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The recently developed Vapor Drying Process for artificially seasoning crossties and poles prior to pressure impregnation with preservatives, which has attracted considerable attention in trade journals (1), (2) in recent months has now been in operation for over a year on one of the full sized creosoting cylinders of the Taylor-Colquitt Company at their Spartanburg, South Carolina, plant. Design work on equipment for the conversion of additional units has been completed and it is expected that six of these will be installed during the ensuing year. A number of improvements developed in the operation of the existing unit, that have resulted in considerable simplification of the equipment, will be incorporated in these new drying units.

Drying by means of this Process is accomplished by exposure of wood in closed vessels to the action of vapors from boiling organic liquids at atmospheric or sub-atmospheric pressures. The vapor generated by boiling suitable organic compounds in an evaporator of conventional design is introduced to the vessel containing the wood in sufficient quantity to maintain a high concentration of the chemical in the atmosphere of the drying vessel. Any appreciable dilution of this atmosphere by steam formed by vaporization of water from the wood is prevented by continuous displacement of the mixture of steam and organic vapor from the drying vessel by the inflowing dry organic vapor from the evaporator.

The mixture of steam and organic vapor discharging from the drying vessel is condensed and the liquids separated by gravity in a tank suitably designed, the water discharging, and the water-free drying agent being returned to the evaporator where it is revaporized to begin another circuit through the system.

For purposes of wood preservation the drying agents generally used are coal tar or petroleum fractions having narrow boiling ranges with initial boiling points in the range of 212°F to 400°F.

Several factors involved in the operation of the Process make it possible to utilize this high temperature range without detrimental effect to the wood, viz., (1) The chemicals used are inert with respect to any injurious reaction with the wood; (2) Oxygen is excluded from the system by displacing it with the organic vapor preventing oxidation; (3) Elevation of the wood temperature much beyond that of the boiling point of water while water is still present in it, is prevented since the contained water is free to vaporize at approximately its atmospheric boiling point; and steam evolved from the wood, which is superheated by contact with the surrounding highly heated vapor, is kept at a very low concentration so that hydrolysis is negligible; (4) The duration of exposure required to effect drying, is relatively short, and since time is a more important factor than is temperature in producing thermal changes in the temperature range which actually obtains in the wood under the conditions of operation, injury from thermal action is inappreciable.

During the more than six years spent in perfecting Vapor Drying considerable time was devoted to fundamental studies of such characteristics as drying rates, effect of temperature on the rate of drying, internal temperatures of the wood obtained with drying agents having different boiling points, uniformity of distribution of vapor in the drying vessel; etc. Certain general relationships have been found in these investigations that illustrate the mechanism of drying and these are presented below in the form of abstracts from some of the unpublished technical reports on this phase of work. By limiting the discussion to one species and size of timber that the number of variables to be considered is kept at a minimum. Since Red Oak crossties are one of the most important items handled in the present commercial operation, this part of the discussion will be confined to that species and to the 7" x 9" dimension tie which comprises the majority used in main line track.

Table 1 contains data obtained in Vapor Drying Red Oak crossties of this size with three petroleum drying agents having boiling points ranging from 250°F to 325°F. The data for each of the drying agents used represents the average obtained in drying four charges. It will be noted in this table that the vapor temperature in the drying vessel was in each case higher than the initial boiling point of the fractions found by distillation of the material by A.W.P.A. Method 11g. This

TABLE 1

Vapor Drying of 7" x 9" Red Oak Crossties with Petroleum Fractions

Drying Agent	V-250	PN-3485	GS-320
Distilling Range of Drying Agent (AWPA Method) (Standard 11g)	230°F to 285°F	260°F to 338°F	320°F to 375°F
Cylinder Temperature during drying	251°F	270°F	325°F
Moisture Content of Ties % of Oven Dry Weight			
Initial	75.0	75.0	75.0
Drying Time Hours		*Heating in Vapor*	
1	73.3	73.1	69.3
2	70.9	70.5	63.6
3	68.8	68.0	59.2
4	67.2	65.6	55.3
5	65.3	63.4	51.9
6	63.6	61.1	48.9
7	61.9	58.8	46.0
8	60.1	56.8	43.5
9	58.6	54.7	40.9
10	57.1	52.9	38.9
11	55.7	51.2	37.0
12	54.4	49.5	35.3
		Vacuum after Vapor	
13	50.9	42.8	31.2
14	49.3	41.2	29.9

difference results from the fact that in the A.W.P.A. distillation apparatus considerably more fractionation is produced than in the Vapor Drying equipment. Because of the absence of any appreciable tendency on the part of the equipment toward fractionation of the drying agent the temperature maintained in the drying vessel more nearly approaches that of the average boiling point of the drying agent, so that fractions which show rather wide distilling ranges as determined by laboratory tests can be used in the operation of the Process without showing appreciable increases in temperature from charge to charge. From the cost standpoint this feature is of importance because the price of fractions having very narrow boiling ranges is usually considerably more than that of wider cuts.

