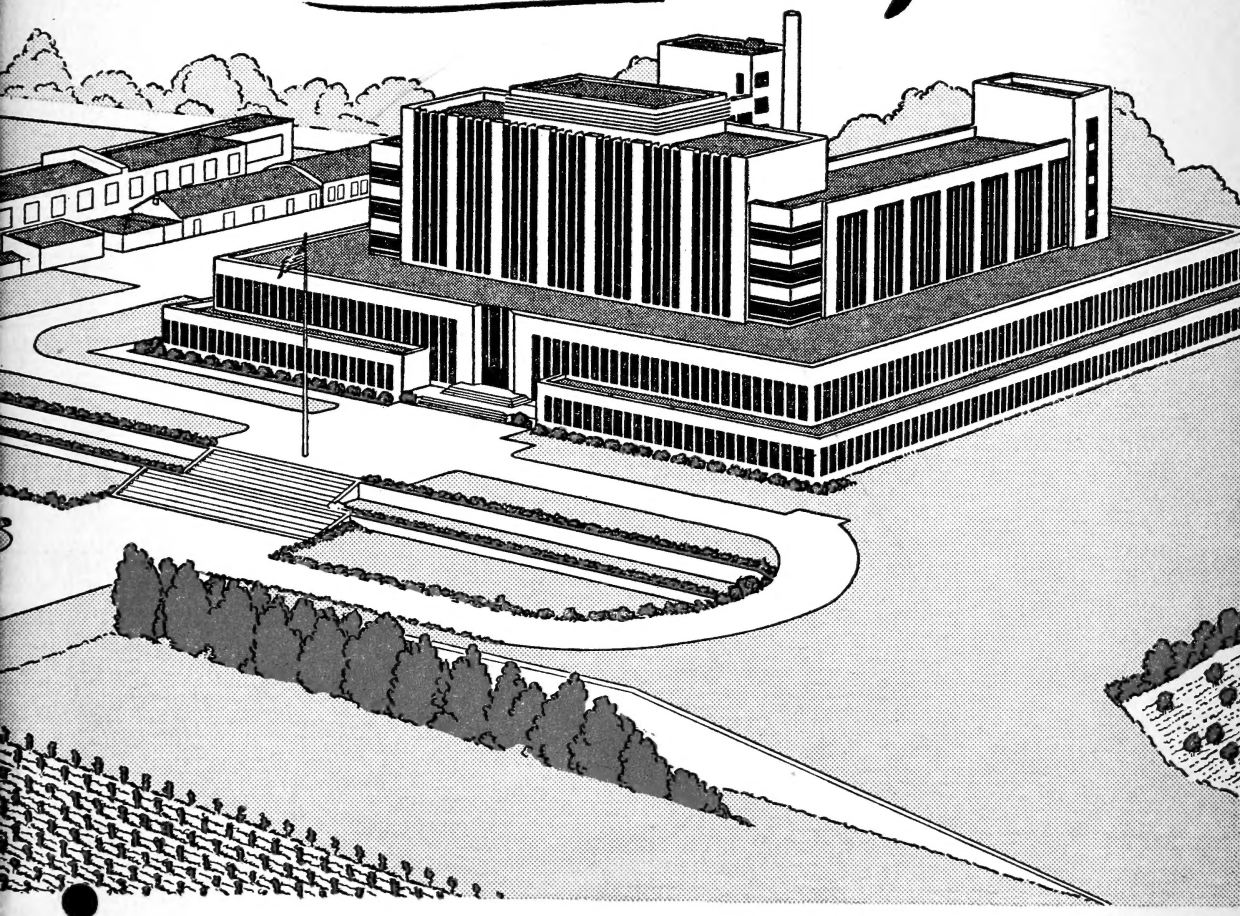
The FOREST PRODUCTS Laboratory



A BRIEF ACCOUNT OF ITS WORK AND AIMS

FOREST SERVICE · UNITED STATES DEPARTMENT OF AGRICULTURE
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Present building of the Forest Products Laboratory, completed in 1932

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A NATIONAL INSTITUTION FOR WOOD UTILIZATION RESEARCH

THE FOREST PRODUCTS LABORATORY is a unit of the research organization of the Forest Service, United States Department of Agriculture. It is the only institution in the United States concerned wholly with the investigation of wood and wood products and their adaptation to diversified fields of use. It was the first and for several years the only institution in the world conducting general research on wood and its utilization; other Governments have since followed the lead of the United States in developing laboratories along similar lines.

Importance of wood utilization

The forest, distinct from all its other services and benefits, supplies a basic raw material—wood—which from the earliest times has furnished mankind with necessities of existence and with comforts and conveniences beyond number. Forests will return maximum values to the people of the United States, only if they are fully and profitably utilized and at the same time are maintained in vigorous condition for the continuous production of timber crops.

Nearly one-third of the continental United States is either in forest or suited by nature mainly or solely to the growing of forests. In a broad sense, the growing of forests appears to be the only economic use to which this enormous area, amounting to over 600 million acres, can be put. The fullest development of this use is of profound importance to the country's prosperity. Aside from providing timber, forested land affords benefits of far-reaching importance, through its favorable influence on stream flow and in preventing exces-

The perpetuation of forest resources and their proper utilization are essential to the country's welfare.

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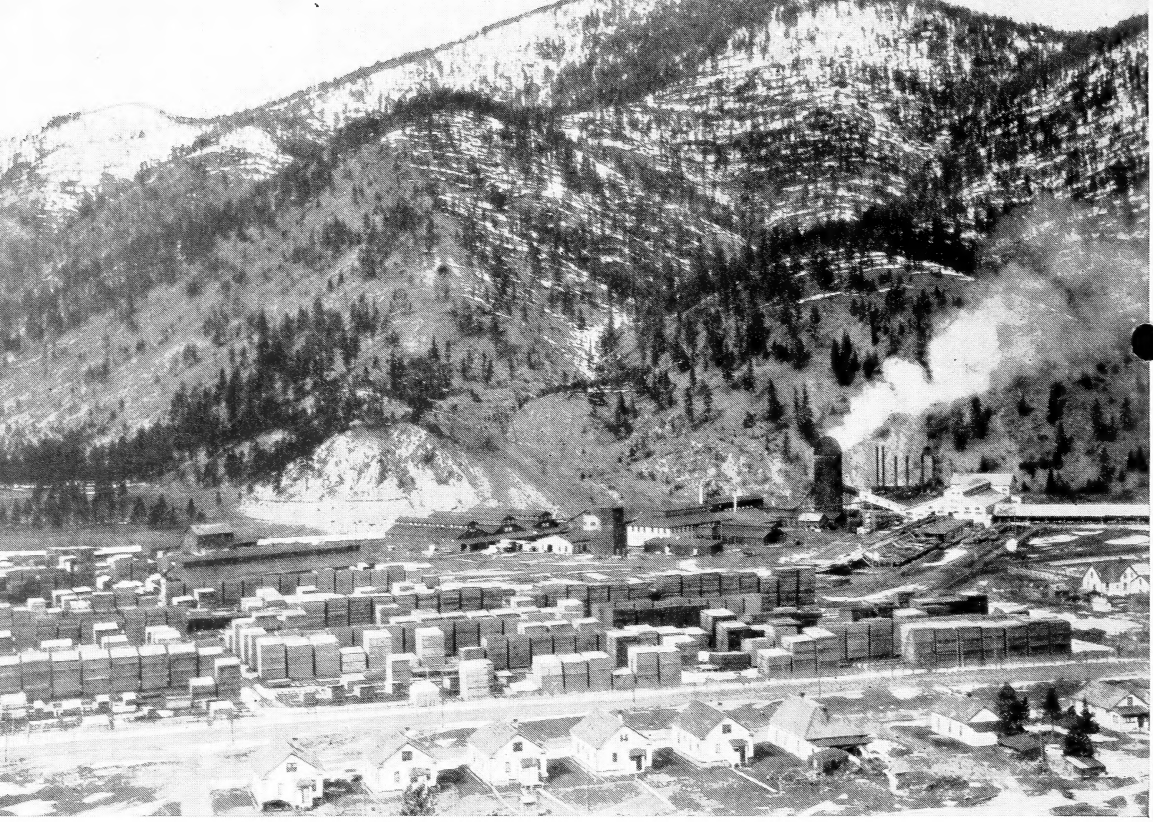


M–14192–F

Employment and wages for thousands of workers are bound up with continued and increasing usefulness of wood in modern life.

sive erosion, in providing shelter and protection for homes, crops, and livestock against wind and drought, in providing forage, in supplying recreational needs, and in furnishing the environmental conditions upon which wildlife of the country depends. In addition it is desirable that a reasonable area of forested land be reserved in its virgin condition for scientific and recreational use. All these benefits, though not easily appraised, in the aggregate represent great values to the public.

While the growing of timber on these lands for the many products demanded by modern civilization represents the more tangible economic value or use, the mere production of an increased timber supply does not satisfy the demands of economic forestry. The utility value of wood must also be maintained and increased. From this standpoint the actual and potential value of these lands as a source of wealth and employment must be gaged in a large measure by the utility value of this principal product. The better adaptation of wood to modern consumption requirements is a matter of direct concern to consumers, whose proper housing and standards of living are bound up with the satisfactory use of wood products; to workmen, who need the hundreds of millions of dollars in wages furnished by employment in the woods, the sawmills, the pulp mills, and broadly diversified fields of wood construction and manufacture; to farmers and other timberland owners, large and small, seeking market outlets for materials from their

M-31281-F

Improved timber harvesting and utilization methods mean increased income to farmers, whose woodland holdings throughout the country amount to 185 million acres.

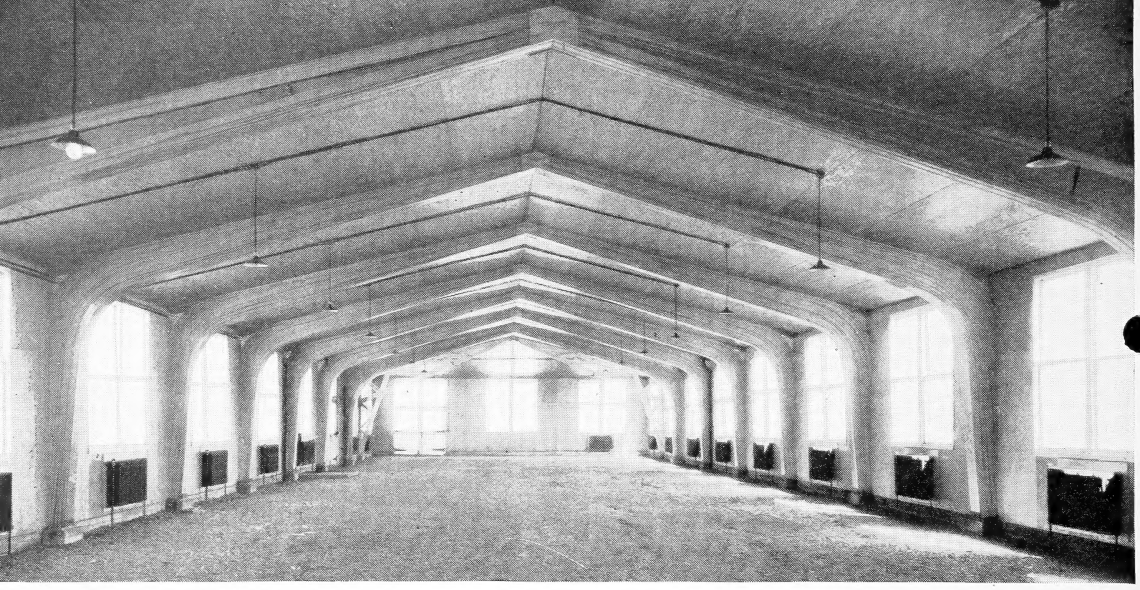
vast aggregate acreage of woodlands; to local communities, counties, States, and the Nation, all of which have a vital interest in stable revenues from forests, forest lands, and successful forest industries. In our national forests alone, the investment in land and timber and the responsibility for a wise utilization of the products require a broad program of research looking to the broadening and stabilization of markets for forest products.

