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PLYWOOD

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5 Claims. (Cl. 20—89)

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This application is made under the act of March 3, 1983, as amended by the act of April 30, 1928, and the invention herein described and claimed, if patented, may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment to us of any royalty thereon.

This is a division of our copending application on which Patent No. 2,321,258 was granted June 8, 1943.

Our invention relates to a process for making an improved plywood consisting of highly compressed resin-treated surface plies that are treated in such a way that they can be assembled and compressed with either a treated or an untreated core in a single operation without the core being appreciably compressed. This is accomplished by treating the plies that are to be compressed with a substantially unpolymerized phenol-formaldehyde resin-forming mix that is truly soluble in water in all proportions, in such a way as to completely permeate the structure, including even that of the solid wood substance of the cell walls; slowly drying, so as to insure further diffusion of the active resin-forming constituents into the cell-wall structure as water is removed, at a sufficiently low temperature to avoid premature polymerization; followed by assembly of the treated plies, with or without the use of additional bonding material, with an untreated dry core or a treated dry core, in which the resin-forming constituents have been previously polymerized, in a hot press at ordinary resin-bonding plywood-assembly temperatures under a pressure sufficient to highly or completely compress the treated plies containing the unpolymerized resinforming constituents without being sufficient to appreciably compress the core, followed by cooling in the press below the boiling point of water before releasing the pressure.

The principal object of our invention is to produce a plywood in such a way that part of the plies become highly compressed and part remain virtually uncompressed when they are subjected to a single assembly and compression operation.

Another object of our invention is to produce a plywood, which is a combination of resin-treated compressed wood and virtually uncompressed wood, in such a way that the resin-treated compressed wood plies are highly or completely compressed under a much lower pressure than that which is required to produce the ordinary resin-treated compressed woods made according to present art.

Still another object of our invention is to produce a plywood, which is a combination of resin-treated compressed wood and virtually uncompressed wood, in which the compressed wood plies are much less subject to moisture adsorption and swelling and/or shrinking than the ordinary resin-treated compressed woods made according to present art.

Still another object of our invention is to produce a plywood having a combination of the desirable properties of resin-treated, laminated, compressed wood and also the desirable properties of normal uncompressed wood.

More specifically, our objectives are:

1. To produce a light-weight plywood with a water- and weather-resistant hard glossy surface that is not subject to face checking.

2. To produce a plywood with a hard, glossy surface finish resulting from the pressing operation which is superior to the surface finish produced by any other plywood assembly or pressing process at comparable pressures.

3. To produce a plywood with superior mechanical properties to those of other plywoods with the same specific gravity.

4. To produce a plywood with an extremely hard surface and resilient core which would be suitable for flooring.

5. To produce a plywood with a bond between compressed and virtually uncompressed plies that is far stronger than could be obtained by gluing compressed plies to virtually uncompressed plies.

6. To produce a plywood in such a way that the treated plies will exhibit a high degree of plasticity in the press and will conform to compound bends such as would be required in molding airplane wings or fuselages.

According to the present art of making resin-treated laminated compressed wood, the assembly and the compression of the face plies could not be carried out simultaneously without the core being highly compressed. This is due to the fact that the appreciably prepolymerized resins used do not enter the cell-wall structure and, as a consequence, do not plasticize the cell walls. Such high pressures have to be used to compress the treated plies, that the untreated plies are also appreciably compressed.

According to our process the treated plies are very much more plastic than those treated according to present art. This increased plasticity makes possible the compression of the treated plies without the untreated cores being appreciably compressed and, as a consequence, makes simultaneous assembly and compression possible.

The simultaneous assembly and compression further makes the glue line an integral part of the resin within the treated plies as both set to a resin simultaneously. Because of this a much better bond is obtained than could be obtained by gluing resin-treated compressed wood to uncompressed wood.

Differences in the manner in which we treat the veneer from the treatment used in making the ordinary resin-treated, laminated, compressed woods account for both the differences in plasticity during compression and differences in moisture absorption and swelling and/or shrinking of the product. For this reason these differences will be described in detail.

Resin-impregnated, laminated, compressed woods are made according to present art by assembling thin sheets of veneer with appreciably prepolymerized synthetic resin glues under such high pressures that the resin partially impregnates the coarse capillary structure of the wood while the compression of the plies is taking place. Under these conditions the solid wood substance of the cell walls cannot be penetrated with synthetic resin and even the microscopically visible capillary structure cannot be uniformly treated. The process at best is one that gives a superficial filming of the fiber-cavity structure with synthetic resin. Because of this and the fact that the synthetic resin is mechanically rather than chemically bonded to the wood, the water resistance of these resin-impregnated, laminated, compressed woods is far short of what it might be. The fact that the synthetic resin does not enter the cell-wall structure of the wood further prevents the synthetic resin from appreciably plasticizing the wood and reducing the pressure necessary to crush the fiber structure.