The initial moisture content values shown in this table were determined by oven drying one-inch thick cross-sections obtained by cutting green 8-1/2 foot ties at a point 2-1/2 feet from the end. The six foot sections remaining were used in the Vapor Drying test. The actual moisture content values found were adjusted percentagewise to a uniform value of 75% since the averages were near this point. Moisture content values for hourly intervals during the drying operation were obtained by weighing the water delivered to the water-drying agent separator, from the drying vessel at these intervals, and subtracting this weight expressed as percent of the oven dry weight of the wood from the moisture content extant at the end of the preceding interval. The drying procedure employed in the Vapor Process usually is carried out in the two steps indicated by division of the moisture content data into "Heating in Vapor" and "Vacuum after Vapor". During the period of heating in vapor the charge is receiving most of the heat for vaporization of the water, from the latent heat of vaporization of the condensing drying agent. While this is taking place a considerable portion of the condensed drying agent is absorbed by the wood. The purpose of the vacuum after heating in vapor is to re-vaporize the condensed drying agent from the wood so that it may be recovered at the separator. A vacuum of two hours duration at 20 to 25 inches of mercury removes practically all of the drying agent from the crossties. It will be noted also that the vacuum removed a substantial amount of water, ranging from about 15% of the total in the case of the charges dried at 352°F to about 33% for those dried at 251°F.

When these moisture content values of the "Heating in Vapor" step are plotted on semi-logarithmic coordinates, as in Figure 1, the data show a linear relation between the logarithm of moisture content and drying time after the system has reached stable operating conditions at the end of the first hour. This relationship has been found to obtain in tests on timbers of various species and dimensions, and is simply the mathematical statement of the law of mass action. In first order reaction equations of this type, slope constants being the specific drying

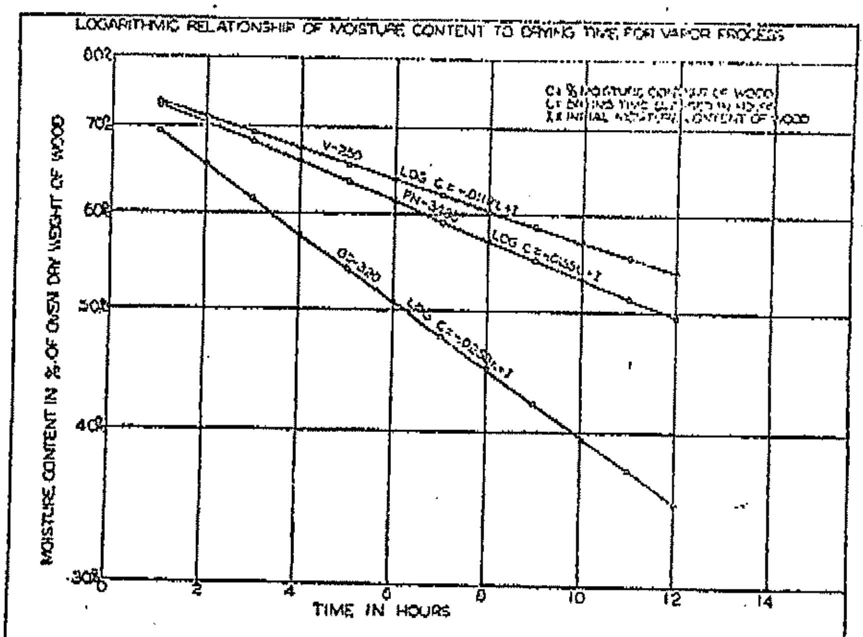

FIG I

rates they are independent of the amounts present and hence the rate of drying wood of a given species and dimensions is independent of the moisture content. In other words, the time required to completely dry a timber of relatively low moisture content would be the same as that required to dry the piece if it were very wet, since the moisture loss is proportional to the amount of water present. This relationship holds in most drying procedures and hence it may be concluded that the actual mechanism involved in Vapor Drying is the same as that of other processes although the rate of drying is much faster.

