Patented June 23, 1936 2,045,350

UNITED STATES PATENT OFFICE

2,045,350

METHOD OF REDUCING THE SHRINKAGE OF WOOD

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No Drawing. Application January 8, 1936, Serial No. 58,218

10 Claims. (Cl. 91—68)

It has been known in the art of wood treating that relatively dry wood, even though kiln dried, will reabsorb moisture from the atmosphere and will thus expand and contract as it becomes moist or as the moisture therein evaporates, respectively. The expansion and contraction of wood may conveniently be referred to as the property of shrinkage, and for the sake of convenience and simplicity in the following description, we shall use this term "shrinkage" in that sense. This shrinkage is of course greater transversely of the fibers than lengthwise thereof and therefore is the critical shrinkage.

Many efforts have been made to treat wood in such a way as to eliminate shrinkage, but to our knowledge none of these efforts has been successful, at least to the same extent as the method described herein. For example, when sheets of wood veneer, treated according to previously known methods, are secured to a surface of substantially constant area, that is to say, one which is substantially non-shrinkable, such veneering will shrink to such an extent as to make it most difficult to hold the veneering on the surface to which it is secured. The glue or other adhesive used for securing the veneering to such surface is usually not strong enough to hold the veneering and prevent its buckling or cracking, as the case may be, depending upon whether the wood expands or contracts. If, however, such veneering can be so treated that its shrinkage is negligible, say less than 1%, then there is no trouble about the glue properly holding the veneering in place. The treatment incidentally results in making the wood more flexible than untreated wood, the amount of flexibility naturally depending largely upon the dimensions of the pieces of wood which are treated.

While we have referred to a piece of veneering as being secured to a substantially constant area, of course what we have said above is also true where such surface has a shrinkage of a substantial amount and the veneer itself has a shrinkage different than that of the surface. The difference in shrinkage is the important thing, and we have found that by our process this shrinkage can be kept within any desired amount so as to avoid buckling or cracking. Normally, the difference in shrinkage should be less than about 1%. For example, if the shrinkage of the base material is 1%, then that of the veneering should not exceed 2%.

While the invention finds a wide use in connection with veneering, nevertheless if wood in other forms than veneering is treated so that its shrinkage is negligible, it becomes valuable for many architectural and other purposes, which need not be enumerated, since they will readily suggest themselves.

We have found that we can obtain our novel product by subjecting wood to the following steps. First it is preferable to treat the wood with an alkali and then with an acid, preferably a volatile one. The wood then may be subjected to drying and ironing, after which it is impregnated in such a way that the fibers of the wood are saturated without leaving any substantial amount of impregnator in the cell cavities of the wood. Then the wood is dried a second time and also ironed again. The foregoing method is one which has been found satisfactory, although in many instances certain steps can be omitted, and this brief outline of the one method is not intended as limiting the invention to that one method. We will now proceed to describe the steps more in detail.

According to our invention, we first subject the wood to an alkali treatment. This alkali may be any one of several well-known alkalies suitable for the purpose. For example, we may use sodium hydroxide, potassium hydroxide, or ammonia, to name several which we have found to be suitable, both as to results and as to cost.

The concentration of the alkali and the temperature and duration of the treatment with the alkali will naturally vary with the different kinds of woods. They will also depend to a large extent upon the amount of flexibility which is desired for the final product. The examples which will be given later will serve as a guide to those skilled in the art. However, the concentration of the alkali and the temperature and duration of the treatment are so selected as to dissolve and remove a substantial part of the resin, pectin, lignin, and other similar components of the wood and so as to leave the cellulose fibers free to any desired degree from such components, which usually encrust the fibers. The above factors of concentration of alkali and temperature and duration of the treatment have an important relation to the shrinkage of the product after the later predrying step, and it is therefore important that these factors be so selected as to keep such shrinkage from being excessive.

It is impossible to give exact figures which will apply to more than one particular sample of one kind of wood, because of the wide variations in characteristics of the various woods. In practice, we conduct preliminary tests on each batch of wood which is to be treated to determine the

correct figures for the above factors. These figures may be determined by graphical or other analysis of the figures obtained from the preliminary tests. We believe it to be essential that such preliminary tests shall be continually run, to control our method.

