Sept. 16, 1969 R. Z. PAGE ET AL 3,467,546

METHOD OF IMPREGNATING WOOD

Filed June 23, 1966 2 Sheets-Sheet 1

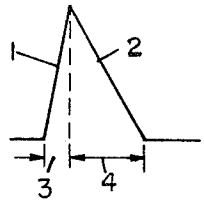


FIG. 1

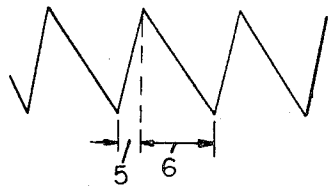


FIG. 2

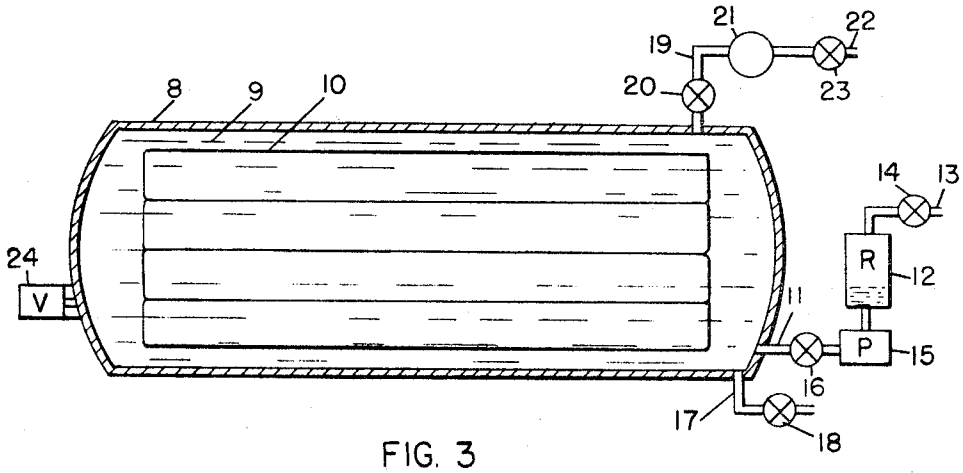


FIG. 3

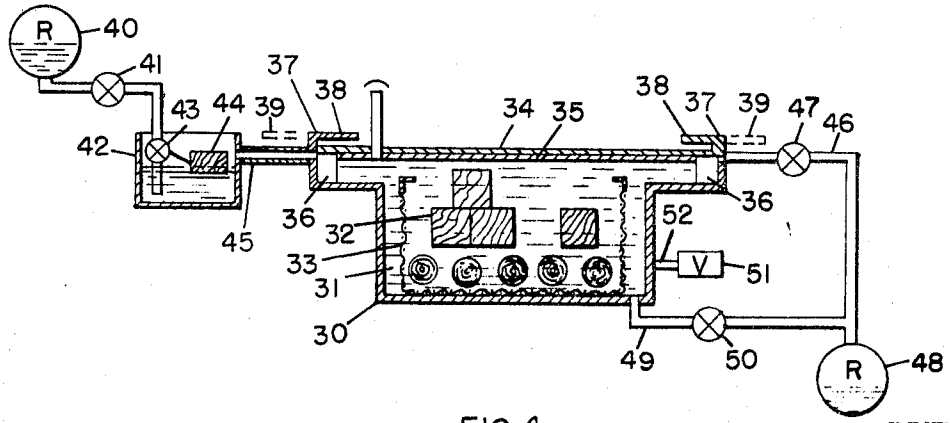


FIG. 4

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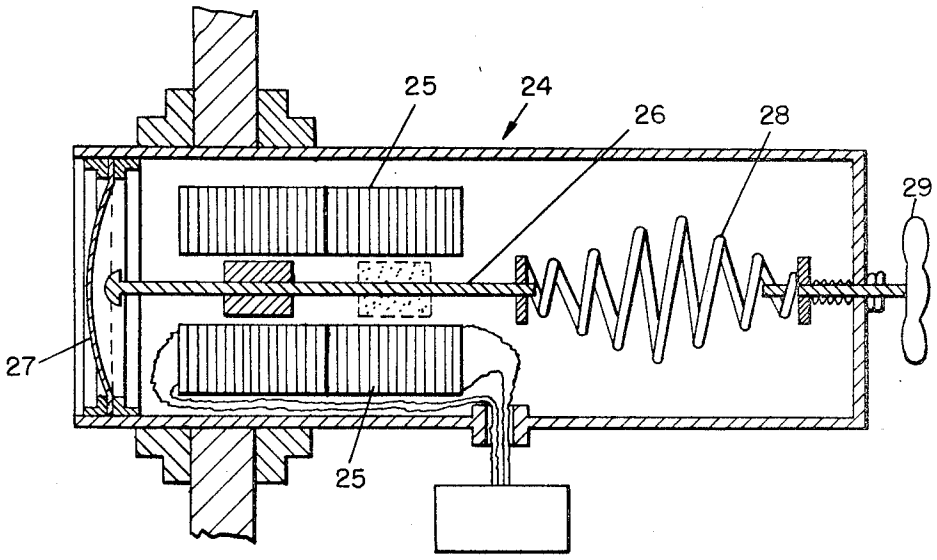


FIG. 5

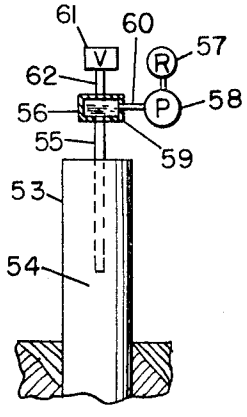


FIG. 6

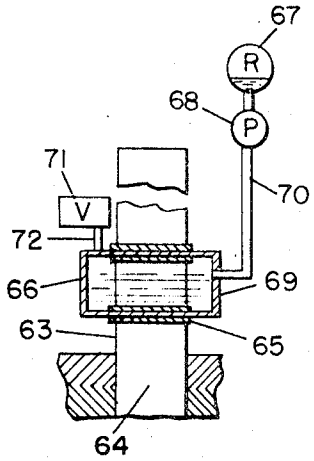


FIG. 7

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METHOD OF IMPREGNATING WOOD

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Continuation-in-part of application Ser. No. 401,616, Oct. 5, 1964. This application June 23, 1966, Ser. No. 564,506

Int. Cl. B05c *3/02*; B44d *1/26, 1/02*

U.S. Cl. 117—116 11 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to a method of preserving wood by the impregnation thereof with a treating liquid in a closed container, and applying saw-tooth wave-form vibrations to the liquid therein so that the liquid will penetrate the wood.

The present application is a continuation-in-part of the copending application Ser. No. 401,616 now abandoned filed Oct. 5, 1964 by the same named inventors and entitled "Method of Impregnation of Wood" which in turn is a continuation-in-part of the application Ser. No. 101,601 now abandoned filed Apr. 7, 1962 by the same named inventors and entitled "Impregnation of Wood," with the first filed application being licensed to the United States Government for governmental purposes without the payment of any royalties thereon or therefore.

The present invention relates to the preservation of wood and wood products by the impregnation thereof with a treating liquid, more particularly, to a method of impregnating wood utilizing a closed container filled with the treating liquid and applying sonic vibrations to the liquid.

Numerous processes have been developed for the preservative treatment of wood and wooden articles. Such processes generally use heat, pressure, and on occasion vacuum to assist the impregnation of the wood with the preservative material. Such treatment generally comprises retaining the wood in treating cylinders or tanks for a number of hours during which time the preservative is slowly forced into the cells of the wood. Non-pressure methods have been devised and these include dipping and in-place treatment by surface applications, but such methods are even less effective. It has also been proposed to apply ultrasonic vibrations to the treating solutions but such processes have not been successful.

The known methods for the treatment of wood as discussed above have a number of the disadvantages. The prolonged treating cycles which are employed in commercial processes contribute materially to the high cost of the treatment. The high temperatures and pressures required for these long periods of time often result in damage to the cellular structure and to the strength of some species of wood. Some woods are virtually untreatable by these known methods since the dip and soak treatment results in only very limited penetration and surface application of solutions results in no appreciable penetration. Various preservative greases and thick emulsions will penetrate from the surface of the wood but cannot be used in many instances where cleanliness and paintability or speed of treatment are important considerations.

