

Nov. 11, 1958

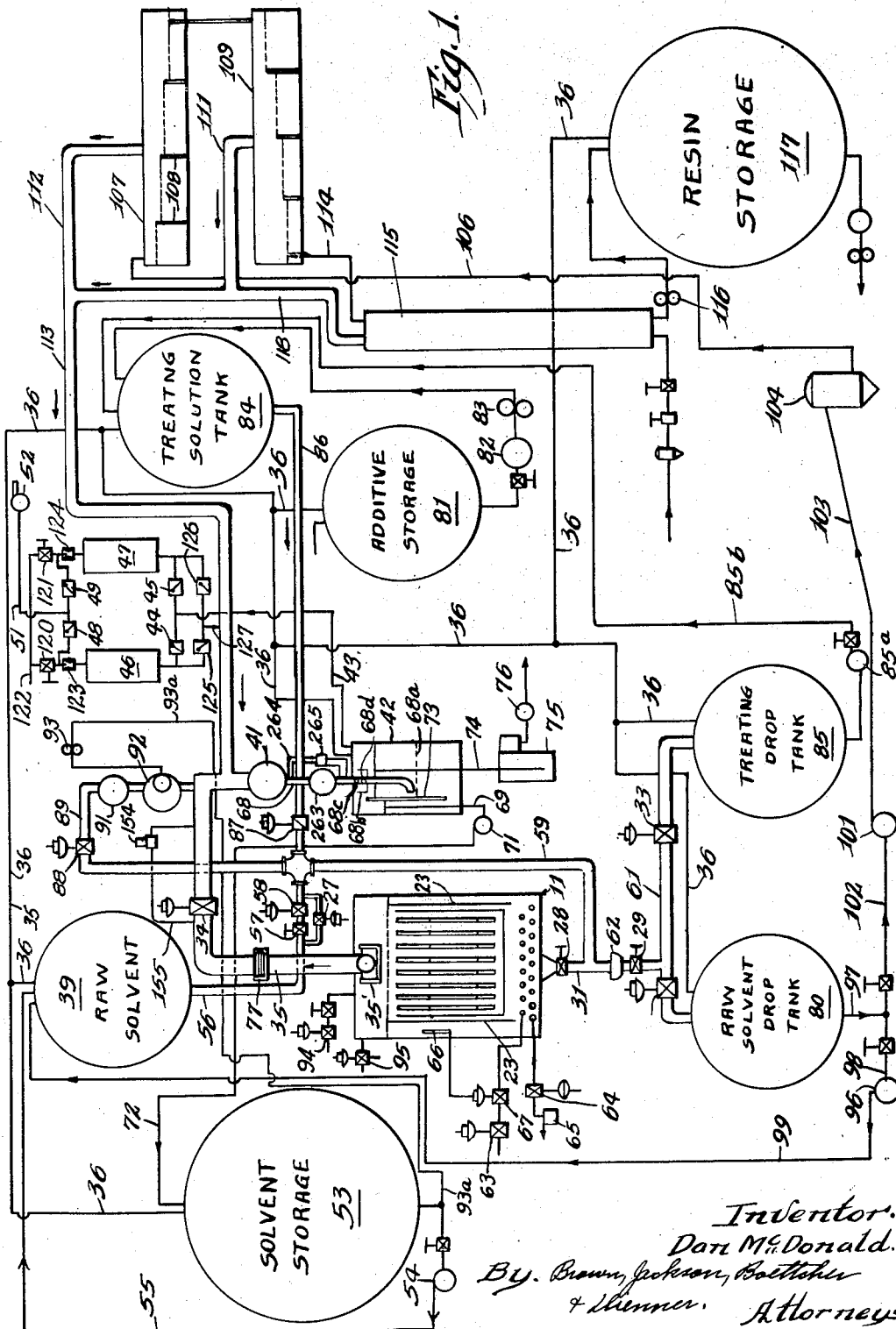
D. McDONALD

2,860,070

METHOD OF DRYING AND IMPREGNATING WOOD

Filed June 4, 1954

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Nov. 11, 1958

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METHOD OF DRYING AND IMPREGNATING WOOD

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6 Sheets-Sheet 2

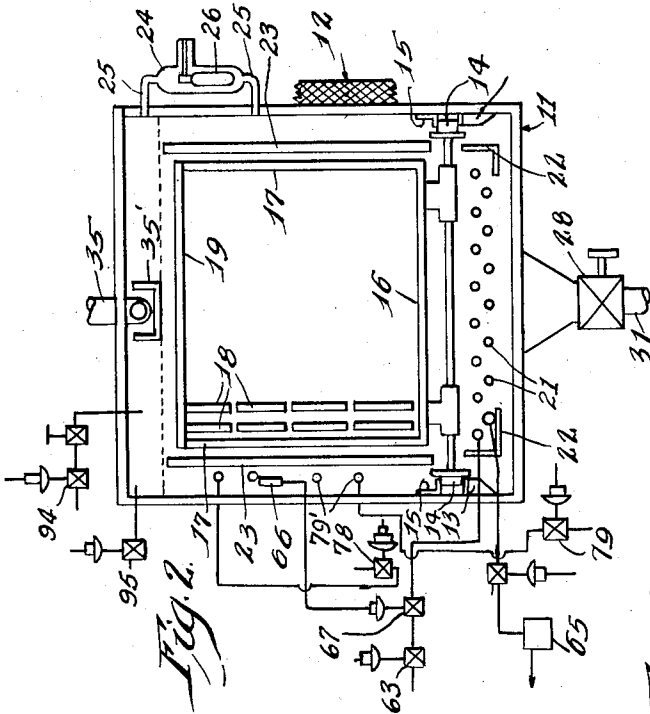


Fig. 2

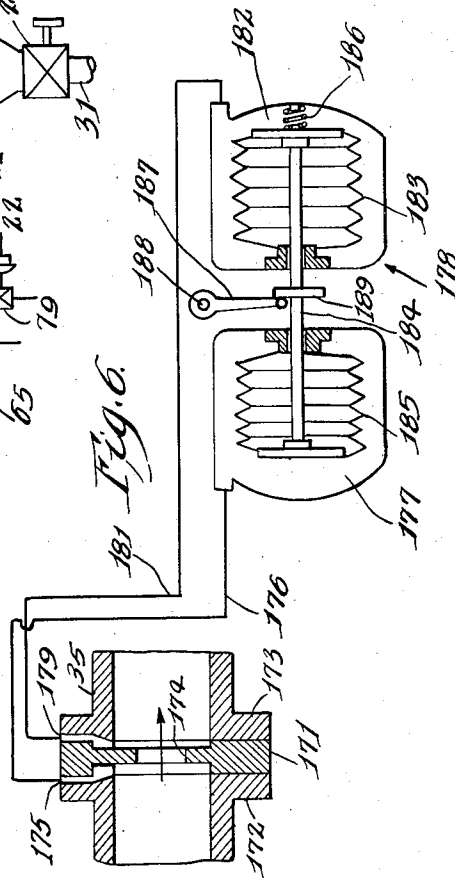


Fig. 6

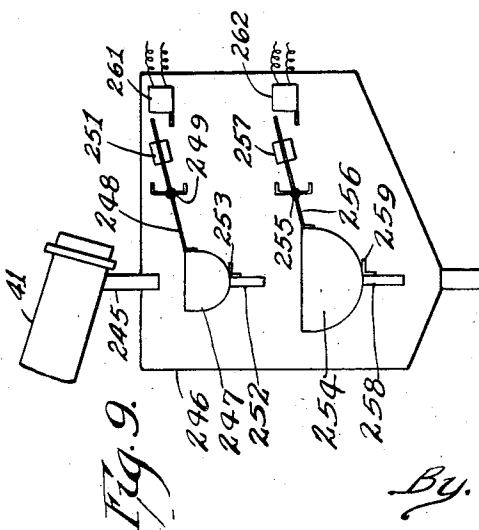


Fig. 9

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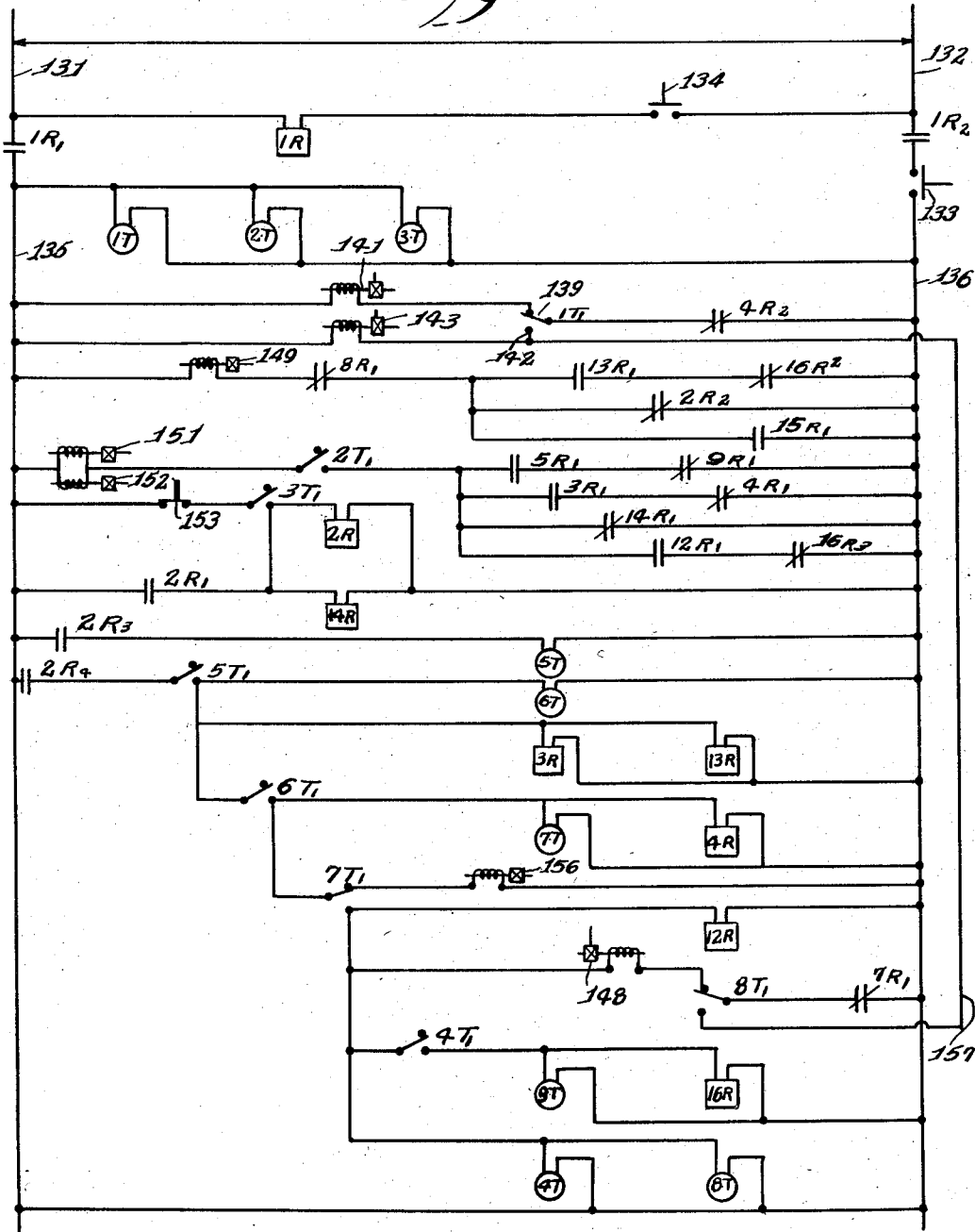
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METHOD OF DRYING AND IMPREGNATING WOOD

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Fig. 3.



