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METHOD OF MAKING PLYWOOD

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My invention relates to the art of gluing, and more particularly to procedures adapted for the formation of plywood and the like and involving the application of the adhesive in discrete-particle form, such, for example, as a dry powder or a suspension of discrete-particles in a fluid.

In general, the object of the invention is the provision of a procedure whereby improved results may be obtained and a better and cheaper product provided.

Other objects will in part be obvious and will in part appear hereinafter.

By plywood I mean to include all structures embodying at least one ply or lamination of wood, whose thickness is not greater than can be caused to adhere to the balance of the structure under the conditions of my process, for instance, of sufficient thinness so that the heat of a hot press can penetrate to the glue line sufficiently to cause setting of the adhesive, and I include in the term plywood, also the term veneering. In this connection it is to be understood that the term "wood" is intended to include not only the natural product, but also artificial woods having a porous structure similar to natural wood, such, for example, as pulp board.

By water resistant plywood I mean plywood whose glue or adhesive binder is of such a nature that subsection of the plywood to twenty-four hours' soaking in cold water does not cause separation of the plies.

In the manufacture of plywood or gluing of wood in general the formation of a glue bond depends upon bringing the glue into a plastic condition in place between the plies to be joined, so that good contact is obtained between the glue substance and the surfaces of the wood when pressure is applied to the assembly and then setting the glue in place so that it forms a strong transversely (i. e. perpendicular to the faces) substantially continuous film joining the two wood surfaces, to which film the penetrating elements are attached. The surfaces of wood prepared for joining as seen under a microscope are very rough and perforated with numerous openings or pores, some of which

extend for a relatively great distance into the wood.

Whether the bond between glue and wood is formed by true adhesion, i. e., specific adhesion, between the glue substance and the wood substance, or whether the bond is mechanical, that is, due to the glue penetrating into the numerous irregularities of the surface of the wood and on being hardened in place, producing a bond due to a keying effect as of plaster on lath, it is obvious that other things being equal, the greater the contact the glue has with the surface of the wood, the better will be the bond formed.

However, if the glue penetrates too deeply into the pores and other openings in the wood, the supply of glue between the surfaces to be joined may be so depleted that a strong transversely continuous film joining the two surfaces cannot be formed, and an inferior bond will result. This condition is known as a starved joint. When two pieces of wood are joined with an adhesive, it will be obvious that there must be a substantially continuous film of adhesive between the two pieces, in a transverse direction. It may be that penetration to a certain extent is necessary beyond the boundaries of this continuous film, but the first requisite is the transversely continuous film; this is the foundation of adhesion.

The extent to which the glue penetrates into the wood depends partly upon the nature of the wood, which varies as to size and number of openings or pores. It depends also upon the effective pressure exerted upon the glue and also upon the fluidity or mobility of the glue while it is under pressure. By fluidity of adhesive I mean those properties of a material which regulate the flow of the material under a given pressure and through a given sized orifice. No matter whether the flow depends on the size of discrete particles suspended or enmeshed in a liquid medium, or whether it depends on viscosity of a true liquid, I include both of these or any other factors which may influence flow, including also plasticity of a discrete particle or collection of particles. I recognize that in case of a suspension, if the orifice is smaller than the swollen particle size, then the rate of flow

may depend on the plasticity of the swollen particles themselves.

In considering the penetration of an adhesive into wood under pressure the structure of wood must be borne in mind. First in importance are the pores of the wood, which, in general in veneer, lie in a direction roughly parallel to the faces of the panel. However, many of the pores are intersected by the faces so that they present openings on the faces into which glue can readily penetrate if it is sufficiently fluid. There are also other openings (rays) in some woods in a direction perpendicular to the faces. The wood cells themselves are much smaller but do permit penetration by the more fluid glues. Besides these openings natural to the wood, there are the checks or cracks that are formed in the cutting of the veneer as well as other irregularities of surface. Thus with wood there are abundant opportunities for a fluid to escape from the surface.

The cold press method of gluing using dry veneer is the most commonly used at present. In this method the plies are assembled in a pile or rack, the cores having been previously passed through a glue spreader which coats both surfaces of the core with a film of liquid glue. After the pile is assembled it is put under pressure and held thus until the glue bond is formed.

There is also in use a method of hot pressing using either dry or wet veneer. In these methods the plates of the press are heated and only one or at most a very few panels are inserted between the hot plates. The spreading of the glue is in general the same as with the cold press method.

In the cold press method it has been the custom to disperse the glue substance in an aqueous medium. By dispersion I mean producing a colloidal system in which dilution can be carried to a high degree without apparent loss of homogeneity in the system. I also distinguish between suspensions and dispersions, as a matter of particle size. Dispersions have particles much smaller than suspensions.