It is therefore the principal object of the present invention to provide a novel and improved process for the impregnation of wood with a treating liquid.

It is a further object of the present invention to provide a process for the impregnating of wood which will insure adequate penetration of the wood by the impregnant and which can be accomplished in a relatively short time with simple and conventional equipment.

The process of the invention may be carried out by immersing an article of wood in treating liquid contained in a pressure treating cylinder. The cylinder is closed and then completely filled with the treating liquid so as to exclude all residual air from the closed cylinder except for that air which is embedded within the wood. A compressional force is then repetitively applied to the liquid surrounding the wood. Such forces are in the form of shock waves which are suddenly applied and then relatively slowly withdrawn. Such shock waves may be provided by applying saw-tooth waveform vibrations to the liquid with the waveform having a steep wavefront and a relatively longer decay time.

A pressure may be applied to the liquid within the closed cylinder in order to increase the pressure above atmospheric pressure. The air which is released from the wood may be periodically or continuously removed from the closed cylinder. Treating liquid may be added to the closed cylinder to replace the liquid which has penetrated into the wood.

Other objects and advantages of the present invention will be apparent upon reference to the accompanying description when taken in conjunction with the following drawings, which are exemplary, wherein:

FIGURE 1 is a diagram showing the waveform of the vibrations used in the present method;

FIGURE 2 is a diagram of the waveforms of a plurality of vibrations as applied in the present method;

FIGURE 3 is a longitudinal sectional view of one form of apparatus used in the present method and showing wooden timbers in a closed pressure treating cylinder tank filled with treating liquid;

FIGURE 4 is a sectional view showing schematically a dip-treating tank apparatus which can be also used for carrying out the present process;

FIGURE 5 is a longitudinal sectional view of the vibrator mounted at one end of the tank in FIGURE 3 for producing the vibrations according to the present invention;

FIGURE 6 is a diagrammatic view showing the manner in which the present invention can be carried out by inserting a hollow probe into the wood to be treated; and

FIGURE 7 is a diagrammatic view showing the manner in which the present process can be carried out by mounting a closed container around the wooden article which is to be treated.

Referring now to the drawings wherein like reference symbols indicate the same parts throughout the various views a specific embodiment of the present invention together with several modifications will be described in detail.

Proceeding to FIGURE 3 there is shown a closed pressure-treating cylinder **8** completely filled with treating solution **9** and having wood indicated at **10** therein. The treating solution surrounds the wood so as to exclude from the cylinder **8** all residual air except for the air remaining within the cells of the wood itself. The impregnant or treating liquid is introduced into cylinder **8** through line **11** which leads to reservoir **12**. The reservoir **12** is connected to a source of supply for the treating liquid through line **13** which has control valve **14** therein. The liquid is supplied to the cylinder **8** by pump **15**. A valve **16** is provided in line **11**.

In order to empty cylinder **8** at the conclusion of the treating process there is provided drain pipe **17** which has a valve **18** therein.

Extending from the top of tank **8** is a low-pressure system pipe **19** which has a valve **20** therein and leads to a vacuum or reduced pressure generating unit **21** which

exhausts through line **22** having valve **23** therein. This system is used to apply decreased pressure during the vacuum phase of some treating cycles and also for the flushing of air from the cylinder **8** by the application of liquid pressure through pump **15**.

While not shown in the drawings a liquid overflow tank may be provided as is known in the art to capture any solution escaping from cylinder **8** when air is removed from the cylinder by flushing with the treating liquid.

In order to apply vibrational energy to the liquid within the closed cylinder a vibrator **24** is mounted at one end of the cylindrical tank **8** as may be seen in FIGURE 3. This vibrator is of the type which produces vibrations having the waveform as shown in FIGURES 1 and 2. This waveform is of the type which has a steep fronted front **1** and a relatively longer trailing surface **2**. These waveforms are further characterized by having a relatively short pressure rise or growth time such as **3** and a relatively longer pressure decay time **4**. It has been found that this waveform should have a decay time at least twice as long as the growth time. In carrying out the process as will be later described the decay time is about 4 times as long as the growth time.

