MANUFACTURE AND GENERAL CHARACTERISTICS OF FLAT PLYWOOD

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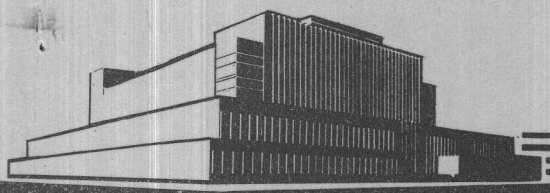

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

MANUFACTURE AND GENERAL CHARACTERISTICS OF FLAT PLYWOOD[1]

By

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U. S. Department of Agriculture

Summary

Plywood is manufactured by bonding thin sheets of wood (veneers) together with adhesives in such a way that the mechanical and physical properties of the wood are redistributed. This manufacture of plywood requires special equipment, knowledge, and technique. Important steps in the process of making flat plywood are outlined here, as well as information on types and grades and some properties of plywood. The information is based upon observations of factory practice and upon extensive experiments at the Forest Products Laboratory.

The Components of Plywood

The essential components of plywood are veneer and adhesives. Both are available to the plywood manufacturer in several grades and types.

Veneer

The veneer commonly produced in this country consists of thin sheets of wood ranging in thickness from 1/100 inch to more than 1/4 inch. It is cut from many kinds of wood, both softwood and hardwood species, and is classified by species and grade.

For plywood manufacture, veneer must be smoothly cut, uniform in thickness, flat, and uniformly dried. The desirable moisture content for veneer at the time it is glued varies with the type of glue used and

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[1] Original report dated April 1925, revised in 1943 and 1956.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

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with the conditions the finished plywood will encounter in service. In any case, however, the distribution of moisture should be uniform throughout the veneer.

Veneer for most kinds of plywood should have a low moisture content at the time it is glued so that, when the glue sets, the moisture content, which is increased by the moisture from the glue, will be near the average expected in service. In most parts of the United States, an average moisture content of 8 percent is recommended for glued products for interior service. In arid regions, this average will drop to 6 percent. In humid regions along the Gulf Coast and in the coastal area of southern California, the average will be about 11 percent. For plywood that is used outdoors, the average moisture content in service in the United States is about 12 percent, except in the dry Southwestern States, where it is about 9 percent.

Ideally, the moisture content at the time the glue sets should be equal to the average expected in the normal service of the glued item. For cold pressing, the moisture content of the veneer as delivered to the gluing operation should be such that, when increased by the water added with the glue, it will equal the average in service. Plywood glued in a hot press is often laid up with veneer that is somewhat drier than may be used in cold pressing. This is to reduce problems with steam blisters that may form when the gluing pressure is released. Hot-pressed panels usually dry considerably during gluing and, consequently, it is often desirable to add moisture by conditioning such panels. For fancy cross-grained veneer, gluing at low moisture content is of particular importance, since drying of the panel from a high moisture content frequently results in checking of the face ply. Glues that set primarily by absorption of water by the wood, such as starch glues, generally require the use of veneers at a lower moisture content than do glues, such as urea resin, that set in part by chemical reactions or other phenomena.

The moisture content of veneer is controlled by (1) drying the veneer in a regulated veneer drier shortly before it is glued, (2) storing the veneer in temperature- and humidity-controlled rooms, or (3) running the veneer through redriers before it is glued.

The temperature of the veneer at the time it is glued is important. When veneer is taken directly from driers or redriers and assembled into plywood at too high a temperature for the glue, there is danger of premature heating of the glue (precure), which may impair the quality of the plywood panel. Such precure is particularly critical with reactive thermosetting resin glues. This condition can be controlled only by knowing the upper

limits of temperature permissible for each glue and by holding back any veneer that exceeds that temperature until it has cooled.

Some types of thick plywood panels are made with a lumber core instead of being built up entirely of veneer. Such panels are known as "lumber-core plywood" or "veneered panels." A common construction is made up of a nominal 1-inch lumber core, cross bands of veneer that are frequently 1/20 inch thick, and faces of veneer 1/24 or 1/28 inch thick. The core is sometimes composed of many small pieces or strips of lumber glued together into a larger piece, to avoid the cupping that may occur in wide, flat-grain core boards. Fiberboards and certain synthetic panel materials have also been used as cores.

