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TO SELECTED MOISTURE CONTENT WITH OIL RECOVERY

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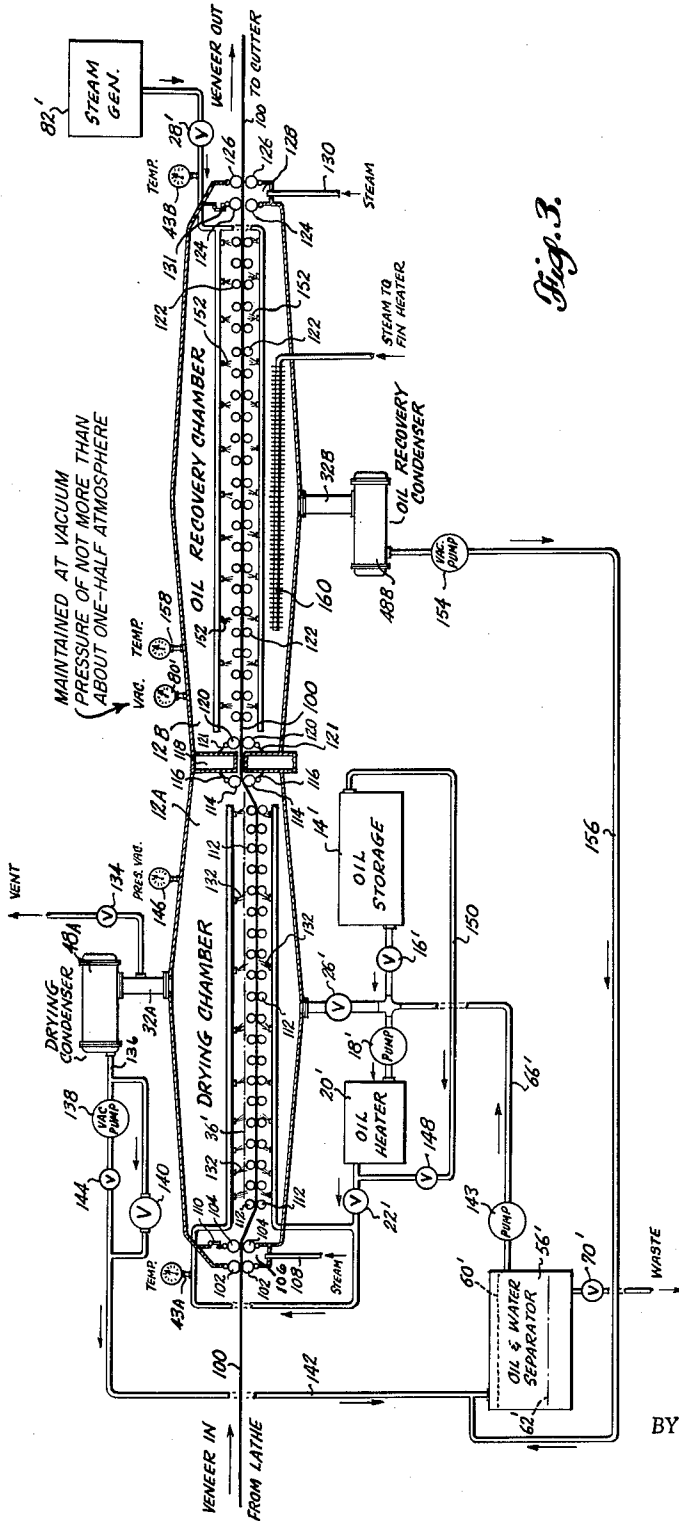


Fig. 3.

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**PROCESS OF DRYING WOOD BY OIL IMMERSION
AND VACUUM TREATMENT TO SELECTED
MOISTURE CONTENT WITH OIL RECOVERY****Richard D. Fies and William W. Johnston, Bend, Oreg.,
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Oreg., a corporation of Nevada****Filed Sept. 27, 1961, Ser. No. 141,054****10 Claims. (Cl. 34—9.5)**

The present invention relates to improvements in drying of wood products by immersion in hot oily liquid under controlled conditions of temperature, pressure and circulation so that a low moisture content is substantially uniformly established throughout the wood regardless of variations in initial moisture content and variations in nature of the wood fiber. In addition, important aspects of the invention involve effective recovery of the drying oil from the wood without material disturbance of the moisture content of the wood.

Techniques are known for rapidly drying wood by a so-called boiling-in-oil treatment, as discussed for example in Report No. 1665 (Revised) entitled "Special Methods of Seasoning Wood; Boiling in Oily Liquids," dated April 1956, and published by the Forest Products Laboratory (FPL), an agency of the U.S. Dept. of Agriculture Forest Service. However, previous attempts to utilize the rapid drying advantage of such oil drying techniques have not enjoyed commercial success in terms of being competitive with established wood drying techniques. This failure has apparently been due to an inability to control the final moisture content of the wood, an inability to recover sufficient oil to avoid an oily appearance in the wood, and because of the substantial added cost of the wood-retained oil, as well as its adverse effect on the flammability of the wood.

