these times would only apply to air drying locations having similar weather as that which occurred during the test. The rapidly decreasing value of using longer air drying times for the simple purpose of reducing shipping weight applies to any location, however.

The material originally classified as being medium sort took 50 and 72 days to air dry to an average moisture content of 30 and 19 percent, respectively. The drying times for the light sort material to these two same final moisture contents were 23 and 35 days. The light sort dried, therefore, in one-half the time of the medium sort lumber. This clearly indicates that (1) faster air drying times and greater air yard throughput would be realized if drying sort segregations were made and that (2) segregation on the basis of weight per bd ft is reliable. The latter was also shown by the kiln drying tests.

Kiln Drying Results

The rationale for the kiln runs was as follows. The initial two runs were designed to determine the drying times and general degrade development on all three grades and drying sorts using the less severe drying schedule. These runs resulted in satisfactory quality with minor apparent losses due to warpage and knot fallout. Based on these results kiln run 3 was designed to examine the effect of the fast kiln schedule on the light segregation material. This run showed that the fast schedule produced significant defects in all pieces containing knots, i.e., the lower grades. Every knot was either star-checked, loose or fell out. Kiln run 4 was, therefore, used to determine the effect of using the fast schedule on the medium segregation material using Select and Better grade lumber only. Kiln run 5 was designed to verify the segregation technique and determine the true value of its use in kiln drying. A summary of the results for all five kiln runs is given in Table 6.

Kiln run 1 with an average initial moisture content of 155 percent dried to an average final moisture content of 19 percent in 18 days and to 10 percent moisture content in 29 days. Kiln run 2, containing light segregation material had an initial moisture content of 81.5 percent and dried to 19 percent moisture content in 10 days and 10 percent moisture content in 16 days. The light segregation, therefore, dried in 44.4 and 44.8 percent less time to 19 and 10 percent, respectively using the same schedule on the same grade material. This shows the value of making a segregation.

Kiln run 3, using the fast schedule on the light segregation reduced the drying time even more, as might be expected. The reductions when dried to 19 and 10 percent final moisture content were 33 and 34.4 percent, respectively. The lower grade material, however, was significantly degraded as discussed before, therefore, these grades should not be dried using the more severe schedule.

Kiln run 4 showed that the upper grades in the medium sort lumber could be successfully dried using the fast schedule, reducing drying time to 19 and 10 percent final moisture content by 22.2 and 29.7 percent, respectively.

Kiln run 5 further confirmed the value of making segregations. The drying time to a final moisture content of 19 percent moisture content for all 8 sample boards was 13 days. The time to 10 percent final moisture content was 20.5 days. The drying of the charge, although of mixed stock, was controlled by the medium portion. This can be clearly seen by comparing the results of kiln run 4 (all medium sort) to kiln run 5. Both used the same schedule and dried in approximately the same time. The use of the fast schedule in place of the moderate schedule reduced the total drying time to 19 and 10 percent by 5 days and 8.5 days, respectively, if one compares kiln run 5 to kiln run 1. These represent time savings of 33 and 29 percent, respectively.

In addition to the longer drying time required, the light portion of the charge was over-dried as shown by the distribution of final moisture contents in Figure 6. This is obviously a severe drawback to drying both sorts together as the light portion will not only be more heavily degraded but is capable of being dried faster and thus overall kiln throughput is reduced. Therefore, medium and light material should not be dried together.

Summary and Conclusions

1. Using weight per bd ft as a criterion, it was found that young-growth dimension lumber can be segregated into either a light sort (≤3.5 lbs/bd ft) or a medium sort (>3.5 lbs/bd ft).
2. In contrast to old-growth lumber, no heavy sort material was found.
3. It is estimated that between 25 to 33 percent of young-growth lumber will be of medium sort and between 67 to 75 percent as light.
4. When air dried, light segregation material dried in roughly 50 percent less time than medium sort material.
5. When air drying light and medium sorts mixed together drying times to average final moisture contents of 30 and 19 percent were 97 and 113 days, respectively.
6. The greatest proportion of weight loss in air drying mixed materials occurs in the first 40-45 percent of total drying time. This is of major significance when drying to simply reduce shipping weights.
7. Light and medium segregations should be kiln dried separately to minimize total dry time.
8. Using a moderate schedule, light segregation lumber can be kiln dried in 10 days versus 18 days for the medium sort.
9. Only the moderate schedule should be used on all lower grades as the fast schedules lead to excessive knot checking, loosening and fallout.
10. Upper grade light and medium material can be dried without excessive degrade using either the fast or moderate schedule.
11. Using the fast schedule light segregation upper grade material can be dried to 19 percent final moisture content in approximately 7 days as compared to 14 days for medium segregation material.

