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CHEMICAL SEASONING OF DOUGLAS FIR

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As a result of the preliminary article on the Forest Products Laboratory method of seasoning wood with chemicals, which appeared in several magazines[1], considerable interest has been manifested in the subject by the lumber industry. The available information evidently needs to be focused so that the industry can judge the commercial possibilities of the process. The broad concept of chemical seasoning is so involved, however, that it cannot be adequately discussed in a short article. Special processes involving various chemicals and drying methods, it seems, must be developed for each industry. In this article the emphasis is placed on the seasoning of Douglas fir in the lumber industry.

Theoretical Aspects of Chemically Seasoning Douglas Fir

When normal wood is subjected long enough to a given constant temperature and relative humidity, it will attain a moisture content that is in equilibrium with the surrounding atmosphere. This moisture condition is known as the equilibrium moisture content and with minor exceptions is the same for all native species of wood. When wood attains an equilibrium moisture content, its contained moisture has the same vapor pressure as the surrounding atmosphere. If, however, the hygroscopic moisture acts as a solvent for a chemical its vapor pressure will be reduced varying degrees depending upon the characteristics of the dissolved chemical. Consequently in a given temperature and relative humidity, chemically treated wood will have a higher equilibrium moisture content than normal wood. Figure 1 shows the equilibrium moisture content of natural wood and wood treated in a saturated solution of sodium chloride. The significance of these curves as applied to chemical seasoning is that during a subsequent kiln drying or air drying in a given relative humidity the surface

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[1] Published in the following: American Lumberman, May 1937; Southern Lumberman, Sept. 15, 1936; The Timberman, Sept. 1936; West Coast Lumberman, Oct. 1936.

