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METHOD INVOLVING THE USE OF CHEMICALS FOR INCREASING THE DRYING RATE OF WOOD

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This application is made under the act of March 3, 1883, as amended by the act of April 30, 1928, and the invention herein described, if patented, may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment to us of any royalty thereon.

Our invention relates to a method for increasing the drying rate of wood by the use of chemicals.

The object of our invention is to provide a means for increasing the drying rate of wood and thereby provide a means for decreasing the time required to dry green wood to a desired moisture content.

A further object of our invention is to provide a means for eliminating or minimizing the water pockets found in wood and at the same time provide a means for reducing the tendency for the wood to collapse in drying.

Our invention is based upon the facts that certain chemicals decompose within the ordinary range of drying kiln temperatures to give gaseous products, or react with constituents in the sap of wood to give gaseous products, and that certain chemicals or the decomposition products of these chemicals have solvent properties with respect to the extractives found in wood. Hence these chemicals tend to open up the capillary structure of the wood and promote the rate of moisture movement in wood.

We have discovered that if wood is treated with certain chemicals, for example, ammonium carbonate ($(NH_4)_2CO_3$) or a mixture of urea ($CO(NH_2)_2$) and sodium bicarbonate ($NaHCO_3$), it will dry faster than similar untreated wood under identical drying conditions, and the tendency for water pockets is reduced. By an empirical experiment, we have discovered that the water in wood treated with these chemicals actually diffuses faster than that in similar untreated wood and therefore the chemicals make possible more rapid drying of wood.

We are aware of the use of chemicals to season wood in a process ordinarily referred to as chemical seasoning. However, the function of the chemical and the results obtained are different from our invention. In ordinary chemical seasoning the vapor pressure characteristics of the aqueous solution of the chemical and the anti-

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shrink properties of the chemical in the wood are of paramount importance; whereas in our invention the ability of the chemical to decompose or react with constituents in the sap in the wood to give gaseous products and the ability of the chemical or its products to dissolve extractives in the wood are the most important properties.

In ordinary chemical seasoning, the primary purpose of the chemical is to prevent surface checking by preventing the surface of the wood from shrinking either by keeping the surface moist or by the anti-shrink effect of the chemical. In practice, the surface layers of the wood are impregnated with the chemical by one means or another after which the wood is dried. Because of the comparatively low relative vapor pressure of the chemical solution in the surface layers of the wood, the surface fibers are kept moist during drying providing the relative humidity of the atmosphere in which the wood is being dried remains equal to or greater than that in equilibrium with the chemical solution. In kiln drying, the atmospheric conditions may be controlled so that the relative humidity of the air is in equilibrium with the chemical solution, but in air drying, this is not possible. Hence in air drying, the anti-shrink properties of the chemical become of more importance, since it is necessary to prevent the surface of the wood from shrinking during the periods of low relative humidity by some means other than keeping the surface moist. Since the surface of the wood does not shrink, surface checking is prevented.

More rapid drying is sometimes possible under the practice of ordinary chemical seasoning because the use of the chemical may permit more severe drying conditions to be used without harmful results to the wood. Under the same drying conditions, however, the treated wood will not dry at a faster rate than untreated wood since nothing in the wood has been altered to promote diffusion of the water. Many woods can be dried satisfactorily in atmospheric conditions that are as severe or even more severe than those that would be used in ordinary chemical seasoning. Consequently, ordinary chemical seasoning is advantageous as far as drying time is concerned only for those woods that require comparatively mild drying conditions.

In the drying of wood, the rate at which the

wood dries is dependent upon the rate at which moisture can move through the wood which in turn is dependent, among other things, upon the presence or absence of air within the wood cells and the size and number of the minute capillaries within the cell wall.

