wood floors for dwellings

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WOOD FLOORS FOR DWELLINGS

Prepared by
FOREST PRODUCTS LABORATORY

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Growth Through Agricultural Progress

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WOOD FLOORS FOR DWELLINGS

Prepared by Forest Products Laboratory,[1] Forest Service

Wood possesses a variety of properties that make it a highly desirable flooring material for homes. Its popularity has continued over the centuries. Wood is still the most extensively used flooring material for homes. Today's markets provide a better basis than ever for the selection and installation of attractive and serviceable wood floors for the modern home. Not only is selection available from a wide variety of woods and grain characteristics, but also from a considerable number of distinctive flooring types and patterns.

Wood flooring constitutes a prime market for many millions of board feet of high-quality hardwoods and softwoods in the United States each year. Because of its importance for home use, the Forest Products Laboratory has for a number of years conducted research on wood flooring with the primary aim of making it an even more satisfactory product. Much of this research has been focused on improved seasoning and other means of making wood more dimensionally stable, on improved methods of installation, and on development of new and cheaper ways of using wood as flooring. Some results of this research, together with related information on installation, finishing, and maintenance, are presented in this publication as an aid to producers and users of wood flooring in homes.

PROPERTIES OF WOOD AS A FINISH FLOORING

The term "finish flooring" applies to the material, other than rugs or carpets, that forms the wearing surface over the structural part of a floor. The extensive use of wood for finish flooring indicates that it possesses in high degree the special properties, qualities, and characteristics that are particularly desirable for this service. These include distinctive and attractive appearance, with wide latitude for adaptability to the style and decorative motif planned for the home; good hardness and wearing qualities, yet with a degree of resilience that provides foot comfort; low heat conductivity, which insures a feeling of warmth to the touch; simplicity and facility of installation; relative freedom from slipperiness, depending on the finish used; and ease of maintenance. These qualities contribute, in varying degree, to pride of ownership and satisfactory service when wood floors are properly installed. They account for the fact that wood flooring has been used in countless homes for hundreds of years.

The special feature of wide choice in appearance and other properties available in wood flooring results from the many species of wood and various grades that are regularly manufactured to meet practically any requirement, from polished brilliance to attractive natural finish. Other surface finishes can alternatively be applied to make the wood floor easily adaptable to any desired scheme of interior decoration. The floor can serve as a background to reflect the decorative motif of the house. The inherent distinctive grain, texture, and depth of color of wood can be made to blend easily and naturally with the color tones of the walls, furniture, drapery, and rugs to create an environment that embodies all that the word "home" stands for.

IMPORTANCE OF MOISTURE CONTENT

The one property of wood that must be given special attention for flooring is its tendency to shrink and swell as its moisture content changes. There are many ways to minimize and control this characteristic, and modern selection, seasoning, and installation methods have contributed greatly. Control factors include the choice of edge-grain over flat-grain material (fig. 1); the use of special flooring patterns; the development of dimensionally stable crossbanded types; proper moisture content at time of installation; and, when necessary, consideration of finishes that retard moisture change. Various means of insuring satisfactory

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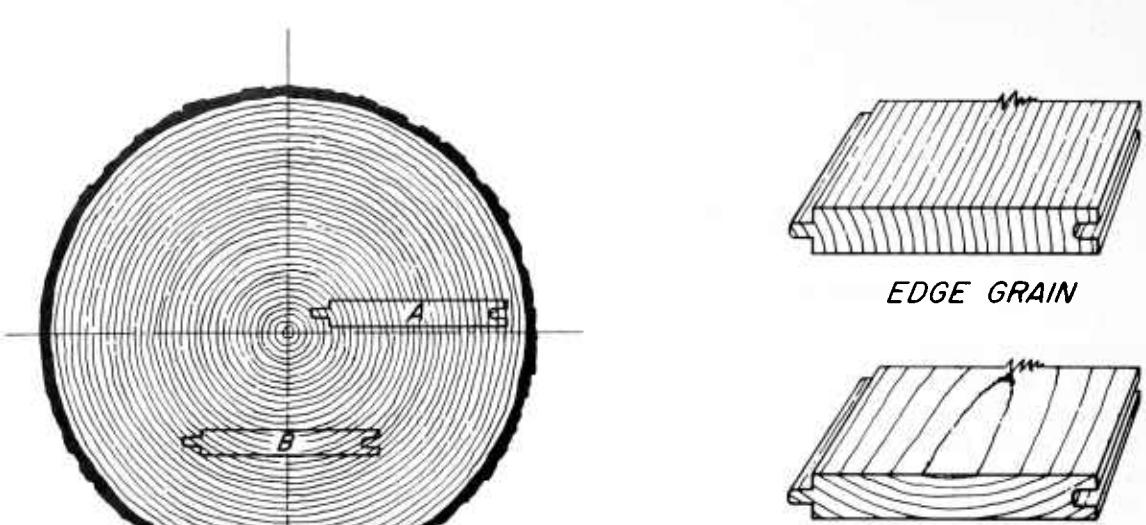

