WOOD GOES TO WAR

By

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In the popular mind this is a war of dive bombers and high-speed armored divisions—yet this war of machines requires a larger quantity and variety of forest products than has been used in any previous war. As a matter of fact, this has been recognized by the Germans for a long time; they put wood second on the list of essential materials—second only to steel—in planning this war.

Lumbermen are aware of the vast quantities of lumber going into the construction of military buildings. However, it is likely that few comprehend fully the list of wood items demanded by war’s insatiable appetite—wood for hangars, scaffolding, boats, wharves, bridges, pontoons, railway ties, telephone poles, mine props, anti-tank barriers, shoring, shipping containers, and air-raid shelters; plywood for airplanes, blackout shutters, prefabricated housing, concrete forms, ship patterns, assault boats, ship interiors, truck bodies, and army lockers; fuel for gasogenes; pulp and paper for surgical dressings, boxes, cartridge wrappers, building papers, pasteboards, gasmask filters, printing, and propaganda distribution; synthetic wood fibers, such as in rayon, artificial wool and cotton, for clothing, parachutes, and other textiles; wood cellulose for explosives; wood charcoal for gas masks and steel production; rosin for shrapnel and varnishes, turpentine for flame throwers, paint, and varnishes; cellulose acetate for photographic film, shatterproof glass, airplane dopes, lacquer, cement, and molded articles; wood flour for dynamite; wood bark for insulation, tannin, and dyestuffs; and alcohol from wood for rubber. Only recently the Government has ordered that all Army truck bodies be built of wood to conserve steel—a use that is currently requiring approximately a million feet of hardwood a day.

The amount of lumber used for containers is almost unbelievable. The number of boxes required for the shipment of ammunition alone runs into the scores of thousands per day. It is estimated that more than seven billion board feet of lumber will be required for containers in 1942 and a substantially greater amount in 1943.

All told our wood needs this year (according to the War Production Board) will exceed 39 billion board feet. Actually we are estimated to be cutting only 33 billion feet. A stock pile of some five billion feet in the hands of manufacturers is rapidly vanishing in the face of this gap between production and consumption.

A Critical Material

The bumper grain crop this year called for additional storage capacity which required release of lumber frozen for military purposes. In the agricultural implement field there is urgent need to replace war-commandeered steel with wood if we are to continue to meet agricultural production goals. Lumber, therefore, has become one more critical material of which we do not have enough.

Eight months ago our war agencies were beginning to seek ways and means of substituting wood for steel wherever practicable, but today they are also frantically searching to find substitutes for wood (often in uses where wood originally replaced steel). Available materials for lumber substitutes include paper and

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fiber products, glass, brick, masonry, and cement. It seems a safe prediction that before long the manufacture of additional hundreds of wooden articles in common use today will be sharply restricted or denied altogether.

The Forest Products Laboratory has been deluged by requests for information about wood, the most urgent of which have come from the Army, Navy, War Production Board, and other war agencies. The Laboratory's big job today is to help solve the manifold wood use problems of these same agencies and of the war industries having the job of winning this war in the factories, in the arsenals, and on the distant fighting fronts.

Six months before Pearl Harbor the research program had been largely swung over to war objectives and since that day the Laboratory has been on a 100 percent war footing. Personnel has been increased from 170 to nearly 500 and the needs of the Army and Navy for additional services and information may require further expansion to perhaps 600 or 700 before the end of the year. Extra shifts have already been added.

Obviously, some of the specific things that the Forest Products Laboratory is doing to help win the war cannot be freely disclosed. These are activities carried on in close cooperation with the Army and Navy. Other important developments which can be discussed are described in the following paragraphs:

**Timber Connectors**

Modern connectors for timber construction are increasingly coming into their own under the urgency of war-time construction. These relatively simple fittings — in the form of rings or plates inserted between surfaces in contact in timber joints — distribute stresses over a much wider area of wood than does the ordinary bolted joint. The result is a joint four or five times as strong as the simple bolted connection.

The determination of engineering data on the modern connectors was carried out by the Forest Products Laboratory during the early 1930's, and it can be said that its general acceptance by architects and engineers arrived none too soon to serve us in this war. However, it did arrive in time, and it has been installed in new factories, airplane hangars, mold lofts, warehouses, and other large industrial and military structures throughout the nation. The connectors lend themselves readily to shop fabrication and quick emergency construction and they are helping wood to serve effectively in the breach left by steel that has been diverted to actual fighting implements. A billion and a half board feet of timber has been used with connectors to date — more than half of this amount in the last year — and a quarter of a million tons of steel has consequently been saved for direct war uses where only steel will serve.