The vibrator **24** is further illustrated in FIGURE 5 and is essentially an electromechanical unit which has electromagnets **25** connected to a suitable source of electricity and driving a slidably mounted core or hammer **26** against a flexible diaphragm **27** which is positioned within the tank **8**. The vibrator is mounted in a port or other opening formed in the end wall of the cylinder. The core **26** is spring biased at **28** and an adjusting handle **29** is provided to adjust the tension on this spring. In operation, this vibrator will deliver a series of sharp blows of steep fronted shock waves into the cylinder by the impacting of the core against the flexible diaphragm **27** which in turn is in direct contact with the treating liquid within the tank. Thus the shock waves are transmitted directly to the treating solution.

It has been determined by a kymograph that the vibrator **24** illustrated in FIGURE 5 delivers shock waves having the waveform as illustrated in FIGURES 1 and 2.

While the present vibrator is electromechanical in nature it is pointed out that any conventional electrically, pneumatically, hydraulically, or mechanically driven item of equipment can be used to deliver the series of sharp blows of steep fronted shock waves to the cylinder. Air hammers such as pneumatic pavement breakers can also be used.

In carrying out the process of the present invention a load of 25 poles of southern pine, each pole 30 feet in length, were placed in a conventional pressure treating cylinder having a diameter of 5 feet and a length of 36 feet. The total volume of the load of 25 poles was 510 cubic feet and the total volume of the cylinder was 710 cubic feet. The remaining 200 cubic feet within the cylinder was filled with 1,488 gallons of a water-borne preservative known under A.W.P.A. (American Wood Preservers Association) as CCA-type A. This preservative is chromated copper arsenate.

The poles were first dried or seasoned by subjecting them to a steaming process at 240° F. for about six hours under a vacuum of 22 inches. Within the tank the poles were then subjected to a pressure ranging from 50–150 p.s.i. for six hours. At the end of this period the poles were impregnated so as to have a retention of this preservative of 0.75 pound per cubic foot.

The above described process is conventional in that the logs are merely subjected to pressure for a period of time.

According to the present invention while the logs are subjected to the pressure within the cylinder steep fronted vibrations are applied to the treating liquid within the tank at a frequency of 120 c.p.s. Each cycle or shock wave had an energy of 2.8 foot pounds. At the end of one hour the poles had a retention of the preservative of 0.75 pound per cubic foot.

The present process therefore accomplished in one hour what previously had required six hours.

During the process of the present invention a pressure is continuously applied to the solution in order to evacuate all of the air from the cylinder which has been displaced from cells of the wood. Concurrently with this evacuation, treating liquid is introduced into the tank so as to maintain the cylinder completely filled.

During the processes as described above the poles will retain 250 cubic feet or 1860 gallons of preservative, and accordingly, this quantity of preservative must be added to the cylinder during the pressure period.

Regardless of the energy level used to apply the shock waves to the treating solution to drive the solution into the wood, and regardless of the length of the treating cylinder, the shock waves produced in the loaded cylinder by the vibrator will travel through the cylinder and the treating liquid with a velocity of $V=E/d$ where E is the bulk modulus of the loaded treating cylinder expressed in square centimeters and where d is expressed in grams per cubic centimeter of the loaded cylinder. When the energy is transmitted from the vibrator to the treating liquid, the energy extends to all portions of the treating liquid, including the liquid which has penetrated into the wood cells and accordingly drives the liquid deeper into the wood from cell to cell to the various connecting openings between the cells and back to compress the air within the wood. The liquid is exposed to previously dry surfaces of the cell walls which become wet by the liquid. With the passing of the compressional force exerted by the steep front of the shock wave, the energy is released from the air within the wood which then tends to again expand to push the liquid back out of the wood. However, the movement of the liquid back out of the wood is hampered.