If the cell is completely filled with water, no water can escape from the cell until the cell wall collapses, or, if the cell wall is sufficiently strong, until the liquid tension of the water is exceeded by the pull of the meniscus in the largest capillary in the cell wall, thus forming a bubble in the cell cavity which on subsequent drying can readily expand, or until sufficient tension is developed to pull back the meniscus in the largest capillary into he cell, thus permitting the entry of air into the cell cavity. Even under severe drying conditions, these reactions take place slowly with the result that a long time is required to dry the wood to a satisfactory moisture content condition. Frequently, even though a rather low average moisture content is indicated by the wood as a whole, localized regions on the inside of the piece may have a very high moisture content. These regions are commonly called water pockets and are composed of a large proportion of cells completely filled with water.

Since water within a cell cavity must leave the cell by passage through the cell wall or through the openings between the cells, such as the pores in the pit membranes, it follows that the water can leave faster if the capillaries in the cell wall are either more numerous or larger in size. In sapwood, diffusion of liquids is relatively rapid when compared to the heartwood of the same species, yet the heartwood and sapwood are structurally identical. The reason for the difference in the rates is that when sapwood is converted into heartwood in the natural development of the tree, various substances are deposited which tend to obstruct the capillaries, thereby reducing the number and size of capillaries.

In our invention the chemical is used to promote a greater diffusion of the water in the wood. At the start of drying, the water soluble chemical diffuses into the cell cavity where decomposition takes place as a result of temperature or reaction with constituents in the wood, thereby forming a slightly soluble gas. The gas forms a bubble which is easily expanded and thus permits water to leave the cell. The chemical or the decomposition products may also have a solvent action on the deposited substances in the wood and thus further promote diffusion by opening up the capillary structure. The gaseous products produced and surplus chemical diffuse into the wood, where similar reaction takes place. The diffusion of the gas is more rapid than that of the chemical since it is not dependent solely upon a continuous path of water, but can diffuse through the air spaces that are present as well. The presence of even a small amount of gas in solution in a water-filled cell cavity is beneficial to the diffusion of water, since under reduced pressure, such as results in drying a full cell cavity, bubbles form more easily because of a decreased surface tension. Thus, greater diffusion and consequently faster drying results even in the event that drying prematurely arrests the diffusion of the chemical. Also, water pockets are largely eliminated.

The procedure to be followed in carrying out our invention consists simply of the chemical treatment of green wood followed by drying in a conventional manner. The success of our invention is primarily dependent upon the proper selection of the chemical or mixture of chemicals. A knowledge of the properties of the chemical or mixture of chemicals, including the behavior with respect to the particular species of wood in question, is, therefore, of paramount importance. The following general properties of the chemical or mixture of chemicals should be considered: (1) temperature of decomposition, (2) products of decomposition, (3) solubility in water of the chemical or mixture of chemicals and of the decomposition products, (4) molecular weight as an indication of the diffusion rate of the chemicals. In use with a particular species of wood, the following characteristics should be considered: (1) reaction with constituents in the wood to give gaseous products, (2) solubility of gaseous reaction products, (3) reaction with constituents in the wood to give precipitates which which may defeat the purpose of the treatment by plugging the capillaries, (4) solvent properties with respect to naturally deposited substances in the wood.

The chemical may be applied to the green wood in one of several ways, namely; (1) by piling the wood with the solid chemical between layers until the chemical has disappeared into the wood, (2) soaking the wood in solutions of the chemicals until a suitable amount of chemical has diffused into the wood, (3) painting, dipping, brushing, or otherwise applying a suitable amount of the chemical to the wood in the form of a solution thickened by a thickening agent such as starch, (4) by pressure treatment. In the case of use of solid piling, or of the thickened solution, if a chemical is used having a high relative vapor pressure, best results will be obtained by incorporating another chemical or mixture of chemicals that will decrease the relative vapor pressure and thereby maintain a solution in which the chemical may diffuse into the wood, unless the relative humidity of the air is artificially, or otherwise maintained high enough to keep the chemical moist. No further diffusion period following chemical application is necessary since the chemical will continue to diffuse into the wood during the drying process, particularly during the initial stages when a major portion of the water columns in the cell structure are continuous from the surface to the transverse center of the wood.

