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INSULATING BOARD, HARDBOARD, AND OTHER STRUCTURAL FIBERBOARDS

Summary

The wood-base fiber panel materials are a part of the rapidly evolving technology based on converting lignocellulose to fiber and reconstituting the fiber into large sheets and panels. While some equipment and techniques used are the same as for producing paper, there are enough differences in techniques used and other requirements for manufacture that a separate treatment of the subject is warranted. This research note describes the various requirements for raw materials and equipment, describes various steps in manufacture, and presents summaries of important strength and physical properties of insulating board, medium-density building fiberboard, and hardboard.

INSULATING BOARD, HARDBOARD, AND OTHER STRUCTURAL FIBERBOARD[1]

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Historical Data

The first documented manufacture of a structural fiberboard on a commercial basis was recorded in England in 1898, and involved a dense, hardboard-like panel produced by hot pressing repulped wastepaper. The first insulating board was produced in Canada in 1909 and consisted of a rigid board made from groundwood-fiber pulp formed in a mold and dried in the sun.

Commercial manufacture of insulating board in the United States was started by the Minnesota and Ontario Paper Co. in 1914, and the Masonite Corporation began producing hardboard in 1928.

At the present time, structural fiberboards are being made from wood, other plant materials, and wastepaper. These boards fall into three general classifications: insulating board, medium-density fiberboard, and hardboard.

General Description of Fiberboards

Insulating Boards

Insulating boards are manufactured for uses in building construction that call for a lightweight, rigid panel with good thermal-insulating properties. In nearly all original uses, the efficiency of the board as a thermal insulator was the important property. In later developments the insulating boards were used not only for thermal insulation but also for structural strength or for sound reflectance suppression, particularly when provided with holes or other

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[1] Slight revision of material originally prepared by the authors in 1958 for the Technical Association of the Pulp and Paper Industry.

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

sound traps. Some present-day products are produced primarily for uses requiring structural strength, and thus have become classified as structural insulating boards.

Insulating board products are manufactured in a range of densities between 10 and 26 pounds per cubic foot, and most of the production falls within the narrower range of 15 to 19 pounds per cubic foot. In the usual manufacturing practice, insulating boards are of two types: an interior-quality type, which is a uniformly light-colored product and usually has a factory-applied paint finish; and an exterior-quality type for sheathing. The exterior-quality type is either impregnated or coated with asphalt, or sometimes both impregnated and coated, to improve its water resistance and strength when wet.

Different products are fabricated from the basic boards. The more important ones and the relative amounts of each are indicated by the following tabulation:[3]

Type	Production (percent)
Building board	5.6
Insulating roof deck	.9
Roof insulation	22.1
Wallboard (3/8 inch and less)	.7
Ceiling tile and acoustical tile	19.8
Plank	.1
Sheathing	31.4
Regular density sheathing Intermediate density sheathing Nail base sheathing	
Shingle backer	1.4
Insulating formboard	.7
Sound-deadening board	([4])
All other	17.3
Total	100.0

The names of most of the products listed define their use, which is almost exclusively in building construction where roof insulation, interior finished board, and sheathing account for by far the greatest amounts. Insulating roof deck, intermediate and nail-base sheathing, insulating formboard, and sound-deadening board are the most recently developed of the products. They are becoming more important in terms of use as is padding and blocking for packaging and backer material for aluminum siding which is listed under "All other." In addition to the "All other" classification, building board and "wallboard," a product classed as being 3/8 inch or less in thickness, often are boards that are subjected to remanufacture by other than the original manufacturer, so they are used in many ways.

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[3] Based on 1964 production.

[4] Reporting started January 1965.

The insulating boards are manufactured products; hence, properties will depend on density, the method of manufacture, type and kind of fiber used, additives introduced, and post-manufacturing treatment. The important properties listed in table 1 can be considered only as indicative of the range in values of the various products manufactured. For any specific product, tests are necessary to establish its properties.

Medium-density building fiberboards are of two types, the laminated paperboard manufactured almost exclusively from repulped wastepaper laminated together with adhesives, and a new homogeneous type manufactured by hot pressing to moderate density a previously dried insulation board mat to which a thermoplastic binder has been added. The laminated paperboard product has been manufactured for many years and has been used mostly as interior wallboard. Some laminated paperboard is given added treatment during manufacture to increase its resistance to moisture, and it is used in more severe exposures such as house siding, soffit lining, and porch ceilings. These boards are laminated by gluing together plies approximately 1/16 inch thick to make boards from 3/16 to 3/8 inch thick.

The homogeneous medium-density building board is manufactured in a nominal 3/8 inch thickness and is sold with a factory-applied prime coat of paint or completely prefinished for siding, either in 12-inch-wide strips for lapped effects or in 4- by 8-foot panels. Properties of the two types of medium-density boards are quite different. As the introduced binder has a large effect on properties, the properties given in table 2 should be considered only as indicative of qualities of some of these products available at the time the tests were made.

Hardboards

Originally all hardboard was manufactured by hot pressing a damp or wet mat and drying this under pressure. It was necessary to place a screen on the lower platen of the press to allow the steam to escape as the board was dried. As a consequence, one surface of the board was smooth while the other bore the impression of the screen (hence the term screenback). Later methods were developed for hot pressing a dry or nearly dry mat, and it became possible to produce a board with both surfaces smooth (S-2-S). Embossed boards that simulate such surfaces as ceramic tile, leather, and basket weaves are produced with patterned cauls.

