Kiln Schedules

for

Douglas Fir and Western Hemlock Dimension Lumber

By Charles J. Kozlik

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Forest Products Research
FOREST RESEARCH LABORATORY
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FOREST RESEARCH LABORATORY

The Forest Research Laboratory is part of the Forest Research Division of the Agricultural Experiment Station, Oregon State University. The industry-supported program of the Laboratory is aimed at improving and expanding values from timberlands of the State.

A team of forest scientists is investigating problems in forestry research of growing and protecting the crop, while wood scientists engaged in forest products research endeavor to make the most of the timber produced.

The current report stems from studies of forest products.

Purpose . . .

Fully utilize the resource by:

- developing more by-products from mill and logging residues to use the material burned or left in the woods.
- expanding markets for forest products through advanced treatments, improved drying, and new designs.
- directing the prospective user's attention to available wood and bark supplies, and to species as yet not fully utilized.
- creating new jobs and additional dollar returns by suggesting an increased variety of salable products. New products and growing values can offset rising costs.

Further the interests of forestry and forest products industries within the State.

Program . . .

Identify and develop uses for chemicals in wood and bark to provide markets for residues.

Improve pulping of residue materials.

Develop manufacturing techniques to improve products of wood industries.

Extend service life of wood products by improved preserving methods.

Develop and improve methods of seasoning wood to raise quality of wood products.

Create new uses and products for wood.

Evaluate mechanical properties of wood and wood-based materials and structures to increase and improve use of wood.

CONTENTS

	Page
SUMMARY	2
INTRODUCTION	3
MATERIAL	4
EXPERIMENTAL PROCEDURE	5
RESULTS	7
Dry-bulb temperatures	7
Emc conditions	7
Fan-reversal periods	8
Verifying charges	8
Loosening of encased knots	9
Warping	9
Final moisture content	9
DISCUSSION OF RESULTS	18
CONCLUSIONS	20

SUMMARY

A more efficient kiln schedule was desired for drying 2- by 10-inch dimension lumber from Douglas fir and western hemlock to an average moisture content of 19 per cent. Unseasoned lumber from several different areas in Oregon was segregated into three classes: fine-grain Douglas fir, coarse-grain Douglas fir, and western hemlock. Effects of 3 dry-bulb temperatures (130, 150, and 180 F), 3 Emc conditions (9, 12, and 15 per cent), and 3 air velocities (150-200, 450, and 600 feet a minute) were studied to determine the most satisfactory kiln schedule. Evaluation of individual charges was based on time in kiln and amount of checking occurring during drying.

Conclusions of the study indicate that an initial dry-bulb temperature of 180 F can be tolerated by both Douglas fir and western hemlock without increased degrade. Initial conditions for Emc of 9 per cent can be followed by conditions for 6 per cent Emc for western hemlock after average moisture content of the wood has reached 22 per cent. The same Emc conditions can be applied to most fine-grain Douglas fir having 10 or more annual growth rings to an inch, if a period of 24 hours at Emc conditions of 12 per cent precedes this application. Douglas fir having a specific gravity of 0.48, or higher, may require initial conditions for 12 per cent Emc longer than 24 hours. Coarse-grain Douglas fir with 6 growth rings to an inch, or fewer, requires Emc conditions of 12 per cent or higher, to reduce degrade resulting from checking. In this kiln schedule, an air velocity of at least 400 feet a minute is required for uniformity of final moisture content.

KILN SCHEDULES FOR DOUGLAS FIR AND WESTERN HEMLOCK DIMENSION LUMBER

by

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INTRODUCTION

There is an increased demand that Douglas fir and western hemlock lumber be kiln-dried to maximum moisture content of 19 per cent. This project was initiated to develop kiln schedules for dimension lumber that would reduce time in kiln and lower costs without decreasing quality.

Schedules published by governmental and private research agencies generally are moderate, but may allow considerable reduction in kiln time. Since commercial kiln schedules vary, with starting temperatures ranging from 130 to 200 F, adjustment in schedules can be recommended to most mills having modern conventional dry kilns.

Before starting this project, members of the West Coast Dry Kiln Club discussed difficulties encountered in drying dimension lumber. The majority agreed that the highest percentage of degrade found in 2-inch planks resulted from excessive warping and lack of uniformity in final moisture content, especially in western hemlock. Dimension lumber less than 10 inches wide was dried satisfactorily in most mills. As a result of this information, decision was to study 2- by 10-inch Douglas fir and western hemlock.

MATERIAL

Lumber for 36 of the 46 charges studied was produced from timber grown near Horton and Dallas, Oregon. Lumber for the last 10 charges was produced near Prineville, Coos Bay, and Foster. Annual growth rings were counted for the last 14 charges, but only a distinction of coarse or fine grain was made for the other charges of Douglas fir. Lumber of fine and coarse grain was mixed in the charges of western hemlock. Growth rings for the fine-grain Douglas fir ranged from 7 to 77 an inch, and for coarse-grain Douglas fir from 3 to 15 rings an inch. The western hemlock had from 5 to 70 rings an inch in individual pieces.