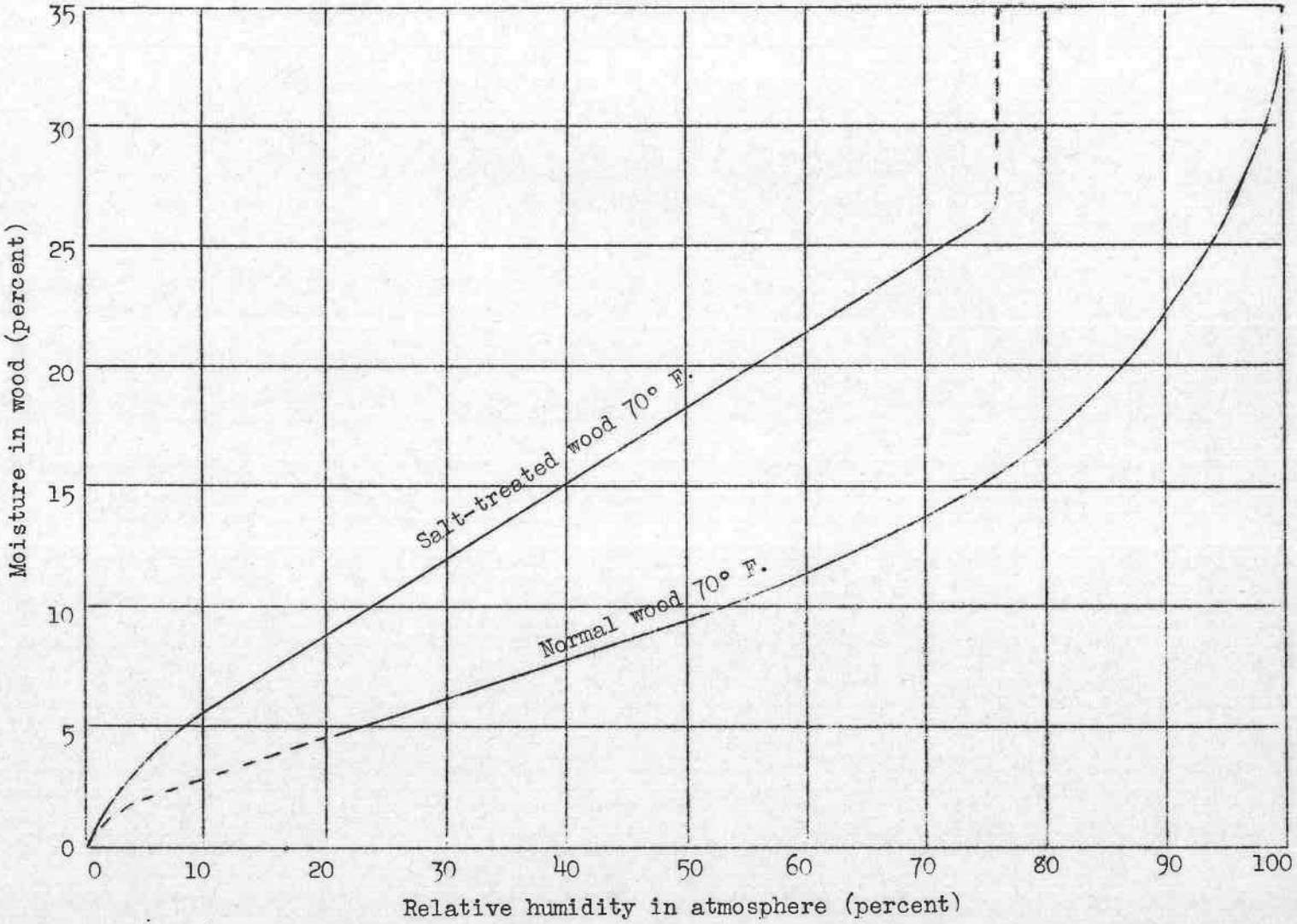

Figure 1.--Equilibrium moisture content of natural wood and wood treated with a saturated solution of sodium chloride.

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fibers of salt-treated wood have a higher moisture content than the untreated wood just beneath the chemically treated zone. For example, by drying wood properly treated in a saturated solution of sodium chloride in air maintained at a constant temperature of 70° F. and at a constant relative humidity of 75 percent, one can prevent the surface of the wood from shrinking and yet ultimately dry the interior untreated portion of the timber to a moisture content of 15 percent. By chemical seasoning methods, therefore, it is possible to dry from the inside out and to prevent the surface fibers from becoming sufficiently dry to induce them to shrink. In this way surface checking is avoided because the surface fibers are not stretched as they inevitably are when kiln dried or air dried without chemical treatment.

The chemical is diffused into the wood. If the moisture content of wood is not high enough to provide a continuous film of water into which the chemical can diffuse, the action of diffusion is impeded. The area in which diffusion can take place increases with the moisture content of the wood. Consequently, the amount, rate, and depth of penetration at which a chemical diffuses into wood are directly associated with its moisture content. In species like oak, for example, there is enough moisture present to support diffusion at a fairly rapid rate for a long time. On the other hand, Douglas fir heartwood, when green, has but little more moisture than is necessary to saturate its cell walls. Consequently, Douglas fir fibers do not have to dry very much before they lose their free water, leaving all the remaining moisture confined to the cell walls. While a chemical will diffuse in hygroscopic moisture the rate is very slow. Thus while Douglas fir is soaking in a chemical solution the chemical diffuses into the water in the wood and the water just beneath the treated zone diffuses outward in the opposite direction toward the surface and eventually is lost to the chemical solution. Owing to its original low moisture content, Douglas fir, when steeped in a hot chemical solution having a relatively low vapor pressure, soon dries enough to slow up the rate of diffusion materially. It has been discovered that 12 by 12-inch Douglas fir timbers have almost the same salt distributions when soaked one and a half months as they have when soaked for a much longer period.

Experience has shown that surface checking control can be accomplished by permitting the chemical to diffuse no deeper than from one-half to five-eighths of an inch. This can be accomplished in from 4 to 10 days depending on the chemical used and the strength of the solution.

The rate at which Douglas fir timbers dry in a saturated solution of sodium chloride is about the same as that for matched timbers that are not in a bath but are subjected to the attained bath temperature and a relative humidity of 75 percent. In view of the fact that the drying rate increases with increasing temperature, everything else being equal, it follows that when it is desired to obtain a

considerable amount of drying while the timbers are in the solution, the bath should be heated.

