Feb. 3, 1948. M. S. HUDSON 2,435,218

APPARATUS AND METHOD FOR DRYING WOOD

Filed Feb. 26, 1945 3 Sheets-Sheet 1

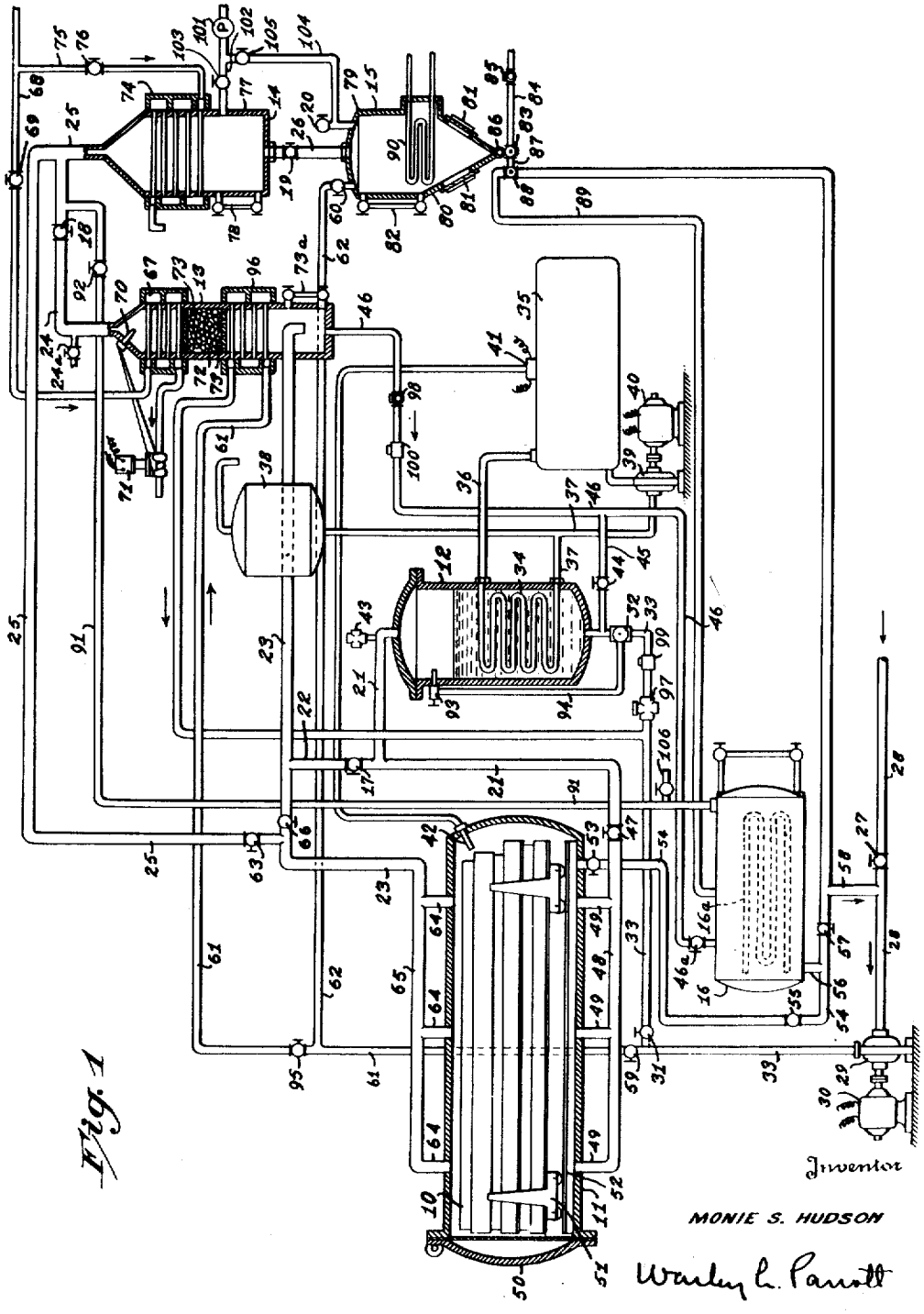


Fig. 1

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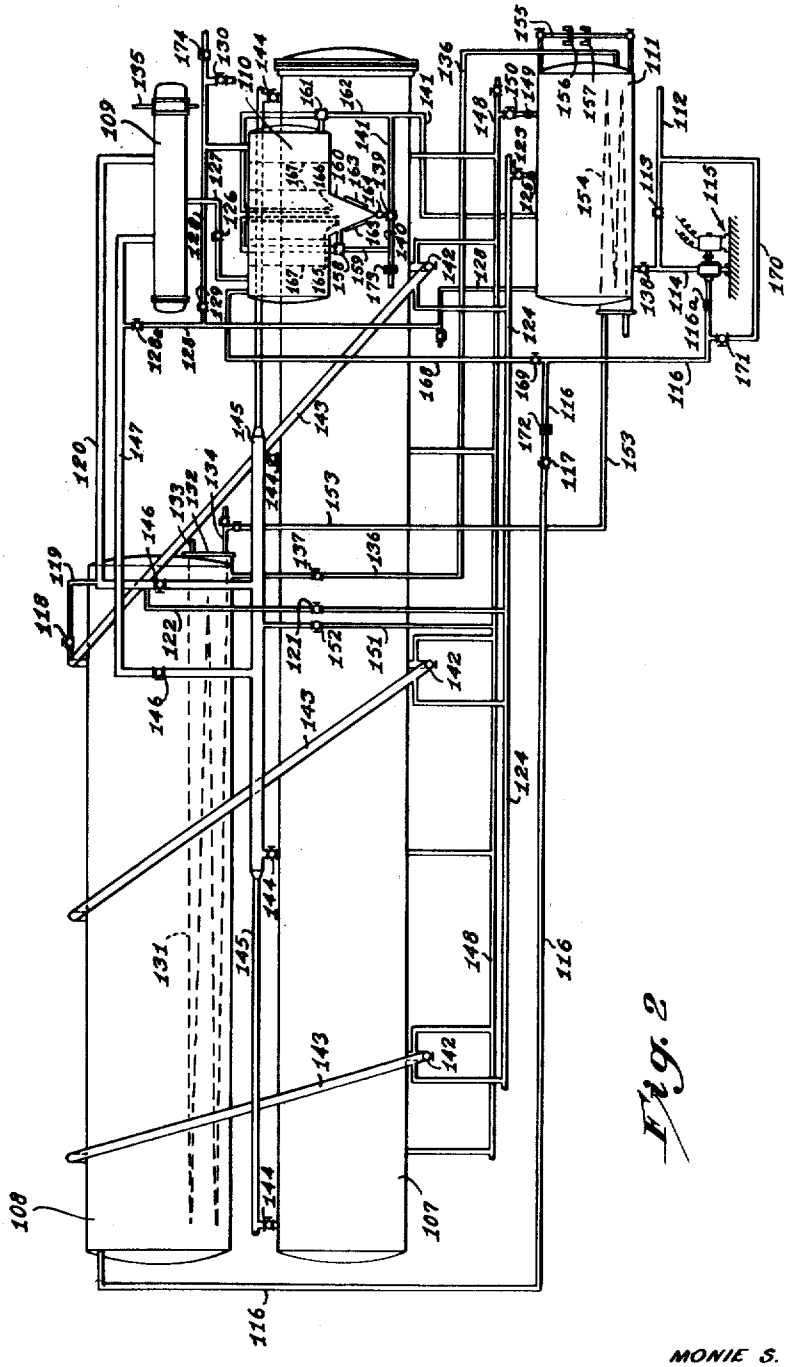


Fig. 2

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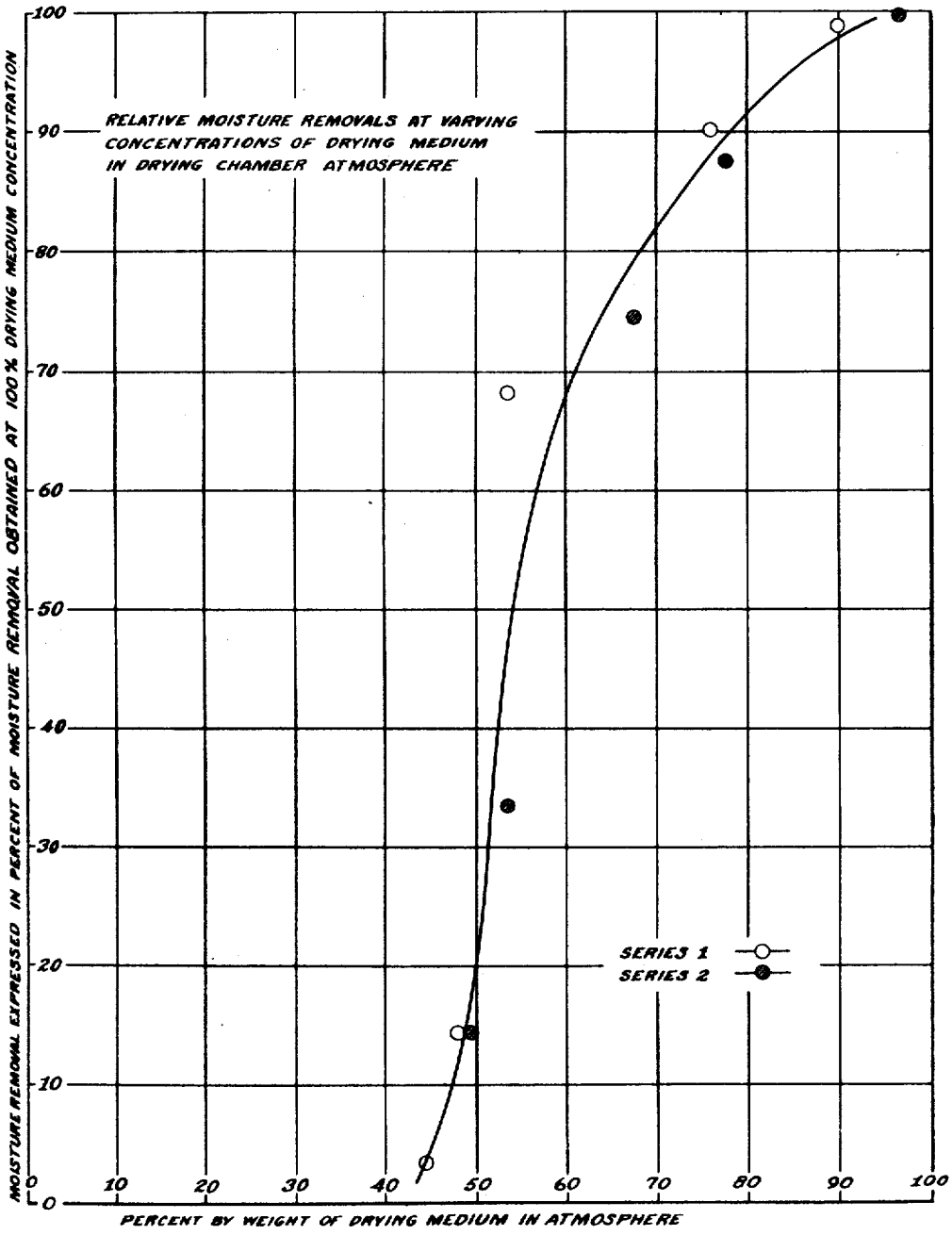


Fig. 3

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UNITED STATES PATENT OFFICE

2,435,218

APPARATUS AND METHOD FOR DRYING WOOD

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Application February 26, 1945, Serial No. 579,851

25 Claims. (Cl. 34—32)

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This application is a continuation-in-part of my co-pending, allowed application Serial No. 431,177, filed February 16, 1942, which was abandoned after transfer of the subject matter to the present application and which was in turn a continuation-in-part of my application Serial No. 324,893, filed March 19, 1940, now Patent No. 2,273,039. The present application covers the subject matter of the apparatus originally disclosed in the above application Serial No. 324,893 and the subject matter of the continuing application Serial No. 431,177, and certain improvements in the apparatus and methods thereof, as described hereafter.