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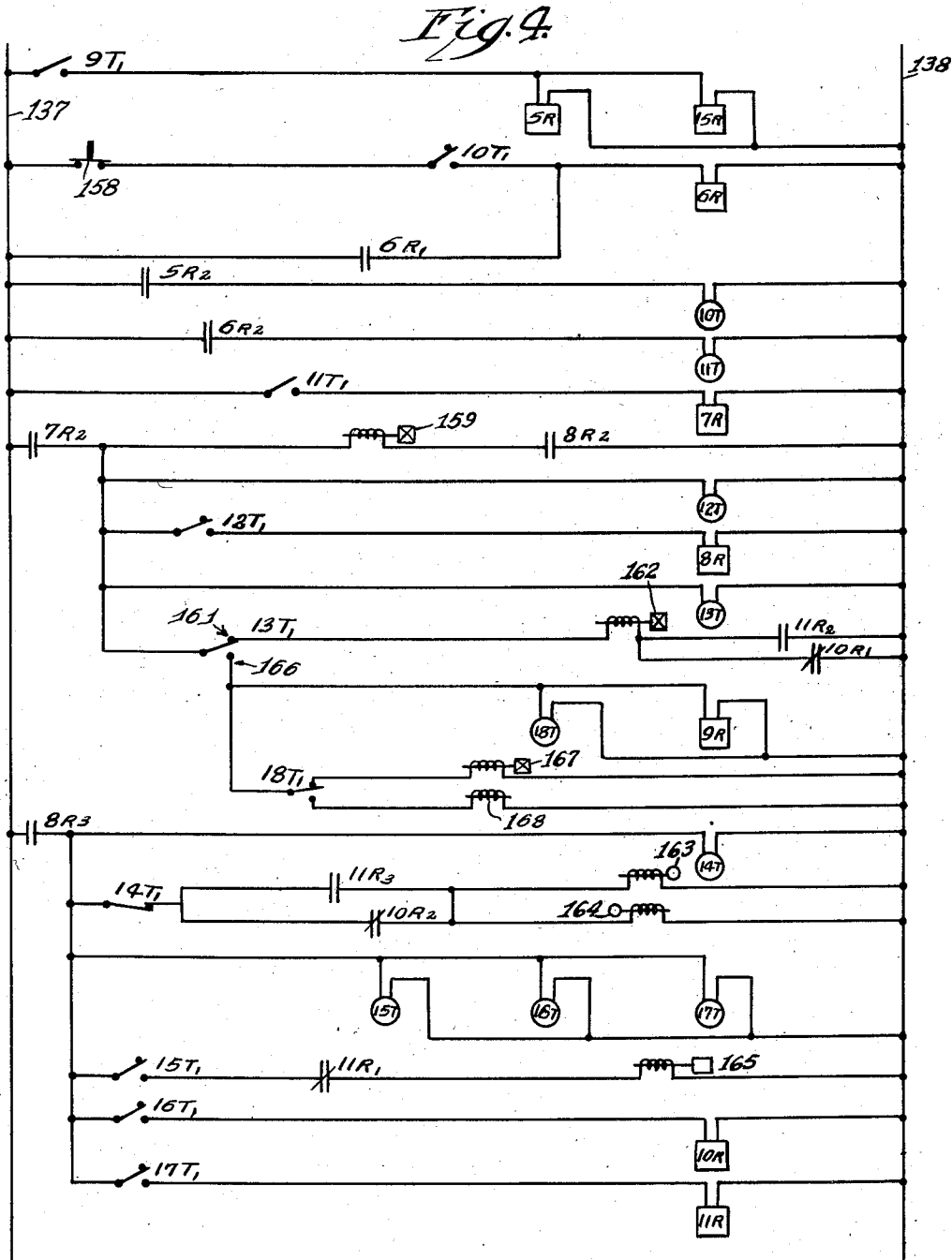
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METHOD OF DRYING AND IMPREGNATING WOOD

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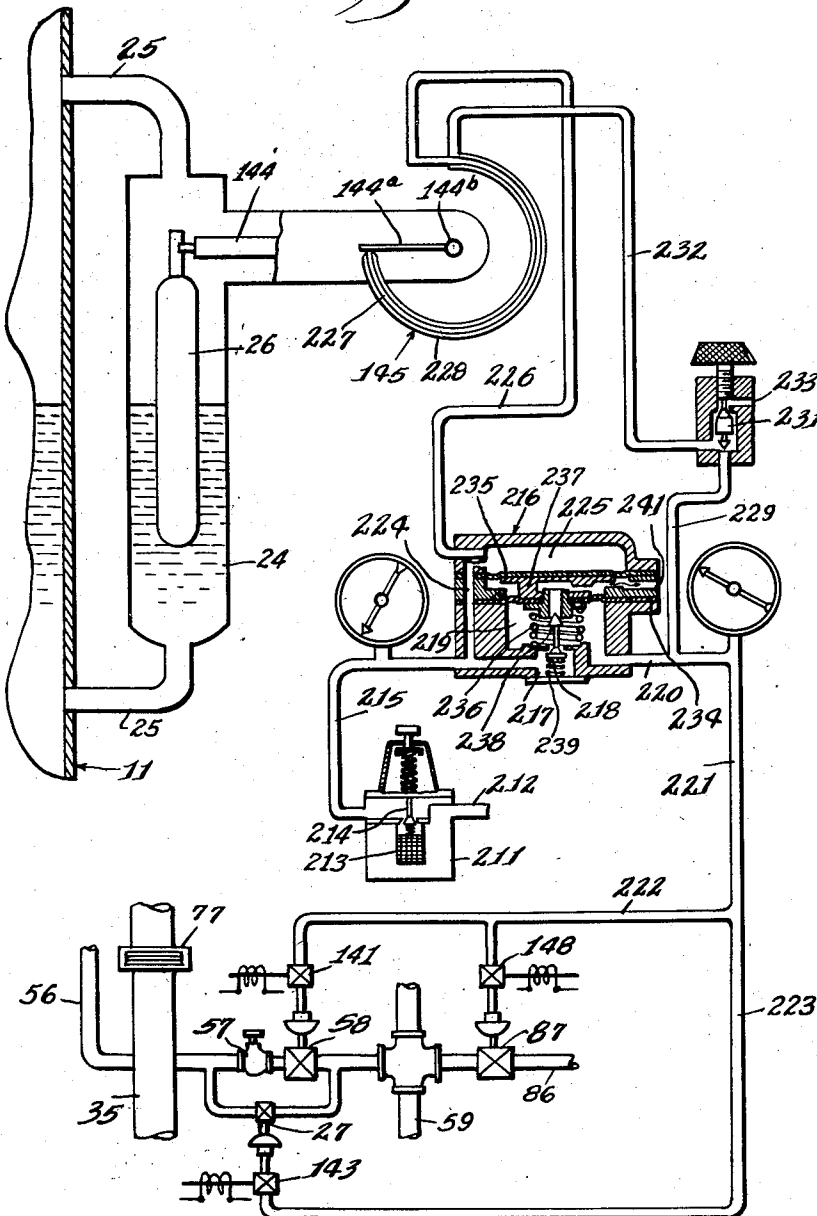
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METHOD OF DRYING AND IMPREGNATING WOOD

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Fig. 5.



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2,860,070

METHOD OF DRYING AND IMPREGNATING WOOD

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Application June 4, 1954, Serial No. 434,390

4 Claims. (Cl. 117—59)

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This invention relates to the treatment of wood with the aid of solvents for removal of moisture, resins and other extractives therefrom, and for otherwise treating the wood.

As heretofore commercially practiced, the most commonly used methods of drying wood have been air drying, that is, ordinary seasoning in air and kiln drying. In addition to drying, other known treatments for wood have included impregnation with materials adapted to protect the wood against decay and attack by insects.

The above mentioned conventional drying methods, even when carefully operated, are recognized generally in the industry as being far from satisfactory because such methods either induce or do not protect the wood from the harmful effects of checking, warping, cupping and mold growth both during and after drying. Another serious and costly disadvantage is the large amount of time such conventional drying processes require. Other defects, well known to the industry, need not be recited here but may be alluded to later during the ensuing description of this invention. However, all such defects have caused serious losses to the lumber industry and have involved for decades constant searching for better drying and wood preserving methods.

A considerable proportion of the wood handled by the lumber industry contains resins, gums and terpenes, which not only are not removed by the prior conventional drying processes, but are often oxidized and changed in composition.

During the aforementioned constant search by the industry for better methods, the possibility of using solvents or other liquids and vapors for various treatments of wood has been considered by prior inventors. Nevertheless, according to available information, their efforts have met with no success or have resulted at best in only limited and partial benefit to the wood, where beneficial at all. Evidence of such prior efforts can be found among such U. S. Letters Patent and publications as Nelson, 937,008, issued October 12, 1909;

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Besemfelder, 1,059,820, issued April 22, 1913; Hollerer, 2,137,404, issued November 22, 1938; Helson 2,216,775, issued October 8, 1940; Anderson, 2,500,783, issued March 14, 1950; Barksdale, 2,507,190, issued May 9, 1950; and Report R1665 of U. S. Forest Products Laboratory at Madison, Wisconsin, dated February 1947.

My invention, as will presently appear, involves principles and techniques in the use of solvents wholly novel, and markedly different from the teachings of said patents and publications, and productive of numerous advantages and results incapable of attainment by the procedures taught in said patents and publications.

My invention involves the use of non-flammable water immiscible solvents in liquid form in drying processes which may be applied to fresh cut green wood, sawed or unsawed, and to wood not freshly cut but in need of drying, and for other treatments for improving the wood and conditioning it for various ultimate uses.

In accordance with my invention, the wood to be treated is immersed in a liquid solvent bath, and while the bath is maintained at an elevated temperature, moisture is removed from the wood and, if the wood be resinous or contains other solvent soluble extractives the resins and other extractives may also be extracted. While moisture and other extractives are being removed, the wood is being improved and conditioned by the solvent in a novel manner in various important respects and is especially conditioned for other subsequent treatments including impregnation and coating by preservatives and other additives of various types.

Wood dried in accordance with this invention, even if not further treated, is different from and superior to wood dried by any other commercial methods known heretofore, as has been convincingly demonstrated by various tests. For example, the harmful effects of checking, splitting, cupping, twisting, case hardening, explosion or collapsing of the cellular structure, and harmful stresses of various kinds inherent in the wood originally and which to some extent invariably or at least frequently develop from other drying methods, are either eliminated or greatly diminished in the practice of this invention.

Wood dried in accordance with this invention and subjected simultaneously to solvent extraction, is better conditioned to absorb uniformly various impregnating and coating materials, as will more readily appear hereinafter.

Another advantage arising from the practice of my invention is that dimensional stability of the wood, long recognized in the industry as a desideratum, is achieved to an unusually high degree both during and subsequent to the drying operation.

The general object of the invention is to provide improved processes for drying, conditioning, and treating wood.

A particular object is to provide a new process and procedure for drying wood while immersed in a liquid solvent bath.

Another object is to provide a new process in which moisture removal and resin removal from the wood may be accomplished in the same apparatus concurrently or in steps.

