Today, our society struggles with forest sustainability. It is clear that we need to sustain vigorously growing, productive forests along with forests that are preserved as wilderness areas. Balancing those needs is the challenge. During the past decade, we have become more aware of the increasing accumulation of carbon in the atmosphere and potential climate changes as a result. Some solutions to today's questions may lie in a familiar path. Throughout this century, making efficient and better use of forest products has eased economic and ecological crises. Wiser utilization of forest products led by research at the USDA Forest Service, Forest Products Laboratory, and other institutions continues to have a significant influence on these concerns and environmental integrity aspects of our forests, as well as the economic health of our nation.

EXTENDING *the* FOREST RESOURCE:

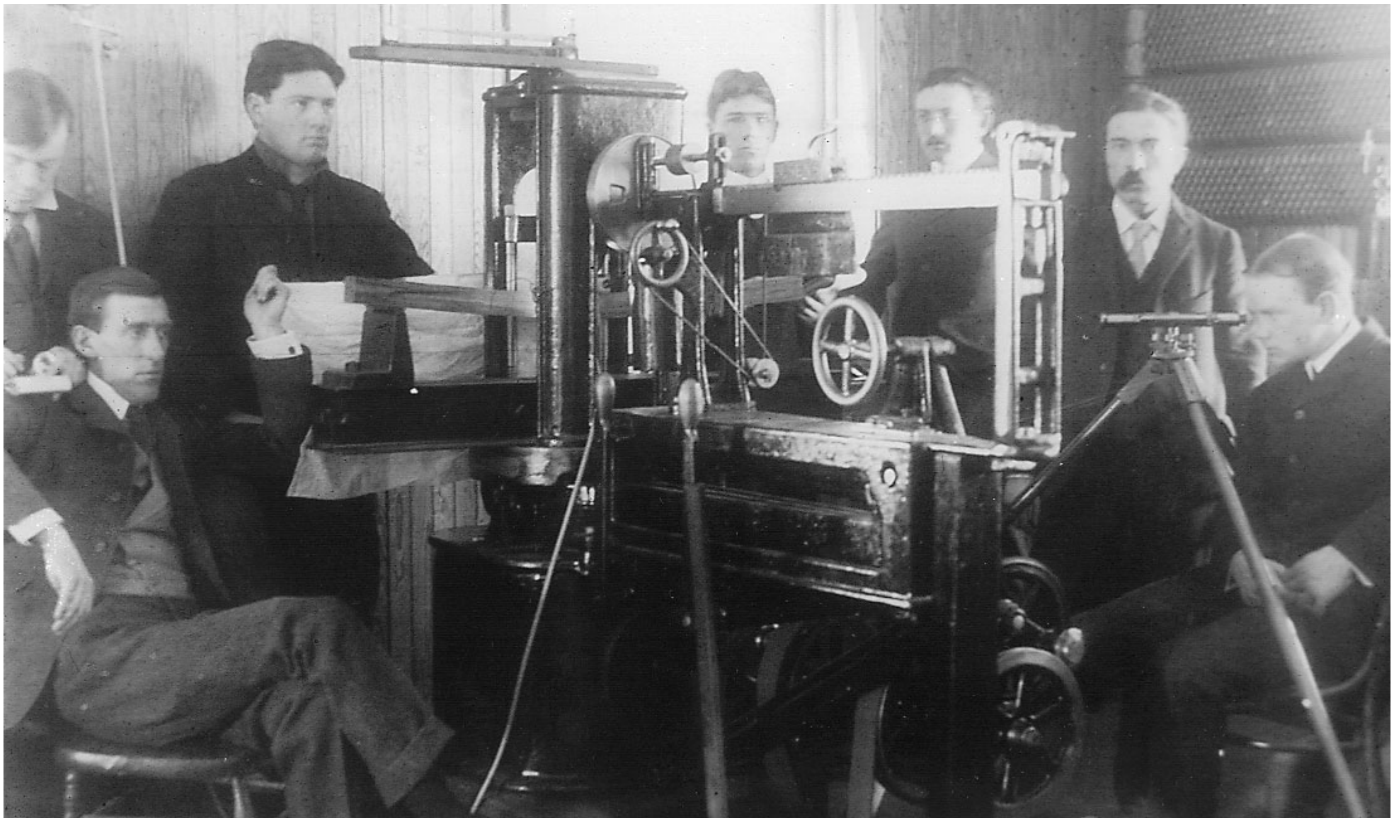
90 YEARS OF PROGRESS AT THE FOREST PRODUCTS LABORATORY

Utilization research in the Forest Service preceded the establishment of the Forest Products Laboratory (FPL) in 1910. Antecedents of early FPL work began in 1888 with Bernhard E. Fernow who was then Chief of the Division of Forestry, Department of Agriculture. Fernow devoted two-thirds of his forestry appropriation to research in wood technology and to inform consumers of the results of research. During the 1890s, Fernow felt that utilization could be increased up to 50% if, for an intended use, the right species were selected and if wood were seasoned to develop its full strength. Thus began a long series of tests on wood and improvements in processing.

In 1905, when Gifford Pinchot was Chief of the Division of Forestry, forest products research was justified as contributing to forestry by conserving wood, and the idea of a Forest Products Laboratory surfaced. By then there were timber testing laboratories in Washington, DC; New Haven, CT; Berkeley, CA; and West Lafayette, IN. In 1909, Harry D. Tiemann moved with the timber testing laboratory at Yale University in New Haven to Madison, WI, and in the same year Secretary of Agriculture James Wilson announced the University of Wisconsin in Madison as the future site of the Forest Products Laboratory. By April 1 of the following year, research was formally underway at the new building on campus, which was

BY JOHN I. ZERBE AND PHYLLIS A.D. GREEN the Forest Products Laboratory's home for the next 20 years.

The early years of research produced fundamental knowledge about wood and its properties that provided the foundation for many technological improvements. Early research concentrated on wood drying and physical properties of wood. Much of this effort was fundamental to applying wood products more efficiently, thereby conserving the resource. Tiemann became an expert on the influence of moisture on timber strength. He found that wood showed a remarkable increase in strength when dried to a certain moisture content. This he termed the "fiber saturation point" or fsp. The fsp not only defines the point at which strength properties begin to change significantly, but also the point at which shrinkage begins to vary with moisture content. It indicates an important boundary change for decay resistance as free water in wood is dispersed and bound water loss begins. This was the beginning of research breakthroughs that have continued throughout FPL's history.