Average specific gravity based on oven-dry weight and unseasoned volume for various charges ranged from 0.40 to 0.48 for fine-grain Douglas fir, from 0.43 to 0.46 for coarse-grain Douglas fir, and from 0.39 to 0.42 for western hemlock.

Material obtained from sawmills was placed under water sprays at the Forest Research Laboratory on the same day it was sawed. Initial moisture content among various charges ranged from 29.4 to 42.2 per cent for fine-grain Douglas fir, from 35.3 to 63.0 per cent for coarse-grain Douglas fir, and from 65.9 to 108.9 per cent for western hemlock.

Standard or better lumber was selected in virtually all instances, so that the effect of various schedules on loosening of encased knots could be determined. Flat-grain material was specified to show the maximum degrading effect from checking and warping.

EXPERIMENTAL PROCEDURE

Effects of 3 dry-bulb temperatures, 130, 150, and 180 F, were tested first. Conditions for equilibrium moisture content of 12 per cent were held constant, as was air velocity, to reduce the number of variables.

Because results were inconclusive for these tests of dry-bulb temperatures on 3 preliminary charges of western hemlock and Douglas fir, lumber for all subsequent experiments was segregated into 3 classes: fine-grain Douglas fir, coarse-grain Douglas fir, and western hemlock.

Two matched charges of fine-grain Douglas fir (1 and 1A in Table 1) were dried at 130 and 180 F at conditions for 12 per cent Emc (equilibrium moisture content). Matched charges of coarse-grain Douglas fir (1 and 1A in Table 2) and of western hemlock (1 and 1A in Table 3) also were dried at the same dry-bulb temperatures and Emc conditions. Results from these charges suggested that an initial dry-bulb temperature of 180 F should be selected as the dry-bulb setting for all 3 segregations in subsequent work.

Maintaining a constant dry-bulb temperature of 180 F, the effects of conditions for equilibrium moisture content of 9, 12, and 15 per cent were tested on 3 matched charges in each segregated class (charges 2, 2A, and 2B in Tables 1, 2, and 3). Air velocity also was held constant.

Conditions for 9 per cent Emc were selected initially for the fine-grain Douglas fir and western hemlock, but conditions for 12 per cent Emc were considered better for the coarse-grain Douglas fir in later testing.

In the third phase of testing, dry-bulb temperature of 180 F and conditions for 9 per cent Emc were maintained for the western hemlock and fine-grain Douglas fir, and conditions for 12 per cent Emc were maintained for the coarse-grain Douglas fir until the average moisture content was about 22 per cent. At this moisture content, the Emc conditions were lowered to 6 per cent.

Each testing phase included charges of end-matched specimens. The evaluation of individual charges was based on time in kiln and amount of checking occurring during drying.

Percentage of planks checked and average number of checks of a given size in a checked plank also determined degree of degrade (See Tables 1, 2, and 3). Loosening of encased knots and amount of warping were measured in evaluating the charges, but were treated as secondary factors.

Size and depth of checks were rated in the following manner:

Small---up to 4 inches long
Medium---from 4 to 10 inches long
Large---over 10 inches long and less than one-fourth the thickness in depth
Degrading---one-fourth the thickness or more in depth, depths of opposite checks to be combined; length to be equal to or more than one-half the width of the piece.

In completing the foregoing steps, 3 different velocities of air as it left the lumber were tested to assess the influence of air movement on drying time and uniformity of final moisture content (Table 4).

After 36 initial charges had been processed, material was collected from areas of Oregon other than the coastal range of mountains bordering the Willamette valley. The described schedule thus was tested on lumber from other sections. The first collection was made from the west slope of the Cascades near Foster and included only western hemlock and fine-grade Douglas fir. Considerable checking already had occurred in this new material when collected. Prior to drying at the Research Laboratory, all visible checks were marked to distinguish them from checks incurred during kiln-drying.

The second collection was made from the Ochoco National Forest near Prineville and included only fine-grain Douglas fir.

The last collection was made from the west slope of the Coast range near Coos Bay, and included both western hemlock and fine-grain Douglas fir.

Moisture content of the lumber before drying was determined by weighing and oven-drying short sections cut from the centers of 16-foot planks when they were sawed into 8-foot pieces for drying. Moisture content during drying was estimated from weights of 6 short pieces dried in each charge. Moisture contents after drying were determined by measuring all pieces with a resistance-type moisture meter to a depth of three-eighths inch.

RESULTS

Results of testing different dry-bulb temperatures, Emc conditions, and air velocities on segregated charges of fine-grain Douglas fir, coarse-grain Douglas fir, and western hemlock were summarized in tables and figures.