Purpose of Laboratory research

Answering to these major economic needs, the research of the Forest Products Laboratory is directed toward the better and more efficient and diversified utilization of forest materials. Scientific research is the means that must be used to gain a more thorough knowledge of wood in its chemistry, growth, and structure, and to determine the techni-

America's huge volumes of logging and sawmill wastes are potential sources of useful products.

M-97-F, M-31511-F



M–26224–F

Laboratory utility building of plywood with glued arches, the first structure of this type in the United States.

cal properties of the hundreds of American wood species and their variations of quality within the stand and in the tree itself. Research must aid in solving many difficult problems—how to utilize more efficiently the small-sized and second-growth trees which will form the bulk of our future forests; how to secure useful service from the many wood species that are now used little if at all; how to turn to economic account the large wastes that occur in the conversion of trees into commodities; how to secure greater service and economy from wood through selection of material, control and modification of its properties, improvement of treating processes, and the development of new and better methods of wood fabrication and conversion.

Cooperation with University

The Forest Products Laboratory was established by the Forest Service in Madison, Wis., in 1910, following acceptance of the offer of the University of Wisconsin to provide a building with necessary light, heat, and power services. This arrangement made possible the coordination and systematic development of Forest Service research activities that had previously been carried on in a number of small laboratories in various parts of the country. A cooperative relationship between the Laboratory and the University of Wisconsin was thus begun which has continued to the present, assuring collaboration in scientific matters and interchange of research facilities for staff and graduate students. The original building was occupied by the Laboratory for 20 years, and additional temporary quarters were provided by the university as increasing work required.

Present building

In 1930 the long-felt need of adequate permanent quarters for the Laboratory was recognized by Congress and construction funds were granted. The

present main building was completed in 1932, representing with later additions to its equipment an investment of well over $1,500,000. The fine site of 10 acres on which it stands, overlooking the city and Lake Mendota, was provided by the State of Wisconsin through the board of regents of the university.

In general plan the main building is U-shaped, about 275 feet in length and over-all breadth, with wings flanking a central court. In its five stories and ground floor it contains a total area of 175,000 square feet, or approximately 4 acres. The Laboratory is provided with plant facilities and experimental equipment suited to the handling, processing, testing, and investigation of wood in many forms, from the raw material of the log to lumber, pulp, paper, turpentine, plastics, and other conversion products.

Accessory structures

Several minor structures on the Laboratory's grounds have been provided for operating or demonstrational purposes. Among these are a receiving and utility building of plywood units framed on glued laminated wood arches, a concrete fire-testing house, a veneer-cutting plant, and open and closed sheds for lumber storage.

Personnel and research divisions

The personnel of the institution is divided about equally into technical staff, comprising research specialists and assistants, and nontechnical staff, including administrative, operating, and clerical workers. The entire organization centers around and is contributory to the work of eight research divisions,

In many investigations the Laboratory's sawmill plays a necessary part.

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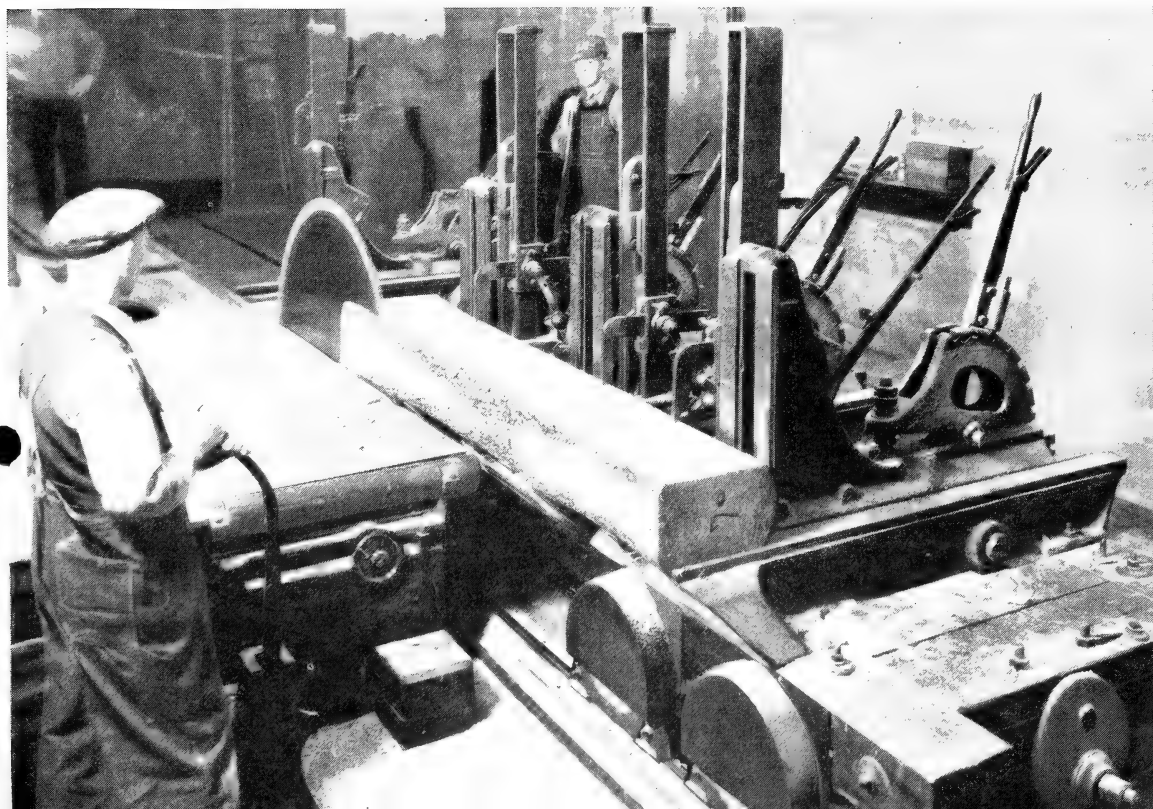

whose fields of investigation are described in the following pages—timber harvesting and conversion; silvicultural relations; chemistry, composition, and derived products of wood; timber mechanics and structural research; wood seasoning and moisture control; wood-treating processes for protection and service; wood pathology; and pulp and paper.

Timber Harvesting and Conversion

Through hasty and wasteful exploitation, millions of acres of forest lands have been left denuded, idle, and abandoned which otherwise might today be supporting their quota of prosperous communities. To obtain better values from existing resources and to safeguard future timber crops require basic changes in timber cutting and conversion practice, presenting many problems which research must help to solve.

Selective logging

Laboratory field crews have demonstrated on many lumbering operations, north and south, that the cutting of

Turning of wooden turpentine cups points the way to profitable utilization of much worked-out timber.

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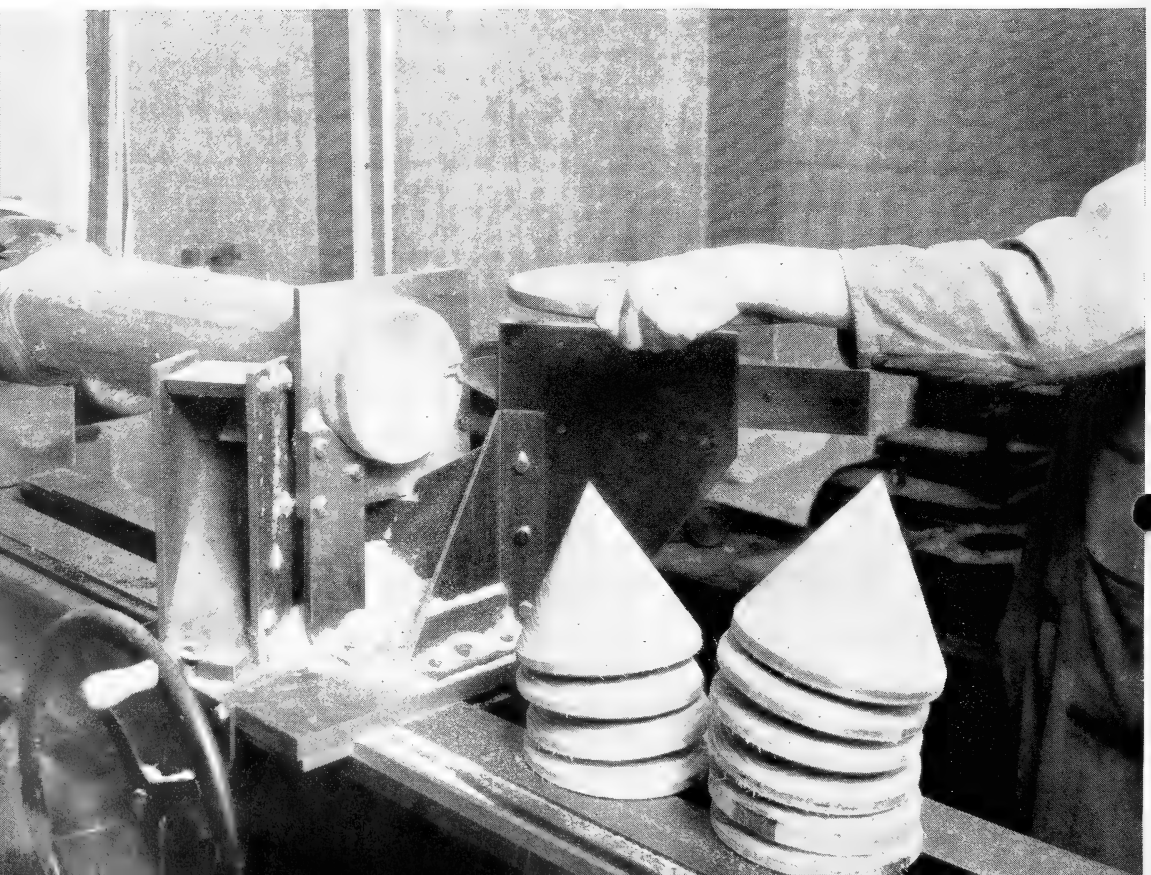
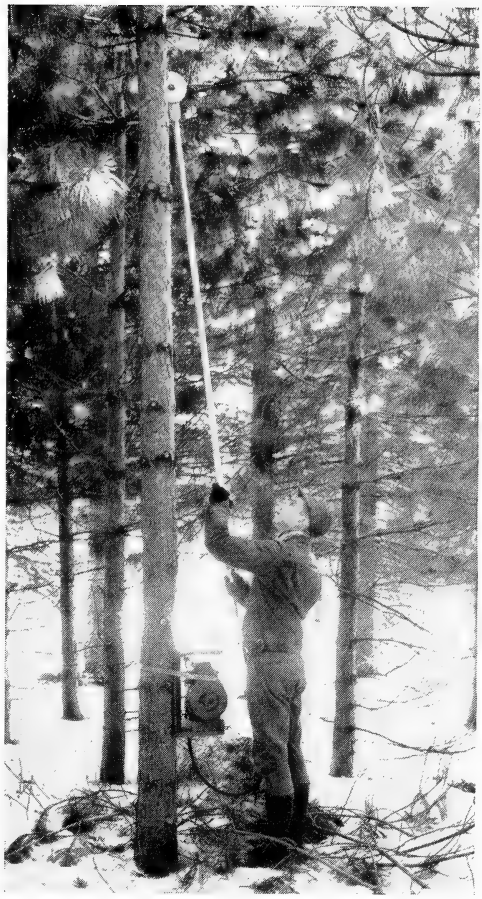


young and undersized trees ranging from 10 to 16 inches in diameter, according to the stand, is destructive not only of future forest values but actually of present profits, since the small trees do not yield enough high-quality lumber to repay costs of handling and manufacture. By selective cutting, taking only the larger trees and leaving the smaller trees to grow, better lumber is produced and a basis is maintained for profitable timber crops in the future. The findings are beginning to be applied in the practice of both large and small operators, with increasing prospects of restocking and reseeding of stands, repeated cuttings, and the economic benefits arising from sustained forest productivity. The studies need to be extended to a wider range of timber types and to the production of commodities other than standard lumber.

