March 10, 1953 G. E. GARD 2,631,109

METHOD OF IMPREGNATING WOOD

Filed Dec. 8, 1948

Fig. 1

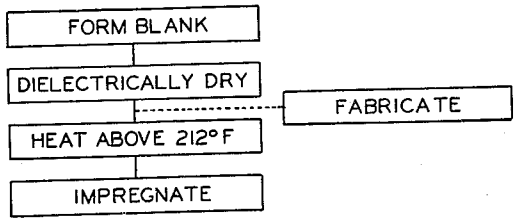


Fig. 2

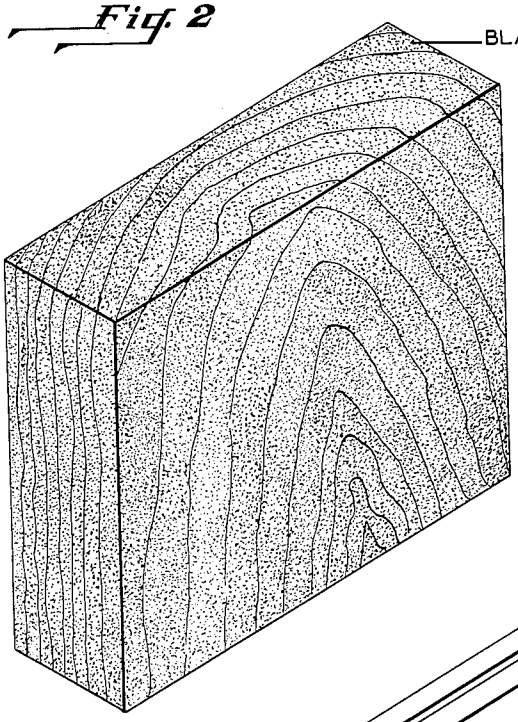
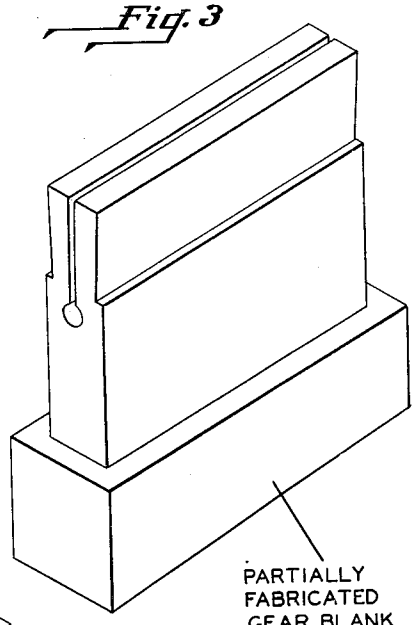


Fig. 3



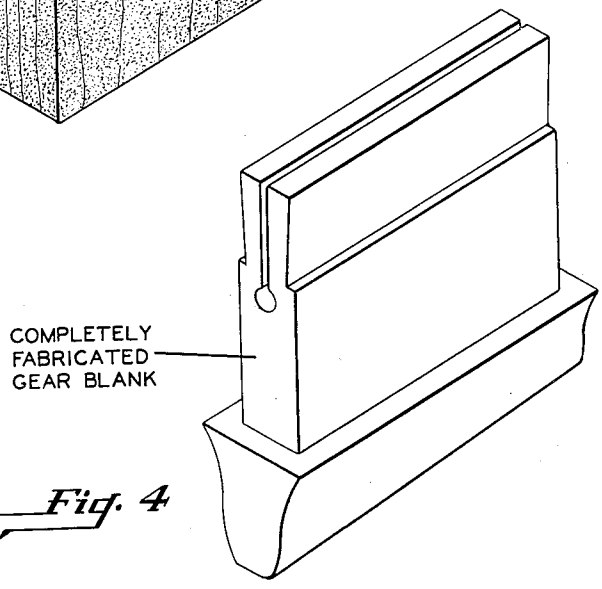


Fig. 4

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Patented Mar. 10, 1953

2,631,109

UNITED STATES PATENT OFFICE

2,631,109

METHOD OF IMPREGNATING WOOD

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Application December 8, 1948, Serial No. 64,151

10 Claims. (Cl. 117—59)

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This invention relates to a method of impregnating wood and is concerned more particularly with a method of impregnating wood with an impregnant subsequent to removal of water from the wood until its water content is essentially zero.

