

HEAT-STABILIZED COMPRESSED WOOD (Staypak)

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Introduction

By compressing wood under conditions that cause sufficient flow of the lignin (the cementing material between fibers) to relieve the internal stresses resulting from the Compression, it has been found possible to eliminate the spring-back tendency encountered in the usual densified wood. When wood is compressed at higher temperatures and moisture contents than are normally used, it does not, when swollen, tend to recover the original uncompressed dimensions. Wood so processed has been named "staypak" by the Forest Products Laboratory. The process is covered by U. S. Patent 2,453,679 which is dedicated to the free use of the public in the United States (15).

Stay-pak has distinct advantages over both the normal densified wood,³ or "improved wood" as it is sometimes called, and compreg.⁴ Whereas densified wood tends to lose its compression to a marked degree under conditions that cause swelling, staypak, although it will swell appreciably, will return to practically the original compressed thickness on drying to the original moisture content.

¹"Staypak" is heat-stabilized, compressed wood that has been heated, during the pressing process, under conditions such that the compression is not lost when the wood is subsequently swollen. Although it will swell appreciably, it will return to practically the original compressed thickness on drying to the original moisture content. It is thus wood that "stays compressed" (12).

²Maintained at Madison 5, Wis., in cooperation with the University of Wisconsin.

³Densified wood is normal untreated wood that has been compressed under conditions that do not cause flow of the lignin cementing material. It has been made from solid wood (4, 6, 7, 10, 11) and also from veneer preferably assembled with a synthetic resin glue (2, 5, 6, 7, 9, 16).

⁴Compreg is resin-treated compressed wood which is stabilized in the compressed form by the resin (3, 13, 14).

The behavior of compreg with respect to recovery of its original dimensions varies depending upon the conditions under which it was manufactured. Because of the stabilizing influence of the resin, it is possible to make compreg with negligible springback tendencies. The advantages of staypak over all compreg, however, lie in its strength characteristics. Although the shear strength parallel to the grain and in a plane perpendicular to the direction of compression of the wood is appreciably lower for staypak than for compreg, the impact strength is about double, and the tensile and bending strengths are approximately 25 percent more than those of compreg.

The manufacturing conditions under which staypak with the optimum dimensional stability can be made will be discussed, together with the characteristics of the material thereby obtained, the species and form of wood that may be used, and the possible uses of the final product. Figures 1 through 7 show some of the properties of staypak. Figure 8 compares Izod-impact breaks of staypak with compreg.

Effect of Moisture Content temperature-time

Variables in Making Staypak

A series of tests were made at the Forest Products Laboratory on yellow-poplar veneer to determine the best combinations of moisture content, temperature and time of pressing to obtain panels with optimum stability. Yellow-poplar was used because it is compressed to a greater extent in making a high-specific-gravity product than are denser hardwoods, and consequently its tendency to recover from compression should be greater. The choice of yellow-poplar, therefore, should accentuate differences in the product made under different conditions. Compressed parallel-laminated panels 13.5 by 9.5 inches by about 0.6 inch were made from 21 plies of 1/16-inch veneer glued with Bakelite resin XC7381. All the panels were compressed at 2,000 pounds per square inch and at temperatures ranging from 300° to 360°F., using veneer conditioned at 30, 50, and 65 percent relative humidity (moisture contents of 6, 9, and 12 percent, respectively) The time that the center of the panel was held at the heating temperature was either 5 or 30 minutes, The results of these tests are given in figures 1 to 4, inclusive.

Figure 1 shows the relationship between the specific gravity to which the wood is compressed and the moisture content, temperature, and time of heating. The wood conditioned at 65 percent relative humidity compresses more readily than the wood conditioned at 30 percent relative humidity especially at the lower temperatures and shorter times, as a result of the plasticizing action of the additional moisture. An increase in temperature for the wood conditioned at the higher-relative humidity has less effect upon increasing the compressibility than the same temperature increase for wood conditioned at the lower relative humidity. The wood conditioned at higher relative humidity is sufficiently plasticized even at the lower temperatures to be almost completely compressed. An increase in the time has a similar effect. Under temperature conditions which do not cause optimum flow, increasing the time makes possible a greater extent of flow.

Figure 2 shows that the water absorption, determined on 3- by 1- by 3/8-inch specimens (1 inch in the fiber direction) according to the Army Air Forces method (1) (weight increase after 24 hours' immersion), is much less for the specimens made from veneer conditioned at 65 percent relative humidity than for specimens made from veneer conditioned at 30 percent relative humidity, except at the highest temperatures. Increasing the time of heating for the less moisture-resistant specimens also greatly decreases the water absorption.

A similar decrease in the equilibrium swelling and recovery from compression, and in the permanent recovery from compression after drying, occurs. Within increasing moisture content and temperature and time of heating (figs. 3 and 4). These two tests were made on cross sections 1/8-inch in the fiber direction that were immersed in water for 40 hours. The equilibrium swelling (fig. 3) under conditions such that the recovery is small (values for material heated at 350° F. and above) is about 25 percent. The reason why this swelling is considerably greater than the swelling of normal wood is that the wood still retains its normal swelling tendency but, because the volume has been reduced to about one-third of normal, the swelling per unit of reduced volume is about trebled. This increased swelling is not so serious as may be thought, for swelling of sizable pieces of highly compressed wood in the absence of a tendency to recover to the uncompressed dimensions, is extremely slow. Even in the small specimens of figure 7 the absorption of water is slow when the wood is properly stabilized. Both the rate and the total amount of dimension change occurring with time are considerably less than for the nonstabilized forms of compreg on the market (13). Staypak swells so slowly in sizable pieces that dimension changes and warping are negligible for most uses. The surface fibers of staypak, however, respond to humidity changes readily and, as a result, staypak weathers on the surface like normal wood, assuming a grayish color with many fine hair-line checks when exposed to direct sunlight and moisture changes for long periods of time without a surface finish.