Selection of Veneer and Lumber

The quality and usefulness of plywood depend largely upon the quality of the veneer from which it is made. In plywood for aircraft or other structural purposes, it is necessary to avoid or closely limit the defects that affect the strength or durability of the plywood. The strength properties of the wood species used must also be taken into consideration. In plywood for the visible parts of furniture, interior trim, and similar purposes, the principal consideration is appearance, and hidden defects that do not impair appearance are generally acceptable.

Core materials for lumber-core panels are generally selected with the object of gaining a stable, smooth material that will not contribute to the warping of the panel nor contain defects that might show through the faces. Woods with a relatively low density, low shrinkage characteristics, a uniform texture, and a reputation for staying flat in service are preferred.

Adhesives

The adhesives available for bonding veneers together to make plywood panels are classified according to their water resistance and the temperature at which they set.

On the basis of setting temperature, these adhesives fall into three general groups: (1) most phenol- and melamine-resin glues and many urea-resin glues, which require temperatures of 200° to 300° F. and are usually set between heated plates; (2) some urea-resin and low-temperature phenol-resin glues, which require temperatures of about

90° to 160° F. and can be set in a room or kiln with controlled temperature; and (3) room-temperature-setting urea-resin, resorcinol-resin, and polyvinyl-resin emulsion glues, and casein, soybean, and starch glues that set at 70° F. or above.

The extremes of water resistance are illustrated by starch glue, which has no appreciable water resistance but is still sometimes used for interior work, and by phenol-resin adhesives that are used for plywood that will withstand any exposure that the wood itself will withstand.

In general, different types of glues require somewhat different control of gluing conditions for optimum joint quality. The recommendations of the glue manufacturer for the use of his own glue should be carefully followed.

The Gluing and Pressing Operation

The problem of applying the glue is principally one of evenly spreading the desired thickness on the surface of the veneer quickly enough to permit placing the veneer and glue assembly under pressure before the glue sets.

When glue is used in liquid form, the core or cross bands of the panels are usually coated on both faces by means of a mechanical roll spreader. Generally, only 1 of the 2 mating veneer surfaces are spread with glue. Scrapers, idler rolls, or the pressure of the main rolls regulate the thickness of the glue layer according to the character of the spreader being used. Rubber-covered rolls with fine corrugations are ordinarily required for liquid resin glues, whereas for vegetable and casein glues either corrugated iron rolls or rubber rolls that are properly grooved may be used. Most liquid glues can also be spread with brushes, paint rollers, or scrapers in small gluing operations, and some resin glues can be applied by spraying.

One type of phenol-resin glue is available as a film that does not require a spreader. The film is cut to the proper size and then inserted between the sheets of veneer. It finds special application for very thin veneers that cannot readily be handled in a glue spreader and through which a wet glue would penetrate readily. Film glues require special control of the moisture content of the veneer.

As the glue is spread, the veneers are assembled in relationship to each other as required in the finished panel. It is standard practice in plywood manufacture to place the grain directions of adjacent plies perpendicular

to each other and to use an odd number of plies so that corresponding plies are located at the same distance from, but on opposite sides of, the center or core ply. It is also important that opposite plies be of the same thickness and same species, or of species that have similar shrinking, swelling, and strength characteristics.

Plywood for special purposes, such as certain aircraft uses, may be laid with the grain directions of alternate layers at angles other than 90 degrees to each other or to the edges of the panel. Such special plywood does not always have an odd number of plies. These constructions, however, must be regarded as infrequent exceptions.

In three-ply panels, the outside plies are referred to as faces and the center ply as a core. In five-ply construction, the outside layers are faces, the first inside plies are cross bands, and the center ply is the core. In panels with a larger number of plies, there is no special name for the plies that lie between the center ply (core) and the cross bands that are adjacent to the faces.

When the glue and veneer are properly assembled, and the glue layer has reached the desired consistency, the assembly is put under pressure. There are two general types of pressing equipment in common use -- the hot-plate press and the cold press.

Hot Pressing

Much plywood is now being glued in hot presses, particularly when the synthetic resin glues are used. At the present time, all gluing with film glues, practically all gluing with phenol-resin glues, and much gluing with urea-resin glues is done in hot presses. Soybean glues and blends of soybean and blood glues are used to some extent in hot-plate presses for moisture-resistant Douglas-fir plywood. Straight blood and resin-blood glues also give their best results when they are hot pressed.