The effect of temperature on the rate of drying with the three petroleum fractions is shown in Figure 2. In this figure the time required to reduce the moisture content of the ties from 75% to 40%, as calculated by means of the drying rate equations shown in Figure 1 are plotted against temperatures of the vapor in the drying vessel. This curve indicates that the relationship of temperature to drying time is not a simple linear function but that as the temperature increases from

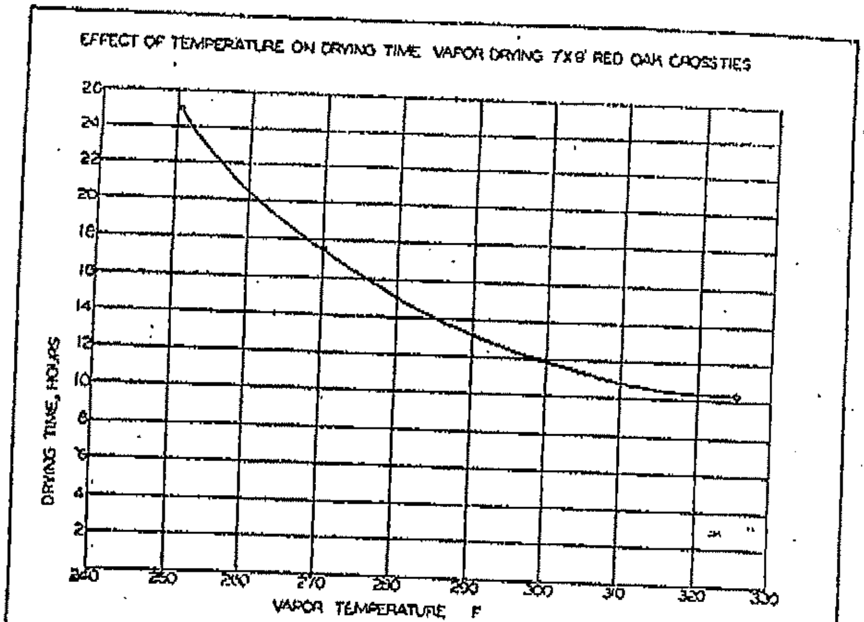

FIG. 2

212°F the drying rates increase tremendously but tend to level off sharply above 320°F.

Figure 3 contains data showing the internal temperatures attained in 7″ x 9″ Red Oak crossties at hourly intervals during heating in vapor which was maintained at a temperature of 350°F—355°F after reaching stable operating conditions. The temperatures were obtained by means of thermocouples situated in the wood at the various depths shown. The thermocouples were sealed into the ties in such a way that no lowering of the temperature by leakage of steam around them could occur. This set of curves shows quite clearly that the temperature of the wood remains well below the vapor temperature as long as water is present because of the cooling effect produced by the virtually free vaporization of water.

The heavy broken line above the Vapor Drying temperature curves represents data reported by MacLean (3) for internal temeratures in 7″ x 9″ timbers after heating in saturated steam at 260°F for ten hours. Here

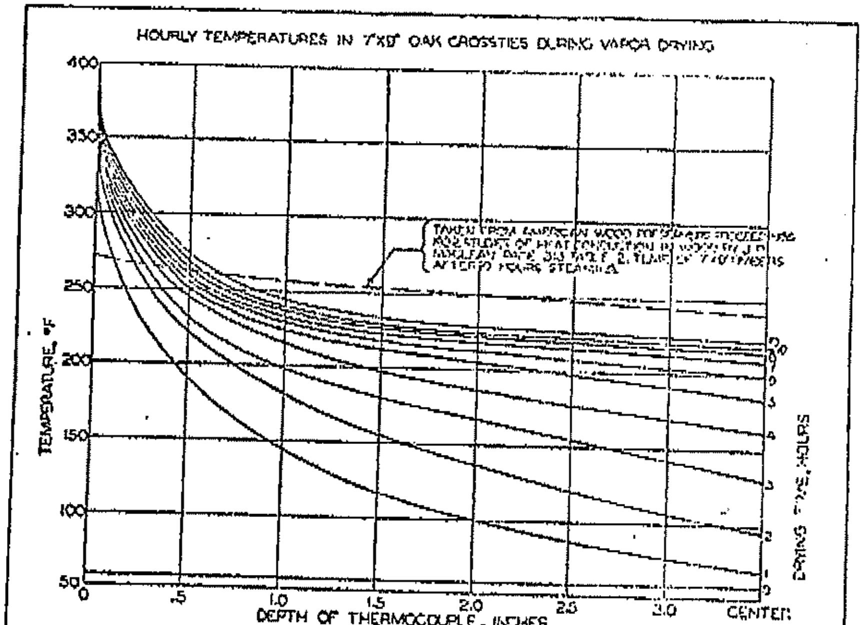

FIG. 3

it will be seen that in ten hours the temperature of the entire cross-section has risen to within a few degrees of that of surrounding atmosphere of steam. This difference between the internal temperatures during Vapor Drying and steaming accounts for the substantial difference in strength of Vapor Dried and steamed timbers. Since the temperature of the wood undergoing Vapor Drying remains near that of the boiling point of water until practically all of the water has been removed the amount of hydrolysis produced is so slight that there is very little strength reduction from this cause. Most of the Vapor Drying agents are immiscible with water so that the boiling point of the mixture is below that of the boiling point of water, and therefore much of the water loss occurs at a temperature below 212°F.