When water is mixed with a glue substance to form a dispersion the fluidity of the dispersion is increased if more water is added. In most instances, as with casein, soya bean and most starch glues, the glue substance is dispersed by the use of alkaline reagents. Animal glue and some modified starches are dispersed with water alone. Blood albumen is dispersed in cold water.

The making of a glue, using the dry glue substance, water and whatever chemical reagents are necessary, requires a high degree of skill, both on the part of the manufacturer of the dry glue substance, as well as the operator who makes the dispersion of the dry glue in the water, and who often must add further chemical reagents.

Besides making a wet glue which primarily must have adhesive properties, other factors must be given due attention. The wet glue must not foam, that is, become full of air bubbles which spoil adhesion and consistency. In the mixing and spreading operation there is abundant opportunity for foam to form and it must constantly be guarded against. The wet glue must be of proper consistency to pick up on the spreader rolls and in turn to leave the rolls for the wood ply when it is passed through the rolls, so as to form a uniform film of glue on the face of the ply of just the required amount. The wet glue must be of such a consistency that it will not be wiped off the face of the plies accidentally in handling. The wet glue must not change materially in either consistency or viscosity with time. That is it must remain as nearly as possible in its original state for a number of hours until a batch of glue can be used.

Besides these factors which have nothing to do with adhesion directly; there are also the very important factors which influence the relation of adhesion to the age of the wet glue. That is, the glue must remain workable and also retain its adhesive properties until it can be used.

It will be seen therefore that there are many factors which must be reckoned with in making a glue, besides the primary factor of adhesion. In fact, oftentimes adhesion must be sacrificed to a certain extent, in order that the secondary factors be correct to make a workable glue.

When in the common process of gluing, a dispersed glue is applied to dry veneer, the dry wood quickly absorbs some of the water from the glue, thus greatly decreasing the fluidity of the film or layer of glue. This decrease in fluidity is necessary to the formation of a good bond, for it prevents the glue from penetrating into the wood too much and thus giving a starved joint. If pressure is applied a few seconds after the glue is applied, and thus before there has been time enough for water to pass from the glue to the wood to thicken the glue, very inferior adhesion will be obtained and it can be shown by microscopic examination that the glue has penetrated deeply into the wood. On the other hand, if too long a time is allowed to elapse between the time when the wet adhesive is applied to the surface of the wood and the time when pressure is applied, then during this time the glue may have dried out too much by reason of the water of the glue having soaked into the wood and when the pressure is applied the glue is not fluid enough to make a proper bond.

Since the laying up of a pile of panels requires from 10 to 30 minutes, the length of time which elapses between spreading of glue and application of pressure, i. e. the "time of assembly", varies from perhaps a minute

or two for the last panels spread to over 30 minutes for the first panels spread. Hence in this process the consistency of the wet glue must always be a compromise between that best adapted for the minimum and maximum times of assembly respectively and like all compromises it cannot suit the extremes. Hence the first and last panels laid are of inferior quality to those in the middle of the rack.

If the glue is fluid enough so that it can stand a time of assembly of 30 minutes and still not dry out too much before pressure is applied, it is so thin that the last panels laid, with time of assembly of a few minutes, have starved joints. If it is made thick enough to escape starved joints on the short time of assembly, then the first panels laid will have dried out too much when pressure is applied. Thus the cold press dry veneer method with wet glue is at best a compromise and has inherent difficulties which have hitherto not been fully solved.

The hot press method using dry veneer has the disadvantages of requiring the drying out of the veneer in a separate operation, as well as the disadvantages connected with the preparation and properties of the glue as regards foam, variation of viscosity with age, and instability of the wet glue previously discussed. It employs the maximum amount of equipment, that is, it uses both a drier and hot presses, which renders it so expensive that it is very little used in the United States. This process employs both dispersed and jellied glues. The dispersed glues are attended with their inherent disadvantages as discussed under cold process. The jellied glues necessarily have a high moisture content, and many of them have the further disadvantage of losing their jelly structure and liquefying when heat is applied. (A jellied glue is one that has been first dispersed and then has been changed to a jelly-like mass by heat or some chemical reagent.)

One of the most serious disadvantages of the methods of gluing just discussed, which use dry veneer, lies in the necessity of drying the veneer as a separate operation. When veneer is dried it tends to check or crack, causing a serious loss. Also the pieces tend to curl and distort rendering them difficult and expensive to handle.

