U. S. Department of Agriculture, Forest Service

FOREST PRODUCTS LABORATORY

In cooperation with the University of Wisconsin

MADISON, WISCONSIN

NOTES ON THE MANUFACTURE OF PLYWOOD

Revised
September, 1922

NOTES ON THE MANUFACTURE OF PLYWOOD

By manufacture of plywood is meant the gluing together of plies of wood, usually an odd number, so laid that the grain of alternate layers is approximately at right angles. In three-ply panels the outside plies are referred to as faces and the center ply as a core. In a five-ply construction the outside layers are faces, the next two plies in order crossbands and the center ply core. The details of gluing, pressing, and drying plywood are not standardized, but these notes on manufacture are based upon observations of factory practice and upon extensive experiments at the Forest Products Laboratory.

Gluing Panels in General

The core or crossbands of the panels are coated with glue on a glue spreader consisting of two rollers, the lower one revolving in a bath of glue and the upper one sometimes being coated from another bath of glue retained between the upper roller and a trough with its lower edge almost touching the surface of the roller. Scrapers or the pressure of the rolls regulate the thickness of the glue layer as desired.

The panels are built up and placed in the press as soon as possible. The actual time consumed between spreading glue on the first panel and the application of pressure to the stack of panels varies greatly in different factories from a few minutes to a half hour or longer. The panels are usually grouped with three to five in a set with caul boards placed between sets and at the top and bottom of the entire lot before pressure is applied. The panels are usually left under pressure for 7 to 24 hours and then taken to the drying room. Shorter pressure periods can be used in some cases when necessary.

Two different methods are used rather extensively in applying the pressure and maintaining it on the panels. The one perhaps most commonly used oonsists in applying the pressure by a hydraulic press and then using retaining clamps to keep the panels under pressure. The hydraulic press is usually equipped with a pressure gauge which shows the amount of pressure applied. The panels are left in the hydraulic press just long enough to apply the proper load and fix the retaining clamps in place. The bundle of panels is then removed on a truck to an out of the way place in the factory where they are usually left until the next day.

By the other method the panels are placed in presses and left until the glue is set. These presses are usually of the hand screw type with no means for measuring accurately the amount of pressure applied.

With glues of the blood albumin type, demanding the use of a hot press, the glue is applied as in the case of cold glue and the panels placed one or more at a time in the hot press. Pressure up to 200 pounds per square inch and temperatures of 212 degrees Fahrenheit or more are usually applied. The panels are kept in the press until the glue is set, varying from two to several minutes, depending upon the thickness of the plies and the panels and the type of cauls used.

Calculation of Pressure in a Hydraulic Veneer Press

For plywood manufacture determination of the correct amount of pressure to use is important. Results of experiments at the Forest Products Laboratory indicate that an excess or a lack may produce a weak glue joint. The exact amount of pressure to apply per square inch of panel surface varies with a number of conditions. However, pressures of 75 to 150 pounds per square inch of panel surface are ordinarily within the range of which good results may be obtained with most glues and under average factory conditions. When animal glue chills in a cold room before

pressure is applied very heavy pressures are then necessary to secure strong joints. In this case pressures of 400 pounds per square inch or more are required.

The determination of the amount of pressure applied per square inch of panel on a hydraulic press equipped with a pressure gauge is simply a matter of calculation. With any hydraulic press, this depends upon three factors: The area of the panel, the area of the piston or ram of the press, and the pressure gauge reading.* The area of the piston in square inches multiplied by the pressure gauge reading in pounds is approximately equal to the total pressure exerted by the plates. The total pressure exerted divided by the area of the panel in square inches gives the pressure secured on the panel in pounds per square inch.

The pressure gauge reading must, therefore, vary with the size of the panels if the same amount of pressure per square inch is to be secured. For example, if the same gauge pressure is applied on panels 10 by 36 inches as on others 36 by 40 inches the pressure will be approximately four times as great per square inch in the first case as in the second.

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* It is assumed of course that the gauge is in good repair and indicating the pressure correctly. Pressure gauges should be checked occasionally to see that they are correct.