Reduction of waste

Research projects to reduce the percentage of waste in harvesting the forest crop approach the problem from several directions—the use of less destructive machinery, the conversion of woods and mill waste into useful products, and profitable alteration of the form of the product. The production of dimension stock cut to size for factory use makes possible the salvaging of a large volume of clear material from slabs, edgings, and defective lumber. Saving in freight on waste, and reduction of cutting required in the factory, have proved to be important factors in reduction of costs to the user. The further development of methods for producing high-quality dimension stock, including its sawing, seasoning, and bundling, is under investigation.



M–30569–F

Development of lightweight power equipment brings nearer the economic possibility of pruning branches and securing growth of wood free of knots earlier in the life of the tree.

Farm woodlands and small holdings

To make possible the production of better lumber by the farm community, a new type of portable sawmill with band saw is under development, and an economical and effective small dry kiln has been designed and tested. Experiments are being made in the use of small material for the production of

glued laminated building panels and other commodities for local and general markets. Selective logging investigations and the development of portable power pruning equipment offer to the small owner possibilities of early and sustained yield of merchantable lumber from his holdings. The turning of gum-collecting cups from southern pine trees that have been "worked out" in turpentining operations indicates the possibility of replacing metal cups, at a considerable saving to woods owners. Utilization of the worked-out timber for rosin barrels and for fruit and vegetable crates is also being studied.

M–26966–F

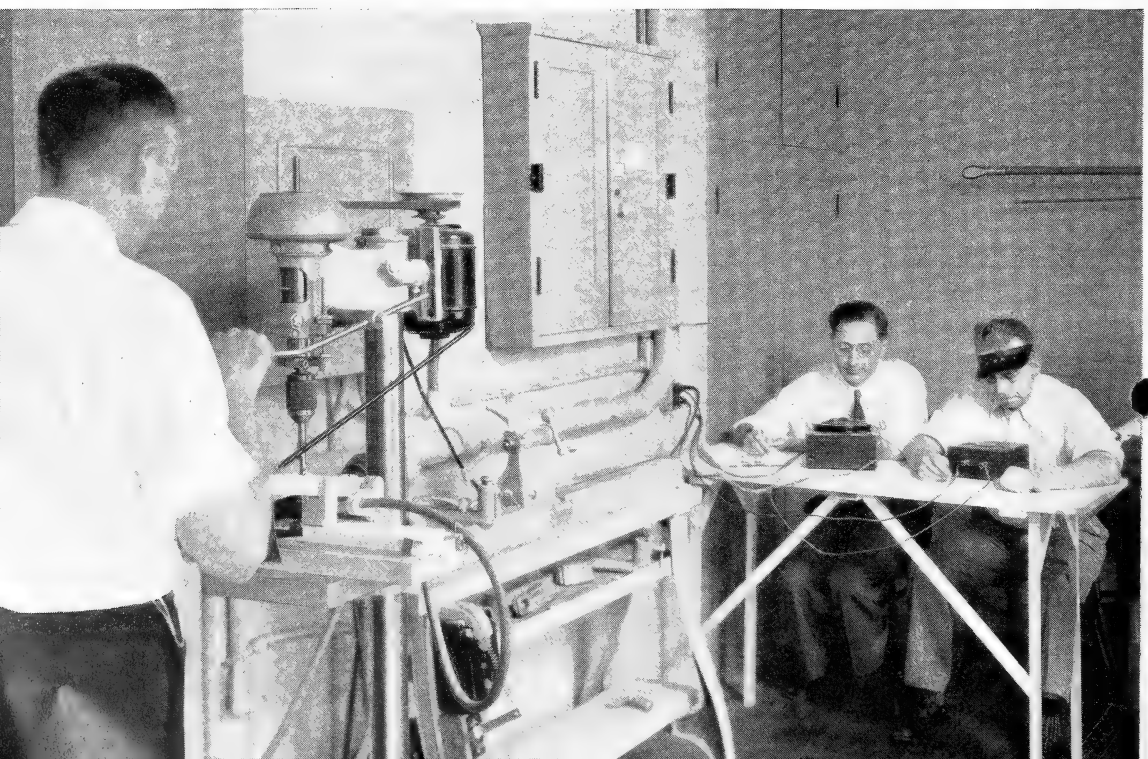
Woodworking tests determine machining qualities of woods now little used.

Machining studies

Many American hardwoods, particularly those from the lowlands and river bottoms, are rejected by users on account of difficulties in seasoning and woodworking. To aid in converting such material from a liability to an asset, a broad program of research is maintained. In addition to chemical seasoning, studies of typical machining operations are carried on together with investigations of physical and mechanical properties of the woods and their adaptability to varied commercial uses such as furniture, automobile bodies, and food containers.

Measuring power required in boring various woods affords one index of woodworking properties.

M–26772–F



Silvicultural relations

In any effort to increase the utilization value of wood, testing and selection assume essential and immediate importance. Fundamental, however, to the general program of forestry and wood use is the problem of control of wood quality at its source. Its solution must be found in the conditions of tree growth, and at this point the research of the Laboratory makes close contact with silvicultural experiments and practices in the field.

Growth and quality of wood

The wide variations in strength, hardness, shrinkage, and other properties of wood produced within a tree species as a result of growth under different conditions have prompted the Laboratory to investigate the possibilities of improving wood quality at the source, that is, while the tree is growing. Wood grown under different natural conditions or under conditions artificially modified with respect to soil, moisture, density of stand, and associated species, is tested and compared in order to find the best conditions to produce the best type of wood for given uses. Although many years are required to grow trees of merchantable size, a change in growth conditions, such as may be effected by removal of neighboring trees, drainage, or pruning, is reflected in the character of the annual growth rings subsequently formed, thus affording a ready means of comparing wood before and after the change was made, the other variables remaining unchanged. The resulting information can be beneficially applied to second-growth timber which is still in the formative stage. For instance, softwoods make their best development as to strength and other desirable properties when spaced moderately close, whereas the quality of hardwoods is sustained or improved by increased opening up of the stand.

Identification

Families, genera, and many individual species of wood may be identified as readily by cell and pore arrangement as by the botanical characteristics of the tree. The specialized service provided by the Laboratory in wood identification is widely used. About 3,000 samples per year are identified. Frequently important questions of use and even

M–29644–F

Width of annual rings and quality of the wood are correlated with factors of climate and soil affecting growth of the tree.

lawsuits hinge on the result of an examination of a few chips or shavings, sawdust, or wood flour. In criminal cases the careful identification of pieces of wood may furnish valuable evidence; an outstanding example was the Laboratory's discovery of the source of the wood from which the ladder used in the Lindbergh kidnaping was made.

M–31575–F

Thousands of wood specimens submitted to the Laboratory are identified by their microscopic structure.

Naval stores

A major forest industry of the United States is the production of gum resin and turpentine, the naval stores of commerce, from the longleaf and slash pines of the South. The United States' world leadership in output has unfortunately been gained and held at a high cost in destructive working of stands and impairment of prospects for future yields. In research looking to the improvement of this situation the Laboratory works in collaboration with the Southern Forest Experiment Station. Field tests and microscopic examination of wound response have shown the practicability of maintaining the flow of oleoresin by light, narrow chipping at as high a yield as by heavy chipping. The establishment of this fact is having wide influence in securing a longer working life for turpentine stands, with greater returns per tree in both naval stores and wood products.

Biochemical research reveals the course of formation of the resin-yielding compounds in the tree; microscopic research seeks to identify and trace the occurrence of these mother substances in the cells of the wood and of the phloem, or inner bark. Progress in both lines of investigation encourages the hope that high-yielding strains may be further developed in oleoresin-producing tree species.

Chemistry, Composition, and Derived Products of Wood

The fundamental facts of wood as a substance must ultimately determine its possibilities as well as its limitations in use. The chemical composition of wood, the arrangement of the constituent parts in the wood cells, and the variation of all such characteristics according to species and growth conditions are investigated for the aid and insight they afford in all fields of wood research—in silvicultural control of the material and its properties, in its selection, its seasoning and handling, its impregnation with preservatives, its use in construction, and its conversion into pulp and derivative products of all types.

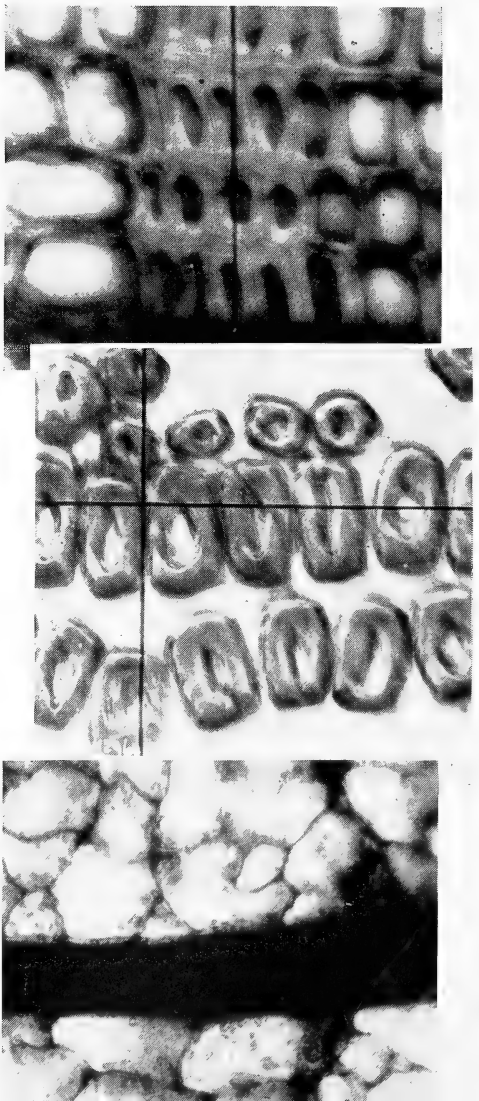
Microstructure

All wood is composed of cells, and visible under higher magnifications are smaller structural units. These subdivisions are being carefully explored. The cell walls are made up of concentric layers, which in turn are composed of fibrils arranged spirally. The fibrils are the smallest units that become evident through any simple mechanical disintegration, but by careful chemical treatment they themselves may be subdivided into spindle-shaped fusiform bodies and the latter into minute spherical units. The spherical unit—the ultimate visible component of the cell wall—is about one hundred-thousandth of an inch in diameter, and beyond it the microscope cannot penetrate. It is possible, however, by indirect methods using the ultracentrifuge and the X-ray, to determine the approximate size and arrangement of submicroscopic units.

To the chemist, wood is a storehouse of raw materials only partially devel-

Top, Cross section of wood, magnified; center, cellulose fibers of wood, with lignin removed; bottom, lignin structure of wood, cellulose removed.

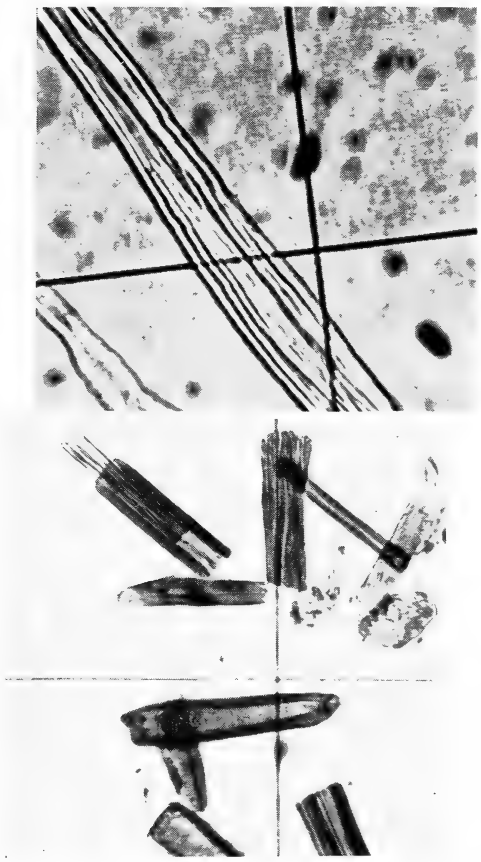
M–2968, M–2960, M–9401–F



oped. It may be analyzed, broadly, as cellulose and lignin, with extractives or infiltrated substances such as resins, gums, tannins, waxes, or the like present to a greater or less extent.