FIGURE 1.—Cross section-of log showing annual growth rings and position from which (*A*) edge-grain flooring and (*B*) flat-grain flooring are obtained.

installation and service of wood flooring are presented.

In a modern home, wood is commonly used in nearly all rooms above grade, the most frequent exception being the bathroom. Other flooring is often employed also in the kitchen, or the kitchen wood floor may be overlaid with other materials. Improved methods of protecting wood from dampness have encouraged its use in basement recreation rooms.

DEVELOPMENTS IN WOOD FLOORING AND IN USE CONDITIONS

Early flooring was mostly of softwood, because of its availability and the relative ease of working it with handtools. Largely, too, it was in the form of random-width planks as they came from the mill. The production of hardwoods that afforded better wear soon followed improvements in manufacturing equipment and seasoning methods. As a result, the use of hardwoods as flooring expanded to where they now provide by far the greater proportion of the total.

Strip flooring was for a long time the only type available, and still accounts for a large proportion of the wood flooring used. Though the early patterns of machine-made strip flooring were very similar to those in use today, there has actually been substantial improvement in seasoning and manufacturing procedures in recent years, which is reflected in improved quality.

For years, the supporting framework for floors was made of wood not only in houses but in most other buildings, and permitted the simple attachment of wood floors by means of nails. Changing construction practices, first in commercial buildings and later in houses, introduced other supporting materials, notably concrete, which have required new ways of attaching the flooring to the supporting structure.

One method in common use for laying strip flooring over a concrete base involves the installation of wood sleepers, generally of 2- by 4-inch material, to support the flooring and serve as a nailing base. The sleepers are fastened to the concrete by anchors or mastic. The expanded use of concrete floor slabs also encouraged the development of many new patterns or forms of wood flooring that could be laid directly on the concrete with a mastic adhesive. The early types were short lengths of standard strip flooring sometimes laid in a herringbone pattern or assembled in small squares, blocks, or tiles, with the grain direction of adjoining squares being alternated as they are laid on the floor.

More recently, blocks or tiles have been made of 3-ply hardwood plywood in a number of thicknesses and with tongued and grooved edges. Several types of small, thin blocks or strips, some mounted on a supporting membrane for ease of handling, are now being marketed. Flooring tiles made from dimensionally stabilized hardwood veneer are also available. They are laid directly in mastic.

Changing conditions in the building industry have created a demand for factory-prefinished flooring, particularly for installations where the

floor must be available for service immediately after installation. Because of improvements in seasoning practice, precision machining, and the development of suitable floor finishes, the flooring industry can supply prefinished flooring that is ready for use when laid.

GUIDE TO SELECTION OF WOOD FLOORING

Various types of wood flooring are described in some detail in later sections. The most important points relating to selection are outlined briefly below as a quick guide to the prospective user.

Strip Flooring

Strip flooring is the most widely used and generally the most economical. It is available in standard patterns and grades in both hardwoods (oak and maple most common) and softwoods (Douglas-fir and southern pine most common). Hardwoods are available prefinished. Strip flooring is most commonly laid by nailing on wood subfloor over wood framing or on sleepers set on concrete slabs. This flooring is usually side and end matched for blind nailing, but is also available in square-edge, which is face nailed. Special types are available for laying in mastic in herringbone and other floor patterns.

