# "CONTROL OF MOISTURE CONTENT IN SPECIAL DRYING PROCESSES"

by

ARTHUR B. ANDERSON *

In looking through the Forest Products Research Society publications, only three articles were published relating to special drying processes. Two of these dealt with vapor drying and the third was concerned with high frequency drying. Thus, it appears in general that not too much research has been devoted to this particular subject, at least, as revealed by literature. The reason advanced by the Forest Products Laboratory at Madison is the limitations or impractibility of some of these special drying methods.

There are seven special methods listed for drying wood, i.e.

1. Vacuum drying
2. Infrared radiation
3. High frequency dielectric heating
4. Chemical seasoning
5. Boiling in oil
6. Vapor drying
7. Solvent seasoning

Each of these will be discussed briefly.

Vacuum drying.

Many different processes have been proposed for using a vacuum to dry wood. Charles Howard was granted a patent for a vacuum process in 1893 and numerous variations have been patented since. No vacuum process for drying lumber has come into general use either here or abroad, except the steaming and vacuum process used to condition poles and other forms of timber prior to preservative treatment.

A vacuum is merely a reduced air pressure and the principles of drying are no different at a very low pressure than at any other pressure. The use of a vacuum alone is not effective for rapidly drying wood. Drying of wood involves two processes, movement of water to the surface of the wood and removal of that water from the surface. A vacuum maintained by continuously withdrawing the vapors from a drying chamber materially aids removal of the water from the surface for a short time but considerable quantities of heat are required to evaporate water. The evaporation of water from wood in the vacuum quickly cools the wood so that evaporation becomes very slow in spite of vacuum. Furthermore, except at the very start, the rate of drying of wood is governed by the rate of moisture movement from the interior to the surface. A vacuum has very

---

* Chief, Division of Forest Products Chemistry, University of California Forest Products Laboratory

little effect on the rate of moisture diffusion through wood. Because of the limited amount of drying possible with one heating in vacuum cycle, a number of cycles of alternate heating and vacuum must be used to dry wood to low moisture content values. The rate of heating of the wood and the diffusion of water through the wood becomes slower and slower as the moisture content is lowered so that the vacuum process becomes increasingly inefficient. If steam is used as a heating medium, a point of equilibrium is reached where the moisture absorbed by the wood during the heating is equal to the amount removed during the vacuum and no further drying occurs. It would be ideal to use humidified air as a heating medium controlling the condition so that little or no moisture is taken from or given to the wood during the heating, but such conditions are difficult to control in the vacuum process. In addition to the limitations of the process, the fact that the equipment is expensive works against commercial utilization.

Infrared radiation.

Since infrared radiation penetrates wood only to a slight degree it does not appear advantageous to use it as a source of heat for seasoning wood because the rate at which the interior heats will depend upon the surface temperature and not upon whether the surface temperature was established by absorption of infrared radiation or by contact with hot circulating air. To apply infrared radiation to all surfaces of each board would seemingly require the single file, board-by-board passage of the lumber through a tunnel on a traveling chain, a highly impractical and costly method. Even though practical solutions were found for the difficulties of using infrared radiation for the seasoning of wood, the cost of electricity would be greater in most localities than the cost of steam.

High frequency dielectric heating

When it was found that high frequency dielectric fields could change electric energy into heat inside of solids it was logical that someone would try to dry wood by this method.

Dielectric heating requires a generating apparatus capable of setting up an electric field that will oscillate at a frequency between condenser plates or electrodes. Wood placed in a powerful electric field oscillating at more than one million cycles per second, is heated quickly throughout to a temperature above the boiling point of water.

If wood were very porous with no resistance to the movement of free water or vapor it could be dried rapidly. In general, however, wood is not very porous.

In permeable woods the temperature levels off slightly above the boiling point as long as free water exists. When only bound water remains the temperature rises. If these high temperatures are prolonged they weaken the wood and lower its resistance to pressure. This may cause local explosions or split the wood wide open.

Apart from technical difficulties high frequency heating is generally too expensive to use for drying wood in this country. The total cost of power, equipment, and maintenance is about $20.00 per thousand board feet. The drying of green sapwood would cost at least $26.00 per thousand board feet. The reason for the higher cost is the greater amount of water present in sapwoods.

In view of the above, high frequency dielectric heating does not appear practical for the general drying of wood. A company in New England has used the method to dry turning squares of birch and maple. The 1-1/2" squares are given a drying period of seven hours in each of three chambers. Only the third chamber uses dielectric heating. The wood is removed from the unit after the 21 hour cycle and then dried in the air under a coarse canvas cover. No cost figures are available.

Chemical seasoning.

