A PRELIMINARY STUDY ON HEAT-STABILIZED COMPRESSED WOOD-"STAYPAK"

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I. INTRODUCTION

It is a general trend that the higher the specific gravity of any species of wood is, the higher strength properties it will afford (I)[1]. High densified wood has been made by compressing the normal untreated wood under high pressure. This type of densified wood, however, tends to lose its compression to a marked degree under unfavorable conditions. As a result of research, The Forest Products Laboratory of the United States Forest Service has been developing a new type of improved high densified wood entitled "heat-stabilized compressed wood" or named as "staypak". The manufacture process consists in compressing wood under the conditions of higher temperature and higher moisture content than normally used. Such process will cause sufficient flow of the lignin to relieve the internal stress resulting from the compression (2).

Staypak, although it will swell appreciably, is more stable than normal densified wood. In comparision with other resin-treated improved woods, such as impreg and compreg (3, 4), staypak has higher impact strength and the merit of ~~without~~ not using any impregnating resin. According to the present procedure, staypak can be made from a variety of species of woods. The only limitation in the choice of species is to avoid the use of resinous, pitchy solid wood. It is assumed that natural resins might interfere with the stablization in making staypak (2).

The manufacture of staypak is most desirable in some countries

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1. Numbers in parentheses refer to Literature Cited, P. 20.

without proper or considerable quantity of tough woods to supply their wood-using industries.

This report may be regard as a preliminary comprehensive study of the properties of various types of staypak. Additionally, the methods for increasing the dimensional stability of staypak will be investigated, and a comparsion of its properties with the properties of other improved woods will be discussed in order to predicate its potential uses.

II. MANUFACTURE OF STAYPAK

The principal procedures of manufacturing staypak were in conformity with the U. S. Forest Products Laboratory's recommendation (2). Three types have been made, namely, solid, laminated and cross-banded staypak.

Solid staypak was made from both solid aspen (Populus grandidentata Michx.) and balsam fir (Abies balsamea Mill). The manufacture procedures may be cited as follows:

I). Selecting solid wood from flat grain stock, free from knots and checks.

2). Conditioning the moisture content of the wood to 8% approximately.

3). For reducing the moisture loss in pressing, a strip of thermosetting glue (Bakelite BC-7613) was applied to the surfaces along both the end and edge grain.

4). Heating the platens of the press to 150°F, pressing the solid wood under the heated platens at the pressure 1,500 pounds per square inch, and increasing the temperature of the heated platens to 300°F,

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2. According to U. S. Forest products Laboratory's recommendation, the temperature of making staypak should be more than 300°F, but in this experiment 300°F was adopted. Because the maximum bonding temperature of Kimpreg (which was used in this experiment is 300°F in ~~ac-~~ accordance with its specification.

maintaining about 35 minutes (including the heating time of both from the heated platens to the center of the 3/4 in. thick board at 300°F about I5 minutes and holding the temperature of the center of the board at 300°F about 20 minutes, galvanometer (5) used for determining the temperature of the center of the board).

5). Cooling the heated platens of the press to about I50°F, one hour and 25 minutes required, then pressure released.

6). Trimming the surfaces along both the end and edge grain coated with thermonsetting glue, and marking the panel number.

Laminated staypak was made from rotary cut I/I6 in. thickness cottonwood veneer (Populus deltoides Marsh.), which has been carefully selected according to Army Air Forces Specification (6). Then the veneer was cut into 9 in. by 8 in. in dimension, conditioned to 8% moisture content, laid up the panels with Tego film alternately to the thickness about I I/4 in. and pressed as previously stated in the manufacture of solid staypak. However, because of the increase of thickness, the time of heating was comparative longer, about 45 minutes were required, including the heating time of both from the heated platens to the heating center of panels at 300°F, about 25 minutes, and the holding temperature of the center of wood at 300°F about 20 minutes; while the time of cooling to I80°F before pressure released was one and half hour.

For increasing the dimension stability of staypak and preserving its high impact strength, Kimpreg Grade 2000, an impregnated plastics paper (containing 50% resin) made by Kimberly-Clark Corporation, was used as a surfacing (3 sheets were used per side) as well as bonding material instead of Tego film.