Usually, the alkali treatment is carried on at atmospheric pressure, with a temperature below 212° F., or, in other words, below the temperature of boiling water. Preferably also, the alkali concentration is relatively low compared to most concentrations previously used in wood treatment. In most instances, we prefer to keep this concentration of alkali below 3%, and in many instances it is much lower than 3%. It should be at a low enough concentration to avoid softening of the wood fibers to such extent as to cause them to lose their continuity as fibers. In any event, the concentration of alkali and temperature and duration of the treatment are such that the natural wood structure is not destroyed to any substantial extent.

The alkali treatment may be carried out by any usual apparatus. For example, if thin pieces of wood are being treated, they may be soaked in a suitable container containing an aqueous solution of the alkali, and, if desired, the alkali treatment may also include the use of vacuum or pressure, or both, in order to obtain a more ready and uniform reaction throughout the body of the wood.

The immediate result of the alkali treatment is to cause the fibers of the wood to be greatly swollen and softened, and possibly other changes take place. Among these other changes it may be noted that the wood is usually darkened in color. The alkali appears to react with the resin, pectin, lignin, etc., which for the sake of convenience we shall hereinafter refer to as the non-cellulosic constituents of the wood, and at any rate to make these constituents more easily removable, leaving the fibers free to be reached easily by the impregnating material subsequently used.

The next step following the alkali treatment preferably is to rinse the wood in water to remove the excess or superficial alkali. Usually, a few minutes washing is sufficient for this purpose. Preferably, the wood is then immersed in an aqueous solution of a volatile acid, by which is meant an acid having a boiling point less than 300° F. While under some conditions it may be possible to use a non-volatile acid, we have found that a volatile acid is highly preferable. Among such acids which are satisfactory, we have used formic, which we find to be preferable, acetic, propionic, dilute hydrochloric, hydrobromic, and hydriodic. With some woods it may be possible to use a non-volatile acid. In this case the acid must be removed by washing before the wood is dried. While this washing has the effect of increasing the shrinkage of the wood at this stage of the process, it may be desirable, with some woods whose natural shrinkage is comparatively low, to employ this method.

The object of this acid treatment is to neutralize any residual alkali that may still be in the wood, and also to bleach the wood to its original color. The acid treatment likewise deflates the cellulosic fibers of the wood which have been swollen by the alkali treatment.

The concentration of the acid and its temperature and the duration of the treatment should be determined by a previous test of samples from the batch being treated. Samples of wood may be subjected to various concentrations, temperatures, and duration of treatment until the desired neutralizing, bleaching, and deflation effects have been obtained.

We find that sometimes the action of the acid may be improved by applying it under pressure, which will cause it to more readily penetrate to the interior of the wood.

We next subject the wood to a drying action which, among other things, results in evaporation of the acid. It will be seen that the evaporation is greatly expedited by using a volatile acid in the previous step, as referred to above. By the use of such an acid, it is unnecessary to submit the wood to washing to remove the acid from the wood. A washing step at this stage is very undesirable for most woods, because it would cause the wood fibers to swell, which we desire to avoid.

The drying may take place in any suitable apparatus, such as a drying tower or kiln, either with or without recirculation of the air therein and either with or without a vacuum.

Next, the wood may be passed through ironing rolls, where it is submitted to a substantial amount of pressure. These rolls may be cold or heated, and are preferably of steel or other hard material so as to perform an ironing action on the wood, thus more completely drying the wood and setting the fibers in their new size and interrelation. This is the result partly of a further deflation of the fibers from their swollen condition produced in the alkali. In many instances, however, this ironing step may be omitted. The ironing may be considered as a part of the drying step and so in the claims for the sake of conciseness we shall use the expression "drying" to mean either drying, or ironing, or both, as described above.

