CHEMICAL SEASONING: ITS EFFECTIVENESS AND PRESENT STATUS

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Introduction

Periodic research at the U. S. Forest Products Laboratory during the last 18 years has indicated that, under certain conditions, chemicals may be profitably employed to supplement conventional air-drying and kiln-drying methods of seasoning wood. This research was undertaken to correct certain difficulties encountered in normal air and kiln drying.

From the facts that the vapor pressure of water diminishes when chemicals are dissolved in it and that a dissolved chemical diffuses from a zone of high to one of low concentration, the Laboratory formulated the following principles:

1. A water-soluble chemical will diffuse into water in green wood. Simultaneously, water in green wood will diffuse into the chemical solution in which it is submerged.

2. When the chemical diffuses into the water in unseasoned wood, this water becomes a chemical solution that has a vapor pressure less than that of water. The treated portion of the wood tends to retain its green dimensions while being dried at a relative humidity in equilibrium with the vapor pressure of the imbibed solutions.

3. The presence of the chemical in the fine swelling structure of wood decreases its normal shrinkage.

To test these principles, the Laboratory conducted a long series of preliminary experiments that showed the validity of the first two principles, but that, in practice, produced a noticeable antishrink effect only on the smaller items.

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[1] Presented at a conference on "Economies in Seasoning," Poland Springs, Me., June 25, 1948.

How Chemical Seasoning Works

If the outer portions of a plank are saturated with a given chemical, they tend to remain moist as long as the vapor pressure of the surrounding air is equal to or higher than that of the solution in the wood. The high moisture content of the surface zones of the chemically treated wood does not decrease the drying rate because the water in the untreated portion will have a normal high vapor pressure and will move toward and be evaporated from the surface at a rate controlled by the temperature and relative humidity of the drying atmosphere. Figure 1 shows a typical moisture and salt distribution in a Douglas-fir heartwood timber after treatment. If a proper balance exists between the relative humidity of the air and the vapor pressure of the solution in the wood, the moisture content of surface fibers will remain high enough to prevent their shrinkage and thus prevent surface checking. An exception is when the moisture content of the wood is still high after treatment, in which case the chemical continues to diffuse from the surface into the fresher water nearer the center and the moisture in the surface zones of the wood becomes less than chemically saturated, and the surface-cell walls lose some moisture and shrink proportionately.

Moisture-retention Properties

The surface fibers of treated wood have a higher equilibrium moisture content than untreated wood when dried under identical conditions of temperature and relative humidity (figure 2). Consequently, chemically treated lumber will not check when the drying conditions are just sufficiently severe to cause checking in untreated lumber. The only reason that chemically seasoned lumber dries faster than untreated lumber of the same species, moisture content, and cross section, dried by ordinary methods, is that, in general, lower relative humidities can be used in drying the treated wood to a given standard of allowable checking than can be used for the untreated wood. The chemicals do not increase the drying rate; they merely permit the use of more severe drying conditions.

Chemical-seasoning agents vary in water-retention properties according to their vapor pressures. The following tabulation shows the relative humidities of air at a temperature of 68° F. that is in equilibrium with the vapor pressures of eight saturated aqueous chemical solutions.

Chemical	Relative humidity of air in equilibrium with vapor pressure of saturated solution at 68° F.
	Percent
Calcium chloride	32
Magnesium chloride	32
Calcium nitrate	59
Ammonium nitrate	68
Sodium nitrate	76
Sodium chloride	78
Urea	80
Ammonium sulfate	81

It is evident from the tabulation that a thin specimen of green wood, thoroughly saturated with a solution of sodium chloride, will neither gain nor lose moisture in an atmosphere of 68° F. and 78 percent relative humidity, but water would condense on it at a higher relative humidity. For this reason, particularly hygroscopic salts are not desirable, since the chemical left in dry wood would attract moisture. Wood that is to be used in greenhouses, where the relative humidities are usually high, should not be given drying chemical treatment that will remain hygroscopic after the wood is dry, but since furniture and interior trim are exposed to relative humidities that average much less than 70 to 75 percent, it is safe, from the standpoint of condensation, to use sodium chloride, but not calcium chloride.

Antishrink Properties

Swelling of wood beyond its green dimensions caused by hygroscopic chemicals varies with the salt. This swelling shows that the dissolved chemical enters the fine swelling structure of the cell wall, since if only the gross capillary structure of the wood were entered, the sections would all shrink rather than swell. Salts known to swell wood most should cause it to shrink most if the salt entered only the cell cavities, for the cell cavities would act as dessicators and the contained solution would dry the cell walls. In general, the more soluble and bulky chemicals have the greatest antishrink effect, since the shrinkage reduction is proportional to the partial volume of the dry chemical in solution. When all of the hygroscopic moisture is saturated with a chemical, its maximum antishrink effect is obtained. It is often desirable to use two chemicals in order to increase the antishrink effect. The first may well be of crystalline nature, quite soluble in water, in which it would have a relative vapor pressure of about 0.75 to be in equilibrium with 75 percent relative humidity; and the second, in a partially saturated chemical solution to which the first should be added, may be one that will not crystallize out when the moisture in the cell cavities is evaporated. The second should also be highly soluble and should not affect the relative vapor pressure of the first.

Salt, urea, and monoammonium phosphate are examples of the crystalline agent, and glycerine, diethylene glycol, molasses, invert sugar, and corn sirup of the noncrystalline chemical. The advantage of the combination is that the partially saturated solution of noncrystallizing chemical gradually becomes more concentrated as the wood dries and continues to diffuse into the moisture in the cell walls. More antishrink is obtained with a chemical-seasoning agent of this type than with crystalline chemicals alone, which must be chosen for vapor-pressure characteristics rather than antishrink properties.

An example of a combination of chemical-seasoning agents is a mixture of salt and invert sugar. The mixture is formed by thinning 66-2/3 pounds of invert sugar with each 100 pounds of water and then adding 35 pounds of salt for each 100 pounds of water in the sirup. Both chemicals of the combination diffuse into the water in the wood. The invert sugar in the cell cavities remains a liquid and continues to diffuse into the cell walls until the solution in the cell is in equilibrium with about 25 percent

relative humidity. The effectiveness of this type of chemical-seasoning agent is illustrated in figure 3. The data presented were obtained from 3/6-inch strips of blackgum that were soaked until saturated before drying.