Plank Flooring

Plank flooring is similar in pattern to strip flooring, but comes in wider, random widths, and is sometimes cross laminated for greater dimensional stability. It is available only hardwoods, but in both the unfinished and prefinished forms. Plank flooring is more expensive than strip flooring. It is usually laid on wood subfloor by blind nailing. Sometimes it is also fastened by screws, with the screwheads commonly covered by wood plugs, usually of contrasting color. Plank flooring is not normally laid directly on concrete slab, but can be put on sleepers.

Block Flooring

Block flooring is available most commonly as squares in two general types—unit and laminated block. Unit block is made up of strips, commonly of standard pattern, splined or otherwise fastened together. Laminated block is crossbanded like plywood, and shrinks and swells less with moisture change than do other flooring types. Both general types of block flooring are available in a variety of hardwood species (oak most common), either unfinished or prefinished.

Block flooring may be laid on wood subfloor by nailing or by laying in mastic, or on concrete coated with mastic. The grade designations for unit block flooring generally correspond to those for strip flooring, but the designations for laminated block flooring frequently vary with the manufacturer. Sizes available range from about 6¾ by 6¾ to about 12 by 12 inches, with 9 by 9 inches being the most common.

Special Patterns

There are many special patterns that do not fit into the classifications just given. One is a thin veneer tile designed for laying in mastic much like resilient flooring. Designed to have improved dimensional stability, this tile is available in a limited number of hardwoods.

WOODS USED FOR FLOORING

About a dozen woods are regularly worked to pattern as flooring. Among these are five hardwoods,[2] namely, oak (including species of both the red and the white oak groups), maple, beech, birch, and pecan. The rest are softwoods, comprising southern pine, Douglas-fir, western hemlock, western larch, and redwood.

Although redwood is not high in hardness, its heartwood is quite decay resistant. Such redwood flooring as is regularly manufactured is intended mainly for porches and similar locations where the wood is exposed to the weather and the decay hazard is high.

Of the other softwoods listed, Douglas-fir and southern pine are those most generally used for flooring in house construction. Hardwoods are generally more popular as a flooring material than are softwoods, partly because of their greater resistance to wear and the natural figure which lends beauty to the finished floor.

[2] Although the terms "hardwoods" and "softwoods" are the most generally accepted popular names for the two broad groups of trees cut for lumber, they are rather misleading to the layman, because they bear no relation to the actual degree of hardness or softness of the wood. Cottonwood, aspen, basswood, and yellow-poplar are all classed as hardwoods, and yet each is softer than longleaf pine, which is classed as a softwood. Similarly, yew is classed as a softwood but is four times as hard as basswood and considerably harder than many of the oaks. The means employed by botanists and wood technologists to separate the two groups are also difficult for the layman to understand. Perhaps the most accurate and most readily interpreted definitions are "trees with broad leaves" for hardwoods and "trees with needles or scalelike leaves" for softwoods. The softwoods are also sometimes called conifers, because they bear cones.

Hardwoods

Oak and maple are the principal hardwoods used for flooring, with beech, birch, and pecan ranking next in quantity. Each piece of hardwood flooring usually bears the trademark of the trade association under whose rules it was graded, the grademark, and the name, number, or symbol of the member mill that manufactured it.

Figures show that 1,200,000,000 board feet of hardwood flooring were produced in 1954. This is 80 percent of all flooring produced, both hardwood and softwood. Oak of various commercial species supplied 92 percent of this hardwood flooring, as compared with 6 percent for maple. The remaining 2 percent consisted largely of beech, birch, and pecan. The small-scale use of sweetgum, ash, hickory, tupelo, cherry, locust, walnut, basswood, and aspen for flooring has also been reported. Their combined use, however, was less than 1 percent of the total for all hardwoods.

Oak

There are about 20 species of oak in the United States that may be considered commercially important in lumber production. Of these, about half are classed as red oaks and the rest as white oaks. This classification of oak into red and white is standard practice commercially in the lumber trade. In the growing tree the differentiation of red oak from white oak is based on botanical characteristics, such as form of the fruit, flower, leaf, and appearance of the bark. In lumber, identification of the oaks is more difficult.