In accordance with my invention I have provided a method and apparatus for drying green or wet wood in a substantially more rapid and efficient manner than heretofore obtainable. Also, this result is obtained without the usual adverse effects on the wood, such as charring, checking, bursting, warping. The element of the required time or duration of the drying treatment is a very important one. The usual yard drying of lumber or other wood requires several months' time; and even kiln drying with steam involves at least several days, and often a week or more. In marked contrast to these prior practices, the method and apparatus of my invention satisfactorily dries wet wood in less than a day's time and in many cases in a few hours' time.

My method comprises generally the treatment of the wet wood in a closed space with a highly heated vapor of an organic material that is inert to the wood and permeates the wood so as to flash-off the moisture as vapor. The liberated moisture vapor and spent organic vapor are conducted away from the drying space and are condensed and separated; the moisture condensate being discharged to waste and the organic vapor condensate being recycled through the system and reused in the drying operation. The drying operation may be carried out at normal pressures or under vacuum, as described hereafter.

In accordance with my above original application Serial No. 324,893, the drying process contemplates the use of a substantially saturated organic vapor as the drying medium throughout the drying operation. This requires continuously feeding a relatively large amount of anhydrous organic drying vapor into the drying chamber at all times, so that the liberated moisture vapor is immediately swept out of the drying chamber and the fresh, hot, organic vapor is continuously brought into contact with the wet wood for liberating the moisture therefrom. The volume of

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organic material required for this type of operation is considerable, and, although it provides the most rapid form of drying, it is desirable in some cases to utilize an economic balance between the rate of drying and the cost of handling the organic material. In such cases, I have found that it is possible to obtain the benefits of my invention from the standpoint of satisfactorily drying the wood without adverse effects thereon, at a somewhat slower rate by permitting the organic drying vapor to be diluted to a definitely limited extent with liberated moisture vapor. In other words, if the organic vapor is fed into the drying chamber in a less amount or at a slower rate than that required for a saturated atmosphere, the drying medium will contain some of the moisture vapor flashed off from the wet wood, and the presence of this moisture vapor will not impair the effectiveness of the drying operation if certain well defined limits with respect to concentration, which will be described hereafter, are observed.

One important feature of one embodiment of my drying method and equipment is the fractional condensation, in a dephlegmator or high temperature, partial condenser, of the liberated moisture vapor and used organic vapor at a sufficiently high temperature to condense the organic vapor but not the moisture vapor; the moisture vapor and some entrained organic vapor then being condensed in a low temperature, complete condenser. The high temperature partial condenser effects separation of much of the organic vapor in vapor phase without cooling it appreciably, so that it may be recovered and returned to the evaporator with its sensible heat substantially undissipated and thus conserve heat in the system.

Another important feature is the collecting and dehydrating, in a heated condensate return vessel, of the condensed organic vapor to remove traces of moisture before the organic vapor condensate is recycled for reuse in the drying operation.

The term "wood" as used in the specification and claims herein is used in a generic sense to include any and all types of green or wet wood or partially seasoned wood, from which it is desired to remove all or part of the moisture content. The method and apparatus of my invention have proven particularly useful in the drying of lumber or similar massive forms of wood, such as telephone and telegraph poles, railroad ties, piles, bridge stringers, etc., which commonly contain as much as 50% to 100% of water on a

dry weight basis. Also, wood chips, pulp flour, etc. may be dried. Effective drying of the wood to low moisture content with hot organic vapor in the system of my invention renders them especially suitable for and receptive to impregnation with preservative materials such as creosote. The system of my invention is especially adapted for the treatment of massive pieces, and utilizing therefor evaporators, drying chambers, condensers, separators and other equipment of industrial size and design, and operable at atmospheric pressure or at pressures somewhat less than atmospheric, but nevertheless practical for large scale industrial use. The drying operation does not require the use of extremely high vacuum, such as is used for degasification and dehydration of electrical and other specialized products having normally only a few percent moisture content.

For effecting dehydration of the wood in accordance with my invention, I may use any suitable organic material which can be vaporized and which vapor will permeate wet wood and flash off the moisture content thereof without deleteriously affecting the wood. This involves simply a selection of a suitable material as above indicated, of which there are numerous and practically unlimited examples. Representative but non-limiting classes and specific examples of satisfactory materials which may be vaporized and used effectively for drying wood in accordance with my invention are as follows:

Organic compounds, whether saturated or unsaturated, chain or cyclic, and any of their homologues that might be suitable for this procedure, such as alcohols, ethers, amines, acids, aldehydes, ketones, esters, halides, cyanides, sulphides, polyhydric alcohols, anhydrides such as phthalic and nitro compounds; of which the following are examples:

n-Decane	n-Decanoic acids
n-Decyl alcohols	n-Decyl ketones
n-Decyl ethers	n-Decyl aldehydes
n-Decyl amines	n-Decyl cyanides
n-Decyl esters	n-Decyl sulphides
n-Decyl halides	

Preferred examples of suitable organic drying mediums are creosote, petroleum distillates, coal tar, wood tar or wood distillates, and the following:

Aromatic hydroxy compounds:
- Phenols
- Cresols
- Xylenols

High boiling acids:
- Oleic

High boiling alcohols:
- Amyl
- Isopropyl
- Isobutyl
- Diethylene glycol
- Glycerol

Aldehydes:
- Butyric aldehyde
- Benzaldehyde
- Crotonaldehyde
- Furfural

High boiling amines:
- Aniline
- Dimethyl-aniline
- Mono-, di- and tri-ethanolamines
- Pyridines
- Quinolines

High boiling esters:
- Butyl acetate
- Amyl acetate
- Butyl lactate
- Dibutylphthalate
- Diamylphthalate
- Glycol monoethyl ether acetate
- Isopropyl lactate
- Octyl acetate
- Diglycololeate
- Glycol stearate

High boiling ethers:
- Diamyl ether
- Diethylene glycol monoethyl ether

Halides:
- Chlorobenzenes
- Chlorinated phenols
- Nitrochlorobenzenes
- ortho-Dichlorobenzenes
- ortho-Nitrochlorobenzenes
- para-Dichlorobenzenes

Nitro compounds:
- Nitrobenzene
- ortho-Nitrotoluenes

Hydrocarbons:
- Benzenes
- Toluenes
- Mesitylenes
- Cumenes
- Naphthalenes
- Diphenyl

Ketones:
- Benzophenone

For a further and more detailed discussion of the method and apparatus of my invention and the particular operation thereof for drying wood, reference is made to the accompanying drawing, in which:

Fig. 1 is a diagrammatic representation of one complete drying system of my invention;

Fig. 2 is a modification of the drying system wherein the usual type of creosoting plant has been modified for operation according to my invention, and the high temperature, partial condenser is omitted; and

Fig. 3 is a graph illustrating the variation in effective drying with variations in drying medium concentration in the drying chamber.

The general system and method of carrying out the drying operations of my invention, with reference at first to Fig. 1 of the drawing, comprises placing the material to be dried, such as wooden poles, or debarked logs, 10, containing a high percentage of moisture, commonly 50% or higher, in a drying chamber 11 and supplying the highly heated organic vapor used for dehydrating the poles 10 from a vaporizer or evaporator 12. The mixture of water vapor liberated from the poles and the spent organic vapor is fractionally condensed in a dephlegmator or high temperature, partial condenser 13, mentioned hereinabove, that condenses a substantial fraction of the organic vapor; the uncondensed water vapor and any steam distilled organic vapor being conducted over to a low temperature, complete condenser 14 for condensation and subsequent separation in a separatory funnel or separator 15 of the organic and water condensates. The partial condenser 13 effects condensation and recovery of a substantial fraction of the organic vapor free of water and accordingly it lightens the normal load on the complete condenser 14 and permits more rapid operation of the system. However, when the moisture content of the wood is low or where somewhat slower drying is economically permis-

sible, as is often the case in plant size operation, the partial condenser 13 may be omitted and the complete condenser 14 used for joint condensation of all of the organic vapor and water vapor.

The high temperature organic condensate from partial condenser 13 and the low temperature condensate returned from the complete condenser 14 through separator 15 are collected and pooled in a condensate return tank 16, as mentioned hereinabove. Small amounts of water contained in the above mentioned low temperature condensate would cause excessive foaming and pressure surges in the system if this condensate were returned directly to the highly heated supply of organic material used for drying. This difficulty is avoided in my improved system by pooling the high temperature organic condensate and the low temperature condensate in the return tank 16, the temperature of which is maintained above the boiling point of water so that the small water content of the collected condensate is flashed-off leaving behind the dehydrated organic condensate which is then safely returnable to the vaporizer 12. The heat necessary for vaporizing the water in the condensate return vessel is supplied principally by the high temperature organic condensate collected there. However, this heat may be supplemented by additional heating means if desired, and when the system is operated without a partial condenser, such additional heating means is principally relied upon. The dewatered organic condensate collected in the return tank 16 is returned as needed to the vaporizer 12 for vaporization and reuse in the drying operation.