After the above steps have been performed, we find that, for most woods, the tendency and ability of the wood to adsorb or absorb moisture and therefore to swell and shrink is greatly retarded and is permanently reduced to a substantial degree. As indicated above, one of the reasons for the improved result obtained at this stage is the fact that we have avoided washing with water to remove the acid. It is known that alkali solutions swell wood more than water, but, on the other hand, it is also known that such swelling can be retained when the swollen wood is soaked in water after removal of the alkali. Thus, by avoiding the use of water to remove the acid, and by thoroughly drying the wood at this stage, the swelling of the wood is greatly reduced. Likewise, the wood appears to be made stronger and more elastic, and consequently a better and more serviceable product results.

The wood is now ready for impregnation, and this we preferably do by the use of one or more foreign substances, impregnating the wood to the fiber saturation point for water at any desired relative humidity of the atmosphere, or to any desired predetermined degree below the fiber saturation point. In other words, we use a sufficient quantity of impregnator to saturate the individual fibers of the wood without any surplus, thus leaving the cell cavities or spaces between fibers substantially free of impregnating substance after the subsequent drying step. We found that by so doing we can obtain a wood in which the shrinkage is reduced to such a negligible figure that the wood will not shrink, crack, or blister. Certain tests have been worked out and are generally accepted as determining fiber saturation, and we employ those tests for that

purpose. Such tests are disclosed in Technical Bulletin No. 282, referred to hereafter.

By impregnating the fibers, they seem to be swollen to a certain amount, which is relatively small, particularly as compared to the swelling caused by the alkali treatment, and then they resist the adsorption of further moisture from the atmosphere. In this connection, we shall use the term "adsorption" in preference to "absorption", as the former appears to be the action which takes place, although, of course, the name given to this action is immaterial. At any rate, the presence of the impregnator in the fibers and its relative lack in the cells between and among the fibers seems to very materially reduce the shrinkage in the ultimate product.

The other steps of the process aid very materially in obtaining a satisfactory result, but in some instances we have been able to substantially eliminate the shrinkage by controlling the impregnation of the fibers as just outlined above, without any of the preceding steps described above.

At the present time the most suitable impregnator which we have found is a substance known commercially as "glycerine", and chemically as "glycerol", or some equivalent substance, such, for example, as glycol or other polybasic alcohol or some substituted polybasic alcohol. Such products are non-volatile and are also miscible with water and hygroscopic. They are also the kind of liquids which may be classified as polar, and we have found that such liquids are preferable as impregnators. The solvent used with the impregnator is usually water, although naturally the particular solvent used with any particular substance would depend largely upon that substance.

We are not certain as to the correct explanation as to why this type of impregnator is desirable, but we do find that it is. Possibly the correct explanation is that a polar liquid is readily adsorbed by the cellulosic wood fibers, and will cause the wood to swell to a relatively small amount, but sufficient so that the liquid may thoroughly permeate the fibers. Non-polar liquids, on the other hand, are not adsorbed by the wood fibers to any substantial degree and do not cause those fibers to swell so that the impregnator may thoroughly permeate them.

Assume that the fibers have been impregnated with a polar liquid impregnator, for example one which is soluble in water, as most such impregnators are. Assume also that a sufficient quantity of impregnator has been used to saturate the fibers at the relative humidity selected as the minimum above which shrinkage is to be substantially eliminated. For example, assume that 20% relative humidity has been selected as the desirable figure.

Now if the humidity of the atmosphere be reduced below 20%, water will evaporate from the impregnator and the wood will shrink. On the other hand, if the humidity of the atmosphere increases above 20%, the impregnator will absorb water from the atmosphere, and a part of it will be forced out of the fibers and into the cell cavities. However, if care has been taken to impregnate substantially to the point of fiber saturation only, at 20% relative humidity, leaving the cell cavities between the fibers substantially free of impregnator, then the cell cavities may receive the excess moisture without causing the wood to become obviously wet, and without substantial swelling of the wood. Similarly, as the humidity of the atmosphere is again reduced, the water previously taken up by the wood will evaporate while the impregnator becomes more concentrated, as before, and is readsorbed by the fibers, and without substantial shrinkage of the wood.

Whether or not the above explanation is the correct one, we find that excellent results are obtained by following the method outlined above, shrinkage at and above the selected relative humidity being reduced to a negligible amount as set forth above. In the claims, it will of course be understood that the expression "selected relative humidity" refers to this minimum, above which shrinkage is so reduced.