The sudden application of energy in the form of a steep fronted shock wave drives the solution through the cells and through the connecting openings between cells. When the pressure peak in the liquid passes, the air compressed within the wood begins to expand, relatively slowly as compared to the rate of compression, and thereby exerts pneumatic pressure against the contiguous solution in the cells most recently filled and wetted by the treating liquid. The friction and drag residual in the characteristics of the treating liquid are set up within the liquid at the cell wall to delay complete return of the liquid by the relatively slowly applied low energy pneumatic pressure within the as-yet non-treated cells. This result can only be achieved with the repetitive steep fronted shock waves having the steep growth time and relatively slower decay time as shown in FIGURES 1 and 2.

The use of repetitive waves having sine waveforms of equal energy levels to the shock waves described above does not produce rapid penetration of wood by the treating liquid. The gradual application of energy in the sine waveforms does not overcome the frictional drag of the solution within the cell walls sufficiently to effect deep penetration.

As described above, the deep and rapid penetration of the wood by preservative liquids by the use of shock waves requires that the entire treating system be essentially free of air or other compressible gases, except for the air within the cells of the wood. Deep penetration of the wood requires that the applied energy drive the solution through the fine structure of the wood while overcoming the frictional and other drag forces and also while compressing the air which is within the wood. When a pocket of air exists within the treating system but exterior to the wood, the applied waveform energy is expended in repeatedly compressing the bubble or pocket of air rather than in forcing the treating solution into the wood. Since air escapes from the wood during the treating of the wood by the application of repetitive shock waves, this air must be flushed from the treating system to permit continuing

penetration by the liquid. It has been shown that within the first 10 to 40 seconds (depending on the species of wood being treated) sufficient air is driven from the wood to form a bubble of such size as to absorb the energy applied and thus prevent further rapid and deep penetration. However when the bubble was removed and the space in the cylinder replaced with treating liquid rapid penetration of the wood was again achieved.

It has been discovered that an increase in the amplitude of the applied energy waves will increase the penetration with each pressure wave, and an increase in frequency at a given level of energy will increase the speed of penetration of the liquid in the wood. The lower limits are usually dependent on economical factors such as the desired reduction of treating time. The upper limits are determined by various inter-related physical factors such as the species, moisture content, and dimensions of the wood, the density and viscosity of the treating solution, the length and loading configuration of the cylinder, and the treating pressure being used. It is pointed out that reductions in the treating pressures will permit increases in the amplitude of the repetitive shock waves superimposed on the treating liquid.

The frequency of the shock waves is somewhat dependent upon the length of the treating cylinder. Commercial treating cylinders generally range from 36 to 180 feet in length. In the longest cylinder the shock waves may travel the length of the loaded cylinder in less than ⅓ of a second and in the shortest cylinders in much less time. As reverberation occurs at the far end of the cylinder away from vibrator, and as reinforcing resonance nodes in the system can produce undesirable uneven penetration of wood by the treating liquid, the most rapid deep penetration of the wood is obtained when the frequency of the shock waves is in even multiples of the time required for the shock wave to travel the length of the cylinder and return to its source. For most combinations of wood species and treating solution, the upper limit of these multiples generally ranges between 200 and 300 c.p.s., although frequencies up to about 750 c.p.s. may be used.

In order to further demonstrate the result of the process of the present invention tests were conducted wherein repetitive steep fronted shock waves were applied to the end of a cylinder loaded with wooden blocks and filled with liquid. The test cylinder was an iron pipe having a one inch inside diameter and a length of six inches with each end being capped and sealed with threaded caps. The source of vibrations was a hair clipper manufactured by Supreme Products Corporation of Chicago, Ill., and designated Model S–11. This hair clipper is of conventional construction in that it includes an electromagnet, a weight vibrating reed, and cutter bars which effect the cutting action. These parts are mounted within a plastic housing of a size to be grasped in the user's hand and during operation the housing will vibrate. The construction of the hair clipper is such that the movement of the weighted vibrating reed causes an equal and opposite movement in the housing which is thereby put into vibration and can deliver a series of blows when held loosely against an object. In this test the clipper housing was held against the threaded sealing cap at one end of the pipe. Each blow by the hair clipper to the end of the pipe produced a shock wave having an energy level of 0.0101 foot pound per square inch of cross-section of the pipe.