Instead of using a separate evaporator for evaporating the organic material used for drying the wood in accordance with my invention, I may employ the arrangement disclosed in my prior Patent No. 2,273,039, issued February 17, 1942. In that arrangement, the organic drying material is fed into the bottom of the drying chamber and evaporated from there by suitable heating means so that the organic vapor produced is brought directly into contact with the wood to be dried. My original arrangement also avoids the necessity of using a condensate return tank, such as shown in Figures 1 and 2 in the present drawings, and instead returns the organic condensate directly to the drying chamber.

With this original arrangement, the water vapor liberated from the wood and the spent organic vapor may be subjected to vapor phase or liquid phase separation. In the vapor phase separation, the major portion of the organic vapor is condensed at a relatively high temperature and returned directly to the drying chamber; and a lesser portion of uncondensed, steam-distilled organic vapor is condensed along with the effluent water vapor, and the resulting condensate is then separated so that the water is discharged to waste and the remaining organic condensate is returned to the drying chamber. In the liquid phase separation, all of the organic vapor and water vapor is condensed together and the combined condensate run through a separator having one line discharging the water to waste and another line conducting the entire organic condensate to the drying chamber.

Any small amounts of entrained moisture in the organic condensate which is returned to the drying chamber in this arrangement would be flashed-off quickly by the heat applied to the drying chamber, and the latter would thereby serve the purpose of the condensate return tank.

While this original arrangement avoids the use of a separate evaporator and also a separate condensate return tank, I have found it advantageous in most practical applications of my drying process to employ these separate pieces of equipment and their operations. Use of a separate evaporator increases the drying capacity of the drying chamber and avoids possible contamination of the wood with the liquid organic material. Use of the condensate return tank avoids returning small amounts of water to the heated drying system, which in some cases, as heretofore mentioned, would produce foaming and pressure surges.

Using apparatus of the type shown in Fig. 1, the poles 10 are subjected to the dehydrating treatment for a few hours, such as for example 4 to 12 hours, until the desired low moisture content or complete freedom from moisture is obtained, as desired. The poles are then ready for removal or for subsequent preservative treatment.

Referring now more in detail to the apparatus shown in Fig. 1, and beginning with all valves closed, the apparatus and method of operation may be described in terms of a typical drying cycle as follows.

Valves 17, 18, 19 and 20 are opened, thus bringing the evaporator 12 to atmospheric pressure through lines 21, 22 and 23, which lead to the partial condenser 13, lines 24 and 25 connecting partial condenser 13 with complete condenser 14, and line 26 leading to the separator 15, which may be opened to the atmosphere through valve 20 mentioned above. Valve 27 is then opened admitting organic drying medium from storage (not shown) through line 28 to pump 29, which is driven by motor 30, and, after opening valves 31 and 32, pump 29 is started and the evaporator 12 is filled through line 33 with organic material to the desired level, usually several inches above the heat transfer coils 34. After filling the evaporator, pump 29 is stopped and valves 27, 31 and 32 are closed.

The circulation of heat transfer medium is then started through coils 34 to bring the evaporator 12 up to operating temperature. The heat transfer medium may be any suitable material, such as a heat transfer oil or diphenyl oxide, and circulation is effected from a heat absorber 35 through line 36 to coils 34 and then back through return line 37 which includes expansion tank 38 and circulating pump 39 powered by motor 40.

Heat input to the evaporator 12 is regulated by a thermostatic control 41 arranged on the heat absorber 35 and actuated by a temperature-sensitive element 42 exposed in the drying chamber 11. By this means, the temperature in the drying chamber 11 may be maintained in correspondence with any desired degree of concentration of organic drying medium, in accordance with considerations to be explained hereafter, by setting the control device 41 at the temperature corresponding to this concentration. The evaporator 12 is also appropriately provided with a safety valve indicated at 43.

Where temperature requirements can be met by steam, the coils 34 may be supplied with steam instead of the special liquids mentioned above. In such cases, it is also possible to lead the steam condensate from the coils 34 to a heat exchanger which may be used to supply the heat requirements of condensate return tank 16. An arrangement of this sort is illustrated in Fig. 2 and will be discussed further in that connection. The customary types of process steam boilers, however,

are limited to a steam pressure of not more than about 200 pounds per square inch, which corresponds to a temperature of about 390° F. The temperature required in the vaporizer or evaporator 12 depends upon the boiling point of the drying medium, which may range from about 260° F. to 450° F. Where temperatures above 350° F. are used, the evaporator is most satisfactorily heated by circulating hot oil.

As the evaporator 12 heats up, the vapors formed pass over through valve 17 to partial condenser 13 which is maintained at condensing temperature by means described below. The resulting condensate may be returned to the evaporator by opening valve 44 in line 45 which branches off of the condensate return line 46 from partial condenser 13. It may also be desirable during this period to allow moderate drainage from evaporator 12 to condensate return tank 16 and effect recirculation of the drained material by pumping from tank 16 to the evaporator, in order to preclude layering or stratification of any water which may be present in the drying medium as supplied to the evaporator from storage and which might thus be trapped at the bottom of the evaporator. This may be done by additionally opening valve 46a so that drying medium will drain from evaporator 12 through line 45 and, together with condensate from partial condenser 13, through line 46 to return tank 16. The drying medium may be returned from tank 16 to evaporator 12 by opening the tank through valve 57 to pump 29, and then starting the pump to recirculate the drying medium through line 33, which includes valve 31, and through valve 32 opened into line 94, which, as described below, discharges into evaporator 12 through spray nozzle 93. Reference is made to the description of Fig. 2 for a disclosure of a further arrangement by which such drainage and recirculation may be effected.

When the temperature in evaporator 12 has reached the level at which the wood is to be processed, valves 17, 18 and 44 are closed, and the organic vapor is allowed to enter drying chamber 11 (in which the wood to be processed has been placed) by opening valve 47 which connects line 21 to a vapor manifold 48 from which the vapor is fed to chamber 11 through inlet ports 49. The ports 49 may be equipped with conventional valve-like dampers (not shown) to insure a uniform rate of flow to all parts of the drying chamber 11, and chamber 11 may be further provided internally with conventional perforated floor plates (not shown) for further dispersing the vapor. Chamber 11 also has a hinged door 58 for introducing and removing the poles 10 (or other material to be processed) which may be supported by means such as tram 51 riding rails 52.

The arrangement described above by which the evaporator 12 may be connected directly to the partial condenser 13 allows the drying chamber 11 to be by-passed so that while the evaporator is being brought up to temperature, or at other times when the evaporator is at operating temperature, the drying chamber may be opened to introduce or remove the material being processed without having to shut the evaporator down or wait for it to heat up. By thus being able to bring the evaporator 12 up to temperature before connecting it to drying chamber 11, it is possible to shorten appreciably the time required to bring chamber 11 up to operating temperature. This time may be further shortened by first building up pressure in evaporator 12 to store additional heat which is then delivered quickly to chamber 11 when valve 47 is opened.

Only a short period, usually about 30 minutes, is required to bring the temperature in chamber 11 up to that of evaporator 12. Material condensing in chamber 11 during this start-up period is drained to condensate return tank 16 by opening valve 53 to line 54 which includes a check valve 55 and is connected to tank 16 through branching line 56. If this material contains substantial amounts of water it can be pumped to separator 15 by additionally opening valve 57 in line 54, which will allow the condensate to flow to pump supply line 28 through connector 59, starting pump 29, and opening valves 59 and 68 so that the discharge to the pump will be led to separator 15 through line 33 to branch line 61 and in turn through line 62 which branches from line 61.

As the drying chamber 11 is being brought up to operating temperature, and after it has been charged with the material to be processed, valve 63 in line 25 is opened to allow the vapors formed, to escape from chamber 11 through outlet ports 64 into outlet vapor manifold 65, from which they pass on through line 23 to line 25, and completely expel air from the system through complete condenser 14 and separator 15 at valve 20. The system is then operated on complete condenser 14 (which is cooled by means described below) with the partial condenser 13 by-passed; the by-passing being continued until the vapor entering the condenser 14 has reached a temperature sufficiently above the boiling point of water (at least 240° F. to 260° F.) to make it possible to pass the vapor through the partial condenser 13 and cause sufficient lowering of the temperature to condense most of the drying medium without condensing water. This temperature will be reached in about one hour after introduction of vapor to the chamber 11 is begun, and within a short time thereafter a level approximately equal to the temperature in chamber 11 is reached. Under this steady condition the partial condenser can be operated satisfactorily. Valve 63 is accordingly closed and valves 66 and 18 are opened, and fractional condensation of organic vapor in partial condenser 13 is begun. Valve 20 may then be closed if it is desired to place the system under liquid seal (not shown).

A condensing temperature, above the boiling point of water but below the boiling point of the organic material, is maintained in partial condenser 13 by tube section 67 through which cooling water from supply line 68 may be circulated by opening valve 69. Tube section 67 controls the temperature of the vapor passing up through partial condenser 13 so that the greater part of the organic component is condensed and may be returned to condensate return tank 16 through line 46 by opening valve 46a. The uncondensed water vapor and any steam distilled, organic vapor fraction effluent from the partial condenser 13 pass over through line 24 and valve 18 into line 25, which leads to complete condenser 14.

Partial condenser 13 is further equipped with a temperature-sensitive element 70, situated in the vapor space above tube section 67 and connected with a thermostatically operated valve 71 on the discharge side of tube section 67. This arrangement allows the rate of flow of cooling water to be regulated in relation to the temperature which it is desired to maintain in partial condenser 13. A desirable range of temperature in this respect is from about 220° F. to 260° F. so

that the water vapor passing over to the complete condenser 14 will be very close to the boiling temperature of water.

Condenser 13 is also equipped with a layer of "Raschig" rings 72, or similar column packing, which is supported between perforated plates 73. The Raschig rings 72 are conventional, numerous, small, ceramic pieces in the form of short, tubular sections or rings, and provide a large surface area for condensation of the organic vapors.

The bottom section of partial condenser 13 in which the water-free organic condensate collects, holds sufficient liquid to allow any entrained water vapor to break away from the surface. A sight glass 73a is also arranged on partial condenser 13 for gauging the liquid level in this bottom section. Photo-electric controls similar to the arrangement described below in connection with Fig. 2, for automatic pumping from the condensate return tank, may, if desired, be provided on sight glass 73a to actuate a valve (not shown) in line 46, in relation to the liquid level in the bottom section of partial condenser 13, and thus effect automatic drainage from condenser 13.