This disadvantage of drying the veneer in separate pieces is eliminated by using the hot press as a drier. When the assembled panel, that is, the pieces of veneer with adhesive interposed, is dried in the hot press, there is less opportunity for the veneer to check, crack or distort. Also the handling of the pieces is less, with attendant economy, since two handlings of the pieces into and out of the drier are eliminated.

It has been attempted in the past to realize the advantages of the hot press with green

veneer. In gluing panels from green veneer by the hot press method, it is desired to form the glue bond and dry the panel out in one operation and it is in fact necessary to remove most of the moisture from the panel in order to set the glue bond.

In this process of gluing a different set of conditions exist, relative to the change in fluidity of the glue substance, than exist in the cold process of gluing dry veneer. The moisture content of green veneer often reaches 125% or more of its dry weight. When glue is applied to this veneer, the wood being already saturated with moisture, no water is taken from the glue substance, and its fluidity is not decreased. On the contrary when heat and pressure is applied the water in the wood tends to dilute the glue substance thus increasing its fluidity. Hence if it is attempted to glue wet veneer by the hot press method with the common dispersed glues no bond is obtained because the glue penetrates into the wood to such an extent that there is practically none left between the surfaces to be joined.

It has heretofore been the custom in gluing green veneer by the hot press method to greatly thicken or gel the glue before applying it to the veneer, by the use of such coagulating agents as heat or formalin. It is possible thus to prevent the glue from penetrating into the wood so completely and to retain on the glue line a remainder sufficiently great to obtain a fairly good bond. However, a large proportion of the glue still penetrates far into the structure of the wood. This penetration robs the glue line of glue substance, thus damaging the bond formed.

There is a further unfavorable effect of excessive penetration besides the one just mentioned in connection with the hot pressing process. The drying out of the veneer in the hot press process depends on the movement of steam in a direction parallel to the faces of the veneer and its escape through the edges. The channels for the escape of steam are largely provided by the pores of the wood which are parallel to the faces of the wood. If, however, these pores become clogged by penetration of the glue substance into them, then the escape of steam is seriously impeded and it may take a considerable length of time to dry the moisture from such plywood. Besides slowing up the drying rate it makes the drying rate irregular; in some places the cells and pores will be less clogged and will dry out faster, in other places slower. Those pores which intersect the glue line will tend to clog more than those which do not. This leads to crooked panels and to difficulties because of ununiformity in their moisture content. It may also lead to blisters because of excessive moisture retained in clogged cell areas at the time the press is opened. Because of the fact that excessive heat must

be used to dry out clogged cell areas, this excessive heat may injure the faces of the panels or cause decomposition of the wood or glue. Thus the green veneer hot plate method with wet glue has also been attended with many difficulties and has never been thoroughly satisfactory.

For purposes of discussion, I classify the commercial methods of plywood manufacture just described as follows:

- "A" Process—hot press, wet veneer
- "B" Process—hot press, dry veneer
- "C" Process—cold press, dry veneer

and I will show hereinafter how my new invention may be used with great advantage to replace all three of these commercial processes.

I have found that many of the disadvantages of present day methods of gluing may be eliminated by the use of a dry adhesive in the hot press method, providing the process is controlled as to certain factors which influence the results, both as respects the character of the adhesive used as well as the physical conditions prevailing during the operation, and when due care is used to properly control the factors which affect the final results, very beneficial results are obtained.

The adhesive in discrete-particle form, preferably in dry powdered form, is spread on the plies. If the wood is undried containing a large part of its original sap moisture, or is wet from lying in water, no water need be added. If the wood be dry, water may be sprayed on the adhesive layer or the wood itself in regulated amount. The plies may then be assembled and pressed in a hot press until sufficiently dry.

The great importance of penetration of adhesive into the wood has been shown in the preceding discussion. Penetration is the factor which most influences the adhesive result obtained, so that whatever influences penetration has a direct influence on the final result.

Penetration may take place either (a) after the press is closed and pressure is applied, or (b) before pressure is applied.

One of the reasons why dispersions have always heretofore been used in gluing, is because they are easily spread mechanically. I spread suspensions, employing different mechanical means than those used to spread dispersions, thereby affecting a great economy as the substances need have, for purposes of my invention, their particles reduced to suspension magnitude only. While I prefer for reasons of simplicity or economy to spread dry powdered adhesive base substances, that is suspensions in air, I am not limited to fluid suspensions in air, but may, by the same means, spread suspensions in water or other liquid medium, and enjoy all the benefits of using suspensions as herein set forth. In particular this may be done in the

"B" process, or when controlling the moisture content of the plywood.

A point I wish to emphasize is that whereas previous gluing has been done with dispersions, and in fact dispersions have been considered as essential to effective gluing, I find that suspensions in air, or in a liquid have many advantages resulting in improved quality of product, besides being much more economical to use.