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Table 1. Young growth redwood weight segregations--
percentages by source and size.

Mill 1.

	Lumber Grade		
	Select & Better	Construction Heart	Construction Common
2x4			
Light	55.2%	82.9%	62.5%
Medium	44.8%	17.1%	37.5%
2x6			
Light	74.0%	76.4%	43.9%
Medium	26.0%	23.6%	56.1%

Combined sizes and grades: Light 66.1%

Medium 33.9%

Mill 2.

	Lumber Grade		
	Select & Better	Construction Heart	Construction Common
2x4			
Light	67.9%	87.1%	91.6%
Medium	32.1%	12.9%	8.4%
2x6			
Light	64.1%	80.7%	70.9%
Medium	35.9%	19.3%	29.1%

Combined sizes and grades: Light 77.4%

Medium 22.6%

Overall results when combined over mills, grades and sizes

Light 72.1%

Medium 27.9%

Table 2. Percentage and number of pieces in the different segregations.

	Percentage of pieces classified as:			
	Construction Heart		Construction Common	
	Light	Medium	Light	Medium
Mill 1	68.0	32.0	45.2	54.8
	(34)[1/]	(16)	(14)	(17)
Mill 2	78.0	22.0	70.7	29.3
	(46)	(13)	(41)	(17)

[1/] Numbers in parentheses are total number of boards per class.

Total number of boards = 198

Total percentage light material = 68.2%

Total percentage medium material = 31.8%

Table 3. Distribution of initial moisture contents in air drying tests by grade and mill.

			Construction Heart	Construction Common
Mill 1				
	2x4	average ($\overline{X}$)	76.6	89.4
		stand. dev. (σ)	35.6	25.7
	2x6	average ($\overline{X}$)	86.0	107.9
		stand. dev. (σ)	40.2	36.1
Mill 2				
	2x4	average ($\overline{X}$)	83.9	74.9
		stand. dev. (σ)	32.7	27.4
	2x6	average ($\overline{X}$)	87.2	102.4
		stand. dev. (σ)	32.4	26.6

Table 4. Air drying times and proportion of medium drying sort material by grade and mill site.

Grade	Mill	Drying time to 19% moisture content (days)	Amount of material in medium sort (%)
Construction Common	1	66	54.8
	2	47.5	29.3
Construction Heart	1	53.5	32.0
	2	51	22.0

Table 5. Length of air drying time needed for given percentage to reach moisture content of either 30 or 19 percent.

Percent of boards having desired moisture content or less	Length of air drying needed so that percent of material given in column 1 has reached moisture content of:	
	30%	19%
100	97	113
90	66	74
80	37	56
70	28	47
60	23	43
40	21	39
30	18	34
20	14	32
10	12	30

Table 6. Summary of all kiln runs.

Kiln run No.	No. of boards	Type of segregation	Schedule used	Sample boards: Initial moisture content $\bar{X}$	Range	Sample boards: Final moisture content $\bar{X}$	Range	Drying time in days to: 19%	10%	End of kiln run
1	86	Medium	Moderate	155.0	115-189	9.7	6.7-18.6	18	29	31.4
2	118	Light	Moderate	81.5	50-118	8.4	7.2- 9.4	10	16	21
3	116	Light	Fast	78.1	45-142	9.0	4.5-18.4	6.7	10.5	12
4	35	Medium	Fast	130.9	86-180	8.4	6.1-14.0	14	20.4	19
5	80	Mixed	Fast	105.4	66-215	12.3	5.0-35.0	13	20.5	19