Most species of oak cut into commercial lumber are used in the manufacture of flooring. They grow under a wide range of climatic conditions in many different kinds of soil. There is, accordingly, much variation in the color of the wood, especially the heartwood; the sapwood usually shades from white to cream color in all species of oak. In the standard grading rules for oak flooring, color is entirely disregarded except in the amount of light-colored sapwood allowed. Sapwood is limited only in the best grade of flooring.

Should a reasonable degree of color uniformity be desired, it can be obtained by selecting the flooring strips for each room that most nearly match in color tone, rather than by laying them at random just as they come from the bundle. If an absolutely uniform color is wanted, special arrangements should be made with the dealer or contractor. The grading rules do not differentiate between red oak and white oak, but the industry is prepared to supply all-red oak stock or all-white oak stock, at a slightly higher cost for selection. As a general rule, red oak flooring is lower in price and more uniform in color than white oak.

A special feature of white oak is the prominence of large rays that make an interesting flake pattern in quartersawed flooring. In certain parts of the United States the preference is for white oak, in others red oak is more in demand. Red oak and white oak are about equal in general properties. Both make a very satisfactory floor of attractive appearance when properly finished.

Maple

Maple flooring is made from sugar maple (*Acer saccharum*), and also from black maple (*A. nigrum*), formerly considered as a variety of sugar maple. The production of lumber from these species centers largely in the Lake States, the Northeastern States, and the Appalachian States. The trade name for both species is "hard maple"; occasionally they are called rock maple. The so-called soft maples—silver maple, red maple, and the western species, or bigleaf maple—are not so hard, heavy, or strong as hard maple, and because of this are not commonly used for flooring. In addition to being heavy, strong, hard, and stiff, hard maple wears well under abrasion and takes an excellent finish. These properties fit it well for flooring.

The heartwood of both species of hard maple is light reddish brown, and the sapwood, which in mature trees is several inches thick, is white, slightly tinged with brown. The contrast in color between heartwood and sapwood in maple is much less pronounced than it is in oak. In the standard grading rules for maple flooring, the varying natural color of the wood is allowed except in special grades.

Beech and Birch

In comparison with hard maple, beech and more especially birch are used only sparingly in the manufacture of flooring. Only 2 of the 15 or 20 species of birch that grow in the United States are manufactured into flooring. Of these, yellow birch (*Betula alleghaniensis*) is by far the most abundant and most important commercially. The other is sweet birch (*B. lenta*). Only one species of beech (*Fagus grandifolia*) is native to the United States. The heartwood of all three of these woods is reddish brown, with a slight variation in color for each individual species. Similar slight variations exist also in the color of the sapwood of the three species, which is of a lighter shade than the heartwood. As in maple flooring, the natural varying color of the wood is an accepted characteristic in grading beech and birch flooring.

Other Hardwoods

The five hardwoods described above supply about 99 percent of all hardwood flooring. The remaining 1 percent is divided among at least 8 native species, including sweetgum, ash, hickory, sycamore, tupelo, cherry, locust, and walnut. Some of these were probably used more because of ready availability than because of any special characteristics. Cherry and walnut together with some exotic woods like mahogany and teak are used largely in parquetry flooring for ornamental effect

because of their color and grain. None of the above is specifically mentioned in grading rules.

Softwoods

The volume of softwood flooring produced in 1954 was 316 million board feet, or 20 percent of all flooring. In 1948, 52 percent of the softwood flooring was southern pine, 41 percent Douglas-fir, and 4 percent western hemlock. The remaining 3 percent was divided among the following 8 species, listed in order of volume: Eastern white pine, ponderosa pine, western larch, eastern hemlock, redwood, spruce, cypress, and the true firs. Some of these species could hardly be recommended where wear is an important factor. The total output of softwood flooring has remained fairly constant, and the chief species have maintained their positions.