A drying oil having a higher boiling point than water cannot be removed from wood to the degree commercially necessary in any reasonable length of time simply by forced air circulation. To get a more rapid recovery of the oil, attempts have been made to increase the temperature at which the residual oil is evaporated or vaporized from the wood, but such increase in temperature to about the boiling point of the oil proves injurious to the properties of the wood in terms of surface cracking, charring, and case hardening. Further, and quite importantly with respect to many commercial usages of wood, a higher order of drying temperature which is well above the boiling point of water entails considerable further reduction in the moisture content of the wood even to the point of desiccation.

For some usages, certain forms of wood products such as veneer should not be dried beyond a low but substantial moisture content, in order to have good bonding or gluing properties. Also, with respect to wood products such as veneer which are bonded or glued by a so-called "hot press" process, any substantial retention of oily liquid in the wood gives rise to an explosion hazard, so is commercially unacceptable. Further, with respect to air scavenging of drying oil from the wood, this procedure of itself has proven sometimes to generate serious hazards because oil vapor and air mixtures can be explosive.

Other attempts have been made to recover drying oil from oil dried wood by vacuumizing the chamber containing the wood. However, vacuumizing techniques have proven unsatisfactory in that while the relative partial pressure of the oil is somewhat improved, the lack of environment circulation results in a poor recovery rate. Vacuumizing alone also has an adverse effect on the moisture content of the wood, since the relative partial pressure of the contained moisture is also improved and the wood continues to dry. It has also been found that if

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there is any substantial evaporation of moisture from the wood during residual oil recovery, such moisture evaporation results in rapid loss of residual heat from the wood, which tends to dampen the evaporation recovery of the oil before a practical amount of oil is removed from the wood.

Steam, when used as a scrubbing agent for the drying oil at atmospheric and superatmospheric pressures, does not provide sufficiently rapid recovery rates to be commercial, because of the relatively low partial pressure of the oil at atmospheric and superatmospheric pressures.

For a more detailed consideration of various prior techniques having to do with oil drying of wood and the attendant difficulties involved, further reference should be made to the aforesaid FPL Report 1665 (Revised); to the original FPL Report R1665, entitled "Special Methods of Seasoning Wood; Boiling in Oil," dated February 1947; to FPL Report 1665-1 (Revised), entitled "Special Methods of Seasoning Wood; High Temperature Drying: Its Application To The Drying Of Lumber," dated November 1957; to FPL Report 1665-2 (Revised), entitled "Special Methods of Seasoning Wood; Solvent Seasoning," dated March 1955; to FPL Report R1665-5 entitled "Special Methods of Seasoning Wood; Vacuum Drying of Wood," dated May 1953; to Western Pine Association Research Note No. 4.311, entitled "Seasonwood Process," dated May 15, 1953; to FPL Report 1642, entitled "How Wood Dries," dated September 1956; to Hutchinson U.S. Patent 2,892,261, and to McDonald U.S. Patent 2,860,070.

One prior oily liquid type wood drying procedure, as disclosed in said McDonald Patent 2,860,070, involves use of a halogenated hydrocarbon such as perchloroethylene, wherein evaporative extraction of the liquid is by removal of an azeotropic mixture of the water and liquid, under conditions including sequenced vacuumizing and steaming. However, removal of the drying liquid as an azeotropic mixture has the disadvantage of removing further moisture as well as drying liquid from the wood, with the result that no effective control as to uniformity of final moisture content can be realized. In fact, an optional procedure when using the McDonald process is that of periodically steaming the wood, apparently to restore a sufficient moisture content therein to permit formation of the characteristic azeotropic mixture.

In contrast to such prior oil drying and oil recovery procedures, the processing technique characteristic of the present invention has the capability of permitting close control of moisture content of the wood, both in the drying operation and in effecting an efficient recovery of drying oil from the wood. Notwithstanding its capability of drying wood to a controlled and readily predeterminable moisture content, the processing of the present invention has the capability within commercially practical processing times of recovering the higher boiling drying oil to the extent of leaving in the wood less than about 0.3% oil, based on the oven dry weight of the wood, so as to avoid any possibility of an explosion hazard in certain wood product fabrication processes to which the wood may be subjected. In contrast, it is to be recognized that oil removal by forced air circulation or by steam at atmospheric pressure has proven to leave on the order of 2% or more oil in the wood. In addition, the drying and oil extraction treatment of the present invention involves temperature conditions within the wood which are not so severe as to cause surface deterioration and strength loss in the wood.

One important aspect of the invention is its realization of fast treatment times, both as to the oil drying step and as to the oil recovery step, so that wood drying can be integrated with wood utilization operations involving fast throughput rates. For example, in the case of veneer for utilization in the fabrication of plywood, a continuous

or substantially continuous drying operation according to the present invention can be integrated with a continuous peeling operation, avoiding any necessity for clipping of the veneer into separate wood types as it comes off the peeling lathe, and obviating the need for separate drying of the veneer types. Conventional operating procedure now involves clipping of the freshly peeled veneer according to the type of wood, i.e. heartwood and sapwood, then hand sorting to segregate the types of wood preliminary to drying. This is because sapwood takes substantially longer to dry than heartwood when dried by conventional techniques. Subsequent to drying, further sorting as to grade must be effected, often with re-clipping. The reason such segregation as to wood type is necessary in conventional practice is that heartwood dried on a sapwood schedule will not effectively bond and sapwood dried on a heartwood schedule will present wet spots which risk "blow out" on a hot press. By virtue of the present invention, the heartwood and sapwood can be dried together, as in a continuous sheet, and the resulting moisture content of each type of wood is exceedingly uniform, and controllably so, within a practical operating tolerance of less than about $\pm 0.5\%$ of the desired moisture content.