In making cross-banded staypak, the procedures were the same as that of laminated staypak, except that the veneer was banded by cross layers. Both Tego film and Kimpreg plastic paper were used.

III. NATURE OF THE TESTS

All the ready made staypak panels were conditioned in the conditioning room at 30-50% relative humidity. The test specimens were cut from each panels in such a manner that the cut surfaces were not overheated, charred or burnished. All cut surfaces have been carefully finished with emery paper. During test, the moisture content of those specimens was 8% approximately.

The tests of this investigation included two major groups ~~tests~~, namely, physical determinations and mechanical tests.

I. Physical Determinations

The physical determinations included compressibility, specific gravity, water absorption, shrinkage, recovery in thickness, swelling in thickness and surface insulation resistance.

The characteristics of those tests will be described as follows:

(1). Compressibility

Compressibility means the percentage of the thickness after pressing to the original thickness including the sum of the thickness of both the number of veneer and the bonding material used.

i. e. $\text{Compressibility\%} = T_p / T_o \times 100$

Where:

T_p = Thickness after pressing.

T_o = Original thickness including the sum of the thickness of both the number of veneer and bonding material used.

(2). Specific Gravity

The method used in determination of the specific gravity of staypak was in accordance with the U. S. Army Air Forces Specification. Three test specimens 1 in. by 3 in. by thickness as supplied of each panels were cut, so each type of staypak had twelve specimens.

In determining the specific gravity, the test specimens have been dried for 24 hours at a temperature of 210° ± 5°F. After drying, the specimens were weighed and the volume were calculated from micrometer measurements. The specific gravity then was computed by dividing the dry weight in grams by the volume in cubic centimeters.

(3) Water Absorption

According to the U. S. Army Air Forces Specifications , the water absorption of staypak was determined.

Nine specimens I in. by 3 in. by thickness as supplied of each panels were cut crosswise of the grain. All original surfaces remaining on these specimens have been removed with sandpaper. Three of these specimens were dipped in No. 0 water reppellent (made by Protection Products Manufacture Company) about three minutes, three of them were coated a single layer of Penacolite SC-4100 made by Pennsylvania Coal Products Company and the other three were in normal condition. Both the coated specimens have been dried over one week before test.

During testing, those specimens were dried at a temperature of 50± 3°C (122 ± 5.4°F) for 24 hours. After drying, the specimens were cooled in desicator, weighed, and then completely immersed in water maintained at a temperature of 25°± 2 C(77°± 3.5°F) for 24 hours. At the end of the 24-hour period, each specimen was removed, the surface moisture quickly absorbed by a dry cloth and the specimens reweighed. The percentage change in weight during immersion was caculated on the basis of the dry weight.

i. e. Water absorption % = Ww - Wd/Wd X 100

Where:

Ww = Wet weight.
Wd = Dry weight.

(4). Shrinkage, Recovery in Thickness and Swelling in Thickness

Three tests specimens I in. by 2 in. by thickness as supplied of each panels were cut along the grain. All original surfaces were polished with sandpaper.

In testing, the thickness, width, and length of each specimen was measured with micrometer individually, then those specimens were conditioned under the condition of 90 % relative humidity until their weights approximately constant, and measured again as before. For drying those specimens, the relative humidity was reduced from 90 % to 30%, at the end of their weights approximately constant, the method of measurement as mentioned above was repeated.

The results were calculated by the following formulas:

Shrinkage % (from 90% to 30% relative humidity = $T''-T'/T'' \times 100$

Recovery in Thickness%= $T'' / To \times 100$

Swelling in Thickness%= $Tp / T'' \times 100$

Where: T'' = Thickness at 90% relative humidity.
T' = Thickness 30% relative humidity.
TO = Original thickness before pressing.
Tp = Thickness after pressing.

(5). Surface Insulation Resistance

The surface insulation resistance between two electrodes which are fastened to a solid insulating material is the ratio of the voltage applied to the electrodes to the current which flows through the surface layers.

The method used in determining the surface insulation resistance of staypak was "the Standard Method of Test for Insulation Resistance of Electrical Insulating Materials" adopted by the American Society for Testing Materials (7) with minor modifications.