Dry-bulb temperatures

Results were inconclusive on 3 preliminary charges of western hemlock and fine-and coarse-grain Douglas fir that were dried at 130, 150, and 180 F at conditions for 12 per cent Emc to examine the effect of the 3 dry-bulb temperatures. Amount of checking did not indicate that one temperature was better than another, and the western hemlock did not dry satisfactorily to an average final moisture content of 19 per cent. Total time in kiln was 236 hours at 130, 146 hours at 150, and 120 hours at 180 F.

The effects on matched charges of segregated lumber dried at temperatures of 130 and 180 F at conditions for 12 per cent Emc are shown in Tables 1-3. Results for 2 matched charges of fine-grain Douglas fir (1 and 1A in Table 1) indicated no difference in the amount of degrading checks, but the run at 130 F required 74 hours additional time. The coarse-grain Douglas fir (1 and 1A in Table 2) showed little difference in checking, but the charge dried at 130 F required an additional period of 54 hours. The 2 matched charges of western hemlock (1 and 1A in Table 3) dried under these conditions indicated considerable checking and 130 hours additional time for the charge dried at 130 F. These results indicated that an initial dry-bulb temperature of 180 F was the desired setting for subsequent work in all 3 segregations.

Emc conditions

Amount of checking occurring in fine-grain Douglas fir dried under 3 different Emc conditions was similar in the 3 matched charges (2, 2A, and 2B in Table 1), but kiln time increased with conditions for higher Emc. Amount of checking in the western hemlock was similar in charges 2, 2A, and 2B in Table 3, but again kiln time was affected greatly. Time in kiln differed in the coarse-grain Douglas fir charges 2, 2A, and 2B in Table 2, but again the amount of checking was similar. Initial conditions for 9 per cent Emc, however, caused considerable damage to both encased and intergrown knots.

During the third stage of testing, Emc conditions were changed during drying. Conditions for 9 per cent Emc were maintained for western hemlock and fine-grain Douglas fir and conditions for 12 per cent Emc for coarse-grain Douglas fir until the average moisture content was about 22 per cent, when the Emc conditions were lowered to 6 per cent. Dry-bulb temperature was kept at 180 F. Results indicated that charges

3 and 4 of fine-grain Douglas fir compared to charges 3A and 4A in Table 1 tolerated Emc conditions of 6 per cent without additional checking. Also, kiln time was reduced. Checking was nearly identical in hemlock charges 3 and 3A in Table 3, with charge 3 requiring 23 fewer hours to dry. Charges 3 and 3A (control) of coarse-grain Douglas fir (Table 2) checked similarly during drying, but charge 3 required 12 fewer hours to dry.

Fan-reversal periods

Although conventional dry kilns deliver adequate flow of air, the effects of 3 different velocities for air, 150-200, 450, and 600 feet a minute, were included as part of this study. Amount of checking varied within the matched charges, but probably this can be attributed to variation of the wood and not to drying conditions. In both classes of Douglas fir, air velocities of 600 and 450 feet a minute produced almost identical drying times and similar final moisture contents. In the western hemlock, charge 4A, having an air velocity of 450 feet a minute, required 24 hours longer to dry than charge 4 with an air velocity of 650 feet a minute. The 3 charges with air velocities from 150 to 200 feet a minute required considerably more kiln time and were less uniform in final moisture content than were all the other charges.

A summary of the results for 36 charges indicated western hemlock and fine-grain Douglas fir from near Dallas and Horton can tolerate an initial dry-bulb temperature of 180 F and conditions for Emc of 9 per cent. After maintaining this drying condition until average moisture content of 22 per cent is attained, Emc conditions can be lowered to 6 per cent. With this schedule, a velocity of at least 400 feet a minute for the leaving air is needed to insure reasonable uniformity in moisture content.

Coarse-grain Douglas fir collected from the same areas tolerated a dry-bulb temperature of 180 F with Emc conditions of 12 per cent. After reaching average moisture content of 22 per cent, Emc conditions were lowered to 6 per cent. Also, the air velocity should be 400 feet a minute or more.

Verifying charges

Charges 7 and 7A in Table 1 were composed of fine-grain Douglas fir from near Foster, with 7A being designated as the control and the laboratory schedule being applied to charge 7. There was a slight difference in checking, for test charge 7 had a higher percentage of checked planks, but control charge 7A required 26 additional hours in the kiln. Amount of checking found on the bark side of 5 randomly selected matched samples of fine-grain Douglas fir is illustrated in Figure 1.

In Table 3, charge 5 was designated as the control charge and charge 5A as the test charge for hemlock from near Foster. The percentage of checked planks was higher in the control charge, which required 15 additional hours of kiln time. Amount of checking found on the bark side of 5 randomly selected matched samples of hemlock is illustrated in Figure 2.

Results for fine-grain Douglas fir collected from the Ochoco National Forest near Prineville showed that both control charge 8A and test charge 8 had similar drying times and amount of checking (Table 1). Checking occurring on the bark side of 5 randomly selected matched samples is depicted in Figure 3.