In practice of the present invention, the residual heat in the wood left from oil drying thereof is utilized to provide the desired temperature for oil recovery, and the evaporation of incident moisture from the wood is inhibited so that the wood does not cool too rapidly. In this connection, it is to be particularly observed that the superheated steam we employ for drying oil recovery is not primarily a heat source, but rather a moisture stabilizer and scrubbing or stripping agent for removing oil vapor as it diffuses to the surface of the wood. Viewed in another manner, the slow dropoff of residual heat level of the wood during oil recovery according to the present invention is considered to result primarily from the moisture stabilization provided by the superheated steam, since such moisture stabilization prevents loss of residual heat in the form of latent heat of vaporization of the wood contained moisture.

In terms of the controlled conditions maintained during the oil drying and oil recovery phases of the process, the functional aspects involved can be summarized as follows. During the oil drying phase with an oil having a distillation range substantially above the boiling point of water, the desired temperature condition is selected to be substantially above the boiling point of water but below the boiling point of the oil and low enough to avoid damage to the wood. With respect to pressure, the oil bath drying is preferably but not necessarily conducted at atmospheric pressure.

A phenomenon of wood drying in a hot oil bath is the formation of a layer of superheated steam bubbles on all surfaces of the wood caused by the diffusion of the wood-contained moisture in vapor form to the surface of the wood. This layer of bubbles clings to the surface of the wood until disturbed or until individual bubbles become large enough to overcome the adhesion and surface tension forces which hold them to the surface of the wood. Such layer of superheated steam bubbles, in effect, envelopes the wood in an atmosphere of superheated steam. This layer also, in effect, constitutes a barrier to heat transfer between the oil bath and the wood which retards heat transfer from the oil to the wood in proportion to the thickness of the layer, and can if properly utilized prevent overdrying and overheating of the wood.

Wood, in an atmosphere of superheated steam, such as that provided by the self-generated layer of superheated steam bubbles referred to above, has been found to reach a point of moisture stabilization wherein it neither gains nor loses moisture, i.e. is at equilibrium. At this point of stabilization, with the moisture content of the wood in equilibrium with the surrounding layer or blanket of superheated steam atmosphere, the amount of moisture

in the wood is essentially dependent upon the temperature of the superheated steam, substantially according to the relation shown in FIG. 2.

This self-generated, protective drying atmosphere, when properly controlled, permits rapid drying of the wood, yet prevents overdrying and overheating thereof, and thereby avoids the harsh effects on the wood which are often considered to be inherent in subjecting wood to a hot oil bath.

The degree to which the layer of superheated steam bubbles shields the wood from the heat of the bath is regulatable to a considerable extent simply by means of varying the extent of circulation of the oil bath. Characteristic of the present invention, the oil bath is circulated rapidly for an initial period, then bath circulation is progressively reduced during further and final drying to allow the vapor barrier surrounding the wood to be retained at all times and to maintain the desired final moisture content in the wood while wet spots which have not yet reached equilibrium continue to dry. In contrast to our control of circulation to achieve a preselected moisture content, it has heretofore been considered that oil bath drying of wood should seek to dry the wood as much as possible, as by maintaining strong circulation throughout the drying phase, without concern as to any precise uniformity of final moisture content.

Wood in an atmosphere of superheated steam reaches an equilibrium moisture content dependent upon the temperature of the superheated steam, as pointed out above. The temperature of the superheated steam envelope or blanket is controlled in our process by the temperature of the drying oil. The thickness and effectiveness of this envelope or blanket of superheated steam is controlled by regulation of the circulation rate of the drying oil bath. Strong circulation and sharp impingement of the drying oil on the steam envelope produces a scrubbing action which partially overcomes the adhesion forces holding the envelope of superheated steam to the surface of the wood, which diminishes the barrier presented to heat transfer from the drying oil to the wood. Conversely, reduced circulation and reduced impingement of the drying oil on the surface of the wood by reduction in its circulation rate reduces the scrubbing action and allows a more effective envelope of superheated steam to surround each piece of wood, slowing the heat transfer from the drying oil to the wood.

As any particular portion of the wood is reduced to a moisture content commensurate with the equilibrium moisture content determined by the temperature of the superheated steam blanket, the moisture content of the wood will stabilize as long as the vapor blanket is not destroyed. Under such conditions, the bath and the wood are at essentially the same temperature, and the vapor pressure of the vapor blanket substantially equals the hydrostatic pressure and surface tension of the oil. Continued strong circulation of the bath prevents temperature related (i.e. superheated steam controlled) stabilization of the final moisture content of the wood, because the strong circulation continues to scrub away the vapor blanket. However, if the bath circulation is sufficiently reduced before the moisture content of the wood is reduced to the moisture content of the superheated steam barrier, then the drying action essentially ceases at the desired point since the vapor blanket continues to surround the wood and there is no force present to impel further movement of water vapor from the wood. As will be understood, relatively wet spots which remain at the time the circulation is reduced to the point of not interfering with the vapor envelope will continue to dry in that the temperature of the wet spots is still below the temperature of the bath so the wet spots continue to absorb heat from the bath and continue to yield water vapor. In essence, the initially relatively strong circulation characteristic of the present invention serves primarily to reduce drying time, while the final circulation rate is

critically established to and serves primarily to allow the existence of a substantial vapor envelope surrounding the wood during the final drying.