FOREST PRODUCTS LAB PHOTO (105P)

Early research at the Forest Products Laboratory concentrated on wood drying and physical properties of wood. Research on the mechanical properties of wood generated more efficient ways to grade and use lumber. This piece of testing equipment was used to test structural properties.

Also emphasized early on was wood preservation research in connection with supplying more serviceable and durable ties and timbers to railroads. Before 1880, about 410 ties per mile of track were replaced annually. The service life of a railroad tie was 7 years or less. The opening of the FPL coincided with decreased per capita consumption of wood and with the early use of wood preservatives. In 1910, when the FPL opened, the average number of ties replaced per mile of track was 239 per year. Because a portion of the ties were being treated, average service life had increased to 11 years. In 1990, the number of ties needing replacement dropped to 61 per mile of track and with almost universal treatment of ties and improved treatment processes the average life has been extended to 20 to 40 years. This is typical for main line tracks that carry heavier rolling stock and experience heavier traffic than earlier in the century.

In its first decade of operation, the FPL expanded into other areas of research, notably pulp and paper and wood chemistry. One of the most comprehensive investigations explored grinding of wood for mechanical pulp in a full-size experimental groundwood mill. Chemical research highlighted the chemical composition of wood and its effects on physical and mechanical properties.

OTHER RESEARCH MILESTONES

During the 20th century, work at the FPL, together with cooperative work at other locations throughout the world, resulted in the accumulation and compilation of knowledge basic to improved wood using technologies. Some of the most important technologies were identified in a Delphi technique survey of research practitioners in academia, government, and industry during the 1990s. The following outlines these key technologies.

More Product, Less Waste from Smaller Trees. One of the newest technologies is oriented strandboard (OSB) manufacturing. OSB production is growing rapidly for use in applica-

FOREST PRODUCTS LAB PHOTO (142N)

Timbers required for railroad ties and bridges put great pressure on U.S. forest resources. Railroad ties were untreated with preservative until after 1910, which resulted in replacement of ties on 50,000 miles of track annually. Some of the Forest Products Laboratory's earliest research developed effective preservatives, which reduced the replacement rate for ties and decreased harvest pressure on forests. Shown here—A wood railroad trestle.

tions such as roof and wall sheathing and subflooring. Like plywood it is laminated in layers with alternating grain orientation. OSB layers have fibers that are aligned in one direction by machine as plywood has sheets of veneer with orientation of fibers along the grain. In both OSB and plywood layers immediately next to each other have fiber alignment that is at right angles to one another. OSB permits optimum use of each log and reduces market pressure for the less available large-diameter timber. It provides an environmentally sound approach to using small-diameter surplus material in stands that should be thinned to reduce damage from wildfires or insect attack.