Still further improved results may be obtained by first using an impregnator which is non-water soluble, using enough of that substance to reach the limit of saturation of the wood for that particular impregnator. Then the wood may be still further impregnated with the water-soluble impregnator referred to above, up to the limit of saturation of the wood for that substance. That is to say, better results are obtained by first using a non-hygroscopic impregnator, and then a hygroscopic impregnator. The first does not cause the fibers to swell as much as the second, and therefore does not permeate the fibers to such an extent as the second.

We believe that the correct explanation as to the improved results obtained by the use of two impregnators is as follows: Assume that a single hygroscopic impregnator is used to saturate the fibers at 20% relative humidity without any substantial excess of impregnator in the cells between fibers. Then assume that the humidity of the atmosphere rises. The hygroscopic impregnator will absorb the moisture in the air and will overflow or ooze out from the fibers into the cells, and if the humidity becomes great enough, will give the wood a feeling of wetness. If, on the other hand, part of the impregnator is non-hygroscopic, then proportionally less water from the atmosphere can be absorbed, and the cell cavities will not be as nearly filled, and therefore there is less liability of moisture becoming evident.

For the hygroscopic impregnator, we find that glycerine or its equivalent is preferable, using water as a solvent, and for the non-hygroscopic impregnator we may use paraffin, beeswax, or the like. As a solvent for the non-hygroscopic impregnator, we use a water soluble polar solvent, such as ethylene glycol monoethyl ether.

The hygroscopic impregnator may be used by itself in combination with the other steps of our method, and excellent results can be obtained, but where the range in humidity to which the finished product is to be subjected is very great, then we find it advisable to use the two impregnators as just described.

The concentration of the impregnating solution, in any case, should be controlled in order to produce the desired freedom from shrinkage in the finished product. First we select the minimum percentage of relative humidity at which the product is to be stabilized, that is, to be maintained substantially free from shrinkage. Then it is necessary to establish by experiment the percentage content of impregnator corresponding to the fiber saturation at the selected humidity. This may be done by any of the methods usually employed for this purpose, some of which are fully described in Technical Bulletin No. 282 of the United States Department of Agriculture, March, 1932, entitled "Strength-moisture relations for wood", by T. R. C. Wilson, of the Forest Products Laboratory.

For example, we impregnate samples of the particular batch of wood to be treated, using various percentages of the impregnator and measuring the shrinkage of the various samples. From the data thus acquired, we may plot a curve similar to those shown on pages 50 to 53 of the aforesaid bulletin, and from that curve may obtain the impregnator content corresponding to fiber saturation, and also the impregnator content at the intersection point, which latter is usually only slightly greater than the former. The intersection point is defined on page 12 of said bulletin as the point where the inclined and horizontal lines of the curve intersect.

We next determine by experiment the concentration of impregnating solution which is required so that the impregnating solution which is retained by the wood immersed therein will contain the amount of impregnator necessary to saturate the fibers, to correspond to the intersection point, or to correspond to any other shrinkage point desired.

Having thus determined the desired concentration and amount of impregnating solution, the wood is immersed in a solution of the required concentration until that approximate amount has been adsorbed by the wood. Sometimes it is difficult to cause the wood to adsorb a sufficient amount of impregnator, particularly after the wood has been dried or ironed. In order to overcome this difficulty, the wood may be first soaked in water before impregnating. This soaking does not restore the wood to as swollen a condition as that in which it left the alkali solution, because the previous drying operation has greatly retarded the tendency and ability of the wood to adsorb moisture and therefore to swell. In fact, this tendency and ability has been permanently reduced to a substantial degree. After a preliminary soaking in water, if the impregnator to be used is water-soluble, the wood may be placed directly in the impregnating solution. If on the other hand, the impregnator to be used is non-water soluble, it is preferable to place the wood first in a bath of the pure solvent used for the particular impregnator, so that that solvent may displace the water in the wood, and then the wood may be placed in a bath of impregnator dissolved in such solvent.

The next step after impregnation is a second drying, which may be carried out in any suitable drying apparatus and which results in the evaporation and removal of the solvent for the impregnating material and the retention within the wood fibers of the non-volatile impregnator. The amount of the remaining impregnator is enough to saturate the individual fibers of the wood without any substantial surplus, as pointed out above.

