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METHOD OF MAKING NONCHECKING PLYWOOD WITH AN AQUEOUS GLUE

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No Drawing. Continuation of application Serial No. 5,727, February 9, 1935. This application July 28, 1937, Serial No. 156,145

3 Claims. (Cl. 144—309)

This application is a continuation of my pending application, Ser. No. 5,727, filed Feb. 9, 1935, for Non-checking plywood and method of making the same.

This invention relates to non-checking multi-ply veneer in which the plies are bound together by a glue or adhesive having water as a vehicle and/or solvent when applied, and it also relates to the manufacture thereof.

This checking results frequently due to shrinkage on drying, because of the presence of amounts of moisture (water) in the multi-ply veneer on gluing together, which are generally great enough to cause checking, if not in all of the product, at least in such a proportion thereof that substantial amounts of the product must be rejected. Multi-ply veneer panels and the like are usually made by gluing two outer facing plies to an inner core ply, the grain of the outer sheets usually running at right angles to the grain of the core. There may, of course, be any number of plies more than one in the multi-ply board, but the grain of each layer usually runs at right angles to that of the next layer. The glue adheres to these plies and binds them in fixed relation before the moisture is expelled from the assemblage. Wood has a tendency to shrink as it loses moisture or dries, this shrinkage being across or at right angles to the grain but not longitudinally of the grain. Due to the different directions of the grain in the different plies, substantial shrinkage is prevented, but if there is too much tendency to shrink it results in breaking the bonds between the wood fibers, that is, the fibers separate laterally and cracks or checks result.

This checking is particularly marked when multi-ply panels are hot-pressed, and woods having a grain structure or annular ring structure similar to those of Douglas fir, yellow pine, quartersawn oak, and the like, that is, woods of non-uniform densities, have a very decided tendency to crack or check in the hard grain when glued together in the usual manner in a hot press. Cold-pressed panels may also be subject to checking under certain conditions, and while my invention is especially adapted for the prevention of checking in hot-pressed panels, it is also useful for the prevention of checking in cold-pressed panels.

Attempts have heretofore been made to avoid checking by drying the wood before gluing it; but other features which I have discovered to be necessary to prevent checking, particularly when a wet glue is used, have heretofore been unknown. Sheet veneer dried to a moisture content of 2% to 3%, or even to 1½%, will reabsorb moisture on standing for any length of time, say, ten, twelve, twenty-four hours, so that its moisture content will range from 7% to 15%, depending on the relative humidity of the atmosphere. This is practically true of all kinds of wood except teak which is not used for plywood. The moisture contents of the wood veneer just mentioned as well as other moisture contents of wood are the percentages of the weight of the water with respect to the dry weight of the wood.

For carrying out the hot-pressing operation, I can use the well known stationary platen hot-plate press, the machine of my Patent No. 1,706,675, issued March 26, 1929; the machine of my application Serial No. 738,640, filed August 6, 1934; the machine of my application Serial No. 5,728, filed February 9, 1935; the machine of my application Serial No. 18,577, filed April 27, 1935; or any other suitable apparatus. I prefer to use the machines of my applications Serial No. 738,640, Serial No. 5,728, Serial No. 18,577, and the machines of my Patents, Nos. 2,137,505 and 2,137,506, the last four being preferred for the purpose of handling a maximum number of panels with a minimum amount of machinery. I prefer to leave the panels in the hot-press only long enough to glue the plies together securely, and for most rapid operation I prefer the continuous hot-press above referred to. Machines ordinarily used for cold-pressing may be used for my cold-pressing operation, such for example as the stationary platen press.

The multi-ply panels are preferably not dried by my method of hot-pressing except only incidentally, and then only to the extent of about 1½% to not over 2½% of moisture (based on the dry weight of the panel), but whatever drying is to be done is done later, that is, after the hot-pressing step. Similarly there is also only a mild and incomplete drying, if any, when I press cold. I prefer not to crush the wood fibers nor compress the wood permanently to any substantial degree although this may be done in special cases, and, in fact, I usually try to disturb the fibers as little as possible since for many purposes it is desirable that the wood retain its natural characteristics. Drying takes place after the hot-pressing or cold-pressing operation, some while the hot-pressed product is on a conveyor cooled by drafts of air, or while the product is in stacks, it being noted that such panels are stacked face-to-face but with separating sticks

between in order to permit ventilation for the escape of the water vapor. Further drying may occur when the product is shipped to or through a locality where there is a tendency to dry, that is, where it is warm or the relative humidity is low. Drying may occur in shipments by sea when the carrier ship is in a drying zone as to temperature and/or relative humidity, or when the product is loaded into compartments of the ship that are heated by the boilers or engines.