During the chemical treatment, other chemicals may be added or incorporated which may impart such desirable properties to the wood as resistance to fire and attack by insects and decay, flexibility and hardness. However, the additional chemicals should be such that they do not combine or react with the seasoning agent or other chemicals in the wood to prevent gas formation or to form precipitates which plug up the capillaries of the wood and thus decrease the drying rate.

Following chemical treatment the wood may be dried in a conventional manner. If a temperature decomposition is relied upon, it is, of course, advisable to use some means for elevating temperatures such as a dry kiln.

Our invention is most useful with those woods that are prone to develop water pockets in drying, that exhibit either or both a high green moisture content or high extractive content and that usually exhibit slow drying rates, but it is also useful in drying wood having ordinary drying characteristics.

The following examples illustrate the effectiveness and practice of the invention but do not limit the invention to the cited examples.

EXAMPLE I

Six vertically grained pieces and six flat-grained pieces of so-called "sinker" redwood stock each measuring 3 inches by 8 inches by 30 inches were end-coated to prevent end-drying and solid piled with sodium bicarbonate between layers, beneath the bottom layer, and on top of the top layer. The sodium bicarbonate was applied at the rate of 40 pounds per 1,000 board feet. The pile was covered with a canvas to minimize drying. The specimens were left in the solid pile for 12 days during which period water was occasionally sprinkled on and in the pile to maintain moist surfaces. On the twelfth day the specimens were unpiled and repiled in a like manner with urea applied at the rate of 100 pounds per 1,000 board feet. The specimens were left in the pile with the urea for 3 days at which time no chemical was visible on the surface of the wood. After chemical treatment the specimens were kiln dried for 46 days with a similar number of matched pieces treated with urea only and a similar number of matched untreated pieces. The following table (Table I) shows the kiln conditions and moisture content of the different groups of specimens after various periods of drying.

It is evident from the data that the rate of drying with the bicarbonate treatment is decidedly increased over that of untreated material and that obtained by using a conventional chemical seasoning agent, namely urea alone.

Table I

Time	Dry bulb temperature	Wet bulb temperature	Relative humidity	Moisture content for chemical treatments by grain types					
				No chemical treatment (controls)		Urea		Urea plus sodium bicarbonate	
				Flat grain	Vertical grain	Flat grain	Vertical grain	Flat grain	Vertical grain
Days	°F.	°F.	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
(1)						193.0	168.0	194.8	170.7
(2)						[3] 203.8	182.9	191.8	170.2
0	115	105	71	196.0	171.7	203.8	182.9	191.8	170.2
4				142.9	136.3	142.5	133.8	134.8	125.6
14				110.7	114.8	108.3	110.3	97.2	97.5
29				79.7	93.3	75.7	88.2	62.2	72.7
46				56.9	77.1	52.6	72.0	40.4	55.7

[1] Before treatment.
[2] After treatment.
[3] The gain in moisture content during chemical treatment is at the surface of the wood. Hence this gained moisture is readily lost in the first few days of drying.

EXAMPLE II

Nine vertically grained pieces and nine flat-grained pieces of so-called sinker redwood stock having the dimensions 3 inches by 8 inches by 28 inches were treated with urea and sodium bicarbonate as in Example I. A like number of matched pieces were treated by soaking for seven days in an ammonium carbonate solution made up by grinding commercial lump ammonium carbonate and mixing with water in the proportions of 200 grams of ammonium carbonate to 525 grams of water. All of the treated pieces were simultaneously placed in the same dry kiln with a like number of matched untreated pieces. All groups were subsequently dried by virtually the same moisture content-temperature schedule. Schedule changes were made by removing the group from the original kiln when it reached the desired moisture content and placing it in a different kiln having the desired kiln condition. The material was dried to a moisture content of about 18 to 20 percent since this is the usual final moisture content range for material of the type used in the experiment. The following table (Table II) shows the results obtained.