No large difference in the amount of checking occurred between control charge 6A and test charge 6 of western hemlock collected near Coos Bay (Table 3), but control charge 6A required 33 additional hours in the kiln. Charges of Douglas fir (Table 1) consisted of 88 per cent fine-grain material. Total checking was nearly the same in control charge 9A and test charge 9, but the control charge required 37 additional hours. The checking occurring on the bark side of 5 randomly selected matched samples of western hemlock is indicated in Figure 4.

A typical schedule maintained for charges dried to verify findings about Douglas fir and western hemlock is illustrated by Figure 5.

Loosening of encased knots

Degrade of western hemlock from encased or intergrown knots was not pronounced, but coarse-grain Douglas fir had excessive degrade resulting from knot holes and breakage of intergrown knots during surfacing. Fine-grain Douglas fir exhibited occasional knot holes and some breakage of intergrown knots during surfacing that was considered normal to most commercial operations.

Warping

Since warping of 2- by 10-inch dimension lumber must be reduced as much as possible in commercial operations, every charge was examined for this form of degrade. The top layer of each charge showed some evidence of cupping, but it was not severe enough to cause splits during surfacing. Heart-center pieces on the top layer showed enough twist to degrade some pieces. Pieces in the second layer showed slight cupping and twist, but not enough to cause drop in grade.

Final moisture content

Uniformity of final moisture content was excellent in all Douglas fir charges, except 6B (Table 1) and 4 (Table 2) when velocity of the leaving air was maintained at 150-200 feet a minute. Final moisture content for these two charges ranged from 12 to 25 per cent. Other charges of Douglas fir had uniformity of moisture content similar to that shown in Figures 6, 7, and 8.

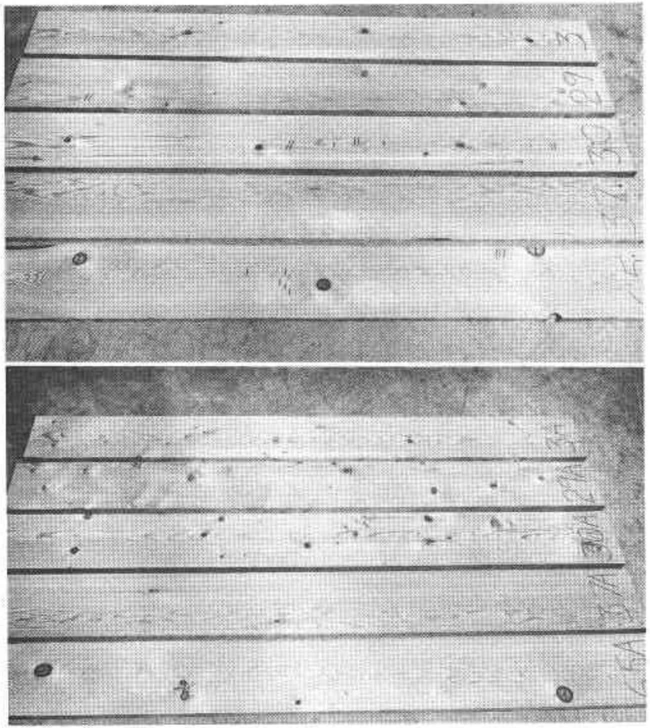

Figure 1. Planks in charge 7 (top), with initial conditions for 9 per cent Emc, checked slightly more, but were in the kiln 26 hours less than charge 7A (below), initially set for 12 per cent Emc.

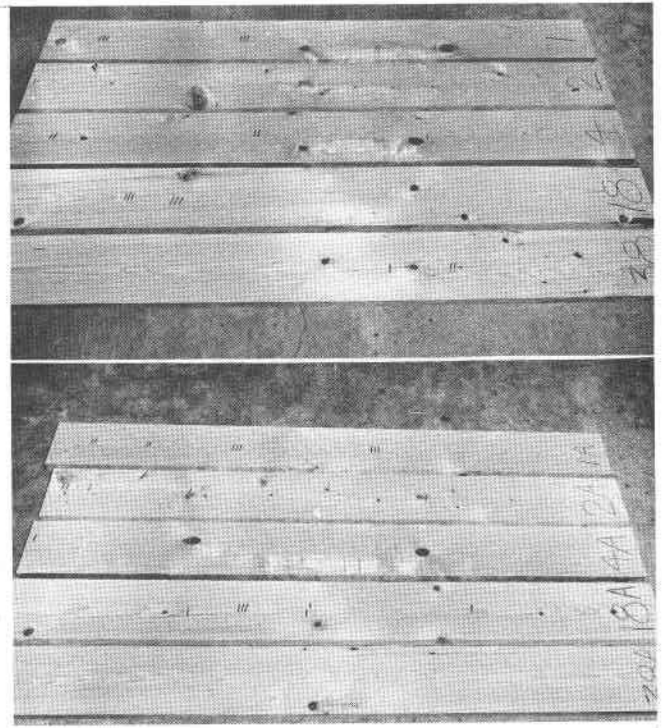

Figure 2. Planks in charge 5 (top), with initial conditions for 12 per cent Emc, checked more and were 15 hours longer in kiln than charge 5A (below), with initial conditions for 9 per cent Emc.