Two specimens 1/2 in. by 5 in. by thickness as supplied of each panels were cut ~~only~~ along the grain. All the specimens were conditioned in a desicator containing density 1.34 of sulfuric acid-water solution kept at 20°C (the relative humidityi in the desicator was closely to 50%) over one week before test. While the moisture content

of the specimens determined was about 9% during test.
In this investigation, the strip electrodes were used as shown in Fig. I and the connections of apparatus for determination of surface insulation resistancew was also represented in Fig. 2.

During test, the deflection method was adopted as the following procedures: (I). Connecting the leaders to the electrodes on the specimenkept in the desicator, (2). closing the key K-I, a deflection on the galvanometer was notablyy observed, (3). closing the key K-2, deflection was very slightly increased and reading the deflection a after I minute or until the deflection unchangable, (4). reversing the connections to the battery and repeating the above procedures, and (5). taking the average value of deflection (D') as determined. Both the face and the sides of each specimens were determined.

Finally, the ratio of current to deflection was determined as shown in Fig. 3 and the procedures are cited as follows: (I). Closing key K-I, (2). reading the deflection on the galvanometer, (3). reversing the connections to the battery and reading the deflection again, and (4). taking the average value of deflection.

$$\because \quad I = V / R$$

Then $I/D = V / RD$

$I/D = I'/D'$

$$\therefore \quad I' = V/RD \quad D'$$

$R' = V'/I' = V'RD/VD'$

Therefore; $= Rs\, b / L$

Where: Rs = Surface insulation resistance per square.
Rs = Twice the surface resistance (R') as measured.
b = The average length of the electrodes, and
L = The distance between the electrodes.

2. Mechanical Tests

The mechanical tests included static bending, compression parallel to grain , shearing perpendicular to plies, hardness and gluing strength. Because of lack of equipment, the "impact strength" test was necessary omitted.

A Riehle´ three screw universal testing machine of sixty - thousand pounds was employed in this investigation, except the hardness test.

(I). Static Bending

The method used in obtaining figures on this test was in conformity with the U. S. Army Air Forces Specification. Three specimens I in. by IO in. by thickness as supplied of each panels were cut lengthwise of the grain.

In testing, each specimen was set up as a simple beam with concentrated midpoint loading. All points of load application, or reaction, was through bearing blocks having a radius more than I/8 in.. The distance between the reaction bearing blocks was more than I6 times the specimen thickness. The load was applied at a rate of 0.05 inch per minute. Simultaneous readings of applied load 50 pounds and corresponding deformation have been taken up to that the stress of proportional limit was over. After passing the stress of proportional limit, load was continually applied until failure occured.

Results were calculated as the following formalas (I):

Stress at proportional limit = $3P'L / 2bd$
Modulus of rupture = $3PL / 2bd$
Modulus of elasticity = $P'L / 4bdy$

Where:

P' = Load at proportional limit, pounds.
P = Maximum load, pounds.
L = Length of span, inches.
b = Breadth of specimen, inches.
d = Depth of specimen, inches.
y = Deflection at proportional limit, inches.

(2). Compression Parallel to Grain

The method used in this test was the same as U. S. Army Air Forces Specification. Three specimens I/2 in. by 2 in. by thickness as supplied of each type were cut lengthwise of the grain. To reduce the effects of unequal loading, spherical seats has been employed during test. The rate of head travel was 0.05 inch per minute. Simultaneous readings of applied load 250 pounds and corresponding deformation have been taken up to that the stress of proportional limit was over. Maximum load also was recorded.

Formulas used in computing the strength values are cited as follows:

Stress at proportional limit = P'/A
Maximum crushing strength = P/A
Modulus of elasticity = $P'L/Ay$

Where: P' = Load at proportional limit, pounds.
P = Maximum load, pounds.
A = Area under direct stress, square inches.
y = Amount the specimen is compressed(i. e., shortened) at the proportional limit, inches.

(3). Shearing Perpendicular to Plies

Because of the thickness of panels less than half inch, according to U. S. Army Air Forces Specification, the test of shearing parallel to plies was omitted. Regarding the test of shearing perpendicular to plies, three cylindrical specimens of each panels were taken as shown in Fig. 4. The diameter of specimen was around 0.375, and the length was more than one inch.