The wood is appreciably darkened in color under the stabilization conditions used in making staypak. The darkening is, undoubtedly, associated with some chemical change of the lignin that occurs under flow conditions. The color change is so sensitive that a series of specimens of a single species arranged in the order of increasing darkness are in the order of increasing stability.

Table 1 gives the properties of yellow-poplar staypak made from veneer containing 9 percent moisture (in equilibrium with 50 percent relative humidity) that was pressed at 2,000 pounds per square inch at a temperature of 340° F. for different periods of time. The data indicate a progressive improvement in the stability as the heating time is increased. Comparison of the data of figures 1 to 4, inclusive, indicates that a 60-minute heating period gives practically optimum stability properties.

The stabilization properties of 0.6 inch thick panels of staypak made from four species of wood, each at three moisture contents, together with the mechanical properties are presented in table 2. The equilibrium shrinkage between 9 and 30 percent relative humidities is given in place of the equilibrium swelling and recovery on water soaking. The measurements were made

in the thickness direction of the panel on 1/8-inch cross sections, as were the recovery measurements. In all specimens the water absorption was equal to or less than the 6 percent allowed in the Army Air Forces specification of June 10, 1942 for compreg, but not quite equal to the value of 2.5 percent allowed in the revised specifications of March 15, 1944.

Attempts to Plasticize Further the Lignin

Attempts were made to plasticize further the lignin of the wood at the time of pressing by using yellow-poplar veneer previously treated with each of the following chemicals: 10 percent of urea, hexamethylene tetramine, and formaldehyde, followed by conditioning at 30 percent relative humidity and pressing at 350° F. for 15 minutes. The compression was not increased nor were the properties improved. Due to the hygroscopic properties of urea, it had an adverse effect upon the stability. Treating veneer containing 9 percent moisture with pyridine, an excellent swelling agent for lignin, also failed to give the expected increase in plasticity under stabilizing conditions. Attempts to make staypak with glycerine replacing the water plasticizer gave an inferior product.

Veneer treated with a diacetone-alcohol solution of lignin so as to increase the lignin content of the wood by about 50 percent aided slightly in reducing the required compression pressure. The resulting staypak was darker in color and was more glossy than normal. The decrease in the required pressing pressure, however, was not sufficiently great to justify the treatment. It thus appears that the use of plasticizers other than water are not practical.

Manufacturing Conditions

Stabilization Temperature

Although the data of figures 1 to 4, inclusive, and table 1 indicate that the use of a temperature of 350° to 360° F. would permit more rapid manufacture of stay-pak, experiments in making large panels of commercial size (54 by 14 by 5/8 to 1-1/4 inches) indicate that these temperatures are too high when used on large pieces because they cause blistering and checking. This degrade in large, thick panels is due to the necessarily increased total time that the material must be in the press in order to get the heat to the center of the panels. The temperature range of 330° to 345° F. has proved to be the most satisfactory for making large panels of staypak that are check- and blister-free, from birch and maple, using the lower temperature for the thicker material .

Moisture Content

It is preferable to avoid moisture contents over 15 percent; it is still better to use veneer at 6 to 10 percent moisture content.

Excessive moisture (a) requires the use of excessive heat energy in raising the temperature of the wood to the required point. (b) increases the chances of the panel blistering or checking upon the release of the pressure, (c) increases the difficulty in properly bonding the plies together, and (d) gives a finished product that tends to lose moisture and shrink with time. As a moisture content of 8 percent may be considered to be a good average service equilibrium value for most parts of the United States, all the developmental work on large panels of staypak has been confined to material conditioned at 30 to 50 percent relative humidity to a moisture content of 6 to 9 percent. The wood has invariably been conditioned both before and after application of the bonding resin. It is believed, however, that the conditioning prior to application of the bonding resin can be omitted when the veneer is originally at approximately the desired moisture content.

Subsequent exposure of the specimens to prolonged low relative humidity, as in heated, unhumidified buildings during the winter months, and heating in an unhumidified oven at 140° F. for 24 hours, showed that staypak made up at moisture contents appreciably above 6 percent tends to end check to some extent.. Staypak that is to be used in heated buildings or exposed to the direct rays of the sun under low relative humidity conditions should, hence, be made from wood conditioned to 6 percent moisture rather than the higher, more suitable values for rapid stabilization.

Moisture Loss in Pressing

One of the chief difficulties encountered in making staypak is the loss of moisture from the end grain of the veneer during pressing. If the final pressing temperature is attained before the wood is highly compressed, sufficient moisture is lost from the ends to prevent them from being properly stabilized. Insufficient stabilization at the ends of the panels can be detected by eye, for then the ends are not as dark in color as they are when properly stabilized. Under conditions such that an appreciable amount of moisture is lost from the end grain, an excessive part of the panel must be trimmed off before use. To avoid this loss of material and to make the process practical, a number of ways of avoiding; end-grain moisture loss were developed. The most effective of these is to load the press cold, apply the full compression pressure, and then heat to about 220° F. at the center of the panel with the platens at about 250° F. The wood is compressed very slightly at first, but as the temperature rises to 220° F. the compression becomes virtually complete. At this temperature the vapor pressure of water is only about 3 pounds per square inch in contrast to the vapor pressure of 120 pounds per square inch at 350° F. The tendency for moisture to be driven out of the wood under pressure up to this stage is therefore relatively small. The compression that occurs at 220° F., however, is sufficiently complete to bottle the contained moisture within the wood. Subsequent heating of the wood to 330° to 350° F. after the compression at 220° F. is fairly complete causes the desired stabilization and completion of compression with a much smaller moisture loss than occurs when the wood is immediately raised to the higher temperature.