L26
543

From the considerations above the following formulas for the calculation of pressures are derived:

$$P = \frac{P' \times A'}{A} \qquad (1)^*$$

or

$$P' = \frac{P \times A}{A'} \qquad (2)^*$$

Where P = gauge pressure in pounds per square inch.
P' = pressure on panels in pounds per square in.
A = area of piston or ram in square inches.
A' = area of panel in square inches.

To illustrate the use of the formulas let the following case be assumed: On a hydraulic press with 10-inch piston what pressure gauge reading is necessary to secure 75 pounds per square inch on panels 24 by 48 inches? Use formula (1)

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*To determine accurately the exact pressure secured the weight of the platen to which the pressure is applied must be taken into consideration. For practical purposes, however, it may be omitted from the calculation, as inaccuracies in the gauge reading, etc., may account for much larger errors. When the weight of the platen is taken into consideration the formulas become:

$$P = \frac{P' \times A'}{A} \text{ plus or minus } \frac{W}{A} \qquad (3)$$

or

$$P' = \frac{P \times A}{A'} \text{ minus or plus } \frac{W}{A'} \qquad (4)$$

Where W = weight of the lower platen plus weight of panels or upper platen alone, as the case may be. The sign of the last member of equation (3) is plus when the pressure is applied by the lower platen and minus when applied by the upper. In equation (4) the reverse is true.

$$P = \frac{P' \times A'}{A}$$

Here P = gauge reading required
P' = 75
A' = 24 x 48 or 1152 (area of panel)
A = 3.1416 x 5² or 78.54, the area of the piston*

Thus P = $\frac{75 \times 1152}{78.54}$ or 1100 the required gauge reading.

A table, showing gauge readings to be used for all sized panels manufactured and for the different pressures used, can be computed and placed near the press where the operator may see at a glance the amount of pressure required on the gauge reading for each run of panels.

Drying

Panels take up a good deal of moisture in gluing and after coming from the press are usually placed on stickers and run into a kiln or left at room conditions for final drying. Dryingunder room conditions is slow and, because of the space required, is expensive. The use of panel kilns has become more common of late years. The necessity for quick drying of panels in connection with aircraft work has aided considerably in this development.

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* The area of a circle is equal to 3.1416 times the square of the radius.

L26
543

Results of experiments in kiln drying aircraft panels have indicated that the essential requirements of minimum injury to the material, a sufficiently rapid drying rate, and convenience and economy of operation can best be met by maintaining a constant temperature of about 120 degrees Fahrenheit and a constant maximum relative humidity which will permit the stock to dry down to the final degree of dryness desired, but which will not allow an appreciable amount of further drying below the required moisture content. The use of constant temperature and humidity conditions which will dry the panels to a definite moisture content makes the drying simple, safe, and easy. For panels, of three and five-ply veneer or of veneer faces and crossbanding and a thick core and glued at a low moisture content, drying at 120 degrees Fahrenheit and the necessary maximum humidity may be accomplished in from a few hours to over night. Temperatures above 120 degrees Fahrenheit have the advantage of decreasing the drying time but are more liable to lower the quality of the panel by inducing checking, warping, and open joints. Panels dried from a high to an excessively low moisture content are very liable to warp and should be dried relatively slowly.

Gluing by a Dry Glue Process

In connection with aircraft work a process of laying veneer with dry blodd glue was worked out at the Forest Products Laboratory.* It consists of making an adhesive by coating a tissue paper with blood albumin glue, allowing it to dry, and using the coated paper as the glue layer for plywood. The sheets of glue are alternated with sheets of veneer until the required number of plies is obtained and the whole is pressed in a hot press. The use of the dry glue enables the construction of plywood with the addition of little or no moisture. Veneers as thin as 1/150-inch can be glued successfully into thin sheets of plywood orpanels.

The process can be used with thicker stock but appears to be adapted especially to fancy, cross-grained, and very thin veneer. It should also prove successful with a number of other adhesives than blood glue. The method eliminates a number of troubles resulting from the use of wet glues, such as checking, warping, open joints, and overlaps, and makes the handling of thin material much easier.

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* At least two patents on similar process have been discovered since that time, one a British patent No. 17,327 issued in 1902 and the other U.S. patent No. 1,299,747 issued in 1919. The value of these patents is not definitely known, but it is suggested that anyone interested in producing this material should familiarize himself with them in order to avois infringement.