Utilization of small logs also permits intensive forest management with short rotations. Using small logs has been improved through focused research on pallets, gluing and end-joining, and chipping.

Chipping and fiberizing research to make composite products that include hardboard, particleboard, medium density fiberboard, and wood/plastic composites leads to a desirable outlet for surplus material.

Akin to using surplus forest growth is utilization of low-grade hardwoods remaining from previously high-graded harvests and wood wastes from forest products manufacturing, construction and demolition waste, and yard wastes. Manufacture of pulp and paper from these wood sources has been facilitated with research on concepts such as Z-direction restraint and press drying. Z-direction restraint consists of applying a clamping action to the thickness dimension of the paper. Press drying refers to squeezing the fiber mat to drain water from pulp. Such mechanical action to remove water is more economical than drying with heat.

New Papermaking Fiber Sources. Recycling paper research was a major program at FPL in the 1960s, and it regained prominence for waste wood and agricultural fibers as well as paper in the 1990s. Recycling extends the useful life of wood fiber and averts accumulation of wood waste in landfills. Recycling results in a fiber resource that will continue to form an increasingly large share of the total fiber resource base.

One of the earliest important contributions of FPL research was the neutral sulfite semi-chemical pulping process. In the 1920s, the process revolutionized the pulp and paper industry by providing a method for the successful pulping of previously unused hardwoods.

Improved Wood Structures and Increased Use of Alternative Species. Other applications of alternative/low-value species include engineered wood products. Species such as red maple and cottonwood have been used successfully in long-lived timber bridges as a result of targeted research.

Before the ascendancy of OSB after 1985, structural plywood provided the preferred means for sheathing building elements and constructing concrete formwork. Structural plywood was dependent on Western sources of supply until research opened the way for manufacturing the product from Southern pine. This permitted broader applications of the product, energy savings in transportation, intensive utilization of cores from peeler logs, and conservation of large-diameter timber by allowing the use of juvenile wood. Manufacturing structural plywood from Southern pine reduced the pressure on Western timber and helped in using the fastest growing softwood resource in the United States.

FOREST PRODUCTS LAB PHOTO (M23214F)

This 1934 photo shows a load of fence posts being inserted into the preservation cylinder at the Forest Products Laboratory treating facilities.

Although glued-laminated timber (glulam) originated in Europe shortly after the turn of the 20th century, FPL research did much to improve its applicability. In the 1930s, T.R.C. Wilson led research in the design, suitability, and economy of laminated arches for use in construction of buildings that required large, clear spans. The advantages of laminated arch construction were reported as moderate cost, use of low-grade stock in center laminations, good fire endurance with members of large cross section, excellent architectural effect, and freedom from checking because of improved drying of smaller components.