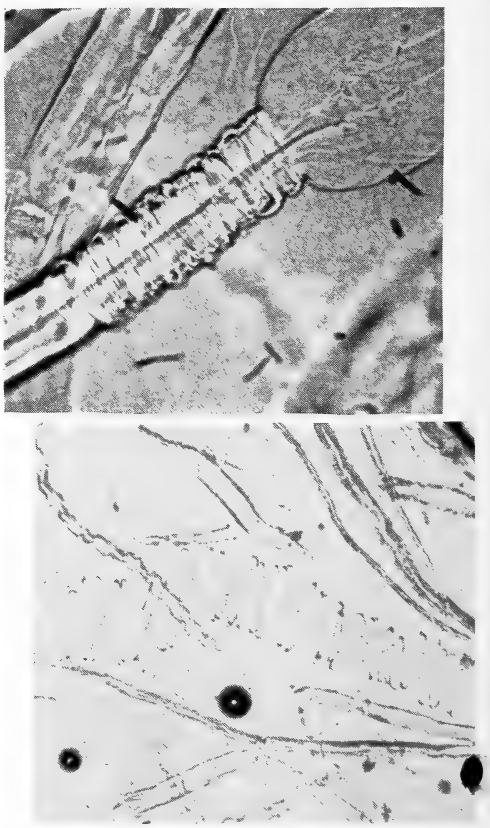
Cellulose

Cellulose, the most abundant constituent of wood, is also the best known and the most extensively developed in commercial processes. It includes the cottonlike substance of the fiber, which is the basis of refined paper pulps and the modern family of products including rayon, lacquers, cellophane, photographic films, gunpowder, and a long list of nitrate and acetate plastics. This cellulose, although closely related to the simple sugar, glucose, is because of its complex molecular structure extremely stable. It is known to exist principally in the fibrils of the cell wall, but there is associated with it a less stable group of materials amounting to almost 40 percent of the total carbohydrate content of the wood and containing pentose sugars and uronic



M–8534–F, M–7931–F

Wood fiber structure: Top, Concentric layers of the cell wall; bottom, "sleeve" structure revealed by endwise slippage.



M–10296–F (B6), M–10330–F (F1)

Wood fiber structure: Top, Filamentlike winding on outer wall of fiber; bottom, the filament removed, showing convolutions.

acids. The Laboratory's studies aim at characterizing the less stable bodies accurately and devising treatments that will include them in useful products along with the stable cellulose. Special possibilities in cellulose conversion are offered by hydrolysis and fermentation with yeasts or bacteria, which the Laboratory has already successfully used in the production of industrial alcohol, acetic acid, and lactic acid from wood.

Lignin

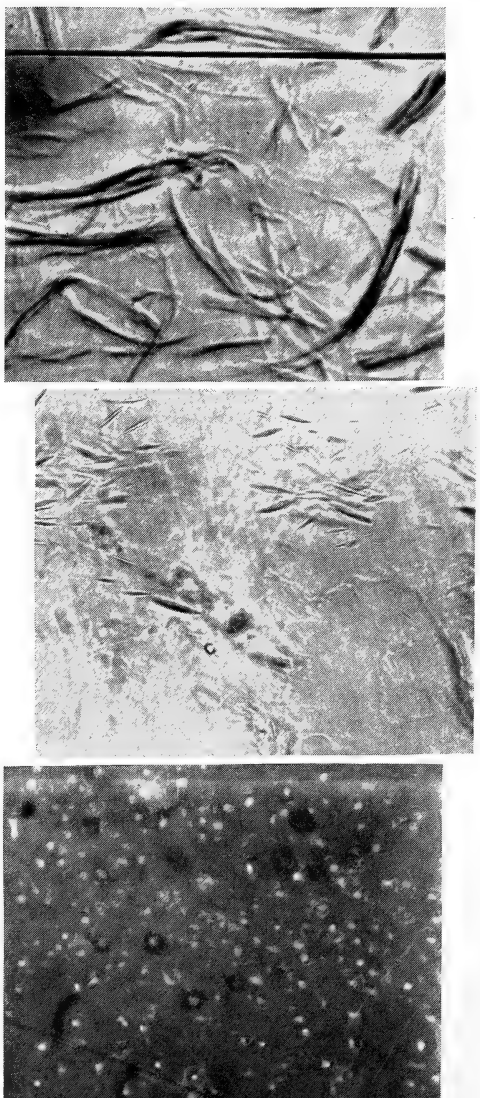
Next to cellulose, the greatest bulk constituent of wood is lignin, the material that surrounds the cellulose fibers and forms a continuous matrix or honeycomb throughout the wood. Lignin has always been considered a waste in the pulping process and as such is discarded. Its use is limited by the fact that its chemical character and relationships have never been clearly determined. The attack on this chemical problem is gradually overcoming obstacles. Special treatments are producing lignin apparently free from degradation products of the cellulose and showing a recognizable chemical structure; characteristics of hardwood and softwood lignins are being more sharply differentiated; and increasing knowledge of the material indicates possibilities of its conversion into useful products.

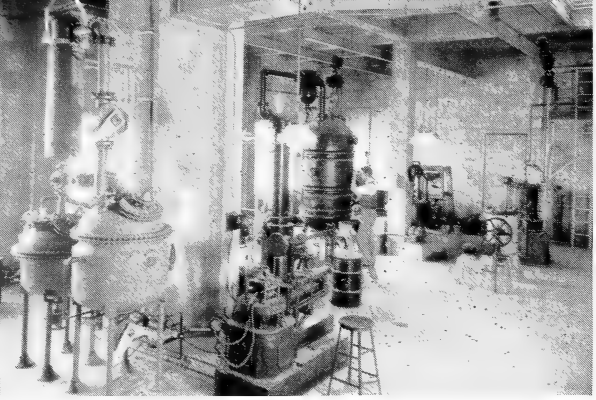
Conversion products

Vast increases of forest market values await the greater development of useful products from wood waste. The best opportunities in this direction seem to be offered by the hydrolysis, condensation, and fermentation processes and the development of special pulp products and wood plastics. The fact that the cell-wall substances of wood are readily convertible into sugars has led to the experimental processing of sawdust as an ingredient of cattle feed. As a further example of the utilization of waste wood, a molding powder of true plastic properties is being developed from sawdust, in which the condensing and

Top, Wood fibers resolved into their component fibrils; center, the fibril subdivided into fusiform bodies; bottom, spherical units of cellulose, the smallest components of the fiber substance visible under the microscope.

M–8617–F, M–9053–F, M–15639–F



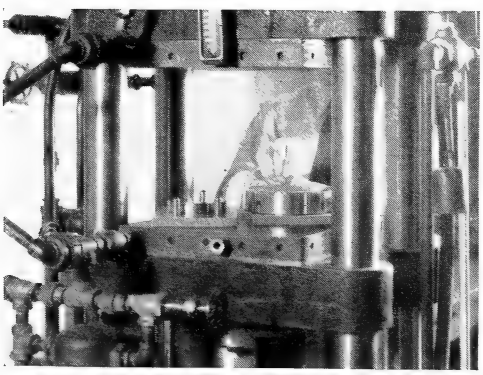


M–24640–F

Equipment of industrial type for chemical wood conversion.

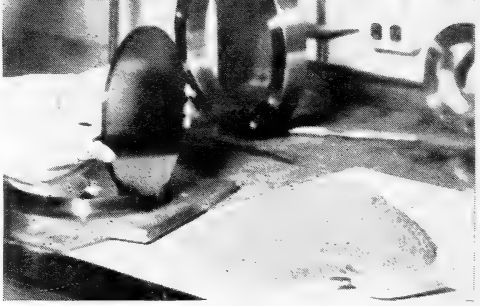
M–31512–F

Lignin comprises approximately one-fourth the weight of wood. A waste material at present, its utilization depends on a better understanding of its composition and chemical relationships.



M–25822–F

By simple chemical means sawdust is changed into a molding compound that can be formed into sheets or shaped articles under heat and pressure.



M–31510–F

A specimen of wood plastic coming from the mold.

adhesive properties of lignin appear to be the formative agency. By pressing the processed sawdust under heat, a sheet material is formed that offers wide possibilities of use as floor tile, wallboard, switchboard panels, and a variety of other products, at a cost per square foot estimated to be equivalent to the general price level of lumber.

Antishrink treatments

Marked improvements in wood utilization will be possible if practical treatments can be perfected, independent of or supplementary to seasoning, that will eliminate its tendency to shrink or swell with changes in moisture conditions. The results of such processing can easily be foreseen in broader and more secure markets for wood, especially in its finer and more exacting uses, as in brush backs, cabinet work, sporting equipment, shoe lasts, and the like. Recent chemical investigations indicate that the desired nonshrinking quality can be secured by the formation and deposit of synthetic resin compounds within the wood substance, so that its subcapillary structure is permanently bonded with a water-resistant material. Further research is proceeding with the aim of determining minimal amounts of materials required for this purpose, and otherwise cheapening the treating process.

Timber mechanics and structural research

Sixty percent or more of the Nation's sawed timber production is used in building and housing. The foundation of proper and efficient use of wood for construction purposes is accurate knowledge of its mechanical properties—its strength in tension, bending, compression, and shear, its toughness, rigidity, and other qualities that determine its resistance to all kinds of stresses. In these respects, as in others, wood was for long the "unknown material." Variable factors of species and growth were not accurately accounted for in strength determinations, and the rough estimates and traditional practices of the past have led to wasteful and unsatisfactory use of untold millions of feet of timber.

Strength tests

To supply dependable data, it was first necessary for the Laboratory to devise proper mechanical and statistical methods for evaluating strength properties and then to proceed with a long and laborious testing program. The

Data from mechanical tests of wood set standards for selection, grading, and engineering design.

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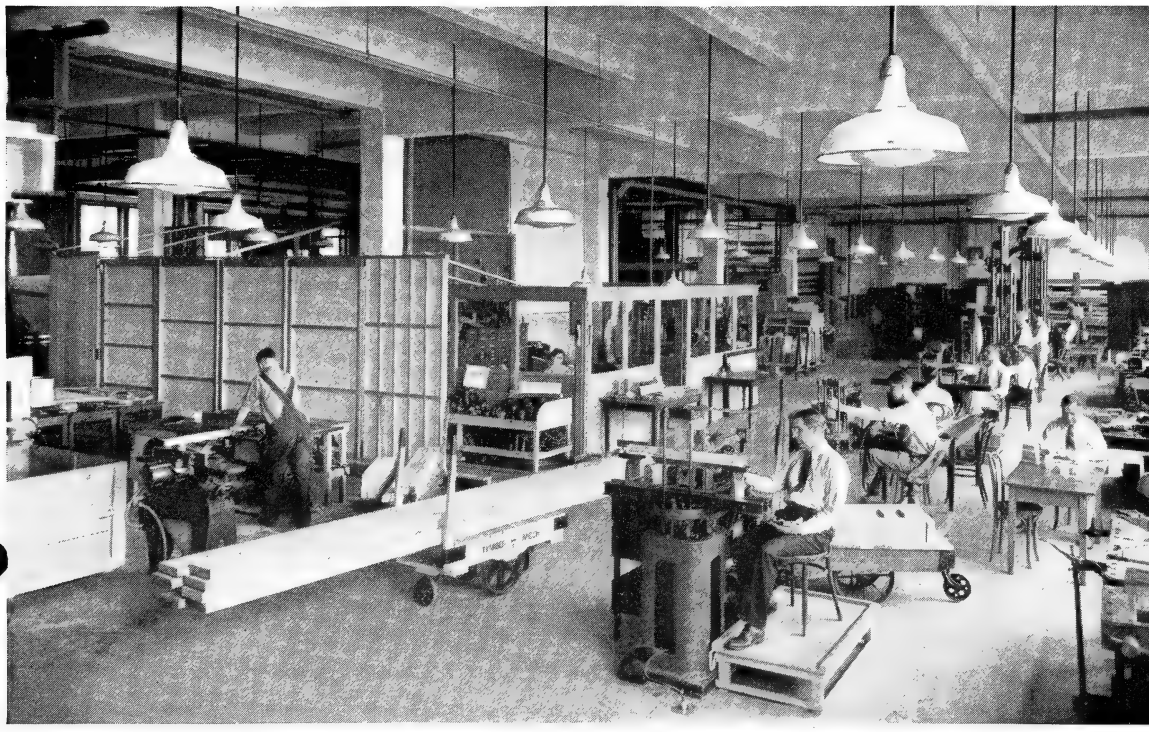
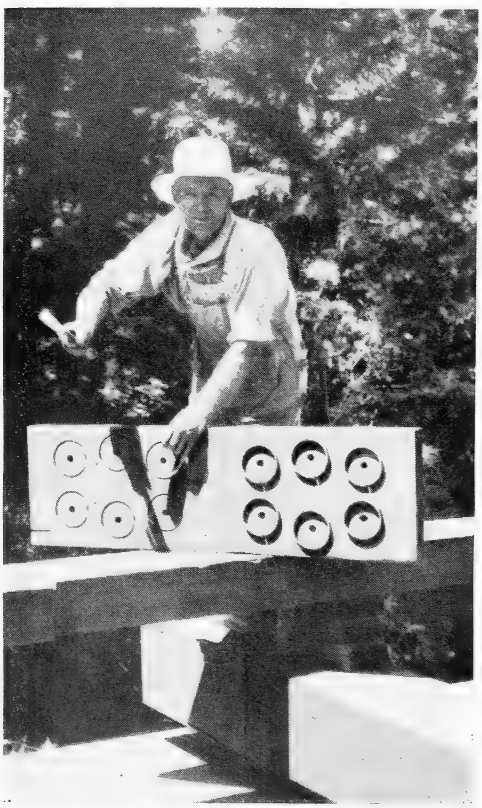