Southern Pine

Southern pine is a name applied to a group of yellow pines that grow principally in the Southeastern States. The group includes longleaf, shortleaf, loblolly, slash, and Virginia pines and several others of minor importance. Except in dimension material and structural timbers, no differentiation in species is made commercially in marketing the products from this group of woods.

The wood of all southern pines is much alike in appearance. The sapwood and heartwood are frequently, although not always, distinctly different in color, the former being yellowish white and the latter a reddish brown. The contrast in color between sapwood and heartwood in southern pine is not generally strongly marked in a finished floor, and the standard grading rules for southern pine permit sapwood in all grades of products manufactured, including flooring, unless otherwise stated.

Should flooring of uniform color be essential, it would be necessary to add a requirement to the standard flooring specifications to obtain this special stock; i.e., only all-sap-face stock to secure a light-colored floor, or all-heart-face material to obtain a reddish-brown floor. However, such a modification of the standard specification for flooring requires special selection of stock for color and, therefore, the cost is higher than that of the established grade.

Douglas-Fir

Douglas-fir, which grows in the western part of the United States and Canada, is occasionally called red fir, coast Douglas-fir, or Oregon pine. Douglas-fir occupies the same important position in the Western and Pacific Coast States that southern pine does in the Southeastern States.

The sapwood of Douglas-fir is creamy white. The heartwood is reddish brown, and as with southern pine, the contrast in color between the two is not so pronounced as to be objectionable in a finished floor. Pieces containing both heartwood and sapwood are admitted in all grades.

Western Hemlock

Western hemlock grows along the Pacific Coast from northern California to Alaska and as far inland as northern Idaho and northwestern Montana. The bulk of that produced comes from Washington. This wood is commercially called west-coast hemlock. Both the heartwood and sapwood of western hemlock are almost white with a pinkish tinge and with very little contrast, although the sapwood may sometimes be lighter in color.

Western hemlock has a combination of properties that make it usable for many types of flooring. Its light, clear color, and good finishing qualities are accountable for its use in flooring where good appearance under moderate wear is the principal requirement. Although it withstands reasonable abrasive or impact service, it mars and dents more readily than the hardwoods and the more commonly used softwoods, such as southern pine and Douglas-fir. Western hemlock flooring is relatively free from warping, and is easy to cut and nail. Experience with western hemlock as a high-grade finish floor, however, has been confined largely to its use as an alternate for hardwoods in bedrooms. For the most part, the use of western hemlock flooring has been confined to the regions of its production.

Other Softwoods

The remaining 3 percent or so of all softwood flooring is supplied by 8 other species. Western larch is similar to Douglas-fir in strength properties, and is often sold in mixture with Douglas-fir of the northern interior States. Some of the species, like ponderosa pine, eastern white pine, and redwood, are softer than is desirable where wear is a factor. Where the flooring will be covered, as with linoleum, this objection would not hold. The decay resistance of redwood in the all-heart grade has prompted its use for porch flooring. Eastern hemlock, spruce, cypress, and the true firs also are made into flooring on a small scale.

TYPES AND GRADES OF WOOD STRIP FLOORING

Types

Hardwood flooring is manufactured in a variety of widths and thicknesses, most commonly in what is known as the standard pattern. The most widely used standard pattern is $^{25}/_{32}$ inch thick and has a face width of 2¼ inches, but other widths and thicknesses are available in this pattern. One edge has a tongue and the other a groove, and the ends are similarly matched (fig.