It is to be emphasized that any time a panel loses moisture, a shrinkage tension is set up tending to separate the cells or fibers of the wood, and when this tension is too great, a separation of fibers occurs which is commonly known as "face-checking". The fibers of wood run generally parallel to each other and a sheet of wood expands or contracts in a direction cross-wise of the fibers (or grain of the wood) as the sheet becomes respectively wetter or drier. Wood fibers are held to each other by adhesive material which is naturally present in the wood and which has more or less elasticity, and which comprises lignin.

In laminated panels wherein the grain of one ply runs cross-wise to the grain of the next ply and wherein these plies are adhesively bound together in fixed relation, changes in length of one ply in a direction across the grain thereof are prevented due to the fact that it is adhesively bound over its whole surface to another ply which cannot change in length in the same direction to the same degree, because wood does not change much, if any, in length along the line of its grain as it becomes wetter or drier. Thus one ply tends to prevent a change in length of another ply adhesively bound thereto when the grains of the two plies are at an angle and particularly at a right angle to each other. A tendency to change in length exists in the plies of such an assembly even though no actual change occurs. As the fibers expand, they tend to crowd each other; while as the fibers shrink, they tend to separate from each other. If the separating force be not sufficiently great, the wood will remain unchecked or uncracked, but perhaps under tension; while if the separating force be too great, something will fail, perhaps the natural binding material of the wood, and a crack or check will result.

In the making of multi-ply panels, wherein the grain of a ply runs at an angle to that of the next adjacent ply, the length of the ply cross-wise of the grain per unit of dry wood in a ply of a given thickness becomes important, since checking will occur on drying a ply that is too long due to the presence of a certain amount of moisture, but it will not occur if it is not too long for such a reason. The amount of moisture present in the assembly which is absorbed in the walls of the wood cells or fibers, regardless of whether this be moisture ordinarily present in the wood, moisture imparted by the presence of the glue, or whatever its source, just after the time the plies and thus the wood fibers become fixed in relation to each other by the setting of the glue, will determine whether or not checking will occur when the completed panel is subjected to arid conditions. In this connection it is to be noted that some glues chemically combine with a certain amount of water when they set and thereby subtract such amounts of water from the total amount that can moisten the wood, and different glues may thus combine with different amounts of water. It is the total amount of water present which can moisten the wood that I control. The moisture present may be of different kinds. Wood in its natural or green state contains water absorbed in the material of the walls of the wood fibers which may be referred to as absorbed moisture; and it also contains water in the hollow centers of these fibers which may be referred to as free moisture. When free moisture is present the fiber walls are completely saturated. On drying such lumber or veneer, the wood will lose weight through loss of moisture to a very large degree before the wood fibers begin to dry out, because on drying, as the fiber wall gives up absorbed moisture, this free moisture contained in the fiber centers is absorbed by the material of the fiber walls and replaces the absorbed moisture that the material of the fiber walls gives off. For example, green wood with a 35% moisture content based on the dry weight of the wood, may lose weight down to 20% moisture and the fibers still be as damp as they were when the wood had a 35% moisture content, due to the absorption of the free moisture contained in the hollow fiber centers. The 7½% moisture, as mentioned in this case, is moisture absorbed and contained in the cell walls and can come from a number of sources, either the natural moisture not dried from the wood, or moisture absorbed from the atmosphere, or moisture that was introduced with glue and absorbed by the cell walls from the glue line. Moisture can enter into the hollow parts of the wood cells after it has been dried out. Immersion in water for a long enough time will cause this. Some woods, for example, cottonwood may contain in the fiber centers and fiber walls an amount of moisture equal to 2 to 3½ times as much water as the dry weight of the wood. Such woods after being dried will pick up an equal amount of water very rapidly. It is the moisture absorbed in the material of the fiber walls that causes expansion or contraction of such walls when the amount of such moisture is increased or decreased respectively, so that there is a maximum expansion of the cell walls which is not decreased on drying the wood as long as free moisture is present in the hollow part of the fibers. Some moisture is supplied to the assembly by the aqueous-type glue used, that is a glue having water as vehicle and/or solvent. Some of the water present is lost by evaporation as the glue dries, and some may combine with the glue solids to form a part of the dry glue bond in the finished panels. The amount of water combined to form a part of the dry glue bond may vary with different glue formulae. Different glues have different water-requirements, that is the amount of water required to make the glue spreadable by machinery, and the water requirement will vary with different formulae. The amount of water converted into solid by combination with other glue components may be quite independent of the amount necessary to meet the water-requirement of that glue. Thus, different glues may supply different amounts of moisture to the assembly. Some moisture may be evaporated off on hot-pressing. There is an interrelation between these various quantities of moisture which I have discovered and which may be modified to control checking.