Another aid, to the stabilization of the wood under heat and pressure, that tends to reduce moisture loss from the end grain of the surface plies, when

veneer is used, is to cut the two face plies about 1/4 inch shorter than the other plies. The assembly of plies is laid up for pressing with the face plies 1/8 inch shorter at each end than the rest of the assembly. This causes the second plies to spread over the end grain of the face plies when the assembly is compressed and, as a result, seal off the end grain capillaries of the face plies. Because of the greater heating and higher average temperature of the face plies during the compression stage of the process, the face plies are more subject to moisture loss than the inside plies. It is desirable to follow this technique in combination with the first method of avoiding moisture loss in making the stabilized, compressed product from veneer.

The end grain moisture loss between the faces of the wood and the press platens or cauls may be minimized by a method that is effective for both veneer and solid wood. A strip of thermosetting glue about 1/2 inch wide is applied to the faces along the end grain. When the veneer assembly or the boards are pressed, this glue sets sufficiently to seal any capillaries formed between the wood and the press platens or cauls, thus preventing capillaries from carrying away water vapor.

Pressure

The pressure of 2,000 pounds per square inch used in making yellow-poplar staypak (figs. 1 through 4, table 1), has been shown to be greater than necessary to make staypak under most stabilization conditions. Excessive pressure tends to cause a spreading of the panels that may reduce the shear strength at right angles to the direction of compression. Pressures of 1,400 and 1,600 pounds per square inch appear to be adequate to give sufficient compression of yellow birch and sugar maple, respectively.

When too low pressures are used, the product is far less dimensionally stable than when it is highly compressed. For this reason it is recommended that staypak always be compressed to a specific gravity of at least 1.30.

Due to the thermoplastic nature of the lignin, it is important that the panels be cooled to somewhat below the boiling-point of water while under the full pressing pressure before they are withdrawn.

Side Restraint

When staypak is made from parallel-laminated veneer or from solid wood in thicknesses of 1/2 inch or more there is a tendency for the wood to spread in the across-the-fiber direction under pressure. When no side restraint is applied, the spreading of the panels is sufficient to reduce appreciably the specific gravity of the product near the edges. This same difficulty is encountered in the manufacture of compreg. Some form of side restraint should be used in making parallel-laminated staypak. This restraint can be provided by using a mold with stiff, sturdy sides capable of withstanding a side thrust of at least 500 pounds per square inch.

When a relatively few panels of each size and thickness are to be made, it will not pay to have a mold made for this purpose. Blocks of wood or packs of veneer strips approximately equal in thickness to the original wood, placed snugly along the fiber-direction edges of the panel assembly will furnish the necessary restraint when pressure is applied. It is necessary that the veneer packs or blocks have their end grain against the panel for then the restraining material shows no tendency to spread in the same direction as the panels. Blocks need not be placed continuously along the edge of the panel to be pressed. Blocks 2 to 3 inches long in the fiber direction of the panel may be spaced 2 to 3 inches apart, thus applying an intermittent restraint along half the length of the panel. There is a slight spreading between restraining blocks, but this is not sufficient to reduce appreciably the specific gravity of the product along the edges of the panel.

Time of Pressing

It has been shown in figures 1 to 4, inclusive, that the stabilization time will vary with the stabilization temperature and the moisture content of the wood. The time that the center of the wood need be held at the optimum temperature will also vary with the thickness of the wood. Thick material, such as 1-1/4-inch panels, will require a longer time to heat and to cool than 7/8-inch panels, thus the center of the thicker material need not be held quite so long at the optimum temperature. Table 3 gives the time required to make 53- by 14-inch panels of birch staypak in two thicknesses from veneer conditioned at 50 percent relative humidity. The time required for heating and cooling the 7/8-inch staypak should be half that for the 1-1/4-inch staypak on the basis of the time varying as the square of the thickness. This was found to be approximately true.

Type and Species of Wood

The thickness of the veneer used has a negligible effect upon the properties of staypak. It is preferable from a manufacturing standpoint to use 1/8-inch veneer or even thicker when parallel-laminated products are sought because of the saving in handling costs and in glue. Staypak has been successfully made from solid wood. This material, which contains no synthetic resin, is comparable in properties with the parallel-laminated staypak made from veneer, showing that glue lines of synthetic resin do not improve the properties of the product.

Tests were made to determine if cross-banded staypak can be made from preformed plywood. Matched panels of preformed plywood and plywood made up at the time of compressing and stabilizing, using a hot-setting phenolic glue, gave similar shear values in the plane of the plies indicating that no injury to the preformed synthetic resin glue lines occurs under the conditions for making staypak. Similar panels made with casein glue gave poor shear strengths in the preformed glue lines indicating that they will not stand the conditions for making staypak. Casein glue can, however, be used in making staypak from veneer when the glue is set at the time of compressing and stabilizing the wood.

Staypak can be made from a variety of species. It has been successfully made from veneer and solid wood of yellow birch, sugar maple, black walnut, and Sitka spruce, from veneer of yellow poplar, cottonwood, sweetgum, and Douglas-fir, and from solid hickory, white oak, red alder, and white fir. Difficulty in stabilizing the product was encountered with solid Douglas-fir and ponderosa pine. This appeared to be due to the natural resins of the wood. Contrary to the findings with other species, the stabilization was best at the ends of the specimens, presumably because the natural resins of the wood were squeezed out of the end grain. The fact that Douglas-fir veneer made satisfactory staypak while the solid wood did not was presumably due to the high temperature drying of the veneer that caused volatilization of part of the natural resins and fixing of the remaining resins, thus reducing the interferences of natural resins with stabilization. The only limitation in the choice of species for making staypak, according to the present procedure, seems to be avoiding the use of resinous, pitchy solid wood.

It is surprising that oak, with its high acidity, was suitable for making staypak. Evidently the tendency for hydrolysis to take place under the manufacturing conditions is not great.

When staypak is made of solid wood it should be made from flat-grain stock free from knots that are the full thickness of the wood. Summerwood will not compress to as great an extent as will springwood because of its high specific gravity. The summerwood rings will not compress to the degree that the wood as a whole will compress and hence they will buckle and distort badly when quarter-sawn boards are used, giving an unhomogeneous product. Knots have a considerably higher specific gravity than the normal wood and will take most of the load in compressing due to their lower compressibility. The knots will therefore tend to spread and crack the board. They are further liable to overstress the press.