Composition of Chemical-seasoning Agent Can be Modified to Attain Specific Objectives

Although the primary function of chemical seasoning is to improve wood drying, various chemical-seasoning agents can be compounded so as to impart certain of their beneficial properties to the wood. Rust-inhibiting chemicals are successfully used. Wood hardness is increased and the natural rate of moisture regain is decreased by using resin-forming chemicals. Chemical-seasoning agents of this type overcome the common tendency of chemically treated wood to act as a condenser when exposed to moist atmosphere. Urea combines with lignin in hardwood to form a thermoplastic. Figure 4 shows a urea-treated oak square that was easily twisted when hot and later retained the twisted shape in which it was held while cooling and stiffening. When 1/2-inch oak squares are dried after treating with dry urea, they are made just as plastic by heating to 212° F. in dry heat as they become when heated while green in steam or boiled water.

Results of tests on yellow birch and persimmon squares, which it was sought to make more suitable for shuttle blocks, are shown in table 1. One group of each species was soaked in buffered-urea-formaldehyde solution for 7 days, and another group of each in the same agent for 14 days. Some of the squares were routed slightly before treatment. Blocks were dried to a low moisture content and tested for hardness by measuring the pressure required to embed a 0.444-inch ball one-half its diameter into the wood.

Buffered urea aldehyde also improves the finishing properties of wood and decreases its tendency to sliver and become rough in use.

Although urea encourages mold growth on treated wood, it somewhat increases its decay resistance. The sugars, alone, render the wood less resistant to decay and molds, but to overcome this shortcoming, a toxic chemical such as sodium fluoride may be added. Wood treated with an agent containing borax becomes more resistant to blue stain. Buffered sodium chloride, while not recommended for stain control, tends to reduce the stain hazard considerably. Buffered urea aldehyde is more effective than urea in retarding decay, but not nearly so effective as the commonly used wood preservatives.

Chemical-seasoning Procedure

Chemical seasoning consists of two steps: (1) treating the green lumber with a chemical, and (2) subsequent drying. Only green or wet wood can be impregnated, since water is the medium through which the chemical diffuses.

Methods of Applying the Chemical

Neither the amount nor the depth of penetration of chemicals has been determined for various items of wood. In the case of Douglas-fir timbers, 40 pounds of dry chemical per thousand board feet gave adequate surface-checking protection. By using a suitable stain, depth of penetration was shown as in figure 5. Generally, more chemicals must impregnate hardwoods than softwoods to obtain the same surface-checking protection. In drying 4- by 6-inch oak timbers, as much as 150 pounds of chemical per thousand board feet were used.

Steeping.--In the earlier experiments wood was submerged and steeped in the solution 1 day for every inch of thickness. The solution temperature depended upon the nature of the wood. This method, while very effective, was found suitable only for small quantities of high-priced material. Although millions of feet of 12/4-inch Southern red oak have been soaked about 4 days per inch of thickness, air-dried, and sold, enormous tank capacity and quantities of solution required for large-scale operation make steeping generally impractical.

Dipping.--When lumber is dipped in a chemical solution, the piece size and the concentration, viscosity, and temperature of the solution affect the quantity of chemical that adheres to the surface of the lumber. The surface of a rough green 2- by 12-inch Douglas-fir plank dipped in a 50-percent urea solution at 65° F. will retain an average of about 40 pounds of dry chemical per thousand board feet. A rough green 6- by 8-inch timber dipped in the same solution retains on its surface only about 25 pounds of chemical per thousand board feet. A saturated urea solution at 125° F. gives a 45-pound retention per thousand board feet to this size timber.

Solubility of many chemicals is not thus affected by temperature. When such solutions are used, they can be made in such concentrations as to give almost any desired retention.

Spray Method.--In the west, an efficient commercial apparatus was built for spraying cross arms and ponton stock. The untreated stock was brought by carrier to a roll case. Individual pieces were placed on rolls on one end, pushed through the spray booth, and then moved on live rolls to the other end of the apparatus and loaded onto carrier packages. In the northeast, preliminary attempts have been made to spray lumber that had been piled for air seasoning.

Dry Spreading.--Urea, salt, or borax, powdered or crystalline, may be applied by spreading it on the surfaces of the green lumber as it is stacked for air or kiln drying. For best results, surfaces should be wet. When the wood does not contain much moisture, the rate of diffusion will be greatly improved by wetting it before the chemical is applied. In dry spreading, lumber is bulk-piled with a sandwich of chemical between each course so that both faces of a board or plank may receive their share of chemical. In time, the chemical dissolves and diffuses into the lumber, after which the lumber is repiled on sticks preparatory to air or kiln drying. In both the bath and dry-spread method the cost of application exceeds the cost of the chemical.

Properties of Chemically Seasoned Wood

Chemicals retained in lumber may modify the properties of the wood, depending upon their kind, amount, and depth of penetration. As the effect of the chemical may be either good or bad, seasoning agents should be chosen with the end use of the seasoned wood in mind.

Corrosion

Most salts are corrosive, although a few, such as the chromates, may inhibit corrosion. The Forest Products Laboratory made an experiment to determine their relative corrosiveness. Common fourpenny nails and kiln-dried Douglas-fir, previously treated with various chemicals, were used. On the basis of the compared strength values of the nails when withdrawn from the boards after accelerated corrosion treatment, the 33 chemicals tested were classified into five groups according to corrosiveness. With 808.3 pounds taken as the tensile strength of new nails, the first group of treatments included the seven least corrosive of the chemicals. Nails in this group had mean tensile strengths after withdrawal of 741.4 to 808.3 pounds. Fifteen chemicals were used in treatment of the second group, which gave strength values of 674.5 to 741.4 pounds; six chemicals for the third group, which gave strength values of more than 607.6 but less than 674.5 pounds; four chemicals for the fourth group, which gave strength of more than 540.7 but less than 607.6 pounds; and one chemical for the fifth group, which gave a mean tensile strength value of less than 540.7 pounds. The upper and lower limit of each group differed by 66.9 pounds, a statistical value indicating that differences less than 66.9 pounds might be due to chance.

The tests showed, as indicated by the above group numbers in the following tabulation, that boards treated with some chemicals seem to corrode nails less than untreated boards, that boards treated with sodium chloride and ammonium sulfate seriously corrode nails, and that common rust inhibitors have no appreciable effect on sodium chloride. The tabulation lists the chemicals in the order of their increasing corrosiveness.