The above mentioned uncondensed water vapor and steam distilled organic vapor fraction effluent from the partial condenser 13 are condensed in low temperature, complete condenser 14, and the resulting condensate is drained through line 26 to separator 15 where separation of water and organic material layers is effected. The condensing temperature in condenser 14 (which should of course be below the boiling point of water, about 180° F., for example) is maintained by a tube section 74 similar to the tube section on condenser 13 and fed from the same circulating water supply line 68 through branch line 75 which includes valve 76.

Complete condenser 14 has a condensate receiving portion 77 which acts as a reservoir when batch separations of water and organic drying medium are being made in the associated separator 15. This reservoir arrangement is completed by valve 19 in line 26 which connects condenser 14 and separator 15. A sight glass 78 is situated on the condensate receiving portion 77 so that the condensate level may be observed and prevented from rising high enough to flood tube section 74.

The separator or separatory funnel 15, of which many modifications are possible, is constructed in the presently described embodiment of my invention as a cylindrical tank 79 having a cone-shaped bottom portion 80. Arranged on opposite sides of the bottom portion 80 are glass windows 81 through which the interface in separator 15 may be observed as drying media and water are separated.

Separator 15 is operated by allowing condensate (drying medium and water), drained from condenser 14 through line 26, to collect in the separator in a sufficient amount, which may be gauged by a sight glass 82, and then shutting off line 26 by closing valve 19 and permitting the condensate to stand until a separation into layers occurs.

The procedure followed after satisfactory layer formation is obtained, will depend on whether the organic drying medium being used is lighter or heavier than water. As the drying medium will usually be lighter than water, the operation of separator 15 is described below on the assumption that such a condition obtains. It will be understood, however, that when the drying medium is in fact heavier than water it will only be necessary to reverse the sequence in which the discharge valves are manipulated.

When the condensate has separated satisfactorily into layers, valve 83, which is a three-way valve situated at the apex of cone portion 80, is opened to line 84 and the lower water layer in separator 15 is drained to waste, the discharge to waste being measured by meter 85 in line 84 as an indication of the progress of the drying operation being conducted in chamber 11. As the interface approaches the apex of cone portion 80, its position is observed through the glass windows 81 and a final sharp cut of the interface is obtained by observing it through bullseye 86. Valve 83 is then opened to line 87 and the remaining substantially water-free condensate is passed through three-way valve 88 to line 89 which leads to condensate return tank 16.

Separator 15 is also connected so that it may be isolated on the circulating system from pump 29 through line 33, valve 59, line 61, branch line 62 and valve 60, and then back through valve 83, line 87, valve 88, line 54, connector 58 and line 28. This connection makes it possible, when the organic material from storage contains water, to conduct the organic material in batches to separator 15 for separation of the water before delivering it to the evaporator. Also, this connection permits recirculation of condensate from return tank 16 in cases where more than usual amounts of water are collected in tank 16 as might occur during the "start-up" periods.

Separator 15 may, if desired, be further equipped with a steam coil 90 in order to heat the condensate in cases where separation is not as rapid as desired. By this means, liquids which possess different density-temperature gradients from that of water may be made to separate more rapidly.

When creosote or petroleum fractions, for example, are being vaporized in evaporator 12, it is desirable to return condensates as quickly as possible from both the separator 15 and the condensate return tank 16 to the evaporator 12. If the lower fractions of these materials which vaporize first in evaporator 12, and are condensed in the partial condenser 13 and complete condenser 14, are allowed to accumulate in condensate return tank 16 and separator 15, it becomes difficult to maintain the temperature in the evaporator 12 constant, since removal of the lower fractions has a tendency to increase the boiling point of the drying medium remaining. Thus, if the condensate is not returned to the evaporator 12 rapidly under these conditions, the temperature of the vapor entering the drying chamber 11 cannot be maintained at a uniform level. For further insuring uniform operating temperature, separator 15 may be modified to effect continuous separation, and condensate return tank 16 may be equipped with controls for automatic return of organic condensate to the evaporator. Arrangements of this sort are illustrated and will be described in connection with Fig. 2.

In view of the high temperature maintained in return tank 16 by hot organic condensate from partial condenser 13, small amounts of water contained in the organic condensate returned from separator 15 are flashed-off in return tank 16 and the resulting vapor may be removed through line 91 by opening valve 92. In cases where the temperature in return tank 16 is not sufficient to boil off the water returned with the organic condensate from separator 15, the supply to evaporator 12 may be introduced through spray nozzle 93

by opening line 94 through valve 32 off of supply line 33 from pump 29. The organic material will then be forced into the vapor space above the liquid in evaporator 12 where the water will be immediately flashed-off and pass on through the drying chamber 11 to the partial condenser 13. Alternatively, as previously pointed out, a suitable temperature may be maintained in return tank 16 by heat supplied, entirely or in supplementary amounts, from auxiliary heating coils indicated in Fig. 1 at 16a.

Return of condensate from condensate return tank 16 to evaporator 12 is accomplished by opening valves 57, 31 and three-way valve 32 to lines 33 or 94, and starting pump 29. After steady operating conditions are established, the condensate being thus returned to evaporator 12 can be profitably diverted to absorb heat from the vapor entering high temperature, partial condenser 13 by opening valves 59 and 95, rather than valve 31, so that the condensate is circulated by line 61 through a lower tube section 96 situated to receive heat from the hot vapor introduced in condenser 13 through line 23.

Through-put of condensed material to evaporator 12 (which is an indirect measure of the amount being vaporized) is determined by meter 97 in line 33 or meter 98 in line 46, or both; check valves (99 and 100, respectively) being included in each line beyond the meter. It is important to have a readily available measure of the through-put, such as meters 97 and 98 provide, in order to regulate properly the heat input to evaporator 12 so that the minimum amount of boil-up required for the processing of material in drying chamber 11 is delivered.

When the desired amount of moisture has been removed from the wood in chamber 11, of which a measure is provided by the amount of water discharged to waste through line 84 as recorded by meter 85, valves 47 and 66 are closed to shut off chamber 11. Valve 17 is then opened and valve 18 is closed, and evaporator 12 is allowed to idle on partial condenser 13 while the processed wood is removed from chamber 11 and preparations are made for a succeeding treatment.

Before the processed wood is removed from chamber 11, however, it is usually desirable to subject the wood to a suitable vacuum period in order to recover some of the organic material that has distilled into the wood and thus leave it free of excess chemical in the outer layers, and also to lower the temperature in chamber 11 so that the processed wood can be conveniently handled. For this purpose, any convenient means for establishing vacuum may be employed, such as vacuum pump 101 which is connected to complete condenser 14 through line 102 and valve 103. The vacuum is impressed on chamber 11 through complete condenser 14 by opening valve 63 in line 25. Vapor is thus drawn from chamber 11 to complete condenser 14 where it is condensed and collected in bottom portion 77. After the vacuum has been impressed for a period sufficient to obtain satisfactory results under the particular circumstances, the collected condensate is drained to separator 15 and separated according to the methods employed during normal operation. If it is desired to continue vacuum for a longer period than can be accommodated in this manner, intermittent separations may be made by equalizing separator 15 with condenser 14 through line 104, which includes valve 105, to allow condensates to enter separator 15 through line 26, and then closing valve 19 and opening separator 15 to the atmosphere through valve 20 so that the separation may be made. Intermittent separations might also be made by employing a conventional vacuum trapping means (not shown) between complete condenser 14 and separator 15.

During this period of vacuum treatment, partial condenser 13 may be vented to the atmosphere through valve 24a on line 24, so that evaporator 12 can be brought up to temperature and otherwise prepared for processing the next charge of wood while the vacuum period is being applied.

The embodiment of my invention illustrated in Fig. 2 operates in substantially the same manner as the apparatus shown in Fig. 1, the major points of difference being that Fig. 2 illustrates an adaption of the usual type of creosoting plant for operation according to my invention, and the high temperature, partial condenser has been omitted from the drying system in this instance.

As illustrated, the apparatus in Fig. 2 comprises a drying chamber 107 of sufficient size to accommodate massive wood pieces, such as telephone poles and the like, and an associated evaporator 108, condenser 109, separator 110, and condensate return tank 111, all of corresponding size and capacity.

Starting with all valves closed, with the drying chamber 107 charged with the material to be dried, and with the evaporator 108 filled to a proper level with organic drying medium (admitted from storage—not shown—through line 112 and valve 113 to line 114 which leads to motor-pump set 115, and pump discharge line 116 which includes check valve 116a and valve 117), the present embodiment of my invention is operated to dry wood as follows:

Evaporator 108 is opened to condenser 109 through valve 118 in line 119 which joins line 120; valve 121 on drain line 122, and valve 123 on drain header 124 which also includes check valve 125, are opened to condensate return tank 111; valve 126 in line 127 running from condenser 109 to separator 110 is opened; and equalizer line 128 is opened between condensate return tank 111 and condenser 109 at valve 128a, and to separator 110 at valve 129, and to the atmosphere at valve 130. The system is thus opened to the atmosphere with the drying chamber 107 by-passed.

Heat is then supplied at a maximum rate to bring evaporator 108 up to operating temperature. For this purpose, the evaporator is provided with a tube section indicated at 131 which is fitted with a header 132 having suitable inlet and outlet connections 133 and 134, respectively, for circulating steam supplied at a pressure of about 125 lb./sq. in. The tube section 131 is adapted for an operating temperature of 275° F.–300° F.

When the temperature in evaporator 108 reaches about 200° F., circulation of cooling water through line 135 to a conventional tube section (not shown) in condenser 109 is started in order to condense water vapor passing over from the evaporator. Also, drain line 136 from evaporator 108 to condensate return tank 111 is opened through valve 137 at this time in order to allow moderate drainage and thus prevent any stratification of water at the bottom of the evaporator; and return tank 111 is opened at valve 138 through line 114 to pump 115, pump discharge line 116 is opened at valve 117, and pump 115 is started to recirculate the drying medium that is drained from the evaporator in this manner.

The water condensate formed in condenser 109, together with any steam distilled organic vapor effluent from evaporator 108, drains to separator

110 through line 127. After the evaporator temperature reaches about 230° F., all of the water vapor will have passed over to condenser 109, so that when water condensate stops collecting in separator 110 and a satisfactory layer formation occurs, the water may be drained to waste by opening three-way valve 139 to line 140, after which valve 139 may be opened to line 141 to drain any organic condensate to condensate return tank 111. Drain line 136 from evaporator 108 is then closed, and, when return tank 111 has been emptied, pump 115 is stopped and lines 114 and 116 are closed. As soon thereafter as the evaporator temperature reaches the boiling point of the organic drying medium and organic condensate begins to collect in separator 110, the drying operation may be started.