general result of this work, extending over many years, has been to place wood on a technical footing with other modern engineering materials. Hundreds of thousands of tests have defined and differentiated the various kinds of strength of more than 160 wood species, including all the more important woods produced for the Nation's markets. Both the methods and the results of this research have been adopted as standard by engineering authorities in the United States and abroad. The data provide a fundamental basis for design, for selection of species for particular uses, and for finding servicable substitutes for the scarcer and higher-priced woods. Many minor species remain to be investigated, and problems of the strength of second-growth material are assuming larger importance with the changing character of the American timber stand.



M–28743–F

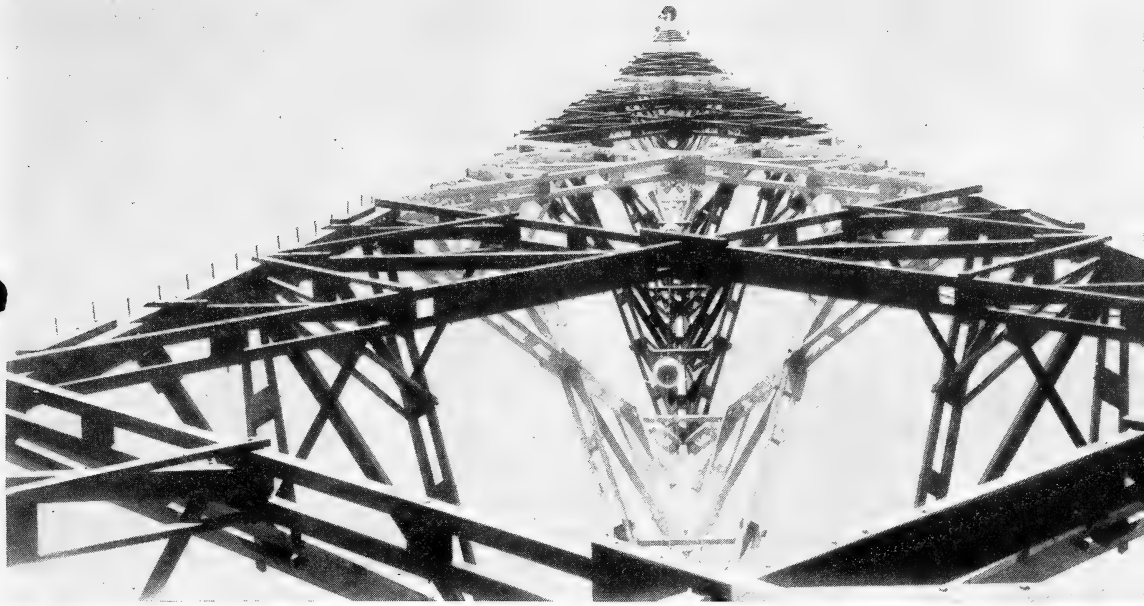
Modern metal connectors act as dowels or keys in the construction of strong timber joints.

Structural investigations

On the foundation of reliable strength values for the principal species, Laboratory research is able to deal effectively with problems of wood structures and structural parts, in which the form, size, and condition of members must be taken into account. Tests of full-sized timbers have demonstrated in quantitative fashion the influence of common defects, such as knots and checks, on strength, with the result that structural designers have been supplied with more efficient working-stress values, building codes are being modernized, and timbers are bought and sold on the basis of strength grades, by which they can be rationally and economically selected for their intended loadings. The value of the Laboratory's contributions to structural practice is further illustrated by the development of a special formula for wood-column design, which has replaced the less accurate ones formerly in wide use, and by the discovery of a new engineering principle applying to beams under shear loading, by which large savings of material are made through the improved design of railway- and highway-bridge stringers and other large members.

Joints and fastenings

Since the joints of a structure are usually its critical points, the strength of the fastenings used in wood is fully equal in engineering importance to the



M–28549–F

A timber radio tower 326 feet high, framed with modern connectors.

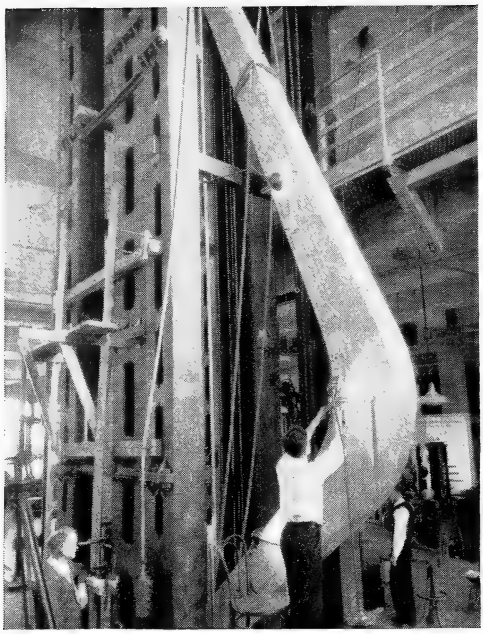
strength of wood itself. Investigations of the common timber fastenings afford detailed data on the holding power of nails, screws, and spikes driven in various kinds of wood and at different angles to the grain. Tests of bolted joints also cover a wide range and have removed a large factor of uncertainty and hazard from timbered construction. A new field of engineering construction has been opened by the investigation of modern plate and ring connectors that act as dowels or keys in wood framing. By means of these connectors new types of large timber structures are coming into being throughout the country, including long-span highway bridges, radio and lookout towers, oil-field equipment, and public buildings.

Prefabricated housing

The provision of easily erected, economical, and comfortable homes for families of small means is one of the most urgent needs of our economic era, and the development of more efficient use of wood for this purpose presents a broad responsibility for research. An intensive study of prefabricated housing is in progress, centering on structural problems and extending into related fields of investigation, such as seasoning, moisture control, painting, and fire resistance. A complete house of plywood unit panels has been worked out and demonstrated. Structural systems and accessory features are being developed for house prefabrication with lumber as well as sheet materials, with a view to speed of erection, durability, and comfort at minimum cost to the owner.

Laminated construction

The modern era of wood construction looks forward to new forms, new methods, and new standards of service, while changes in the forest stand neces-

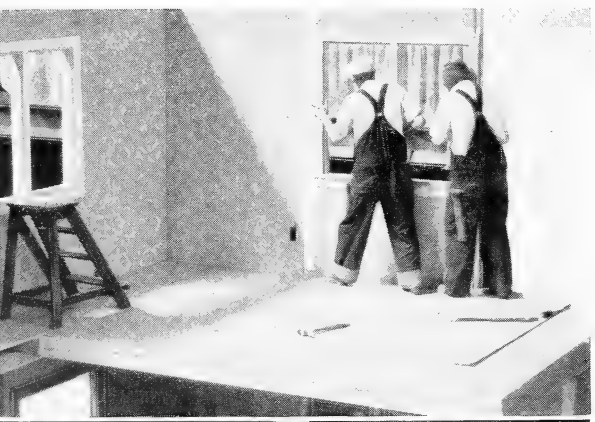


M–25188–F

Testing the strength of a glued laminated wood arch.

Development of wood prefabricated house construction.

M–28751–F, M–26006–F



sitate more efficient use of material from smaller trees. These conditions give constantly increasing importance to Laboratory investigations and tests of laminated and plywood construction in all its phases, from simple veneer samples to built-up wall and floor sections and laminated wood arches subjected to loadings of thousands of pounds. Tests are made to determine the strength of plywood of different combinations of species, the effect of increasing the number of plies, of varying the ratio of core thickness to total panel thickness, and of joining with various kinds of glues. Possibilities of spliced, laminated, and composite construction of beams, panels, columns, and arches built up by both nailing and gluing are under investigation with a view to increasing the economy of wood construction through the utilization of small pieces and material of low grades. New types of construction embodying these principles are demonstrated, such as the utility building of plywood supported by glued arches, now undergoing service tests on the Laboratory grounds.

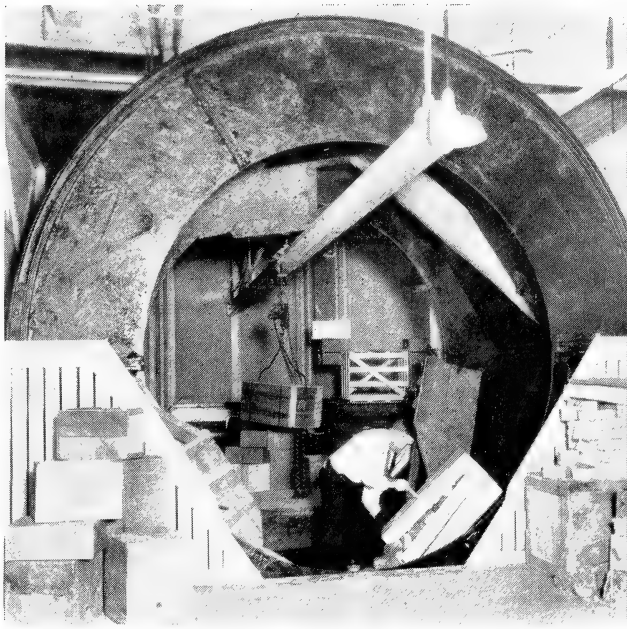
Shipping containers

An essential service performed by wood in commerce and daily life is in the form of containers for commodity shipments. The work of the Laboratory in improving the strength and serviceability of boxes and crates has promoted the more efficient utilization of billions of board feet of lumber, and has led to savings to the consuming public, in freight handling charges, losses, and damage to goods, amounting to millions of dollars a year.

It is frequently possible to redesign a container so as to reduce the amount

of material required, to save shipping weight and warehouse space, and at the same time to make it stronger and safer. The principal American wood species have been classified for box making, box designs have been standardized and specifications prepared for the proper number, size, and spacing of nails. Through the cooperation of railway companies, box makers, and shippers, the Laboratory's findings and recommendations are widely used.

Container investigations are carried on with the aid of special equipment, including dummy loading materials and testing machinery which subjects packages to repeated shocks and vibrations such as they would receive in transit. In addition to studies of the design and fabrication of wooden, veneered, and composite containers and the improvement of commercial specifications, the work has been extended to the broad field of fiberboard containers, in which increasing quantities of wood are being used in the form of pulp. The investigation includes strength tests of the component papers, the formation of commercial and experimental types of boards, and the production and testing of finished boxes, with the purpose of bringing to this important class of containers the engineering principles and methods that are so largely improving the service of wooden containers.