With respect to condition control during recovery of drying oil from the wood, the desired temperature condition of having the wood at substantially above the boiling point of water is most suitably and practically established by utilizing the residual heat remaining in the wood from the drying operation. As to pressure condition, it has been found that a vacuumized environment is essential for practical oil recovery rates at temperatures materially below the boiling point of the oil, and in this regard practice has indicated that the pressure should be subatmospheric to the extent of about one-half atmosphere or less. Coupled with such reduced pressure and elevated temperature conditions, markedly improved oil recovery is effected by adding to the environment superheated steam at a temperature having substantially the same equilibrium moisture content as the desired moisture content of the wood.

Thus, it is seen that the present invention involves an oil drying phase and an oil recovery phase wherein the wood is controlled as to uniformity of moisture content by the maintenance of a superheated steam environment which surrounds the wood throughout both phases of treatment, with such environment being provided by a self-generating steam envelope or blanket surrounding the wood throughout the drying phase, and being provided by a continuous impingement of superheated steam on the wood during the oil recovery phase under conditions of reduced pressure, to improve the rate and extent of oil oil recovery.

These and other objects, features, purposes and advantages of the invention will be apparent from the following description of certain system forms and operating procedures characteristic of the invention, taken together with the accompanying illustrations, wherein like numerals refer to like parts, wherein prime numerals refer to corresponding parts of similar function, and wherein:

FIG. 1 is a schematic flow diagram of a batch-type oil drying and oil recovery system, such as for experimental practice of the invention;

FIG. 2 is a graphical presentation showing the equilibrium moisture content of wood in superheated steam environment at various temperatures; and

FIG. 3 is a diagrammatic view of a continuous oil drying and oil recovery process for treating freshly peeled veneer.

FIG. 1 illustrates a typical, batch-type processing system characteristic of the invention, wherein wood to be dried is placed in several separated layers on platform 10 of treating chamber 12, and held down therein by suitable means (not shown). With the wood in place, treating chamber 12 is closed and filled with a drying oil such as Standard Odorless Thinner to above the level of the lumber by delivering oil from oil storage reservoir 14 through valve 16, circulating pump 18, oil heater 20, flow regulation valve 22 and perforated circulation headers 24 arranged along one side of treating chamber 12 and extending at least most of the length thereof to direct sprays or jets of the incoming oil on substantially all exposed wood surfaces. During the time treating chamber 12 is being filled, return valve 26 is closed. Steam supply valve 28 remains closed during the drying operation. Outlet valve 30 in the vapor line 32 leading from treating chamber 12 is normally open, and is used only in the event a superatmospheric pressure is desired in chamber 12 during drying, in which case it is regulated to provide constricted outflow from the chamber 12, the pressure head in chamber 12 being suitably indicated, as by pressure gage 34.

When the desired oil level in treating chamber 12 is attained, which can be ascertained by suitable means such as by simply viewing the liquid level 36 in viewing window 38, oil storage supply valve 16 is closed and outflow

valve 26 is opened to establish return flow from chamber 12 to pump 18, as indicated at 40. Then, the desired circulation rate of the oil bath in treating chamber 12 is established by regulation of valve 22, the desired rate of flow and correspondingly the extent of circulation of oil in chamber 12 being suitably indicated, as by flow-meter 42.

Assuming an atmospheric pressure condition in treating chamber 12, and assuming the wood being dried is $\frac{1}{8}$ " Douglas fir veneer, for example, the oil being recirculated in chamber 12 can suitably be at a temperature averaging about 240° F.-290° F., say 265° F., to give a stabilized moisture content of about 3% (cf. FIG. 2). The average bath temperature has been found to be about 10-20° F. less than the incoming oil temperature reflected by temperature probe 43, so that the incoming oil temperature corresponding to an average temperature of 265° F. is about 280° F., for process control purposes.

The drying time involved can be about forty minutes, exclusive of a filling time of about forty seconds, and exclusive of a drain time of about one minute. When most of the so-called "free" water has been vaporized from the wood (in contrast to the so-called "bound" water, i.e. the wood fiber saturating water), the reduced vapor outflow in line 32 results in a temperature reduction being reflected by temperature gage 44. Concurrently with such temperature reduction, valve 22 is progressively throttled to reduce the rate of circulation of the oil bath. Such control of bath circulation can be accomplished manually, or can be effected by temperature responsive flow control means, in a manner known per se. When there is substantially no further water vapor being given off the wood, the temperature reflected by gage 44 stabilizes, at which time the drying operation can be discontinued simply by opening valve 16, stopping pump 18 and draining the oil back to oil storage 14 through valves 26 and 16, as indicated at 46.

During the oil drying phase, the vapors produced are an admixture of oil vapor and water vapor (predominantly oil vapor in the case of use of Standard Odorless Thinner as the oil), and the drying oil vaporized during drying is recovered by passage of the vapors through water cooled condenser 48, with discharge of condensed liquid through condenser discharge line 50 and valve 52, which is open in the direction indicated at 54, to separator 56 where the oily condensate and water condensate separate into two layers by virtue of relative immiscibility and difference in specific gravity. In separator 56, the oily condensate forms on the top, and the respective oil and water levels 60 and 62 are suitably sensed, as by display through a viewing window 64, with the liquid levels being maintained so that the oily condensate overflows into return line 66, as indicated at 68. One procedure by which such discharge of recovered oil from separator 56 can be effected is by means of an electrical probe (not shown) or other liquid level indicating device, which senses water level 62 and controls the extent of outflow of water through separator discharge valve 70.