Theoretically the rate at which a chemical will diffuse into wood containing free water is proportional to the absolute temperature of the bath. Since, however, the range in absolute temperature encountered in chemical seasoning is comparatively small, the rate at which a chemical will diffuse into green Douglas fir may be considered a constant. Therefore, with the exception of increasing the drying rate during the soaking process, elevated bath temperatures serve no useful purpose, and due to their deleterious effects on wood should be avoided in treating refractory items. The maximum safe bath temperature which may be used varies with the size and the nature of the item being treated.

Laboratory Technic and Results

The foregoing presents a rough concept of the basic principles involved in the Forest Products Laboratory method of chemical seasoning. The following paragraphs give specific processes with respect to Douglas fir that have resulted satisfactorily.

Crossarms

Any chemical treatment applied to crossarms should be of a type that will keep the electrical conductivity of the crossarm at a minimum. For this reason invert sugar was used instead of sodium chloride in the experiments on the chemical seasoning of crossarms.

When crossarms of green Douglas fir are steeped in a 40 percent solution of invert sugar for 2 days, they can be subsequently seasoned without the development of checks to a moisture content of approximately 15 percent in 5 days and to 12 percent in 7 days by the use of the following schedule:

Temperature °F.	Relative Humidity Percent	Number of Days
160	85	2
170	62	2
180	50	To end of run

So far the crossarms used in the chemical seasoning experiments have been end coated prior to kiln drying, but perhaps subsequent experiments may prove this precaution unnecessary. Since a 40 percent solution of invert sugar is in equilibrium with a relative humidity of

about 95 percent, crossarms treated with this chemical are apt to surface check and end check during subsequent air seasoning.

Wide Douglas Fir Planks

Flat-sawed Douglas fir planks that are wide and thick require careful kiln drying if surface checking is to be avoided. The expense of this process operates against its general adoption as a commercial practice. Moreover, this class of material will most surely check and split during normal air seasoning. Owing to these seasoning difficulties it is not surprising that wide plants are often shipped green. Chemical seasoning methods are helpful in either kiln drying or air drying such items. After steeping in a saturated solution of sodium chloride maintained at 160° F. for 2 days, 3 by 12-inch flat-sawed planks of Douglas fir were satisfactorily kiln dried to an average moisture content of 14 percent in 4 days by the following schedule:

Temperature °F.	Relative Humidity Percent	Number of Days
160	70	2
170	60	1
180	50	1

One lot of flat-sawed 3 by 12-inch Douglas fir planks was boiled in a saturated solution of sodium chloride for 4 days during which time they dried without degrade to an average moisture content of 12 percent. At the same time the cores of these planks had an average moisture content of 16.5 percent.

Another lot of flat-sawed 3 by 12-inch Douglas fir planks was steeped in a 40 percent solution of invert sugar at 120° F. for 2 days and kiln dried with the salt-treated planks. (See previous drying schedule.) When removed from the kiln these planks had an average moisture content of 16 percent and were free from any seasoning defect. When treated 2 days in a saturated solution of sodium chloride 3 by 12-inch planks were air dried in an unheated shed at Madison, Wis., without checking. Matched material when treated with a 40 solution of invert sugar checked under identical drying conditions. The better behavior of the salt treated planks during air seasoning is, of course, due to the lower vapor pressure of the salt solution.