**Glued Laminated Arch**

Another timber construction principle that became available just in time to help fight this war is the glued laminated wood arch. The Laboratory worked out the basic design principles that have enabled architects and engineers to design arches of greatly varied size and shape to support — with no obstruction to floor and overhead space — many vital structures, such as hangars, drill halls, and garages; a transport airplane hangar with laminated arches having a span of 152 feet, will house the largest transport planes now being designed.

Place one type of glued laminated arch on its back and you have something with the appearance of a boat keel. That is the precise naval use in which the technique of shaping thin laminations and gluing them into strong curved shapes may
serve to harass Hitler and his undersea minions. The lamination principle is also being applied to airplane wing beams. The development of the new synthetic resin glues—with their high resistance to moisture—is helping in this development. These glues require heat to set them, however, and the Forest Products Laboratory has built and is testing electrostatic heating equipment for setting glue in laminated structural members and for seasoning of critical lumber items.

New Designs for Boxes and Crating

Co-operating with the War Department, the Laboratory is extensively engaged in the development of designs and specifications for boxes and crates and for loading and packaging of ordnance equipment and munitions, including tanks, guns, and other combat equipment for the expeditionary forces. Items must be so packed as to arrive whole free from moisture, rust, and decay, plainly marked, readily and quickly accessible, protected against pilferage, and packaged so as to conserve weight, lumber, and vital cargo space. Similar services are being given to Lend-Lease and other Government war agencies as required. Hundreds of thousands of items are involved, and in practically all cases better packages are developed, with savings of vital shipping space of from 5 to 30 percent.

Radio commentator Raymond Gram Swing recently made this observation, "We are living in a time when the ton of cargo space is the most important unit of power in the United Nations' war."

Seasoning Problems

In a great many products ranging from gunstocks to airplanes, seasoning is becoming a critical bottleneck in lumber production despite the fact we are unfortunately compelled to use lumber practically green from the saw in much construction work.

Chemical seasoning as developed at the Laboratory is at least a partial answer to the seasoning problem, making possible faster drying schedules and cutting losses through checking and degrade to a minimum. For example, early in this war three-inch Douglas-fir planks needed for pontoons required 28 days to season in a dry kiln, and even then about a fourth of the stock dried had to be thrown out because of degrade. The high loss made seasoning of such stock uneconomic. With Laboratory methods of chemical seasoning, however, the drying time was cut to less than a week and degrade losses cut to 1 or 2 percent. The success with pontoon stock has since led to application of the chemical seasoning process to other types of thick lumber.

Here is another example—in a shoe last block, an item in our Lend-Lease program. Under ordinary methods of seasoning, involving air drying followed by kiln-drying, six months or more may be needed to dry maple shoe lasts to the proper moisture content. With good kilns and effective kiln schedules, the Laboratory has dried such stock experimentally in about 45 days.

Chemical seasoning materials have been adapted to extend the supply of wood for shuttles needed by the textile industry, which is working under the burden of large orders for uniform cloth and other war goods. Dogwood has a combination of hardness, fine texture, toughness, and smooth wearing qualities long recognized and demanded by the industry. Demand has pushed the price up to $1 a board foot, and still the demand cannot be met. The Laboratory has treated other species, notably birch and persimmon, with chemicals, thereby increasing their hardness by as much as 45 percent. Textile mills are now trying Laboratory-treated shuttles experimentally. With similar chemical treatment, maple
bobbins have also been produced more rapidly and with a degree of hardness that promises to give them longer life in service and to eliminate the need for the metal ferrules now applied to the ends.

The modern semiautomatic rifle and the carbines with which our growing armies are being equipped require wooden gunstocks. Black walnut is the preferred species. Here again, seasoning is a bottleneck in production that can be materially widened. Stepped up kiln schedules and techniques developed at the Laboratory to reduce the drying time of these walnut gunstock blanks from 70 to about 50 days have been suggested to the industry.

At the same time, research has shown that black cherry is an excellent substitute species for black walnut. Cherry has a specific gravity about the same as that of walnut, and can be kiln-dried in about two-thirds the time. It has very similar machining qualities, according to tests made in an eastern gunstock plant.