To start the drying treatment, valve 118 is closed, and valves 142 are opened to introduce organic drying medium from evaporator 108 to drying chamber 107 through vapor intake lines 143. Outlet valves 144 are also opened into the vapor header 145 situated over drying chamber 107, and the vapor header is in turn opened through valves 146 into lines 120 and 147 running to condenser 109; and drain line 148 (which also includes check valve 149) is opened at valve 150 to condensate return tank 111, and line 151 connecting vapor header 145 with drain line 148, is opened at valve 152.

As the drying chamber 107 is cold when the organic drying medium is first admitted, some of the drying medium condenses and drains through line 148 to condensate return tank 111. The steam discharge from evaporator tube section 131 is accordingly diverted at this time through line 153 to heat exchanger coils 154 in return tank 111 to heat the organic condensate collecting there. While the condensate in return tank 111 is heating up, the liquid level, as gauged by a sight glass 155, is maintained just above the top of heat exchanger 154 by opening valve 138, as required, to drain organic condensate through line 114 to pump 115 which may be started to return the condensate through line 116 and valve 117 to evaporator 108. When the temperature in return tank 111 reaches about 230° F., photoelectric cells 156 and 157 adjustably arranged on sight glass 155 may be operated to pump the organic condensate automatically. That is, when the liquid in return tank 111 reaches an upper level that will be indicated in sight glass 155 where the upper photoelectric cell 156 is located, an electrical circuit (not shown) to the motor-pump set 115 is energized and the pump is operated until the liquid in tank 111 falls to a level that will be indicated in sight glass 155 where the lower photoelectric cell 157 is located, whereupon the motor-pump circuit de-energizes and the pump stops operating. When the liquid in tank 111 again reaches the above mentioned upper level, the operation cycle is repeated. By adjusting the photoelectric controls for automatic pumping between narrow level limits, the composition of the drying medium in the evaporator is maintained more nearly uniform with a consequent improvement in the uniformity of the evaporator temperature and operation, especially when, as previously mentioned, drying media having fairly wide boiling ranges, such as creosote and petroleum fractions, are used.

As the drying chamber 107 is brought up to operating temperature and substantial amounts of liberated water vapor mixed with spent organic vapor begin to pass over to condenser 109 forming condensate which collects in separator 110, automatic separations may also be made. For this purpose, separator 110 is equipped with an auxiliary, electrically controlled, valve 158 controlling the flow in a line 159 running from near the top of the cone portion 160 of the separator to line 140 which carries the separated water to waste. A second valve 161 of the same type is situated on a line 162 tapping the lower portion of the body of the separator and running to the organic condensate line 141 to condensate return tank 111. As previously pointed out, separator 110 receives mixed water and organic condensate from condenser 109 through line 127. For batch operation, the layers which form as each batch is allowed to stand are selectively drained to the appropriate discharge line by manipulating valve 139 in accordance with observations of the interface in windows 163 and finally in bullseye 164.

For automatic operation, valve 139 is closed and the auxiliary valves 158 and 161 are used to allow the separator to be drained continuously. To operate the separator in this manner, valve 158 is arranged in a normally closed position and valve 161 in a normally open position, each of these valves having actuating circuits running to a pair of electrodes 165 and 166, respectively. These electrodes are disposed inside the separator 110 and are designed to complete the circuit to their respective valves when immersed in the water layer being separated, the water acting as a conductor between the electrodes. The mixed water and organic condensate is accordingly allowed to drain continuously from condenser 109. Baffle plates 167, comprising perforated partitions or other baffle means spaced laterally in separator 110, slow the flow of entering condensate so that channeling is prevented and layer formation is substantially effected by the time cone portion 160 is reached; the tortuous flow imposed by the baffle plates 167 spaced beyond the cone portion 160 further insuring that only substantially water-free organic condensate reaches the outlet to line 162 through auxiliary valve 161. As a result, an interface is maintained at a substantial level in cone portion 160, and, as auxiliary valve 161 is disposed in open position, continuous discharge from the organic condensate layer is effected through lines 162 and 141 to condensate return tank 111, and water is intermittently drained through line 159 and line 140 to waste by actuation of valve 158.

The efficiency of the continuous separation is maintained, despite variations of the interface level due to the difference in amounts of water vapor liberated at different stages of the drying process and other fluctuations in operating conditions, by actuating the auxiliary valves 158 and 161 through electrode pairs 165 and 166 in relation to the interface level. Thus, electrode pair 165 actuating valve 158 is disposed in cone portion 160 at a level slightly above that of the inlet to line 159 through valve 158. As long as the interface level remains below the level of electrode pair 165, operation continues as described above and valve 158 remains closed. If the interface rises above the level of electrode pair 165, the circuit to valve 158 is energized so that this valve opens and allows additional discharge of water through line 159. Usually this additional discharge will cause the interface to return gradually to a point below the electrode pair 165, whereupon valve 158 returns to closed position. However, at certain times the relative

proportion of water in the condensate flow to separator 110 may be large enough to cause the interface to continue to rise. To prevent the water layer from flooding the inlet to line 162 under these conditions, the second electrode pair 166 is positioned at about the level of the bottom of the body portion of separator 110 in order to close auxiliary valve 161 when the interface rises to this level. Only water will then be discharged from the separator until the interface level falls below electrode pair 166 and allows valve 161 to return to its normally open position so that organic condensate may again be drained to condensate return tank 111.

Automatic operation of separator 110 in this manner, together with the automatic condensate pumping controls available on condensate return tank 111 allow a very rapid and efficient handling of the organic drying medium in the liquid phase. The condensate collected in return tank 111 is conditioned for return to evaporator 108 by heat exchanger 154 which maintains a temperature in tank 111 above the boiling point of water so that small amounts of water drained off with the organic condensate from separator 110 are immediately vaporized in tank 111 and pass off through line 128 and valve 128a to line 147 and are thus returned to condenser 109.

Besides being arranged for return of organic condensate to evaporator 108, the discharge line 116 from pump 115 has two branches, one of which—line 168—runs through valve 169 to separator 110, and the other—line 170—doubles back through valve 171 to supply line 112 so that return tank 111 may be emptied to storage when desired.

Provision for measurement of through-put to evaporator 108 is made by situating a meter 172 in line 116, and a second meter 173 is arranged in line 140 to measure the water discharged to waste as an indication of the progress of the drying operation.

After the wood being processed in chamber 107 has been dried to the degree desired, a suitable vacuum period, such as heretofore described in connection with Fig. 1, may be imposed to recover organic material from the outer layers of the wood and to lower the temperature of chamber 107 so that the processed wood can be conveniently handled. For this purpose, the heat to evaporator 108 is cut off; the photoelectric controls 156 and 157 are disconnected, and condensate return tank 111 is pumped empty; the vapor intake lines 143 are closed at valves 142; and the drain header 124 from vapor intake lines 143 is closed at valves 121 and 123, and line 128 is closed at valve 128a. The equalizer line 126 between separator 110 and condensate return tank 111 is then closed to the atmosphere at valve 130 and opened to a means for establishing vacuum (not shown) at valve 174. When the system has thus been subjected to a vacuum for a suitable period, the vacuum is broken, the dried wood is removed from chamber 107 and preparations are made for a subsequent treatment.

Using an apparatus of the type described herein, I have found it possible to dry wood pieces up to 5 inches in diameter completely in about 2 hours, and pieces as large as 12 inches in diameter in about 8 hours; in each case between 20 and 30 pounds of water per cubic foot are removed, in the time stated, from initially stump green wood.

In carrying out the drying operation, the atmosphere in the drying chamber should be limited to a moisture vapor content of not more than about 50% of the total vapor in the chamber. The critical nature of this moisture vapor limit is illustrated by Fig. 3 of the drawing, which is a curve showing the relative moisture removals at varying concentrations of the drying medium in the atmosphere in the drying chamber. This curve was derived from data obtained from actual tests conducted with six foot sections cut from forty-five foot Southern pine poles having a diameter of about 9 inches. The initial moisture content of the pole on which the tests designated in Fig. 3 as series 1 were run was about 83%, and that of the pole for the series 2 tests about 53%. The pole sections were each dried for six hour periods at a particular drying medium concentration in the drying chamber atmosphere, as indicated in Fig. 3. The moisture removal data obtained in this manner were then extrapolated to a drying medium concentration of 100%, and expressed as a percent of the indicated moisture removal at 100% concentration. The resulting values are shown plotted in Fig. 3.

The rapid decrease in the effectiveness of the drying operation at the moisture vapor limit of 50% is approximated is strikingly illustrated in Fig. 3. While it is possible to operate at a maximum moisture vapor content approaching 50%, such operation falls at the point of steep descent in terms of relative moisture removal, and consequently close control must be exercised in regulating the drying chamber atmosphere in order to obtain effective drying operation. In usual practice it is desirable to operate below the critical concentration of 50% moisture vapor. A commercially advantageous concentration of drying medium is about 65%, corresponding to a moisture vapor content of about 35%.

The advantage of a concentration of about 65% is further indicated by noting from the curve in Fig. 3 that the relative amounts of water removed when operating at 50% and 75% drying medium in the drying chamber atmosphere are about 20% and 85%, respectively, and that above a drying medium concentration of 75% the increase in water removal is much lower. A concentration of 65% is thus about the point of most economic use of drying medium. The concentration may be further increased to advantage when the rapidity of drying is important in the particular drying operation being undertaken, but unless this factor is of particular importance, it is advisable from the point of view of economic operation not to exceed a concentration of about 90%.

In connection with the regulation of the atmosphere in the drying chamber according to the considerations stated above, I have found that the water vapor in the critical proportions stated behaves as a fixed gas in the chamber, since the atmosphere in the chamber is maintained at a temperature above the boiling point of water throughout the drying period, after the start-up period, thus precluding the presence of water as liquid in the chamber; that the organic vapors, when mixed in the drying chamber with water vapor in the critical proportions recited above, substantially obey Dalton's law in the range of temperatures which will give a concentration of organic vapor in excess of substantially 50% by weight in the atmosphere surrounding the material being dried when water vapor in a corresponding proportion is the "B" component of the system (in the case of polar substances

whose molecules associate with those of water in the vapor phase, obviously Dalton's law does not obtain. However, it is possible to determine empirically the temperatures which will insure a percentage of such organic drying medium in the vapor in excess of substantially 50%); and that the water vapor, when present in concentrations of not more than substantially 50% by weight, behaves as an inert material with respect to hydrolyzing action on the wood when it is in the presence of vaporized organic substances constituting not less than substantially 50% of the total weight of vapor in the system.