Another important object is to provide methods and apparatus for controlling the process steps and operations automatically.

Another object is to provide a process in which a liquid solvent bath is employed for drying wood and the same solvent is used as a carrier for impregnating material.

Another object of the invention is to provide a new process and apparatus in which resin extraction may be

coordinated in various ways with moisture removal and with impregnation.

Another object is to provide a process for drying wood more rapidly than has been customary heretofore and under controlled conditions which prevent damage to the wood.

Another object is to utilize a liquid solvent bath in drying of wood whereby the vaporization of moisture as an azeotrope vapor from the wood may be effected at a selected temperature, dependent upon the pressure and the solvent employed, which will be substantially below the boiling point of water at such selected pressure.

Other objects of the invention not yet mentioned may be alluded to hereinafter as may be observed and appreciated after perusal of this specification.

In the drawings, to illustrate the nature of the invention, apparatus of preferred form is shown for use in practicing certain preferred methods included within the invention, although I do not thereby intend to limit the scope of my invention either to the details of construction of such apparatus nor to the precise methods described.

Figure 1 is a schematic flow diagram in which the apparatus indicated is shown not according to a uniform dimensional scale nor necessarily in preferred relative positions, but rather in such a compact arrangement as lends itself to a single figure flow diagram.

Figure 2 is a cross sectional view on an enlarged scale of the retort shown in Fig. 1.

Figure 3 is a schematic drawing of part of the electrical control circuit forming a portion of the invention.

Figure 4 is a schematic drawing of the remainder of the electrical control circuit.

Figure 5 is a schematic illustration of a liquid level control system forming a part of the invention.

Figure 6 is a diagrammatic illustration of an orifice device and flow meter employed in the invention.

Figure 7 is a diagrammatic illustration of a switch mechanism associated with the flow meter.

Figure 8 is a diagrammatic illustration of the same switch mechanism in another position.

Figure 9 is a schematic illustration of an alternative apparatus, which may be substituted for the apparatus of Figs. 6, 7 and 8.

The equipment shown in the flow diagram of Fig. 1 is adapted for use in drying of woods which are difficult to dry or easy to dry, for drying woods having high, low or no resin content, and for impregnating any of these woods with additives, such as those which retard or prevent moisture re-absorption, those which prevent mold, those which protect the wood against attack by termites and insects, and other additives which may improve the hardness, strength, finish or general appearance of the wood or impart to it any other useful characteristics.

However, to bring into the description of a single process the use of all the equipment shown, I shall first describe the drying of typical southern yellow pine, having a high resin content, and its subsequent impregnation with linseed oil, to retard subsequent re-absorption of moisture.

The apparatus

The retort, generally indicated as 11, is a tank of any desired dimensions and shape, formed of steel or other suitable materials having closed sides, top and bottom and preferably encased in a suitable layer of insulation 12. In view of the pressure to which it may be subjected, both above and below atmospheric, it should be suitably constructed and braced. A pair of rails 13 extending longitudinally within the retort constitute a track for the wheels 14 of lumber bearing cars. This track will be aligned with conventional track rails outside the retort, as is customary in connection with lumber kilns and a tightly sealable door, not shown, may

be provided at either or both ends of the retort for admitting and discharging the loaded cars and sealing the retort before it is filled with solvent. When the car or cars are at rest in the retort their wheels will be underneath hold-down flanges 15 secured to the retort walls, which prevent the lumber-laden car from floating upwardly when immersed in the solvent.

The details of construction of the cars are subject to wide variation, but in general should include a floor 16 which should have numerous perforations or passages to permit free flow therethrough of solvent, and side walls 17 which should likewise be perforated or which may be largely open frames. The lumber should be stacked in such a manner as to facilitate its uniform treatment by the solvent. One appropriate method is indicated, wherein boards 18, for example, preferably of uniform thickness and of the same species, are shown stacked longitudinally on edge and are uniformly spaced by vertically extending spacers or "stickers," not shown, to allow the heated solvent as it rises to contact opposite vertical faces of each of the boards as uniformly as is practicable. Suitable means such as bars 19 detachably secured to the car side walls and extending across the top of the stacked lumber may be used to prevent the boards from floating out of the stacked load. The stickers preferably are suspended from the bars 19 to hang vertically therefrom, and preferably are rust proof metal tubes of cylindrical shape so that they will have merely line contact with the boards.

Preferably, bundles of heating coils 21 utilizing steam, for example, as a heating medium, will be placed between the angular baffles 22, which are suitably fixed in the retort for heating the solvent and causing it to rise in convection currents through the stacked lumber to overflow the lateral vertical imperforate baffles 23 which are suitably mounted in the retort. The solvent overflowing baffles 23 will return outside of the baffles 23 downwardly and around underneath and upwardly between baffles 22 to the heating coils for re-heating. Positive circulating means may be added where needed. It has been observed that vapor bubbles emerging from the wood and rising with the solvent aid the circulation of the solvent.

The position of the liquid level control mechanism shown diagrammatically in Fig. 5 is indicated in Fig. 2 in part by a casing 24, which communicates with the interior of the retort 11 below and above the liquid level therein by pipes 25 and contains a hollow float element 26. This float and associated mechanism, shown in Fig. 5 and hereinafter described in detail, cooperate with other liquid supply valves, as explained later, but especially control a by-pass throttling valve 27 (Figs. 1 and 5) to maintain a liquid level in the retort sufficient to completely submerge the wood and overflow the tops of baffles 23. Valve 27 is smaller than the other valves which are employed to supply solvent to the retort. Other suitable liquid level control means may be employed, if desired.

In a wood treating plant of commercial size, the valve 27 and various other valves described as automatically operated should, because of their large sizes, be operated by some appropriate source of power, compressed air, for example, in which case the auxiliary valving for supplying and regulating the air to actuate such large valves may be electrically controlled, as by solenoids, for example, responsive to thermostatically controlled or pressure controlled or time controlled relays or other appropriate mechanisms.

The automatic operation of these valves and other controls in proper sequences will be described hereinafter in connection with the electrical circuits of Figs. 3 and 4 and the schematic diagram in Fig. 5. For conciseness and clarity, the functions of the valves and other apparatus will now be described without explaining here

the electrical and pneumatic circuits by which they are actuated.

Drying

Assume that one or more carloads of southern yellow pine boards are stacked and run into the retort 11 and the door or doors thereof have been closed tightly to seal them. Assume also that the solvent to be used is the chlorinated hydrocarbon, perchlorethylene, having a boiling point of about 250° F. and a water-solvent azeotrope point of about 190° F. at atmospheric pressure. Hand valves 28 and 29 in pipe 31 will be open, power operated valves 32 and 33 will be closed, power operated valve 34 in vapor line 35 will be opened and as solvent flows into the retort the air will be displaced therefrom through line 35, through a condenser (later described as 41) in part into a system of pressure equalizer lines consisting of interconnected pipes 36. Some of the air will flow into the raw solvent tank 39 from which solvent is flowing. All of the displaced air initially flows into condenser 41, which may be a conventional water cooled surface condenser, and some of it flows thereafter through the gravity separator 42 (later described), vapor line 43, through one or both check valves 44 and 45, one or both carbon absorbers 46 and 47, one or both check valves 48 and 49, line 51 and exhaust blower 52 to atmosphere.

Solvent for the operation is originally supplied to tank 39 from storage tank 53 by means of pump 54 and line 55. To supply the retort from the tank 39 the solvent may be allowed to flow by gravity through pipe 56 through the normally open hand valve 57, the now open power operated valve 58, pipe 59, entering pipe 31 above strainer 62, thence into the retort. When the retort is filled to or nearly to the desired level, the large flow capacity valve 58 will be closed ordinarily by a timer mechanism or by the liquid level control system shown in Fig. 5. The liquid level controlled throttling valve 27 having a much smaller flow capacity is called upon after the timer mechanism, later described, has closed valve 58. The throttling valve supplies solvent to establish and or maintain the liquid level high enough to overflow baffles 23 and keep the lumber entirely submerged and to add liquid solvent to the retort as solvent is absorbed into the wood and is also evacuated from the retort in vaporous form.

Meanwhile, or shortly thereafter, power operated steam valve 63 is opened to supply steam to the heating coils 21 in the bottom of the retort, and power operated condensate valve 64 is likewise opened, allowing steam condensate to escape through a conventional or suitable condensate trap 65.

Too rapid application of heat to the fresh load of lumber should be avoided, hence that hazard is minimized if the solvent as it enters the retort and contacts the lumber be at a temperature well below its azeotrope boiling point. It is desirable that the entire load be heated gradually and uniformly and the rate of evaporation of moisture from the wood be moderate enough to avoid harmful checking of the surfaces, as would occur if drying were too rapid.

Suitable thermostatic control equipment symbolized by the thermostatic element 66 and steam valve 67 which it controls, may be relied upon to control the steam supply to bring the body of the solvent eventually up to a desired temperature range between the azeotrope boiling point and the solvent boiling point, at the existing pressure.

As this drying step begins, azeotrope vapor forms both at the outer surface of the wood and interiorly wherever the penetrating solvent contacts water or water vapor, and where sufficient latent heat is supplied at such points to cause the azeotrope vapor to evolve. The evolved azeotrope vapor rises into the vapor space within the retort above the level of the solvent and is evacuated through pipe 35 connected to the vapor trough 35' which

extends longitudinally and centrally of the retort. Any condensate forming in the trough may be returned to the liquid body in the retort by appropriate drain means, not shown. Pipe 35 delivers the vapor into condenser 41, where substantially all of the azeotrope vapor is condensed. The condensate flows through pipe 68 into gravity separator 42, wherein the heavier perchlorethylene separates from the water and is withdrawn by pipe 69, and pump 71, and delivered by pipe 72 to solvent storage tank 53. The separated water may be withdrawn from the opposite side of the separator baffle 73 through pipe 74 into a seal tank 75 and thence through a water meter 76 to drain. Thus the amount of water evaporated from a load of wood of known volume or weight, i. e., 15 board feet or pounds, may be measured for various information purposes.

As shown in Fig. 1, the lower open end of pipe 68 is curved to avoid delivering the condensate vertically downwardly, and terminates at or above the interface level 20 68a between the separated solvent and water. Above the maximum water level, determined by the overflow pipe 74, the pipe 68 has affixed thereon and sealed thereto a trough 68b, open at the top. Just above the floor of the trough is a series of holes such as 68d and above them another series of holes 68c. Vapors accompanying the condensate will escape through the upper holes, while any condensate escaping therewith will immediately drain back into pipe 68 through holes 68d.

As some of the solvent may not be condensed in 41, and air and other gases expelled from the wood may accompany solvent vapor into separator 42, the carbon absorber system associated therewith and with the exhaust fan 52 will evacuate these gases and vapors from the separator 42, absorb the solvent vapor and discharge the air and other non-condensibles to the atmosphere without wasting any appreciable amount of solvent. Hence the solvent cost of the process is one of initial investment and not a continuing or recurring new expense of any substantial amount.

The combined effect of the condenser 41, absorber 46 or 47, and the exhaust blower 52 is to lower the pressure in the retort 11 slightly below atmospheric pressure. This reduced pressure serves to prevent leakage of solvent vapors to the atmosphere should leaks inadvertently develop in the solvent vapor lines. If it be desired to lower the retort internal pressure even more and thus reduce the azeotrope boiling point, suitable expedients may be employed therefor such, for example, as inserting a suitable vacuum pump between the condenser 41 and the separator 42. This expedient will be described later.