Oil return line 66 from separator 56 returns the oil to chamber discharge line 72 below valve 26, so that when treating chamber 12 is filled with recirculating drying oil the level 36 thereof is maintained at all times since oil outflow from separator 56 accumulates with the recirculating oil coursing pump 18. Gravity return separator 56 is advantageously positioned so that the oil level 60 therein is slightly above the oil level 36 in treating chamber 12, as shown.

To provide vapor balance throughout the system, separator 56 and oil storage 14 are respectively suitably vented as indicated at 72 and 74, and such vents 72, 74 can advantageously be interconnected, if desired.

After the oil bath has been withdrawn from treating chamber 12 at the end of the drying phase, and to initiate the oil recovery phase of the process, vacuum pump 76 is started and valve 52 is shifted to place vacuum pump

76 on outflow line 50 from condenser 48, with flow as designated at 78, valves 22 and 26 being meanwhile fully closed and valve 30 fully opened if partially closed during the drying step.

Vacuum pump 76 establishes a subatmospheric pressure in treating chamber 12, the extent of partial pressure being suitably indicated as by vacuum gage 80 in vapor line 32. When the partial pressure is suitably established in treating chamber 12, as at a reading of about 12–14 inches Hg, a slight amount of superheated steam flow and circulation in treating chamber 12 is established by partially opening steam valve 28 which is connected to a suitable steam supply 82 from which steam is available at a suitable temperature. For example, the steam delivered to steam inlet valve 28 can be at a temperature when released into chamber 12 which corresponds to the desired equilibrium moisture content in the treated wood. Should the desired moisture content of the wood be about 3% (corresponding to the moisture content established by the average bath temperature at the wood surfaces of about 265° F. during the drying phase), the desired steam temperature at temperature gage 43 should substantially correspond, according to the relation shown at FIG. 2, i.e. be about 265° F., in the example selected. In practice, comparatively little steam vapor provides an adequate impingement and circulation to effectively strip the vaporizing residual oil from the wood surface. The amount of superheated steam vapor introduced to the oil recovery environment suitably can about equal the amount of oil vapor evaporated from the wood. In other words, during the oil recovery phase, flowmeter comparisons can be made of the quantity of water condensate and the quantity of oil condensate appearing as outflows from separator 56, and steam valve 28 regulated to keep these quantities substantially equal. A comparatively greater amount of steam can be used, but is not to be preferred, since it makes little additional contribution to the desired moisture stabilization and scrubbing action. At the temperatures involved, there is no substantial heat transfer between the steam and wood.

For the earlier indicated example involving drying treatment of 1/8" Douglas fir veneer (half heartwood and half sapwood), oil recovery utilizing the residual heat remaining in the wood from the drying operation and establishing a superheated steam environment in chamber 12 for four minutes resulted in a reduction of the residual oil content to about 0.25%, without substantial change of moisture content, the final moisture content being about 3.0%.

Other examples and a comparison of the oil recovery efficiency of the superheated steam in a vacuumized chamber, and comparisons with results obtained by use of superheated steam at atmospheric pressure, and by use of a vacuumized chamber without superheated steam, are presented below.

Analyses of selected wood samples taken after the drying phase but before the oil recovery phase indicate that the oil content of the wood after oil drying but before oil recovery varies considerably depending upon the type of wood and is in general in the range of from about 5% to about 12%.

As a first comparative example, showing typical oil recovery under conditions involving steam atmosphere at atmospheric pressure, a sample of Douglas fir sapwood veneer .220 inch thick with an initial moisture content of 65% was dried at an average temperature of about 260° F. for five minutes according to the procedure discussed in connection with FIG. 1, then during the oil recovery phase was subjected to superheated steam at about 260° F. at atmospheric pressure for ten minutes. Six inch sections cut from the ends of the veneer after drying and oil recovery exhibited a final moisture content of 3.4% and a final oil content of 1.97%. A corresponding section taken from the center of the veneer exhibited a final moisture content of 3.42% and a final oil content of

1.78%. This example demonstrates that while the resulting moisture content was substantially uniform throughout the wood, the oil recovery by superheated steaming at atmospheric pressure is commercially unsatisfactory, leaving a residual of about 2%.

As a second comparative example, showing the effect of using vacuumizing alone for oil recovery, a .200 inch thick Douglas fir sapwood veneer with an initial moisture content of 12% was oil dried for five minutes at an average temperature of about 265° F., then subjected to a partial pressure of fourteen inches Hg for seven minutes during the oil recovery phase. The final moisture content of the veneer was 2.98% and the final oil content was 2.2%.