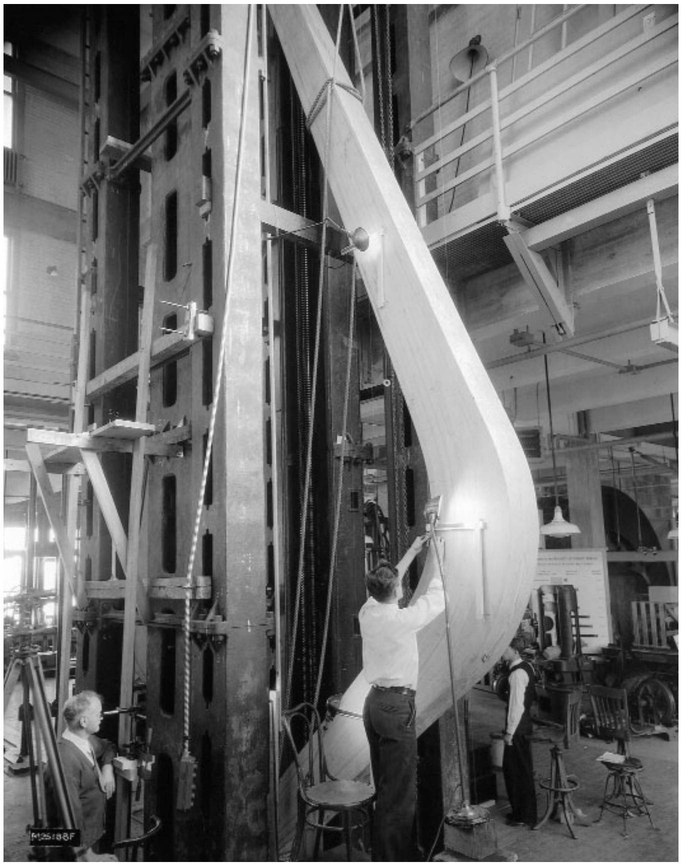
Glulam is generally fabricated to fill specific building design needs, but newer forms of glued member beams are manufactured serially as stock items. They include shapes such as rectangular cross sections, I-beams, and box beams. Generically, the members with square cross sections are known by terms such as laminated veneer lumber or preslam. Much of this technology derived from a project known as slicewood in the 1960s at the FPL.

Better Measurements and Material Application Lead to Safer, Stronger Products. Establishment of the fsp concept was not the only fundamental contribution to the nature of moisture movement in wood. Alfred J. Stamm and others at FPL, including L.F. Hawley, studied capillary properties, heat of wetting, and moisture diffusion in wood. This led to better understanding of mechanisms in the drying and pressure treatment of wood.

Although testing of mechanical properties of wood parallels the entire history of FPL research, a significant refinement in testing was nondestructive testing or nondestructive evaluation (NDE). NDE significantly improved precision in applying engineering principles to reduce the mass of material needed to carry a load safely. Current visual grading rules for wood are often too conservative, inaccurate, and, many times, wasteful. NDE can reduce costs in using wood.

The development of engineering standards to use wood in structures more efficiently goes hand-in-hand with better assessment of wood strength. The FPL has been a major cooperator with standards-writing agencies such as the American Society for Testing and Materials, American National Standards Institute, and the American Lumber Standards Committee in developing standards for wood structures.

After World War II, the use of trussed rafters in light frame construction greatly reduced the amount of lumber needed for house construction, and open planning for better traffic flows within the structures was facilitated. Labor savings also accrued as less raw material was consumed. The FPL was a leader in developing designs for better application of ring connectors, nail-gluing, and toothed plate connectors in trussed rafters. Ring-connectored wood trussed rafters were a logical development following the use of ring connectors for efficient transfer of shear stresses in joints of structures using larger timber members. The use of ring connectors started in Europe, but FPL research developed the basic design data through which they could be applied efficiently in North America. Nail gluing consists of applying plywood gusset plates spread with glue to truss joints and applying pressure through closely spaced nailing until the glue sets. Toothed plate connectors are a later



FOREST PRODUCTS LAB PHOTO (M25188F)

Research at the Forest Products Laboratory brought the use of glued-laminated timber to the United States in the 1930s. This photograph was taken for Mr. T.R.C. Wilson on January 14, 1935. Wilson was an early FPL researcher who did extensive work on wood arches and other structural components. This is glulam arch D-1 in a testing machine.

development that permits rapid assembly of trussed rafters through pressing of the toothed metal plates by machines.

Fuel From Wood. Another important area of research at FPL dating back to the first decade of operation was utilization of wood for fuel. First emphasis was on distillation with products that included charcoal and methanol. This was soon followed by research to produce ethanol from wood. FPL also worked on gasification of wood during World War II. However, the most substantial contributions of FPL research to the use of wood for fuel have been in the field of ethanol, and contributions to the literature are continuing.

Improved Wood Processing Techniques. Along with improvements in wood itself, improvements in ancillary materials for use with wood have shared research emphasis. Essential co-products for using the wood resource effectively are glues or adhesives and resins. Gluing research at FPL has contributed to better and more economical glues as well as better control of emissions to the environment from components such as formaldehyde and volatile organic compounds (VOCs).

Along with better products and improvements in product application, processing research at FPL has also helped significantly in conserving the resource. For many years, improvements have been made in reducing the kerf in sawing solid lumber. Improvements resulted from bandsaws used instead of circular saws, better tooth configurations in saws, and better metals and alloys used in saw manufacture. Significant advances were made with the initiation of a sawmill improvement program by FPL and the State & Private Forestry arm of the Forest Service in 1970. Besides improvements in quality control in bucking and sawing, the program was characterized by implementation of computer assistance in log breakdown.