As the operating example now being described involves typical southern yellow pine having a substantial resin content, while the drying operation is proceeding, some resin is also being dissolved into the solvent, which, at the elevated temperatures existing, has a high solvent capacity for the natural wood resins, terpenes, gums, pitch and other similar extractibles which, for the sake of brevity, are herein referred to merely as resins.

To satisfy many commercial requirements it will be desirable to solvent extract the bulk of the resins from the wood while the wood is being dried. For other requirements it may be satisfactory merely to re-distribute the resins from localized concentrations of the same to a more uniform dispersion throughout the wood. Resin extraction by means of this invention causes knots to become tightened rather than loosened, which latter fault is characteristic of kiln drying. Resin extraction of the wood improves it for painting and eliminates the bleeding of pitch through the paint. When the resins are extracted from such woods glue retention is also improved.

In the lumber industry it is considered that water present in wood exists largely in two forms or conditions. The greater part, termed "free water," exists between or outside of the cells, while a lesser part designated as

"combined" water is believed to be combined physically, if not chemically, in the cell structure. Many green woods contain as much as 100% moisture, that is, the weight of the moisture is equal to the bone-dry weight of the wood. Other green woods have as much as 300% moisture. The free water evaporates more readily and rapidly than the combined water and when all of the free water has been removed, the remainder, usually about 25%, which is known in the industry as the "critical moisture content," evaporates more slowly.

Soaking

While it is possible to dry non-resinous and resinous woods down to a final specified moisture content of 7-12% moisture in a single continuous drying step, without soaking, in general the drying will be improved and shortened and the resin extraction and/or dispersion made more thorough in the case of resinous woods, if the drying procedure be interrupted by one or more soaking periods. When soaking is employed the soaking may be conducted at various intervals in the drying cycle, but most advantageously after the moisture content has been reduced to 50% or less.

In operating in accordance with my invention, the rate of moisture evaporation from the wood at a given period in the process is an ascertainable factor on which certain controls of the process may be and desirably are based. During the early evaporation of moisture, largely free moisture, which is evacuated in the azeotrope vapor, the evolution of this vapor, consisting of 5.3 parts of perchlorethylene to 1 part of water, is very rapid, and continues at a high rate until the free moisture has been largely removed. However, as the critical moisture content is approached, the volume of azeotrope vapor evolved per unit of time drops off sharply. This stage in the process constitutes a very favorable time to initiate the first soaking period, although I sometimes find it advantageous to anticipate this period, that is, before the remaining moisture content has reached the critical moisture content.

At whatever be the selected instant the rate of vapor flow is in a measurable proportion to the instant moisture content and by means of the vapor flow measuring apparatus hereinafter described in detail I may select that instant and interrupt the drying process by stopping the evolution of azeotrope vapor, and cause solvent to penetrate the wood to facilitate further drying and, in the case of a resinous wood, facilitate the solvent extraction of the resins.

Thus, when the initial drying period has continued long enough to lower the moisture content of the wood to a desired range which may, if desired, be at some point between 25 and 50% or higher, the rate of flow of azeotrope vapor through the orifice plate device in line 35, generally indicated as 77, will be utilized to effect the actuation of the apparatus shown in Figs. 6 and 7 and initiate any one or more of several procedures, as may be desired, to condense vapors then within the wood and allow the solvent to penetrate the wood more readily and deeply. This penetration step is herein termed "soaking."

In one procedure the solvent bath may be cooled to at least several degrees below the azeotrope boiling point 190° F., which will cool the wood and cause the desired condensation of vapors therein, inducing a lower pressure in the wood. To do this, steam supply valve 63 and condensate outlet valve 64 will be closed, and power-operated water supply valve 78 and power-operated water outlet valve 79 may be opened, enabling cold water to flow through the cooling coils 79', thus cooling the solvent bath to below 190° F. When it is deemed that the solvent has sufficiently penetrated the wood the foregoing mentioned valves will be re-operated to cut off the cold water and restore the steam supply, raising the solvent bath temperature high enough to cause the evolution of azeotrope vapor to resume.

As a variation of the preceding cooling method I may withdraw some or all of the hot solvent bath and replace it in equivalent amount with another solvent bath having a low enough temperature to offset the residual heat in the wood and apparatus, and to cause condensation of the vapors in the wood. It should now be apparent that the above two cooling methods may be combined if desired.

A further alternative procedure for condensing vapors in the wood is to raise the pressure in the retort high enough to effect the desired vapor condensation. This has an advantage over the cooling method in that vapor condensation may be accomplished faster merely by closing valve 34 and injecting steam at 15 to 25 pounds' pressure, for example, into the retort, hence only a few minutes is required.

A still further alternative procedure, which will be referred to later in connection with, and which is provided for in, the circuit diagrams, involves closing the vapor outlet valve 34 when it is desired to soak, cutting off the supply of steam to coils 21, if desired, and allowing the azeotrope vapor retained and accumulating in the retort to become superheated by the residual heat in the solvent and the retort. The action of the absorber and condenser normally maintains a slight suction on the retort, but with the vapor valve 34 closed a pressure builds up in the retort sufficient to compress the vapors in the wood and cause the solvent to penetrate the wood. If desired the equipment may be arranged to leave the steam supply on during the soaking period.

Drying after soaking

After soaking the wood a desired length of time, which may, for example, be about one-half hour or somewhat less for soaking pine lumber one inch in thickness, and proportionately longer for thicker lumber, the vapor valve 34 may be re-opened and the heating steam turned on again, whereupon the lumber resumes evolving azeotrope vapor and continues to do so until the moisture content is further reduced to a desired extent, which in many instances may be as low as 7 to 10% moisture if the wood is not to be impregnated.

When the moisture content is reduced to the desired level, the solvent will be drained from the retort through normally open valves 28, 29, strainer 62 and power-operated valve 32 to drop tank 80, while valve 33 is kept closed. This solvent will contain most of the gums, resins and terpenes originally contained in the wood.

If the wood is to be impregnated with an additive, the foregoing moisture evaporation should be terminated preferably at about 15 to 25% residual moisture content.

Treating

The next step is treat the lumber in another bath of solvent, preferably more of the same solvent, but containing an appropriate impregnating material. One such material is boiled linseed oil, which is soluble in the halogenated hydrocarbons. When the yellow pine becomes impregnated with such oil to the extent of about eight pounds of oil per thousand board feet, and is later exposed to moisture, re-absorption of moisture is greatly reduced or largely eliminated, the lumber mill will remain dimensionally stable and is improved for machining and other wood working techniques. More or less oil and other oils may be used. Also, insect and termite repelling chemicals, fungicides, mold preventatives, various water repellants, dyes and other chemicals, including plastics, also soluble in the solvent, may be substituted for the linseed oil or used in addition thereto and simultaneously. All of these additives are intended to be referred to herein by the term "wood preservatives" and preferably should have boiling points higher than the azeotrope boiling points and preferably higher than the solvent boiling point, and should not form ternary azeotropes with the solvent and water.

One or more additive storage tanks such as 81 may

be provided and the liquid material contained therein may be metered through a conventional liquid flow meter 82 while being delivered by pump 83 into the treating solution tank 84 where it becomes dissolved in a body of the solvent contained therein and delivered thereto by any appropriate means, for example, from the drop tank 85 by pump 85a and line 85b. If the tank 84 contains pure solvent a desired relative proportion of additive will be metered and pumped into it. If the solution in tank 84 has previously been used for treating lumber and its former additive ingredients thereby diminished they may be replaced from the tank 81. The additives must be soluble in the solvent, have higher boiling points than the solvent and not be of a character to form ternary azeotropes with the water and solvent.

To treat the lumber with a solvent solution containing one or more of additives of the character above described, the treating solution is conducted from tank 84 through pipe 86, power-operated valve 87, pipes 59 and 31 into retort 11, filling the retort high enough to submerge the load of wood. Preferably during the foregoing described draining and refilling of the retort the steam supply to the heating coils 21 will be cut off, but will be turned on again when the retort is refilled.

Hence, with the retort filled with the treating solution and steam in the coils the wood is re-heated in this bath by the solution, which may be heated to a temperature range of about 210° to 245° F. During the relatively short heating period which follows, some of the remaining moisture in the wood begins to emerge therefrom as part of the azeotrope vapor, hence the vapor valve 34 is held open to allow such vapor to flow to the condenser and carbon adsorber system. As solvent thus escapes from the retort in the azeotrope vapor the throttling valve 27 should be open during this period to supply make-up solvent to keep the wood wholly submerged. Before the remaining moisture in the wood is reduced to the final desired or specified moisture content the valve 34 will be closed, as well as other valves necessary to seal the retort and the pressure is allowed to build up therein again as before explained, to condense the vapors in the wood and to cause the bath liquid to penetrate the wood, this time, however, carrying the treating additive material into the wood along with the solvent.

When sufficient penetration has been attained, valve 34 will be re-opened and further evaporation of moisture will occur, accompanied by evaporation of solvent from the interior of the wood as the azeotrope vapor is being evolved. This evaporation period is continued until nearly the final specified moisture content of the wood (7% to 12%, for example, or whatever may be specified) is attained. Thereupon the throttling valve 27 is closed and valves 33 and 88 are opened, dumping the entire liquid contents of the retort and pipe 59 into the treating drop tank 85.

When the retort is completely drained of treating solution valves 33 and 34 will be closed, sealing off the retort. Thereafter, valve 88 in line 89 will be opened to connect the bottom of the retort through pipes 31, 59 and 89 to a suitably cooled pre-cooler and pre-condenser 91 and wet vacuum pump 92. Liquid pump 93 will be started to supply a suitable seal liquid such as solvent from pipe 93a and tank 53 to the wet vacuum pump 92, this latter pump discharging directly to condenser 41.

When vacuum is being applied to the retort, the wood still retains a temperature in the neighborhood of 190° F. or higher, resulting from previous heating. The residual heat in the wood will supply the heat necessary for evaporating the azeotrope vapor formed by residual moisture and residual solvent in the wood. Enough vacuum should be applied to reduce the boiling point of the moisture and solvent far enough below the temperature of the wood so that said residual heat will be adequate.

The solvent vapors, then in the retort, are relatively heavy vapors hence are advantageously withdrawn from

the bottom of the retort and as they are drawn out by the vacuum pump and condensed a substantial sub-atmospheric pressure develops in the retort, lowering the azeotrope boiling point below 190° F. and effectively aiding the stripping of solvent from the wood.

The moisture still remaining in the wood aids greatly in the solvent stripping, while solvent remains to be stripped, hence prior to this time the wood should not be dried bone dry.

The evacuation of azeotrope and solvent vapors may be aided by admitting steam through valve 94 to help force the other vapors through the bottom of the retort. Additionally, as a further aid to solvent stripping and with some woods to add moisture to the wood to equalize stresses and prevent case hardening, the vacuum valve 88 may be closed for a time to enable steam pressure to build up in the retort. Whether or not such steam pressure is created, and usually it is advantageous to do so, a final vacuum will be pulled on the retort through opened valve 88, the stripping steam will be shut off and when the wood is stripped of solvent a vent valve 95 will be opened admitting air to restore atmospheric pressure to the interior of the retort so that the retort door may be opened.

Alternatively, when the retort has been drained and before treating solvent is added, in view of the fact that azeotrope vapor still remains within the hot wood, the mere introduction of treating solvent at a temperature substantially below the azeotrope boiling point will cause these vapors to condense in the wood and thus the treating solvent is drawn into the wood without the aid of especially created pressure. Under these circumstances the above mentioned short evaporation period, the closing of the vapor 34 and the subsequent development of pressure in the retort become unnecessary.