Hardboards are produced in three qualities: A service grade, a standard grade, and a tempered grade. The service grade is made in the lowest density consistent with uniform manufacturing to effect a flow of lignin and a satisfactory bond. This density varies with different processes, but service-grade hardboards usually have a density of about 55 pounds per cubic foot. Standard-grade hardboards are pressed to a density of about 62 pounds per cubic foot. When standard-grade boards are given a treatment consisting of dipping them in a blend of drying oil or other oxidizing resin and then baking them at elevated temperature to stabilize the resins, they are classified as "treated" or "tempered." The tempered boards are about 5 percent heavier because of the treatment than are standard boards. Tempering increases density, stiffness, strength, hardness of surface, and water resistance, and makes the board more brittle.

Hardboard is manufactured in thicknesses of 1/10 to 5/16 inch and is used for any purpose calling for its combination of strength, hardness, density, and uniform surface. About one-half of the hardboard produced finds outlets in industrial markets for such uses as panels and backs in television and radio cabinets, door panels, sun visors in automobiles, interior paneling in railway passenger cars, drawer bottoms and dust dividers in furniture cabinets, and skins and egg-crate cores for flush doors. The remaining production is sold through retail lumberyards and is used mainly for wall covering, siding, cabinetwork, and underlayment in housing, although some finds a use in signs and bin liners.

There are many variations in processes for manufacturing hardboard, and these are reflected in the strength and physical properties as summarized in table 3. Because of the broad range for most properties, actual tests of a given product should be made if an accurate evaluation is required.

Insulation boards, medium-density building fiberboards, and hardboards are made in many panel sizes. For some uses they are cut to special sizes at the factory. The common panel size is 4 by 8 feet, although such other sizes as 4 by 9, 4 by 10, 4 by 12, and 4 by 16 feet are available. A few insulation board manufacturers make special sizes in 8-foot widths.

Raw Material Requirements

Pulps

Wood is the main source of fiber for structural fiberboards. Other sources of lignocellulosic fiber include bagasse (fiber from sugar cane), flax shives, cereal straw, and wastepaper. Technically speaking, any species of wood or other type of lignocellulose can be used to manufacture a structural fiberboard. However, it becomes more difficult to use certain kinds of fibrous materials when restrictions in quality are imposed. The number of species, kind of lignocellulose, and form they are in become further restricted when economies of procurement, storage, handling, and manufacture are considered.

Originally, because developments in structural fiberboard manufacture were modifications of existing pulp and paper manufacture, softwood species were used exclusively for insulating board and hardboard. At present more hardwood than softwood is used for insulation board and hardboard. In direct contrast, four times as much softwood as hardwood is used for pulp and paper manufacture.

Species used for board manufacture in the United States include, among softwoods, Douglas-fir, lodgepole pine, white fir, redwood, white pine, jack pine, and southern pine; and, among hardwoods, aspen, basswood, paper birch, sweetgum, black willow, yellow-poplar, and red oak. An examination of the list of hardwoods indicates that, with the exception of red oak, all species now used are medium to low in density. However, numerous laboratory experiments have shown that suitable insulating board and hardboard can be made from the denser species.

Besides the trend from softwoods to hardwoods, there is a definite trend toward use of the dense hardwoods. The Masonite Corporation, which originally used softwood exclusively in its plant at Laurel, Miss,, in 1957 turned to hardwood for its entire 800 tons of raw material per day for hardboard. An insulation board plant in a southern state and several hardboard plants have been built to use oak and other dense hardwoods as major raw materials.

Many plants produce insulating board and homogeneous medium-density building fiberboard from groundwood fiber; hence the wood must be in the form of bolts for pulping. At some insulating board plants and most of the hardboard plants, chips prepared from the residue from other forest products industries are utilized for raw material. In this respect, board manufacturing plants are in much the same position as are pulp and paper mills. More and more waste material from other wood-using industries are being converted into chips. Some plants are jointly owned and operated with an integrated sawmill or plywood plant and depend on its residue for raw materials; others rely for raw material on the chipped material of one or more such mills near by.

Bark can be tolerated to a greater extent in board than in other pulp and paper products, even though appearance is marred and strength properties are lowered. Many manufacturers making quality products eliminate bark from their raw material in order to reduce the dirt content, since it is difficult to separate bark from dirt.

Other lignocellulosic materials used for raw material in this country are bagasse, flax shives, extracted licorice root, and repulped wastepaper. Cereal-grain straw, papyrus, palms, and bamboo are used in other parts of the world. Cornstalks have been used for the manufacture of insulating board, but because the variation in growth from year to year and the short harvest period (with consequent large storage requirements), this raw material has not been used extensively. Bagasse--the term given waste sugar cane stalks from which the sugar has been extracted--is widely used. Even with this raw material the storage problem is a major one because the harvest period in the Southern States is at the most 2-1/2 months long.

Bagasse constitutes the major raw material used in about one-third of the insulating board produced in the United States. The fiber is coarse and stringy, so quantities of repulped paper or other finer pulp are blended with the bagasse pulp to increase board stiffness and improve its surface. One insulation board manufacturer and most, if not all, manufacturers of the laminated paperboards use wastepaper. Wood is the main raw material used in all hardboard made in this country.

Sizing Materials and Binders

Certain additives are introduced into a board during manufacture to serve one or more purposes. These additives are usually classed as size or binder. Sizing materials improve water resistance, and some also improve the bonding and felting of the fibers. Rosin and petrolatum are the main sizing agents for insulating boards, medium-density building fiberboards, and hardboards. Rosin is added to the pulp suspension and then precipitated with alum. Petrolatum is added usually in a molten state to the hot stock before refining. Starch size is used for interior-type insulating boards to provide an improved surface for factory-applied finishes. Asphalt is used as sizing for sheathing-quality insulating board; it is added either as an emulsion to the refined stock and precipitated with alum, or as finely ground particles directly to the refined stock. In insulating boards, asphalt serves the dual purpose of improving water resistance and the bond.