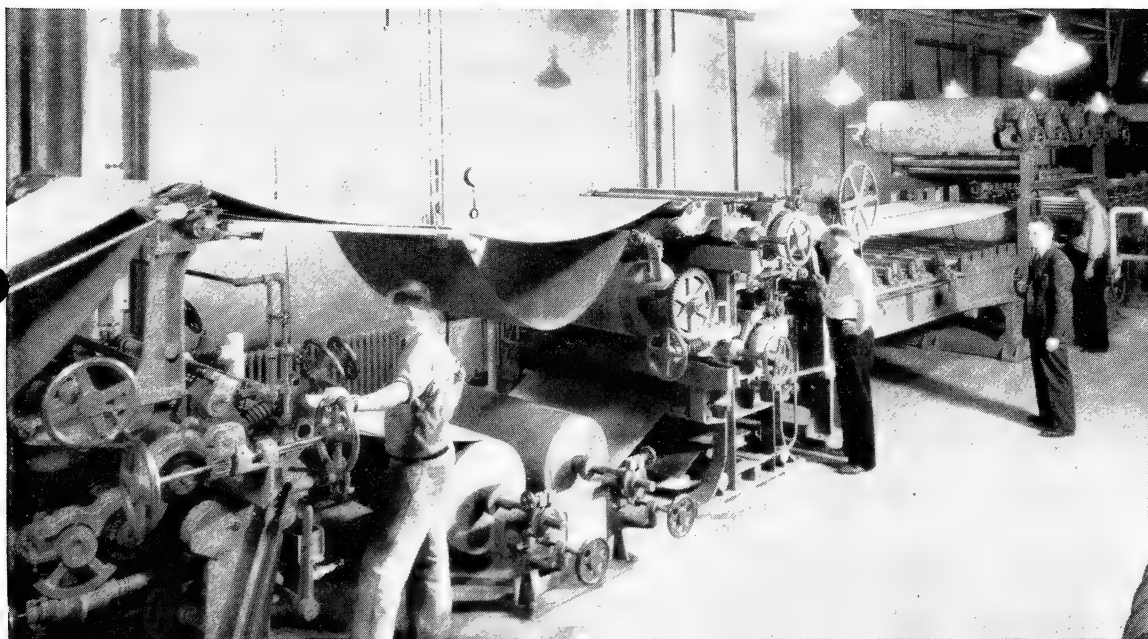


M–22077–F

Revolving drum for testing boxes and crates.

Equipment for corrugating and gluing fiber container board.

M–26068–F



Wood seasoning and moisture control

Wood in nature is a material combined with one-third to two and a half times its weight of water; a freshly cut log 16 feet long and 18 inches in diameter may have a liquid content of more than 100 gallons.

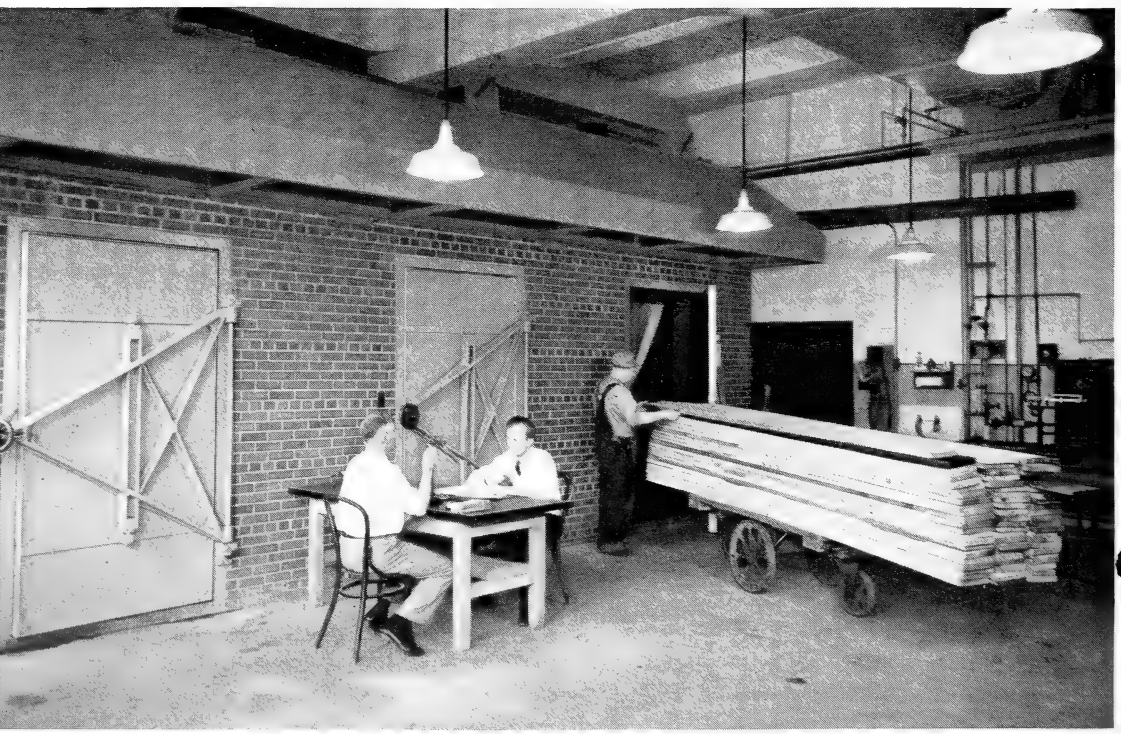
For most uses of wood it is imperative that the greater part of this water be removed, a requirement that gives rise to the complex problems of seasoning. When wood dries, it shrinks. The amount of shrinkage is different in different directions in the piece, and the result of uncontrolled drying is more or less severe damage by checking, splitting, and change of shape. Unsuccessful seasoning is the cause of the nonuse of many wood species and tremendous losses of material of other species, and is a prolific source of difficulties and dissatisfaction with wood in service. To improve this situation through adequate control of seasoning operations is a major task of scientific research.

Air-drying

Seasoning in the open air may be termed the natural method of wood

Three of the Laboratory's dry kilns for experimental seasoning of lumber.

M–31266–F



drying, and under proper safeguards it remains the most economical method for many hardwoods and the bulk of lower grades of softwoods. Long series of tests have shown the common sources of loss and damage in this field and means of bringing them under control. Important factors determined are proper exposure of the pile with respect to sun and wind, proper spacing of lumber at different stages of drying, adequate support to prevent warping and bending, and measures to prevent stain and decay, including elevated pile foundations and proper yard drainage.

Kiln-drying

The development of the lumber dry kiln arose from the need of speeding up the seasoning process. Very generally, however, its use has been attended with serious problems and variable results, owing to the lack of precise technique. The Laboratory's kiln-seasoning investigations are centered on underlying physical principles, together with the development of apparatus and methods to perform the drying efficiently. A number of completely equipped experimental dry kilns with accurate control of temperature, humidity, and air circulation are in constant use to test every desired variation of conditions in the seasoning of sample lots of lumber.

Substantial accomplishments are shown as a result of the work thus far. Practical methods have been developed for seasoning the principal commercial hardwoods and softwoods, many of

Wood samples are removed and weighed to determine moisture conditions in walls.

M-31609-F

which were previously considered incapable of being kiln-dried from the green condition. The engineering design of dry kilns has been radically improved. More than 5,000 commercial kilns embodying principles developed at the Laboratory are in operation, and new installations so designed by far outnumber all other types.

It is estimated that improvements in kiln seasoning resulting from the Laboratory's research are already saving American wood users more than $10,000,000 annually, and even larger savings are possible as the findings are more widely applied. Further investigations are under way toward the adaptation of kiln practice to many difficult species and to special sizes, including precut dimension stock. Work has begun on a broad program of research to correlate the more severe conditions of drying with their effects on wood quality, with the aim of setting up higher ranges of speed for the safe kiln seasoning of all species.

A necessary supplement to seasoning research is the improvement of methods of lumber storage and handling. All the care expended in the original drying may be wasted because of reabsorption of moisture by the stock while in transit or awaiting sale. Studies of this problem are pointing the way to better protection of lumber at all stages, from the mill yard to the finished structure. Special attention is being given to control of moisture content of lumber in closed sheds.

Chemical seasoning

The steeping of wood in a salt solution preliminary to drying in the kiln or in the yard offers a new approach to the most difficult seasoning problems. The treatment brings about a state of moisture equilibrium in which the wood dries from the center outward, reversing the usual direction, and in the final dry condition the salts absorbed act in some way to hold the wood against shrinkage and change of shape. By this method large timbers have been dried practically without checking—a result never before attained—and wood of several

Salt treatments offer new means of seasoning the most difficult wood species.

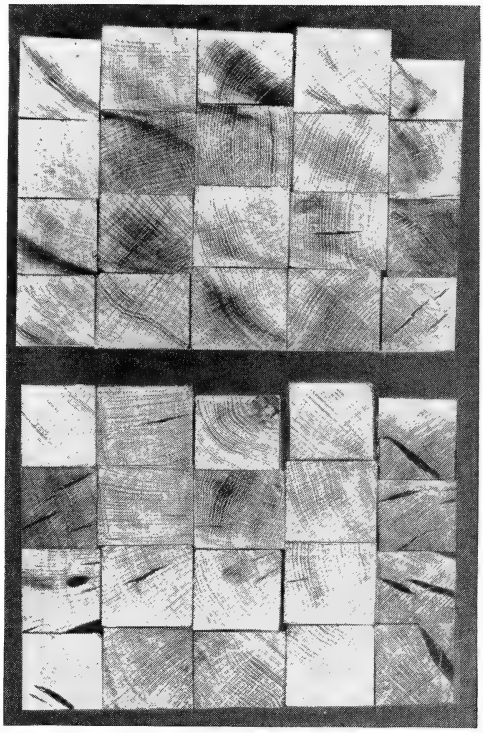
M–31514–F

of the most refractory species has been seasoned rapidly and with little damage. Further work is being done to perfect the process, which holds among its possibilities the release of millions of feet of little-used hardwoods for satisfactory service.

Moisture control

By whatever means it is accomplished, the seasoning process has one main purpose—to fit wood for the moisture conditions it will meet in service. Research is contributing to this end in many ways. Instruments for the quick determination of wood-moisture content have been developed and are now manufactured and sold commercially. By extensive field tests the principal wood-moisture climates of the United States have been charted as a guide to seasoning for different regions. Definite moisture tolerances are thus determined for lumber according to localities and uses and are finding an increasing place in commercial specifications.

The modern development of air-conditioning systems for homes and other buildings is introducing serious winter problems of moisture transfusion, sweating, and ice formation in walls. A thorough investigation has been undertaken to determine the rate of moisture movement in wood wall panels of different types at various temperatures and humidities and the effectiveness of sheet barrier materials in bringing it under control.



M–31513–F

Results of salt seasoning of swamp oak. Upper group, salt seasoned; lower, specimens from the same planks seasoned by ordinary methods.

Wood-treating processes for protection and service

Surface or impregnation treatments of wood to protect it or to increase its service value in other ways are a common necessity and have been practiced, with varying success, from the earliest times. With the increasing volume and diversity of wood uses in the modern era, the aid of research in examining, improving, and developing all kinds of treating processes has become increasingly important.

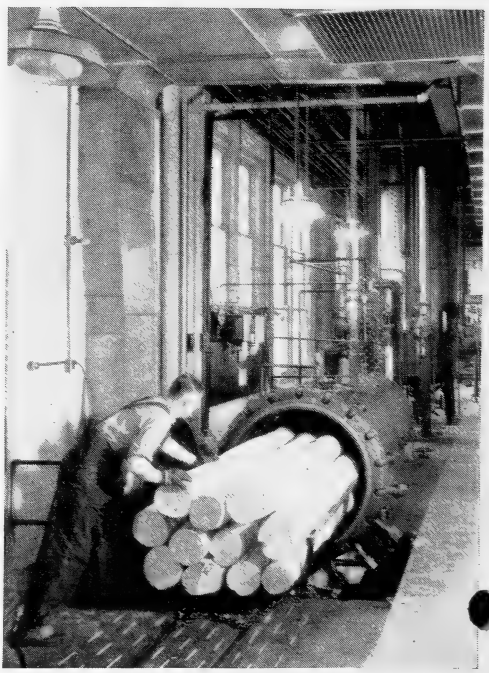
Protection against decay

Decay is by far the greatest destroyer of wood in service. Practical methods of preventing it mean large money savings to wood users, more lasting and satisfactory wood structures and utilities, and the curbing of a heavy drain on forest resources. The effectiveness and relative cost of coal-tar creosote, zinc chloride, mercury salts, and many other preservatives in protecting wood against decay, insects, and other destructive organism are studied in experimental treatments and field tests of great numbers of treated specimens, including railway ties, piling, poles, posts, and building timber. Research in impregnation processes is leading the way to better treating methods and greater certainty of long-service life of wood at lower cost. These studies are of additional benefit in extending preservative treatment to wood species not before successfully treated.