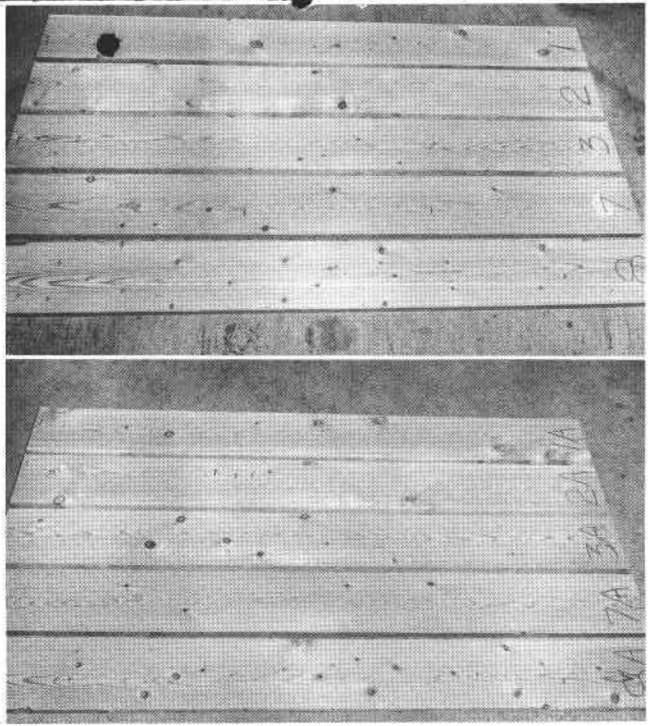

Figure 3. Planks in charge 8 (top), with initial conditions for 9 per cent Emc, had identical drying times and similar checking to charge 8A (below), with initial conditions for 12 per cent Emc.

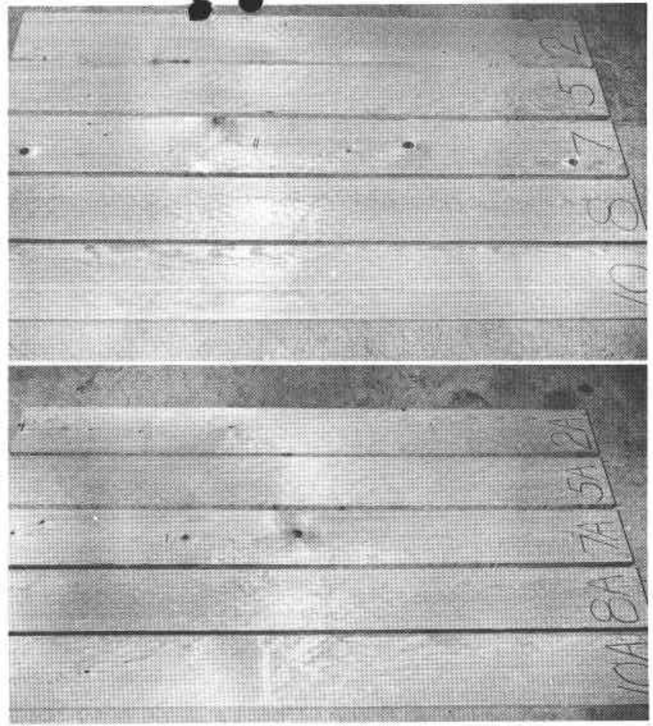

Figure 4. Planks in charge 6 (top), with initial conditions for 9 per cent Emc, checked similarly, but were in kiln 33 hours less than charge 6A (below), with constant conditions for 9 per cent Emc.

Key to checking: I , small check; II, medium check; III, large check; IIII, degrading check.

Uniformity of final moisture content in western hemlock was not altogether satisfactory in most instances. Range in final moisture content was similar to that encountered in industry when there is no segregation between light and heavy pieces in a kiln charge. Normally, about 60 per cent of the material dried to a low range of moisture content, 34 per cent dried to a moisture content ranging from 15 to 21 per cent, and about 6 per cent dried to 22 per cent (and over) in moisture content. Range in final moisture content for charges of hemlock from areas near Foster and Coos Bay is shown in Figures 9 and 10.