In testing, the specimens were tested in a three-plate self-aligning testing jig as specified. The load application rate was 0.025 inch per minute and the direction of loading in respect to the grain and laminations was in accordance with Fig. 4.

Results were computed by the formulae:

Maximum shearing strength perpendicular to plies = $P/2 \times A$

Where: P=Maximum load,pounds; A=cross sectional area of cylindrical specimens, sq. in.

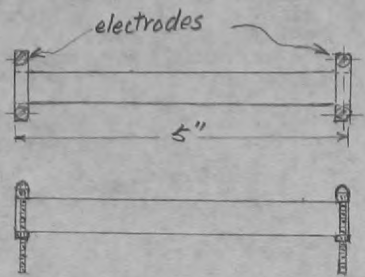

Fig. 1. Strip Electrodes

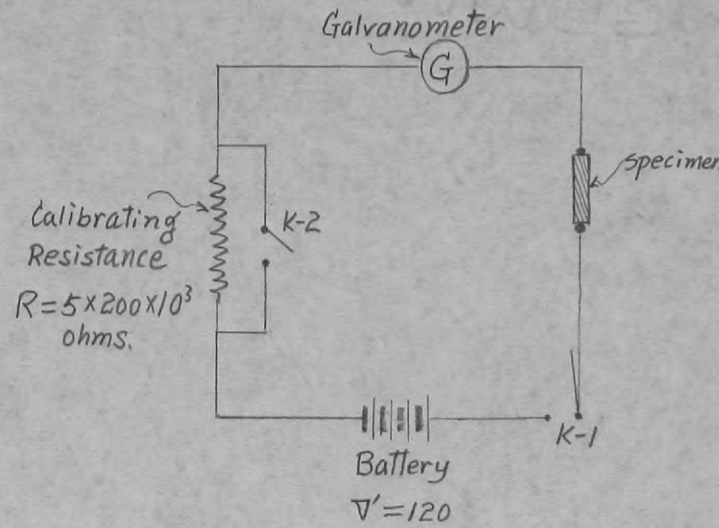

Fig. 2. Diagram of Connections for Determination of Insulation Resistance.

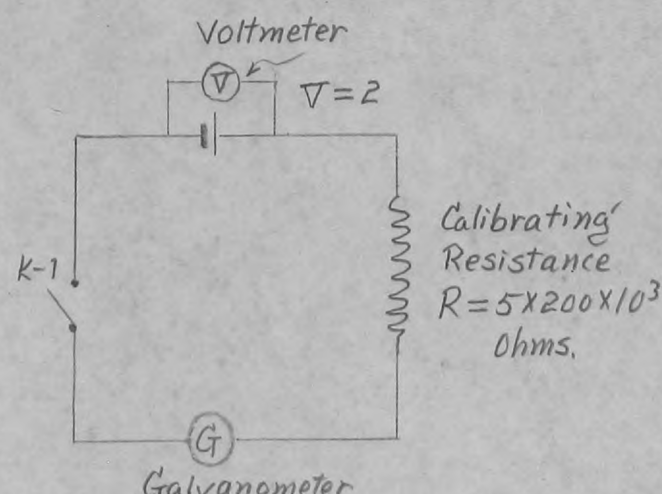

Fig. 3. Diagram of Connections for Determining the Ratio of Current to Deflection

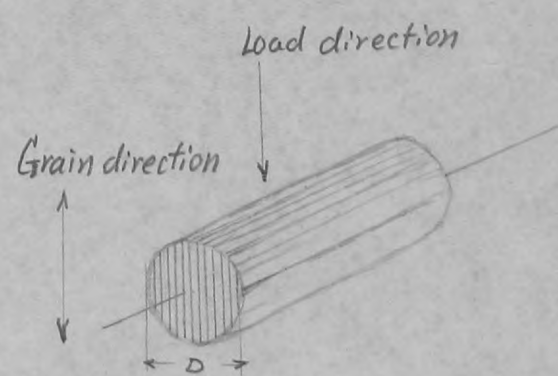

Fig. 4. Specimen of Shear perpendicular to plies.