Resin-treated, laminated, compressed wood made according to our invention overcomes all of the aforementioned shortcomings of compressed wood made according to prior art. We have found that our method of treatment not only insures the distribution of the resin-forming mix throughout the solid wood substance of the cell walls, but also utilizes the resin-forming mix in such a way as to give a chemical bond between the polar groups of the wood and the phenol and formaldehyde of the resin-forming mix. Because of this our treatment gives a much more complete and permanent protection against moisture adsorption and swelling and/or shrinking than is obtained by following the methods of prior art.

We have also found that our treatment appreciably reduces the pressure necessary to compress the veneer to substantially the maximum compression because of the fact that resin-forming constituents within the solid wood substance of the cell walls act as plasticizers for the compression of the fibers. We have demonstrated experimentally that Douglas fir, spruce, and aspen veneer treated according to our method, followed by drying under conditions that will not set the resin, can be compressed to substantially the ultimate possible compression in a hot press under a pressure of 300 pounds per square inch.

The cell walls of dry wood contain no void structure for liquids to enter. Water, however, exhibits such a strong attractive force for wood that it is able to work its way between the structural units of the solid wood substance, pushing them apart and adding its volume to the volume of the wood substance. This dimension change of the wood substance is the cause of swelling and/or shrinking of wood. Water may carry along certain dissolved amterials into this intimate structure of the solid wood substance, of which the cell walls are composed, or the dissolved materials may diffuse into the intimate cell-wall structure that already contains water. We have found that solutes can enter the intimate structure of the solid wood substance in these two ways only when they are in true solution and their molecular weight is small. We have further demonstrated that when the solute molecules have a greater affinity for the wood than for the water, they cause the wood to swell even more than in water alone. This is due to a greater amount of solution than of water alone being taken up within the intimate cell-wall structure.

We have discovered that in order to obtain appreciable and permanent reductions in the swelling and/or shrinking of wood, it is necessary to use a substantially unpolymerized resin-forming mix in which the molecules are sufficiently small to completely penetrate all of the structure, including that within the solid wood substance of the cell walls. We have further discovered that it is not only important that the size of the active resin-forming molecules be small but also that they show greater affinity or bonding force for wood than is shown by water, which results in swelling of the wood beyond the swelling in water. We have found from experiments that both aqueous solutions of phenol and formaldehyde and their substantially unpolymerized mixtures meet these penetration, bonding, and swelling requirements. We have also experimentally demonstrated that a few commercial phenol-formaldehyde resinoid mixes that are truly soluble in water in all proportions are sufficiently unpolymerized to meet these three requirements.

We believe that the polar groups of both phenol and formaldehyde attach themselves to the polar groups of cellulose and lignin, which are normally the seat of adsorption of water in the presence of the aqueous solvent. When the aqueous solvent is removed on drying, most of the phenol and formaldehyde molecules remain fixed on these active groups, not only throughout the coarse capillary structure of the wood but within the solid wood-substance structure of the cell walls. When the resin is formed by the application of heat, the active groups of the wood also enter into the reaction to form substantially a phenol-formaldehyde-cellulose resin and a phenol-formaldehyde-lignin resin at the junction between resin and wood throughout the structure of the cell walls, as well as on the cell-wall surfaces.

We have found that when the resin-forming mix is appreciably prepolymerized it will not enter the solid wood-substance structure of the cell walls, and further, it will show very little tendency if any to chemically bond to even the accessible structure. For this reason moisture adsorption and swelling and/or shrinking are but slightly reduced and then only over relatively short periods of time. The lack of chemical bonding power of the appreciably prepolymerized resin is due to the fact that the active groups of the resin-forming constituents have reacted with each other and, as a result, are no longer available to bond to the active polar groups in the wood.

We consider the treatment of wood with a substantially unpolymerized phenol-formaldehyde, resin-forming mix that is soluble in wa-

ter in all proportions, followed by polymerization in place, to be an essential feature of this process as such a treating solution makes possible not only the intimate treatment of the entire structure within the solid wood substance, which is normally accessible to water, but also the chemical bonding of the resin to the wood. This treatment is not to be confused with the well-known treatments which merely force appreciably polymerized phenol-formaldehyde resins into the coarse capillary structure of dry wood with or without the aid of an organic solvent, in which case the resin can only be mechanically bonded to the wood over a very small fraction of the internal surface that is available to water.