Strength Properties

The strength properties of staypak are considerably higher than those of the normal wood from which it is made, the strength increases being about in direct proportion to the compression (table 2). The tensile strength, modulus of rupture, and modulus of elasticity in bending are significantly greater than for compreg of the same specific gravity. This is due to the fact that resin contributes to the weight and volume but not to these particular strength properties. Compreg, however, has a slightly higher compressive strength than staypak, due to the fact that resin does contribute to this property to a greater extent than to the increase in weight and volume.

The chief advantage of staypak over adequately stabilized compreg is its superior impact strength. Staypak, in general, has twice the Izod values of compreg. The break across the specimen is fibrous in contrast to the granular break of compreg, indicating a lack of embrittlement in the staypak (fig. 8).

Figures 5 and 6 show the notched toughness values for the specimens of yellow-poplar staypak of figures 1 to 4, inclusive. Figure 5 shows that staypak made from veneer in equilibrium with high relative humidity has somewhat higher

notched toughness values than the material made from veneer in equilibrium with lower relative humidity. This is due to the increased plasticization caused by increased moisture content, which results in an increased specific gravity under a fixed pressing pressure, as is shown by figures 1 and 6.

Izod impact values vary considerably less with specific gravity than do the notched toughness values. It has been shown prior to this time (8) that at the highest specific gravities the notched-toughness values should be divided by 11.0 to convert to Izod values in foot-pounds per inch of notch, while at normal wood specific gravities the notched-toughness values should be divided by 6. The data indicate that both the notched toughness and the Izod values of compressed wood are independent of the degree of stability imparted to the product prior to any recovery of the unstabilized specimens.

The shear strength parallel to the grain and in a plane perpendicular to the direction of compression of the wood (in the plane of the plies when veneer is used) is appreciably lower for staypak than for compreg. Any fibers that are ruptured during the pressing of compreg are rebonded with the resin within the plies. In staypak there is no resin present to do this. Unlike most properties, which do not seem to vary appreciably between species, the shear in the plane of the plies varies at least twofold between the species tested (table 2). A series of tests of the double cylindrical shear (1) parallel to the grain and in a plane perpendicular to the direction of compression gave average values of 3,700 pounds per square inch and 3,400 pounds per square inch for birch staypak (specific gravity 1.37) using 3/8-inch and 1/2-inch diameter specimens, and 4,500 pounds per square inch and 3,900 pounds per square inch for maple staypak (specific gravity 1.35) using 3/8-inch and 1/2-inch diameter specimens. Where shear in the plane of the plies is important staypak made from maple or birch should be used. Where this shear value is not of great importance, the staypak can be made from more readily available species.

A series of panels was prepared to determine if the high temperature to which the wood is heated in making staypak has any effect upon the shear in the plane of the plies. The data are given in table 4, segregated as to the position of the shear block in the panel and the position in the thickness direction of the blocks at which the shear tests were made. The fact that there is no consistent variation with temperature indicates that the lower shear strength of staypak as compared with compreg is due to the absence of resin within the plies rather than to the unusually high temperature of the process. The corresponding shear strengths for an uncompressed matched panel are also given in table 4. The shear strengths of the compressed staypak are all higher than for the uncompressed controls, even though they are not quite so high as for compreg.

Maple staypak made from veneer conditioned at 30, 50, and 65 percent relative humidity (table 2) will meet all the Army Air Forces strength requirements for compreg (1) over the complete range of stabilization conditions tested. Birch, gum, and cottonwood staypak will meet all the strength requirements except the shear strength in the plane of the plies. In this property birch staypak will give borderline values, while gum and cottonwood will give values somewhat below the specified values.

Gluing Staypak

Preliminary gluing tests indicate that staypak can be glued to itself or to normal wood more readily than can compreg. Good joints were obtained with various hot- and cold-setting urea and phenolic glues.

Although good glue joints giving 100 percent wood failure can be obtained with small blocks that have not been surfaced, large thick panels are seldom sufficiently flat to give very good glue joints. A means of making the surfaces plane for gluing by scraping them with a special knife has been developed.

Attack by Termites

Preliminary termite exposure tests of birch staypak under severe outdoors conditions for 6 months indicate that staypak shows little if any resistance to attack and is considerably inferior to compreg in this respect.

Potential Uses of Staypak

Stay-pak should have many uses, for it has an Izod impact strength about twice that, of stabilized compreg and appreciably greater than that; of unstabilized-compreg. Consequently it should be less susceptible to concentration of stresses. It has a greater stability than most of the high-impact-strength compregs, and it is potentially cheaper to produce. Service tests are being conducted on shuttles and picker sticks made of staypak for use in looms in textile mills. Because staypak is less notch sensitive than compreg it should be more suitable for spar plates and various fittings. It should also be suitable for tool handles, mallet head, pulleys, silent gears, and various tooling jigs and dies. Because of its greater swelling than that of compreg, staypak will not be so suitable for water-lubricated bearings or other underwater uses.

Summary

Solid flat-sawn nonresinous wood and veneer spread with glue and assembled in parallel-laminated or cross-banded form can be compressed to a high specific gravity product that does not tend to spring back under moisture absorbing conditions when it is pressed under conditions that cause some flow of the lignin. The conditions for making this material, called staypak, and its chief physical properties have been determined. It is shown to have several strength properties superior to compreg, most notable of which is its greater impact strength. Although it is not as dimensionally stable as compreg, it is sufficiently stable for many uses.

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Table 1.--Effect of variations in the stabilization time of yellow-poplar staypak upon its properties¹

<u>Minutes</u>	Specific gravity	Water absorption	Equilibrium swelling and recovery	Permanent recovery	Notched toughness
10	1.35	5.8	47.7	19.8	135
20	1.36	4.3	38.0	9.7	141
30	1.36	3.5	33.2	6.4	130
60	1.37	3.2	26.8	2.5	125

¹Wood preconditioned at 50 percent relative humidity to 9 percent moisture content, pressed at 2,000 pounds per square inch, final stabilization temperature 340° F., final thickness of panel 0.6 inch.