Side-Cut Timbers

Figure 2 shows the moisture-time curve of salt-treated 6 by 12-inch timbers and also shows the drying conditions used. In two previous experiments after a 2-day and 15-day treatment in a saturated

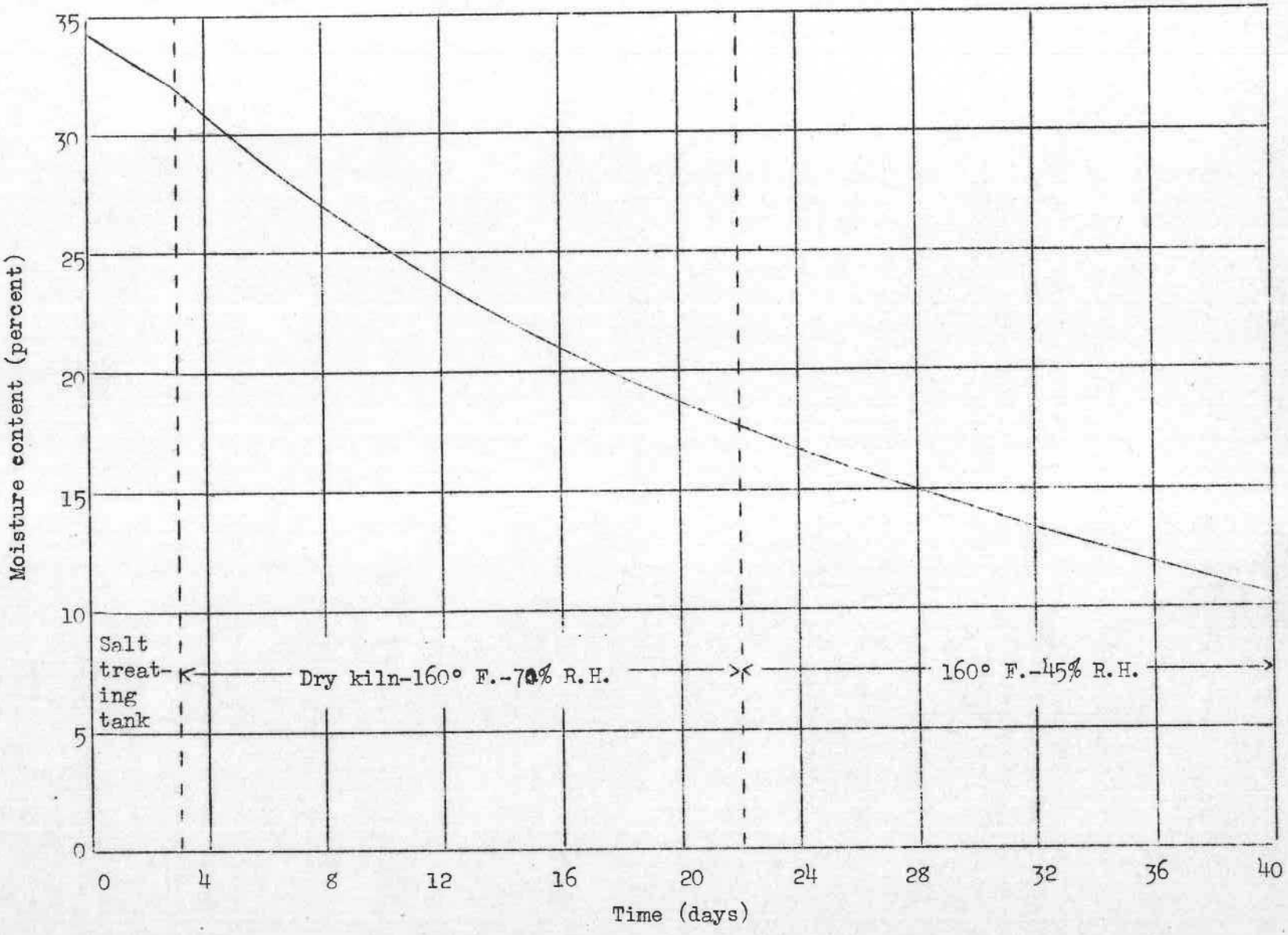

Figure 2.--Moisture-time curve for salt-treated and kiln-dried 6 by 12-inch side-cut Douglas fir timbers..

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solution of sodium chloride, respectively, each group was kiln dried in a constant temperature of 160° F. and a relative humidity of 60 percent without the development of seasoning degrade other than some end checking. As all three groups dried at about the same rate, drying with an initial relative humidity of 70 percent seems the safer and, consequently, better practice.