Chemical Treatment	Group No.
Monoammonium phosphate + 2 percent potassium dichromate	1
Sodium dichromate	1
Calcium nitrate	1
Potassium sulfate + 2 percent potassium dichromate	1
Borax	1
Untreated	1
Sodium phosphate	1
Zinc acetate	2
Sodium nitrate + 2 percent potassium dichromate	2
Magnesium chloride	2
Magnesium sulfate + 2 percent potassium dichromate	2
Calcium nitrate + 2 percent potassium dichromate	2
Sodium nitrate	2
Manganese sulfate	2
Potassium sulfate	2
Calcium chloride	2
Monoammonium phosphate	2
Magnesium sulfate + 2 percent potassium dichromate	2
Magnesium sulfate + 2 percent sodium dichromate	2
Sodium carbonate	2
Magnesium sulfate (chemically pure)	2
Magnesium sulfate (epsom salts)	2
Magnesium chloride + 2 percent potassium dichromate	3
Sodium chloride (chemically pure)	3
Sodium sulfate + 2 percent potassium dichromate	3
Sodium sulfate	3
Sodium chloride (CP) + 2 percent potassium dichromate	3
Sodium chloride (CP) + sodium chromglucosate 7.25 grams per liter water	3
Sodium chloride (commercial) + 2 percent potassium dichromate	4
Sodium chloride (commercial grade) + 2 percent sodium dichromate	4
Sodium chloride (CP) + sodium chromglucosate	4
Sodium chloride (commercial grade)	4
Ammonium sulfate	5

In a field study, the Laboratory found treatment of Douglas-fir timbers with sodium chloride by the bath method a success from the standpoint of check control and reduction of drying time, but a failure due to the damage done by the sodium chloride to metal of the kilns.

The Laboratory made a preliminary corrosion test of a proprietary sodium chloride chemical-seasoning agent, conveniently called buffered sodium chloride, for which the manufacturer has claimed corrosion-inhibiting properties. This test indicated that a commercial kiln would not ordinarily be damaged in drying lumber with the proprietary chemical-seasoning agent.

In general, organic chemicals are not corrosive. Urea was readily substituted for salt in the chemical-seasoning of Douglas-fir timber. Aside from its noncorrosive properties, urea is not the equal of common salt as a chemical-seasoning agent. Corn sirup, invert sugar, and molasses are also noncorrosive, and, because of their vapor-pressure characteristics, are much better than refined and more expensive table sugar. They are effective used alone or in combination with water-soluble crystalline chemicals.

Condensation

To be an effective chemical-seasoning agent, an aqueous solution should have a relative vapor pressure in equilibrium with a relative humidity of about 75 percent. The property of a chemical solution that keeps surface fibers of treated wood moist in relative humidities of less than 100 percent is called water retention.

The relative humidity with which a chemical solution is in balance establishes the minimum relative humidity to which the wood may be exposed without shrinkage of surface fibers. Treated wood exposed to relative humidities higher than the relative vapor pressure of the imbibed solution will condense moisture. For rapid drying and minimum stress, the relative vapor pressure of the treating solution should be low. To reduce condensation on wood in service, the relative vapor pressure of the absorbed chemical should be high. A chemical-seasoning agent should be chosen that is the best compromise between the desire for rapid, safe kiln-drying and the least trouble from condensation when the finished product is put to use.

Since the chemical is concentrated in the outer fibers so that much of it is removed in dressing the lumber, and since chemically seasoned wood products that are kept dry during use do not usually create condensation problems, it is easy to overemphasize the seriousness of condensation in chemical seasoning. However, cypress has been rendered unfit for use in humid climates because of deep penetration of sodium chloride. Since the chemical diffuses into wood as long as its moisture content is high, no more chemical should be used than is needed to control surface checking. The movement of chemicals away from the surface (figure 6) toward the interior of wet wood is one reason that the full benefits of chemical seasoning are not realized in seasoning oak. Conversely, when such diffusion is more or less lacking, as in Douglas-fir and pine heartwood, chemical seasoning appears to best advantage.

Some chemicals do not cause treated wood to sweat in relative humidities that exceed the relative vapor pressure of the treating solution. For example, while the relative vapor pressure of sodium chloride and urea are substantially the same, salt-treated wood will become damp in relative humidities slightly in excess of 75 percent, but the same degree of dampness will not develop in urea-treated wood unless exposed to a relative humidity of 90 percent or more. Resin-forming chemicals such as buffered-urea-formaldehyde solutions become nonhygroscopic when the resin is formed. Chemical-seasoning agents of this type are to be preferred when it is necessary to protect the product and its finish from the effects of moist atmosphere.

Electrical Conductivity

Electrolytes impregnated into wood materially reduce its electrical resistance, so that if high electrical insulation is required, salts should not be used as chemical-seasoning agents. From the standpoint of check control, sodium chloride proved a very satisfactory chemical-seasoning agent for Western redcedar poles. In analyzing a mass of electrical-resistance measurements, however, it was found that the mean electrical resistance of untreated Western redcedar poles at about 17 percent moisture content was 17.4 ohms. Salt-treated poles at the same moisture content averaged but 0.123 megohms. Apparently the salt treatment reduced the electrical resistance of these poles almost 140 fold.

Influence of Chemicals on Color

When chemicals are physically or chemically combined, each of them loses some of its individuality and at the same time contributes some of its characteristics to the new mixture. Any predrying chemical treatment so alters the properties of wood that it is more or less a new product. The properties of the new wood-chemical complex are controlled by the nature of the chemical-seasoning agent and the technique of employing it.

The natural color of wood is not much altered by sodium chloride, buffered sodium chloride, or diethylene glycol, which tend to reduce the darkening effect of air-drying. Other chemicals, particularly the ammonia compounds, such as urea, monoammonium phosphate, and ammonium sulfate, tend to give the wood a fumed appearance. These effects are increased by high kiln temperatures. After a time, the color becomes more or less uniform regardless of depth of the original penetration. Ammonia compounds may be preferred if a fumed appearance is desired, but they should be avoided when a white wood product is preferred.

In contrast to its effect on the color of treated wood, when combined with formaldehyde, urea tends to bleach hardwood somewhat and to preserve and intensify the natural brightness of the wood. Invert sugar and diethylene glycol are examples of agents that do not alter the color of treated wood unless the drying temperature exceeds 150° F. Low-grade corn and cane sirups, being dark themselves, tend to darken the treated wood. Attractive effects in oak trim and flooring are obtained by treating the wood with a combination of urea and blackstrap molasses. Chromates, used alone or as a corrosion inhibitor in conjunction with other salts, darken the wood considerably.

Effectiveness of Various Chemical-seasoning Agents

Chemicals

Few chemicals give promise of being satisfactory seasoning agents. A good one should be comparatively cheap and quite soluble in water. Its saturated solution should be in equilibrium with about 75 percent relative

humidity, and it should be noncorrosive to any metal fastening and ferrous kiln parts. Only buffered sodium chloride, buffered urea aldehyde, and, for some uses, urea, meet all requirements. Basic treatments with these agents can be supplemented with other chemicals for specific objectives, such as stain resistance, increased antishrink, or increased fire resistance.