The application of a hygroscopic chemical to green wood followed by air seasoning or kiln drying is called chemical seasoning. Although, under certain conditions, considerable drying can take place during chemical treatment, the present use of the process involves comparatively short treating periods during which little or no drying occurs. The purpose of the chemical is to reduce or prevent surface checking during seasoning rather than to accomplish actual drying or to speed the drying.

The Forest Products Laboratory in Madison developed a process utilizing urea to reduce checking of Douglas fir timbers during air seasoning or kiln drying. The treatment is largely used in the seasoning of high grade Douglas fir timbers, particularly flat grain clears and ponton stock. No wide-spread commercial use has been made however of any chemical seasoning process other than that for Douglas fir.

The objective of the pre-seasoning treatment is to impregnate the outer zones of lumber with chemicals to a depth of about 1/10 the thickness with the highest concentration at or near the surface. The chemicals maintain the outer zones at a higher moisture content during drying than occurs within untreated wood. The hygroscopic nature of the salt keeps the treated wood more moist. The shrinkage tendency of the outer zones is thereby reduced and their tendency to surface check is lessened.

Numerous chemicals have been tried. Common salt is the most effective in reducing surface checking but corrodes metals. Urea appears to be the best or most economical chemical for pre-seasoning treatment. Its effectiveness in reducing surface checking is variable, however, with other species than Douglas fir, for under some conditions, urea treated oak may check worse than untreated oak. Urea corrodes copper bearing metals and discolors wood.

The cost of treating green wood is influenced by the method employed. The soaking method, generally the most efficient in reducing surface checking, requires a large investment in chemicals, tanks and other equipment. The solution becomes discolored with use in discoloring the wood. Wood is soaked in the chemical about three days per inch of thickness. Dipping, spraying, and brushing are cheaper than the soaking method eliminating the tank and the large amount of chemical needed to fill it. The lumber with chemical is piled in alternate layers using from 60 to 100 lbs. of chemical per thousand board feet, allowing about three days per inch of thickness. When the chemical has been absorbed the lumber is piled for seasoning.

Boiling in Oil.

Wood can be rapidly dried by submerging it in hot oil and boiling off the water. The Boulton process for conditioning timber before preservative treatment consisting of submerging the wood in hot preservative in a treating cylinder and speeding up the removal of water vapor by drawing a vacuum, is used extensively in the West.

In the boiling-in-oil method the wood is submerged in a water repelling liquid such as petroleum oil, creosote, or molten wax which has a boiling point considerably above that of water. The liquid is gradually heated until the temperature of the bath is somewhat above the boiling point of water. The water in the wood is turned into vapor and the vapor comes to the surface of the wood and boils off. As the water vapor at the surface boils off more vapor is formed in the wood and diffused to the surface. The boiling is very rapid for easily dried woods such as pine sapwood, as long as there is bulk water present in the wood cells. The heat absorbed by the water as it vaporizes tends to keep the temperature of the wood down to the boiling point of water. A thin film of nearly saturated water vapor protects the surface of the wood from the severe drying conditions of practically zero relative humidity in high temperature in the oil itself. When the free water is gone from the cavities of the cells and the only water left is that contained in the cell walls the protective vapor layer becomes very thin or disappears and the surface becomes subject to the severe conditions of the heating oil.

Lumber dried by this process retains severe case-hardening stresses at the end of drying. These stresses result in warping when the lumber is resawn or machined. There is no way to relieve these stresses without giving the lumber a conditioning treatment in a kiln or other chamber equipped for controlled humidity and temperature conditions.

By carrying out the process in a closed cylinder and drawing a vacuum in the space over the oil the water can be boiled off at a lower temperature. Below fibre saturation however, the wood will not dry so fast as with the higher temperature because the drying rate will be a function of the rate of diffusion in the wood. The rate of diffusion of moisture through wood is much greater at the higher temperatures.

While the water is coming out of the wood some of the oil goes into the wood. When the wood is taken from the bath some oil can be drained off or greater amounts can be removed by using an oil solvent or a vacuum. Usually relatively large quantities of oil remain in the wood after drying which is of course objectionable, not only from the cost standpoint, but also absorbed oil is detrimental for painting purposes, etc.

Vapor drying.