The use of one solvent bath for drying and a second bath for treating, as above described, constitute the proper procedure whenever the wood contains resins which could become dissolved into the solvent during drying. If, however, the wood being dried contains no resin, or other such extractives, and is to be treated with an impregnating additive, such additive may be incorporated in the original solvent bath at the start of the drying operation, as such a bath will not be contaminated by resins and may be re-used.

The wood, substantially free of resins, if it originally contained resins, and dried to the desired final moisture content and impregnated with the selected additive or additives may now be removed from the retort.

During the stripping action the solvent in the treating solution is removed from the interior of the wood as a vapor, hence the additive which the solvent carried into the wood remains in the wood, intimately and thoroughly dispersed therein.

As heretofore stated, the solvent received into drop tank 80 will contain resins extracted from resinous type woods. These resins can be valuable by-products of the process. If their concentration is not deemed too great in any given batch of solvent, the solvent may be returned by pump 96 and pipes 97, 98, and 99 to solvent tank 39. Whenever the resin concentration warrants it the batch or some of it may be delivered by pump 101 and pipes 97, 102, and 103 through filter 104 and pipe 106 to a still 107 which may advantageously be of the cascade type having weirs such as 108 over which the solution may flow as steam coils or other suitable heating means (not shown) evaporates the solvent as a solvent vapor therefrom. Another similar still 109 is connected in series as shown and the solvent vapor from both may be delivered by pipes 111, 112 and 113 to the condenser 41, whose functioning has been described heretofore.

The resin concentrate, more or less free of solvent, may be delivered by pipe 114 into a ring-packed column 115 of conventional type to be finally stripped of solvent by means of steam in an obvious manner. The solvent-

free resin may then be pumped by pump 116 to the storage tank 117 while the solvent and steam as an azeotrope vapor is delivered by pipes 118, 111 and 113 to condenser 41.

If both absorbers 46 and 47 have been in use and become solvent saturated they may be regenerated by opening valves 120 and 121 which will admit stripping steam from supply line 122 which, passing through ejectors 123 and 124 will strip solvent from the carbon, the suction causing check valves 48 and 49 to close. The steam and solvent will pass through check valves 125 and 126 through line 127 into the pipe 113 for delivery to the condenser 41.

The automatic control

The invention comprehends automatic control of the process steps, and employs apparatus which is in part timer controlled and in part responsive to conditions which develop in the process. A schematic diagram of the control apparatus is shown in Figures 3 and 4 and its manner of use will now be explained.

The electrical circuit shown in Figure 3 is supplied with electric current from a suitable source at 110 volts and 60 cycles, for example, as represented by the power wires 131 and 132. The automatic valves hereinafter mentioned are generally large in a commercial plant and preferably are opened by air powered mechanism of conventional nature, and preferably are so arranged and designed as to be normally closed, for example by springs, in the absence of process operation or whenever there is a power or air failure. Compressed air for opening these valves may conveniently be supplied, as shown, by solenoid-operated valves (under control of the electrical circuit). The details of construction of these conventional valves do not constitute a part of this invention, hence are not shown.

The electrical circuit includes one hand-operated switch, one door-operated switch, two switches responsive to the azeotrope vapor pressure occurring during the evaporation of moisture, several motor-operated timers which cause cam-operated switches to open or close, and a number of relays. Closing of the hand-operated switch initiates a cycle of operations which are thereafter automatically controlled and which terminate when the charge of lumber in the retort has been dried and treated and is ready for removal.

The retort 11, in which one or more carloads of lumber may be placed at a time for treatment in accordance with this invention, is a well reinforced steel chamber provided with a door (not shown) which can be tightly sealed to retain the liquid solvent employed to submerge the lumber. There is shown in the circuit diagram in Figure 3 a door limit switch 133 of any suitable construction, the details of which do not constitute a part of this invention, but which will remain open until the door is closed.

Assuming that the retort has been loaded with lumber and the door limit switch 133 is closed and all of the apparatus is in condition for the beginning of a cycle of process steps, the operator will then close the start-stop button 134 which will supply current to relay 1R in Fig. 3, which upon being energized will close the normally open relay contact 1R₁ and normally open relay contact 1R₂ thus supplying voltage to the bus bars or wires 135 and 136 extending vertically in Figure 3 and also at the same time supplying voltage to the bus bars or wires 137 and 138 of Figure 4, which may be considered a continuation of wires 135 and 136 of Figure 3. When voltage is thus supplied to the wires 135 and 136, timer motors 1T, 2T and 3T are energized.

Drying

Timer 1T, when it begins to operate, maintains a circuit from wire 136 through normally closed switch 4R₂, 75

through the upper closed contact 139 of the timer switch 1T₁ (Fig. 3) through the coil of a solenoid-operated air valve 141 which controls the supply of compressed air to open and hold open the overhead raw solvent supply valve 58. Valve 58 supplies solvent to the retort until the lumber is submerged or nearly submerged; whereafter timer 1T, whose cycle is adjustable and may be of about 5 minutes, operates switch 1T₁ at the end of its cycle to cut off current to solenoid of valve 141 and supply current through its lower contact 142 to the coil of solenoid valve 143 which supplies compressed air to open and hold open the throttling valve 27, which admits enough solvent to the retort to keep the lumber submerged and the liquid level in the retort high enough to continuously overflow the baffles 23.

The overhead solvent supply valves 58, 27 and 87 are controlled not only during the sequence of operations now being described but are also subject to control by the liquid level control device 24 (see Fig. 5) so that the solvent in the retort may never rise above a predetermined level, which preferably is about four inches above the top of the wood contained in the retort and sufficient to overflow the baffles 23.

As shown in Fig. 5, when the liquid level is below the desired level the float element suspended on the pivoted float arm 144 rotates a flapper 144a toward a Bourdon tube 145. In a manner hereinafter explained, this movement causes air to be supplied to the solenoid operated valves 141, 143 and 148 adequate, if any one of them be open, to actuate their respectively associated valves 58, 27 and 87 to full open position. However, when the liquid level in the retort reaches the desired predetermined level the cooperative action of the float and associated mechanism reduces this air supply pressure to such an extent that none of the valve 58, 27, or 87 can be actuated to open position even if their associated control valves be open. Air actuated valves of this type, which are air actuated to open position against spring pressure, are well known, and customarily they have suitable bleed ports or the equivalent so that if they be deprived of actuating air pressure their springs will close them.

When voltage has been applied initially on the closing of the start-stop button 134, current is supplied through the coil of the solenoid-operated air valve 149 from wire 135 through the coil through normally closed switch 8R₁ of relay 8R and normally closed switch 2R₂ of the relay 2R to the wire 136. When valve 149 is thus operated it supplies compressed air to open the vapor valve 34 so that air and vapors may flow from the retort. Compressed air supply pipes connected with the various valves are not shown in the drawings, except in Fig. 5.

Timer 2T, also now operating, serves to delay the opening of the retort steam valve 63 until liquid solvent entering the retort at the start of operations has filled the retort to, or partly to, the desired maximum level or at least has covered the steam coils. Hence, the switch 2T₁ is normally open as shown in Fig. 3 but closes after a predetermined short interval when timer 2T completes its cycle, establishing circuits from wire 135 through the coils of the solenoid-controlled air valves 151 and 152 through then closed switch 2T₁ and normally closed switch 14R₁ of relay 14R. The valve 151 then supplies compressed air to open the retort steam valve 63 to admit steam to the coils in the retort for heating the solvent, while valve 152 supplies air to open the steam condensate drain valve 64. Usually about two minutes after the solvent begins to flow into the retort it is appropriate to admit steam.

Timer 3T, also now operating, has the function of preventing the intermediate vapor flow switch 153 associated with the vapor flow meter from exercising any control over the operations until switch 3T₁ of timer 3T is closed. When the timer 3T runs for its set time cycle and closes switch 3T₁ there will be a sufficient amount of

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vapor passing through the retort vapor line 35 to prevent the intermediate vapor flow switch 153 from closing.

During this period the solvent bath becomes heated by the steam coils to well above the azeotrope boiling point, preferably in the range of 210° to 240° F., and moisture is being removed from the wood as a part of the azeotrope vapor. This drying period continues until it is terminated by the vapor flow meter actuating the intermediate vapor flow switch 153. This period will usually require several hours, dependent upon the nature of the wood being dried and the dimensions of the wood, thicker pieces requiring more time than thin ones.

Soaking

Later when the vapor flow through the orifice plate 77 drops to the point where the intermediate vapor switch 153 can close, voltage will then be impressed from wire 135 through the vapor flow switch 153 and timer switch 3T₁ and the coils of the 2R and 14R relays to wire 136. When relay 2R becomes energized all of the switches on this relay are operated and switch 2R₁ closes, establishing thereby a holding circuit for relays 2R and 14R directly between wires 135 and 136, making them no longer dependent on vapor flow switch 153 for current.

When relay 2R is energized switch 2R₂ opens cutting off current from solenoid-operated valve 149, thus cutting off air from vapor valve 34, which closes. Relay 14R, now energized, opens switch 14R₁, thus cutting off current from air valves 151 and 152 which close and respectively cause the retort steam valve 63 and condensate valve 64 to close. The residual heat in the solvent bath and in the heavy steel walls of the retort will cause azeotrope vapor to evolve in the retort a few minutes until the vapor becomes superheated and imposes such pressure on the wood as to cause condensation of the vapors therein, allowing the solvent to penetrate it and initiate the soaking period. Should the retort pressure exceed a predetermined figure the safety relief valve 154 in by-pass 155 will relieve the pressure.

Voltage will also pass from wire 135 through the normally open but now closed switch 2R₃, through the motor of timer 5T to wire 136. This starts timer 5T operating, which controls the length of the raw solvent soaking period. This timer 5T is adjustable and its cycle will usually be set to allow about half an hour or a little more for each inch of thickness of the lumber to be soaked.

The length of the soaking period is automatically terminated by the timer 5T which at the end of its cycle causes switch 5T₁ to close and thus to supply current from wire 135 through the normally open but now closed switch 2R₄ and switch 5T₁ (now closed) through the motor to timer 6T to wire 136.

Drying resumed

Switch 5T₁, when closed also supplies current through relay 13R to energize it whereupon switch 13R₁, which is normally open, but which now becomes closed, establishes a circuit from wire 136 through normally closed switch 16R₂, through 13R₁, through 8R₁ (normally closed) and the solenoid of valve 149 to wire 135.

Thus when voltage is supplied to the control valve 149 for vapor valve 34, the latter opens relieving pressure in the retort and enabling the azeotrope vapors therein to resume flowing to the condenser 41.

The closing of switch 5T₁, at the end of the soaking period, also closes a circuit from wire 135, through closed switch 2R₄, closed switch 5T₁ and relay 3R to wire 136. When relay 3R is thus energized switch 3R₁ closes establishing a circuit from wire 136, normally closed switch 4R₁, switch 3R₁, closed switch 2T₁, and the coils of air control valves 151 and 152 to wire 135, thus reopening the steam supply valve 63 and condensate valve 64 to supply heat to the solvent for further drying.