We have found that veneer may be treated by either of the two general types of treating methods and give a product substantially the same in all of its properties:

(1) Dry veneer or partially dry veneer can be treated in a vacuum-pressure treating cylinder according to the well-known practice used for treating wood with preservatives. The material to be treated is stacked in the treating cylinder, a high vacuum is applied, the aqueous resin-forming solution is run into the cylinder to completely immerse the material, followed, when necessary to obtain the desired penetration, by the application of pressure. We have experimentally demonstrated that $\frac{1}{8}$-inch Douglas fir veneer can be completely treated in this way in 15 to 20 minutes.

(2) Undried veneer direct from the cutter knives can be treated by merely soaking it in the treating solution at room temperature or a slightly elevated temperature (100° F.). We have found that the time of soaking will vary with the temperature, the amount of active resin-forming constituents that it is desired to have diffuse into the veneer, and the moisture content, thickness, specific gravity, and species of the veneer. We have found that normal undried $\frac{1}{8}$-inch Douglas fir veneer will require about 24 hours soaking at room temperature to take up sufficient resin-forming constituents to form 30 percent of the weight of the veneer of resin within the intimate cell-wall structure of the veneer. By raising the temperature to 100° F., the rate of diffusion will be more than doubled without an appreciable deleterious prepolymerization of the resin taking place. We have found that undried $\frac{1}{32}$-inch red gum veneer will take up about 40 percent of its weight of resin-forming constituents by soaking for 1 hour in an aqueous resin-forming solution containing approximately 40 percent of active resin-forming constituents when maintained at 100° F.

We have found that forming 30 to 40 percent of resin, on the basis of the dry weight of the wood, within the intimate cell-wall structure of the wood gives substantially the optimum protection against moisture adsorption and swelling. We have found that this amount of resin corresponds very closely to the amount necessary to saturate the solid wood-substance structure of the cell walls. Forming larger amounts of resin in the wood necessitates part of the resin being formed in the fiber cavities where it is wasted. Forming smaller amounts of resin within the wood structure gives a proportionally smaller reduction in moisture adsorption and swelling and does not give a satisfactory bond upon assembly of the plies without the use of additional bonding material. We, hence, recommend that 30 to 40 percent of the weight of the dry wood of resin should be formed within the solid wood-substance structure.

We also recommend that in treating veneer by the pressure method that the resin-forming mix be diluted with water to the extent that when absorption is complete, the synthetic resin content of the wood will be between 30 and 40 percent. We have found, in the case of wood with an average specific gravity, that dilution of the resin-forming mix with an equal volume of water gives the desired take-up of resin-forming constituents.

We have found that it is necessary for the resin-forming constituents to be quite uniformly distributed throughout the solid wood substance of the cell walls of the wood, rather than being deposited within the coarse capillary structure, in order for the treatment to appreciably minimize subsequent moisture adsorption and swelling. We have demonstrated that this can be accomplished when dry veneer is treated by the vacuum-pressure treating method by letting the veneer soak in the treating solution for about a day after removing from the treating cylinder, or stacking the treated veneer outside of the solution for one to two days under non-drying conditions, that is, avoiding the setting up of a relative humidity difference between the wood and the surrounding air by maintaining the wood at the same temperature as the surrounding air and avoiding the circulation of air around or through the wood. The pressure treatment merely carries the treating solution into the coarse capillary structure of the wood. Time is required for the solution to diffuse from the coarse capillary structure of the wood into the cell walls.

We have also found that it is necessary to dry the veneer slowly after the combined pressure and diffusion treatment or after the simple diffusion treatment. We have found that in order for the resin-forming constituents to continue to diffuse into the cell walls of the wood as water is removed by evaporation from the coarse capillary structure, the rate of moisture removal should be slow and steep moisture gradients within the veneer should be avoided. We have found that when veneer is dried at a temperature not exceeding 120° F. and under a relative humidity of not less than 75 percent that the resin-forming constituents continue to diffuse into the cell walls from the fiber cavities during the drying process, and that premature setting of the resin is avoided. When the wood is practically in equilibrium with the drying conditions, the relative humidity may be dropped so as to dry the wood to about 6 percent moisture content.