Drying of wood is basic to its most effective use in many applications, and it accounts for a major share of wood processing costs. Drying of wood has been an important part of FPL research—from using wood in aircraft in World War I through new methods of drying for today. The objective is to determine the best way to season lumber as quickly and inexpensively as possible with minimal degrade. Publication of the *Dry Kiln Operator's Manual* with efficient dry kiln schedules for various wood species was a landmark effort in bringing research discoveries into practical application.

THE IMPACT OF THE FOREST PRODUCTS LABORATORY

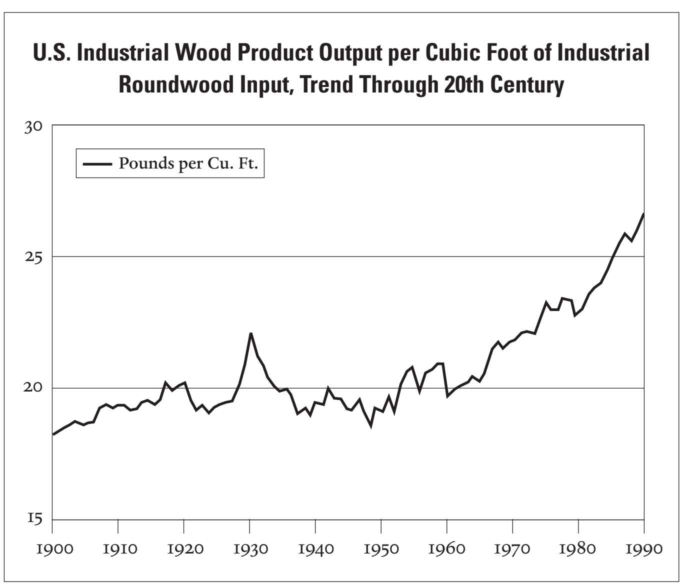
Benefits in Improving Timber Supply, Conserving the Resource, and Reducing Adverse Environmental Impacts. Being able to use material that was formerly wasted, utilization of small-diameter logs, more efficient processing, better standards for application of materials with more precise assessment of strength properties, greater product durability, and recycling of wood and wood fibers have all contributed to greater efficiency in using the wood resource. There has been a steady growth in recovery of product from roundwood input from the beginning of Forest Products Laboratory influence, and a steeper rise since 1950 (see figure below).

Other important benefits of intensive utilization include less drain on the timber inventory, sequestering carbon from the atmosphere in standing timber and wood products in use, conservation of energy through use of wood for fuel and use of wood as a material, stand improvement through use of small-diameter timber, and reduction of calamitous high intensity forest fires together with watershed protection through control of understory brush with managed utilization.

The trend of improvement in industrial product output from the raw material harvest continues to climb at a rapid pace. Incorporation of fundamental knowledge into product development maintains gains through new technology at the FPL, often with cooperation from other innovators in government, academia, and industry. Recycling research is helping the Post Office find pressure-sensitive adhesives for stamps that will not cause problems when these stamps are themselves recycled. Polyoxymetalate bleaching research will help the paper industry through elimination of some environmental problems with chlorine bleaching. Composites from lower value material will continue to improve and have higher benefits, sometimes through cooperation with the plastics industry. Other environmental research in cooperation with other government agencies will enable use of wood as a material to save energy, sequester carbon, and provide sources of energy from wood to save fossil fuels and

FOREST PRODUCTS LAB PHOTO (M150668–6)

Improved sawmilling and drying techniques developed at FPL allowed significant improvements in the quantity of usable lumber recovered from a log. Here, in 1981, sawing a log in flitches that were subsequently dried then cut into lumber (SDR or saw, dry and rip) reduced the amount of warp that resulted from the drying process.



reduce emissions of carbon dioxide and other greenhouse gases to the atmosphere. Partnerships for advancing technology in housing (PATH) will expand the development and use of new technologies that will make American homes stronger, safer, and more durable, more energy efficient and environmentally friendly, easier to maintain, and less costly to operate. In these ways the FPL will pursue its mission to improve the use of wood through science and technology , thereby contributing to the conservation and management of the forest resource. n

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