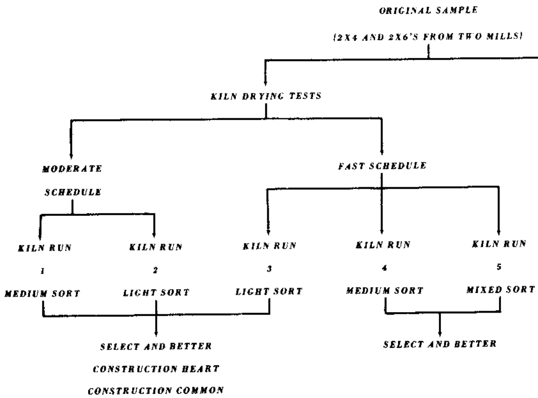

Figure 1. Experimental design used in the air and kiln drying tests.

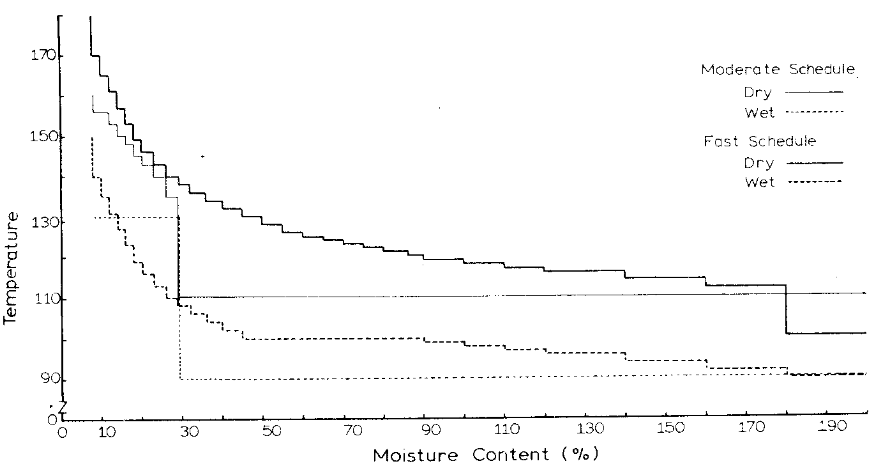

Figure 2. Moderate and fast kiln schedules used.

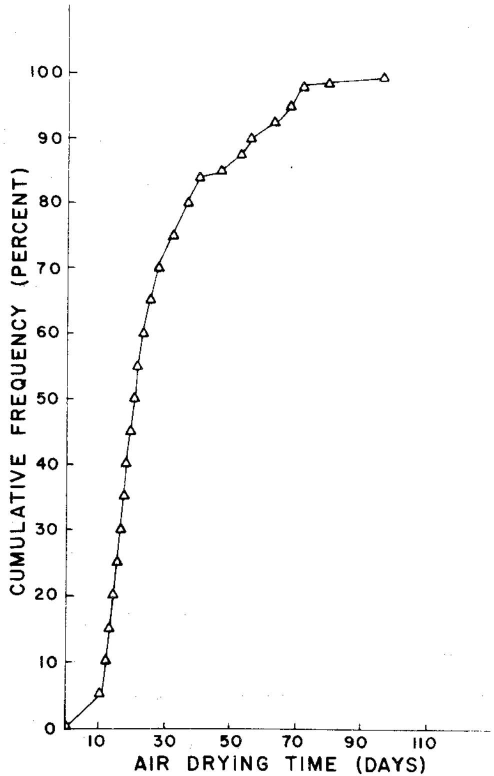

Figure 3. Cumulative frequency plot of percent of material having moisture content of 30 percent or less versus air drying time in days.