(4) Hardness

Rockwell hardness test was adopted in this investigation, conforming to the requirements of the Standard Method of test for Rockwell Hardness of metalic materials of the Amercian Society for Testing Materials.(8)

The area of specimens were cut more than one inch square thickness as supplied, more than 1/4 in. Each panel had more than four specimens. A Wilsom Rockwell hardness testing machine was employed.

During the test, the machine was so adjusted that the major load of 100 kg. would be fully applied in from 6 to 8 seconds. A 1/4-in. ball penetrator was used. M scale was adopted for recording. Each sample has been tested more than three times, and average results were taken/ The room temperature was 81°F.

(5) Gluing Strength

The testing method used in this test was that developed by the Forest Products Laboratory of the United States Forest Service (9) and subsequently adoped. However, because the material was not enough, the standards size (3/4 in. by 2 in. by 1 3/4 in.) was reduced to 1 in. by 1 in. by thickness as supplied. Caein glue(Perkins metal veneer glue) was selected as the boning material. Before applying glue, the surfaces to be jointed were carefully smoothed. The glue was prepared according to the "Directions for Using Perkins Metal Venaer Glue Powder", The proportion of glue and water was 1 to 1 3/4. The samples were glued under the condition of double spread, 15 grams of prepared glue per side per square foot, assemblage time 15 minutes, and bonding pressure, 150 pounds per square inch. After the glued

Joints had aged about one week, all samples were cut into shear specimens, and tested as the shearing strength test for the wood. The percentage of wood failure also was carefully recorded. The r results were computed as the formulae:

Maximum ~~shearing~~ Gluing strength = L/A

Where:
L = Maximum load, pounds.
A = Area under shearing, square inches.

IV. RESULTS AND INDICATIONS

I. Data Obtained from the Tests and Indications

The mechanical and related data on the various types of staypak studied, obtained by means of the testing procedure as previously stated, are presented in Table I.

In investigating Table I, some significient indications have been noted, these indications are stated by the sequence of the column headings as follows:

(I). Compressibility (Column 5)----- No much difference of compressibility can be observed among those different types of staypak, especially both the laminated and cross-banded staypak.

(2). Specific gravity (Column 6)----- "When too low pressure 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"(2). As a result of this test, every type of staypak shows almost the same specific gravity and lower than 1.30. It indicates that the pressure used in making those staypaks is not enough, pressure of more than 1,500 pounds per square inch in making staypak from those light woods is advisable.

(3). Water absorption (Columns7, 8 and 9)------It is a general principle that the higher resin content substance, the higher water resistance it will be. In considering the result of water resistance of staypak shown in Table I, this principle has also been approved. Kimpreg type staypak has more resin content (about 5%) than the others, so it gives the least water absorption. Solid type staypak which contains no synthetic resin shows the highest percentage of water absorption. While Tego film type staypak contains less synthetic resin (about 2.5%) than Kimpreg type, but more than solid type, so its percentage of water absorption is between both of them.

The construction of cross-banded type staypak has more end grain than laminated type staypak, correspondingly, it has more chance to absorb water and higher percentage of water absorption is noted in Table I.

In comparing the effect of coatings to the water absorption of staypak, it is remarkable noted that Penacolite shows the best and wonderful result, almost three times percentage of water absorption was reduced in comparsion with that of the uncoated staypak . Water repellent although had somewhat effect in the reduction of water absorption, but it is not so worthy to consider as Pencolite did.

(4). Shrinkage(Columns 10, 11, and 12) ----- The longitundinal shrinkage of any type of staypak was less than 1/100, it may be neglected from the practical view. Any type of staypak banded with Kimpreg had the least shrinkage because of its highest water resistance. The thickness shrinkage is very notable, especially in the solid type staypak. Since cross-banded staypak had half of the wood grain in one direction, and half at right angles herto, its tendency to shrink amd swell should be largely neutralized (8), hence the widthwise shrinkage of the cross-banded staypak is very slight and the least.