When thin plywood is hot-pressed, two or more panels may be placed together between the heated plates. Only one thick panel is pressed in each opening. Hot presses usually have many plates and openings between them, so that a number of panels can be glued in one pressing operation. Particularly when panels with thin faces are being glued, the press must be closed promptly after the panels are inserted in order to avoid partial setting (precure) of the glue before pressure is applied.

The time required in the hot press depends on the thickness of the material being glued and on the glue being used. Some glues require setting temperatures in the neighborhood of 300° F., while others can be cured at 212° F. or below. Since the innermost glue line must be heated to the required temperature, the pressing time depends on the distance the heat must travel from the plates to reach this glue line. The time may vary from 2 or 3 minutes for very thin panels to an hour or more for panels 2 or 3 inches thick. The time required can be calculated by the use of mathematical formulas that consider wood thickness, species, moisture content, press temperature, and setting temperature of the glue. Charts from which the rate of heating of a panel may be determined are available.[2] Glue manufacturers can usually furnish specific recommendations for obtaining best results with their respective glues.

The amount of pressure required in hot-press gluing varies with the kind of wood being glued. Heavy, dense woods can withstand higher pressures than lighter, softer woods. In any panel assembly, the maximum pressure to be used is controlled by the species of lowest density in the assembly. For woods of low density, such as basswood, yellow-poplar, and spruce, pressures of 100 to 150 pounds per square inch are used. With medium-density woods, such as sweetgum, walnut, Douglas-fir, and mahogany, the pressures to be used lie between 150 and 200 pounds per square inch, and for high-density woods, such as yellow birch and hard maple, the pressures may be from 200 to 250 pounds per square inch or even higher. In any case, the pressure must not be so great as to crush the wood or produce excessive compression in panels under the conditions of heat and moisture prevailing in the panel, nor so low that the glue will not be pressed out into a thin, continuous film in complete contact with the surfaces to be joined. Precautions must be taken to be certain that total pressure is adequate and that it is uniformly distributed over the entire joint area.

Cold Pressing

Panels bonded with glues that are pressed without heating are stacked and placed in the press as soon as possible after the glue is applied. The actual assembly time permitted between spreading glue on the first veneer and the application of pressure to the stack of panels must be

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[2] MacLean, J. D. The Rate of Temperature Change in Wood Panels Heated Between Hot Plates. Forest Products Laboratory Report No. 1299. 1955.

definitely limited, although it varies with different glues from several minutes to a half-hour or longer. The assembly time also depends on the temperature of the glue line during this period. The time decreases as the temperature increases.

The panels are accumulated in a pile up to 30 inches or more in height, with flat caul boards separating the pile into groups of 2 to 7 or more panels. Rigid, smooth pressboards are put on the top and the bottom of the stack of panels, and the assembly is placed under pressure.

Two cold-pressing methods are used extensively to apply and maintain pressure on the panels. The one applicable to all cold-press glues consists of applying the pressure with a hydraulic press and then keeping the panels under pressure with retaining clamps. The hydraulic press is usually equipped with a gage to show the total amount of pressure applied. The panels are left in the press just long enough to apply the proper load and to tighten the retaining clamps in place. The bundles of panels are then removed on a truck and stored in the factory until the next day. It is important to make sure that the temperature of the panels is maintained at or above the minimum curing temperature for the glue used throughout the required pressure period.

By the other method, currently used with certain types of glues, the panels are placed in presses and left a few minutes until the glue takes an initial set. The panels are then carefully removed from the press and stored undisturbed at the necessary temperature. The curing of the glue proceeds to completion under no pressure except that of the stack of panels.

Control of pressure is important in cold-pressing operations, just as it is when hot presses are used. In general, the pressures suggested previously are applicable. Crushing of the wood by excessive pressure is less likely to be encountered in cold-pressing than in hot-pressing.

The determination of the amount of pressure applied per square inch of panel by a hydraulic press equipped with a pressure gage is simply a matter of calculation. The principal factors that determine the amount of pressure applied are: the area of the panel, the area of the piston or ram of the press, and the pressure-gage reading. The area of the piston in square inches multiplied by the pressure-gage reading in pounds is approximately equal to the total load exerted by the plates. The total load exerted divided by the area of the panel in square inches gives the approximate pressure on the panel in pounds per square inch. To obtain

exact pressures on the panels it is necessary to correct the above calculations for the weight of the movable parts of the press, which may increase or decrease the pressure applied, depending on the design of the press. This correction is important for large presses and small panels.