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Draining of retort

Timer 6T, which was started at the end of the cycle of timer 5T, limits the duration of the heating period after the soaking period, by closing switch 6T₁ at the end of its cycle thus simultaneously energizing relay 4R, the motor of timer 7T and through normally closed switch 7T₁ energizing the solenoid of air control valve 156 which supplies air pressure to open the raw solvent drain valve 32. When relay 4R becomes energized the normally closed switch 4R₂ (shown near the top of Fig. 3) opens, which action cuts off the supply of current to the air control valve 143 for the raw solvent throttling valve 27, closing both valves. The raw solvent drain valve 32, now being open, enables the solvent in the retort to drain into the raw solvent drop tank 80. Also the energizing of relay 4R causes the normally closed switch 4R₁ to open, cutting off the supply of current to the control valves 151 and 152 for the retort steam and condensate valves, respectively, thus allowing these valves to close.

Treating

Timer 7T controls the length of time the raw solvent drain valve will be open. When the motor of the timer 7T completes its cycle at the end of such period of time as is required for draining the raw solvent, timer 7T then operates timer switch 7T₁ de-energizing valve 156, closing valve 32 and supplying current to the relay 12R (Fig. 3), to timers 4T and 8T and to the air control valve 148 which supplies compressed air to open the overhead solvent treating valve 87. This latter circuit passes from wire 135 through closed switches 2R₄—5T₁—6T₁—7T₁ lower contact—solenoid 148—8T₁ upper contact, closed switch 7R₁ to wire 136.

When relay 12R becomes energized at the end of the cycle of timer 7T it closes normally open switch 12R₁ whereby current is supplied from wire 136, through closed switches 16R₃—12R₁—2T₁, and solenoids of valves 151 and 152 to effect the opening of steam valve 63 and condensate valve 64. The treating solvent entering the retort is thus heated and the vapor valve 34 being open evaporation of moisture from the wood is resumed when the temperature rises above the azeotrope boiling point.

Timer 8T functions to control the length of time the overhead treating solvent valve shall remain open, this time being the amount of time required to supply treating solution to the retort to submerge the lumber therein and to cause the solvent to approach or attain a level high enough to overflow baffles 23.

When this period has concluded timer 8T shifts the switch RT₁ from the position shown in Fig. 3 where it is shown supplying current to the control valve 148 for the treating valve 87 downwardly to its lower contact where it supplies current through wire 157 to control valve 143 which supplies air under pressure to the raw solvent throttling valve 27, which serves as before to maintain the solvent level in the retort during this drying period.

Treating solvent soak

As said above, when timer 7T completes its cycle, timer 4T was energized and begins to run and to function to determine the length of time that the vapor valve 34 remains open prior to the treating solvent soaking period. When timer 4T completes its cycle, switch 4T₁ will close supplying energy to timer 9T and relay 16R and when the latter is energized normally closed switch 16R₃ opens and cuts off current to control valves 151 and 152, causing the steam valve 63 and condensate valve 64 to close. At the same time closed switch 16R₂ opens and thus cuts off current from the control valve 149 which will cause vapor valve 34 to close. Thereupon the vapor will be retained in the retort and will become superheated by residual heat in the retort and its contents enough to create pressure enough to cause vapors in the wood to condense, whereupon the solvent containing the treating

additive or additives begins to soak into the wood. Thus timer 4T initiates the treating solvent soaking period.

In addition to initiating the treating solvent soaking period timer 4T also, while it is still running its cycle, not only serves to postpone the energizing of relay 16R but also the energizing of timer 9T. When the latter is energized its cycle begins at the beginning of the soaking period and terminates at the end of the soaking period at which time it causes normally opened switch 9T₁ (top of Fig. 4) to close, thus supplying current to relays 5R and 15R. When 5R is energized switch 5R₁ closes and supplies current from wire 136 through normally closed switch 9R₁ to control valves 151 and 152 which open the steam valve 63 and the condensate valve 64. At the same time when relay 15R operates it closes switch 15R₁ (Fig. 3) and supplies current through normally closed switch 8R₁ to control valve 149, thus causing vapor valve 34 to open. At this time evaporation of further moisture from the wood resumes.

Normally open switch 5R₂ (Fig. 4) also is closed by relay 5R and supplies current to the timer 10T. Timer 10T during its cycle continues to hold open the circuit through the minimum vapor flow switch 158, the timer operated switch 10T₁ then being normally open. When treating southern yellow pine lumber one inch in thickness the cycle of timer 10T will be somewhat less than an hour.

Subsequently, when timer 10T closes the switch 10T₁ and the minimum vapor flow meter switch 158 becomes closed by the effect of a small vapor flow, a circuit is then established through relay 6R (top of Fig. 4) closing normally open switch 6R₁ establishing a holding circuit for relay 6R. The closing of switch 6R₂ when relay 6R is energized establishes a circuit through the motor of timer 11T.

Timer 11T establishes a time delay between the actual closing of the minimum vapor flow switch 158 and the opening of the treating solvent drain valve. Experience has shown that the vapor flow at or about the time when control is desired by the minimum vapor flow is insufficient, with present available equipment, for controlling with extreme accuracy the time when the retort should be drained. Hence, the minimum vapor flow switch is allowed to operate at a somewhat higher pressure such as can be relied upon to give consistently a fairly accurate indication of the amount of vapor flowing, after which the evaporation of azeotrope vapor is continued under control of timer 11T for a predetermined period before the drain valve is opened. Such a delay period is subject to variation and in the handling of certain kinds of wood such as southern yellow pine may be approximately one hour.

When switch 11T₁ (Fig. 4) is closed at the end of the cycle of timer 11T, the relay 7R (Fig. 4) becomes energized. Normally closed switch 7R₁ (Fig. 3) is now opened, cutting off current through wire 157 to valve 143, thus causing the solvent throttling valve 27 to close. The energizing of relay 7R also closes switch 7R₂, thus supplying current to the control valve 159 which supplies compressed air for opening the treating solvent drain valve 33 shown in Figure 1, thus draining the retort.

Simultaneously with the opening of the treating solvent drain valve 33, the now closed switch 7R₂ closes a circuit through the upper closed switch contact 161 of timer switch 13T₁ and 10R₁ and the coil of the solenoid operated valve 162 supplying air pressure to open vacuum valve 88 so that pipe line 59 may be drained while valve 33 is open.

The closing of switch 7R₂ also supplies current to the motor of timer 12T, which functions to control the amount of time the treating solvent drain valve 33 shall thereafter be open. As soon as timer 12T closes switch 12T₁ a circuit is then established through relay 8R which upon being energized opens the normally closed switches 8R₁ (Fig. 3) and 8R₂ (Fig. 4). Switch 8R₁

upon being open removes voltage from the control valve 149 so that the vapor valve 34 will close. Switch 8R₂ upon being opened removes voltage from the control valve 166 which controls the treating solvent drain valve 33, closing the latter.

When timer 11T closed switch 11T₁ and energized relay 7R and thereby closed switch 7R₂, as stated above, a circuit is likewise established through the motor of timer 13T, starting that timer to operate, and which through the upper switch contact 161 of switch 13T₁ controls the length of time the solenoid 162 shall remain energized and hence the length of time the vacuum valve 88 shall remain open.

When the retort has been drained and the relay 8R has been energized, the normally open switch 8R₃ (Fig. 4) being closed establishes a circuit between wire 137 and 138 through the motors of timers 14T, 15T, 16T and 17T, thus simultaneously starting these timers. At the same time current is supplied through the then closed switch 14T₁ and the closed switch 10R₂ simultaneously to the solenoid operated switch 163 which starts the vacuum pump 92 shown near the top of Fig. 1. At the same time solenoid operated switch 164 is energized to start the liquid seal pump 93.

Timer 14T controls the length of time that the vacuum pump 92 and the seal liquid pump 93 shall operate.

At this point in the cycle of operations all of the valves in the system are closed with the exception of the vacuum valve 88 and the retort steam supply valve.

As soon as timer 15T reaches the end of its cycle, switch 15T₁ closes, voltage is impressed through normally closed switch 11R₁ (Fig. 4) through a control valve 165 which supplies compressed air to open a retort steam fitting valve 94 (Fig. 2) allowing stripping steam to enter the retort.

When timer 16T reaches the end of its cycle, switch 16T₁ closes and relay 10R (Fig. 4) becomes energized, which removes voltage from control valve 162, closing the vacuum valve 88. Normally closed switch 10R₂ likewise opens, deenergizing solenoids 163 and 164 which then stop vacuum pump 92 and seal pump 93.

After vacuum valve 88 is closed, stripping steam continues to be fed into the retort to build up positive steam pressure therein. When timer 17T reaches the end of its cycle, switch 17T₁ closes and 11R becomes energized, opening normally closed switch 11R₁, which de-energizes the retort steam stripping control valve 165 and also closes normally open switch 11R₂, which re-energizes vacuum control valve 162 to open vacuum valve 88 and switch 11R₃ closes to supply current to solenoid 163 to actuate vacuum pump 92 and solenoid 164 to actuate seal pump 93 so that vacuum again is pulled on the retort.

When timer 13T reaches the end of its cycle, the switch 13T₁ is actuated to de-energize solenoid 162, closing vacuum valve 88 and to transfer power through its lower switch contact 166 to a circuit leading through motor of timer 18T, starting the latter, and supplying voltage also to relay 9R. When relay 9R is energized switch 9R₁ (Fig. 3) normally closed, now opens cutting off voltage to the retort steam supply control valve 151 and condensate control valve 152.

When 14T finishes its cycle switch 14T₁ opens, de-energizing solenoids 163 and 164, stopping the vacuum pump 92 and seal pump 93.

Current through the upper contact of timer switch 18T₁ energizes solenoid controlled valve 167, which supplies air to open and hold open the vent valve 95 (Figs. 1 and 2) admitting air into the retort to raise the pressure to atmospheric so that the door may easily be opened. At the end of timer 18T's cycle, switch 18T₁ moves to its lower contact to supply current to the coil of a warning horn 168, signifying that the wood is ready for removal from the retort. The start-stop button is manually put in stop position and opening of the

door will open the door limit switch, and automatically the electrical circuits will be restored to original starting position.

The following are the approximate time cycles set on the various timers for 2" thick dimension southern yellow pine:

1T-----	5 min.
2T-----	2 min.
3T-----	3 hrs.
4T-----	1 hr.
5T-----	1½ hrs.
6T-----	1 hr.
7T-----	12 min.
8T-----	4 min.
9T-----	1 hr.
10T-----	2 hrs.
11T-----	1 hr.
12T-----	14 min.
13T-----	1 hr. 44 min.
14T-----	1 hr. 31 min.
15T-----	10 min.
16T-----	25 min.
17T-----	1 hr.
18T-----	10 min.

The details of construction of the timer mechanisms above referred to do not constitute a part of the invention. While other suitable timers may be employed, timers manufactured by the R. W. Cramer Company of Centerbrook, Conn., have been used satisfactorily herein. As indicated in this specification, their motors are started by current supplied through control contacts in the circuits of Figs. 3 and 4 to initiate their individual timing intervals. At the end of such interval each timer operates a switch in the load circuit, for example, see 12T, or 13T, in Fig. 4, and the timer maintains this condition until the control contact is broken, which would occur here when either switch 133 or 134 is opened. These timers, for example, Cramer type TEC, then automatically reset themselves to repeat their operation when again required to do so. The interval of each timer may be adjusted manually within its individual design limits, hence an operator may make substantial variations in the time limits of the various steps of the process.