(5). Recovery in thickness and swelling in thickness (Columns 13 and 14)-------No certain relation among the various types of staypak has been indicated from the result of recovery in thickness. However, it is obviously that the swelling in thickness of staypak made from Kimpreg is comparative slight and the least among them, solid staypak shows the most unstable, and while the laminated staypak is between both of them.

(6). Static bending and Compression parallel to grain (Columns 15, 16, 17, 18, 19, and 20)------- It indicates that both static bending and compression parallel to grain strength show of solid balsam fir staypak show the highest strength figures. It is a tendency that staypak made with Kimpreg has higher strength than either solid aspen staypak or laminated staypak except the lower modulus of elasticity.

" The deflection of a beam under load varies inversely as the modulus of elasticity; that is the higher the modulus the less the deflection". The modulus of elasticity therefore serves as a means of the stiffness or rigidity of wood(11). The general believe that cross-banded or laminated wood will lack some of the stiffness of solid lumber(10,12) is approved from these results of both the static bending or compression strength too.

(7). Shearing perpendicular to plies (Column 21)-----The result of maximum shearing strength perpendicular to plies of this test is approximately double the value as that of the U. S. Forest Products Laboratory did. The actual reason is not found yet. It is to be noted that laminated staypak has the highest figure from the various types of staypak's view, it might be due to that part of the force applied to the cross-banded staypak was loaded as parallel to plies instead of perpendicular to plies.; while the solid wood staypak could be considered as the lack of adhesive to increase its strength in comparsion with other types of staypak(10).

(8). Rockwell hardness(Column 22)------The result of the Rockwell hardness test shows a great variation , even within the same type of staypak. However, staypak made with Kimpreg indicates the highest figure.

(9). Gluing strength (Columns 23 and 24)-----The result of gluing strength test indicates that staypak can be successfully glued to itself; however, the surface of the staypak made with Kimpreg is too smooth, so that the glue might be readily squeezed out when pressure was applied in gluing, lower percentage of wood failure was shown, hence, more care in gluing Kimpreg type staypak to obtain the full strength of the staypak is required.(9)

(10). Surface insulation resistance (Columns25 and 26)----- The result of surface insulation resistance indicates that the resistance is gradually reduced from solid wood staypak, normal cottonwood, cross-banded staypak to laminated staypak. Surface insulation resistance of the face sides is greater than that of the lateral sides.

From those indications as previously mentioned, in general speaking, it may be concluded that ~~staypak~~ laminated staypak bonded either with Kimpreg or Tego film is more advisable, especially the Kimpreg type. No distinct advantage of cross-banded staypak can be found according to the present results. Although solid wood type staypak is favorable to some of the strength, it is not so stable as the other types; furthermore, the comparative great variation of its properties is also to be considered. Staypak made from different species of wood has shown some different characteristics. Penacolite SC-4100 can be used as coating for increasing the stability of staypak.

2. Machinbility Record

"Machining properties like many others that affect the utility of wood vary with specific gravity or weight. The heavier woods as a rule yield a smooth finish, and heavy species frequently machine better than light pieces in the same wood. On the other hand, heavy wood requires more power, dulls tools more quickly, and tends to split more readily with nails".(13). Staypak although slightly approaches to the characteristics of plastics, it is largely favorable to the properties of wood itself (14). Because of its high specific gravity, so its machining properties are correspondingly as what mentioned above.

According to the preliminary experience, in sawing staypak, either hand saw or power saw could be used, however, power saw is more deserible because of its higher power. No matter what kind of saw was used, the saw was more readily dulled in sawing the solid balsam fir type staypak and Kimpreg staypak. It was wisely to change the saw as necessary, otherwise, the staypak would be burned or charred.

In planing staypak, bother hand planer and power planer could be furnish a very smooth surface, especially the in sawing the solid aspen staypak, however, power planer was more preferable. In addition, it was to be noted that the grinding angle must be enough to give the cutting edge adequate strength to resist wear, or nicking, and the necessary rigidity to minimise deflection due to the impact on the edge each time it cut the wood(15), particulary in in cutting both balsam fir and Kimpreg staypak. Certainly, the shallowest cut gave much the best results with progressively poorer work as deeper cuts were made.