Homogeneous medium-density building fiberboard requires additional bond strength beyond that provided by the natural bond, A thermoplastic resin is used to produce the stronger bond. During manufacture, a dried mat similar to an insulating board but containing the binder is first made, then it is compressed in a hot press. The binder is required to stabilize the board and prevent it from swelling in thickness with moisture changes that occur in service. For hardboards many manufacturers use phenolic resins as binders. These resins increase water resistance as well as bonding strength.

A wide range of other materials are added to the board either during or after manufacture to impart some special property to it. These include fire-retardant impregnants and coatings, and chemicals that improve the resistance of the boards to decay and such insects as termites. The practice of treating structural fiberboards for fire resistance is limited to the use of intumescent paint coatings for interior factory-finished insulating board. One or two insulating board manufacturers treat their product with chlorinated phenols or arsenical compounds for insect and decay resistance.

Sheathing-quality insulating board is either impregnated with asphalt or coated with it after manufacture. Some boards are both impregnated and coated. Asphalts used for coating usually have relatively low melting points, so that they can be applied by roller, and penetrate the board rather than remaining on the surface as a continuous film.

About one-half of the hardboard produced is given an oil-tempering treatment after hot pressing. Oil-tempering materials include the following drying oils--linseed, tung, Perilla, soya, and tall oil, as well as some oxidizing hydrocarbons refined from petroleum and synthetic resins such as alkyd resin. These are sometimes used singly but usually in blends.

Water

Water is an important raw material for board manufacture. The requirement varies with the plant design and may be as high as 10,000 gallons per ton of product.

In plants designed with a closed white water system for stock requiring no washing, about 3,600 gallons of water are required per ton of product.

In recently developed air-felting systems for manufacturing hardboard, no water is added to the fiber between refining and forming the board. In these plants, as little as one-tenth as much water is required--360 gallons per ton of board.

Board Manufacturing Processes

While special equipment is required for the manufacture of each of the boards described, manufacturers use different equipment for making products which fall within each classification. Figures 1, 2, and 3 show some of these variations.

Figure 1 is a schematic flow diagram for the manufacture of insulating board.

Figure 2 is a schematic flow diagram for the production of two types of medium-density building fiberboards, homogeneous building fiberboard, and laminated paperboard.

Figure 3 is a schematic flow diagram for hardboard manufacture.

Pulping and Fiber Preparation

Structural fiberboard is generally manufactured from whole wood fiber in the form of individual fibers and fiber bundles obtained mainly by mechanical pulping methods. The principal pulping methods are groundwood, attrition milling (with or without previous softening treatment), the Asplund defibrating process, the Masonite explosion process, and to a limited extent the semichemical process.

Whole wood fiber, other than groundwood, is generally made from untreated wood in the green condition or from wood that has been treated with steam or hot water. Since moisture and heat weaken the middle lamella (the material that bonds fibers together), hot, wet chips subjected to a crushing and shearing action can be converted to a pulp containing relatively few broken fibers.

In figure 1, flow diagram for production of insulating board, station 2 denotes the initial step in manufacture of this board, the grinder for groundwood pulp, the chipper for systems requiring pulp chips, and shredders for such raw materials as bagasse, straw, and wastepaper. The pulping unit (station 3) is for wood chips and the hydropulper for other types of raw material. Station 4 shows the refiner, classifier, or the refiner-classifier. In many systems, such as the Asplund Defibrator, stations 3 and 4 are combined.

Some or all of the fiber produced by any of the above methods, except attrition milling, may require further refining. This is usually done in attrition mills of either the single- or double-disk type. In some systems, a screen classifier is placed in the line ahead of the refiner, so that all acceptable fiber goes to the stock chest without further loss of material or quality; only the reject material is routed through the refiner for reduction. In some systems it is possible to eliminate the screen classifier by adjusting the setting of the plates on the refiner for classifying purposes.

The techniques and equipment for fiber preparation for medium-density fiberboards are essentially the same as those used for insulating board and are shown in figure 2, which is the schematic flow diagram for that type of board.

Fiber preparation for both air- and wet-felted hardboard is essentially the same as for the other kinds of structural fiberboards (fig. 3). The requirement for insulating board is a mixture of coarse fiber and fines or a binder stock. Hardboard requires a freer stock of a more uniform fiber classification.

Fiber for air-felted hardboard is prepared in the Asplund Defibrator process or an adaption of steam cooking and attrition milling. Disk refining is done without adding water, to minimize the problem of drying. In some operations, enough heat is developed during refining to dry the fiber.

Groundwood

Coarse groundwood stock is used for about half of the insulation board produced from wood in the United States. It is produced in conventional pulpwood grinders equipped with coarse-burred artificial stones of 16 to 24 grit with spiral or straight patterns.

Attrition Milling

Same species can be fiberized in single- or double-rotating disk mills when in the green or water-soaked condition. Others must be heated in water or steamed before they can be fiberized. Steam is generally preferred for commercial operations, even though steam and hot water appear to give the same results. The treatment varies from a few minutes at high pressure (100 to 300 p.s.i.) to several hours at low pressure (25 p.s.i.). Boards of satisfactory strength can be made from stock obtained in a yield of about 85 percent after milling.

Asplund Process

The Asplund process is a continuous pulping process by which moist wood chips are fiberized at high temperatures (150° to 180° C.) in the presence of steam. This process takes advantage of the fact that, at high temperatures, the bond between fibers is weakened so that fiber separation is facilitated.

The Asplund Defibrator is designed for continuous introduction of chips into a steam chamber, continuous refining of the chips in a single rotating disk mill in the presence of steam, and for continuous discharge of the pulp.