Little drying should be permitted until a reasonable amount of chemical has diffused into the timbers if end checking in the bath is to be entirely prevented. The 3-day chemical treatment was planned with this in mind. It consisted of adding sufficient salt to cold water containing the timbers to bring the solution to about 30 percent of saturation (in equilibrium with about 93 percent relative humidity) after which it was allowed to stand 24 hours during which time the bath was well agitated. Next the solution was increased to about 70 percent of saturation (in equilibrium with about 84 percent relative humidity) and the bath was left for another 24 hours. The solution was then saturated (equilibrium at 75 percent relative humidity) and the temperature gradually elevated to 160° F. where it was maintained from 6 to 8 hours. If it is necessary to dry timbers of this size perfectly free from end checks, some such treatment as the foregoing must be given. The amount of end checking that occurs when 6 by 12-inch side-cut Douglas fir timbers are treated at room temperatures in a saturated solution of sodium chloride perhaps is not large enough to warrant the additional expense of gradually increasing the solution strength of low vapor pressure solutions. Experiments have shown that when certain end coatings are applied to timbers prior to treatment the hazard of end checking is greatly reduced. Therefore, under certain circumstances perhaps end coatings can be profitably used in chemically seasoning timbers of this kind.

To date, air seasoning experiments following chemical treatment have not included large side-cut timbers. However, the kiln conditions used in drying the foregoing three groups of timbers were more severe than would be normally found in any part of the United States except the arid Southwest. It is reasonable to infer, therefore, that side-cut Douglas fir timbers up to 6 by 12 inches in size can be successfully air seasoned after treating in a chemical solution which has approximately the same vapor pressure as a saturated solution of sodium chloride. It is suggested, however, that for best results the air seasoning should be accomplished in an open shed.

12 by 12-inch Boxed-Heart Douglas Fir Timbers

By chemical seasoning methods the prospects of successfully seasoning boxed-heart timbers are more promising than heretofore. Large boxed-heart timbers of Douglas fir can be chemically treated and then satisfactorily kiln dried without checks provided the kiln

is susceptible of close relative humidity and temperature control. The major portion of the drying can be accomplished either in the kiln or in a chemical solution, depending upon which procedure is the more expedient. Soaking the timbers for a period of 2 weeks is long enough to give the desired penetration of the chemical. If seasoning is to be accomplished in the solution, the bath temperatures should not exceed 160° F. at any time. In order to prevent end checking in the bath it is necessary to maintain the temperatures as low as possible for the first week. In using sodium chloride it is best to bring the concentration of the solution up to saturation gradually. This procedure reduces the rate of end drying while the timbers are in the bath and permits a more adequate treatment of the end grain. Figure 3 shows the drying schedule used in kiln drying 12 by 12-inch boxed-heart Douglas fir timbers after a 14-day treatment in the salt bath. From the curve it may be seen that this class of material can be dried to a moisture content of 16 percent in approximately 85 days.

Commercial Aspects

The experiments conducted so far at the Forest Products Laboratory on chemical seasoning have been directed toward only one problem; namely, the drying of large timbers and refractory items of wood without seasoning degrade. The experiments have been so satisfactory as to make it desirable to give serious consideration to the commercial application of the results. For example, thought should be given (a) to the best type of equipment and the ultimate cost of the treatment, (b) to means of preventing the surface of timbers from becoming damp when exposed to high relative humidities, (c) to means of controlling the loss of electric current in items which demand high electrical insulation, (d) to the matter of controlling the corrosion of metal fastenings used in the assembly of salt treated wood.

The experiments indicate that the cost of the absorbed chemical is low. In general, a satisfactory chemical treatment is one in which the weight of the absorbed chemical is equal to 2 percent of the weight of the oven-dry wood. In timbers as large as 12 by 12 inches in size this amount of chemical is somewhat excessive, but for purposes of cost estimation the 2 percent value may be considered as a constant for all sizes. If the cost of chemical treatment and subsequent kiln drying is assumed to be 30¢ a thousand board feet per day, it is easy to estimate the cost of drying various sized timbers by this process. The following table shows the estimated costs of chemically seasoning the indicated items of Douglas fir from a green condition to a moisture content of 15 percent. The values are set down as calculated, and are to be considered merely as guides.