One of the problems of major importance studied in commercial operation of the Process has been that of degree of uniformity of distribution of the vapor throughout the tram loads of timber being dried. Such studies were made in the semi-commercial Pilot Plant but since each tram in this unit could accommodate only seven ties the results obtained were not considered to be indicative of what would occur in drying trams containing sixty to seventy ties. When the commercial unit was installed provision was made for entry of vapor to the cylinder at three points equally spaced along its length. Four ports of discharge were placed at the half-way points between the intervals set by the inlet points. Determinations of uniformity of temperature in the drying vessel and of distribution of moisture in ties situated at various points in the charge have revealed that even with a drying vessel eight feet in diameter and 115 feet long a single port of entry at the midpoint and two ports of discharge near the ends, the vapor distribution is highly uniform. Further evidence of the uniformity of distribution of vapor in the drying vessels has been found by comparison of the specific drying rate constants obtained in small experimental units containing a single tie, with those obtained for drying in a commercial unit holding 800 ties. Using the same drying agent and ties of the same dimensions in the two drying units the drying rates have been found to be identical.

Unlike processes employing fixed gases which require fans or other mechanical means to provide adequate circulation and distribution the basic physical factors involved in the Vapor Drying Process tend inherently to establish this. As an example assume that a saturated organic drying agent is introduced to the vessel at its boiling point of 300°F; the vapor will tend to flow toward any accessible portion of the vessel which is at a temperature lower than 300°F under a pressure head amounting to the difference between the vapor pressure of the drying agent at 300°F (760 mm of mercury since the system is open to the atmosphere) and its vapor pressure at the lower temperature. If the vapor pressure of the drying agent is, say, 200 mm of mercury at 200°F then the pressure head tending to transport the vapor to any point that is at 200°F, is 560 mm. However, in drying flat surfaced timbers such as sawn crossties or lumber it is necessary that separation strips be employed so that these surfaces can be reached by the vapor, but the strips used need not be more than about 1/2 inch thick.

Because of the variations in current practice employed in preparing timber for preservation it would be impossible to make a generalized comparison of the economics of the Vapor Drying Process as compared with other processes that would hold true for various species and types of timber being treated. However a comparison based on the two main products that are being seasoned by means of the Vapor Process viz.;

TABLE 2

Tabulation of Comparative Cost Items for Creosoted Oak Crossties Manufactured by the Vapor Drying and Air Seasoning Methods

	Air Seasoned	Vapor Dried
1. Cost of Green Ties	x	x
2. Cost of anti-checking irons and applying them	x	None used
3. Unloading and stacking on seasoning yard	x	None
4. Interest on investment in ties while seasoning 12 to 16 months	x	None
5. Insurance on ties in storage	x	None
6. Cullage caused by development of seasoning defects	x	Far less than in air seasoned stock
7. Loading for treatment	x	x
8. Adzing and boring	x	x
9. Cylinder time consumed in Vapor Drying	None	12 hours
10. Steam consumption	None	About 30 pounds of steam used per cubic foot of wood dried from 75% to 40% moisture content
11. Drying Agent Used	None	0.25 to 0.50 pounds per cubic foot of wood
12. Cylinder time consumed in impregnation	8 hours	4 hours
13. Creosote required to obtain complete penetration	x	Less creosote required to obtain complete penetration than in air seasoned ties

x — Symbol repeated in Vapor Dried Column indicates cost is same as for air-seasoned.

Oak crossties and Pine poles, with the currently used procedures of air-seasoning and steaming will serve to indicate the economic factors involved. Table 2 contains a qualitative comparison of these factors in terms of the various operations that determine the manufacturing cost of Oak crossties as produced by the Vapor Drying and air-seasoning procedures.