In the manufacture of articles of wood, it is frequently desirable to impregnate the wood to eliminate dimensional changes which normally occur through the loss or gain of moisture in the wood, and also to preserve and protect the wood against deterioration. For example, in the manufacture of nonsparking gears, such as are frequently used in the cork grinding industry, wooden gear teeth are employed. The teeth are mounted in a metal frame and considerable difficulty has been experienced because of the dimensional instability of the wood, loss of moisture and concomitant shrinkage causing the teeth to become loose, resulting in excessive wear and damage to the teeth. Warping of the teeth has also been encountered as well as other difficulties which arise because of dimensional changes in the gear teeth.

In the manufacture of cork composition and the like by high frequency dielectric heating, it is desirable to provide a mold in which the cork composition can be confined during heating. Wood is properly suited for this purpose, provided the moisture can be removed from the wood and replaced with a material which will remain within the pores of the wood under the conditions encountered in use. It is essential that no substantial checking of the wood grain occur either in preparation or in use. The wood must be subject to no substantial dimensional change in use since such dimensional change might introduce cracks in the mold which would be undesirable from the standpoint of the application of a high frequency voltage. The molds must be capable of withstanding continued reheating without substantial dimensional change. Since the rate of dielectric heating and voltage insulating value of the mold will vary drastically with any change in the moisture content of the wood, it is essential that a constant level of water content be maintained and this should be essentially zero for best operating results.

There are many other industrial applications of wood where permanent resistance to dimensional change or resistance to deterioration or both are important considerations. The present invention is directed to the problem of rendering wood substantially proof against dimensional change by a method which is economically practicable, relatively inexpensive, and operable without deleterious effect on the wood.

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A more specific object of the invention is to provide a method of impregnating wood by which the pores of the wood may be impregnated substantially throughout the entire extent of the body of the wood, leaving no space within the body for moisture.

Another object of the invention is to provide a method of wood impregnation which may be economically effected without any substantial splitting or checking of the wood, even though the wood to be treated contains substantial quantities of water prior to impregnation.

A further object of the invention is to provide a method of wood impregnation in which water is removed from a blank of regular geometry without deleterious action on the blank which would militate against subsequent fabrication operations and impregnation is effected either subsequent to fabrication or immediately after water removal.

An additional object of the invention is to provide a method of impregnation which will not require the usual pressure or vacuum systems but which will provide for substantially complete impregnation of the wood.

A still further object of the invention is to provide a method by which substantially complete impregnation at atmospheric pressure may be achieved in a relatively short period of time.

One of the most common methods of impregnating wood is to immerse air or kiln-dried wood in a suitable impregnating bath disposed within a container and then apply pressure to the bath and the wood in the container to force the impregnant into the pores of the wood. This is a relatively slow process and one which is not always effective for securing sufficiently complete impregnation to insure against dimensional change in the impregnated wood and eliminate the possibility of moisture gain which is objectionable, as mentioned above. Vacuum processes of wood impregnation have also been used as well as combination pressure and vacuum processes, performed as alternate pressure application and vacuum creation. These processes have not been completely successful in accomplishing full impregnation and they are, of course, relatively expensive, both in the cost of necessary equipment and in operating expense.