Vapor flow meter and switches

In Figure 1 there is shown an orifice device 77 interposed in the vapor flow pipe 35, and in the electrical circuits of Figures 3 and 4 there are shown in circuit an intermediate vapor flow switch 153 and a minimum vapor flow switch 158. These devices and their functioning will now be further described in connection with Figures 6, 7 and 8.

The orifice device which is shown schematically in Figure 6 consists of a plate 171 clamped between two flanges 172 and 173 interposed in the vapor flow pipe 35. The plate has an orifice 174 having a diameter smaller than the pipe diameter.

In the assembly there is provided a duct 175 on the high pressure side of the orifice plate connected by pipe 176 to the high pressure chamber 177 of a Barton No. 211 differential flow meter, generally indicated as 178, and schematically illustrated in Figure 6. Another duct 179 communicating with the face of the low pressure side of the orifice plate is connected by pipe 181 to the low pressure chamber 182 of the same meter.

As this Barton meter manufactured by Barton Instrument Corporation of Los Angeles, California, is a well-known commercially available device and as its construction is not a part of this invention it is not illustrated herein in detail, but is illustrated schematically. It will suffice here to state that the low pressure bellows 183 has its movable end operatively connected by a rod or shaft

184 to the movable end of the high pressure bellows 185, which shaft is subject to pressure from an adjustable compression spring 186. A follower arm 187 fixed on a torque shaft 188 is urged by a suitable spring (not shown) to maintain contact with a collar 189 fixed on rod 184. Differential pressure impressed on the bellows effects reciprocation of rod 184, which is utilized to oscillate an indicating pointer (not shown) and the two switch actuating arms 191 and 192 which are fixedly mounted on the torque shaft 188 at a point somewhat removed from the arm 187.

A bell crank level pivoted at 193, generally indicated as 194, has relatively angularly adjustable arms 195 and 196, the upper one maintaining constant contact with actuator arm 191, the lower, 196, carrying a magnet 197, such as an "alnico" magnet. As shown in Figure 7, wherein the actuator arms occupy the angular position which they have at zero flow position, this magnet is close enough to the fixed position of the non-tilting mercury switch tube 198 to attract a responsive magnet 199 fixed on the wire 201 and swing the wire 201 about its coiled spring portion 201' into the mercury pool 200 in the bottom of the tube to close an electric circuit therethrough to wire 202, the latter being permanently in contact with the pool. This is the minimum vapor flow switch 158 schematically and more simply shown in Figure 4.

When the vapor flow through the orifice is substantially higher than the flow which has been selected to constitute the minimum set point, which might be about 250 cubic feet per minute, for example, the differential pressure action of the vapor flow meter will have the arms 191 and 192 in an angular position enough degrees counter-clockwise from the position shown in Figure 7 to have moved the magnet 197 clockwise far enough so that its magnetic field no longer will hold magnet 199 in opposition to the pull of its associated spring 201' and the spring loaded wire 201 will spring out of the mercury pool 200 and the switch will be open. The coil spring 201' tends normally to open the minimum vapor flow switch.

Leads 203 and 204 in the non-tilting fixed mercury tube 205 close a circuit through a mercury pool 200', except when the "alnico" magnet 206 carried by another similar adjustable bell crank 207 is close enough to exert a magnetic pull on magnet 208 and pull wire 204 out of the mercury pool 200' against the opposing tension of spring 204', which tends normally to close the intermediate vapor flow switch 153.

Figure 7 shows a normally closed circuit in tube 205, which is switch 153. Figure 8 shows magnet 208 responding to magnet 206 and the intermediate vapor flow switch 153 is open. Torsion springs (not shown) acting on the pivoted bell cranks 194 and 207 about their axes cause them to maintain constant contact with their respective actuating arms 191 and 192.

It should be understood that in the early stage of the wood drying the vapor flow will be much in excess of the vapor flow measured at the intermediate control point. While the vapor flow meter is moving up to and past the intermediate point the timer system will keep this meter out of the circuit, hence it can have no operating control on the process.

The intermediate vapor flow switch 153, in actual use, is adjusted so that when the vapor flow diminishes to a desired predetermined vapor flow, which might be 600 cubic feet per minute of vapor flow, for example, the magnet 206 will become rotated far enough counter-clockwise to release magnet 208 and allow this switch to close.

Retort solvent level control

While other suitable controls may be employed, that which is shown diagrammatically in Fig. 5 works satisfactorily and its coordination with other parts of the invention will now be described.

The apparatus shown in Fig. 5, with the exception of the solenoid operated valves 141, 143 and 148 and the air operated valves associated therewith and the connections thereto, is manufactured by Fisher Governor Company of Marshalltown, Iowa. This Fisher equipment includes a filter tank 211 into which air is supplied through the tube 212 from an air pressure supply line, the air passing through a filter 213 past a manually adjustable valve 214, thence by pipe 215 into a double diaphragm assembly generally designated as 216. This air enters a chamber 217 and flows past the spring loaded valve 218 into the chamber 219, whenever valve 218 is open.

Part of the air admitted into the chamber 219 then flows through pipes 220 and 221 into pipe 222 which supplies air to the control valves 141 and 148, and through pipe 223 to supply air to the control valve 143.

Some of the air entering through pipe 215 rises through duct 224 and bleeds through a small orifice shown near the outlet of duct 224 into the upper chamber 225 and thence flows through pipe 226 through the central duct 227 shown in the Bourdon tube 145 and emerges through a nozzle opening in the end of the tube adjacent the flopper 144a, at a rate of flow equal to the rate of flow through said orifice, unless the nozzle opening is restricted by the flopper 144a. The flopper 144a is fixed on the same pivoted shaft 144b as is the float arm 144, hence the position of the float element 26 is one factor in determining whether the flopper restricts the tube nozzle. When the nozzle opening is unrestricted by the flopper the pressure in the upper chamber will be zero. Another factor depends on the pressure applied to the outer duct 228 in the Bourdon tube by means of air supplied through pipe 229 past the manually adjustable double ended valve 231 into the pipe 232. Valve 231 is employed to proportion the amount of air allowed to flow to pipe 232 or through the bleed port 233. Increased air pressure supplied by pipe 232 will tend to straighten the Bourdon tube, thus being a factor in the spacing between the flopper and the tube end, which affords a means of varying the maximum liquid level in the retort.

The lower diaphragm 234 and the upper diaphragm 235, together with spring 236, suspend the central unit 237 so that it functions as a floating valve seat in respect to the valve 238. When this valve seat presses down far enough on valve 238 this movement not only closes valve 238 but unseats valve 218, against the action of spring 239, which condition is shown in Fig. 5.

The valves 58 and 87 are large capacity valves to permit rapid filling of the retort 11. Subject to the control of their associated solenoid operated valves 141 and 148 they are actuated toward open position in opposition to conventional springs (not shown) if the air supplied to them exceeds a certain predetermined pressure. The other valve 27 in the by-pass around valve 58 is a smaller valve having preferably a weaker spring and may be opened by air pressure which is insufficient to open valves 58 or 87.

When the retort 11 is being filled, for example, by solvent supplied through valve 58, and float 26 is below the filled level, flopper 144a restricts the escape of air from the Bourdon tube. Thus air pressure accumulates and is retained in upper chamber 225 sufficient to force unit 237 downwardly, closing valve 238 and holding valve 218 open, whereby enough of the line pressure in pipe 215 will be impressed through pipe 221 and 222 to hold valve 58 open.

Should the retort solvent level reach a predetermined level at or close to the desired filled level before timer 1T has completed its cycle and has actuated switch 1T, to deenergize solenoid operated valve 141 and thus cause valve 58 to close, the liquid level control itself will operate to close valve 58, as follows.

When the liquid level rises in the retort high enough to cause flopper 144a to move away from the end of the Bourdon tube 145, air will escape more rapidly from

the central duct 227 and thus the pressure in the upper chamber 225 will decrease. The central unit 237 in the diaphragm assembly will be raised by spring 236 and by the air pressure in chamber 219 until valve 218 closes and valve 238 opens, whereupon air will escape past the valve 238 and through duct 241 to atmosphere. This will decrease air pressure in chamber 219 and pipe 221, allowing valve 58 to be closed by its own spring.

When timer 1T, in this example, completes its cycle switch 1T₁ will shift, de-energizing valve 141 and energizing valve 143, whereafter should the air pressure supplied by lines 221 and 223 through the now open valve 143 be great enough it will open valve 27 and throttle it to supply solvent to the retort just rapidly enough to offset solvent loss from the retort and maintain the desired liquid level therein.

It will now be perceived that whenever the solvent level drops, due to evaporation or other causes, the flopper will approach the end of the Bourdon tube and diminish the flow of escaping air. This will cause air pressure in chamber 225 to increase forcing the floating valve seat down until it pushes down on valve 238, stopping the wasting of air past that valve and unseating valve 218 and restoring air pressure to chamber 219 and pipe 221 which if sufficient will reopen or further open any air operated solvent supply valve whose associated solenoid operated control valve is open at the time, thus to increase or restore solvent flow to the retort. During a drying period it would be the throttling valve 27 which would thus be regulated by the diaphragm assembly.

Variations in air pressure transmitted to pipe 232 will cause the Bourdon tube to distend or contract, thus varying the maximum level in retort within desirable or permissible certain limits controllable by valve 231.

It has been mentioned in the foregoing description that the rate of azeotrope vapor flow in the retort diminishes noticeably as the instant moisture content of the wood approaches the critical moisture content. This diminution is readily detectable when the moisture content has dropped to the neighborhood of 50% or thereabouts. Soaking at this time before further drying has appreciable advantages. Instead of directly measuring the vapor flow by means of the variations in pressure thereof I might determine the rate of azeotrope vapor evolution or flow at a selected interval of time by measuring the condensate derived from this vapor in such period of time, measuring either the water condensate or the solvent condensate or both together. The measurement thus taken, either of rate of flow, or volume or weight of the condensate, could be used to indicate to the operator when the drying operation should be interrupted and the soaking step initiated. Also at a later interval similar information could be utilized to determine when to terminate the drying and treating operation. Instead of merely indicating to the operator when to initiate these changes, automatic control could be provided automatically responsive to the measurement of the condensate.

As steam furnishes the heat for the azeotrope vapor evolution in the retort, it will be recognized that the rate of steam consumption will vary in proportion to the rate of azeotrope vapor evolution. Accordingly, as an alternative control method, I might measure either the flow of steam into the coils 21 or the steam condensate emerging therefrom by conventional flow measuring devices and regulate the soaking and drying periods by correlating such devices with the control circuits in accordance with the same principles governing the use of the Barton flow meter.

In the event that the azeotrope vapor condensate is to be measured, as suggested above, to determine when to begin soaking the wood and when to terminate drying of the wood in the solvent bath, it would be preferable to measure the combined condensate before gravity separation of the solvent and water. In such case a separate

condenser would be added to receive and condense vapors from pipe 113 and discharge them into the separator 42, so that the condenser 41 would then receive vapor only from the retort.