Simple and inexpensive preservative processes for fence posts and structural timber on the farm have been devised and are being further developed for use with various woods and new and cheaper preservatives. Large numbers of inquiries are received annually regarding the relative value of wood-treating chemicals and methods. Authoritative and impartial information in such cases is bringing substantial savings to thousands of wood users.

Fireproofing tests

Fireproofing investigations stand high in potential importance. If by the



M–23214–F

The effectiveness of wood-preservative materials is determined by impregnation treatments.

addition of chemicals the combustion of wood can be materially retarded, the danger of spread of fire in and by wooden structures can be largely decreased. Laboratory research in this field extends over a wide range of chemical treatments and types of fire-resistive construction. Treated wood specimens are tested in specially designed combustion apparatus. Full-sized house parts are subjected to flame test in a separate building equipped with a panel furnace having 67 large gas burners. Although highly effective fireproofing treatments are now available, they are too expensive for general construction purposes. The objective of research is to reduce costs and to bring the benefits of fire-retardant wood within reach of the average home builder.

RE–11208–M4

In fireproofing investigations full-sized house parts are subjected to test in a panel furnace.

Painting and moisture-proofing

The Laboratory is making definite contributions toward more lasting and satisfactory service of paints and other coatings used on wood. The relative efficiency of large numbers of moisture retardants and varnishes has been determined. Exposure tests of painted panels in many locations have demonstrated the relative paint-holding power of the principal commercial wood species. Useful discoveries have been made in methods of applying paint to wood and the choice of priming materials.

Examination of numerous failures in the repainting of houses shows, however, that the life of a coating cannot be wholly predicted from the immediate conditions of application, but that the service given depends on a proper or improper combination of the new paint with coats that have preceded it. This fact points to the need of a thoroughgoing classification of house paints according to the long-time maintenance programs of home owners. The work of classification, recently begun, involves a wide range of chemical research and service tests. The findings already indicate that by a proper distinction of paint types the

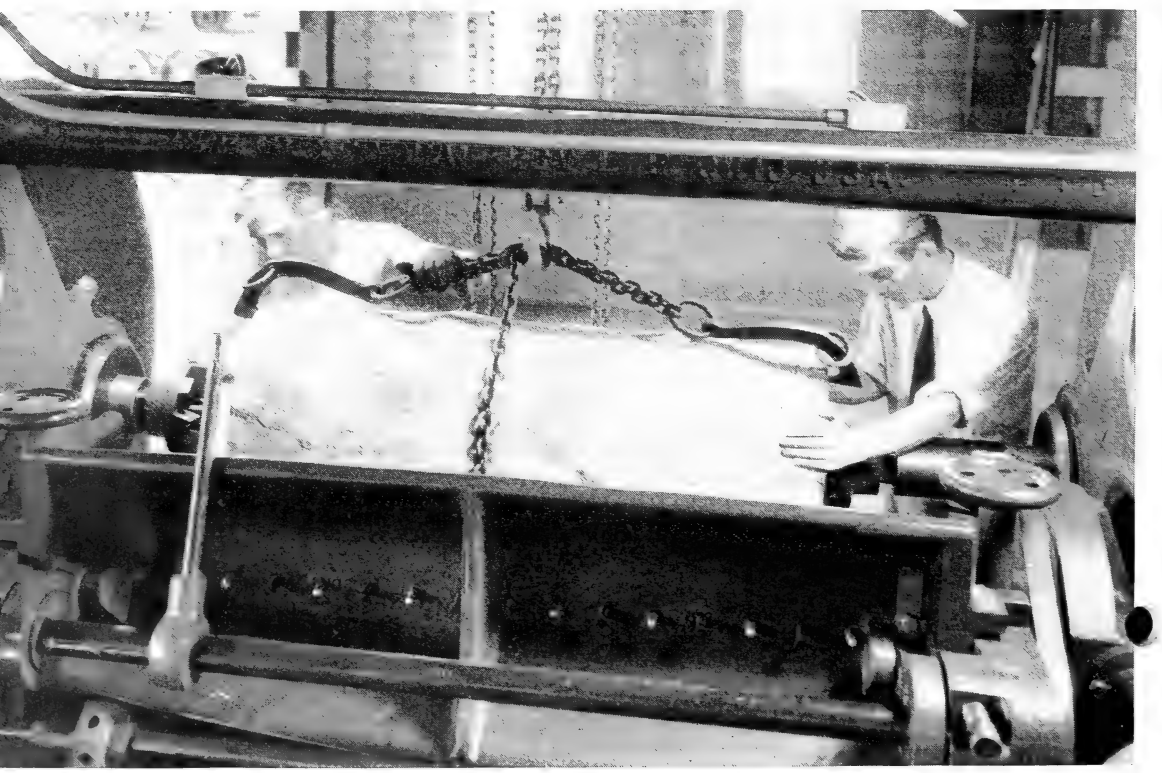
complexity of present paint markets may be greatly simplified, with resulting benefits to the user in lower costs and better service.

Gluing

Gluing is a process as old as the wood working art, and in the era of composite and laminated construction that is now beginning its importance is destined to increase. Many problems of wood gluing have been solved by Laboratory research. Effects of the many variables involved in gluing—temperature, glue consistency, kind of wood, kind of glue, thickness of spread, time of

M–29826–F

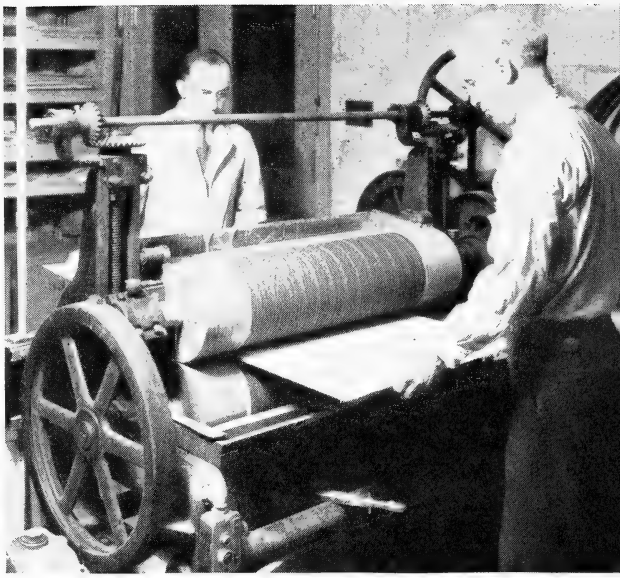
Protective efficiency of paints on wood is studied by exposure of panels.



Plywood research begins with the cutting of veneer from the log. M–29798–F

spreading, time in press—have been isolated and evaluated, and the result is that by proper observance of these factors all commercial woods can today be glued with animal, vegetable, blood, or casein glue in joints that are stronger than the wood itself. Woodworking industries are applying the findings of research, with corresponding benefit to users, in better products, more economical service, and reduced waste of wood.

Problems of far-reaching importance that remain for investigation pertain to the permanent water resistance of glue joints and to fundamental improvements in the nature of adhesives. Glues that contain no water are being developed. The active aid of research is needed to make them cheaper, better, and more generally adaptable.



M–30142–F

Mechanical spreading of glue.

Veneer and plywood

Plywood is sheet material made by gluing together thicknesses of veneer with the grain of successive layers at right angles. Present-day utilization trends point to increasing importance of plywood in construction and fabrication. Factors in its favor are its strength, the uniformity of its properties, and the large lightweight units in which it can be produced. There is need for a more exact determination of the properties of plywood as they are affected by the kind, quality, and dimensions of veneer, the number of plies, gluing and pressing technique, and other manufacturing variables. A comprehensive investigation of these problems is under way. The sheet material is obtained from the log in the Laboratory's veneer-cutting plant. The veneer is glued up into plywoods of various types and thicknesses, which are tested singly and in structural combinations. The tests include determinations of strength, resistance to weathering, and moisture and heat diffusion, as well as the effectiveness of different glues and gluing methods used in making the plywood.

Wood pathology

Investigations of defects in wood and wood products caused by fungus infection are conducted at the Laboratory by the Division of Forest Pathology, Bureau of Plant Industry, United States Department of Agriculture, in correlation with other Laboratory activities.

Wood-destroying fungi

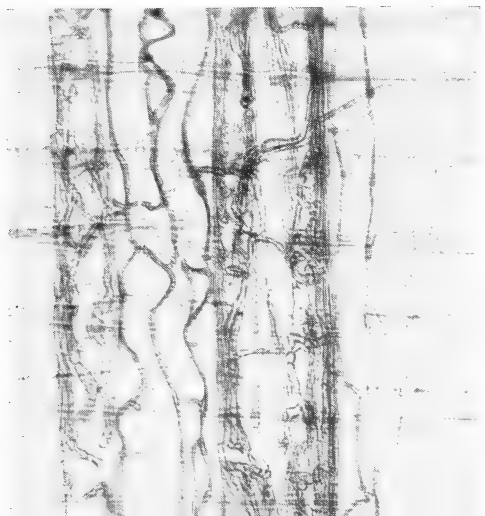
The effects of wood-destroying fungi upon the structure and service life of wood are examined, and temperature and moisture conditions favorable and unfavorable to fungus growth are determined. The causes of decay in buildings and wood products are investigated. Rules of construction for the avoidance of decay have been developed, with consequent large savings to thousands of home owners.

Toxicity of preservatives

The toxicity or fungicide value of wood-preservative chemicals is determined by their effects on typical wood-destroying and staining fungi grown in pure cultures. The adaptation of various chemicals to mechanical or hand-dipping treatments of freshly sawed lumber is a phase of the study having wide commercial application in the prevention of sap stain during air seasoning.

A blue-stain fungus in wood (magnified).

M–15156–F



Yard sanitation

Heavy losses to users occur as a result of the storage of wood under improper conditions of drainage, ventilation, and exposure. Studies and recommendations are made, in cooperation with other divisions of the Laboratory, for improving storage of general lumber stocks at sawmills and retail yards and for the better storage of pulpwood and pulp, box lumber, veneers, staves, vehicle parts, and other wood products.

2184–M

A decay fungus in wood (magnified).

Pulp and paper

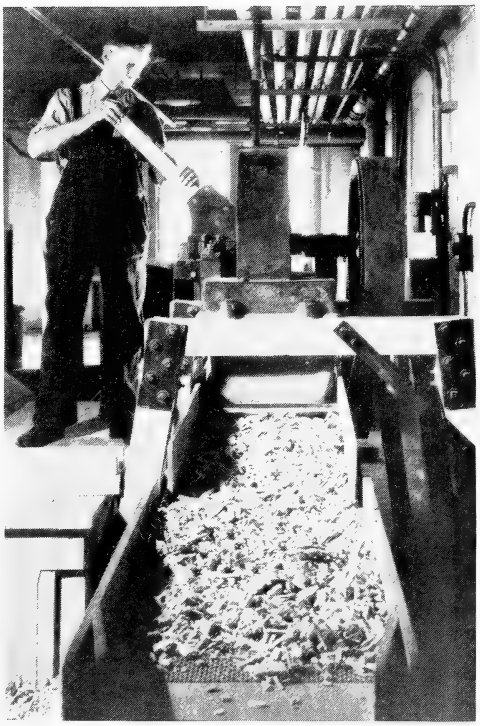
The purpose of the Laboratory's pulp and paper investigations is to increase possibilities of economical production, higher yield, and better pulp quality from our native woods, including those now little used or unused. Millions of tons of pulp and paper are imported annually into the United States from abroad to supplement waning supplies of eastern spruce, balsam fir, and hemlock, which have heretofore been the mainstay of the domestic industry; meanwhile, other American woods are being wastefully used or neglected which, if adapted to pulping purposes, could supply our present paper requirements several times over. Alteration of these conditions would mean better returns to forest management through the utilization of small trees and thinnings, profitable yields from lands now idle, and employment and wages for thousands of workers.