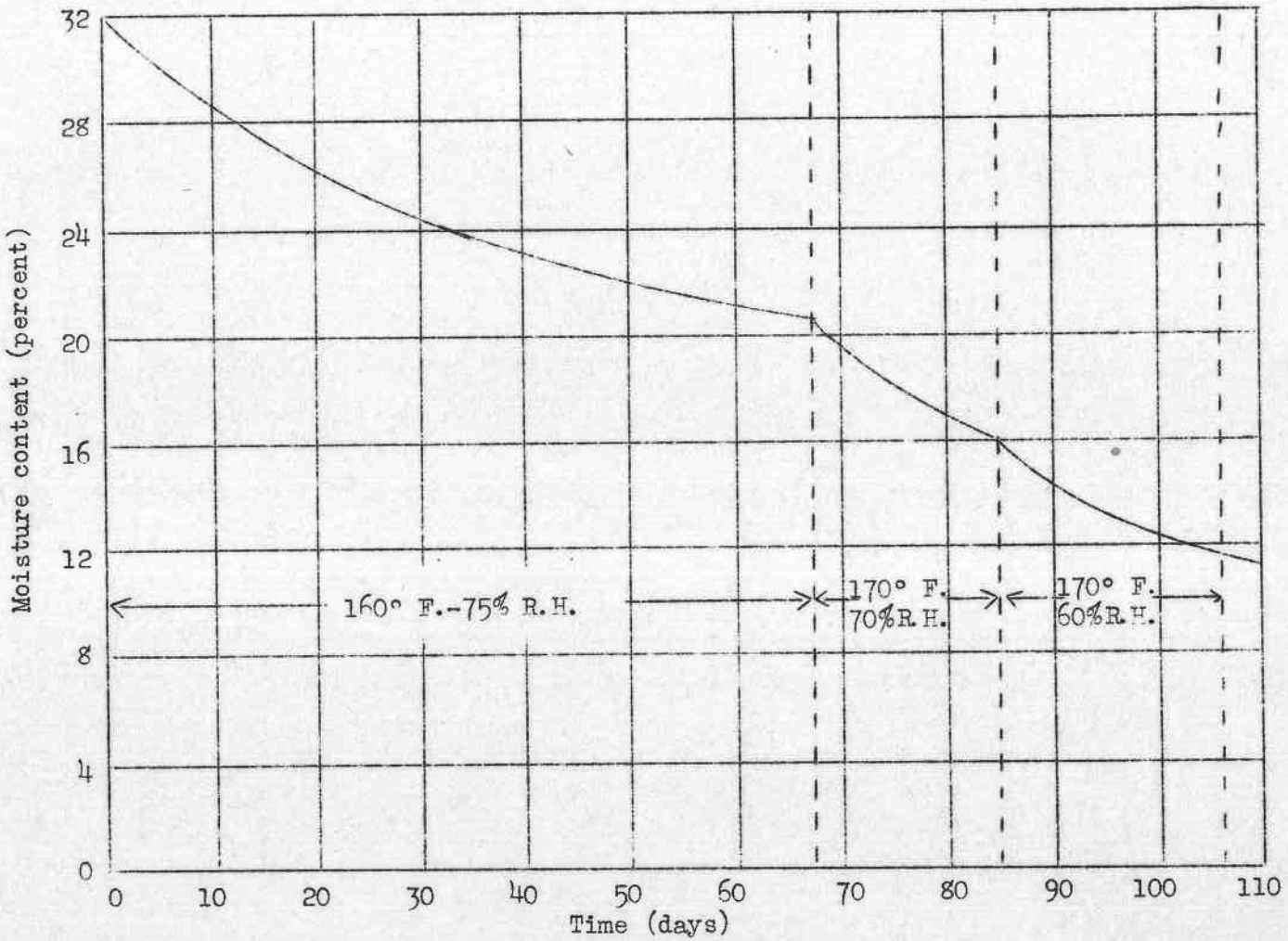

Figure 3.--Moisture-time curve for kiln-dried 12 by 12-inch boxed-heart Douglas fir timbers.