Plywood for Airplanes

Owing to the scarcity of metals, increasing quantities of plywood are going into training and combat planes, gliders, and cargo planes. Plywood has been manufactured and used in airplanes in the United States for years. But before plywood goes into modern military craft in which the lives of American airmen are at stake, the Army and Navy must be assured that plywood can, as an engineering material, take the terrific punishment to which such planes are subjected. This calls for the immediate development and testing of mathematical formulae by which the specific properties of plywood, such as resistance to fatigue, buckling, and torsion, can be more accurately calculated for design purposes. To obtain these formulas the Laboratory’s engineering staff has been greatly expanded and, in order to expedite the testing required, a force of women is operating test equipment in two shifts from 6 o’clock in the morning until 11 p.m.

New Glues

The recent development of highly water-resistant synthetic resin glues for plywood necessitates that these glues, as they come on the market in ever increasing numbers, be carefully checked to assure that they measure up to certain standards. The Laboratory is constantly making tests of new glue formulations in order to inform the public, and particularly the armed services, regarding new products which may or may not have been adequately tested by their producers.

Along with the new glues and the use of flat plywood there has been developed by various manufacturers the process of molding plywood by means of fluid pressure applied through flexible bags or blankets of rubber or other impermeable material. This development frequently termed "bag-molding" is of particular importance at the moment in the making of aircraft parts of various degrees of curvature. In size these parts may vary from a fairing for a tail wheel to a half fuselage complete with bulkhead rings. They include all combinations of single and double curvatures, cylinders, paraboloids, portions of a sphere—in short, any curved piece for which a mold can be made and later separated from the finished product. The Laboratory is conducting experiments to extend the scope of the process and to produce specimens such as test cylinders with which to study buckling and other plywood design criteria.
Impreg and Compreg

The search for chemical treatment that would make wood a substance less affected by moisture—protect it, that is, from shrinking and swelling and consequent warping, cupping, twisting, and the like—has led to two distinct, yet closely related, products: impreg and compreg.

Strips of ordinary veneer are the raw material from which impreg and compreg are usually made, although the process is applicable to thicker wood. The problem was to protect the wood cells against the comings and goings of moisture which cause swelling and shrinking. Various materials were tried over a period of years; the most successful have proven to be modern synthetic substances called phenolic resins.

It was found that when these resins were dissolved in water, a solution was obtained which penetrated not only the cell cavities, but also the very cell walls of wood, displacing the moisture within the cell structure. Upon heating, this solution became permanently fixed within the wood, and a material of very high water resistance was the result. Thus was born impreg.

With this treated veneer, the next step logically was to make an improved plywood. In the course of these experiments a number of more or less unexpected developments came about. Most outstanding was the fact that when the resin treated veneers were placed in a press before they had been heated to "set" the resins, the sheets, or laminations, had a decided tendency to become plastic as pressure and heat were applied simultaneously. In fact, it was found that, in hot pressing, the laminations could be compressed into a product one-half or one-third their original combined thickness. And when taken from the press, this product retained its compressed dimensions even when soaked in water for prolonged periods. Moreover, it was found that no glue was needed to bind the resin-treated veneer sheets to each other, enough of the resin within each sheet was squeezed out to form a strong bond between adjacent sheets. Here, then was a product (now known as "compreg" wood) extremely resistant to moisture, with hardly any detectable shrinking or swelling, with a glossy finish and surface hardness approaching that of glass. Its properties, too, were remarkable.

Subsequent tests disclosed the fact that compreg can be molded to single or double curvature. For the period of the war emergency, it will doubtless remain a material solely for military uses. It is now being tested in various military applications, notably propellers, aircraft landing wheels, torpedo boat electrical control housings, and other parts requiring high strength and waterproof qualities.

Propellers demonstrate the adaptability of compreg to a nicety. Where great strength is needed, as at the hub, high pressure can produce this strength. The rest of the blade may be compressed only to mold it to the correct aerodynamic curvatures and proportions in order to produce an efficient, yet relatively light member.

Similarly, compreg faces and impreg cores can be assembled into a product that is light in weight, yet possessing high moisture resistance.

Plastics

The Forest Products Laboratory has under development three distinct types of plastics. These are (1) plastic wood, which is a product little changed in appearance from ordinary wood; (2) a molding powder and a molding sheet—both of which are wood plastics as distinguished from plastic wood and produced from sawdust or other wood wastes and contain a relatively high content of lignin; and (3) a laminated paper plastic of great tensile strength and having other properties which give it much promise as a substitute for aluminum and other metals.
The plastic wood process was discovered in the course of experiments in chemical seasoning. Searching for a chemical that would draw water to the surface of green lumber so that fast drying would not set up stresses within the wood which would check and degrade it, wood was treated with urea.