Vapor drying is the drying of wood by subjecting it to the vapors produced by boiling an organic chemical and removing the mixed vapors of water and the chemical from the drying chamber. Recently Hudson, of the Taylor-Colquitt Company, Spartanburg, South Carolina, developed a vapor drying process for railroad ties and poles. The process has been patented and is being used commercially. The wood is heated in the hot vapors of an organic chemical such as xylene, until most of the desired water removal is accomplished. Then the vapor supply is shut off and a vacuum is drawn. The process is carried out in a closed chamber. Atmospheric pressure and a temperature of approximately $300^{\circ}F$. are used during heating. The mixed vapors of chemical and water are continuously drawn off and condensed, the water is separated out and discarded and the chemical is recirculated through the evaporator to the drying chamber. The final vacuum removes most of the organic chemical absorbed by the wood during the heating. Before preservative treatment is started any residual chemical vapors in the cylinder are driven off by steam. The progress of drying in the vapor seasoning process is indicated by the quantity of water that is collected in the decanting chamber.

Oak and gum cross ties can be dried from the green condition to 20% moisture content in twelve hours compared with average air seasoning times of twelve to fifteen months for oak and eight months for gum. Southern pine poles 8" in diameter at midlength can be dried from 90% to 35% moisture content in ten hours. These moisture content values are satisfactory for preservative treatment.

The processes developed for seasoning railroad ties and poles is also capable of rapidly removing enough water from lumber to bring it to the moisture content values required for construction and other uses. 1" Southern pine lumber can be vapor dried to 5% content in five hours or less. Such drying results in checking of the heartwood, and although sapwood does not check, both heartwood and sapwood become very severely case-hardened. This severe case-hardening may prove very difficult if not impossible to remove by ordinary conditioning treatments. The process in its present form thus does not appear to be applicable to lumber except for low use items where checking and case hardening may not be objectionable.

Solvent Seasoning

When wet wood is continuously extracted with a solvent that is miscible with water, the solvent will remove the water as well as the extractives from the wet material even if the solvent is used cold. This, basically, is the solvent seasoning method.

In the Western Pine Association solvent seasoning method, the lumber is placed on end in a closed drying chamber or extractor. Hot acetone is continuously sprayed over the lumber until most of the desired water removal is accomplished. The acetone containing both water and the pitch from the wood is continuously drained from the extractor and recirculated back to the spray head. When the water content of the mixture reaches a certain point some of the mixture is drawn off as effluent and sent to a still to recover the acetone for reuse while the water plus extractives are drawn off from the bottom of the still. As the effluent is withdrawn from the extractor an equal volume of fresh acetone is added. This is all under automatic control. The moisture content of the lumber is controlled by the specific gravity of the acetone being circulated over the lumber. When the solvent becomes dry so does the lumber. Also automatic recorders are available to note the total quantity in gallons of effluent coming from the extraction chamber together with amount of water present in the effluent thus giving a continuous record of the amount of water removed from the lumber charge as it is being seasoned.

The second step in the drying process after the spray is shut off consists of fanning heated air over the lumber to complete the drying and remove the absorbed acetone. Following this an inert gas and steam are introduced into the extractor to reduce the fire hazard and increase acetone recovery. Wood dries more rapidly by this method than by ordinary methods. The Association estimates that ponderosa pine can be solvent seasoned in one-half to one-fourth the time required for kiln drying depending upon type and size of lumber being seasoned. When optimum solvent seasoning conditions are used these time schedules can be further reduced. Two reasons for this fast drying are the rapid rate of heat transfer by the liquid and the low relative humidity of the almost water-free acetone. In addition the acetone flows vertically through the sapwood boards thus bringing the drying medium into intimate contact with all the wood, not merely the surface as in ordinary drying methods. The acetone does not pass through the heartwood although some does diffuse in from the sides of the boards. The process actually increases the strength of ponderosa pine from five to ten percent, the process up-grades lumber varying from 50¢ to $4.50 per thousand and there is practically no de-grade due to cupping, warping and splitting. In addition the process yields rosin as a co-product from ponderosa pine at the rate of about 80 lbs. per 1000 board feet. This yield of rosin could be materially increased by using the effluent from the lumber to extract ponderosa pine stumpwood chips in another extractor which is hooked in series with the lumber drying chambers. Such stumps would yield about 450 pounds of rosin per ton of stumpwood which would greatly increase the yield of extractives.

The Western Pine Association has completed its pilot-plant testing of the process and they have determined the cost of solvent seasoning to be about $1.88 per thousand board feet for ponderosa pine lumber. They noted one objection to the process and that is the black knots fall out. This is not a serious objection since one company has shown that plugging black knotted lumber greatly increases its value.

The merits of solvent seasoning have not been evaluated for all lumber other than western pines, however some preliminary studies have shown that solvent seasoning will season refractory woods such as tanoak which cannot be seasoned satisfactorily by conventionally used methods. The University of California Forest Products Laboratory plans to study and appraise solvent seasoning as applied to California hardwoods which are not now being used because of the seasoning problems involved. Solvent seasoning may be the trigger which will release hardwoods which are now looked upon as weed species.