The increment in length of a moist wood ply over that of the ply when dry, measured cross-wise of the grain, depends on the amount of moisture absorbed in the walls of the wood cells or fibers. This amount, at the time the axes of the wood fibers are fixed relatively to each other by the setting of the glue, because it determines

the amount of swelling of the cells' walls, also determines the degree of their tendency to contract on drying and therefore determines the degree of probability of resultant checking. This "effective" amount of moisture is equal to the amount of moisture absorbed in the cells' walls just before the glue is applied to the wood, plus that imparted by the glue, minus that lost by combining to form the solid glue line, minus that lost by evaporation. The amount of moisture absorbed in the material of the walls of the wood fibers or cells is the same as the amount of moisture carried by the wood only if there is no free water in the hollow interiors of the cells, and it is only the moisture absorbed in the cell walls and not the free water within the cells' hollows which causes them to swell. The amount of the "effective" moisture is thus equal to the amount carried by the wood just before the glue is applied thereto, plus that imparted by the glue, less that lost by combination, less that lost on evaporation, less the amount of "free" moisture remaining.

I can control the amount of moisture carried by the wood in an obvious manner, as by drying if too moist, and I can so control it that all of it will be absorbed in the material of the walls of the cells or fibers of the wood, so that there will be no free moisture in hollow spaces within the fibers. I can control the amount of moisture imparted by the glue as well as the amount lost by combining to form the solid glue line, by choosing a glue having a suitable water requirement and content while still having the desired consistency and capability of being spread by machinery, and also having the ability to combine with a suitable quantity of water to form the solid glue line. By suitably co-ordinating the amount of moisture absorbed in the walls of the wood cells or fibers at the time the glue is applied to the wood, the amounts of moisture added thereto, and the amounts subtracted therefrom, I can control the amount of moisture absorbed in the walls of the wood cells or fibers, and thereby prevent checking in the completed panels.

My method, generally stated, comprises having the content of "effective" moisture, namely that absorbed in the walls of the wood fibers just as the glue sets to permanently fix the axes of the fibers of a ply in positions spaced relatively to each other, less than 8%, the critical value being somewhere around 7½%. I am not certain of the exact value of the fraction, but the critical maximum value is less than 8%, and for all practical purposes it may be considered as 7½%; and as a matter of safety it seems best to have it substantially below 7%, and with it not over 5%, say 4% to 5%, or even less, the invention is practically "foolproof" and does not require special precautions other than the 5% feature in large scale or mass production. Plies of practically all woods in the green state have too much moisture, and a preliminary drying thereof is necessary, but the invention may include the use of plies of dryer woods so that it may not be necessary for me to subject them to a preliminary drying step in practicing my process. There is no substantial difference between using a previously dried wood and drying an "effective" wood that is too moist before using it.