Upon heating the wood, the usual procedure, it was noted that it had suffered a striking change. It had actually become plastic and could be twisted, bent to extreme curvatures, or shaped over forms. On further experimentation, it was found that when wood was treated with urea-aldehyde this chemical combined with the lignin in the wood to form a thermosetting plastic. When cooled this time, the wood became hard and held its shape permanently.

This product certainly challenges the imagination, but it is so new that there has been little opportunity to test its properties; and, while some applications of the process are being examined, such developments must be devoted exclusively to war work.

The plastic molding compound and the laminated sheet already mentioned are outgrowths of Laboratory research on the innate plastic and bonding qualities of lignin. Both are made from hardwood wastes, and their commercial development therefore promises an outlet for much wood that is today necessarily discarded in the woods and at the sawmill.

For more than a decade the molding compound has been under development at the Laboratory.

Shortly after Pearl Harbor, representatives of a leading storage battery manufacturer visited the Laboratory in a desperate search for a material to replace hard rubber used in their battery boxes and covers. By this time, the molding compound had been developed to a fair state of utility and was technically known as hydrolized wood. It was decided to try it for battery cases because of its known acid resistance, and the product resulting gave clear indication of being an adequate substitute not only from this standpoint, but because it proved lighter in weight by a third, and possessed better strength. As a plastic, moreover, it requires only about half as much resin as the general purpose plastics on the market today.

An offshoot of the hydrolized wood molding compound is the hydrolized wood laminating sheet. Though still in the development stage, it appears to have the same resin economy, moldability, and resistance to acids and water that have already been exhibited by the molding compound.

A strong paper base plastic is the Laboratory's newest material. Its development to its present promising stage has been literally a matter of months. It is made of a new type of paper developed at the Laboratory and impregnated with synthetic resins, after which thin sheets are compressed together into sheets or shapes. This plastic is more than twice as strong in tension as the conventional paper plastics.

Its translucent amber color is characteristic, as is the smooth finish. Most important, however, is its strength. The tensile strength is, in fact, equal on a weight basis to that of aluminum. It can be molded to desired shapes at temperatures and pressures and on equipment now used for making plywood. It is highly resistant to moisture, and remains extremely stable at both high and low temperatures. Tests indicate that it is more resistant to scratching and denting than aluminum, and does not splinter, tear, or flower out when pierced by bullets.

A leading manufacturer has begun experimental production of structural aircraft parts, and the Army and Navy are giving the paper plastic consideration as a substitute to alleviate growing shortages of other materials. Its properties,
which can be varied in manufacture to meet special needs, also give promise for its use in water craft ranging from small boats to large cargo vessels, and in flying boats.

Chemicals

Lignin, the material that once was thought to have been put in wood largely to plague the paper mill chemists, has been demonstrated to offer a source of a number of chemicals vital to the war effort. A year or two ago the Laboratory first used hydrogen under pressure to break lignin down into a number of constituents that were in some cases brand new to the chemist. Frankly the stuff was being torn apart to find out how it was put together—an exercise in pure chemistry. The experiments have been repeated on a pilot-plant scale and the original results verified and extended.

In the light of the events of the last nine months those results no longer are of purely academic interest. Here are some of the chemicals obtained—stripped of their technical nomenclature: a chemical for doctoring motor fuel to produce high antiknock qualities; glycols (for possible use as anti-freeze agents); glycerine, the ingredient of explosives that the Government is trying to recapture from the housewife's skillet; phenols, for making an infinite variety of plastics to serve where only plastics can serve and to replace metals; industrial alcohol, used in making formaldehyde, constituent of important plastics for bonding plywood and for producing plastics of the bakelite type. This is not the complete roster of lignin constituents—some of the other materials are resins that appear to be possible lacquer bases and others appear to have possibilities as plasticizers—but the list suffices to indicate that wood, before long, may be coaxed to yield a group of products comparable to those obtained from coal tar and by similar processing.

In connection with the process of lignin hydrogenation, it is interesting to note that when wood itself, not just lignin, is hydrogenated the lignin breaks down into similar intriguing fractions and the cellulose comes off in the form of pulp. Some day something should come of this process which converts all of the wood into tractable chemical products.