Table 2.--Properties of staypak made from veneers of four species conditioned a three relative humidities¹

Species	Veneer conditioned at relative humidity of	Final pressing temperature	Average specific gravity	Final pressing pressure	Water absorption	Shrinkage in thickness from 90 to 30 percent relative humidity	Recovery in thickness	Static bending			Compression parallel to fibers			Forest Products Laboratory block-shear test for plus lines		A. A. P. ² shear	Forest Products Laboratory notched toughness	Isod Impact Tests made by Forest Products Laboratory Bekelite Corporation	
								Fiber stress	Modulus of rupture	Modulus of elasticity	Fiber stress	Maximum modulus of elasticity	Parallel to plus lines	Perpendicular to plus lines	Perpendicular to plus lines				
	Percent	°F.		Pounds per square inch	Percent	Percent	Percent	Pounds per square inch	Pounds per square inch	1000 pounds per square inch	Pounds per square inch	Pounds per square inch	1000 pounds per square inch	Pounds per square inch	Pounds per square inch	Pounds per square inch	In.-lb.	Ft.-lb. per inch	Ft.-lb. per inch
Sugar maple	30	350	1.35	1,800 to 2,100	6.0	6.3	16.9	12,040	140,970	4,044	14,580	22,950	13,901	4,568	7,398	7,600	130.2	10.6	10.4
	50	345	1.35	1,600 to 2,200	5.9	6.1	11.7	19,730	137,680	3,984	12,210	19,980	13,763	4,094	7,404	7,050	121.2	9.3	10.9
	65	340	1.36	1,400 to 2,200	4.8	5.9	5.7	18,970	135,690	3,789	10,180	17,940	13,750	3,811	6,353	7,880	117.2	10.8	10.1
Yellow birch	30	350	1.37	1,800 to 2,200	4.6	5.9	8.1	24,040	142,790	4,740	14,260	22,860	14,043	3,632	6,322	6,830	129.3	11.4	10.6
	50	345	1.38	1,800	3.1	5.4	6.4	21,340	142,670	4,710	12,750	21,350	14,136	3,502	5,322	7,240	123.9	10.6	10.7
	65	340	1.36	1,600 to 2,200	3.4	5.5	5.0	18,980	136,720	4,080	10,690	17,980	13,732	2,700	5,063	6,940	117.6	11.1	11.6
Sweet gum	30	350	1.33	1,800 to 2,200	4.7	5.7	10.3	19,890	137,120	3,707	10,830	20,790	13,555	2,578	5,354	6,280	123.2	10.4	10.0
	50	345	1.30	1,600 to 1,800	5.2	5.3	5.1	16,760	130,580	3,180	9,700	18,680	13,075	2,464	5,913	6,240	114.1	10.8	9.7
	65	340	1.35	1,600 to 2,000	5.3	5.5	9.6	19,720	136,740	3,955	10,090	19,530	13,590	2,411	4,203	5,920	146.1	11.5	11.2
Cottonwood	30	350	1.37	1,600	4.0	5.6	13.0	22,650	134,850	4,420	11,730	21,340	14,114	2,192	5,287	5,080	146.0	13.3	10.9
	50	345	1.38	1,400 to 1,600	4.4	5.7	6.9	20,130	135,940	4,532	11,170	19,870	13,826	1,830	4,823	5,260	140.1	12.3	10.6
	65	340	1.37	1,200 to 1,800	4.2	5.9	7.1	18,710	132,400	4,184	10,280	18,730	13,647	2,051	4,997	5,620	144.1	14.0	11.8

¹Panel thickness approximately 0.6 inch. Time of heating at maximum temperature, 20 minutes. Each value represents the average for two specimens cut from each of four panels.

²Army Air Forces double shear test on cylindrical specimens (ref. 1). Tests made by Bekelite Corporation.

Table 3.--Time for making 53- by 14-inch panels of yellow birch staypak of two different thicknesses from veneer conditioned at 50 percent relative humidity

Operations	Time	
	7/8 inch thick	1-1/4 inch thick
	<u>Minutes</u>	<u>Minutes</u>
Heating platens.....	15	15
Heating center of wood to 335° F. ..	30	70
Holding temperature at 335° F.	15	10
Cooling to 85° F.	25	45
Total.....	85	140

Table 4.—Effect of temperature and time of heating in making yellow birch stappak upon the shear strength parallel to the grain and in a plane perpendicular to the direction of compression

Curing temperature	Curing time	Shear									Minimum	Maximum
		Edge block ¹	Block next to edge ¹	Block next to center ¹	Center block ¹	Near top of blocks ²	Center of blocks ²	Near bottom of blocks ²	Average			
°F.	Minutes	Pounds per square inch	Pounds per square inch	Pounds per square inch	Pounds per square inch	Pounds per square inch	Pounds per square inch	Pounds per square inch	Pounds per square inch	Pounds per square inch	Pounds per square inch	Pounds per square inch
<u>Compressed to Specific Gravity 1.36 to 1.38</u>												
300	5	3,048	2,776	2,603	2,651	2,845	2,637	2,693	2,725	2,308	3,270	
300	15	3,029	3,311	3,168	2,866	2,842	3,421	2,911	3,058	2,282	3,548	
315	15	2,762	3,011	2,625	2,471	2,966	2,865	2,320	2,717	2,075	3,310	
330	15	3,050	3,287	3,220	2,724	2,970	3,210	3,138	3,106	2,767	3,387	
345	15	3,048	3,047	2,987	2,473	3,131	3,057	2,613	2,933	2,448	3,495	
									Grand average	2,908		
<u>Uncompressed Control</u>												
300	15	2,240	2,148	2,095	2,119	2,639	2,011	1,802	2,151	1,633	2,712	

¹Each value is the average of three tests made at center and near each face of the blocks.