It will be noted that my process of control provides first a method of controlling the factors so that readily dispersible substances may be used if desired and still obtain good results.

With the dispersible class of adhesives, there is no limit to the amount of water which is taken up by the adhesive, that is, if more water is present it mixes homogeneously with the adhesive layer and so the fluidity keeps on increasing as long as more water is presented. In this case, therefore, it is more difficult to insure against excessive penetration. Control may be exercised by previously decreasing the amount of moisture in the wood itself so that there will not be enough present to dilute the adhesive layer to the point where excessive penetration results.

Examples of dispersible adhesives that can be used with close control in my process are animal glue or gelatin, blood albumin, soluble starches and sodium silicate.

Examples of non-dispersible materials which may be used in certain instances in procedures embodying the present invention are soya bean flower, other oil seed flours, seed flours generally, unconverted starches, gluten, and casein.

It will be seen that penetration of adhesive must be controlled, no matter which form of adhesion is relied upon to form the bond (i. e. whether specific or mechanical adhesion). Either one requires that good contact be obtained between the glue and the surfaces to be joined and that a good portion of the adhesive be left on the "glue line" when the process of forming the bond is completed. With dispersible adhesives it is of particular importance that the penetration be limited.

In any method involving the simultaneous gluing and drying of green unshrunk veneer it is obvious that the tendency of the veneer during drying to shrink and grow narrower transversely (that is tangential shrinkage) will involve serious strain both on the veneer and glue joint particularly when in the manufacture of plywood the middle ply or core is laid at a right angle to the faces. It is also obvious that the tendency of the veneer to grow thinner in drying (radial shrinkage) involves no such strains. Most common woods normally shrink over twice as much tangentially as radially. The tangential shrinkage in many woods is as much as one inch for each foot of width. Both forms

of shrinkage take place only during the removal of the last 25% of moisture contained in the wood. This moisture is loosely combined with the cellulose of the cell walls and is therefore called "fibre saturation moisture." (Fibre saturation point is the maximum water thus contained in the cellulose, and averages 25% to 30% with most woods. Free water is that contained as such in or between the cells, over and above the fibre saturation point.)

In the "A" process with wet glues, means have previously been known for eliminating or neutralizing objectionable tendencies for tangential shrinkage by the use of three stages of drying, including a final separate drying operation when the fibre saturation moisture is removed under heat and pressure in presses so as to cause the wood cells to collapse in the radial direction with beneficial densification of the wood, while the frictional resistance of the press-plates resists tangential shrinkage. In previous practice this method of control has been expensive to apply as it both involved a separate drying operation and used the hot plate press equipment as well as a dryer to perform it. Reference is made to the description of this process in U. S. Patent 1,369,743, of which I was co-inventor. Under my condition of dry gluing in the "A" process I find that this control and elimination of shrinkage and beneficial densification of the wood may be performed all in one operation instead of in three, both with added efficiency and without any expense whatever all in the hot press, for the panels are already in the hot press and the moisture is to be removed in any case and it is therefore simply necessary to adjust the hydraulic pressure to secure the necessary frictional resistance on the surface of the panels to prevent tangential shrinkage taking place. This results in densification that is radial (i. e. in a direction at right angles to the face of the plies) shrinkage, which takes the place of tangential shrinkage. A considerable loss of area is thereby saved, and a stronger panel results from the densification. In the previous methods deficiencies in the control of penetration necessitated the use of three stages in manufacture, whereas my present process enables this to be done in a single operation.

This is a discovery of importance, as one of the most serious obstacles to the "A" process hitherto has been either inability to satisfy the tangential shrinkage tendencies of the wood or else the cost of applying as a separate operation the remedy previously described. The application of this principle of controlling shrinkage also greatly improves the saleability of the product besides eliminating the principal source of spoilage.

It has a further important advantage in greatly improving the water resistance of the glue bond, by the fact that as the bond

has been formed while the veneers are in the green unshrunk condition of maximum tangential expansion and the wood dried while in that condition, and the wood cells deformed exclusively in the direction of radial shrinkage, the tendency to a subsequent tangential movement by a rewetting is eliminated. The gain in water resistance using the same quantity and kind of glue substance with the "A" process is frequently 50% as compared to a similar panel made from pre-dried veneer by the "B" process.

In general under my conditions of control and dry gluing new opportunities are made available for controlling and influencing the physical character of the wood either as a whole or locally. For example in the "A" process the wood may be densified and altered in structure as a whole by the previously mentioned method of resisting tangential collapse of the cells and inducing radial collapse during the drying out of the fibre saturation moisture in the press so that an altered wood is produced. With cottonwood for instance I have demonstrated that panels made in this manner sand and stain better and are more resilient than similar panels not densified.