Influence of Drying Methods

Predrying treatment is but one part of the chemical-seasoning process. Methods of drying the treated lumber have more effect on the resultant drying rate and on seasoning losses than the chemical treatment. Despite a current impression that chemical seasoning is dedicated to the cause of rapid seasoning, in research on chemical seasoning more time is spent in studying drying schedules than in seeking more efficient chemical-seasoning agents. A predrying treatment supplements, but does not replace, the recognized seasoning factors, temperature and relative humidity.

Although chemically treated lumber can be safely kiln-dried at relative humidities ruinous to similar untreated material, treated wood has its own critical temperature and relative humidities that may not be exceeded without damaging results. With reasonable and identical drying conditions, properly treated chemically seasoned lumber always dries with less checking than untreated lumber. For the same amount of checking as in untreated stock, matched treated stock can be dried faster. The main advantage of chemical seasoning is that it allows the drying of wood items, that defy ordinary kiln- and air-drying practices, without serious seasoning degrade.

Before the advent of chemical seasoning, attempts to dry large Douglas-fir timbers were futile. Many preliminary experiments showed that final success was due not alone to the chemical treatment, but equally to the drying schedule of 160° F. and 73 percent relative humidity for the entire drying period. At 70 percent relative humidity, many of the timbers checked. Similar items treated with urea had to be dried in a temperature of 140° F. and a relative humidity of 80 percent.

Drying Time

When drying time and degrade are compared on the basis of economies, first one and then the other factor will assume importance, depending upon the value of the product and the cost of drying. It then becomes a matter of either taking more time if the value of the product is too high to permit degrade, or taking more degrade if the cost of drying is relatively high.

In general, it may be said that, other conditions being the same, treated and untreated stock dry at the same rate. Chemically treated stock dries faster only when, because of its improved seasoning characteristics, it is dried by a more severe drying schedule.

The drying rate of urea-treated Douglas-fir items, size for size, is not quite so rapid as for salt-treated material because of the lower

temperatures required for the urea. In all sizes more than 3 inches thick, however, both treatments reduce the drying period of that of untreated items by one-half.

There is some evidence that under identical kiln conditions some urea-treated items dry faster than similar items treated with other chemical-seasoning agents. After 3-inch redwood had been treated with urea and sodium bicarbonate, it subsequently dried in about one-half the time of matched material treated with other chemicals under identical conditions.

By best commercial practice, from 45 to 50 days are required to dry untreated 10/4 walnut gunstock blanks. By an accelerated schedule, urea-treated 10/4 gunstock blanks were, through successive runs, dried in from 26 to 29 days, exclusive of a 5-day treating period. Matched material treated with buffered urea aldehyde dried in 37 days. This apparent advantage of urea over the buffered-urea-aldehyde treatment may or may not have been significant. Ordinarily, buffered-urea-aldehyde-treated stock can be dried by more severe conditions than would be safe to use in drying urea-treated material.

Oak grown in various localities differs so much in its drying characteristics that miscellaneous data regarding its drying rates and tendency to check are likely to be misleading. Comparisons of the drying rates of salt-treated and untreated oak are necessarily based on the same species cut from the same area. Overcup oak from Catahoula Parish, La., was used in a study for the reduction or elimination of surface checking and honeycombing. Very conservative kiln schedules were employed. The following tabulation shows the times taken in kiln-drying the various items of salt-treated and untreated overcup oak from a moisture content of 100 percent or more to a moisture content of 10 percent or less.

Items	Drying time	
	Salt-treated	Untreated
Inches	Days	Days
1 x 10	48	120
2 x 2	62	124
2 x 4	90	164
2 x 8	90	176
3 x 3	138	196
3 x 6	221 (to 15 percent moisture content)	262
3 x 12	221 (to 15 percent moisture content)	262 .

Since the controls degraded badly, it was evident that the practical limit of drying time had already been exceeded. As the salt-seasoned groups dried without serious degrade, it was evident that they could be dried with a much more severe schedule. Accordingly, two additional runs were made,

one composed of salt-treated 1- by 10-inch boards, the other of salt-treated 2- by 8-inch planks. The schedules employed in these runs were based on all the available information concerning the drying characteristics of salt-treated overcup oak and were designed to give the fastest drying rate consistent with degrade.

By these accelerated schedules the salt-treated 1- by 10-inch boards were dried in 17 days, including 4 days of soaking in the salt solution, and the 2- by 8-inch planks were dried in 38 days, including 8 days soaking in the salt solution. Not only did the salt treatment make it possible to dry these two items in about one-half the time required to dry the untreated material, but the salt-treated material was of much higher quality.

Chemical-seasoning Agents and Drying Degrade

Sodium chloride was used exclusively in the early chemical-seasoning experiments because it was readily available and had the proper relative-vapor-pressure characteristic. Its control of surface checking was satisfactory. Figure 7 illustrates the honeycombing that developed in matched salt-treated and untreated control groups. In this figure, each set of vertically piled overcup squares represents the width of the dry matched treated and untreated planks before they were ripped. Thus the figure not only shows that the salt treatment improved the quality of the stock, but that it also decreased its shrinkage. Despite a very conservative schedule in drying the untreated material, it degraded quite badly. No attempt was made to obtain the maximum rate of drying for the salt-treated group, yet it dried from a moisture content of 100 percent or more to 10 percent in less time than required to dry the controls and with much less degrade.

The honeycombing data from this extensive study are given in table 2. These data indicate the greater yield of perfect squares cut from salt-treated overcup oak. Thus, 29 percent of the salt-treated, air-seasoned 3- by 12-inch planks were free of honeycomb, and 75 percent of the 3-inch squares produced from them were free of honeycomb. None of the 3- by 12-inch air-dried untreated planks were free of honeycomb, and but 7 percent of the squares produced from them were entirely free of seasoning blemishes.

Noncorrosive organic chemical-seasoning agents also tend to reduce honeycombing in thick oak, as shown in table 3. None of the treatments, however, were as effective as that with sodium chloride, shown in table 2. The data in the two tables are not strictly comparable because, first, the species of oak represented differ; and, second, the data given in table 3 were derived from 4- by 6-inch planks, whereas 3- by 12-inch planks are the largest of the items listed in table 2.

Chemical-seasoning in the Northeast

Results of a study[2] involving the air-drying of thick beech after treatment with buffered sodium chloride, reported by Peck, Baker, and Carter, are in accord with general experience, namely, that regardless of

[2] "Chemical Treatment and Seasoning of Thick Beech Stock," Forest Products Laboratory Report No. R1708, April 1948.

the methods of chemical application, treated material has had fewer drying defects than the untreated. In the study, the dry-spread method was significantly better than the spray or dipping treatment. More experience should improve the latter methods.