²Each value is the average of four tests made on blocks from the four positions from edge to center of the panel.

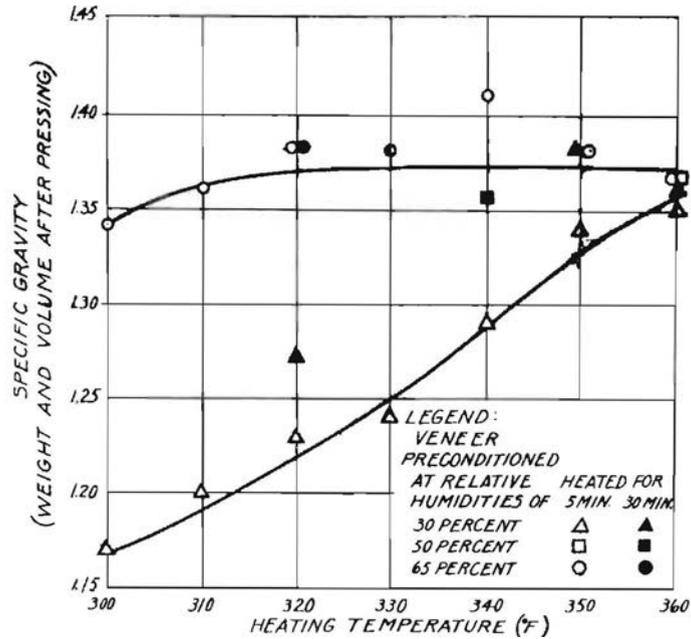


Figure 1.--Effect of the relative humidity at which the veneer was conditioned, the final heating temperature, and the time upon the specific gravity of parallel-laminated yellow-poplar staypak pressed at 2,000 pounds per square inch.

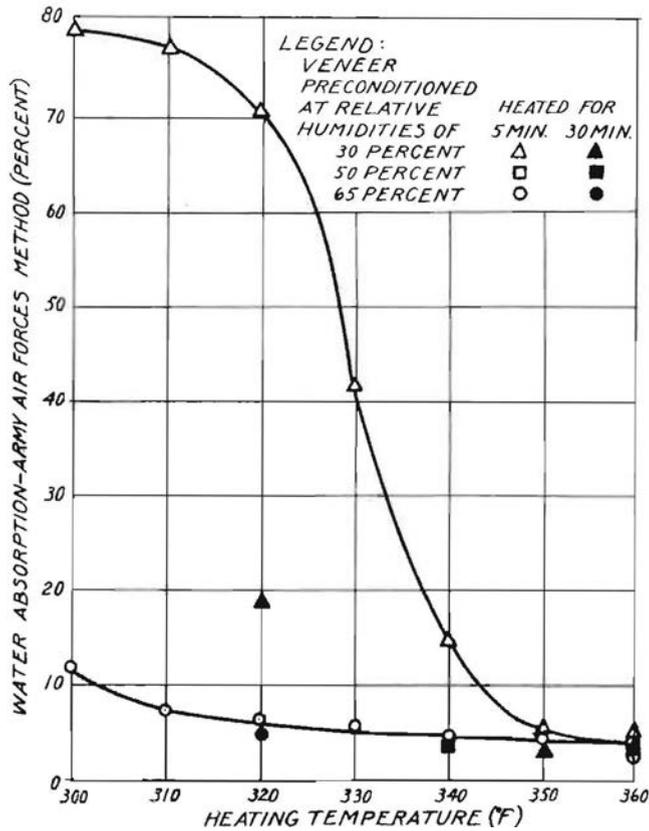


Figure 2.--Effect of the relative humidity at which the veneer was conditioned, the final heating temperature, and the time upon the water absorption of parallel-laminated yellow-poplar staypak pressed at 2,000 pounds per square inch.

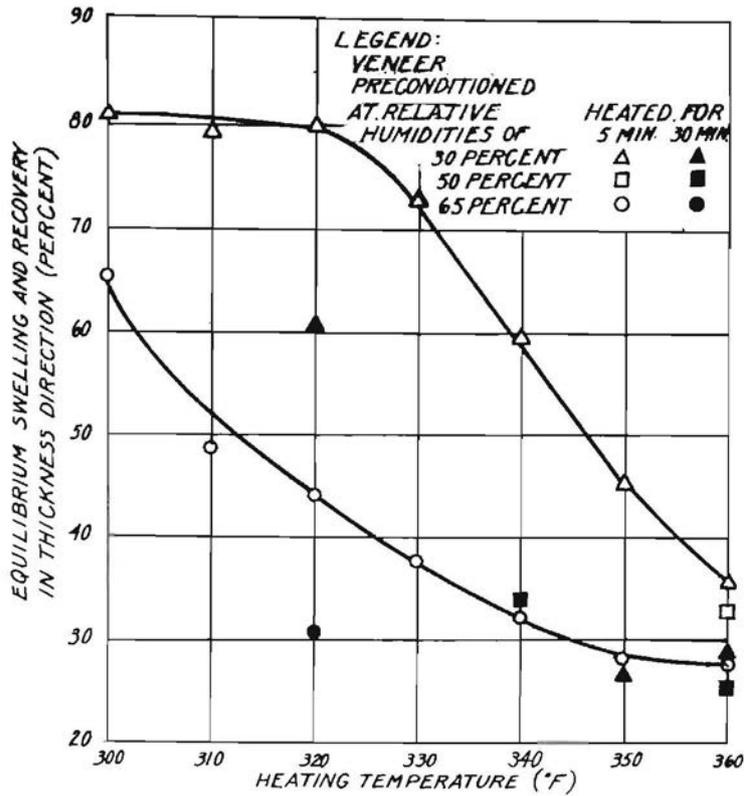


Figure 3.--Effect of the relative humidity at which the veneer was conditioned, the final heating temperature, and the time upon the equilibrium swelling and recovery in the thickness direction of parallel-laminated yellow-poplar staypak pressed at 2,000 pounds per square inch.