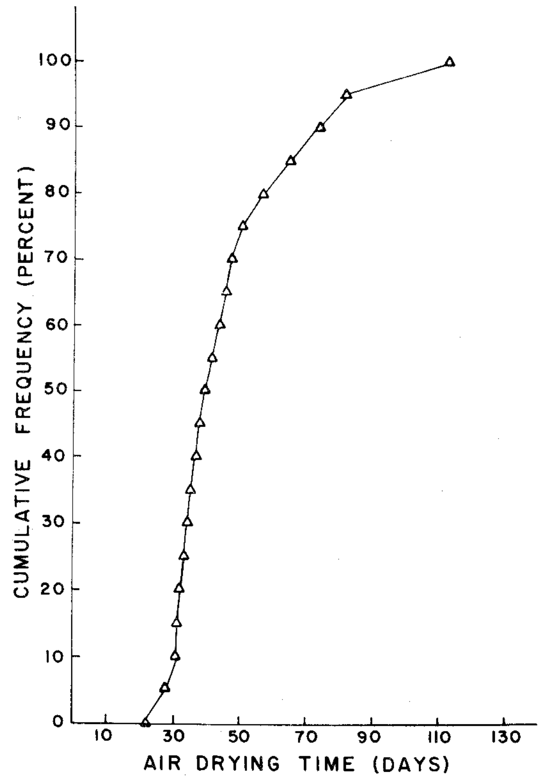

Figure 4. Cumulative frequency plot of percent of material having moisture content of 19 percent or less versus air drying time in days.

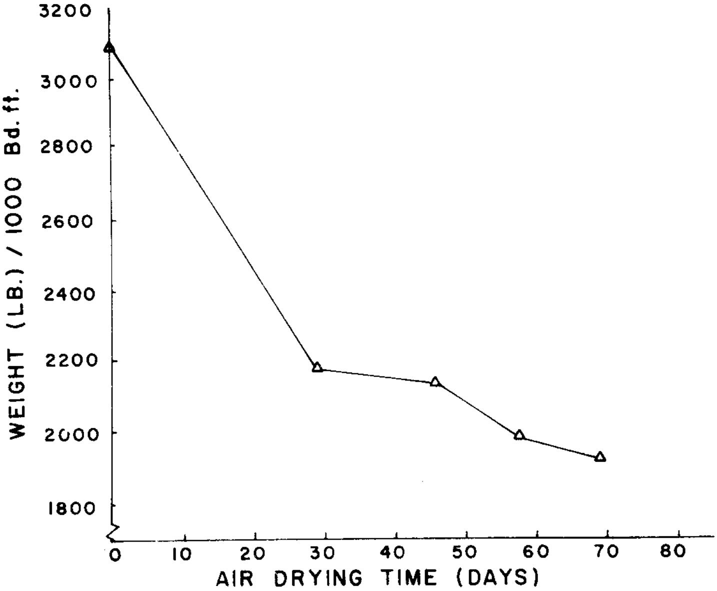

Figure 5. Weight in lbs/MBF versus air drying time in days.

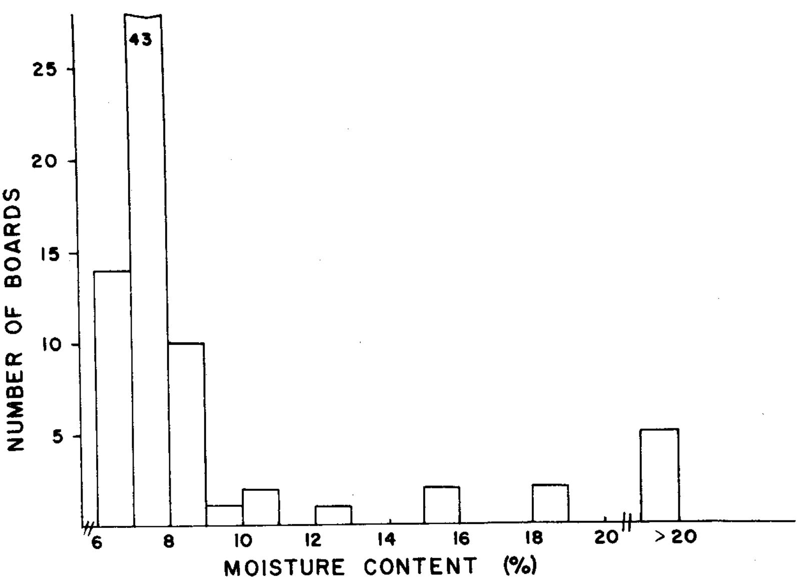

Figure 6. Final moisture content distribution for kiln run 5.