Present and Future of Chemical Seasoning

Until it can be shown that the benefits of the chemical-seasoning process result in more profits, there will be no prospect that the industry will adopt chemical seasoning, regardless of how it controls surface checking. At present, the lumber industry can control drying time more economically by limiting the degree of seasoning. Hence, the saving in drying time can hardly be expected to bear the entire cost of the chemical treatment. Chemical seasoning is potentially a vital tool that the industry may use profitably when the public insists on check-free lumber that is dried to a specified moisture content.

At present, there may be any number of opportunities to use profitably chemical-seasoning methods in drying specialty items. The properties of a plentiful but little-used species may be modified enough to take the place of a less plentiful and more expensive species that is normally used for a given item. Large-scale commercial acceptance of chemical seasoning, however, probably must await more favorable economic conditions.

At present, chemical seasoning is not a process that replaces ordinary kiln- and air-drying. It merely supplements these methods. Chemical seasoning saved a situation for the West Coast industry when it was necessary to season high-grade ponton lumber. It was abandoned, however, when ponton stock was no longer needed. The present status of chemical seasoning is like that of reserve water power that may be utilized as the occasion demands.

Table 1.--Average hardness of yellow birch and persimmon
shuttle-block squares chemically seasoned and
resinified with buffered-urea-aldehyde solution

Species	Soaked in buffered-urea-aldehyde solution for:		Untreated[1]
	7 days	14 days	
	Pounds	Pounds	Pounds
Persimmon			2,300
Square	2,380	3,363	
Routed	2,575	3,284	
Yellow birch			1,260
Square	1,662	1,898	
Routed	1,943	1,979	

[1] Values reported in "Strength and Related Properties of Woods
Grown in the United States." U.S.D.A. Technical Bulletin
No. 479 (1935).

Table 2.--Extent of honeycombing in kiln-dried and air-seasoned salt-treated and untreated overcup oak

Size	Group	Honeycombing							
		Individual squares				Original pieces			
		None	Slight	Medium	Bad	None	Slight	Medium	Bad
Inches		Percent							
1 x 10	Kiln-dried, untreated controls	(Not cut into				35	25	40	0
	Kiln-dried, salt-treated					100	0	0	0
	Air-seasoned, untreated controls	squares)				45	40	15	0
	Air-seasoned, salt-treated					95	0	5	0
2 x 2	Kiln-dried, untreated controls	76	21	3	0	76	21	3	0
	Kiln-dried, salt-treated	98	1	1	0	98	1	1	0
	Air-seasoned, untreated controls	59	15	17	9	59	15	17	9
	Air-seasoned, salt-treated	100	0	0	0	100	0	0	0
2 x 4	Kiln-dried, untreated controls	64	30	5	1	45	43	10	2
	Kiln-dried, salt-treated	95	4	1	0	90	8	2	0
	Air-seasoned, untreated controls	48	48	2	2	35	55	5	5
	Air-seasoned, salt-treated	98	2	0	0	95	5	0	0
2 x 8	Kiln-dried, untreated controls	57	38	5	0	20	60	20	0
	Kiln-dried, salt-treated	92	4	3	1	75	10	15	0
	Air-seasoned, untreated controls	32	53	15	0	0	40	60	0
	Air-seasoned, salt-treated	100	0	0	0	100	0	0	0
3 x 3	Kiln-dried, untreated controls	47	28	5	20	47	28	5	20
	Kiln-dried, salt-treated	84	11	5	0	84	11	5	0
	Air-seasoned, untreated controls	35	20	19	26	35	20	19	26
	Air-seasoned, salt-treated	89	9	0	2	89	9	0	2
3 x 6	Kiln-dried, untreated controls	54	27	13	6	30	37	18	15
	Kiln-dried, salt-treated	94	4	1	1	85	10	3	2
	Air-seasoned, untreated controls	22	35	10	33	0	35	10	55
	Air-seasoned, salt-treated	92	8	0	0	85	15	0	0
3 x 12	Kiln-dried, untreated controls	32	21	23	24	0	15	40	45
	Kiln-dried, salt-treated	90	8	2	0	85	10	5	0
	Air-seasoned, untreated controls	7	29	25	39	0	0	29	71
	Air-seasoned, salt-treated	75	14	11	0	29	29	42	0

Table 3.--Extent of honeycombing and surface checking in chemically
treated 4- by 6-inch Appalachian white oak kiln-dried
to a moisture content of approximately 12 percent