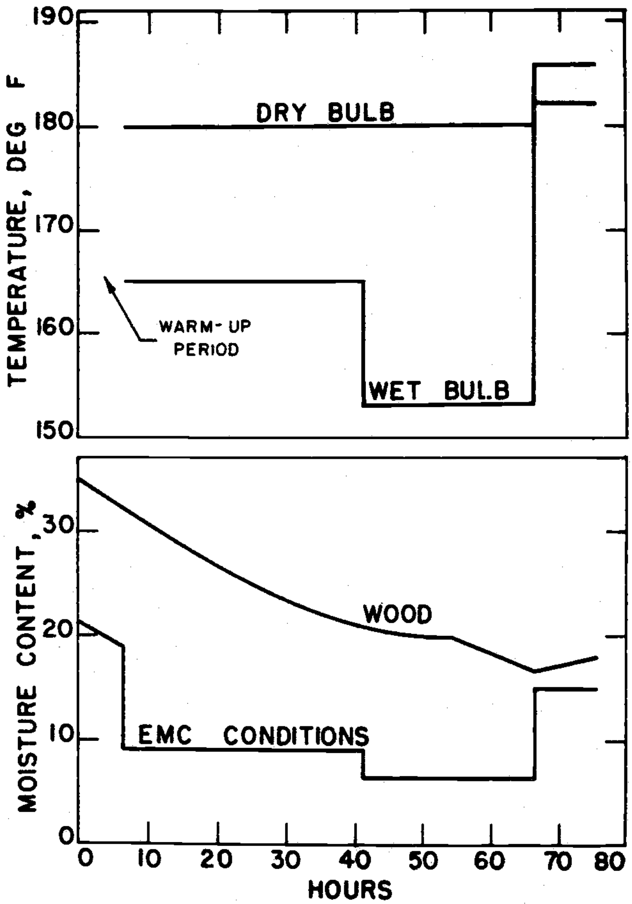

Figure 5. Kiln schedule and rate of drying for fine-grain Douglas fir (Table 1) in charge 9, typical of charges dried to verify results from suggested schedule.

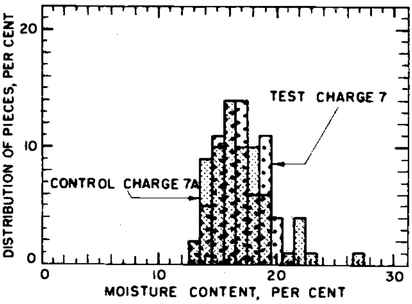

Figure 6. Distribution of moisture content for Douglas fir collected near Foster.

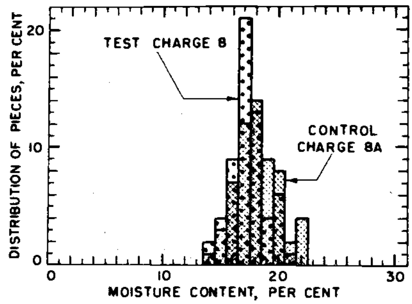

Figure 7. Distribution of moisture content for Douglas fir collected in Ochoco National Forest.

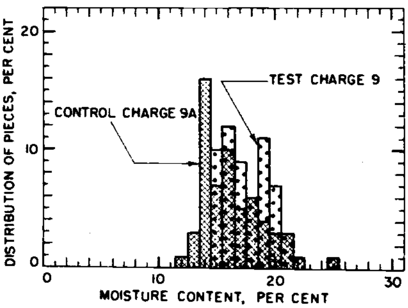

Figure 8. Distribution of moisture content for Douglas fir collected near Coos Bay.

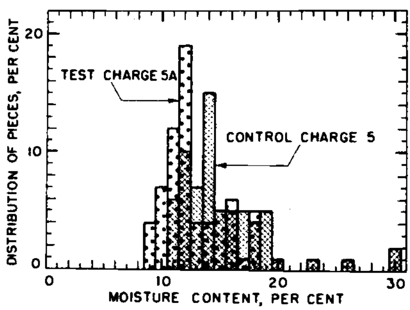

Figure 9. Distribution of moisture content for western hemlock collected near Foster.

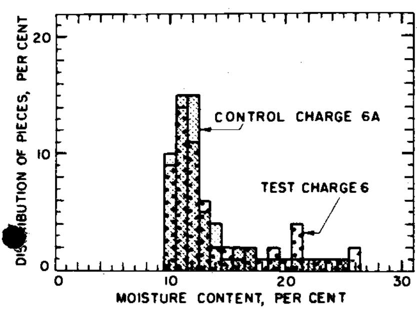

Figure 10. Distribution of moisture content for western hemlock collected near Coos Bay.

Table 1. Drying Conditions and Results for 2- by 10-Inch, Fine-grain, Douglas Fir Dimension Lumber.