Concerning the extent of time necessary to recover the residual oil effectively, a further comparative example involved .130 inch thick Douglas fir sapwood veneer with 18% initial moisture content, which was oil dried at an average temperature of about 270° F. for four minutes, then subjected to superheated steam at about 275° F. and under a partial pressure of fourteen inches Hg with steam introduction for the period of two minutes. The final moisture content was 2.32% and the final oil content was 2.56%. However, a like sample, having an initial moisture content of 25% was subjected to a closely similar drying procedure (at 278° F.), then vacuumized to fourteen inches Hg, and superheated steam introduced for four minutes during the oil recovery phase, the resulting sample exhibiting a final moisture content of 2.04% and a final oil content of 0.26%. The sharp drop in final oil content evinced by this latter example indicates the oil recovery phase must be carried for a substantial, although still comparatively short time.

As a further comparative example characteristic of the invention, three pieces of Douglas fir sapwood veneer .130 inch thick with an initial moisture content of 28% were stacked in the treating chamber with spacers in between the individual pieces, then subjected for four minutes to an average drying temperature of about 275° F., then vacuumized at fourteen inches Hg and steam was trickled in at a temperature of about 275° F. for four minutes. The top piece exhibited a final moisture content of 2.62% and an oil content of 0.22%, the middle piece exhibited a final moisture content of 2.41% and a final oil content of 0.28%, and the bottom piece exhibited a final moisture content of 2.31% and a final oil content of 0.21%. The variation in moisture content in this example as to a comparatively lesser moisture content toward the bottom of the chamber was caused, it is believed, by a steam heating coil at the bottom of the treating chamber, which heated the lower layers of wood by radiation during the oil recovery phase, and resulted in relatively higher wood temperatures in the lower layers.

A further example is presented below which demonstrates the uniformity of drying accomplished by the processing of the present invention as between heartwood portions of sapwood portions of the wood, and as compared with the moisture content levels attained in these various types of wood by conventional veneer drying techniques involving a hot air environment. The example also serves to show a performance evaluation as to gluing characteristics, appearance and workability.

To evaluate the properties of veneer oil dried according to the present invention, like samples of heartwood and sapwood Douglas fir veneers were cut from the same pieces, with one sample of each being subjected to oil drying and oil recovery according to the present invention and with another sample of each being dried by forced circulation of an environment of heated air in a conventional steam heated veneer dryer. The veneer oil dried with vacuumized steaming according to the present invention, demonstrated a sapwood moisture content of 2.8% and a heartwood moisture content of 3.0%, while the conventionally dried sapwood demonstrated a moisture content of 3.6% and the conventionally dried heartwood demonstrated a moisture content of 4.5%. Observations

as to the oil dried veneer indicated it had a nearly undetectable odor before pressing, and that the odor was not apparent during and after hot pressing the veneer into plywood. As to sanding characteristics, after pressing, no discernible differences in the oil dried and the conventionally dried plywood panels were observed. As to gluing characteristics, glue flow and penetration properties appeared the same in both types of samples, and knifed bonds were comparatively extremely similar. Glue spreading characteristics and strength properties were likewise remarkably similar.

FIG. 2 is a graphical presentation of the approximate equilibrium moisture content of wood in a superheated steam atmosphere, to show the correlation involved as between processing temperature and resulting moisture content in the wood.

FIG. 3 is a diagrammatic view of a modified form of system for practicing the oil drying and oil recovery techniques of the invention, which system is adapted for use in continuously processing veneer or like wood while being conveyed in the form of a strip or sheet. Except as otherwise indicated, the system components shown in FIG. 3 are functionally like those in the system illustrated at FIG. 1, and respectively corresponding components are designated by prime numerals, while separate components of related function are designated by corresponding letter-modified numerals.

In the system shown at FIG. 3, the veneer or like wood sheet 100 moves substantially continuously through drying chamber or tunnel 12A, thence through an oil recovery chamber or tunnel 12B, and can receive the veneer 100 directly from the peeler lathe as an integrated system, with subsequent delivery to a clipper or the like.

Drying chamber 12A contains the drying oil bath, the level of which is indicated at 36'. The veneer 100 is fed into chamber 12A through infeed rolls 102, 104 which comprise a part of an ante-chamber 106 wherein is maintained a steam atmosphere at a pressure slightly above the pressure in the drying chamber, the steam atmosphere in ante-chamber 106 being provided from a suitable steam source, as indicated at 108. Chamber 106 and rolls 102, 104 provide an essentially vapor tight ingress of sheet 100 into drying chamber 12A so substantially no loss of vapors therefrom results. To this end, chamber 106 vents suitably into drying chamber 12A, as by flap valve 110.

After entry into chamber 12A, veneer sheet 100 is submerged below level 36' of the oil bath by coursing a series of guide rolls 112, then passes out of the drying chamber 12A through feed rolls 114. Seal flaps 116 are provided in conjunction with rolls 114 to maintain the drying chamber 12A vapor seal. The veneer sheet 100 then proceeds through slotted structural member 118 and infeed rolls 120 with associated seal flaps 121 into oil recovery chamber 12B, then through a series of guide rolls 122, then out of the oil recovery chamber 12B through pairs of vapor seal rolls 124, 126, which comprise a part of exit chamber 128, providing a vapor seal for oil recovery chamber 12B by maintaining a steam atmosphere at a slightly superatmospheric pressure, such steam atmosphere being suitably supplied, as indicated at 130, the slight vapor outflow from exit chamber 128 being vented into chamber 12B through flap valve 131.