The final step of the process consists in again ironing the wood by passing it through a series of rolls of steel or other hard material, which may be either heated or cold and which are so adjusted as to exert a suitable pressure on the wood. The amount of pressure in this ironing step, as in the preceding one, is on the order of that given by a commercial ironing machine, such as used in laundries.

The ironing at this stage seems to compress the wood and to finally set the fibers in their permanent condition and interrelationship. It also seems to result in a diminution of the swelling and shrinkage (which for simplicity we are referring to herein as shrinkage) which the wood undergoes between the stabilization point of relative humidity and 100% relative humidity. This final ironing step also seems to make the wood stronger and more elastic than in its raw condition.

We will now give a few examples of treatments which have been performed, which we believe will furnish a sufficient guide to those skilled in the art so that they may practice the invention. Each example indicates a piece of veneer, although similar results would of course be obtained with thicker wood.

Example I

A piece of white pine veneer was treated with alkali in the form of a 0.48% sodium hydroxide solution at 177° F. for two hours, after which it was subjected to a ten minute treatment with formic acid of a 2.38% concentration. The sample was then suspended for one hour in a current of dry air at about 150° F. It was then permitted to soak in water over night and then impregnated with glycerine for two hours, the glycerine having a specific gravity of 1.0770. The sample was then dried by again being suspended in a current of dry air at 150° F. for one hour, after which it was ironed by being passed through an ordinary laundry ironing machine, at as great a pressure as could be conveniently used without tearing the wood.

The result was a piece of veneering in which the shrinkage was substantially zero as compared to a shrinkage of 3.5% in the raw veneering before treatment.

Example II

A piece of veneering of avodire wood was subjected to the same alkali, acid and drying treatment as in Example I, and was likewise soaked in water over night. It was then impregnated with glycerine for two hours, the glycerine in this instance having a specific gravity of 1.0689. The sample was then subjected to the same drying and ironing treatment as in Example I, and the resulting product showed a shrinkage of 0.4% as against an original shrinkage in the raw material of 4.7%.

Example III

A sample of white birch veneer was treated for two hours in a 0.125% solution of sodium hydroxide, and then for ten minutes was treated with a 3.05% solution of sulfuric acid, after which it was dried and soaked in water as in Example I. It was then impregnated with glycerine, this treatment lasting for two hours and the glycerine having a specific gravity of 1.1256. The sample was then dried and ironed as in Example I. The product showed a shrinkage of 0.8% as against a shrinkage in the original piece of 9.6%.

We believe that the above examples, with the detailed description of our method given above, will be sufficient for those skilled in the art to practice the invention. Numerous samples have been treated, and we find that by properly controlling the various steps as outlined above, no difficulty is had in obtaining products of various kinds of woods having the desired shrinkage. In each case, the resulting sample was flexible enough for use as veneer, and usually the flexibility is increased by the treatment, as is also the resiliency and strength. This may or may not be the case, however, in all instances, because the principal thing sought for is a control of the shrinkage, and so flexibility, resiliency, or strength may be sacrificed in the interests of shrinkage, if found necessary. Usually, however, no material sacrifice in those properties is

called for, and in fact usually there is an improvement of those properties by the treatment.

Where a piece of wood is to be joined to the surface of another material, the amount of shrinkage required would depend upon the shrinkage of that surface, as pointed out above.

In the three samples given above, it will be seen that in each case we employed the step of soaking the wood in water before impregnation and after drying and that we also omitted the first ironing step. In some instances, we find that predrying is sufficient without the ironing, and in other instances we find that the soaking in water after drying can also be omitted. That soaking was allowed to continue over night merely as a matter of convenience, as in many other examples we have found that a much shorter time, for example six hours, is enough.

While we have described the invention more or less in detail, it is to be understood that those details can be varied within wide limits without departing from the scope of the invention as defined by the appended claims.