Charge	Dry bulb	Emc	Average moisture content		Operating time	Checks							
						Small		Medium		Large		Degrading	
			Initial	Final		Checked planks	No. checks[4]	Checked planks	No. checks[4]	Checked planks	No. checks[4]	Degraded planks	No. checks[4]
	Deg F	%	%	%	Hr	%		%		%		%	
1	130	12	32.1	15.0	187	96	5	39	2	28	1	11	1
1A	180	12	31.7	15.9	113	89	6	21	2	21	3	11	2
2	180	9	39.2	16.7	75	61	3	33	2	17	1	0	0
2A	180	12	42.2	17.8	110	78	4	11	2	22	1	6	2
2B	180	15	41.8	19.9	230	78	4	17	2	11	2	6	1
3	180	9	29.4	16.2	65	80	5	30	2	17	2	0	0
	180	6											
4	180	9	40.5	16.2	57	64	4	32	2	12	2	4	2
	180	6											
3A	180	9	30.7	17.1	71	81	5	29	3	26	1	3	1
4A	180	9	38.4	15.0	102	60	3	23	2	6	2	2	5
5	180	12	38.4	16.1	88	64	3	24	2	4	1	0	0
	180	6											
5A	180	9	36.0	17.3	75	58	3	28	1	6	2	2	2
	180	6											
6	180	9	39.5	16.3	73	43	3	14	1	7	1	0	0
	180	6											
6A	180	9	37.6	18.8	71	48	3	16	1	7	1	2	2
	180	6											
6B	180	9	38.2	17.2	101	39	3	7	1	4	1	9	1
	180	6											
7[1]	180	9	33.4	16.9	89	66	3	29	2	13	1	1	1
	180	6											
7A[1]	180	12	33.4	17.0	115	53	2	22	2	12	2	1	1
	180	9											
8[2]	180	9	39.3	17.5	65	57	3	23	3	10	2	0	0
	180	6											
8A[2]	180	12	37.6	18.3	65	47	3	25	2	7	2	2	1
	180	6											

9[3]	180	9	35.2	17.8	78	65	4	22	2	10	2	3	1
	180	6											
9A[3]	180	12	35.2	16.4	115	68	5	17	3	8	2	0	0
	180	9											

[1]Material collected from timber grown near Foster. [2]Material collected from timber grown in the Ochoco National Forest. [3]Material collected from timber grown near Coos Bay. [4]Average for planks that were checked.

Table 2. Drying Conditions and Results For 2- by 10-Inch, Coarse-grain, Douglas Fir Dimension Lumber.

Charge	Dry bulb	Emc	Average moisture content		Operating time	Checks							
						Small		Medium		Large		Degrading	
			Initial	Final		Checked planks	No. checks[1]	Checked planks	No. checks[1]	Checked planks	No. checks[1]	Degraded planks	No. checks[1]
	Deg F	%	%	%	Hr	%		%		%		%	
1	180	12	35.3	15.9	96	71	5	26	3	6	2	0	0
1A	130	12	35.9	15.2	150	79	6	29	2	18	2	3	2
2	180	9	50.8	15.8	86	87	4	30	2	13	2	3	1
2A	180	12	50.5	15.6	136	73	4	30	2	17	1	0	0
2B	180	15	49.2	15.7	243	67	6	20	1	10	1	0	0
3	180	9	45.2	16.2	77	74	4	10	2	2	2	2	2
	180	6											
3A	180	12	48.5	16.4	89	72	2	12	1	0	0	2	1
	180	6											
4	180	12	52.6	17.1	143	82	4	22	2	2	1	2	2
	180	6											
4A	180	12	56.5	17.0	129	42	5	13	1	0	0	4	1
	180	6											
4B	180	12	63.0	16.1	124	84	4	13	2	4	1	0	0
	180	6											

[1]Average for planks that were checked.

Table 3. Drying Conditions and Results for 2- by 10-Inch Western Hemlock Dimension Lumber.

Charge	Dry bulb	Emc	Average moisture content		Operating time	Checks							
						Small		Medium		Large		Degrading	
			Initial	Final		Checked planks	No. checks[3]	Checked planks	No. checks[3]	Checked planks	No. checks[3]	Degraded planks	No. checks[3]
	Deg F	%	%	%	Hr	%		%		%		%	
1	180	12	96.5	15.5	146	59	3	26	2	15	1	0	0
1A	130	12	93.3	16.4	276	82	4	37	2	8	1	13	2
2	180	15	85.8	14.6	324	23	1	8	2	8	1	0	0
2A	180	12	108.9	14.3	233	41	1	3	1	0	0	0	0
2B	180	9	104.2	14.0	159	46	2	11	1	6	1	0	0
3	180	9	65.9	12.9	123	45	2	28	1	25	2	0	0
	180	6											
3A	180	12	76.8	12.1	146	43	2	20	2	12	2	0	0
	180	6											
4	180	9	80.1	14.4	95	33	3	7	1	9	1	2	1
	180	6											
4A	180	9	77.2	15.8	119	45	2	9	1	7	1	0	0
	180	6											
4B	180	9	85.5	13.9	182	31	2	4	6	0	0	0	0
	180	6											
5[1]	180	12	77.1	15.3	117	66	2	45	2	19	2	1	1
	180	6											
5A[1]	180	9	77.1	12.0	102	61	2	37	2	12	2	4	1
	180	6											
6[2]	180	9	103.7	14.2	151	37	2	17	1	5	1	0	0
	180	6											
6A[2]	180	9	97.9	13.0	184	37	2	18	1	13	1	0	0

[1] Material collected from timber grown near Foster.

[2] Material collected from timber grown near Coos Bay.

[3] Average for planks that were checked.

Table 4. Air Velocities Tested.