Masonite Explosion Process

In the Masonite explosion process, wood chips are subjected to high-pressure steam in a "gun" or pressure vessel equipped with a quick-opening valve. It is essentially a high-temperature (about 550° F.) acid hydrolysis. The chips are steamed at about 600 pounds per square inch steam pressure for about 1 minute, and the pressure is then increased to about 1,000 pounds per square inch and held constant for about 5 seconds. With the sudden release of this pressure, the chips are exploded into a coarse fiber mass. The treatment in the explosion chamber (gun) will vary somewhat with the species of wood being converted to fiber. The steaming period or the period of high pressure is varied in accordance with the condition and kind of wood and the size of the chips.

Several things occur during the high-temperature, high-pressure period. The fiber-to-fiber bond at the middle lamella is weakened so that, upon release of pressure, the chips are blown into a mass of fibers and fiber bundles. The lignin is not removed from the fiber mass but is made more plastic by the heat and moisture; hemicellulose is hydrolized, becoming pentose sugar, some of which is converted to furfural that polymerizes to form furfural resins. The exploded fiber is refined in disk refiners, screened, and washed in the same way as board fiber produced by other processes, The resultant pulp is free of the highly hygroscopic hemicelluloses and contains large amounts of activated binder.

Washing

Fibers are washed in cylindrical washers. A wire-covered cylinder rotates in a suspension of fibers in water and retains a layer of fibers on its surface. This layer is then showered with fresh water, which displaces the liquid in the stock. In most washers, vacuum pumps are used to lower the pressure inside the cylinder.

The amount of washing required for fiber for structural fiberboard depends on the species or kind of raw material, extractives and other solubles produced as a byproduct of pulping, amounts of fines that must be removed (washing assists in their removal), and properties required of the final board. Some species of wood pulped by moderate methods with mild conditions of cooking may require no more washing than they get during normal thickening operations.

Addition of Size and Binder

In wet processes of board manufacturing, size and binders are usually introduced into the stock while it is fluid enough for mixing. Rosin, asphalt, and paraffin size are introduced as emulsions, Paraffin is sometimes introduced in the molten state, usually into stock that is at a temperature above the melting point of the paraffin. Binders, such as finely ground dispersions of asphalt, are added to insulation board stocks and phenolic resins to hardboard stocks, usually while the stock is cold, to improve strength properties. In air-felting hardboard processes, phenolic resin binder and paraffin size are introduced before the chips enter the refiner or in the refiner proper, in which the heat and mixing action disperse them over the surface of the fiber.

Papermaker's alum, or ferric sulfate, along with sulfuric acid if necessary, is used to affix resin and size on the fibers while the stock is in a tank or chest. Usually 85 percent or more of the size or binder added is retained in the board.

Stocks for smooth-surfaced hardboard may require other additives. Occasionally 1 to 3 percent of linseed oil (emulsified form) is added to groundwood or other relatively raw wood-fiber stocks. Unlike attrition-milled, well steam-cooked chips or explosion-type pulp, which contain binders made plastic by the heating process, relatively raw wood-fiber pulps need an added binder.

Fiber Testing

The freeness or drainage-rate test is the most important test for determining the qualities of the fiber before forming it into boards. The Oliver, Williams, and Canadian freeness testers have been used by board manufacturers, but with limited success. The Defibrator freeness tester was developed for freely draining stocks, such as are required for board manufacture. In that test a mat is formed on a wire screen at the bottom of an 8-1/2-inch-diameter cylinder from a suspension of 128 grams of fiber in 10 liters of water. The drainage time, in seconds, required for the suspension to dewater and for 10 liters of air to pass through the mat when acted upon by a vacuum is considered to be a measure of the freeness. Freeness indexes for suitable insulation and hardboard stocks range from 12 to 40 seconds on the Defibrator freeness tester. The Structural Fibrous Materials Committee of TAPPI has also developed a freeness tester for such stocks. This tester, known as the TAPPI SFMC drainage-time tester, is being evaluated and gives promise of acceptance for board evaluation.

Board stocks made wholly or mainly from repulped wastepaper are relatively very slow to drain. The one manufacturer of an insulating-type board who uses repulped paper as a base for the board uses a system of multiple deckle box frames that minimizes the importance of the long drainage time of the pulp. The manufacturers of laminated paperboard overcome the slow drainage by forming mats only about 1/16 inch thick, as compared to 3/8 inch or mote with other wet-felted board.

Board Machines

Fiberboards are generally formed on special cylinder- or Fourdrinier-type machines. After it is wet-pressed, the board, containing 50 to 70 percent of moisture, is cut into sheets 8 to 12 feet wide and 8 to 24 feet long by means of a traveling saw and fed automatically into multiple-deck dryers heated by means of steam coils. Some dryers are equipped with blowers that force heated air over the surface of the board. The fuel used is natural gas, burned in the air stream produced by the blowers. The dryers range in length from 150 to 600 feet.

Repulped newsprint is converted into insulation-board mats in a deckle-box type of machine. In this machine a measured quantity of the fiber suspension is delivered to a frame open at top and bottom and resting on an endless-wire screen supported on rollers. After the majority of the water has passed through the wire screen, the frame (deckle box) is raised while the wire screen is moved the distance of the open frame (about 4 ft.) then stopped, and the frame is lowered to receive another charge. The wet sheet is then compacted in a stationary wet press while the wire is not in motion and another sheet is being formed with the deckle box.

In several types of machines, the board is formed from dried fiber suspended in air. In these machines, fiber is introduced into an air stream and either blown against a moving wire screen or allowed to settle on a moving belt. Some of these machines are equipped with scrapers or scalping units to remove excess material from the top to make the surface more uniform. Since such board is bulky, means are provided to compact it further before the final hot pressing.