The oil bath in drying chamber 12A is recirculated by pump 18', through thermostatically controlled heater 20', and is delivered into chamber 12A through a series of spray heads 132 arranged above and below the veneer sheet 100, which spray heads 132 serve to provide the controlled circulation of the oil bath in a manner characteristic of the invention. The extent of the circulation of agitation provided in the oil bath is regulatable by flow control valve 22', and the spacing between the successive spray heads 132 progressively increases along the line of travel of the veneer sheet 100 through the chamber 12A, as shown, in order that the veneer sheet 100 be first sub-

jected to strong bath circulation then to progressively reduced bath circulation. Vapor outflow from drying chamber 12A is taken off by outflow line 32a, leading to dryer condenser 48A, thence to separator 56' from whence the oil condensate is returned to circulation through line 66', and the water condensate is regulatably discharged through valve 70'. In vapor outflow line 32A, a vented pressure relief valve 134 serves as an overpressure relief valve.

The flow line 136 from the condensate side of drying condenser 48A leads to vacuum pump 138 and pressure regulation valve 140, either of which can feed line 142 leading to separator 56'. If a substantially atmospheric pressure is desired in drying chamber 12A, vacuum pump 138 is not operated, its flow control valve 144 is closed, and pressure regulating valve 140 is fully opened. If a superatmospheric pressure is desired in drying chamber 12A, pressure regulation valve 140 is partially closed the degree necessary to reflect the desired pressure on pressure-vacuum gage 146. If a subatmospheric pressure is desired in drying chamber 12A, vacuum pump valve 144 is opened, vacuum pump 138 is operated, and pressure regulation valve 140 is closed. Regulation of the vacuumization to maintain a desired subatmospheric pressure, as reflected by pressure-vacuum gage 146, is accomplished by valve 144.

Automatic discharge of oil condensate from separator 56' is effected by pump 143, which can be suitably operated, as by a float switch mechanism (not shown) sensing the oil level in separator 56'.

To start up the drying chamber 12A, and assuming all of the oil is initially in oil storage 14', valves 22' and 26' are checked to be closed, valves 16' and 148 are opened, and pump 18' is started to recirculate all of the oil through oil heater 20', line 150 and oil storage 14'. Then, when the oil has attained temperature, valve 22' is opened and valve 148 closed to deliver oil to the drying chamber 12A. When the desired oil level 36' is reached, valve 26' is opened and valve 16' is closed. As soon as the oil coursing drying chamber 12A has recirculated for sufficient time to bring the drying chamber 12A to desired operating temperature, as indicated by temperature gage 43A, the drying chamber is ready to receive veneer sheet 100.

In oil recovery chamber 12B the characteristic superheated steam environment at reduced pressure for recovering residual drying oil from the veneer is maintained by controlled delivery of steam from steam supply 82' through valve 28' into a series of spray heads 152 arranged above and below the veneer 100, the vacuumized condition being maintained by vacuum pump 154 pulling through recovery condenser 48B and vapor outflow line 32B, the condensate outflow from vacuum pump 154 being returned to separator 56' through return line 156. Temperature gage 43B reflects the inflow steam temperature, temperature gage 158 reflects the ambient temperature of chamber 12B, and vacuum gage 80' monitors the partial pressure condition of chamber 12B.

Start-up heat for chamber 12B, as well as maintenance heat if necessary, can be appropriately provided, such as by steam heater means or the like, as indicated at 160.

As will be apparent, wide variations are possible with respect to the design layout of a continuous wood strip processing system such as shown at FIG. 3. By way of typical further example, the various guide rollers 102, 104, 112, 114, 120, 122, 124, 126 can be arranged to provide multiple, vertically stacked, wood strip flow arrangements in chambers 12A and 12B, to increase throughput capacity of the system and permit faster infeed from a peeler lathe or the like, with the various flow paths for the strip being fed in sequence in a manner analogous to the banks of flow paths conventionally provided in certain veneer drier conveyor arrangements.

In general it will be seen that the wood drying and drying oil recovery technique of the invention are appli-

cable to various species of wood (e.g. softwood or hardwood), to various wood types (e.g. heartwood and sapwood) and to various wood forms (e.g. veneer and 1" sawn lumber). However, it is considered that its techniques have especial advantages and utility in commercial drying of thin, cut grain, pervious wood forms wherein the initial moisture can vaporize and undergo surface diffusion to reach a moisture content equilibrium with the superheated steam environment relatively rapidly.

As used herein, the terms "oil" and "drying oil" relate to water-immiscible liquid treating media having a boiling point or distillation range substantially higher than the boiling point of water, and having a substantial vapor pressure at temperatures in the range of 250°-300° F. Various suitable drying oils are known in the art, such as various high boiling hydrocarbon fractions, vegetable oils and mineral oils. One satisfactory oil for the purpose is aliphatic (high-aniline) petroleum solvent Standard Odorless Thinner, marketed by Standard Oil Company of California, with a distillation range of 347° F.-399° F. Additives in small amounts can also be employed with the drying oil for various purposes, such as high-melting point waxes or other water resistant agents, fire-retardant chemicals, preservatives, insecticides, and dyes, for example.

From the foregoing, the various above-indicated objects, advantages and features of the invention, as well as further variations in the details of the systems and processes disclosed, will be apparent to those skilled in the art, within the scope of the following claims.