According to the present invention, the wood to be impregnated is first subjected to a high frequency electrical field to heat the wood by the dielectric effect to remove moisture from the wood

until it has an essentially zero water content, and the temperature of the wood is then elevated to a degree above the boiling point of water but below the charring temperature of the wood. By heating the wood dielectrically, two important advantages are derived over conventional drying methods. First, it is possible to rapidly completely dry the wood by a substantially uniform generation of heat at an extremely low temperature, compared with normal commercial practice, and thus eliminate end grain checking and cracking, even though the wood initially contains an extremely large amount of water. Second, by dielectric heating it is possible to deliver the wood to the impregnating bath at a substantially uniform temperature throughout; whereas, with ordinary drying methods, the outer portions of the wood are heated to a higher degree than the inner portions. By having the interior of the wood at least as high as the exterior and possibly somewhat higher due to heat losses from the surfaces during and subsequent to drying, an unusually effective "vacuum" action is obtained without evacuating equipment when, as a subsequent step in the process of the present invention, the heated wood is immersed at normal atmospheric pressure in an impregnating bath the temperature of which is substantially lower than the temperature of the wood.

In the attached drawing:

Figure 1 is a flow diagram indicating a preferred sequence of steps to be performed in carrying out the method of this invention;

Figure 2 is a perspective view of a wood blank of the type used in the fabrication of a gear tooth;

Figure 3 is a perspective view illustrating a partially fabricated gear tooth; and

Figure 4 is a perspective view illustrating a completed gear tooth, ready for assembly in a supporting metal frame.

Appropriate notations have been applied to the various items shown in the drawing.

A method of impregnating a blank for the formation of a gear tooth will be described as typical of the present invention, but it will be understood that the invention is not limited to any particular size or shape of blank or article, the method being one of general application.

In the manufacture of a gear tooth, a blank of air or kiln-dried hard maple wood may be used, although relatively green wood containing a large quantity of moisture may be treated, if desired. Air-dried or kiln-dried wood normally contains in the order of 10% of water and green wood may contain as much as 25% or more of water. Preferably, the blank is of regular geometry, such as a rectangular piece in which the length, width, and thickness are each uniform throughout. This facilitates uniform heating for water removal, as will be more fully discussed. A gear tooth blank 2" thick by 7" wide by 6" long will be considered typical.

The blank is placed between electrodes connected to a source of high frequency power such as a conventional electronic oscillator delivering a frequency of 10 megacycles and a voltage of about 1 kilovolt per inch of thickness of the blank disposed between the electrodes. The power applied is so adjusted that the temperature of the blank is elevated to about 210° F. There is a dissipation of vapor from within the wood as this heating continues. Heat is generated substantially uniformly throughout the extent of the blank by subjecting the blank to the high frequency field; and, as a result, rapid dissipation of water from the wood is effected at a low temperature as compared with usual wood drying where superheated steam is generally used and where, due to the combined effect of the non-uniformity of the heating and the high temperature application, objectionable edge checking and cracking occur and complete water removal is difficult to achieve. Water removal should be accomplished as soon after the blank has been formed as possible, particularly where green wood is used, for there is a tendency for the wood to end check after cutting where moisture is permitted to leave the blank adjacent the freshly cut surfaces.

Usually about five to ten minutes' time is required to remove substantially all the moisture from within a blank of the size mentioned utilizing the electronic oscillator referred to. In some instances, longer periods of time may be required depending upon the type of wood, the size of the blank, its moisture content, the initial temperature of the blank, and other variable factors. The application of the high frequency field to the blank is continued until the water content has been reduced to essentially zero. There may be some water chemically bound in the cellulosic structure of the material, but reference is made to the water disposed within the mass, essentially within and between the fibers, as the term "water content" is generally recognized in the lumber industry. By "essentially zero" there is contemplated a moisture content of not more than 2% and generally less than 1% and more frequently a bone dry condition, insofar as this is physically possible.

After the wood has had its water content reduced to essentially zero, the dielectrical heating is preferably continued at a higher voltage, 2 kilovolts per inch of thickness in the blank under consideration, and the temperature of the wood is raised above the boiling point of water. The temperature to which the wood is elevated will depend to a large extent upon the particular saturant to be employed as well as the type of wood, the size of the blank, and other variable factors. The wood temperature should in all events be higher than the temperature of the impregnant and should preferably be at as high a temperature as can be safely and economically attained. As a general rule, it may be stated that the working range for the temperature of the wood will lie between 212° F., the boiling point of water, and the charring temperature for the particular wood employed. The range normally used will be between 250° F. and 350° F. and optimum results will be obtained with most woods when the temperature is between 275° F. and 325° F. In the specific example under consideration, the temperature of the maple blank may be raised to 300° F.