A panel having a moisture content of 4% to 5% at the time of completion of manufacture, will absorb some moisture if left in a moist atmosphere. This will compress the fibers but will not injure the bonds between them so that moisture can be taken out again during storage or use in or shipment through a hot or dry place without the occurrence of face-checking. The ordinary working conditions throughout the northern part of the United States in the summer are about 8% moisture content of the wood. In the South, Arizona, Texas, and Oklahoma, and other arid parts of the United States, there are conditions where the moisture content of the wood will be around 5½% or less, and in special instances perhaps as low as 4%, so that there a completed panel having a moisture content of 10% may lose 4%, 5% or 6%; or even more if the moisture content of the panel was higher than 10% at the time of completion of manufacture. All this will result in panels splitting very badly, or face-checking. There is no part of the United States where a panel will normally be subjected to shrinkage conditions below the original 4% or 5% moisture content of the panel at the time of completion, so that if the panel is made with a 5% or a 4% to 5% moisture content, it will not be subject to face-checking anywhere in the United States. It is to be noted that some regions of the United States have as low a relative humidity as any other locality in the world. By following the method hereinbefore set forth, a finished panel results in which the natural binder (lignin) is under a compressive strain under all normal conditions except in the case of an extremely dry climate. This is effective because at the time the glue sets the moisture content of the assembly is less than the above-mentioned critical value.

The structure of wood, in general, consists of a number of parallel longitudinal hollow fibers (the grain), held together by natural binder material or lignin between them. When wood plies are assembled and glued together with the grains of adjacent plies running crosswise of each other, there is a tendency for the distance between the axes of the fibers of each ply to become fixed. Since the fibers themselves swell with an increase in moisture, if the distances between the centers of the fibers beome fixed at a time when the wood plies are dry and the centers closer together, and the finished ply is then subjected to an atmosphere which is more moist, the wood fibers swell and the distance between the circumference of one fiber and that of the next fiber becomes greatly lessened. This compresses the lignin binder material, but since it has a certain amolunt of elasticity and is capable of a certain amount of compression or stretching without harm, this is not harmful unless the compression or stretching is excessive. Too much compression may cause buckling and too much stretching may cause checking.

If, however, the wood ply is assembled and glued under conditions in which the surrounding moisture is comparatively large, and the "effective" moisture of the assembly at the time the glue sets is considerably greater than 7½%, the wood is in an expanded condition, the distances between the centers of the fibers is comparatively large, and the fibers do not crowd each other. When this manufactured panel is then subjected to a dry atmosphere, the fibers shrink in size, and since the distances between the centers is then fixed by adherence to the next ply the grain of which runs in a different direction, this shrinkage must be taken up in a stretching of the lignin binder. It is this stretching of the lignin binder, when great enough to break it, that causes checking.

In general, a wood panel which is normally under compression, with the fibers of a ply crowding each other, results, when operating under usual climatic conditions of 10% or greater moisture content in the atmosphere, when the "effective" moisture content of the assembly is less than 7½% when the axes of the wood fibers become fixed in relation to each other. Such crowding results in avoidance of checking on exposure to arid conditions.

This invention is not limited to the use of any particular glue but any good veneer glue having water as a vehicle and/or solvent may be used, provided the water-requirement of such glue and the amount of glue necessarily applied do not introduce more water into the wood than as above explained. Some glues have been proposed or are on the market which can be used in the application of my invention and others may perhaps be developed.

The sheet stock used is usually ⅛ of an inch thick, so that a three-ply panel will be ⅜ of an inch thick, the core and outside veneer sheets being usually of the same thickness. 3,000 square feet of ⅛ inch Douglas fir sheet stock, dried to a 5% moisture content, which will make 1,000 square feet of three-ply panel ⅜ of an inch thick, weigh approximately 1,000 to 1,020 pounds; so that it will be seen that the introduction of 24 pounds of water in the glue will be the equivalent of the introduction of about 2.4% of additional water based on the dry weight of the wood, and thus raise the water content of the wood, which before the application of the glue was, for example, 4.75%, to 7.15%. Fifty pounds of the complete unconverted-starch glue, that is, with the necessary water therein, described in the co-pending application Serial No. 754,834, for "Water-proof starch-base adhesives", filed November 26, 1934 by Russell G. Peterson and myself, now issued as Patent No. 2,141,313, dated Dec. 27, 1938, contain about 24 pounds of water. Fifty pounds of such glue are required to make 1,000 square feet of a three-ply Douglas fir panel ⅜ of an inch thick. This is a wet glue of fairly low water content. Any glue having water as a vehicle and/or solvent and having a proper low water content (the minimum water content being limited by the water requirement) is suitable. Such a glue that does not contain more than two parts of water, by weight, to one of adhesive ingredient is a low water content glue suitable for use with this invention. A glue having from one to one-and-a-half parts of water, by weight, to one of adhesive ingredient is, of course, more desirable.