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Table 1.--Estimated cost of chemically seasoning four items of Douglas fir

Item	Drying period including time in the chemical solution	Cost per thousand feet, BM		Total cost
		Drying	Chemical at 1¢ per pound	
	Days			
Crossarms	7	$ 2.10	$ 1.60*	$ 3.70
3 by 12	6	1.80	.45	2.25
6 by 12	26	7.80	.45	8.25
12 by 12	96	28.80	.45	29.25

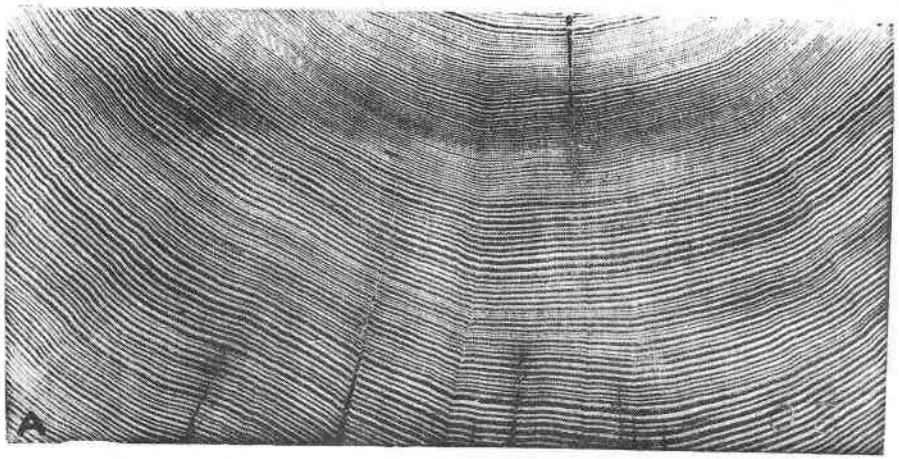
*For this item only, invert sugar was used in order to keep the loss of electric current in crossarms at minimum. The cost of the invert sugar is estimated as 4¢ a pound.

In order to justify the seasoning of material of large size, ordinarily shipped green, the industry must get a premium for large, dry timber because the freight costs for shipping the excess water are not enough to pay for the cost of drying. This is based on the fact that approximately 570 pounds of water per thousand board feet are removed from Douglas fir by drying from a green condition to a moisture content of 15 percent, which at a 72¢ freight rate, amounts to a saving of $4.10 when dried timbers are shipped in place of green. According to these calculations, if the cost of seasoning must be borne by the reduced freight charges, sizes much larger than 3 by 12 inches must continue to be shipped green. On the other hand, when green refractory material of large size is unsuitable for the use intended, walking beams for example, chemical seasoning offers a possible solution.

Preliminary experiments indicate that the chemical seasoning of material of smaller size, such as 4/4 and 8/4 Douglas fir of common grade, offers good promise. The usual drying period required to season these items can be reduced by chemical seasoning methods. Moreover, it is possible that the reduction in grade due to loss of knots will be somewhat less than when straight kiln drying is practiced. This will be best realized when chemicals having high antishrink properties are used.

Summary

Several items of Douglas fir have been satisfactorily chemical seasoned on a laboratory scale green from the saw to a moisture content of 7 percent, which is a degree of seasoning not normally attained in use. Crossarms, 3 by 12 flat-sawed planks, 6 by 12 side-cut timbers, and 12 by 12 boxed-heart timbers were dried to a moisture content of 15 percent practically free of seasoning blemishes in 7, 6, 26, and 96 days, respectively. The cost of chemical seasoning the smaller items would probably be less than the cost of air drying or kiln drying them to the same standard of quality and moisture content. Although the costs of chemically seasoning large items, such as boxed-heart 12 by 12's, would probably be greater than the cost of air drying them the quality of the chemically seasoned timbers is vastly superior.