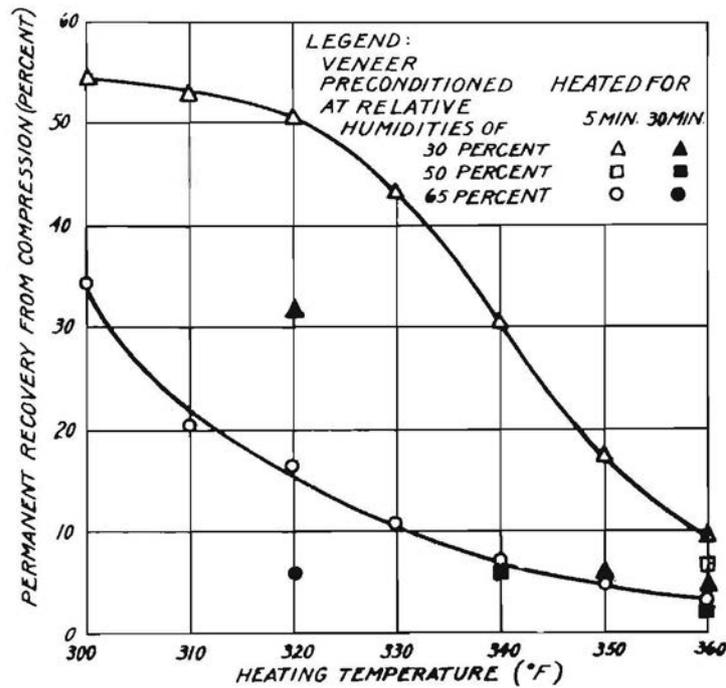


Figure 4.--Effect of the relative humidity at which the veneer was conditioned, the final heating temperature, and the time upon the permanent recovery from compression, of parallel-laminated yellow-poplar staypak pressed at 2,000 pounds per square inch.

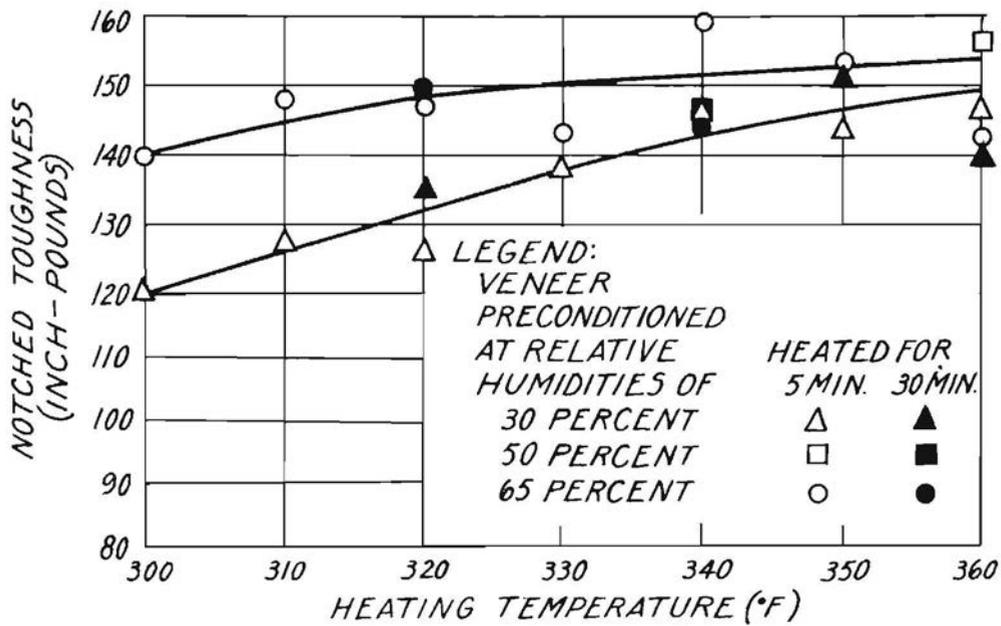


Figure 5.--Effect of the relative humidity at which the veneer was conditioned, the final heating temperature, and the time upon the notched toughness of parallel-laminated yellow-poplar staypak pressed at 2,000 pounds per square inch.