Chemical treatment	Honeycombing				Average maximum checking per piece
	None	Slight	Moderate	Severe	
	Percent	Percent	Percent	Percent	Inches
Buffered-urea-aldehyde bath	48.7	36.0	12.8	2.5	49.6
Buffered-urea-aldehyde dip	36.0	41.0	17.9	5.1	54.3
Urea-diethylene-glycol dip	43.6	30.8	23.1	2.5	60.5
Diethylene-glycol bath	43.6	48.8	5.1	2.5	61.0
Urea-diethylene-glycol bath	43.6	41.0	15.4	0	67.0
Urea bath	41.0	46.2	7.7	5.1	80.0
Urea dip	15.4	59.0	15.3	10.3	138.3
None	12.8	53.8	10.3	23.1	153.4
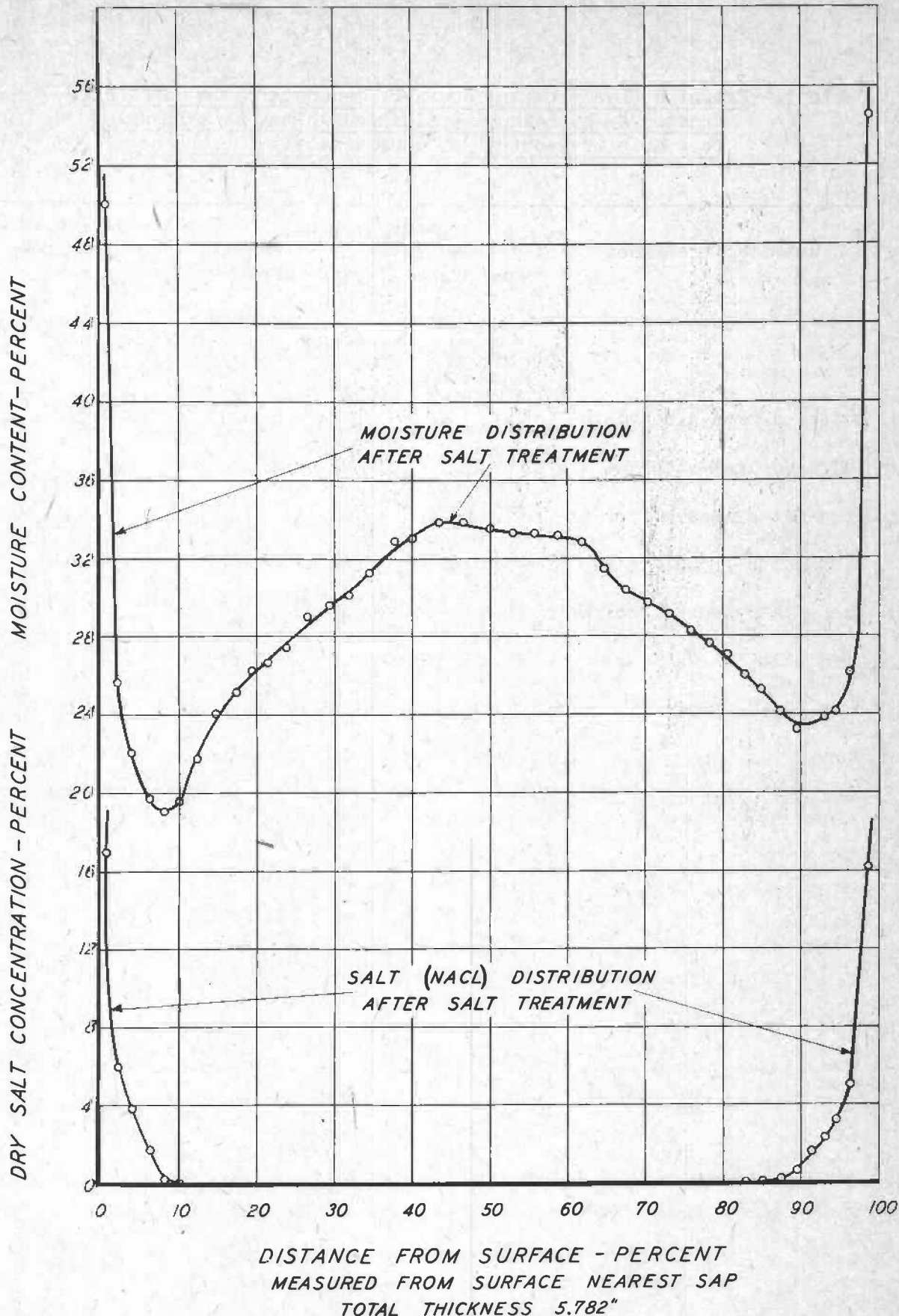
Figure 1.--Moisture and chemical distribution in a 6- by 12-inch
Douglas-fir heartwood timber after soaking 7 days in a saturated
sodium chloride solution.