It will be noted that my process is also applicable to the gluing of dry veneer, as by the hot press method "B" process in the following way:

I have indicated before, the importance of the moisture content of veneer as being one of the factors, in fact one of the most important factors, influencing penetration and hence the final adhesion. I have also indicated means of control of the process to secure good results when it is desired to glue green or wet veneer, that is, veneer where the amount of moisture is in excess of that required by the glue substance. In this case, of course, I do not attempt to control the moisture of the veneer.

The moisture of the veneer, of course, is subject to control if my process is desired to be carried out by providing such control; in other words, the veneer can be dried to any degree desired before the adhesive is applied to it in the dry state. For example, it can be dried down to the point where it will supply just enough moisture to the adhesive, due regard being had to the amount of moisture which will escape when the heat is applied.

Also, if desired, the veneer may be dried to a very low content of moisture, so low in fact that it cannot supply any moisture to the adhesive substance. Under these conditions I then provide the proper amount of moisture to secure the desired fluidity in the adhesive layer by adding moisture either to the surface of the wood to be glued or to the dry adhesive which has previously been spread on the surface of the wood, that is, the dry adhesive is first spread on the dry veneer by a suitable apparatus which gives

a uniform spread and then the required amount of water is added to this dry adhesive by any means which will give a uniform amount of water. The amount of water, of course, which is to be added must be under control and must be pre-determined by trial, that is, it is found what amount of water best suits the wood and the adhesive to secure the proper conditions of fluidity and penetration. The plies are then assembled and pressure and heat is applied to dry the adhesive layer and set it to a permanent bond.

For instance, I spread soya bean flour containing 13% of moisture on bone dry veneer and after pressing obtained a bond of about 100 lbs. dry strength. If more water is added to the flour it is no longer a dry powder and it is no longer spreadable as a dry powder but by spreading the 13% moisture containing flour in the usual way and then spraying on a sufficient amount of moisture to bring the water content up to 25% of the dry weight of the flour a bond of 190 lbs. dry strength was obtained. It is therefore evident that with this wood and this adhesive a water requirement of 25% produces satisfactory results.

Under these same conditions with bone dry wood and dry flour I obtained equal strength by sponging or spraying on the wood an amount of water equal to 50% of the weight of the glue, the difference in amount of water being due to a lesser amount being effectively absorbed by the glue substance under these conditions.

This "B" process, it will be noted, presents also certain advantages from the standpoint of using dispersible materials. In attempting to glue wet veneer with dispersible materials the great difficulty is to prevent excessive dilution of the adhesive layer. With the above described modifications, however, of my process, it will be noted that just the right amount of water may be added to dispersible material so as to attain just the right condition of fluidity and hence of penetration. For example, some modified starches are largely dispersible in water. In attempting to glue wet veneer with such starches it is very difficult to secure the proper control methods to produced good commercial results. The same starches, however, when used in my modified process, which provides control of the moisture in the veneer or on dry veneer gives very good results. Likewise animal glue if finely ground produces a badly starved joint with heat and green veneer, but may be made to produce an excellent bond with heat and dry veneer. For instance, I found that with cottonwood and animal glue, I only obtained a bond of 60 lbs. strength with green veneer in my "A" process, but with dry veneer and the surfaces lightly moistened in the "B" process

I obtained an exceptionally strong bond of 200 lbs. dry strength.

It will be remembered that I previously said that jellied glues had been used in the hot press dry veneer ("B" process), and at first thought it might seem as though these presented a parallel case to my use of dry adhesives in this process. But when it is considered that jelly glues have necessarily a very high water content and a tendency to liquefy under heat, it will be seen that dry adhesives have many important advantages.

For example, blood jelly glues contain as high as seven parts of water to one of dry substance. They must have such high water content so that they can be spread. Comparing the action of such a jelly with my dry adhesive which may be used in this process with as little as one-quarter part water to one part of dry substance and it will be seen that an entirely different case is presented as far as fluidity of adhesive and consequent penetration is concerned and that the latter case is far easier to control to get best results. The high moisture content of the jellied glues when used with dry veneer naturally presents serious difficulties in connection with assembly time, absorption of glue water into the dry wood with accompanying expansion troubles, which my very low moisture requirement avoids.

With dried blood albumen reduced to a fine powder I have produced bonds of very high strength with one-quarter part of water sprayed on the glue substance in my "B" process. Not only is this a reduction of from 85 to 95% in glue water as compared to wet gluing practice, but owing to the complete control of penetration obtained by this method, not only are the difficulties connected with penetration in wet gluing avoided but other means of control of assembly-time-penetration such, for example, as are desirable with this adhesive in my "A" process may be avoided under these conditions.