The water requirement and, therefore, the water content are determined by the viscosity of the solution or mass and its ability to flow and be spread mechanically by rollers or other mechanical means. A converted-starch glue can ordinarily not be used commercially with less than two-and-a-quarter parts of water to one part of adhesive ingredient, and it is then so viscous that threads of glue fly in the air as the sheets of veneer are removed from the glue rollers. Such a glue is therefore to be avoided. Casein glue such as described by the Forest Products Laboratory bulletins contains from two-and-one-quarter to two-and-three-quarters parts, by weight, of water to one part of adhesive ingredient. Such a glue is best avoided. Vegetable-seed-residue glues, such as the commercial soya bean glues, contain not less than three parts, by weight, of water to one of adhesive ingredient, and sometimes as high as four-and-one-half parts of water to one. Such glues are also best avoided in practicing my invention.

The glues mentioned in my applications above referred to are useful. Phenol-aldehyde condensation product glues and perhaps other condensation products also, which have water as a vehicle and/or solvent and blood albumen glues which have water as a vehicle and/or solvent may be used since the blood albumen is soluble in one-and-one-half parts by weight of water to one of albumen, with the addition of a little alkali, for example, ammonia. The various condensation product glues referred to above may be divided into two classifications, i. e., aqueous and non-aqueous, that is, those which have water as a vehicle and/or solvent and those which do not, and the distinction is perhaps best explained by reference to an illustration. Phenol-formaldehyde condensation products may be made by treating under suitable conditions a suitable mixture of phenol and an aqueous solution of formaldehyde such as the ordinary commercial 40% solution. At first the reagents are dissolved or dispersed in water and this condition may continue during the first part of the condensation. At a later stage of the condensation reaction the reaction mass separates into a liquid aqueous layer and a liquid oil-like layer. The aqueous layer is usually discarded in the plastic and coating arts as the oil-like liquid is the partially condensed product. This invention is limited to the use of aqueous glues, that is glues having water as a vehicle and/or solvent so that the use without water of the oil-like condensation products or of any other products which do not include water as a substantial and essential element of the glue, is not a part of the present invention. Included within the scope of this invention, however, are glues which contain or which may react to produce an adhesive element which may be non-aqueous when set or even before they set, provided however that the glues contain or develop a substantial amount of water as vehicle and/or solvent when it is applied to the work to be glued. The glues mentioned as useful in practicing my invention are given by way of example and it is not to be understood that my invention is limited to them only.

Not only the water content of the wet glue needs to be considered, but also the amount of glue required, as well as the losses due to evaporation and combination with the adhesive element of the glue since these features combined determine the amount of water actually added to the plywood assemblage, and it is the "effective" content of moisture (water) present, as determined by the amount of water so added to the plywood assemblage plus the amount already there that is important.

Knowing the amount of moisture lost and the amount of water added in the glue, it is a simple matter to calculate a permissible moisture content of the plies just before the glue is applied thereto in order to obtain a permissible amount of moisture in the hot-pressed panels, and with the use of the glue described in the above mentioned application of Peterson and myself, a moisture content of the individual panels just before the glue is applied thereto of 4% to 5% results in panels which do not check even when subjected to arid conditions. As a matter of practice I have the moisture content of each

of the wood plies entering into my multi-ply veneer panels at not over 5%.