Hot Pressing to Produce Hardboard and Medium-Density Building Fiberboard

Mats are compressed in multiplaten hot presses to densities between 50 and 80 pounds per cubic foot for hardboard and about 35 pounds per cubic foot for medium-density building fiberboard. Insulation board is not hot pressed. Presses as large as 4 by 16 or 5 by 18 feet with 20 openings and capacities in excess of 1,000 pounds per square inch are used.

Sreenback Hardboard

When a wet-felted board is hot pressed as it comes from the board former, its moisture content is so high that screens must be used to allow steam to escape as the board is dried in the press. These screens mark one side of the board, hence the name "screenback hardboard." The same is true when damp air-felted mats are hot pressed. The press cycle used may involve a breathing cycle to insure proper drying and may range from 7 minutes for 1/8-inch hardboard to 15 for 1/4-inch hardboard. Platens of presses are usually steam heated, although hot water and hot oil are used extensively, particularly in Europe. The temperature of the platens is maintained at 340° to 400° F. A recent innovation to make an essentially S-2-S board from a wet mat is to use specially perforated cauls to permit, with light sanding, both surfaces to be smooth,

S-2-S Hardboard

Hardboards smooth on both sides are made from pulp mats dried to a low moisture content. Specially prepared wet mats are dried to a moisture content of less than 1 percent before being hot pressed. Drying is done by heating the insulation board mat in an oven or a high-frequency heating unit. The mats are then pressed between smooth platens at pressures exceeding 1,000 pounds per square inch and a temperature of 500° F. for about 2 minutes.

Oil Tempering of Hardboard

It is common practice in Europe to heat-treat hardboard. This is commonly called heat tempering, in contrast with the American practice of tempering boards with oil and then baking them. While either heat treatment or oil tempering makes the hardboard more brittle, it does improve such properties as hardness, modulus of rupture, and stiffness and reduces water absorption appreciably. Oil tempering consists of dipping boards in the blend of drying oils and resins and then running them between pressure rolls to remove excess oil and aid its penetration into the board. Amounts of oil. in excess of 3 percent of resin solids based on the weight of the board usually are required to produce the necessary tempered quality. The oil is stabilized by baking the board at temperatures usually from 320° to 340° F. for several hours.

Humidification of Structural Fiberboards

It is not general practice to humidify insulating boards. Final moisture content on leaving the dryers is lower than equilibrium for most uses, but the boards are porous and change moisture content readily when exposed to high or low relative humidity use, Manufacturers recommend on-the-job conditioning of the board before it is placed in service.

Hardboards, being dense, come to equilibrium much mare slowly. Equilibrium moisture content values for interior uses are 4 to 5 percent and for exterior uses average from 6 to 9 percent. Boards coming from the hot press are usually at a much lower moisture content, so manufacturers humidify the boards to a moisture content of at least 4 percent before shipping them.

Humidification is done at relative humidities of 80 to 85 percent and temperatures of between 100° and 140° F. in continuous or batch-type kilns. The principal problem during humidification is to maintain temperatures and humidities as high as possible without causing fiber raising in the surface of the board.

Laminating of Paperboard

Four or more layers of paperboard are laminated together to form boards of the required thickness. Protein adhesives are used in boards for interior use and water-resistant adhesives for more severe applications. Adhesives are applied to both faces of alternate inner plies by roller-type glue spreaders. The plies are brought together and the adhesive set up as the combined boards pass between a series of hot rolls which apply the pressure required. The continuous strip is sawed into sheets as it leaves the laminator.

Trimming, Further Processing, and Packaging

After the boards are made, dried, hot pressed, and humidified, final manufacture includes trimming to length and width, fabricating special edges, such as chamfers, tongue-and-groove or shiplap joints, painting, punching, drilling, scoring, and embossing.

These operations are performed by nearly automatic equipment, but even so, in most plants as much manpower or more is required to operate the equipment for conversion to usable products as is required to form, dry, and hot press the board.

Large panels are wrapped two or four to the package, and smaller components like plank or tile are either wrapped in paper or packaged in containers. Automatic wrapping and packaging equipment are used to a limited extent.

Table 1.--Range of physical and strength properties of structural insulating board

Board property	Value	Unit
Density	10-26	Lb. per cu. ft.
Specific gravity	0.16-0.42	
Modulus of rupture	200-800	P.s.i.
Modulus of elasticity (bending)	25,000-125,000	P.s.i.
Tensile strength parallel to surface	200-500	P.s.i.
24-hour water absorption	1-10	Percent by volume
Tensile strength perpendicular to surface	10-25	P.s.i.
Linear expansion from 50 to 90 percent relative humidity	0.2-0.5	Percent
Thermal conductivity	0.27-0.45	B.t.u. in. of thickness per sq. ft. per hr. per °F.

Table 2.--Range of physical and strength properties of medium-density building fiberboard

Property	Value for laminated paperboard	Value for homogeneous board	Unit
Density	31-37	37	Lb. per cu. ft.
Specific gravity	0.50-0.59	0.59	
Modulus of rupture	[1]900-2,000	[1]1,950-2,300	P.s.i.
Modulus of elasticity (compression)	[1]100,000-700,000	....	P.s.i.
Tensile strength parallel to surface	[1]650-2,000	....	P.s.i.
Compression strength parallel to surface	[1]500-950	....	P.s.i.
24-hour water absorption	9-150	5.5	Percent by weight
24-hour thickness swelling	....	2.5	Percent
Maximum linear expansion[2]	0.2-1.30	0.2	Percent
Thermal conductivity	0.5-0.6	0.55	B.t.u. in. of thickness per sq. ft. per hr. per °F.

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[1] Lower value in the across-the-board direction.