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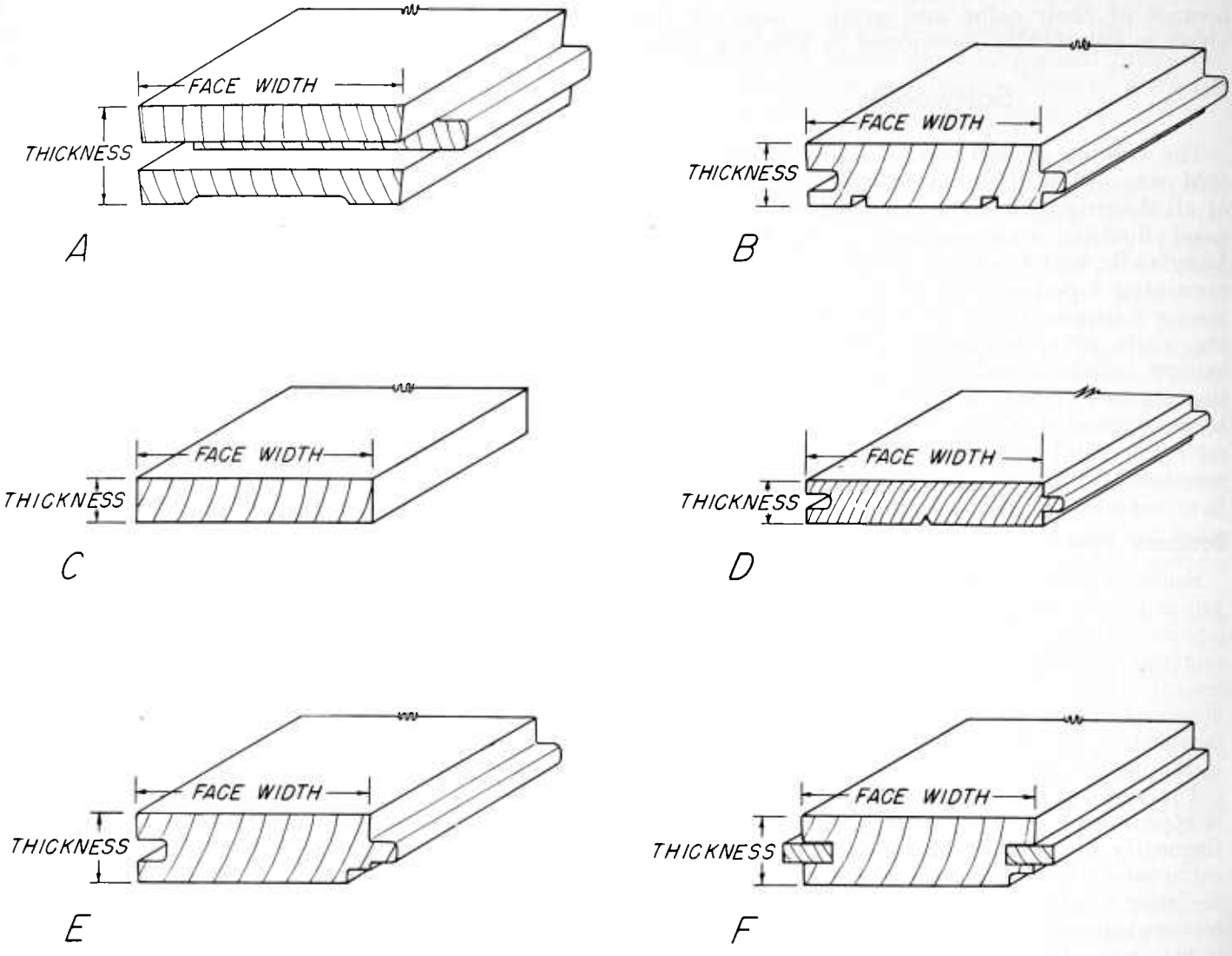

FIGURE 2.—Types of flooring: *A*, Side and end matched; *B*, side matched, plain end; *C*, square edged; *D*, scratch backed, sometimes used on softwood flooring; *E*, flat backed with notched recess for laying directly in mastic; *F*, flooring with spline.

2, *A*). The strips are random length, varying from 1 to 16 feet in length in separate bundles. The proportion of short pieces will depend on the grade used. Some softwood flooring is side-matched only, the ends being square (fig. 2, *B*).

Flooring of standard pattern is generally hollow backed (fig. 2, *A*) or scratch backed (fig. 2, *D*). The top face is generally slightly wider than the bottom, so that when the strips are driven tightly together, the upper edges make contact but the lower edges are slightly separated. Standard pattern flooring may be installed over wood framing by nailing to the subfloor or to wood strips or sleepers over a concrete base. This type of flooring is commonly installed by blind nailing at the intersection of the tongue and shoulder, so that no nails show in the finished floor.