Thus by my "B" process I am able to produce new results impossible either by the prior art of wet gluing or by my "A" process of dry gluing green wood.

This lowering of the water requirement by my controlled methods of dry gluing is readily apparent in view of my conditions permitting a reduction of the water requirement with a large class of glue substances to the amount necessary to induce a moderate degree of plasticity in the glue substance as distinguished from the far greater amount required for aqueous dispersion, and obtaining proper spreading consistency.

Aqueous dispersions require from 1 1/2 parts to 7 parts of water to one of glue substance. Sufficient plasticity for my process is obtained with 1/4 to 1 1/2 parts of water and the higher amounts are only required under special conditions where for some reason low

heat is necessary or a time value is involved. In general $\frac{1}{2}$ part of water up to an amount not substantially exceeding the weight of the adhesive meets most conditions in the "B" process as contemplated by the present invention.

The advantages of my invention over the previous "B" process, i. e., dry veneer hot press, as formerly applied using wet glue, are:

1. Penetration is controlled.
2. Elimination of all the disadvantages connected with the preparation and spreading of the wet glue.

3. Economy of drying in the hot press, due to less water in glue.

4. Advantages of economy of glue material, stain, and water resistance.

5. Enables minimum contact of moisture with wood, under conditions where this is desirable, such as very thin faces. This protection of the wood from injury by the glue water is accomplished by applying the water necessary to the dry powdered glue, after the latter is spread on the wood.

Under the condition of dry gluing with vegetable proteins in both the "A" and "B" processes I find that the degree of insolubility attained by the resulting bond may be greatly influenced by the intensity of the application of heat during the pressing operation. For instance with soya bean flour containing 45% protein I have obtained a 50% increase in the wet breaking strength of the bond by increasing the steam pressure applied to the press plates from 10 lbs. to 125 lbs. and as the drying time in this instance is reduced from 120 minutes at 10 lbs. pressure to 20 minutes at 125 lbs. pressure I have determined that the intensity of the application of heat is of great importance. With vegetable adhesives in general I find it advantageous to use the maximum intensity of heat available up to the point where injury to the product by decomposition begins to take place. By so doing both the efficiency of the drying operation and the water resistance of the bond are greatly improved.

In the "B" process a local but very beneficial alteration of the physical character of the wood affecting only a thin layer of wood contiguous to the glue line may be produced by moistening these surfaces with the water required to modify the physical state of the glue substance. This moistening has the effect of quickly swelling the exposed fibres on the surface. These present a greater surface therefore for the attachment of the glue bond and being plastic under pressure are amalgamated with the glue film as to form a very strong bond. The depth of the layer of softened and swollen fibres may readily be controlled by regulating the amount and temperature of the water applied and the duration of assembly time.

Thus, densification of a thin film of wood contiguous to the glue substance may be carried to a considerable extreme by using high hydraulic pressure during pressing without crushing the wood as a whole, which, by this method, remains dry and hence able to resist high pressures without being permanently deformed.

For example, in the "B" process I have produced bonds of exceptionally high strength by sponging the surfaces of dry cottonwood veneer with water, then spreading with dry soya bean flour and pressing between heated plates. When these bonds are examined in section under the microscope, contiguous to the glue line there appears a thin layer of wood fibres completely surrounded by and amalgamated with the dried glue substance. This layer is dense and free from voids. It is thus evident that the moistened swollen layer of wood fibres produced by the sponging has been both densified by the hydraulic pressure and simultaneously penetrated by and amalgamated with the plastic glue substance while the dry wood fibres, not affected by the moisture, have not been made yielding and plastic by moist heat and hence have been able to resist a considerable amount of hydraulic pressure without being distorted or altered. This highly densified and amalgamated layer of wood fibres at the glue line supplies undoubtedly in large measure the explanation of the unusually high breaking strengths noted in this process. This furnishes an extreme example of the benefits of my methods of controlling penetration, for the bonding of glue substance and wood is in this instance practically complete.

Glue bonds of very high strength may thus be produced even with woods which are difficult to glue because under these conditions a very complete amalgamation of glue substances with a thin layer of softened wood is thus produced and as the removal of the fibre saturation moisture from the wood and the dehydration of the glue substance takes place simultaneously, the collapsed wood cells are securely held in their final condition by the glue substance. By controlling the temperature and amount of water applied to the wood surfaces the thickness of the layer of wood product can also be controlled and also the depth of glue penetration. The resulting plywood is flatter, stronger and better bonded than dry veneer hot plate plywood produced by previous methods of wet gluing as the necessity of dealing with the larger amount of water inherent in wet gluing, is avoided and control of penetration conditions and results is also much better. This method of local wetting of the contiguous surfaces of the plies also affords a means of controlling the moisture of the ply as a whole so that it is kept below the point at which appreciable expansion due to moisture

takes place. This eliminates danger of checking and creeping of plies during assembly which have been so troublesome in the prior art of wet gluing with heat and dry veneer. The low amount of moisture is still sufficient to soften the adhesive to the extent required for satisfactory penetration.