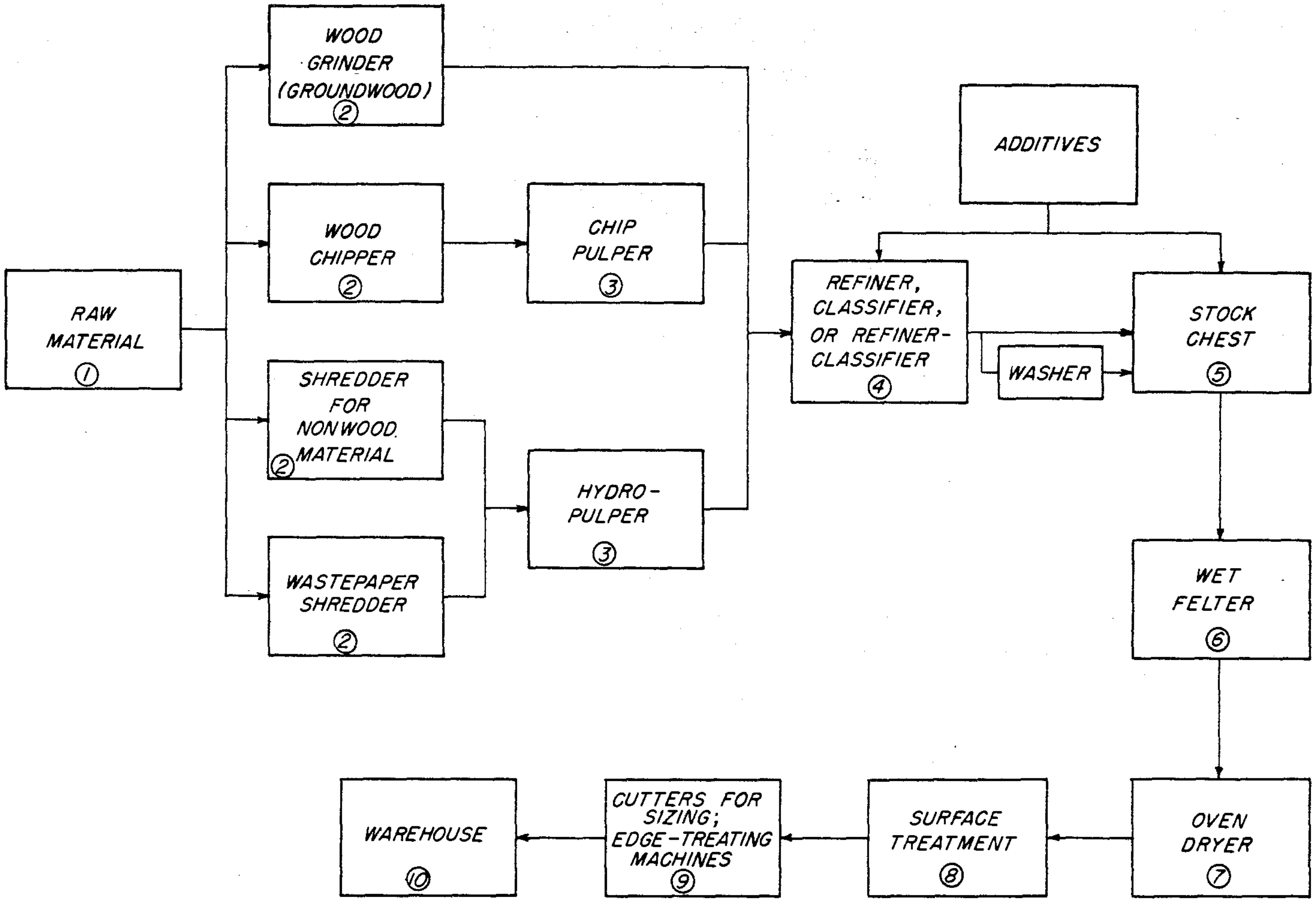
[2] Between equilibrium at 50 and at 90 percent relative humidity. Lower value for laminated board parallel to long dimension of the sheet, high value across long dimension.

Table 3,--Range of physical and strength properties of hardboard

Property	Hardboard	Tempered hardboard	Unit
Density	50-80	60-80	Lb. per cu. ft.
Specific gravity	0.80-1.28	0.93-1.28	
Modulus of rupture	3,000-7,000	5,600-10,000	P.s.i.
Modulus of elasticity (bending)	400,000-800,000	650,000-1,100,000	P.s.i.
Tensile strength parallel to surface	3,000-6,000	3,800-7,800	P.s.i.
Compression strength parallel to surface	1,800-6,000	3,700-6,000	P.s.i.
24-hour water absorption	3-30	3-20	Percent
Thickness swelling[1]	10-25	8-15	Percent
Linear expansion[2]	0.15-0.45	0.15-0.45	Percent
Thermal conductivity	0.8-1.40	1.10-1.50	B.t.u. in. of thickness per sq. ft. per hr. per °F.

[1] After 24-hour soak.

[2] Between equilibrium at 50 and at 90 percent relative humidity.