L26
543

Factors Affecting the Warping of Plywood

Symmetrical Construction

On account of the great difference in shrinkage of wood in the direction parallel to the grain and perpendicular to it, a change in moisture content of plywood will inevitably either introduce or relieve internal stresses. Take, for example, a three-ply construction and subject it to low humidity conditions so that the moisture content of the plywood is lowered. Because the grain of the core is at right angles to the grain of the faces, the core will tend to shrink a great deal more than the faces, in the direction of the grain of the faces. This shrinkage subjects the faces to compression stresses and the core to tensile stresses. If the faces are of exactly the same thickness, of like density and otherwise balanced the stresses are symmetrically distributed and no cupping should ensue.

Now let itbe assumed that one face of a three-ply panel has been glued with the grain in the <u>same</u> direction as the core, and that the moisture content of the panel is reduced. It is obvious that the internal stresses are now no longer symmetrically distributed, inasmuch as the compressive stresses in one face have been removed. This face now shrinks a great deal more than the other face in the direction of the grain of the latter. The result is that cupping takes place.

L26
543

The necessity for exercising care in sanding the faces of a panel is obvious, inasmuch as different thicknesses on the faces would introduce unequal forces with changing moisture content and produce distortion.

In order to obtain symmetry it is also necessary that both faces of symmetrical plies be of the same species, or species of approximately the same properties.

To summarize: A plywood panel to retain its form with changes of moisture must be symmetrically constructed. Symmetry is obtained by using an odd number of plies. The plies should be so arranged that for any ply of a particular thickness there is a parallel ply of the same thickness and of the same species or properties on the opposite side of the core and equally removed from the core.

Direction of the Grain of the Plies

b In the discussion of symmetry of construction it was understood that the successive plies were always glued with the grain either parallel or exactly at right angles to the core. In careless construction this may not always be the case. Tests have shown that deviations as small as five degrees from the standard 90-degree construction may introduce considerable twisting.

In building up a three-ply veneer panel the core should be glued with the grain at 90 degrees with the faces, or as close to this as feasible.

Moisture Control

The previous discussion brought out the fact that a change in moisture content of a panel may introduce cupping and twisting in the panel if it is not carefully constructed. Hence it is highly desirable that all plies be at about the same moisture content before gluing, and that the moisture content of the panel when it leaves the drying room should be about the same as it will average when in use. The limits of from 10 to 15 per cent moisture in the finished panel will usually give satisfactory results when the panel is in service in the open air. For use in heated buildings, at least a part of the year, as in furniture a somewhat lower moisture content of seven to eight per cent will ordinarily give best results.

Veneer for furniture panels should generally be low in moisture, so that when removed from the press the moisture content, increased by the moisture from the glue, will be as near as possible to that required for factory use. For fancy, cross-grained veneer the gluing at low

moisture content is of particular importance, since drying of the panel frequently results in checking of the face. Non-water-resistant glues also require the use of dry veneer, but with casein and blood glues it is possible to use wet veneer.

Good strength and water resistance can be obtained with these water-resistant glues with veneer at a moisture content as high as 50 per cent. For maximum wet strength of plywood the veneer should be glued at a moisture content which would bring the panels to about 30 per cent or more when removed from the press. The high moisture content of the panels made in this way necessitates considerable care in drying if a good quality panel is to be secured, and it is improbable that much use can be made of this method of gluing in furniture manufacture. It offers possibilities, however, for cutting costs in the manufacture of articles where glue strength, water resistance, or speed of manufacture is more important than appearance.

Relation of Density of Veneer to Warping

Numerous tests have shown that the warping of plywood panels when subjected to varying moisture contents is least for the panels made of low density veneer, such as basswood, poplar, and cedar, and that, in general, warping increases with increasing density.

Effect on Warping of Increasing the Ratio of the Core to the Total Plywood Thickness

A high proportion of core to total plywood thickness helps to maintain a flat unwarped surface. In general, the core should comprise 5/10 to 7/10 of the total thickness of the panel where flatness is an important consideration. Of three-ply panels having cores of the same weight the panels having cores of low density, such as poplar and basswood, will, in general, show less warping than the panels having high density cores, such as maple and birch.