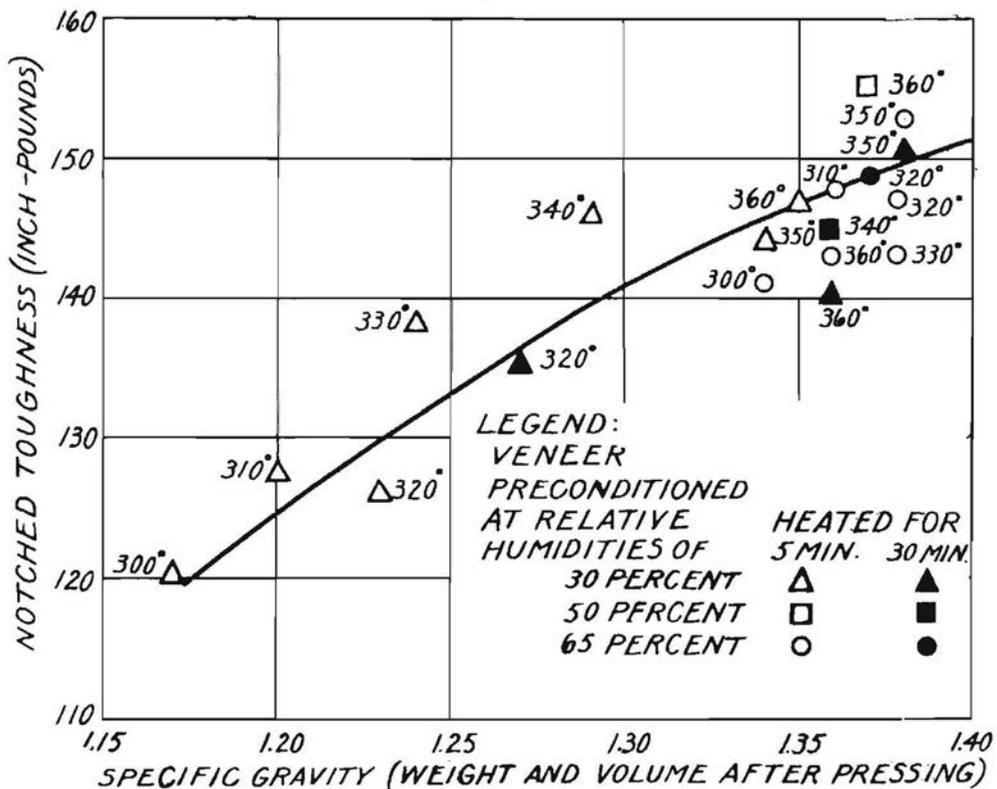


Figure 6.--Data of figure 5 plotted to show that differences in notched toughness for panels made from veneer conditioned at different relative humidities are due to differences in the specific gravity to which the wood is compressed.

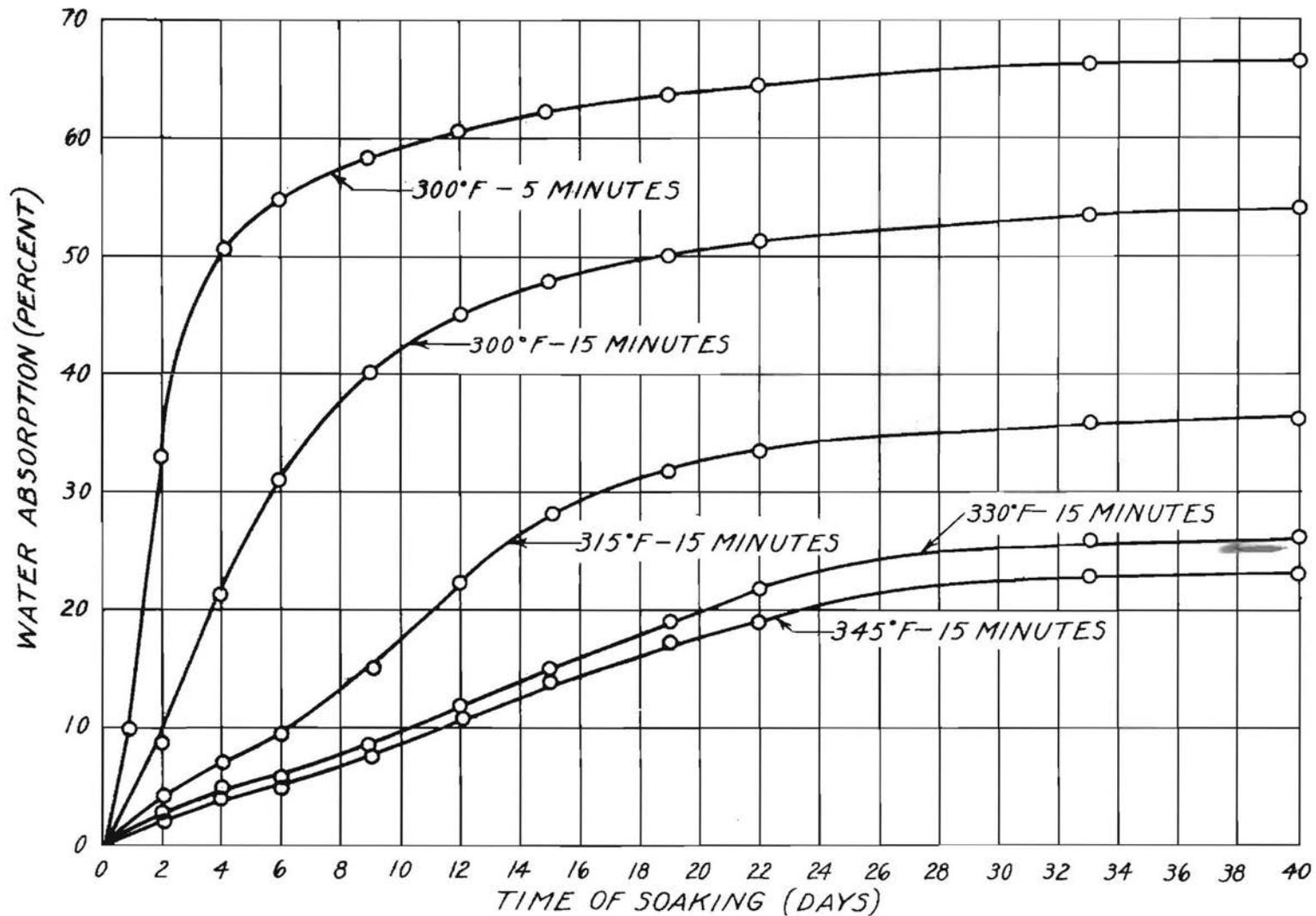


Figure 7.--Rate of water absorption by birch staypak made from veneer conditioned at 50 percent relative humidity and pressed under different stabilizing conditions. The stabilizing time is the time that the center of the specimen is held at the optimum heating temperature. The specimens were 1 by 0.75 by 3 inches, the 1-Inch dimension being in the fiber direction.

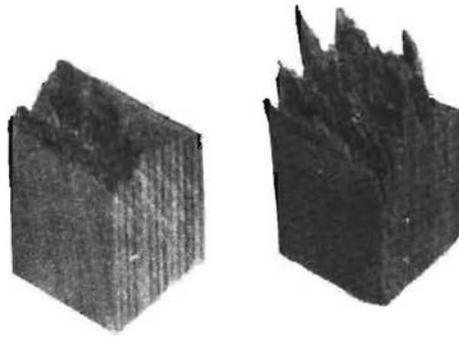


Figure 8.--Comparison between the Izod impact breaks
of compreg (left) and staypak (right)

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