ZM23339F
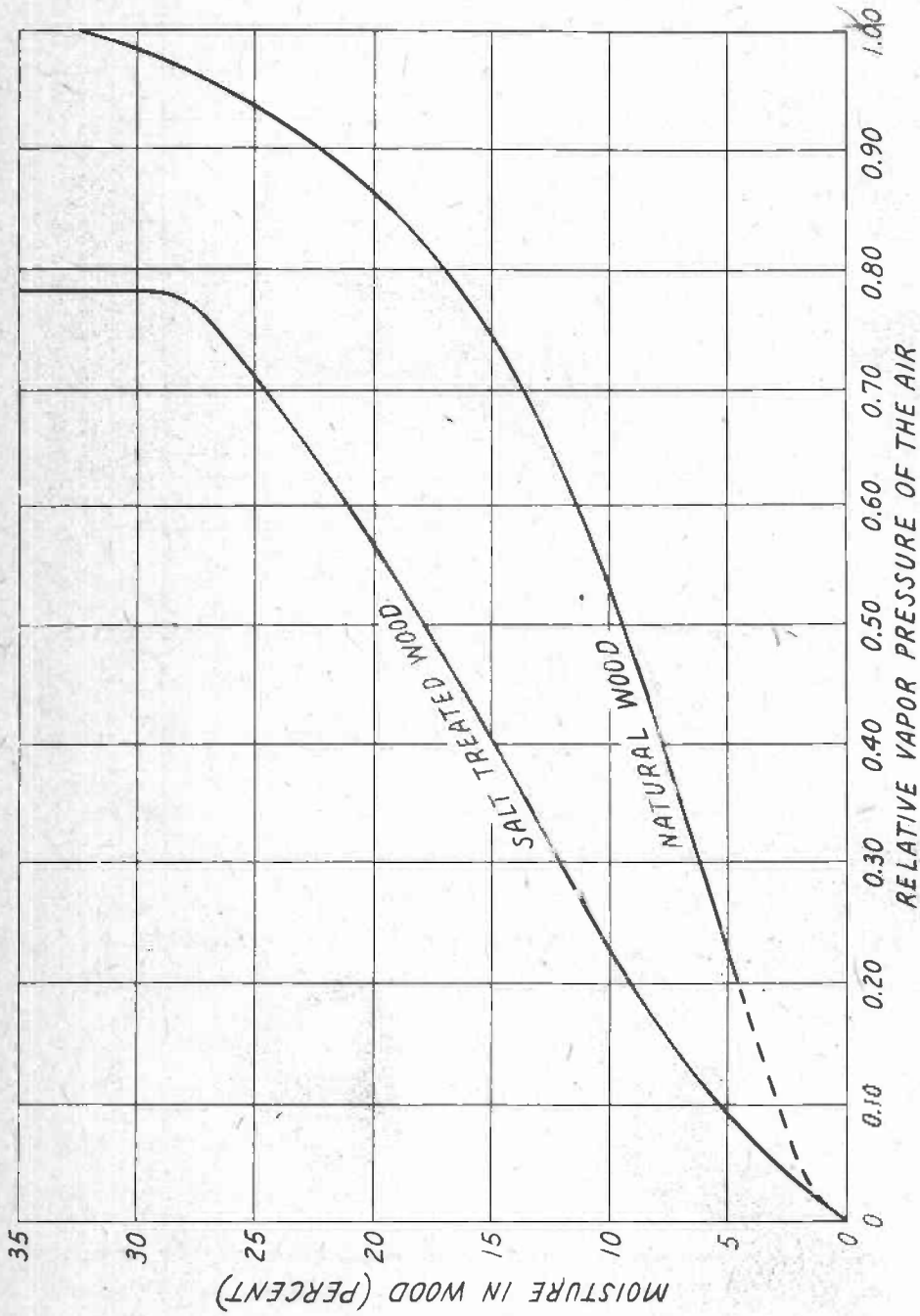
FIG. 2

EQUILIBRIUM MOISTURE CONTENT OF NATURAL WOOD
AND WOOD TREATED WITH A SATURATED SOLUTION OF SODIUM CHLORIDE.
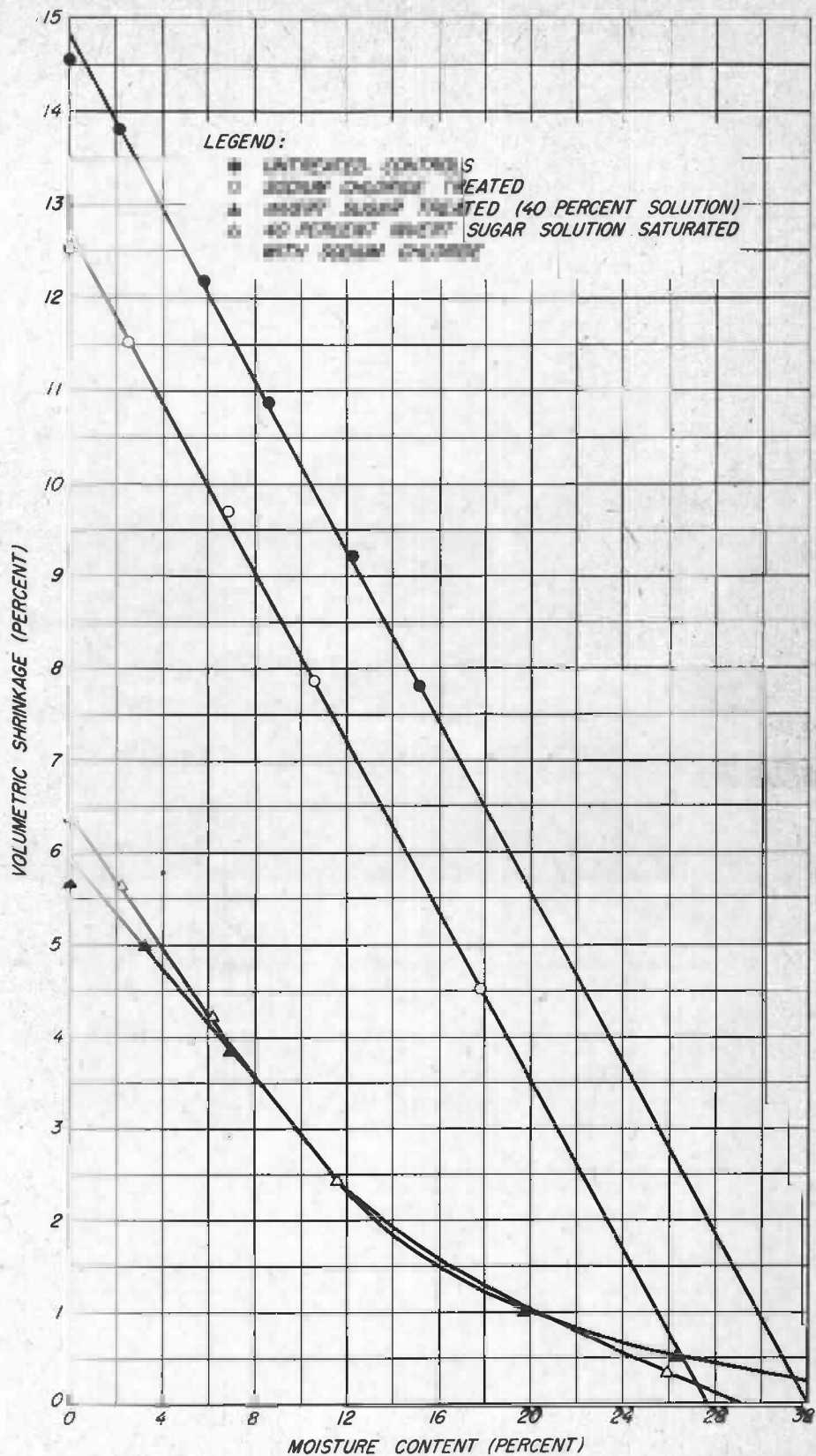BOTH CURVES FOR A TEMPERATURE OF 70°F.

Z M 35871 F

Figure 3.--Moisture-shrinkage relation of blackgum strips
chemically treated as indicated.

Figure 4.--Urea-treated oak square twisted when hot and retaining twisted shape in
which held while cooling and stiffening.