It is apparent from the preceding description that checking can be avoided by making the permanent distances between axes of the wood fibers so small that contraction of the fibers due to drying under arid conditions will not be sufficient to make the circumferences of adjacent fibers recede from each sufficiently to break the natural binder in the wood. The proportions of moisture given above are suitable for making non-checking plywood of the kinds of wood ordinarily used for that purpose and which ordinarily are subject to checking. Since it is the above described absorbed "effective" water that normally controls the thickness of the fiber walls and therefore the distances between the axes of the fibers, it is essential to control only the amount of this absorbed water at the time that the distances between these axes become fixed by the setting of the glue. As above described, 7½% of absorbed water is critical, and less than 5% is practically foolproof. A practical empirical way to control this is to adjust the amounts of water in the wood used and the glue used so that the total thereof amounts to the chosen figure, for example 7%, 6%, less than 5%, 4 to 5%, etc., without considering the evaporation and chemical combination losses; or these losses can be measured and taken into account so that the amount of water in the wood used plus the amount in the glue used minus these losses is the chosen figure.

The chemical combination loss and the evaporation loss may be considerable. Frequently 30 to 40 minutes elapse in shop practice between applying the glue to the core and pressing, and the circulation of air over these plies carries off a considerable amount of moisture. Such lossses may amount to say 2 to 3 or 6 to 7% of the dry weight of the wood.

While I have stated various details, yet I wish it to be understood that some of these may be varied without departing from the spirit of the invention the scope of which is defined in the appended claims.

It is not particularly material to certain aspects of this invention whether the water in glues having it as a vehicle and/or solvent functions as one or the other or as both, provided it is an essential part of the glue and dissolves, dilutes, disperses, or carries the glue solids in any manner before the glue sets. I therefore apply the term "vehicle" to the water, in the appended claims, without making any distinction between the terms "vehicle" and "solvent".

By the term "permanently homogeneous fluid glue" as used in the appended claims, I mean one which is homogeneous at the time of application to the wood plies and which remains homogeneous from the time of mixing or making the finished glue until the glue has been applied and is no longer fluid due to setting.

Having described my invention, what I claim and desire to secure by Letters Patent is:

1. A process for the production of multi-ply veneer by controlling the amount of moisture in the plies and glue prior to their assembly, comprising drying veneer sheets to a moisture content of about five per cent (5%), adding a homogeneous fluid glue thereto, said glue containing less than two (2) parts of water by weight, to one part of the adhesive ingredient in such quantity that the total amount of moisture in the glue will be approximately two and four-tenths per cent (2.4%) of the dry weight of the wood, assembling the veneer sheets with the glue therebetween, and finally hot pressing the assembled veneer sheets until the glue has set, thus reducing the original moisture content of the assembly by the amount lost in hot pressing.

2. A process for the production of multi-ply veneer by controlling the amount of moisture in the plies and glue prior to their assembly, comprising drying veneer sheets to a moisture content of about five per cent (5%), adding a homogeneous fluid glue thereto, said glue containing less than two parts of water, by weight, to one part of the adhesive ingredient in such quantity that the total amount of moisture in the glue will be approximately two and four-tenths per cent (2.4%) of the dry weight of the wood, assembling the veneer sheets with the glue therebetween, and finally hot pressing the assembled veneer sheets until the glue has set while removing from one and one-half to two and one-half per cent (1½ to 2½) of moisture, so that the total moisture content of the assembly varies from about seven and four-tenths per cent (7.4%) at the beginning of the pressing operation to approximately five per cent (5%) at the end of the pressing operation.

3. The process of making a non-checking multi-ply wood veneer panel by controlling the amount of moisture in the plies and glue prior to their assembly, comprising preliminarily drying wood plies, assembling the wood plies face to face with the grain of one ply running crosswise to the grain of the next adjacent ply, coating said plies with a glue comprising a water soluble glue base and a limited amount of water as a vehicle and solvent for said base therebetween, the total amount of water in the wood plies after said drying plus the amount of water in the glue being less than seven and one-half per cent (7½%), and finally hot-pressing the assembled plies together until the glue has set, thus reducing the original moisture content of the assembly by the amount lost in hot pressing.

GEORGE H. OSGOOD.

CERTIFICATE OF CORRECTION.

Patent No. 2,150,658. March 14, 1939.

GEORGE H. OSGOOD.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, first column, line 69, for the words "an 'effective'" read a; line 71, for "a" read an "effective"; and second column, line 53, for "amolunt" read amount; page 5, second column, line 37, for "2½" read 2½%; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 6th day of June, A. D. 1939.

(Seal)

Henry Van Arsdale
Acting Commissioner of Patents.