The "treating solution" used was water with a dye added. Ambient temperature and pressure was used. The wood used was spruce, southern pine, and Douglas fir (Intermountain).

In this test identically shaped blocks (several blocks of each species of wood) were used. The size of the blocks was such that a block could fit into the test cylinder. Sets of control blocks were submerged in the colored water for periods of 1, 2 and 3 hours. The test blocks in the treating cylinder were subjected to the effects of repetitive shock waves for periods of 1, 2 and 3 minutes. To determine the penetration of the blocks by the colored water the blocks were blotted dry at the surface then dried thoroughly for several hours before they were split longitudinally in both the radia and tangential planes.

The results of this test were as follows: 1, 2 and 3 minutes of vibration of spruce produced twice the penetration obtained in 1, 2, and 3 hours of submerged soaking without application of shock waves. Vibratory treatment of southern yellow pine produced in minutes approximately 3 times the penetration obtained in corresponding hours of soaking. The application of repetitive shock waves to intermountain Douglas fir produced in the sap wood of this species in minutes about four times the penetration obtained in the corresponding hours of soaking. During the above tests the treating cylinders to which the waves were applied were kept filled with liquid so that no residual air was present. The other test blocks were merely submerged in the test liquid in an open container. It has been found that by applying compressional energy of less than 0.01 foot pound per square inch of cross-section of the treating cylinder **8** at frequencies of approximately 120 c.p.s. and less in substantially steep fronted shock waves, the penetration of various species of wood is increased from 200 to 300 percent in 1/60 of the treating time.

Proceeding next to FIGURE 4 there is illustrated a dip-treating tank modified for the treating of wood by the method disclosed herein.

In FIGURE 4, the dip-treating tank **30** is filled with treating liquid **31** which completely surrounds the wood **32** which is being treated and which may be supported in a metal basket **33**. A lid **34** is provided for the tank and is in direct contact with the treating solution **31**. An auxiliary or under-structure **35** for the lid **34** is provided to mechanically meet the upper limit of the treating solution **31** and thus provide for an air-free container. The lid **34** is supported at the supports **36** and is capable of limited vertical movement within the channels **37**. The lid **34** is relatively loose fitting and thereby permits escape of air around its edges when the tank is filled with treating liquid. Anti-splash lids **38** are provided so that solution escaping around the edges of the lid is not lost. The anti-splash lids may be folded back when not in use to the positions indicated by the dotted lines **39**.

A reservoir **40** is provided for the treating solution which flows through a valve line **41** to a float chamber **42**. The float chamber has a valve **43** controlled by float **44** and communicates with the treating tank to supply line **45**. The float chamber functions to keep the treating chamber filled with the solution and to keep air bubbles completely flushed out. When the level of the solution within the treating tank lowers because of the treating solution impregnating the wood, the float **44** lowers and opens the valve **43** to admit additional solution into the tank from the reservoir **40**.

An over-flow line **46** having a valve **47** therein drains into a storage reservoir **48** with the valve being closed when the tank is not in use.

In addition there is a drain line **49** having valve **50** therein which is open only when the tank is being drained into the storage reservoir **48**.

A vibrator **51** or other source of compressional wave energy having a steep wave front configuration is mounted directly to the tank or may be connected to the tank by a rod or other device **52** to transmit the vibrational energy to the tank and to the treating solution.

If desired the source of vibrations may also be positioned within the treating solution.

Suitable equipment for the removal of air and filling of the tank such as described above in connection with FIGURE 3 may be provided as desired and a supplementary to the steps involved in the present process.

In FIGURE 6 there is illustrated a post, pole, pile or

timber which has been treated with a preservative at its exterior **53**, but which has developed decay in the interior untreated portion such as shown at **54**. In this process, a long open ended probe or needle **55** is driven into the center of the wood and attached to a resonating solution chamber **56**. A surplus liquid reservoir **57** is connected to a source of pressure **58**, such as a pump, spring loaded mechanism and the like, which supplies a treating solution **59** to the wood **54** through a tube **60** and the resonating chamber **56** and probe **55**. A source of steep wave front vibrational energy in the sonic range indicated at **61** may be applied in direct contact with the resonating chamber **56** or connected by a rod or other acoustic transmitting means such as **62**. In place of driving a long narrow needle or probe into the wood, a hole may be drilled into the wood to the desired depth and a short pipe screwed into the wood. A tapered screw thread facilitates this procedure. The elevated pressure supplied to the treating fluid by the pump **58** may be replaced by gravity feed of the treating liquid. However, when this is done, there are some energy losses through the solution to the reservoir.