In considering the turning property, it also indicated satisfactory result, particulary in using higher turning speed,

During boring, a clean, smooth cut with a minimum disturbance of the grain on the cut surface has been shown. The difference among various types was not so widely as they did in many other machining properties. However, it was occasionally happened that the solid aspen staypak might give a rather rough boring surface. While in boring Kimpreg staypak, the surfaces bonded with Kimpreg plastic paper were easily torn off, so attention should be exercised.

As regards sanding, a pleasant result also has been shown. However, small scratches were occasionally happened, particulary in sanding solid aspen staypak, so the finer abrasive must be used to avoid obvious scratches. Additionally, the pressure applied on the abrasive must be not too high, otherwise, the staypak would be burned, such fact was more readily observed in sanding solid balsam fir staypak.

V. POTENTIAL USES OF STAYPAK

The properties of the staypak as made above either bonded with Tego film or Kimpreg willmeet all the U. S. Army Air Forces Specification's strength requirements for compreg(6).and it does not make much difference in property in comparsion with papreg(16), except the lower compression strength (Table 2.) but staypak has more than twice the shearing strength and possibly higher impact strength of the other materials, and meanwhile excels the standards of the U.

S. Army Air Forces Specification. The water resistance of staypak can be greatly improved with the Penacolite coating without affecting its strength properties. On this treating, it can be made more stable than before. On account of those distinct advantages, staypak should have many uses, such as the making of propellers to replace compreg or papreg. " 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 heads, pulleys, silent gears, and various tooling jigs and dies". (2)

In considering the cost of manufacturing staypak, such as in making solid wood staypak as Mr. A. J. Stamm, Chief of division of dervied Products, U. S. Forest Products Laboratory, pointed out, ~~that~~ "it is necessary to have stock free from checks and knots that extend through the thickness. This requirements alone may reduce the yield from a shipment of wood tremendously. It hence appears that the cost of staypak on a volume basis would of necessity be at least three times the cost of the clear raw material(doubled because of the compression and trebled by the processing)." However, this excessive expense should be balanced on account of its greatly improved properties.

In making staypak, because it requires higher pressure than compreg, greater initial investiment will be demanded for the high pressure equipment. Such an initial investiment will be justified owing to the omission of the use of any impregnating resin, particularly in a comparatively longer time operation. With regard to the rather long time of heating and cooling, it could be improved by some other engineering methods, as high frequency heating might be considered(17, 18, 19, 20, 21, 22). So staypak is pontentially cheaper to produce.

Table 1. Properties of Various Types of Staypak (a)

Type	Species	Number of plies of veneer	Average thickness (b)	Compressibility	Specific gravity, o. d. based on o. d.
1	2	3	4	5	6
			Inch	Percent	
Solid wood	Aspen (Populus grandidentata Michx.)	solid	0.44	35.2	1.25
	Balsam fir (Abies balsamea Mill.)	solid	0.25	35.3	1.23
Laminated with Tego film	Cottonwood (Populus deltoides Marsh.)	20	0.48	37.5	1.28
Laminated with Kimpreg	" " "	18	0.45	37.1	1.26
Cross-banded with Tego film	" " "	18	0.44	36.7	1.28
Cross-banded with Kimpreg	" " "	18	0.45	37.2	1.26

(a). All the data shown in this table are average values, the total number of tests was 1,800 approximately.
(b). Each type of staypak had four panels, average size was about 9 in. by 18 in.

Table 1. (Continued)

Water absorption			Shrinkage, from 90% to 30% relative humidity			Recovery in thickness	Swelling in thickness	
uncoated	coated with water repellent	coated with Penacolite	length	width	thickness			fiber stress
7	8	9	10	11	12	13	14	15
Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Pounds per sq. in.
10.4	9.8	3.6	0.08	3.5	12.7	38.2	7.9	22,104
12.8	8.8	4.1	0.03	1.9	12.1	40.2	13.6	26,433
6.5	6.0	2.3	0.08	1.2	9.2	43.5	6.6	22,260
2.1	1.9	0.6	0.17	0.4	7.0	40.6	1.8	23,669
8.0	7.7	2.2	0.43	0.2	12.2	40.5	5.7	15,791
3.1	2.3	0.8	0.31	0.2	6.9	41.6	2.0	17,362