The need of a broad and dependable domestic basis of pulp supply seems destined to become more and more urgent as time goes on. The utilization of pulp products in the United States reached 13 million tons in 1929. Despite a temporary recession it is again on the increase, with a prospective annual consumption of 25 million tons within this century. The development of new paper commodities and pulp conversion products such as rayon and cellophane is mounting in volume and variety. Meanwhile, world consumption of pulp is also increasing with changing habits and standards of literacy in many countries abroad, and it is entirely possible that, as American requirements approach a maximum, cheap and abundant pulp imports such as we enjoy at present may no longer be forthcoming.

These considerations emphasize the importance of better and more adequate utilization of our own pulpwood resources. Toward its accomplishment the Laboratory has mobilized a varied research attack.

Additional species for pulping

By systematic pulping tests the Laboratory determines basic data for

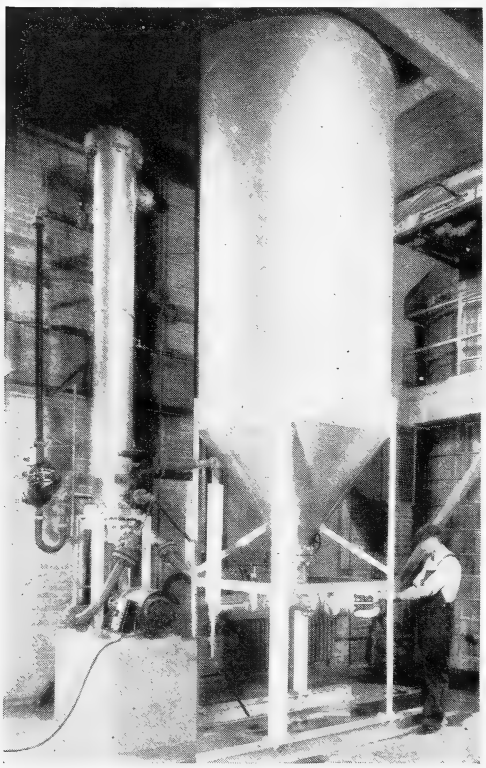


M–22506–F

Wood is reduced to pulping size by use of a mechanical chipper.

American woods as regards their adaptability to standard pulp-manufacturing processes, their yields, chemical consumption, bleaching characteristics, and other factors of production. Applying and amplifying the results, present studies are centered on the development of useful pulps from important species and regional groups.

In the Northeastern and Lake States the stands of second-growth hardwoods—maple, birch, beech, and aspen—that have sprung up in the wake of logging offer possibilities as a supplementary source of pulpwood. Experiments with these woods are being carried forward. It has been shown that in the grinding of hardwoods a proper dressing of the stone surface will pulp the wood with minimum destruction of fiber length, and also that if the high pentosan content of these species is retained in chemical pulps, much stronger papers can be produced from them than had been thought possible. Studies of aspen pulping have been especially helpful in increasing paper production from a prolific species that at present has few uses.



M–26174–F

Pulping experiments over a wide range of chemical concentrations and pressures are made possible by use of a chrome-nickel lined digester.

The Laboratory has devoted special attention to the production of newsprint from southern woods. Because of the large tonnage of newsprint consumed by the United States and the fact that much of this is imported from abroad, the possibilities of developing a domestic source of supply, particularly from the plentiful southern species, has commanded increasing interest. However, certain disadvantages such as poor color and high resin content in the pines, particularly the older stands, in contrast with the eminently suitable properties and cheapness of northern spruce have retarded any realistic development of a newsprint industry in the South, although experimental sulphite and ground-wood pulps of newsprint grade were produced at the Laboratory more than 20 years ago.

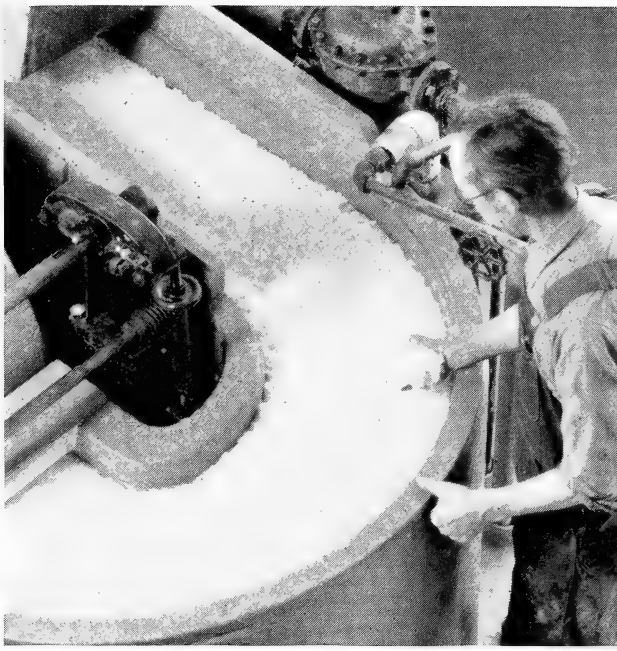
Increasing costliness of spruce and balsam, combined with the fact that the young second-growth pine is fairly free from heartwood and relatively low in resin, has tended to renew research efforts in newsprint production and experiments at the Laboratory and elsewhere. By selecting young pine trees of limited heartwood and resin content, newsprint-grade papers have

been produced on a laboratory and semicommercial basis from combinations of sulphite and ground-wood pulps, such as are normally used by the industry in manufacturing this type of paper.

Since production of newsprint by this method requires specially selected wood, which is an added cost and leaves much heart-bearing cull wood to be disposed of, the Laboratory has developed the use of semibleached sulphate pulp as a substitute for the sulphite, and has proved the effectiveness of this procedure by extended tests. The alkaline sulphate process readily reduces heartwood, does not require light-colored wood, and practically eliminates the possibility of pitch difficulties. The currently proposed newsprint developments in the South are in practically all cases tending toward this latter method of conversion.

The Laboratory has not only produced newsprint from various combinations of pine but has also used mixtures of pine with such southern hardwoods as gum. These developments offer possibilities for use of the southern hardwoods and for minimizing pitch troubles should these arise in mill operations.

In the forests of the Pacific Northwest, the Nation has other great supplies of actual and potential pulpwoods. Enough Douglas fir is left on the ground as logging waste each year to duplicate almost our entire pulp output from domestic sources—if Douglas fir can be adapted to diversified pulp production. The Laboratory is working to secure this result by special modifications of the sulphate and other processes. Experimental papers of good quality and strength have been obtained. Pulping experiments also with western larch, white fir, red cedar, Sitka spruce, and other western species are returning a promising variety of book, writing, wrapping, and newsprint papers.



M–26380–F

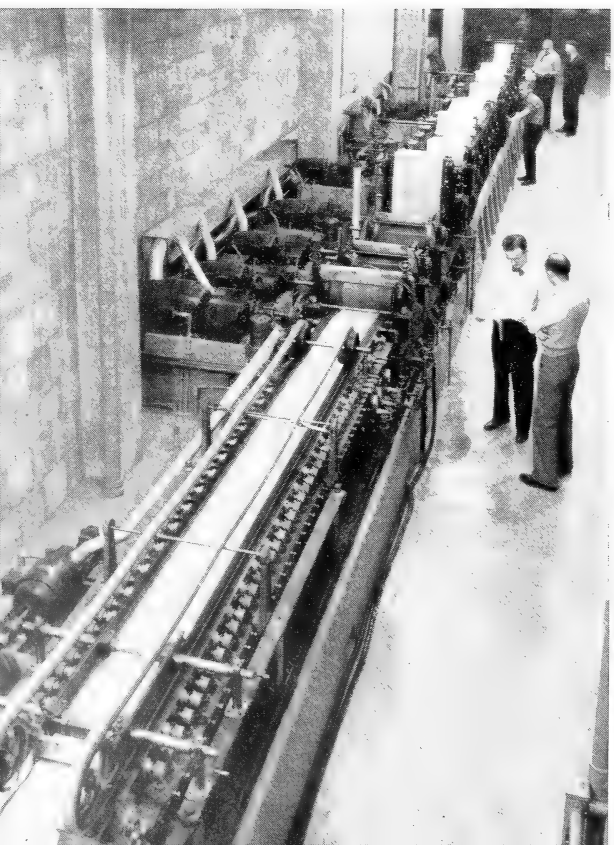
On the way to the paper machine the pulp, after bleaching, is further refined in the beater.

Improvement of pulping processes

As urgently needed as the extension of pulping to new species is the progressive improvement of pulping operations, looking to the more efficient utilization of woods of all species. Studies of chemical pulping are carried on constantly and are showing the way to substantial increases of yields and improvement of pulp quality. Application of the findings is resulting in more satisfactory and economical production through a proper balance of

M–26040–F

The tensile test—one of many tests used in evaluating paper quality.



M–26399–F

An experimental Fourdrinier machine, with press and drier rolls and calender, transforms the pulp into finished paper. Operating elements are under precise control.

the factors of time, temperature, and concentration of chemicals in cooking. Research in wood grinding is likewise establishing useful principles of control which are having a wide effect in improved quality of pulp and lower power consumption; an extended program of grinding studies is in progress with new and complete equipment.

A special contribution of the Laboratory to the procurement of high yields from the standard and less-used pulping species is the development of the so-called semichemical processes. Whereas the usual chemical methods return only 40 to 50 percent of the wood as useful fiber, the new processes return from 55 to 80 percent. In one of them neutral chemicals are used, in another acid sulphite liquors, and in a third alkaline reagents. In each process the pulping of the partially cooked wood is completed in a rod mill or other disintegrating device. An interesting application is the conversion of extracted chestnut chips into container board, now proceeding commercially on a large scale.

The use of a soda or ammonia base for sulphite pulping offers a distinct advantage over the use of the customary lime base, in that the liquors can be effectively applied in cooking not only the common pulpwood species but also the more resinous woods not now reducible by the sulphite process. The Laboratory is advancing the technique of the new method, by means of which much additional raw material for white papers may be made available to both northern and southern mills. Furthermore

definite progress is being made in the development of a recovery system to return the used chemicals cheaply. This step is necessary to the general adoption of the new bases. Its successful accomplishment will be of immense public benefit by making possible the elimination of sulphite waste-liquor discharges, which at present are a major source of stream pollution.

Pulp refinement and paper making

The utility of a given wood species for paper production is not determined by its pulping behavior alone but by the possibilities of adapting the pulp to the varied requirements of paper making. Laboratory research is therefore intimately concerned with all the other manipulations involved—bleaching, beating, refining, paper-machine operations, and finally the testing of the finished product and the salvaging of waste fiber and chemicals. Many tasks lie ahead, as for instance the correlation of fiber properties with intensity of beating, the improvement of multistage bleaching processes, and the analysis of some 30 machine variables in relation to the strength, finish, inking quality, glare, and moisture resistance of the finished paper.

How to use the laboratory

All the information that the Forest Products Laboratory has gained through years of research is available to the public. Every year thousands of inquiries are answered by letter and problems are discussed with those who come to the Laboratory seeking advice on problems of wood utilization.

In cases where the problem presented is of such scope and difficulty as to warrant a cooperative research project, the work will be undertaken if consistent with the Laboratory's public objectives and subject to advance agreement as to methods and payment of costs. The Laboratory's guiding purpose in such studies is to secure facts that will promote the best use of wood. A pamphlet explaining the cooperative service more fully is obtainable on request.

Laboratory publications are available covering the main findings of its research work, and classified mailing lists are maintained for the distribution of current information in different fields of wood use. General visitors are conducted through the Laboratory at regular hours.

Inquiries should be addressed to the Director, Forest Products Laboratory, Madison, Wis.

WISE TIMBER USE IS THE BEST TIMBER CONSERVATOR

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