When the atmosphere in the drying chamber is controlled in accordance with the critical conditions described above, the drying operation is characterized by absence of hydrolytic effects; the wood and wood products are effectively dried in a satisfactorily rapid time period, e. g., less than 15 hours in the case of green poles of 12" diameter and in shorter periods for less severe examples; the fuel costs, at a drying medium concentration of about 65%, are reduced to about 50% of that involved where the process is operated using percentages of organic drying material in the vapor phase of substantially 100% by weight, and the heat input is also materially decreased which in turn decreases the amount of organic material in the vapor and reduces the amount of organic condensate which must be handled.

In analyzing data from operations using my process on runs utilizing various percentages of organic material to water vapor (evolved from the wood), I have found that there is a logarithmic relation between the amount of water remaining in the wood at any given instant and the drying time. For example, a graph of the drying operation will yield a straight line if the logarithm of the concentration of water in the wood, expressed as the amount or percentage of water per unit volume or unit weight of wood, is plotted against time. For various percentages of organic materials in the vapor phase, which corresponds to various temperatures, the slopes of these straight lines differ. The slope constants of these lines indicate the rate of drying. This relation between water removal and drying time may be used to predict the drying effect obtainable after any given period of drying.

To regulate the drying process according to the considerations described above, vapor-pressure-temperature relations of the organic material to be used in the process are determined from samples, and a graph is made up based on Dalton's law calculations showing the relation of percentage by weight of organic material in the vapor phase (water being the "B" component) to temperature. The drying chamber temperature necessary to maintain a given concentration of organic drying medium in the drying chamber may then be selected by finding the temperature on the chart corresponding to the desired concentration. By thermostatically controlling the heat input to the evaporator as previously mentioned by means of a temperature-sensitive element exposed in the drying chamber, as at 42 in Fig. 1, which is set to maintain the temperature selected as above, the desired concentration of organic drying medium in the atmosphere in the drying chamber is obtained and maintained.

As a further illustration of the materials and procedure used in drying wood according to my invention, the following non-limiting examples are given:

A. Typical analyses of organic drying media that have been employed successfully in carrying out the vapor drying process of my invention:

COAL TAR FRACTIONS

Example I.—Crude light coal tar solvent

Color	Straw
Specific gravity 38/38° C	.868
Condition at 60° C	Liquid
Initial boiling point	91° C.

Distillation:	Per cent distilling
To 100° C	2.4
100 to 110° C	14.7
110 to 120° C	29.3
120 to 130° C	23.2
130 to 140° C	21.1
140 to 150° C	5.9
Residue above 150° C	3.4

Example II.—Crude xylol

Color	Medium straw
Specific gravity 38/38° C	.852
Condition at 60° C	Liquid
Initial boiling point	121° C.

Distillation:	Per cent distilling
To 130° C	6.0
130 to 135° C	19.3
135 to 140° C	19.9
140 to 145° C	22.5
145 to 150° C	14.5
150 to 155° C	9.0
Residue above 155° C	8.8

Example III.—Solvent naphtha

Color	Water white
Specific gravity 38/38° C	.831
Condition at 60° C	Liquid
Initial boiling point	134° C.

Distillation:	Per cent distilling
To 140° C	2.8
140 to 145° C	25.8
145 to 150° C	32.3
150 to 155° C	17.6
155 to 160° C	9.5
160 to 170° C	9.9
Residue above 170° C	2.1

Example IV.—Crude heavy coal tar solvent

Color	Dark amber
Specific gravity 38/38° C	.952
Condition at 60° C	Liquid
Initial boiling point	137° C.

Distillation:	Per cent distilling
To 150° C	.8
150 to 160° C	2.4
160 to 170° C	18.8
170 to 175° C	30.3
175 to 180° C	28.1
180 to 190° C	15.5
Residue above 190° C	4.1

Example V.—Special coal tar distillate (180 to 210° C.)

Color	Dark amber
Specific gravity 38/38° C	.976
Condition at 60° C	Liquid
Initial boiling point	176° C.

Distillation:	Per cent distilling
To 180° C	.7
180 to 190° C	38.2
190 to 200° C	36.0
200 to 210° C	15.2
Residue above 210° C	9.9

Example VI.—Neutral oil of coal tar

Color	Dark brown
Specific gravity 38/38° C	1.008
Condition at 60° C	Liquid
Initial boiling point	189° C.

Distillation:	Per cent distilling
To 190° C	1.5
190 to 200° C	5.5
200 to 210° C	21.3
210 to 220° C	25.8
220 to 230° C	20.1
230 to 240° C	13.2
240 to 250° C	5.8
Residue above 250° C	6.8

PETROLEUM FRACTIONS

Example VII.—Light naphtha

Color	Water white
Specific gravity 38/38° C	.742
Condition at 60° C	Liquid
Initial boiling point	104° C.

Distillation:	Per cent distilling
To 110° C	1.7
110 to 115° C	10.3
115 to 120° C	22.1
120 to 125° C	20.1
125 to 130° C	15.9
130 to 140° C	21.4
Residue above 140° C	8.5

Example VIII.—Medium naphtha

Color	Water white
Specific gravity 38/38° C	.777
Condition at 60° C	Liquid
Initial boiling point	166° C.

Distillation:	Per cent distilling
To 170° C	11.7
170 to 175° C	54.0
175 to 180°C	20.5
Residue above 180° C	13.8

Example IX.—Light distillate

Color	Straw
Specific gravity 38/38° C	.795
Condition at 60° C	Liquid
Initial boiling point	166° C.

Distillation:	Per cent distilling
To 210° C	15.9
210 to 235° C	32.7
235 to 250° C	26.2
250 to 270° C	17.2
270 to 285° C	7.9
Residue above 285° C	.1

B. Examples of the vapor drying process of my invention:

Example X.—Vapor drying of red oak crossties

Using apparatus arranged as described above, nine successive changes of eighteen red oak crossties taken from green stock were dried according to my invention. Moisture determinations indicated an average initial moisture content of about 70%. The drying medium used was a coal tar distillate of the type identified in Example IV above. The temperature of the drying chamber was brought up to the boiling point of the drying medium in about an hour and a half after the first introduction of vapor. This temperature was maintained for a period of 12 hours. Introduction of vapor was then stopped, and vacuum corresponding to about 25 inches of mercury was applied to the drying chamber for 2½ hours.

The final moisture content of the crossties after this treatment was about 28%.

Example XI.—Vapor drying of black gum crossties

The procedure outlined in Example X was repeated in drying two charges of black gum crossties having an initial moisture content of about 59%. The final moisture content after the drying treatment was 27%.

Example XII.—Vapor drying of mixed hardwood

The drying operation was carried out with five charges each consisting of twenty crossties selected from newly cut, mixed hardwood stock. The drying medium used was a coal tar distillate of the type identified in Example IV above. The operating conditions and moisture removal obtained are indicated below:

Charge	Heating		Vacuum		Average Initial Per cent Moisture	Average Final Per cent Moisture
	° F.	Hrs.	Hrs.	Inches of Mercury		
1	325	12	2.5	25	64.1	24.5
2	325	6	2	26	66.6	42.1
3	330	12	2	26	86.2	32.7
4	330	8	2	25	93.8	51.7
5	325	6	2	25.5	94.6	63.1

Example XIII.—Vapor drying under vacuum

The procedure of Example XII was repeated with three similar charges from the same stock, except that the vapor drying was carried out under vacuum in order to lower the operating temperature by lowering the boiling point of the drying medium. The drying medium was heated at atmospheric pressure to a temperature corresponding to the boiling point of the drying medium at the vacuum to be used. The drying chamber was then brought up to temperature under vacuum, and the vacuum was maintained for the periods indicated, after which the introduction of vapor was stopped and the drying chamber was subjected to a final vacuum period. The operating conditions and moisture removal obtained are indicated below:

Chg.	Heating			Final Vacuum		Average Initial Per cent Moisture	Average Final Per cent Moisture
	° F.	Inches of Mercury	Hrs.	Hrs.	Inches of Mercury		
1	290	13.3	9	2	26	76.2	48.8
2	250	20.6	12	2	26	68.9	40.6
3	220	24.0	15	1	25.5	78.0	51.4

In each case the crossties treated in the manner illustrated in the foregoing examples were markedly free from the adverse effects, such as checking, loss of fiber strength due to hydrolysis, case hardening, and warping, usually attendant upon the drying of wood. It will also be noted from the examples that wood may be conditioned according to the present invention with great facility for subsequent preservative treatment, for which a moisture content of 30% is generally considered optimum.

By means of the apparatus and method described and illustrated above, I have found it possible to dry wood products rapidly and efficiently and without the objectional imperfections which have resulted from the processes heretofore available. Although it has been found that equipment similar to that described is the most suitable for the operation, it should

be understood that variations may be employed which do not depart substantially from the invention herein disclosed and which will give substantially the same results. The equipment may also be adapted to drying kilns, or similar drying apparatus, in a manner which will greatly reduce operating time and increase the effectiveness of operation.

It will be noted that in the above disclosure, the methods employed are for the handling of organic drying media which are immiscible with water. In using the apparatus in conjunction with drying media which are miscible with water, it would of course be necessary to eliminate the liquid phase separator and substitute a receiving tank which would be employed as a distillation unit in conjunction with suitable fractionating columns. Also, it is apparent that the organic drying medium used in the arrangement shown should exist as a liquid at temperatures below the boiling point of water, to obviate any difficulties due to solidification of the drying medium in the separator or the condensers. To prevent the occurrence of this undesirable condition, a margin of safety between the temperature at which the drying medium begins to deposit solids and the temperature of the boiling point of water should be maintained at all times. Where it is desirable to use an organic drying medium which has a melting point above that of the boiling point of water, it is possible to establish the proper temperature characteristics for the organic material by employing it incorporated in a suitable solution. All of the organic drying media referred to above are inert to wood and wood products, that is, they have no deleterious effect on the wood. Any reactions which take place between the drying medium and the wood are of a beneficial nature.

I claim:

1. An apparatus for preserving and drying wood comprising a drying chamber, means therein for supporting the wood, an evaporator for supplying a drying medium in vapor phase to said chamber, a high temperature partial condenser for receiving water vapor and drying medium in vapor phase from said chamber and for condensing the vaporous drying medium to liquid phase, a condensate return chamber, a line leading from said partial condenser to said return chamber for returning condensed drying medium thereto, another line leading from the partial condenser to the evaporator, and a line leading from the return chamber to the evaporator for supplying condensate thereto, a low temperature complete condenser, a separator associated with said complete condenser, a line leading from the partial condenser to the complete condenser to deliver thereto uncondensed vapors of the drying medium, and water vapor, separate lines leading from said separator to said evaporator and to said return chamber respectively for returning condensed drying medium thereto, and a line leading from said return chamber to the line leading from the partial condenser to the complete condenser for delivering vapors from the return chamber to said complete condenser.