By my controlled methods of dry gluing many special conditions can be met by compromises between the "A" and "B" processes. For instance, it is often advantageous to use predried face stock and green unshrunk center stock and vice versa and these compromises between the two methods may be made in any degree with improved results as to cost of manufacture and character of product.

While certain specific examples of modes of carrying out the invention have been given, it is to be understood that the invention can be utilized in a wide variety of procedures, and since certain changes may be made in the above exemplified method without departing from the scope of the invention, it is intended that all matter contained in the above description shall be interpreted as illustrative and not in a limiting sense.

Reference is made to the following patents issued on applications constituting continuations in part of the present case: Nos. 1,851,949, 1,851,950, 1,851,951, 1,851,952, 1,851,953, 1,851,954 and 1,851,955.

Reference is also made to the following applications which are continuations in part of the present case: Serial No. 518,944, filed February 28, 1931, and Serial No. 538,983, filed May 21, 1931.

Reference is also made to the copending application of Irvin F. Laucks, Charles N. Cone and myself, Serial No. 351,822, filed April 1, 1929.

I claim:

1. The method of making plywood from wet, unshrunk plies of wood in a single stage in a hot press without tangential shrinkage by employing a dispersible adhesive base substance applied as a dry powder to said plies, setting the limit of the penetration of said adhesive into said plies, and applying pressure of a magnitude sufficient to prevent tangential shrinkage and to densify the wood and heat of a degree to dry out the assembly.

2. The method of making plywood comprising applying to the plies an adhesive base substance in powder form dry at the time of spreading; and providing the dry plies with a quantity of water ranging from one-quarter ($\frac{1}{4}$) to one and one-half ($1\frac{1}{2}$) parts of water to one (1) of glue substance which determines the penetration of the adhesive.

3. The method of making plywood, comprising applying to wet unshrunk plies an adhesive base substance in the form of a suspension in a fluid at the time of spreading; determining the degree of penetration of said

adhesive substance into the plies by means of the adhesive being in discrete particle form; and removing the moisture by heat while the assembly is under relatively high pressure, whereby tangential shrinkage is prevented and the wood is densified, the drying, densification and prevention of tangential shrinkage proceeding simultaneously.

4. The method of making plywood, comprising applying to wet unshrunk plies an adhesive base in powder form dry at the time of spreading; setting the limit of the degree of penetration of said adhesive substance into the plies; then eliminating the moisture while said plies are subjected to pressure and heat, and substantially avoiding tangential shrinkage by subjecting the assembly to pressure inhibitive of tangential shrinkage while the moisture is being eliminated, whereby in a single operation a densified plywood with substantially no tangential shrinkage is produced.

5. The method of making plywood from wet unshrunk plies of wood in a single stage in a hot press without tangential shrinkage, by employing a dispersible adhesive base substance in discrete particle form, controlling the penetration of said adhesive into said plies, and applying pressure of a magnitude sufficient to prevent tangential shrinkage and to densify the wood and heat of a degree to dry out the assembly.

6. A method of gluing, which comprises supplying at the glue line a blood adhesive base and a plasticizing agent in an amount substantially just sufficient for the plasticization and coagulation of the adhesive material under bonding conditions, and subjecting to bonding conditions.

7. The process of gluing, which comprises providing at the glue line a blood adhesive base and water in the proportion by weight of approximately four parts of adhesive material to one part of water, and subjecting to bonding conditions.

8. The method of gluing which comprises supplying in powdered form to a surface to be incorporated an adhesive base of the character which is dispersible in cold water, assembling and subjecting to bonding conditions the penetration being controlled without the presence of added materials by limiting the moisture available to substantially the amount required for the gluing.

9. The method of gluing which comprises supplying blood albumen in powdered form to a surface to be incorporated, assembling and subjecting to bonding conditions, the penetration being controlled without the presence of added materials by limiting the moisture available to substantially the amount required for the gluing.

10. The method of gluing which comprises supplying modified starch in powdered form to a surface to be incorporated, assembling

and subjecting to bonding conditions, the penetration being controlled without the presence of added materials by limiting the moisture available to substantially the amount required for the gluing.