Z M 78474 F

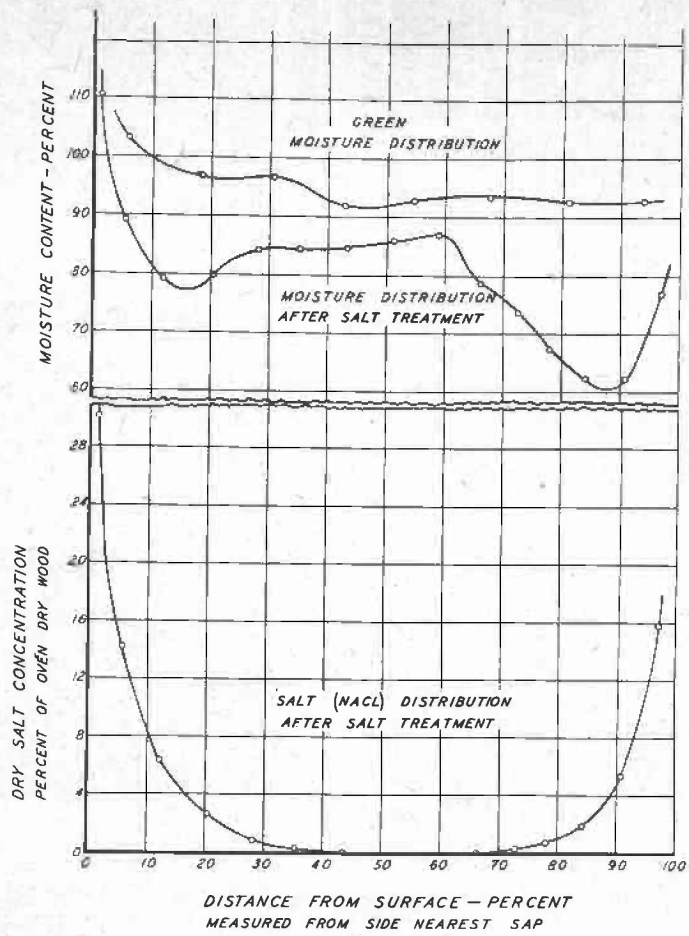Figure 5.--Depth of penetration of Douglas-fir timbers by dry chemical shown by
  use of suitable stain.
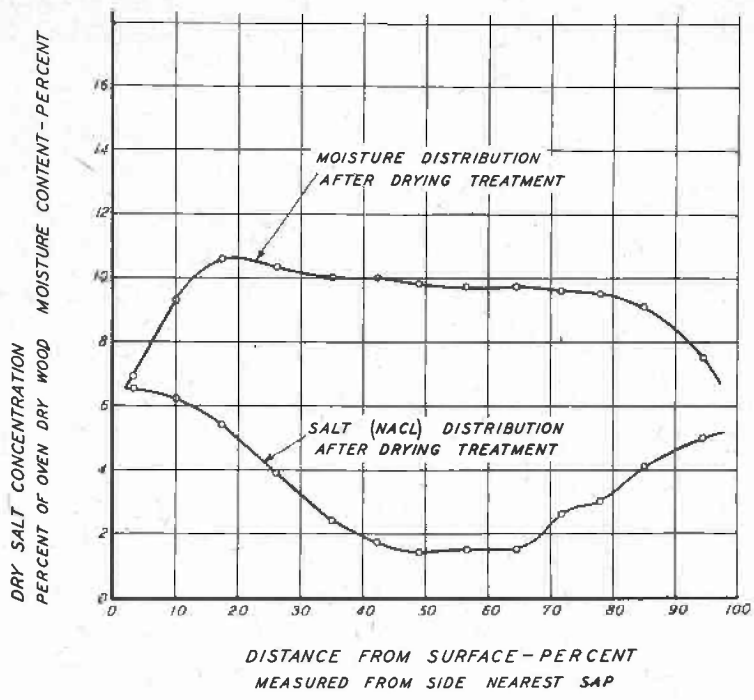
Figure 6.--Distribution of sodium chloride before and after air-
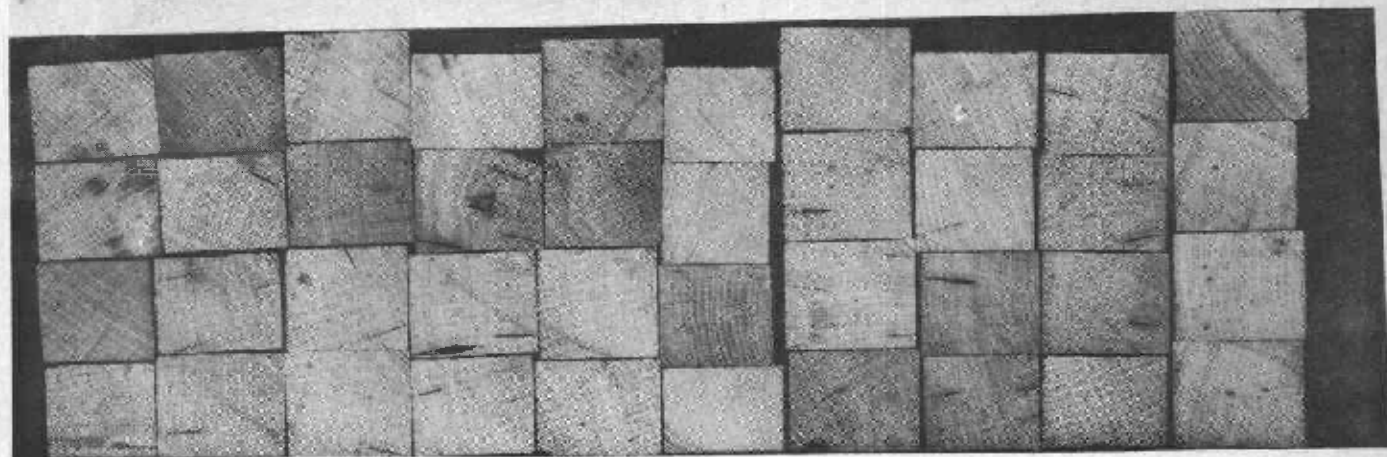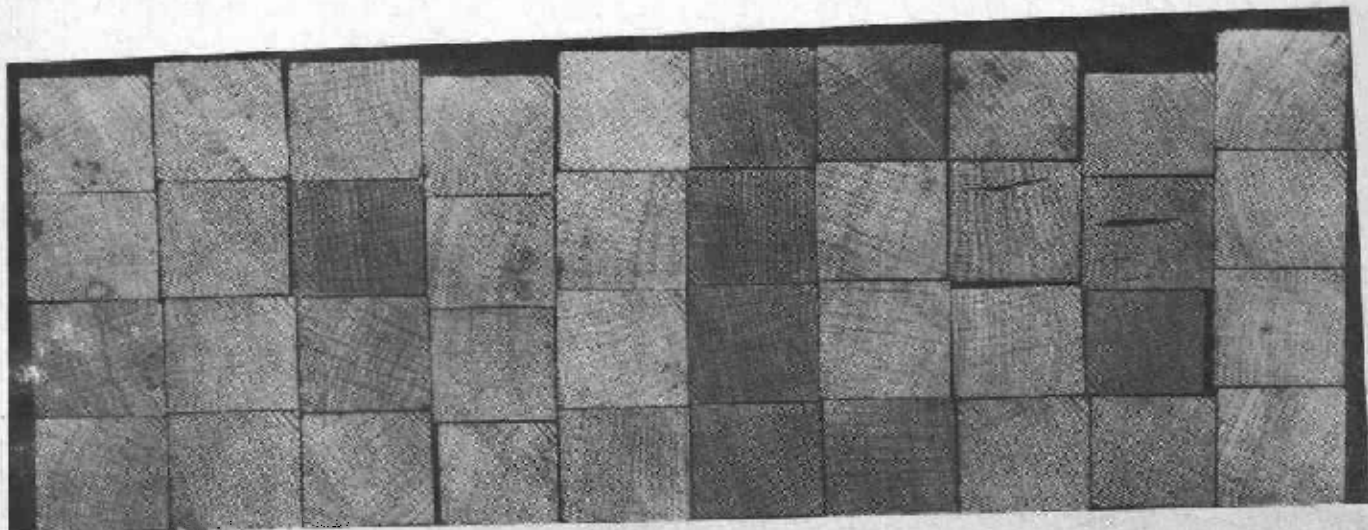drying, showing movement of chemical away from surface.

Figure 7.--Development of honeycombing in matched salt-treated and untreated control groups of kiln-dried overcup oak. Upper group is salt-treated, lower is control group.