Table II

Kiln Schedule		Moisture content at which schedule changes were made and total time required to dry to given moisture content					
Temperature		Controls (untreated)		Urea and sodium bicarbonate		Ammonium carbonate	
Dry bulb	Wet bulb	Moisture content	Time	Moisture content	Time	Moisture content	Time
FLAT-GRAIN STOCK							
° F.	° F.	*Percent*	*Days*	*Percent*	*Days*	*Percent*	*Days*
----	(1)	----------	------	171.1	------	171.5	------
----	(2)	----------	------	170.2	------	176.8	------
115	105	161.1	0	170.2	0	176.8	0
		51.0	56				
120	108	38.8	73	38.6	56	38.2	56
135	121	31.8	82	33.6	60	33.3	60
150	130	27.4	89	26.7	67	25.3	67
End of drying		19.5	98	19.9	74	17.6	74
VERTICAL-GRAIN STOCK							
----	(1)	----------	------	143.3	------	140.0	------
----	(2)	----------	------	139.4	------	148.2	------
115	105	136.5	0	139.4	0	148.2	0
		44.7	56				
120	108	39.1	67	38.9	56	40.2	56
135	121	36.6	70	34.2	60	35.8	60
150	130	27.6	82	27.5	67	28.8	67
End of drying		20.6	91	20.1	74	20.5	75

[1] Before chemical treatment.
[2] After chemical treatment.

It is apparent from the data that the use of the chemical has made possible a considerable saving in drying time.

EXAMPLE III

The diffusivity factor, the percentage of moisture per hour flowing transversely with respect to the fiber direction when the moisture gradient is one percent per inch in the direction of flow (similar to diffusivity as used in heat flow), for treated and untreated redwood was determined from matched specimens 1 inch by 1 inch by 30 inches. Two treatments were used as follows:

1. Soak 7 days in an aqueous solution made according to the proportions of 7.4 grams sodium bicarbonate, 18.5 grams urea, and 74.1 grams water.

2. Soak 7 days in an aqueous solution made according to the proportions of 27.6 grams ammonium carbonate and 72.4 grams of water.

The diffusivity factor for redwood treated by each of the above treatments was found to be 0.0014 percent per hour per inch at 120° F. while that of untreated material was found to be 0.0011 percent per hour per inch. The drying time varies inversely as the diffusivity factor; hence the treated material should dry to a given moisture content in roughly ¾ to ⅘ the time required for untreated material. These values check the results given in Example II.

Among the chemicals which may be useful for increasing the diffusion of water in wood and therefore helpful in reducing the time required to dry wood are the carbonates, bicarbonates, thiocarbonates, thionates, sulfides, formates and acetates of ammonia, sodium, potassium, calcium, magnesium, lead, zinc and other metals. Because of their solvent properties, organic solvents that are miscible in water such as the alcohols, ketones, aldehydes and acids, preferably those of low molecular weight and boiling point and those that swell wood, may also be useful.

Having thus described our invention, we claim:

1. A process of drying wood which comprises impregnating with and diffusing into the sub-surface of wood a material that generates a gas within the cellular structure of the wood at the temperature of the subsequent drying operation, the wood being maintained in contact with the material for a period sufficient to cause penetration into the sub-surface of the wood, the material impregnated into the wood being sodium bicarbonate and urea, and then subjecting the wood to kiln-drying.

2. The process of drying wood described in claim 1 comprising impregnating the wood with sodium bicarbonate and subsequently impregnating the wood with urea and thereafter subjecting the impregnated wood to kiln-drying.

3. The process of drying wood described in claim 1 comprising impregnating the wood with sodium bicarbonate by piling the wood with sodium bicarbonate between layers of wood while maintaining the surfaces of the wood moist, then impregnating with urea by repiling the wood with urea between layers of wood, and subjecting the wood to kiln-drying.

4. A process of drying wood comprising piling the wood for several days with sodium bicarbonate between layers of wood while maintaining the surfaces moist to cause impregnation of the sodium bicarbonate into and diffusion into the subsurface of the wood, repiling the wood for several days with urea between layers of wood, causing impregnation and diffusion of the urea within the wood, and thereafter kiln-drying the wood.

5. The process of claim 4 in which the sodium bicarbonate is applied in the ratio of about 40 pounds per 1,000 board feet, and the urea is applied in the ratio of about 100 pounds per 1,000 board feet.

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