11. The method of making plywood, which comprises associating a dry shrunken close-textured ply with a wet unshrunken loose-textured ply, an adhesive base in discrete particle form being interposed therebetween, and subjecting to bonding conditions under pressure of a magnitude sufficient to prevent tangential shrinkage of a wet loose-textured ply.

12. The method of making plywood, which comprises associating a dry shrunken close-textured ply with a wet unshrunken loose-textured ply, a powdered adhesive base having been supplied to at least one of the associated surfaces, and subjecting to bonding conditions under pressure of a magnitude sufficient to prevent tangential shrinkage of the wet loose-textured ply.

13. The method of making plywood, which comprises associating dry shrunken close-textured face plies with a wet unshrunken loose-textured core, a powdered adhesive base having been supplied to at least one of each pair of associated surfaces, and subjecting to bonding conditions under pressure of a magnitude sufficient to prevent tangential shrinkage of the wet loose-textured ply.

14. The method of making plywood, which comprises associating wet unshrunken loose-textured face plies with a dry shrunken close-textured core, a powdered adhesive base having been supplied to at least one of each pair of associated surfaces, and subjecting to bonding conditions under pressure of a magnitude sufficient to prevent tangential shrinkage of the wet loose-textured ply.

15. The method of making plywood from a plurality of wood plies including one or more dry shrunken plies and one or more green unshrunken plies in the same assembly in a single stage of heat treatment, by applying an adhesive, controlling the penetration of the adhesive into the plies and simultaneously applying heat and pressure to the assembly, the moisture in the green plies being sufficient to plasticize the adhesive, the heat being sufficient to dry out the assembly, and the pressure sufficient to densify the green plies and avoid tangential shrinkage therein.

16. The method of making plywood from moist unshrunken plies in a single stage of heat treatment, by applying an adhesive, controlling the penetration of the adhesive into the plies, and simultaneously applying heat and pressure to the assembly, the heat being sufficient to dry out the assembly, and the pressure sufficient to prevent tangential shrinkage and densify the wood.

17. The method of making plywood from dry shrunken plies, comprising the steps of

swelling a superficial layer of wood fibres on the surfaces to be united by the application of moisture in a limited amount, applying dry discrete particles of an adhesive base capable of being rendered plastic by moisture, assembling the parts and applying pressure, whereby the swollen wood fibres and plasticized adhesive are amalgamated to form a bond characterized by having its penetration limited by the depth of the layer of moistened fibres.

18. The method of making plywood from dry shrunken plies, comprising the steps of swelling a superficial layer of wood fibres on the surfaces to be united by the application of moisture in a limited amount, applying dry discrete particles of an adhesive base capable of being rendered plastic by moisture, assembling the parts and applying pressure and heat, whereby the swollen wood fibres and plasticized adhesive are amalgamated and dried to form a bond characterized by having its penetration limited by the depth of the layer of moistened fibres.

19. The process of forming plywood which comprises providing at the glue line an adhesive base in discrete particle form and an amount of water in a proportion by weight of approximately four parts of adhesive material to one part of water, and subjecting to bonding conditions.

20. The method of gluing, which comprises applying adhesive base material in discrete-particle form to a surface to be incorporated, supplying water in an amount not substantially exceeding 1 part of water to 1 part of adhesive base material, and subjecting an assembly including said surface to bond-forming conditions.

21. The method of gluing, which comprises applying adhesive base material in powdered form to a surface to be incorporated, supplying water in an amount not substantially exceeding 1 part of water to 1 part of adhesive base material, and subjecting an assembly including said surface to bond-forming conditions.

22. The method of gluing, which comprises applying adhesive base material in powdered form to a surface to be incorporated, supplying liquid in an amount not substantially over 1 part of liquid to 1 part of adhesive base material, and subjecting an assembly including said surface to bond-forming conditions.

23. The method of gluing, which comprises applying animal glue in powdered form to a surface to be incorporated, supplying water in an amount not substantially over 1 part of water to 1 part of animal glue, and subjecting an assembly including said surface to bond-forming conditions.

24. The method of gluing, which comprises applying albuminous adhesive base material in powdered form to a surface to be incorporated, supplying water in an amount not

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substantially exceeding 1 part of water to 1 part of adhesive base material, and subjecting an assembly including said surface to bond-forming conditions.

5 25. The method of gluing, which comprises applying modified starch in powdered form to a surface to be incorporated, supplying water in an amount not substantially exceeding 1 part of water to 1 part of adhesive base material, and subjecting an assembly including
10 said surface to bond-forming conditions.

In witness whereof, I hereunto subscribe my name this 24th day of January, 1929.

THEODORE WILLIAMS DIKE.

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