What is claimed is:

1. The process of drying wood comprising immersing the wood in a hot bath of water-immiscible drying oil having a boiling point substantially above the boiling point of water under controlled conditions of bath circulation, temperature and pressure and for a time such that the moisture content of the wood is rapidly reduced to and substantially stabilized at a selected value in the range of about 2% to about 7% by weight, separating the wood from the oil bath, and maintaining the moisture content of the wood within said range while removing at least most of the residual drying oil from the wood by maintaining the wood under a vacuum pressure of not more than about one-half atmosphere and at a temperature of at least about 240° F. in a circulating atmosphere of superheated steam until the drying oil content of the wood is less than about 0.5% by weight.

2. The process of drying a sheet of peeled veneer during conveyance thereof, comprising a drying phase involving conveying the sheet through a circulating bath of water-immiscible oil heated to an average temperature in the range of about 250° F.-300° F., the bath circulation around the sheet progressively gradually decreasing during its course of travel through the bath, and the rate of travel of the sheet through the bath being such that a substantially uniform moisture content of from about 2% to about 7% is established in the sheet by the time it leaves the bath, such process further comprising an oil recovery phase involving conveying the oil dried sheet through an environment of super-heated steam under a vacuum pressure of not more than about one-half atmosphere while impinging superheated steam thereon to reduce the residual oil content of the strip to less than about 0.5% by weight without overdrying the veneer, and recovering oil from the vapors given off during both the drying phase and the oil recovery phase.

3. The process of claim 2, comprising maintaining the oil recovery environment at a temperature substantially equal to the average temperature of the oil bath.

4. The process of drying cut-grain wood such as veneer and the like to a uniform, low but substantial moisture content by oil bath immersion, with oil recovery so that only a negligible amount of residual oil remains in the wood, said process comprising immersing the wood in a bath of water-immiscible oil under controlled condi-

tions of temperature, pressure and bath circulation so that a superheated steam blanket surrounds the wood at all times during the immersion thereof in the oil, the moisture content of the various portions of the wood thereby being rendered substantially uniform and of a value essentially determined by the equilibrium moisture content characteristic of the wood at the temperature of the superheated steam blanket, said process further comprising removing the wood from the oil bath, impinging superheated steam on the wood while the wood is still hot and until the oil content thereof is reduced to less than about 0.5% by weight, such superheated steam being under a vacuum pressure of less than about one-half atmosphere and being at a temperature substantially the same as the temperature of the oil in which the wood was immersed during drying thereof, and recovering by condensation essentially all of the oil vapor produced during drying of the wood and during subatmospheric steaming thereof.

5. The process of recovering water-immiscible drying oil from wood which has been dried to a substantially uniform moisture content by immersion in the drying oil at a temperature substantially above the boiling point of water; said drying oil recovery process comprising maintaining the moisture content of the wood substantially constant while evaporating the residual drying oil from the wood to the point where the final oil content is less than about 0.5% by exposing the dried wood while still hot to an environment of superheated steam under a vacuum pressure of not more than about one-half atmosphere.

6. The process of claim 5, wherein said oil is an aliphatic hydrocarbon having a distillation range of substantially 350° F. to 400° F.

7. The process of recovering water-immiscible drying oil from thin wood which has been dried to a substantially uniform moisture content by immersion in the oil at a temperature of about 250° F.-300° F.; said process comprising evaporating the residual drying oil from the wood to the point where the final oil content is less than about 0.5% by weight, such evaporation of residual drying oil being effected by exposing the dried wood while still hot to superheated steam under a vacuum pressure of not more than about one-half atmosphere and at a temperature of about 250° F.-300° F.

8. The process of recovering water-immiscible drying oil from thin wood which has been dried to substantially uniform moisture content by immersion in oil at a temperature substantially above the boiling point of water; said process comprising evaporating at least most of the residual drying oil from the dried wood by exposure of the dried wood while still hot to an environment of superheated steam under a vacuum pressure of not more than about one-half atmosphere for a time to reduce the oil content of the wood to less than about 0.5% by weight while maintaining the moisture content of the wood substantially constant, in the range of from about 2% to about 7% by weight.

9. The process of recovering water-immiscible drying oil from wood which has been dried to substantially uniform moisture content by immersion in a bath of high boiling point, water-immiscible oil at a temperature substantially above the boiling point of water and less than the boiling point of the oil, said process comprising evaporating most of the residual drying oil by exposure of the dried wood while still hot to a circulated environment of superheated steam at substantially the same temperature as the oil bath and under a vacuum pressure of not more than about one-half atmosphere for a time to reduce the oil content of the wood to less than about 0.3% by weight.

10. A system for fast drying wood by immersion in hot, water-immiscible oil and for recovering residual oil from the wood after immersion; the drying phase of said system comprising an enclosed drying chamber contain-

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ing a hot oil bath, means conveying the wood into said drying chamber and through the oil bath, means for heating and recirculating the oil bath, and means condensing the vapors given off in said drying chamber; and the recovery phase of said system comprising an enclosed oil recovery chamber, means conveying the wood through and out of said oil recovery chamber, means maintaining said oil recovery chamber under a vacuum pressure of not more than about one-half atmosphere, means for condensing oil vapor drawn off said oil recovery chamber, and means returning the oil condensate recovered from said drying chamber and said oil recovery chamber to the oil bath in said drying chamber.

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