We have discovered that veneer treated and dried according to our invention can be simultaneously assembled with a dry untreated core and compressed to form a product with highly compressed faces and a virtually uncompressed core in a single operation in a hot press heated to 300° F. to 350° F. without the use of additional bonding material between faces and core. The core may be a single ply or a combination of several plies that have been pre-assembled or that are assembled with a hot-press glue at the same time that assembly with and compression of the face plies is accomplished. The pressure used will depend upon the species used for the faces and for the core as well as the degree of compression desired. We have shown that most of the softwoods (coniferous or needle-leaved woods) can be compressed to almost their theoretical compression, after having been subjected to our treatment with a resin-forming solution, under a pressure of only

300 pounds per square inch. Aspen and a few other soft hardwoods (deciduous or broad-leaved woods) will compress with equal ease, but most of the hardwoods require greater pressure to completely compress the treated plies. Untreated hardwoods and softwoods will be compressed but slightly under a pressure of 300 pounds per square inch. As a result of this, we have been able to successfully make the combination of highly compressed and virtually uncompressed plywood with several different combinations of species under a pressure of 300 pounds per square inch.

We have shown that the surface of the compressed plies is appreciably improved by cooling the press platens below the boiling point of water before releasing the press pressure. Evidently the hot product is still slightly plastic and yields slightly under the stresses set up during cooling. When cooled in the press, this deformation of the product is impossible. We, hence, recommend that the plywood be partially cooled in the press before releasing the pressure.

We have found yellow poplar to be a very suitable wood for the core as it has a rather high compressive strength for its specific gravity. When treated spruce, Douglas fir, and aspen faces were compressed onto the yellow poplar cores at pressures of 300 pounds per square inch, the faces were compressed to about 40 percent of their original thickness, whereas the core retained 94 percent of its original thickness. The specific gravity of the faces was thus increased about 2.5 times, whereas the specific gravity of the core was increased about 6 percent.

The treated faces may also be made of less compressible hardwoods such as yellow poplar. If yellow poplar is also used for the core, the faces can be only partially compressed when appreciable compression of the core is to be avoided. In such a case it is advisable to use additional phenolic bonding material as it is possible that insufficient resin-forming constituents are exuded from the treated ply to form a perfect bond. Under a pressure of about 300 pounds per square inch, the treated yellow poplar face plies are compressed to about two-thirds of their original thickness. Under pressures sufficient to double the specific gravity of the poplar face plies, the untreated poplar core would be compressed to about 80 percent of its original thickness.

We have shown that the compression of the core can be reduced and the weather resistance of the plywood as a whole increased by treating the core with phenol-formaldehyde resin-forming constituents according to the procedure of our invention, followed by polymerization of the resin within the cell-wall structure of the core by the application of heat prior to assembly of the plies. This treatment increases the compressive strength of the core material by about 50 percent and hence will diminish the compression occurring under a definite load. The treatment of the core will also diminish the swelling and shrinking of the wood substance and, as a result, will diminish the internal stresses caused by changes in the equilibrium relative humidity.

The following examples illustrate the manner in which the treatment, assembly, and compression of the veneer to form the combination of resin-treated compressed wood and virtually uncompressed wood may be commercially applied. As these examples give only a few of the number of possible ways of carrying out our process, we do not wish to limit ourselves to the specific procedure or type of equipment, but to the nature of the treating solution, the manner of insuring that the resin-forming mix diffuses into the solid wood substance structure of the cell walls, and the assembly and compression conditions, all of which are essential to accomplish the objectives of our invention herein described.

Example 1.—Take clear green spruce veneer for the plywood faces direct from the cutter knives and immerse in an aqueous solution consisting of equal parts by weight of phenol, formaldehyde (aqueous 40 percent), and water together with a suitable catalyst such as hexamethylene tetramine (about 2 percent) at about 100° F. Let the veneer soak in the solution for a period of time necessary for the wood to take up by diffusion an amount of the resin-forming mix necessary to form 30 to 40 percent of the weight of the dry wood of resin within the wood structure. Remove the wood from the treating bath and slowly dry at a temperature not to exceed 120° F. and a relative humidity of at least 75 percent. When the veneer is practically in equilibrium with these conditions, the relative humidity should be dropped to about 30 percent so as to bring the veneer to a moisture content of about 6 percent. Take yellow poplar dried to a moisture content of 6 percent or less for the core. Assemble this with the treated spruce faces without the use of additional bonding material in a parallel or cross-banded manner in a hot press at a temperature of 310° F. and a pressure of 300 pounds per square inch for a period of 15 minutes. Cool the press platens below 212° F. and withdraw the finished product with compressed resin-treated faces and only a slightly compressed core.

Example 2.—Take clear dry or partially dry spruce veneer and stack it on edge in a vacuum-pressure treating cylinder with some form of spacers between the sheets of veneer to hold them slightly apart. Apply a high vacuum on the cylinder and then run in the treating solution identical to that given in Example 1 so as to completely immerse the veneer. After about 20 minutes remove the veneer from the treating cylinder and stack it and permit it to stand for one to two days under nondrying conditions, that is, at room temperature in a room free from air circulation. Dry, assemble, and compress the veneer according to the procedure given in Example 1.