Charge	Air velocity Ft/min
Fine-grain Douglas fir (Table 1)	
6	600
6A	450
6B	150-200
Coarse-grain Douglas fir (Table 2)	
4	150-200
4A	400
4B	575
Western hemlock (Table 3)	
4	650
4A	450
4B	150-200

DISCUSSION OF RESULTS

The study demonstrated that a dry-bulb temperature of 180 F is not too severe for any of the 3 segregated classes, but influence of Emc conditions is critical. In all charges of western hemlock, the effect of conditions for 9 per cent Emc was not so severe as in some charges of Douglas fir. The amount of checking in western hemlock was low in all charges except 1, 1A, 5, and 5A (Table 3). The high percentage of checking in these charges could not be traced to a specific cause. Considerable checking showed in charges 5 and 5A when the lumber was received. All visible checks were marked, but hairline checks, or checks hidden because of the rough surface of the material, were not marked. These unmarked checks no doubt added to the total checking occurring during kiln drying.

Fine-grain Douglas fir usually dried successfully at initial conditions for Emc of 9 per cent. One must consider, however, which element is more important, time in kiln or quality of product. If some quality can be sacrificed, then Emc conditions of 9 per cent can be maintained initially, followed by lowering to conditions for 6 per cent Emc after the average moisture content is 22 per cent. To obtain a product of higher quality, Emc conditions of 12 per cent are suggested for the first 24 hours, followed by conditions for 9 per cent Emc until the average moisture content is 22 per cent. At this moisture content, change to conditions for 6 per cent Emc is justified. A schedule of this type should be favorable for all Douglas fir dimension lumber.

If a particular area is producing Douglas fir similar to the material from the Ochoco National Forest used in this study, a fast schedule, eliminating the step for conditions of 12 per cent Emc, could be followed without risking additional degrade. This material had a specific gravity of 0.40, a small percentage of summerwood, and many pieces with considerable sapwood. This type of material is not characteristic of Douglas fir from the Willamette valley or coastal areas.

Coarse-grain Douglas fir with fewer than 6 growth rings to an inch appeared to withstand a starting temperature of 180 F, but when dried with initial conditions for Emc of 12 per cent did not compare in quality with the fine-grain Douglas fir dried at conditions for 9 per cent Emc. Drying of lumber at conditions for 12 per cent Emc was not altogether satisfactory, because there was considerable checking in all charges in Table 2, and encased knots loosened excessively. Additional work was not done on coarse-grain Douglas fir because such material was not available at the various mills contacted.

Regardless of starting temperature or species, from 5 to 6 hours were required to warm the lumber to the desired wet-bulb temperature before initiating the drying cycle as shown in Figure 5. During the warming period, dry-bulb temperature was held as closely as possible to wet-bulb temperature to prevent severe drying before the lumber had become heated thoroughly.

Except for pieces containing heart center on the top layer, the 2 top layers of each charge showed only slight cupping and twist. Warping in other layers of a charge was in thin lumber that was not held down adequately by stickers and weight of the boards above. Uniformly sawed lumber that is piled and stickered properly should not warp excessively, therefore, except for pieces with heart center in the top layer of a load.

Range in final moisture content in most charges of Douglas fir was confined to limits closer than usual, and average moisture content was below 19 per cent. The narrow range of final moisture content likely would not have been obtained by schedules followed in the study if charges had been taken from the kiln at the 19 per cent average. Charges that averaged 16 or 17 per cent moisture content had drying times equal to, or less than, commercial practice, and degrade from checking did not exceed that found in commercial practice.

Average moisture content of hemlock ranged from about 12 to 16 per cent. Even at these low averages, uniformity of final moisture content was not sufficient. Time in kiln and degrade resulting from checking were equal to, or lower than, results from commercial practices, however. Pieces with moisture content over 21 per cent comprised 6 per cent or less of each charge. Again, removing hemlock from the kiln at 19 per cent average moisture content would leave some pieces with moisture content above 21 per cent, and yet other pieces would have dried to moisture contents between 11 and 15 per cent.

CONCLUSIONS

An initial dry-bulb temperature of 180 F can be tolerated by Douglas fir and western hemlock dimension lumber without increased degrade.

Initial conditions for equilibrium moisture content of 9 per cent, followed by conditions for 6 per cent Emc after the average moisture content of the wood has reached 22 per cent, are satisfactory for western hemlock.

The same Emc conditions maintained for western hemlock can be recommended in most instances for fine-grain Douglas fir having 10 or more rings to an inch, if applied after 24 hours at conditions for 12 per cent Emc. Douglas fir having a specific gravity of 0.48, or higher, may require initial conditions for 12 per cent Emc for a period longer than 24 hours.

Coarse-grain Douglas fir (6 rings to an inch, or fewer) requires initial conditions for equilibrium moisture content of 12 per cent, or higher, to reduce degrade resulting from checking and from knot holes or damage to knots.

In adopting the kiln schedule thus described, velocity of at least 400 feet a minute for leaving air is required for uniformity of final moisture content.

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