In FIGURE 7 there is shown a utility pole **63** which has been previously treated but which has lost much of its preservative near the ground line and may be in danger of decay which could rapidly progress to the untreated interior at **64**. A modified arrangement, somewhat similar to that of FIGURE 6, may be employed and includes expander rings **65** which encircle the poles and secure a resonating chamber **66** thereto. The treating liquid flows from a reservoir **67** to pressure source **68** which delivers a solution **69** through a connecting pipe **70** to the resonating chamber **66**. A vibrator **71** is provided as a source of vibratory waveform energy and the energy is transmitted to the resonating chamber through a connecting link **72**.

Thus it can be seen that the present invention has disclosed a novel and effective process for the rapid and thorough impregnation of wood with a treating solution. For purposes of comparison the present process is a decided improvement over existing pressure treating of wood since the present process applies steep fronted waveform vibrational energy to the treating liquid within the tank and the tank is completely filled with the wood and treating liquid so that there is no residual air within the tank. It can be readily appreciated that the frequency and amplitude of vibratory energy applied to the wood under treatment may vary considerably depending on the particular conditions involved. However the results of the present invention of significantly more rapid and thorough impregnation of wood will always be obtained when the waveform of the vibratory energy is steep fronted and the system is completely filled with treating liquid.

What is claimed is:

1. In the method of impregnating wood with a treating liquid, the steps of immersing an article of wood in a container of treating liquid as an impregnant, closing the container and completely filling the closed container with the treating liquid to exclude all residual air from the closed container so that the only air within the closed container is the air embedded within the wood, and applying saw-tooth waveform vibrations to the liquid within the closed container to increase the penetration of the wood by the treating liquid, the vibrations having a maximum frequency of 750 c.p.s. with the energy waveforms of the vibrations being shock waves having a steep wave front and relatively longer decay time.

2. In the method as claimed in claim **1** with the additional step of applying pressure to the liquid within the closed container to increase its presence above atmospheric pressure.

3. In the method as claimed in claim **2** with the pressure being up to 200 p.s.i. above atmospheric pressure.

4. In the method as claimed in claim **1** with the additional step of removing from the closed container the air which is released from the wood during the impregnating of the wood by the treating liquid.

5. In the method as claimed in claim **4** with the air being removed periodically from the closed container.

6. In the method as claimed in claim **4** with the air being removed continuously from the closed container.

7. In the method as claimed in claim **1** with the additional step of introducing treating liquid into the closed container to replace the liquid penetrating into the wood.

8. In the method as claimed in claim **1** with the frequency being of the order of 120 c.p.s. and each wave having about 0.01 foot pounds of energy per square inch of container cross section.

9. In the method as claimed in claim **1** with the decay portion of the waveform being at least twice as long as the wave front.

10. In the method of impregnating wood with a treating liquid, the steps of introducing a hollow open ended probe connected to a supply of impregnating liquid into the wood, and applying saw-tooth waveform vibrations to the supply of impregnating liquid to increase the penetration of the wood by the liquid, the vibrations having a maximum frequency of 750 c.p.s. with the waveform of the vibrations having a steep wave front and a relatively longer decay time.

11. In the method of impregnating wood with a treating liquid, the steps of bringing an article of wood into contact with impregnating liquid within a closed container, completely filling the closed container with the liquid to exclude all residual air from the closed container so that the only air within the closed container is the air embedded within the wood, and applying saw-tooth waveform vibrations to the liquid within the closed container to increase the penetration of the wood by the liquid, the vibrations having a maximum frequency of 750 c.p.s. with the waveform of the vibrations having a steep wave front and relatively longer decay time.

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U.S. Cl. X.R.

117—120