The frequency of the source of high frequency power will vary depending primarily upon the geometry of the load and the heating rate desired. Frequencies between approximately .5 megacycle and 40 megacycles are preferred. The voltage gradient or watt density used in heating the wood will be dependent upon the type of wood, open or tight grain, and the grain length, as well as other variable factors. The rate of heating should be such that the development of excessive pressures and explosions of the wood fiber are avoided. As mentioned above, gear teeth blanks of hard maple about 2" x 7" x 6" were heated successfully with a voltage gradient of 1

kilovolt per inch of thickness during drying, elevated to 2 kilovolts per inch after drying.

The wood blank substantially completely freed of water and while at an elevated temperature is immersed in an impregnating bath which is to fill the pores of the wood and thus prevent the wood from taking on any moisture. Where thermoplastic impregnants are used, the temperature of the impregnating bath should, of course, be sufficiently high to melt the impregnant and render it sufficiently fluid that it will be capable of penetrating the wood to the desired extent. Where liquid impregnants are used they may be at room temperature. The general rule is to have the temperature of the saturant as low as possible and the wood temperature as high as possible, both consistent with limitations imposed by safety and sound commercial practice, for the utmost advantage in rapid and complete penetration of the impregnant is achieved when the temperature differential between the wood and the impregnant is at its maximum. A temperature differential of at least 50° F. should exist for economical commercial practice with most woods and usual impregnants.

By having the wood at a higher temperature than the temperature of the impregnating bath, there is a "vacuum" action created upon the cooling of the wood within the bath, and since the temperature of the interior of the wood is at least as high as that of the exterior and preferably higher, as the wood cools down from the outside toward the center of the piece impregnant is drawn into the body, completely filling the pore space in the wood, throughout the whole body.

In making a gear tooth, it has been found that ceresin wax forms an ideal impregnant, for it not only preserves and protects the wood against deterioration and dimensional change, but it also serves as a lubricant at the surface of the finished tooth. When ceresin wax is used, it is melted, and the heated blank is immersed in the melted impregnating bath. Ceresin wax having a melting point of 160° F. heated to 170° F. will be found to rapidly and effectively penetrate a maple blank of the dimensions given above, heated to 300° F. at the time of immersion, in a period of thirty to sixty minutes, during which time the wood will absorb 25% of its weight of the ceresin wax. The quantity absorbed will vary with different woods as well as different impregnants. Generally 15% by weight based on the weight of the dry wood will be a minimum for close-grained woods.

Subsequent to impregnation, the blanks are removed from the impregnating bath, wiped free of excess impregnant, and are then ready for fabrication.

Observations which have been made of wood blanks treated in accordance with the foregoing method, as well as dielectric measurements which have been taken, show no measurable absorption of water by the treated pieces, and no measurable dimensional changes have occurred in articles fabricated from blanks treated in accordance with the invention.

In the manufacture of a mold wall for the dielectric heating of cork compositions, blanks of maple wood 3" thick by 11" wide by 18" long were treated. The high frequency oscillator delivered a frequency of 10 megacycles and the initial voltage gradient or watt density was .5 kilovolt per inch of thickness which was continued until drying was effected and was increased to 1 kilovolt per inch of thickness for the subsequent heating to about 300° F. A shrinkage of ¼ of an inch in an 11-inch width or across the grain direction was noted, and a slight warpage resulting from stress relief in the blank was observed, approximating a ⅛ inch displacement in the center of the 11-inch width. No substantial checking was noted and the warpage was, of course, so slight that it was merely necessary to slightly increase the nominal dimensions of the blank prior to treatment The blanks were approximately ¼ inch greater than the over-all dimensions of the final panels. If minor warpage of the work piece during water removal is a factor of any considerable importance, the work piece may be placed under pressure between the electrodes during the drying process. This will tend to reduce or eliminate all warpage, although generally there will be some minor deformation of the blank upon removal from the press due largely to the release of stresses within the body of the blank.