2. An apparatus for preserving and drying wood comprising a drying chamber, means therein for supporting the wood, an evaporator for supplying a drying medium in vapor phase to said chamber, a high temperature partial condenser having a high temperature tube section, and said condenser being adapted for receiving water vapor and drying medium in vapor phase from said chamber and for condensing the vaporous drying medium to liquid phase, a condensate return chamber, a line leading from said partial condenser to said return chamber for returning condensed drying medium to the return chamber, a line leading from the partial condenser to the evaporator for returning condensed drying medium to the evaporator, a line leading from the return chamber to the evaporator for supplying condensate to the evaporator, a line leading from the return chamber to said tube section of said partial condenser for delivering condensate to said tube section, and a line returning from said tube section to said evaporator to deliver the condensate to the evaporator.

3. An apparatus for drying and preserving wood, comprising a closed receptacle defining a treating chamber having means therein for supporting the wood for dehydration and impregnation, an evaporator in which a liquid drying medium is vaporized, a conductive connection through which the vapor is taken from the evaporator into the treating chamber at a temperature higher than that of the vaporization point of the moisture content of the wood, and interconnected means for progressively removing from said treating chamber the spent treating vapor commingled with the moisture vapor liberated from the wood during its treatment under the surrounding and permeating influence of the supplied vapor in the chamber, said interconnected means including a high temperature partial condenser cooperatively communicable with said treating chamber and said evaporator for condensation of said treating vapor only, and a low temperature complete condenser cooperatively communicable with said treating chamber, said high temperature partial condenser, and said evaporator for condensation of both treating vapor and moisture vapor.

4. An apparatus for drying and preserving wood, comprising a treating chamber in which the wood is placed and confined for dehydration and impregnation, means within said chamber for supporting the wood, an evaporator in which a liquid drying medium is vaporized, a conductive connection through which the vapor is taken from the evaporator into the treating chamber at a temperature higher than that of the vaporization point of the moisture content of the wood, means for progressively removing from said treating chamber the spent treating vapor commingled with the moisture vapor liberated from the wood during its treatment under the surrounding and permeating influence of the supplied vapor in the chamber, and means for separating from the removed moisture vapor the spent treating vapor taken therewith from the treating chamber and returning a condensate of such spent treating vapor to said evaporator for reuse, said last named means comprising a condensate return chamber connected to said evaporator, a high temperature partial condenser connected to said treating chamber, said evaporator and said condensate return chamber for condensation of said treating vapor only, and a low temperature condenser connected to said treating chamber, said high temperature partial condenser, said evaporator and said condensate return chamber for condensation of both treating vapor and moisture vapor.

5. A closed system adapted for drying green or wet wood with a heated organic drying vapor, in which the drying medium is condensed and re-

cycled for reuse in the system, comprising a drying chamber having means for housing and supporting the wood therein, an evaporator connected to said chamber for vaporizing the organic drying medium and supplying the hot vapor to said chamber, a high-temperature, partial condenser connected with said drying chamber for receiving the moisture vapor liberated from said wood together with the used organic drying vapor, means for maintaining the operating temperature of said partial condenser sufficiently high to prevent condensation of said moisture vapor but sufficiently low to effect condensation of said organic vapor, means for conducting the uncondensed moisture vapor away from said partial condenser, a receiver connected with said partial condenser for receiving said condensed organic drying material only, and means for recycling the organic condensate from said receiver to said evaporator for reuse therein.

6. A closed system adapted for drying green or wet wood with a heated organic drying vapor, in which the drying medium is condensed and recycled for reuse in the system, comprising a drying chamber for housing the wood and having means therein for supporting the wood, an evaporator connected to said chamber for vaporizing the organic drying medium and supplying the hot organic vapor to said chamber, a high-temperature, partial condenser connected with said drying chamber for receiving the moisture vapor liberated from said wood together with the used organic drying vapor, means for maintaining said partial condenser at sufficiently high temperature to prevent condensation of said moisture vapor but sufficiently low to effect condensation of said organic vapor, a low-temperature, complete condenser connected with said partial condenser for receiving the uncondensed effluent therefrom and for condensing the moisture vapor and residual organic vapor, and means for separating the water and organic liquid components of this condensate, a return vessel connected with said partial condenser and with the organic condensate delivery portion of said separating means whereby to receive only condensed organic drying medium, and means for recycling the organic condensate from said return vessel to said evaporator.

7. A closed system adapted for drying green or wet wood with a heated organic drying vapor, in which the drying medium is condensed and recycled for reuse in the system, comprising a drying chamber for housing the wood and having means therein for supporting the wood, an evaporator connected to said chamber for vaporizing the organic drying medium, a high-temperature, partial condenser connected with said drying chamber for receiving at least some of the moisture vapor liberated from said wood together with some of the used organic drying vapor, means for maintaining said partial condenser at sufficiently high temperature to prevent condensation of said moisture vapor but sufficiently low to effect condensation of said organic vapor, a low-temperature, complete condenser connected with said drying chamber and with said partial condenser for receiving therefrom the uncondensed organic vapor and moisture vapor and condensing the same, a separator connected to said complete condenser for receiving and separating the water and organic liquid condensates, a return vessel connected with said drying chamber, and with said partial condenser and with the organic condensate delivery portion of the separator whereby to receive only condensed organic drying medium, and means for continuously recycling the organic condensate from said return vessel to said evaporator

8. The system as set forth in claim 5, and in which the operating temperature of said partial condenser and said organic condensate return vessel is approximately 230° F. to 260° F. whereby moisture vapor is prevented from condensing and organic vapor is condensed in said partial condenser and receiving vessel.

9. An apparatus for preserving and drying wood comprising a drying chamber, means for supporting the wood in said chamber for direct contact of a drying medium with the wood, an evaporator for supplying a drying medium in vapor phase to said chamber, a high temperature partial condenser for receiving both water vapor and drying medium in vapor phase from said chamber, means for cooling said partial condenser sufficiently to condense only the vaporous drying medium to liquid phase, a condensate return chamber, a line leading from said partial condenser to said return chamber for returning condensed drying medium to said return chamber, another line leading from the partial condenser to the evaporator for returning condensed drying medium directly to the evaporator, a line leading from the return chamber to the evaporator for supplying condensate from said chamber to the evaporator, a low temperature complete condenser, a separator associated with said complete condenser, a line leading from the partial condenser to the complete condenser to deliver to said complete condenser uncondensed vapors of the drying medium and water vapor, and lines leading from said separator to said evaporator and to said return chamber for returning only condensed drying medium to the evaporator and to the return chamber, respectively.

10. A rapid, high temperature method of dehydrating wood in a closed space, which is characterized by substantially complete drying of the wood in a matter of several hours instead of days, comprising providing and maintaining in said space a saturated atmosphere of a non-aqueous, inert, organic vapor that does not deleteriously affect the wood and which permeates the wood to effect rapid removal of the moisture therefrom, the vapor being maintained at a high temperature substantially above the vaporization temperature of the moisture in the wood so that the moisture is flashed off, immediately and progressively removing the liberated moisture vapor during the drying operation until the desired degree of dryness of the wood is obtained, fractionally condensing said liberated moisture vapor and used organic vapor to effect condensation of the organic vapor only, separating said moisture vapor from the condensed organic vapor and condensing and discharging said moisture vapor condensate from said closed space, conducting said organic condensate to a receiving vessel and recycling it therefrom for reuse in the drying of the wood.

11. A rapid method of dehydrating wood in a closed space by means of an organic vapor and requiring less than one day's time for completion, comprising surrounding and permeating the wood with an inert vapor of an organic compound heated to a temperature within the range of substantially above 212° F. up to about 450° F. so that the organic vapor at said high temperature causes

the moisture in the wood to be flashed off, immediately removing said liberated moisture vapor from the dehydrating operation so that condensation of said moisture vapor into liquid water and hydrolysis of the wood are avoided, maintaining throughout the drying operation the temperature of the organic vapor substantially above the condensation temperature of the moisture liberated from the wood, fractionally condensing said liberated moisture vapor and used organic vapor to effect condensation of the organic vapor free of moisture, separating said moisture vapor from the condensed organic vapor and condensing and discharging said moisture vapor condensate from said closed space, conducting the resulting, dewatered, organic condensate away from the closed space, and recycling said organic condensate for reuse in the drying of the wood.

12. The method of dehydrating wood which comprises subjecting the wood in a closed space to the rapid drying action of an inert organic vapor of a hydrocarbon having a boiling temperature in said space substantially higher than that of water, maintaining said organic vapor at a temperature substantially above 260° F. such that water vapor liberated from the wood is not permitted to condense to form liquid water in said closed drying space, continuing the introduction of fresh, heated organic vapor to remove the liberated water vapor from the drying space, continuously removing during the drying operation the liberated moisture vapor and the used organic vapor as a vapor mixture, passing said mixture through a relatively high temperature zone which causes condensation of said organic vapor but not of the water vapor, separating said moisture vapor from the condensed organic vapor and condensing and discharging said moisture vapor condensate from said closed space, and recycling the resulting organic condensate free of water for reuse in the drying operation.

13. A method of drying and preserving wood and wood products which comprises placing the same in a chamber, continuously introducing into said chamber an atmosphere of a drying medium having a boiling point above the boiling point of water, continuously removing water vapors evolved from the wood and wood products and the drying medium in vapor phase from said chamber, condensing at least a substantial part of the drying medium, pre-heating the condensate of the drying medium by passing the same in heat exchange relation to the vapors of the drying medium being condensed, returning the preheated condensate to the drying medium supply, condensing any remaining drying medium vapor for recovery, and condensing the water vapor and discharging the condensate thereof to waste.