A table showing gage readings to be used for all sizes of 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 gage for each run of panels.

Conditioning and Finishing of Plywood Panels

Once the glue has set, the panels may then be ready to trim and sand at once, or they may require further curing or redrying before further work is done on them.

Veneers for cold pressing are often at a higher moisture content before they are glued than those for hot pressing. Panels glued cold with the common types of aqueous glue take up a good deal of moisture when they are glued and are often placed on stickers after they come from the press and run into a kiln or left at room conditions for final drying. Drying under room conditions is slow, and is expensive because of the space required.

Results of kiln-drying experiments have indicated that the essential requirements of minimum injury to the panels, convenience, and economy of operation can be met by maintaining a constant temperature of about 120° F. and a constant maximum relative humidity that will permit the stock to dry down to the desired moisture content in a relatively short time but which will not allow appreciable drying below this point. The use of constant temperature and humidity conditions that will dry the panels to a definite moisture content makes the drying simple and safe. Panels of three- and five-ply veneer, or of veneer faces, cross bands, and a thick core, that are glued at a low moisture content, may be dried at 120° F. and the necessary humidity in a few hours or overnight. Temperatures above 120° F. have the advantage of decreasing the drying time, but they are more likely to lower the quality of the panel by inducing checking, warping, and open joints unless the humidity is carefully controlled. Panels dried from a high to an extremely low moisture content are likely to warp unless they are dried relatively slowly.

When plywood is hot-pressed, the veneer is likely to lose considerable moisture. This loss favors checking and warping. It is advisable, therefore, to add moisture either by applying water to the panels immediately after they are removed from the hot press and stacking them in solid piles, or by exposing them to controlled humidities. Other methods, some of them patented, are also used.

Trimming and Sanding

The plywood panels are trimmed on standard ripping and cut-off equipment. The equipment must be in good condition and accurately set up, otherwise the panels will not be square.

The trimmed panels are usually sanded, and this too is a critical operation. Most of the care used in making a perfectly balanced panel by selecting veneer of uniform thickness, moisture content, and suitable species is wasted if one face is sanded appreciably thinner than the other.

Storage

Plywood should be stored under conditions that will not appreciably change the moisture content of the panels. Stacking in solid piles with the panels directly over each other and with a solid cover over the top of each pile protects the panels against rapid changes in moisture content, warping, dust accumulation, and discoloration by light. Direct drafts of heated air from hot air ducts or unit heaters, or of cool humid air from open windows or humidifiers, should be avoided because they may bring about rapid moisture content changes at panel edges. Wrappings covering the edges and ends of panels may retard moisture changes and will help protect edges from dirt and mechanical damage.

Some Properties of Plywood

The chief advantages of plywood, as compared with solid wood, are its approach to equalization of strength properties along the length and width of the panel, greater resistance to checking and splitting, and less change in dimensions with changes in moisture content. The greater the number of plies for a given thickness, the more nearly equal are the strength and shrinkage properties along and across the panel and the greater is the resistance to splitting.

Shrinkage of Plywood

The shrinkage of plywood varies with the species, the ratios of ply thicknesses, the number of plies, and the combination of species. Three-ply panels, with all plies in any one panel of the same thickness and species, were dried from a soaked to an ovendry condition at the Forest Products Laboratory. Measurements showed about 0.45 percent shrinkage parallel to the face grain and 0.67 percent shrinkage perpendicular to the face grain, with ranges of from 0.2 to 1 percent and 0.3 to 1.2 percent, respectively. The panels tested ranged in thickness from 1/10 to 1/2 inch. For all practical purposes, shrinkage of plywood in thickness does not differ from that of solid wood.

Three-ply plywood of 69 species, including many tropical woods, was tested at a British laboratory. It was concluded that the average shrinkage of plywood in width and length was about 1/25 that of veneer of solid wood across the grain.

Balanced Construction

A plywood panel must be symmetrically constructed to retain its dimensions and form when the moisture content changes. Balance 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 distant from the core.