M 114 404

Figure 1.--Schematic flow diagram for insulating board manufacture. Wood grinding (step 2) may be preceded by a caustic soda soak to soften fiber,

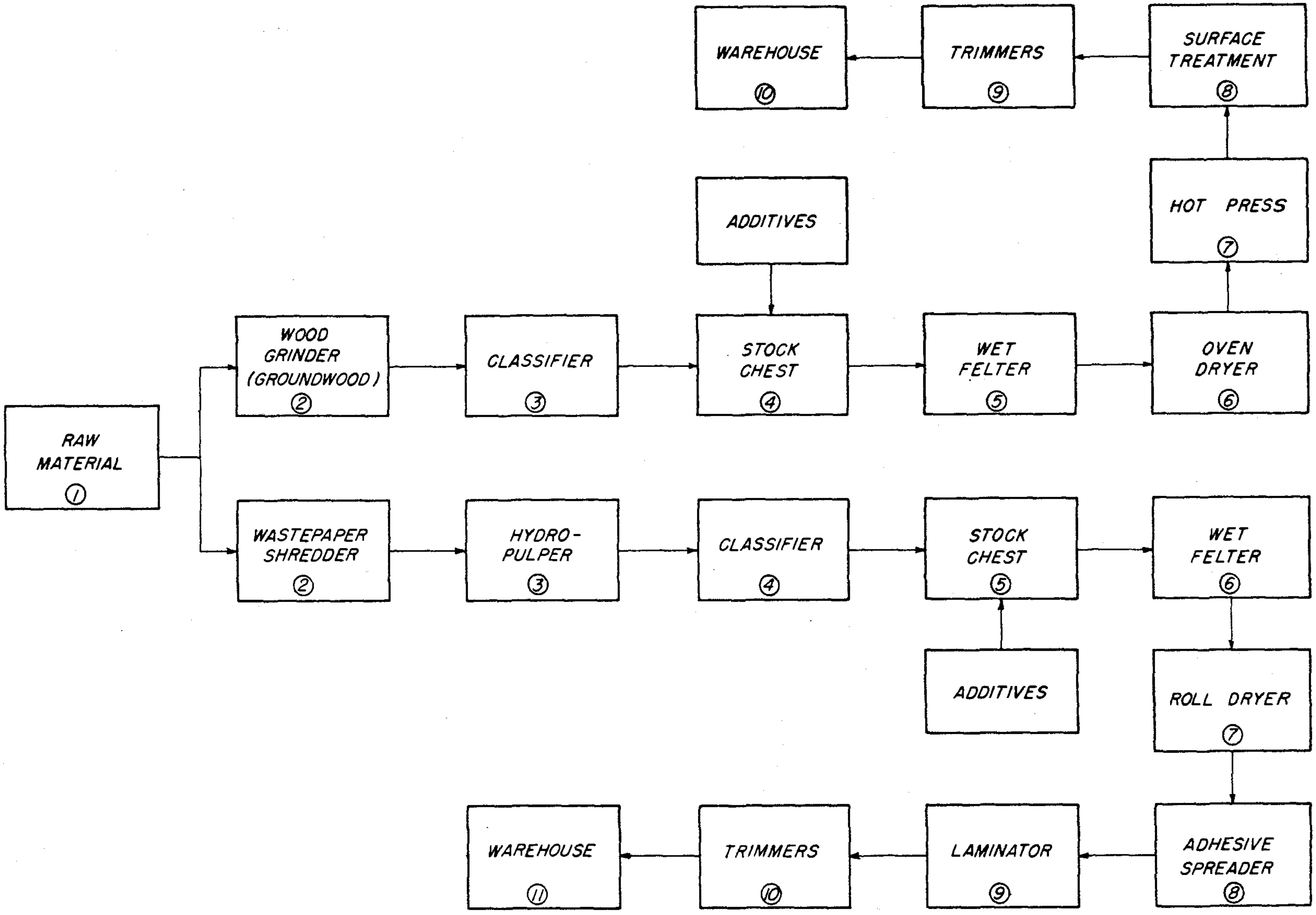


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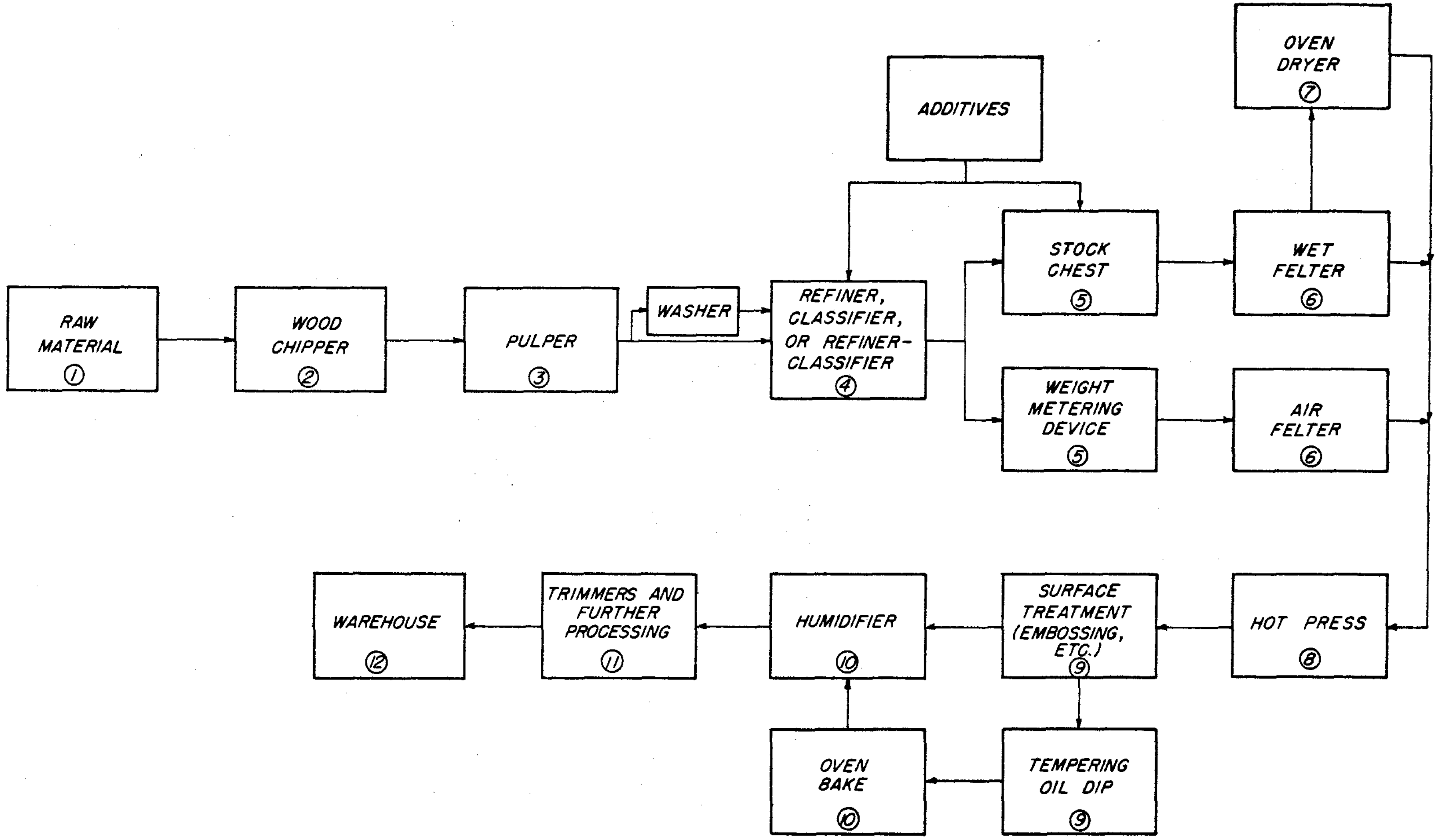
Figure 2.--Schematic flow diagram for production of two types of medium-density building fiberboard. Upper series, homogeneous building fiberboard; lower series, laminated paperboard.