We claim:

1. The method of reducing the shrinkage of wood which comprises the successive steps of substantially removing the non-cellulosic substances from the wood, as by an alkali treatment or the like, while preserving the natural structure of the wood, treating with glycerol or a like non-volatile impregnator carried by a relatively volatile vehicle, and then drying to drive off said vehicle, the amount of said impregnator being sufficient to substantially saturate the wood fibers at a selected relative humidity, and after said drying operation leaving the cell cavities of the wood substantially free of the impregnator.

2. The method of reducing the shrinkage of wood which comprises the successive steps of substantially removing the non-cellulosic substances from the wood, as by an alkali treatment or the like, while preserving the natural structure of the wood, drying to set the fibers, treating with glycerol or a like non-volatile impregnator carried by a relatively volatile vehicle, and then drying to drive off said vehicle, the amount of said impregnator being sufficient to substantially saturate the wood fibers at a selected relative humidity, and after said second drying operation leaving the cell cavities of the wood substantially free of the impregnator.

3. The method of reducing the shrinkage of wood which comprises treating it with glycerol or a like non-volatile impregnator carried by a relatively volatile vehicle, and then drying to drive off said vehicle, the amount of said impregnator being sufficient to substantially saturate the wood fibers at a selected relative humidity, and after said drying operation leaving the cell cavities of the wood substantially free of the impregnator.

4. The method of reducing the shrinkage of wood which comprises saturating the fibers with two impregnators, first with paraffin or a like non-hygroscopic one and then with glycerol or a like highly hygroscopic one, each carried by a relatively volatile carrier, and drying, the amount of each impregnator being sufficient to substantially saturate the wood fibers at a selected relative humidity, and after said drying operation leaving the cell cavities of the wood substantially free of that impregnator.

5. The method of reducing the shrinkage of wood which comprises saturating the fibers with two impregnators, first with paraffin or a like non-hygroscopic one and then with glycerol or a like highly hygroscopic one, each carried by a relatively volatile carrier, and then drying, the total amount of impregnator used being sufficient to substantially saturate the wood fibers at a selected relative humidity, and after said drying operation leaving the cell cavities of the wood substantially free of impregnator.

6. The method of reducing the shrinkage of wood which comprises the successive steps of substantially removing the non-cellulosic substance from the wood, as by an alkali treatment or the like, while preserving the natural structure of the wood, treating with a volatile acid and drying to set the fibers, treating with glycerol or a like non-volatile impregnator carried by a volatile vehicle, and then drying to drive off said vehicle, the amount of said impregnator being sufficient to substantially saturate the wood fibers at a selected relative humidity, and after said second drying operation leaving the cell cavities of the wood substantially free of the impregnator.

7. The method of reducing the shrinkage of wood which comprises the successive steps of substantially removing the non-cellulosic substance from the wood, as by an alkali treatment or the like, while preserving the natural structure of the wood, treating with a volatile acid and drying to set the fibers, and treating with two impregnators, first with paraffin or a like non-hygroscopic one and then with glycerol or a like highly hygroscopic one, each carried by a relatively volatile carrier, and drying, the total amount of impregnator being sufficient to substantially saturate the wood fibers at a selected relative humidity, and after said second drying operation leaving the cell cavities of the wood substantially free of impregnator.

8. The method of reducing the shrinkage of wood which comprises the successive steps of substantially removing the non-cellulosic substances from the wood, as by an alkali treatment or the like, while preserving the natural structure of the wood, treating with glycerol or a like non-volatile impregnator carried by a relatively volatile vehicle, and then drying to drive off said vehicle, the amount of said impregnator being sufficient to substantially saturate the wood fibers at a selected relative humidity, and after said drying operation leaving the cell cavities of the wood substantially free of the impregnator, and finally ironing the resulting product.

9. The method of reducing the shrinkage of wood which comprises the successive steps of substantially removing the non-cellulosic substances from the wood, as by an alkali treatment or the like, while preserving the natural structure of the wood, drying to set the fibers, and then impregnating with glycerol or a like non-volatile impregnator.

10. The method of reducing the shrinkage of wood which comprises the successive steps of substantially removing the non-cellulosic substances from the wood, as by an alkali treatment or the like, while preserving the natural structure of the wood, treating with a volatile acid and drying to set the fibers, and then impregnating with glycerol or a like non-volatile impregnator.

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