It is preferred to dielectrically heat wood blanks of regular geometry (such a blank has been illustrated in Figure 2), for this makes possible the use of conventional dielectric heating equipment without any special precautions to prevent undesired overheating in certain areas of the blank which might occur if the pieces were not of the regular contour and such irregularity was not taken into account in the design of the electrodes. Irregularly shaped blanks may be treated in accordance with the invention, however, and it is also within the scope of the invention to treat finished or partially completed articles. Where the cost of the impregnant is a major factor, it has been found possible to practice the invention in this order: form the blank, subject the blank to the high frequency electrical field to reduce the water content to essentially zero, then fabricate the blank to an article of substantially the desired final shape (as shown in Figure 3), reheat the blank, preferably by the dielectric effect, to a temperature above the temperature of the impregnant but below the charring temperature of the wood, and then impregnate. Any final finishing operations which may be necessary can then be effected. Figure 4 shows a completed gear tooth finished from the fabricated blank of Figure 2. Where minor warpage is not objectionable or can be conveniently obviated by pressure application, the process may be carried out on completely finished articles.

While it is preferred to utilize the dielectric effect for elevating the temperature of the blank to the desired degree subsequent to drying, this is not essential, for a blank which has been dielectrically dried may be heated in an oven, for example, and then impregnated. In most instances, however, the preferred practice will be to dielectrically dry, then continue the application of the high frequency field to elevate the temperature of the blank to the desired degree and immediately immerse in the impregnating bath.

The invention is not limited to any particular wood but is applicable to fibrous materials of various sorts in which the attainment of dimensional stability is a problem and is particularly useful where it is necessary to secure substantially complete filling of the voids within the fibrous material by an impregnating agent, as in the case of mold walls for dielectric heating where, as mentioned above, the presence of mois-

ture affects the rate of dielectric heating and the voltage insulating value of the mold wall.

While in the typical example reference has been made to ceresin wax as an impregnant, other materials may be used. Where complete filling of the void space is desired, a melted impregnant is generally preferred, but for other uses solvent types of impregnants may be substituted. Synthetic resinous impregnants, such as phenol aldehyde resin in which water or alcohol may be employed as the solvent, depending upon the stage of polymerization of the resin, are typical of the solvent type of impregnants. With this latter type of impregnant, it may be maintained at about room temperature at the time of immersion of the blanks to be treated

Generally it is desirable to impregnate the whole of the article, but with the present invention it is possible to localize the heating and impregnate only in those areas which have been heated. For example, local impregnation of end sections of wood is frequently desired, and this may be economically accomplished by the method of this invention.

While I have illustrated and described certain preferred embodiments of my invention, it will be understood the same is not limited thereto but may be otherwise embodied and practiced within the scope of the following claims.

I claim:

1. In a method of impregnating wood with an impregnant, the steps comprising subjecting the wood to a high frequency electrical field to heat the wood by the dielectric effect to a temperature below about 212° F. until its water content has been reduced to essentially zero, heating said wood to a temperature substantially above 212° F. and immersing said wood heated to a temperature substantially above 212° F. and at essentially zero content of water in a bath of impregnating material the temperature of which is at least 50° F. lower than the temperature of the wood.

2. In a method of impregnating wood with a thermoplastic material, the steps comprising subjecting the wood to a high frequency electrical field to heat the wood by the dielectric effect to a temperature below about 212° F. until its water content has been reduced to essentially zero, heating the wood to a temperature substantially above 212° F. and below its charring temperature, and immersing said wood while so heated in a bath of thermoplastic impregnant heated to a temperature above the melting point of the impregnant but at least 50° F. lower than the temperature of the wood.

3. In a method of impregnating wood with a thermoplastic material, the steps comprising subjecting the wood to a high frequency electrical field to heat the wood by the dielectric effect to a temperature below about 212° F. until the water content of the wood has been reduced to essentially zero, thereafter raising the temperature of the wood to between 250° F. and 350° F., and immersing said wood while so heated in a melted bath of thermoplastic impregnating material heated to a temperature above its melting point but below 250° F.