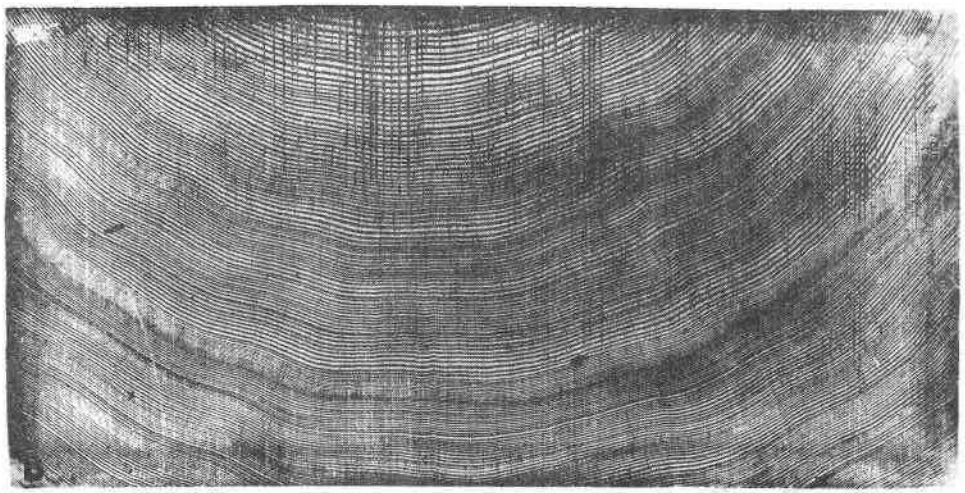


Plate 1.--Sections of 6 by 12-inch Douglas fir timbers. A, After air seasoning to a moisture content of 15 percent; B, after chemical seasoning to a moisture content of 6 percent.

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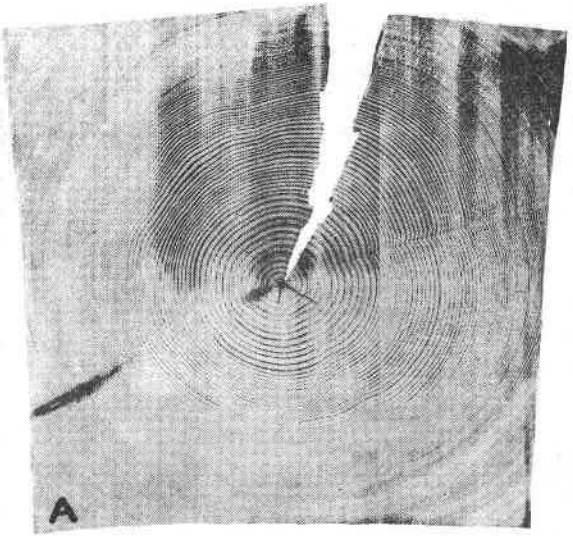

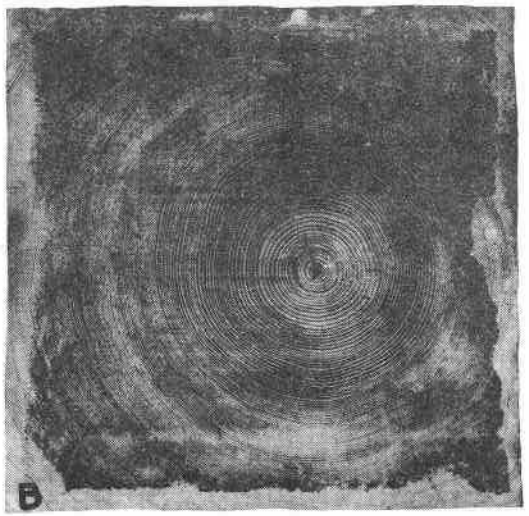

Plate 2.--Sections of 12 by 12-inch Douglas fir timbers. A, After air seasoning to a moisture content of 15 percent; B, after chemical seasoning to a moisture content of 10 percent. Border indicates the depth of penetration of the chemical.