The difference in impregnation time and creosote retention between the Vapor Dried and air seasoned ties, shown in Items 12 and 13 of this table are a result of the difference in temperature of the ties at the time of impregnation. The air seasoned ties are at atmospheric temperature when placed in the cylinder and although the cylinder is filled with preservative at 200°F the preservative temperature decreases as it is injected into the relatively cool timber which slows down its rate of inward movement because of increased viscosity. Injection of the preservative into the Vapor Dried ties is not retarded in this manner since the internal temperature is as high or higher than that of the preservative. The higher fluidity of the preservative in the Vapor Dried ties makes it possible to obtain the required penetration in a shorter time than in the air seasoned ties, and also allows more of the excess preservative to be expelled from the former when equal amounts are injected. Whereas a preservative injection of about ten pounds per cubic foot into air seasoned ties will result in a final retention of about eight pounds per cubic foot, about 14 pounds per cubic foot can be injected into the Vapor Dried ties to obtain the same retention.

When all of these factors are considered in arriving at actual costs it will be found that the Vapor Dried ties will cost slightly more than the air seasoned, but the improvement in condition as to checking and splitting in the Vapor Dried ties should more than offset this. Moreover, the Vapor Dried ties installed in test track have shown virtually none of the progressive development of checks and splits that occurs in air seasoned ties, which indicates that their service life will be greater. In seasoning other hardwood species such as Gum in which decay is a serious hazard during the air seasoning period, particularly in the South, the Vapor Drying Process possesses even greater advantages.

In Table 3 the cost items for Vapor Drying are compared with those for the widely used steaming process for the conditioning of pine poles prior to preservative treatment. Important advantages of the use of the Vapor Drying Process on poles are lower shipping weight because of the greater water removal, and the considerably greater strength of the Vaor Dried poles (2), since they are not subjected to the hydrolic effects of steaming.

TABLE 3

Tabulation of Comparative Cost Items for Creosoted Pine Poles Manufactured by the Vapor Drying And Steaming Processes

	Steamed	Vapor Dried
1. Cost of Green Poles	x	x
2. Machine Peeling	x	x
3. Framing	x	x
4. Loading for treatment	x	x
5. Cylinder time steaming or vapor drying	x	x
6. Steam consumption	About 12 pounds of stem per cubic foot of wood dried from 90% to 75% moisture content	About 30 pounds of steam used per cubic foot of wood dried from 90% to 35% moisture content
7. Drying Agent Used	none	0.25 to 0.50 pounds per cubic foot of wood
8. Cylinder time consumed in impregnation	x	x

x — Symbol repeated in Vapor Dried column indicates cost is same as for steaming.

Commercial use of the Vapor Drying Process has thus far been limited to the drying of wood preparatory to preservative treatment. The final moisture content, required to obtain proper preservative treatment usually ranges from 25% to 40% and since treated products such as crossties and poles are exposed to the weather in service there would be no particular advantage gained in drying them to a lower moisture content.

At the present time a comprehensive experimental program is being carried out to determine the applicability of the Process, for drying lumber to the moisture content range of 6% to 12%, from both the standpoint of operational technique and equipment required. The results so far obtained in this work have shown that easily penetrated woods such as Southern Pine and the sapwood of a number of hardwoods such as Maple, Gum, Birch, etc., of one inch thickness can be successfully dried in 5 to 7 hours using the same non-polar drying agents that are used for drying timber in preparation for preservative treatment. The heartwood of refractory species such as Red Gum and White Oak have been found to develop collapse when dried to low moisture content in such short periods with these drying agents. The use of polar drying agents that tend to keep the wood swollen during the period of heating in vapor shows promise as a means of overcoming this difficulty, and this modification of the Process is now undergoing further test.

The equipment needed for drying of lumber is essentially the same as that used in the present commercial installation for preparing timber for preservative impregnation except that the drying vessel may be constructed of lighter material than is required to withstand the high pressures used in impregnation. The factor controlling wall thickness in the design of plants for drying lumber is the vacuum employed after heating in vapor which is used to recover the condensed drying agent from the wood. This vacuum is equivalent to about 12 pounds per square inch externally applied pressure and since the construction required to prevent collapse under externally applied pressure is heavier than that required to prevent rupture from an equal interval pressure, vessels designed to operate under this vacuum would have wall thicknesses adequate for operating at about 75 pounds per square inch internal pressure. The wall thickness required to resist externally applied pressures is far less for vessels of cylindrical shape than rectangular, consequently the drying vessel can be constructed more economically in the form of a cylinder. The question as to the adaptation of the Process to conventional equipment such as kilns has been thoroughly considered and although it would be possible to install linings in these that would prevent the escape of the organic vapor during the heating cycle it would not be economically feasible to reinforce such structures to withstand the vacuum step. Because of the high rate of throughput of lumber that is possible with the short time cycles of the Vapor Drying Process the size of the equipment required for a given production capacity is much less than would be required when using kiln drying methods, and while the type of construction is more expensive, the actual cost of the drying unit would be about the same.

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