4. In a method of impregnating wood with a thermoplastic material, the steps comprising subjecting the wood to a high frequency electrical field to heat the wood by the dielectric effect to a temperature below about 212° F. until its moisture content has been reduced to essentially zero, heating said wood to a temperature of about 300° F., and immersing said wood heated to a temperature of about 300° F. in a bath of melted waxlike material heated to a temperature of about 170° F.

5. In a method of impregnating maple wood with a thermoplastic material, the steps comprising subjecting the wood to a high frequency electrical field to heat the wood by the dielectric effect to a temperature of about 210° F. until its moisture content has been reduced to essentially zero, thereafter heating the wood to a temperature between 275° F. and 325° F., immersing said wood while so heated and while at a substantially zero moisture content in a melted bath of impregnating material at a temperature substantially below the temperature of the wood, and maintaining said wood in said impregnating bath until at least 25% by weight of impregnant based on the weight of the dry wood has been disposed within the body of the wood.

6. In a method of impregnating wood, the steps comprising subjecting the wood to a high frequency electrical field to heat the wood by the dielectric effect throughout its extent to a temperature about the boiling point of water until its moisture content has been reduced to essentially zero, subjecting the wood to the further action of a high frequency electrical field to elevate the temperature of the wood throughout to a degree above 212° F. and below the charring temperature of the wood, with the interior portion of the wood at a temperature at least as high as the temperature of the surface portions, and immersing said wood while so heated into a fluid bath of impregnating material the temperature of which is below 212° F.

7. In a method of completely filling wood throughout its body with an impregnant to eliminate the absorption of moisture by the impregnated wood, the steps comprising subjecting the wood to a high frequency electrical field in two stages, first to heat the wood to a temperature about the boiling point of water where water will be driven therefrom until the water content of the wood has been reduced to essentially zero; and, second, to heat the wood to a temperature substantially above 212° F. but below its charring temperature after substantially all of the water has been removed from the wood to thus produce a heated body of wood free of end checking or cracking the temperature of which is higher within the body than at the surfaces thereof, and applying a fluid impregnant to said body at a temperature which is substantially below the temperature of the wood, whereby the wood upon cooling will cause the impregnant to be drawn into the body thereof to completely fill the same therethroughout.

8. In a method of impregnating wood, the steps comprising subjecting the wood to a high frequency electrical field to heat the wood by the dielectric effect to a temperature of about 212° F. where moisture will be driven from the wood until the water content of the wood has been reduced to essentially zero, subjecting the wood to a further action of a high frequency electrical field to heat the wood to a temperature between 270° F. and the charring temperature of the wood, and immersing the wood while so heated into a bath of impregnating material the temperature of which is below 212° F.

9. In a method of impregnating wood, the steps comprising confining said wood between pressing surfaces, subjecting the wood to a high frequency electrical field in two stages, first to heat the wood by the dielectric effect to a tem-

perature about the boiling point of water until its moisture content has been reduced to essentially zero, and second to heat the wood to a temperature between 212° F. and its charring temperature, the second-stage heating being effected by subjecting the wood to a high-frequency field at a higher voltage than in the first-stage heating, and applying to the wood while so heated a melted impregnant the temperature of which is lower than the temperature of the wood.

10. In a method of substantially completely filling wood throughout its body with a waxlike impregnant to eliminate the absorption of moisture by the impregnated wood, the steps comprising subjecting the wood to a high-frequency electrical field in two stages, first to heat the wood to a temperature of about 210° F., at which water will be driven from the wood, until the water content reaches essentially zero without cracking or checking of the wood, and second to heat the wood to a temperature between about 275° F. and about 325° F after substantially all of the water has been removed from the wood

to thus produce a highly heated body of wood free of any checking or cracking, the temperature of which is higher within the body than at the surfaces thereof, and immersing the body so heated in a melted bath of waxlike impregnating material, the temperature of which is at least 50° F. lower than the temperature of the wood, whereby the wood upon cooling will cause the impregnant to be drawn into the body in order to substantially completely fill the same therethroughout.

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