It will be noted that the foregoing examples are directed toward the treatment with a resin-forming mix consisting of equal parts of phenol, formaldehyde, and water containing 2 percent hexamethylene tetramine as catalyst. We may vary the proportion of phenol, formaldehyde, and water in the treating mix over an appreciable range, substitute aqueous ammonia or other alkalies such as sodium hydroxide for the hexamethylene tetramine catalyst, and appreciably change the concentration of the catalyst and attain substantially the same results as are obtained in Example 1. We may also substitute cresol for phenol or we may use an aqueous solution of a commercial phenol-formaldehyde-catalyst mix that is substantially unpolymerized and completely soluble in water in all proportions in place of the treating solution described in Example 1.

It will be further noted that the foregoing examples are directed toward the use of spruce for the faces and yellow poplar for the core. We have shown that any species of veneer which is readily compressed in a hot press after receiving our treatment may be substituted for the spruce faces and give a product with highly compressed faces under the pressing conditions given. We

have shown that such softwood veneers as Douglas fir and sugar pine and such hardwood veneers as aspen work satisfactorily under the pressing conditions given. We have also shown that other species of veneer with relatively high compressive strengths, such as the gums, can be substituted for the yellow poplar core. The less compressible species can also be used for the treated faces if complete compression of the faces is not necessarily required. When such woods are used under the pressing conditions given, we have found it advisable to use additional bonding material between the plies as insufficient bonding material exudes from the treated faces because of the reduced compression. We have also shown that the pressing pressure may be appreciably increased to more completely compress the less compressible treated faces if a partial compression of the core is not considered detrimental for the purpose to which the material is to be put. The core may further consist of a single ply or multiple plies that have been pre-assembled or that are assembled with the use of a hot-press glue at the same time that assembly with and compression of the face plies is accomplished.

It will also be noted that the foregoing examples are directed towards the use of treated faces with an untreated core. We have shown that a more weather-resistant product and a less compressed core can be obtained if the core is also treated and dried in the same manner as the face plies, followed by heating to about 200° F. for several hours prior to assembly so as to prepolymerize the resin.

Having thus described our invention, we claim:

1. A wood product consisting of dense, compressed, permanently water-resisting phenol-formaldehyde resin-treated face-plies, having hard weather- and chemical-resistant, smooth finished surfaces and a distribution of resin throughout the cell-wall structure, the resin being chemically bonded to the polar groups of the wood constituents of the face plies, which face plies are integral with an untreated, substantially uncompressed core, the resin bond being chemically continuous with the resin throughout the face plies.

2. A wood product consisting of dense, compressed, permanently water-resistant phenol-formaldehyde resin-treated face plies, having hard weather- and chemical-resistant, smooth finished surfaces and a distribution of resin throughout the fine cell-wall structure, the resin being chemically bonded to the polar groups of the wood constituents, which face plies are integral with a similarly treated, uncompressed core, the resin bond being chemically continuous with the resin throughout the face plies.

3. A wood product consisting of a dense, compressed, permanently water-resistant phenol-formaldehyde resin-treated face-ply, having a hard weather- and chemical-resistant, smooth finished surface and a thorough distribution of resin throughout the fine cell-wall structure, the resin being chemically bonded to the polar groups of the wood constituents, which face ply is integral with an untreated, substantially uncompressed core, and with an uncompressed second face ply treated similarly to the first, the compressed face ply-uncompressed core resin bond being chemically continuous with the resin throughout the compressed face ply.

4. A wood product consisting of a dense, compressed, permanently water-resistant phenol-formaldehyde resin-treated face-ply, having hard weather- and chemical-resistant, smooth finished surface, and a distribution of resin throughout the cell-wall structure, the resin being chemically bonded to the polar groups of the wood constituents, which face ply is integral with a similarly treated, virtually uncompressed core and second face ply, the compressed face ply-core resin bond being chemically continuous with the resin throughout the compressed ply.

5. A laminated wood flooring consisting of a dense, compressed phenol-formaldehyde resin-treated upper face ply, having a hard water- and chemical-resistant, smooth finished surface and a distribution of resin throughout the cell-wall structure, the resin being chemically bonded to the polar groups of the wood constituents of the face ply, which face ply is integral with an untreated, virtually uncompressed core and with an under surface ply treated similarly to the upper face ply, virtually uncompressed, the compressed upper face ply-uncompressed core resin bond being chemically continuous with the resin throughout the compressed upper face ply.

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