A change in the moisture content of plywood will either introduce or relieve internal stresses because of the great difference in the shrinkage of wood in the directions parallel and perpendicular to the grain. When the grain of the core is at right angles to the grain of the faces, the normal shrinkage of all plies across the grain is largely prevented by a very small change in dimensions of the adjacent ply or plies in the direction of the grain. If the faces are of exactly the same thickness, of like density, and otherwise balanced, the stresses are symmetrically distributed and no cupping will result.

Warping of Plywood

The tendency of plywood to warp as a result of stresses caused by shrinking and swelling is largely eliminated by balanced construction. On the other hand, if one face of a three-ply panel has been glued with the grain

in the same direction as the core and the moisture content of the panel is reduced, the internal stresses will no longer be symmetrically distributed, because one face ply does not restrain the core from shrinking while the other ply does. Cupping takes place as a result. Cupping may occur to a lesser extent in any three-ply plywood panel that is unbalanced in construction because the opposite faces are unequal in thickness, density, shrinkage, or other properties. In a five-ply panel, the cross bands must be properly matched to prevent cupping of the panel.

Twisting is another form of warping that may be encountered in the manufacture of plywood. Tests have shown that deviations as small as 5 degrees between the grain directions of any 2 corresponding plies, such as cross bands, may introduce considerable twisting. One method of eliminating twisting is to cut the veneer sheets so that the direction of the grain is parallel to the edges of the sheets. The direction of grain may be tested by splitting the veneer or by other suitable means.

It is not always convenient nor possible to cut the veneer in the exact direction of the grain. In such cases, the tendency to twist may be eliminated if the veneers are so glued that the grain of opposing plies is parallel, even though its direction is not exactly perpendicular to that of the core. This matching of plies may be accomplished most easily when sliced veneer is used and pieces that were adjacent in the flitch are glued on opposite sides of the core so that they will have the same relative position as they had in the flitch. When maximum freedom from warping is required and rotary-cut veneer is used, it may be necessary to examine each sheet to make sure it is laid in the correct position.

If veneered panels are built up of five plies, the direction of the grain of the cross bands is the most important factor in preventing twisting. The faces of five-ply veneered stock may exert some influence in causing or preventing twisting, but their influence is not so marked as the influence of the cross bands.

A change in the moisture content of a panel may introduce cupping and twisting if the panel is not carefully constructed. Hence, it is highly desirable that all plies, particularly the faces and the cross bands, be at about the same moisture content before they are glued.

Numerous tests have shown that when the moisture content of plywood panels is varied, warping is least for the panels made of low-density veneer, such as basswood, poplar, and cedar, and that warping increases with increasing density.

A high proportion of core thickness to total plywood thickness helps to maintain a flat, unwarped surface. In general, the core of a three-ply panel should be one-half to seven-tenths of the total thickness of the panel if flatness is an important consideration.

The Face Checking of Plywood

Because the face veneers on plywood panels are restrained from shrinking and swelling by the crossbands or core of the panel, stresses resulting from changes in moisture content may develop to the point where checks open in the surfaces. The checking pattern may vary greatly, and what might be considered objectionable checking for an exacting use, such as finely polished furniture, might be unnoticeable in a satin-finished surface.

Checking tendencies vary with species, and depend on the inherent characteristics of the wood, such as shrinkage and density. Edge-grained face veneers shrink less in width than flat-grained veneers of the same species, and consequently are less likely to check. Deep knife checks, which may develop when the veneer is cut on the lathe or slicer, may affect the early development of face checks. In general, the tight or unbroken side of the face veneer is used for the outer panel surface. This is advantageous, unless subsequent sanding removes much or all of the unbroken wood surface. When the loose side is out, checking is likely to occur early unless the sanding removes all of the knife-checked surfaces.

Thin veneers are less likely to develop face checks than thicker veneers of the same species under the same conditions. Gluing the face veneer parallel to the ply immediately beneath it increases, in effect, the thickness of the face, and therefore tends to increase surface checking.