Table 1. (Continued)

Static bending		Compression parallel to grain (c)			Shearing perpendicular to plies, maximum shearing strength
Modulus of elasticity	Modulus of elasticity	fiber stress	Maximum	modulus of elasticity	
16	17	18	19	20	21
Pounds per sq. in.	1,000 pounds per sq. in.	Pounds per sq. in.	Pounds per sq. in.	1,000 pounds per sq. in.	Pounds per sq. in.
32,171	4,026	9,914	12,394	2,419	10,393
42,710	5,981	12,254	17,851	2,737	———
34,606	3,254	11,028	15,387	1,824	14,017
35,675	3,368	11,643	16,227	1,773	14,689
22,265	2,245	7,419	9,826	1,029	11,043
25,685	2,335	8,950	12,529	1,280	11,930

(c). In testing cross-banded staypak, the load was not complete compression parallel to grain.

Table 1. (Continued)

Rockwell hardness (d)	Gluing strength (casein glue)		Surface insulation resistance (e)	
	Maximum gluing strength	wood failure	faces	sides
22	23	24	25	26
M scale	Pounds per sq. in.	Percent	Megohms per square	Megohms per square
23(7633)	941	100	1,206	986
40(20-65)	743	80	1,204	578
33(25-50)	1,035	100	60	37
48(34-60)	907	50	91	94
35(15-55)	1,018	100	118	50
44(25-67)	989	54	485	124

(d). Figures in parenthemes indicate the Rockwell hardness number range.
(e). The insulation resistance on both the face sides and lateral sides of normal cottonwood is 703 megohms per square.

Table 2. Properties of Compreg, Papreg, Staypak and Normal Laminated Wood

	Specific gravity	Water absorption	Static bending			Compression // grain			Shearing perpendicular to plies	Impact Izod
			fiber stress	Modulus of rupture	modulus of elasticity	fiber stress	maximum	modulus of elasticity		
	1	2	3	4	5	6	7	8	9	10
		Percent	lbs./sq. in.	lbs./sq.in.	1,000,000 lbs./sq.in.	lbs./sq. in.	lbs./sq.in.	1,000,000 lbs./sq.in.	lbs./sq. in.	ft.lbs. per inch
Army Air Forces Specification (4)	1.28-1.38	6		35,000	2.7		20,000		5,000	5
Normal Laminated Wood*	0.47	90.2	6,000	13,000	1.6				3,000	5
Laminated Staypak With Tego Film	1.28	6.5	22,000	34,000	3.2	11,000	15,000	1.8	14,000	
Laminated Staypak With Kimpreg **	1.26	2.1	23,000	35,000	3.3	11,000	16,000	1.7	14,000	
Staypak	1.37	4.0	22,000	34,000	4.4	11,000	21,000	4.1	5,000	13.3
Compreg (16)	1.35	less than one	21,000	36,000	3.5	16,000	24,000	3.5		3-7
Papreg (16)	1.38	6.0	~~29,000~~	30,000	3.0	17,000				5

* This result was investigated by Mr. William D. Eisenhauer, School of Forestry and Conservation, University of Michigan (unpublished, 1945).

** This result was tested by U. S. Forest Products Laboratory (2).

VI. SUMMARY

Solid flat-saw aspen and balsam fir and cottonwood veneer bonded with Tego film or Kimpreg and assembled in parallel-laminated or cross-banded form cah be made into a " heat-stabilized compressed wood" or named " staypak". The chief properties of those different types of staypak have been determined. The comparsion of the properties indicates that the parallel-laminated type bonded with either Tego film or Kimpreg is the best type of staypak, especially the letter type. No distinct advantage can be found in making staypak from cross-banded veneer. Solid wood type staypak is not so stable as that of the other types. The properties of staypak are different according as different species of wood.

It has been shown that staypak has several strength properties superior to compreg as well as papreg, most notable of which is its greater shearing strength and possibly higher impact strength. Although it is not as dimensionally stable as compreg, such a defect can be greatly improved by using the coating Penacolite SC-4100, in general, the uncoated staypak is sufficiently stable for many uses.

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