14. A system adapted for drying green or wet wood with a heated organic drying vapor comprising a drying chamber for housing the wood, means for supporting the wood in the drying chamber for contact with the organic drying vapor, means communicably connected with said chamber for producing and supplying to said chamber the organic drying vapor, a condenser connected with said drying chamber for receiving and condensing the moisture vapor liberated from the wood together with the used drying vapor, a separator connected with said condenser for separating substantially the water from the condensed drying vapor, means for removing from the separator and from the system said water condensate, a receiving vessel communicably connected with said drying chamber for receiving therefrom hot organic drying vapor condensate which heats the receiving vessel, this latter condensate being at a temperature higher than the boiling point of water and having a boiling point higher than that of water, said vessel also being communicably connected with said separator for receiving therefrom relatively cool organic drying vapor condensate containing some water, which water is then heated in said receiving vessel by said hot organic vapor condensate sufficiently to vaporize said water, a conduit connecting the top of said receiving vessel with said condenser for conducting said water vapor back through said condenser and disposal therefrom as aqueous liquid condensate, and said receiving vessel also being connected with said organic vapor producing means for supplying thereto the dewatered, organic liquid condensate.

15. A rapid, high temperature method of dehydrating wood confined in a closed space comprising introducing into said space and in contact with the wood, an atmosphere of an inert, organic vapor that does not deleteriously affect the wood but permeates the wood to effect rapid removal of the moisture therefrom, the vapor being maintained at a high temperature substantially above the vaporization temperature of the moisture in the wood, continually removing the liberated moisture vapor during the drying operation until the desired degree of dryness of the wood is obtained, condensing said liberated moisture vapor and used organic vapor, substantially separating the water vapor condensate from said organic vapor condensate and discharging said water vapor condensate to waste, conducting off and collecting in another space the hot organic vapor condensate that forms in the closed, wood-drying space, also collecting in this second space the relatively cool, aforesaid, used, organic condensate and which contains an amount of water not removed in the aforesaid separation, this water content then being heated and vaporized in said second space by said hot organic vapor condensate, which has a higher boiling point than water and its temperature in said second space being higher than the boiling point of water, the water vapor produced in this second space being conducted directly to said first mentioned condensing operation and there condensed and discharged to waste, and recycling the resulting dewatered organic condensate from said second space for reuse in the drying operation.

16. A rapid, high temperature method of dehydrating wood in a closed space, comprising providing in said space an atmosphere of highly heated, inert, organic vapor that does not deleteriously affect the wood and which permeates the wood to effect rapid removal of the moisture therefrom, the vapor being maintained at a high temperature substantially above the vaporization temperature of the moisture in the wood so that the moisture is flashed off, removing the liberated moisture vapor during the drying operation sufficiently to limit the amount of moisture vapor present in the drying chamber to an amount not exceeding approximately 35% of the total amount of vapor in the drying chamber and thereby preventing degradation of the wood being dried, fractionally condensing the liberated and removed moisture vapor and used organic vapor to effect condensation of the organic vapor only, separating the uncondensed moisture vapor from the organic vapor condensate, condensing the water vapor and discharging the resulting condensate from said closed space, conducting said organic

condensate to a receiving vessel and recycling it therefrom for reuse in the drying of the wood.

17. An apparatus for drying green or wet wood with a heated organic drying vapor, in which the drying medium is condensed and recycled for reuse, comprising a drying chamber for housing the wood and having means therein for supporting the wood, an evaporator connected to said drying chamber for vaporizing the organic drying medium and supplying the hot organic vapor to said chamber, means for progressively removing the moisture vapor liberated from said wood together with the used organic drying vapor from said drying chamber, means for recovering the used organic vapor including a condenser and associated means for separating the water and organic liquid components of the condensate formed in said condenser and means for discharging the water component to waste, a return vessel connected to receive the recovered organic condensate and associated means for maintaining the condensate in said return vessel at a temperature above the boiling point of water to vaporize any water entrained with the recovered organic vapor condensate, means for conducting off water vapor from said return vessel back to said condenser for discharge to waste, and means for recycling the organic condensate from said return vessel to said evaporator.

18. An apparatus for drying green or wet wood with a heated organic drying vapor, in which the drying medium is condensed and recycled for reuse, comprising a drying chamber for housing the wood and having means therein for supporting the wood, an evaporator provided with a heat exchange unit and means for passing heated fluid through said heat exchange unit for vaporizing the organic drying medium, said evaporator being connected with said drying chamber for supplying the hot organic vapor to said chamber, a condenser connected with said drying chamber for receiving the moisture vapor liberated from said wood together with the used organic drying vapor and for condensing the moisture vapor and organic vapor, means for separating the water and organic liquid components of the resulting condensate and discharging the water to waste, a return vessel connected to receive the organic condensate from said separating means and provided with a second heat exchange unit and means for passing the heated fluid supplied to said first mentioned heat exchange unit, through said second heat exchange unit whereby the condensate received in said return vessel may be maintained at a temperature above the boiling point of water to vaporize any water entrained in the organic condensate received from said separating means, means for conducting off water vapor from said return vessel, and means for recycling the organic condensate from said return vessel to said evaporator.

19. An apparatus for drying green or wet wood with a heated organic drying vapor in which the drying medium is condensed and recycled for reuse, comprising a drying chamber for housing the wood and having means therein for supporting the wood, means for vaporizing the organic drying medium and supplying the hot organic vapor to the wood to be dried, means for progressively removing the moisture vapor liberated from the wood together with the used organic drying vapor from said drying chamber, means for condensing the major portion of the used organic vapor and means for returning the resulting condensate for revaporization and use in the drying chamber, means for condensing the remaining lesser portion of the organic vapor and the water vapor to form a mixed condensate, means for separating the two condensates, means for discharging the separated water condensate to waste, and means for recycling the remaining organic condensate for reuse in the drying chamber.

20. The process of drying wood with vapors of a heated organic drying medium which comprises subjecting the wood in a closed drying space, having exhaust and supply ports, to an atmosphere of the vapors of said organic drying medium, supplying the vapors of said organic drying medium to said closed drying space at a temperature sufficient to vaporize and liberate the moisture in the wood and maintain the liberated water vapor in vapor phase in said closed drying space, and removing the liberated water vapor and spent organic vapor from said closed drying space throughout the drying process by supplying additional organic vapor through said supply port and thereby displacing the liberated water vapor and spent organic vapor from said drying space through said exhaust port, said additional organic vapor being supplied at a rate that provides in said closed drying space a concentration of organic vapor of at least 50% by weight but less than that of a saturated atmosphere of said organic vapor.

21. The process of drying wood with vapors of a heated organic drying medium which comprises subjecting the wood in a closed drying space, having exhaust and supply ports, to an atmosphere of the vapors of said organic drying medium, supplying the vapors of said organic drying medium to said closed drying space at a temperature sufficient to vaporize and liberate the moisture in the wood and maintain the liberated water vapor in vapor phase in said closed drying space, and removing the liberated water vapor and spent organic vapor from said closed drying space throughout the drying process by supplying additional organic vapor through said supply port and thereby displacing the liberated water vapor and spent organic vapor from said drying space through said exhaust port, said additional organic vapor being supplied at a rate that provides in said closed drying space a concentration of organic vapor of at least 65% by weight but less than that of a saturated atmosphere of said organic vapor.

22. The process of drying wood with vapors of a heated organic drying medium which comprises subjecting the wood in a closed drying space, having exhaust and supply ports, to an atmosphere of the vapors of said organic drying medium, supplying the vapors of said organic drying medium to said closed drying space at a temperature sufficient to vaporize and liberate the moisture in the wood and maintain the liberated water vapor in vapor phase in said closed drying space, and removing the liberated water vapor and spent organic vapor from said closed drying space throughout the drying process by supplying additional organic vapor through said supply port and thereby displacing the liberated water vapor and spent organic vapor from said drying space through said exhaust port, said additional organic vapor being supplied at a rate that provides in said closed drying space a concentration of organic vapor from about 65% to 90% by weight of the total mixed organic vapor and liberated water vapor.

23. A rapid, high temperature method of dehydrating green or wet wood in a closed space,

the wood commonly containing 50% to 100% moisture on a dry weight basis and the drying being effected without adversely affecting the strength and other desired properties of the wood, comprising vaporizing in a heated vaporizer an organic drying medium that does not deleteriously affect the wood, subjecting said wood to an atmosphere of the vapor of said organic drying medium in said closed space, the vapor of said organic drying medium being maintained in said closed space at a temperature substantially above the boiling point of water and thereby causes the moisture in the wood to be flashed off, immediately and progressively removing the liberated moisture vapor and spent organic vapor during the drying operation, condensing said vapors and separating the predominant portion of the moisture condensate and discharging same to waste, collecting the organic vapor condensate in a heated space and boiling off therein any remaining water condensate entrained in said organic condensate so as to dehydrate substantially completely said organic condensate, carrying off the resulting moisture vapor for recondensation and discharge to waste and recycling said dehydrated organic condensate to said vaporizer for reuse in the drying operation.

24. A method as defined in claim 23 and in which the atmosphere of drying vapor used is a substantially saturated organic vapor atmosphere.

25. A method as defined in claim 23 and in which the organic vapor is obtained by heating an organic compound selected from the class consisting of creosote, petroleum distillates, coal tar, wood tar and wood distillates.

MONIE S. HUDSON.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,059,820	Besemfelder	Apr. 22, 1913
2,273,039	Hudson	Feb. 17, 1942
2,293,453	Clark	Aug. 18, 1942

Certificate of Correction

Patent No. 2,435,218. February 3, 1948.

MONIE S. HUDSON

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Column 16, line 25, for "operation at" read *operation as*; column 19, line 52, Example IX, under the heading "Per cent distilling" for ".32.7" read *32.7*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 6th day of April, A. D. 1948.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.

the wood commonly containing 50% to 100% moisture on a dry weight basis and the drying being effected without adversely affecting the strength and other desired properties of the wood, comprising vaporizing in a heated vaporizer an organic drying medium that does not deleteriously affect the wood, subjecting said wood to an atmosphere of the vapor of said organic drying medium in said closed space, the vapor of said organic drying medium being maintained in said closed space at a temperature substantially above the boiling point of water and thereby causes the moisture in the wood to be flashed off, immediately and progressively removing the liberated moisture vapor and spent organic vapor during the drying operation, condensing said vapors and separating the predominant portion of the moisture condensate and discharging same to waste, collecting the organic vapor condensate in a heated space and boiling off therein any remaining water condensate entrained in said organic condensate so as to dehydrate substantially completely said organic condensate, carrying off the resulting moisture vapor for recondensation and discharge to waste and recycling said dehydrated organic condensate to said vaporizer for reuse in the drying operation.

24. A method as defined in claim 23 and in which the atmosphere of drying vapor used is a substantially saturated organic vapor atmosphere.

25. A method as defined in claim 23 and in which the organic vapor is obtained by heating an organic compound selected from the class consisting of creosote, petroleum distillates, coal tar, wood tar and wood distillates.

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