When the face veneer is delivered to the spreader for cold-press gluing, it should have a moisture content not higher than the average moisture content that the panel will attain in service. A higher moisture content at the time of gluing will result in increased stresses in the panel after it is pressed and dried, and may lead to early checking. Exposure of the panel to alternating high and low humidities may also lead to early checking. In most cases, panels may be exposed to normal indoor humidity changes, which will bring about moisture content changes of as much as 8 percent between the high and low points, without developing surface checks. Exposure to more severe changes may result in checking. Finishes that retard the rate of moisture content change, such as high-grade

synthetic resin varnishes or high-grade house paints, will retard surface checking but usually will not prevent it.

Types and Grades of Plywood

The quality of plywood and of the veneer from which it is made is, for some purposes, covered by specifications. During World War II, for example, large quantities of aircraft plywood were produced under an Army-Navy aeronautical specification. Among the commercial standards[3] currently in common use, the most important are CS 45, Douglas Fir Plywood, and CS 35, Hardwood Plywood.

The type of plywood is determined by the quality of its glue bond. Examples of plywood types and some of the glues typically used are:

Type	Glue-line quality	Typical glues used
Douglas-fir:		
Exterior	Permanent under exterior use	Phenol resin
Interior	Water resistant	Soybean, blood, or extended phenol resin
Hardwood:		
Type I	Fully waterproof	Phenol resin or melamine-urea resin
Type II	Water resistant	Urea resin (sometimes moderately extended)
Type III	Moisture resistant	Casein, urea resin (with extension)

[3] Copies obtainable at 20 cents each from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

The quality of the veneer in a panel determines its grade. Douglas-fir veneer is classified into grades N, A, B, C, and D, depending on its firmness and smoothness and on the presence of knots, splits, patches, pitch pockets, wormholes, and open defects of certain sizes. The best grade of Douglas-fir panel, N-N, is intended for a natural finish. A-A has sound, smooth veneers that are free of any defects, but it may have well-made patches on each surface. Hardwood veneer is similarly classified into grades 1, 2, 3, and 4. Grade 1 includes face veneer that meets certain requirements as to color, pattern, general appearance, and defects, as defined for individual species. Grades 2, 3, and 4 are based on the occurrence and severity of defects, such as knots, knotholes, burls, mineral streaks, and wormholes. The standard also has provision for custom selections of grain and matching for special uses. The standard for hardwood plywood also includes specifications for lumber-core panels and, if it is required, for edge banding of such panels.

The standards also cover such subjects as sanding, thickness tolerances, number of plies, standard panel sizes, and plywood tests. They provide for inspection of plywood at plants that subscribe to the service and that wish to certify their product as meeting the requirements of the standard.

Some types of plywood are available that are not made entirely according to the specifications of the commercial standards. Some firms market special "marine grade" plywood that usually differs from the best grade of exterior or type I plywood in that no open defects are allowed in inner plies. Cigarette-proof furniture plywood is made with a metal foil immediately beneath the thin face veneer. The foil is said to carry away heat so fast that the face veneer and finish are not scorched.

Plywood is also available with various types of paper-plastic overlay surfaces, some of which are the decorative type, while others are the utility type. Medium-density paper-plastic overlays provide smooth, check-free, paintable surfaces. High-density paper-plastic overlays provide dense, hard, water-resistant surfaces that are sometimes decorative. Panels are also available with striated, brushed, textured, and other types of treated surfaces.

References

This report is necessarily limited in presenting the amount of the information available on the manufacture of plywood. A more thorough introduction to the subject can be obtained by consulting the publications listed below:

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SUBJECT LISTS OF PUBLICATIONS ISSUED BY THE

FOREST PRODUCTS LABORATORY

The following are obtainable free on request from the Director, Forest Products Laboratory, Madison 5, Wisconsin:

List of publications on Box and Crate Construction and Packaging Data

List of publications on Chemistry of Wood and Derived Products

List of publications on Fungus Defects in Forest Products and Decay in Trees

List of publications on Glue, Glued Products and Veneer

List of publications on Growth, Structure, and Identification of Wood

List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products

Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen

List of publications on Fire Protection

List of publications on Logging, Milling, and Utilization of Timber Products

List of publications on Pulp and Paper

List of publications on Seasoning of Wood

List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components

List of publications on Wood Finishing

List of publications on Wood Preservation

Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

Note: Since Forest Products Laboratory publications are so varied in subject no single list is issued. Instead a list is made up for each Laboratory division. Twice a year, December 31 and June 30, a list is made up showing new reports for the previous six months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. Each subject list carries descriptions of all other subject lists.