While some other suitable apparatus could be used, I have shown diagrammatically in Fig. 9 apparatus which could be used and would be responsive to the rate of flow of azeotrope vapor condensate. The condensate of intermingled solvent and water, instead of discharging directly to gravity separator 42, as in Fig. 1, would as shown in Fig. 9, drain from condenser 41 through pipe 245 into a sealed chamber 246 and fall into the cup 247 fixed on arm 248 pivoted at 249, having a suitable counterweight 251. When the condensate flow exceeds a predetermined "intermediate" rate of flow, as it would in the early stages of wood drying, the drain stem 252 would not drain the cup as rapidly as it was being filled and the cup would be held in the downwardly tilted position shown in Fig. 9, resting on a support bracket 253. The condensate overflowing the cup 247 would spill into the lower cup 254 pivotally supported at 255 on arm 256 and having a suitable counterweight 257. The drain stem 258 of the lower cup will be gauged to drain at a predetermined rate which may, for example, correspond to the vapor condensed at the same vapor flow rate which enables the minimum vapor flow switch 158 of Fig. 4 to close. Condensate in excess of that rate would flood the lower cup and hold it down against the support bracket 259, the excess overflowing into the bottom of the tank and then draining into a pipe such as 68 for delivery to the gravity separator 42.

The drain stem 252 of the upper cup may be gauged to drain condensate at a predetermined rate such as, for example, the amount that would be condensed at the vapor flow rate which enables the intermediate vapor flow switch 153 of Fig. 3 to close. When this rate is reached in the drying process and the upper cup drains it will be tilted up by its counterweight and the arm 248 will contact and close a suitable switch 261 which would take the place of switch 153 in the circuit of Fig. 3.

Later in the drying and treating process, when the flow of azeotrope vapor condensate drops enough so that the lower cup will cease flooding and will drain, the arm 256 affixed to that cup will be tilted to close a suitable switch 262, which would take the place of the minimum vapor flow switch 158 of Fig. 4. The drain stems of these two cups could be regulatable or replaceable to cause these cups to tilt upwardly after any selected flow rates of condensate had been attained. Thus the devices of Fig. 9 could be utilized with the control circuits of Figs. 3 and 4 for the same general control purposes.

In the event that it may be desired to evaporate moisture from the wood under sufficient vacuum to lower the azeotrope boiling point very substantially below 190° F., the boiling point of the perchlorethylene-water azeotrope, I may, as said before, interpose a motor driven vacuum pump 263 between the condenser 41 and the gravity separator 42. When this pump 263 is so interposed there will also be provided a by-pass 264 around the pump and in the by-pass a check valve 265 opening toward the separator 42. The motor of this vacuum pump will then be energized under control of an automatically operated switch (not shown) connected to the control circuit whenever the vapor valve 34 is opened and will be de-energized whenever valve 34 is closed. When the pump is stopped condensate from condenser 41 may flow to the separator through the by-pass. The check valve 265 will be closed by suction exerted on it whenever pump 263 is operating.

Whenever azeotrope vapor has been removed from the retort 11 at a pressure lower than would or could later conveniently be exerted by the solvent stripping vacuum pump 92 it would be advisable and preferable to allow or cause the wood to become heated to a temperature considerably above the azeotropic boiling point which

would be determined by the suction effect of pump 92 before that pump is put into operation. This could be accomplished by shutting off the vacuum pump 263 shortly before the retort is drained, and allowing the solvent bath to heat the wood to the desired extent above the last mentioned boiling point. Heat could be supplied to the wood otherwise, as by steaming, if desired.

Whatever the temperature and pressure in the retort may be during the drying or impregnation steps, there should be enough superheat in the wood during the stripping step to supply the necessary latent heat of evaporation to the solvent being stripped. If the considerable mass of metal in the retort be at this time above the azeotrope boiling point during the stripping step this heat will be of assistance.

Furthermore, when the stripping step is commenced there should remain in the wood more than enough moisture from which to form azeotrope vapor with all of the solvent then present in the wood. Thus all of the solvent may economically be stripped from the wood, to avoid solvent losses in the process. The use of steam to supply such moisture, in part, is possible but is less economical.

While the solvent frequently referred to herein is the non-flammable, water-immiscible perchlorethylene, other non-flammable, water-immiscible chlorinated and halogenated hydrocarbon solvents, including fluorinated hydrocarbons, may be substituted therefor, provided their physical characteristics are suited to the purposes of this invention and the cost of employing them is found to be economical. Such desirable solvents are non-flammable and have a constant azeotrope boiling point. The choice of solvent may vary in accordance with availability and price, and the various particular operating conditions under which it is desirable or feasible to dry or otherwise treat a particular type of wood.

Among the various chlorinated hydrocarbons which may be employed are perchlorethylene and trichlorethylene. Of these perchlorethylene is preferred. Its boiling point is 250° F., its azeotrope boiling point with water is 190° F., and the azeotrope ratio is 5.3 pounds of perchlorethylene to 1 pound of water. About 90 B. t. u.'s are required to evaporate 1 pound of perchlorethylene. Perchlorethylene is non-flammable and its toxicity characteristics render it reasonably safe to use, much more so than some of the chlorinated hydrocarbons not here listed.

Among the presently known fluorinated hydrocarbons having boiling point low enough for convenient use in this invention are the following, identified only by formulae and boiling points, as it is believed they are as yet without individual names.

	* C.
55 C ₇ F ₁₆ -----	82
C ₈ F ₁₈ -----	102
n-C ₇ H ₂ ClF ₁₁ -----	95
n-C ₇ H ₂ Cl ₂ F ₁₀ -----	115
n-C ₇ H ₂ C ₃ F ₉ -----	142
60 n-C ₇ H ₂ Cl ₂ F ₈ -----	135
n-C ₇ H ₂ F ₁₂ -----	125
C ₂ Cl ₄ F ₂ -----	91-92
CClF -----	111.5
C ₃ HCl ₄ F ₃ -----	127-129
C ₃ Cl ₅ F ₃ -----	152
65 C ₄ HCl ₃ F ₄ -----	109-110
C ₅ HCl ₃ F ₆ -----	110-112
C ₅ HCl ₂ F ₉ -----	81
C ₅ Cl ₂ F ₆ -----	87

Reference has been made heretofore to the use of plastics as additives for impregnation of the wood. A number of the materials belonging to this broad class may be used in connection with this invention. Among them are those which may advantageously be dissolved

in an appropriate solvent and introduced into the retort with the wood, as are other treating solvents heretofore described, after the wood has been dried down almost to a desired final moisture content. To be useful in this manner the plastic material should readily penetrate the wood when in solution at temperatures below the solvent boiling point. If the plastic be a thermo-setting plastic its setting temperature should be substantially higher than the water-solvent azeotrope boiling point, and preferably higher than the boiling point of the solvent in which the plastic is held in solution. After impregnation of the wood in a manner similar to the impregnation procedures heretofore described, the solvent containing the unabsorbed plastic may be drained from the retort and the residual solvent may then be evaporated from the wood as an azeotrope vapor along with residual moisture in the wood, after which the wood may be heated by any appropriate means to the setting temperature of the plastic absorbed therein. If the setting temperature of the absorbed plastic is low enough the setting might be accomplished by heating the wood by means of steam while still in the retort. However, other means of heating the wood with or without pressure may be resorted to, if desired.

Whatever plastic is employed it is preferred that it shall not form ternary azeotropes with the water and solvent.

I may also use a thermo-plastic material or other plastic which will remain in solution in the solvent during and after impregnation and allow it to harden in the wood after the solvent has been drained and stripped therefrom.

For example, polystyrene may be dissolved in perchlorethylene and used as the impregnating material, after the wood is dried preparatory to that step. When the wood is thus impregnated with polystyrene and the solvent has been stripped therefrom the polystyrene hardens but not to a brittle state and the wood thus impregnated is moisture resistant and acquires tremendous toughness and ability to resist wear and abrasion. This type of plastic is especially valuable as a carrier of color, which suggests many possibilities of enhancing the appearance of the wood along with durability.

It will be recognized that the present invention lends itself readily to the economical and advantageous impregnation of wood by various suitable plastics within the retort following the drying of the wood.

This application is a continuation-in-part of my application Serial No. 176,385, filed July 28, 1950, which was formally abandoned subsequent to the filing of the instant application.

While I have shown and described preferred methods and apparatus for the practice of this invention, it should be understood that numerous changes and variations in the foregoing are contemplated and may be made without departing from the principles and scope of the invention as expressed in the claims which follow.

Having shown and described my invention, I claim:

1. A wood treatment process which comprises submerging the wood in a liquid bath in a container closed to the atmosphere, said bath containing as the essential drying agent a halogenated hydrocarbon solvent which is immiscible with and heavier than water, a solvent for resins, non-flammable, and has a constant water-solvent azeotrope boiling point, the bath being at a temperature range between the solvent boiling point and the boiling point of the azeotrope of the solvent with water, and while maintaining the bath within the said temperature range, continuously drawing off from the bath the evolved azeotropic vapor with its water content effective for maintaining the bath water-free, thereby removing from the wood the more loosely held portion of the water content thereof, thereafter effecting condensation of vapors within the wood and thereby causing the bath solvent to pene-

trate the wood, subsequently resuming vaporization of moisture from the wood to remove the more tightly bound portion of the water content therefrom while drawing off the evolved vapor with its water content, separating the wood from the liquid, subjecting the thus treated wood to sub-atmospheric pressure while removing solvent therefrom, raising the temperature of said wood, and again subjecting the resulting wood to sub-atmospheric pressure to remove residual solvents therefrom.

2. A wood treatment process which comprises submerging the wood in a liquid bath in a container closed to the atmosphere, said bath containing as the essential drying agent a halogenated hydrocarbon solvent which is immiscible with and heavier than water, a solvent for resins, non-flammable, and has a constant water-solvent azeotrope boiling point, the bath being at a temperature range between the solvent boiling point and the boiling point of the azeotrope of the solvent with water, and while maintaining the bath within the said temperature range continuously drawing off from the bath the evolved azeotropic vapor with its water content effective for maintaining the bath water-free, thereby removing from the wood a first portion of the water content thereof, thereafter effecting the condensation of the vapors within the wood and thereby causing the bath solvent to penetrate the wood, subsequently resuming vaporization of moisture from the wood to remove a second portion of the water content therefrom while drawing off the evolved vapor with its water content, subjecting the thus treated wood to sub-atmospheric pressure while removing solvent therefrom, then submerging the wood in a liquid bath composed of a similar solvent containing a wood preservative of a character not to form ternary azeotropes with water and the solvent, increasing the pressure to which the treated wood is being subjected to atmospheric pressure, heating the liquid bath containing the submerged wood while removing water therefrom, separating the thus treated wood from the liquid bath, subjecting the thus treated wood to sub-atmospheric pressure to remove some solvent therefrom, raising the temperature of the thus treated wood, and again subjecting the wood to sub-atmospheric pressure while removing additional residual solvent therefrom.

3. The process of claim 2 wherein the food preservative is pentachlorophenol.

4. A wood treatment process which comprises submerging the wood in a container closed to the atmosphere in a liquid bath containing as the essential drying agent a halogenated hydrocarbon solvent which is immiscible with and heavier than water, a solvent for resin, non-flammable, and has a constant water-solvent azeotrope boiling point, the bath being at a temperature range between 250° F. and 190° F. at atmospheric pressure and with the bath within said temperature range, continuously drawing off from the bath the evolved azeotropic vapor with its water content effective for maintaining the bath water-free, said water removal being continued until the moisture content of the wood is not over about 50% by weight based on the wood, thereafter effecting condensation of vapors within the wood and thereby causing the bath solvent to penetrate the wood, subsequently resuming vaporization of moisture from the wood to remove a desired amount of the more difficultly removable portion of the water content therefrom, while continuously drawing off the evolved vapor with its water content, separating the wood from the liquid, and subjecting the thus treated wood to sub-atmospheric pressure while drawing off evolved vapors from the lower portion of the container.

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