M 114 406

Figure 3.--Schematic flow diagram for hardboard manufacture.

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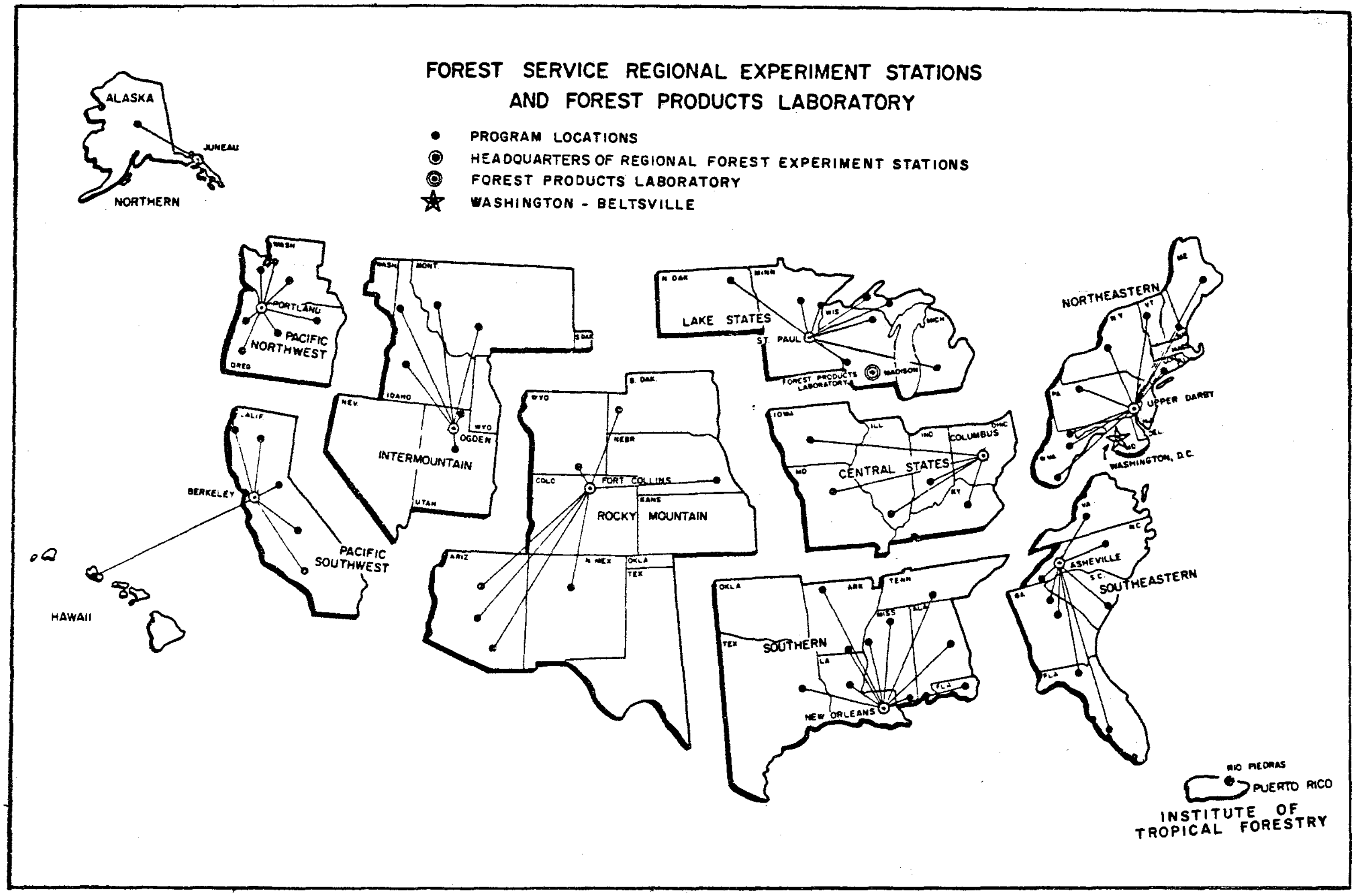

Forest Service regional experiment stations and Forest Products Laboratory