Another pattern of strip flooring used to a limited degree has square edges and a flat back (fig. 2, *C*). This is generally thinner than the standard pattern and is usually installed by face nailing. The nails are driven and set so the floor filler used in finishing will fill and conceal the holes.

The majority of strip flooring is laid by concealed or blind nailing to wood subfloors or to wood sleepers. While some strip flooring is laid directly in mastic on a concrete base, largely using short lengths in special designs such as herringbone, it is more common, for this type of base, to use special patterns specifically designed for laying in mastic (fig. 2, *E* and *F*). Generally, these have flat backs for greater contact with the adhesive and, in addition, a recess milled into the lower surface below the tongue to reduce the possibility of mastic being forced up through the opening between adjacent strips and thus staining the wearing surface.

Some square-edged and flat-backed flooring is made for laying in mastic. This generally is grooved on the edges for insertion of a spline and has a mastic trap on the side (fig. 2, *F*).

Softwood flooring is made both end matched and with plain ends. It is made with a hollow back, or sometimes with a single V-shaped groove in the back (fig. 2, *D*).

Grades and Sizes

Standard flooring grades are based almost wholly on appearance. That is, they exclude or severely limit such defects as knots, wormholes, and the like in the higher grades and permit increasing sizes and numbers of these characteristics in the lower grades. Natural variations in color are generally not limited except that, in certain grades, the amount of the lighter colored sapwood is restricted. Special grades, selected for color, may be obtained in maple, beech, and birch. This is generally limited to the highest grade (clear) in which all-sap or all-heart maple and all-heart beech or birch may be obtained. The extra selection for color increases the cost of these special grades as compared with the standard grades.

Oak

Oak is regularly manufactured into plainsawed and quartersawed flooring. Most of the oak flooring used is plainsawed, the lower priced of the two. Quartersawed oak is characterized by a rather striking figure, and by a minimum shrinking and swelling in width. The term rift-sawed has come into common use in recent years. In practice, this means a type intermediate between true plainsawed and true quartersawed, and produces a less striking figure than the latter. Oak flooring is graded under the rules of the National Oak Flooring Manufacturers' Association (table 1).

TABLE 1.—*Grade, description, and dimensions* [1] *of oak flooring* [2]

Kind of flooring	Grade		Standard length
	Name	Description	
			Feet
Quartersawed	Clear	The face shall be practically clear, admitting an average of ⅜ inch of bright sap. The question of color shall not be considered.	2 and up; av., 4¼.
Do	Select	The face may contain burls, small streaks, pinworm holes, slight imperfections in working, and small tight knots that do not average more than 1 to every 3 feet.	2 and up; av., 3¾.
Plainsawed	Clear	The face shall be practically clear, admitting an average of ⅜ inch of bright sap. The question of color shall not be considered.	2 and up; av., 4¼.
Do	Select	The face may contain burls, small streaks, pinworm holes, slight imperfections in working, and small tight knots that do not average more than 1 to every 3 feet.	2 and up; av., 3¾.
Do	No. 1 Common.	Shall be of such nature as will lay a good residential floor and may contain varying wood characteristics, such as flags, heavy streaks and checks, wormholes, knots, and minor imperfections in working.	2 and up; av., 3.

[1] All grades are made in the following combinations of thickness and width: $^{25}/_{32}$-inch thickness, 3¼-, 2¼-, 2-, and 1½-inch widths; ½- and ⅜-inch thicknesses, 2- and 1½-inch widths.

[2] Data are from rules of the National Oak Flooring Association in effect June 17, 1957. All flooring listed is kiln-dried, grade-marked, trade-marked, hollow backed, and side and end matched. For lower grades than those listed above and for square-edge strip flooring, see the latest issue of the grading rules of the National Oak Flooring Manufacturers' Association, 814 Sterick Bldg., Memphis, Tenn.

By far the most common thickness for oak flooring used in homes is $^{25}/_{32}$ inch, although thinner flooring is available for use where service is light or for installation as replacement over existing floors. Flooring thicker than $^{25}/_{32}$ inch is made, but is intended for use under heavy service rather than in homes.

Although the great bulk of oak strip flooring is end and side matched, some square-edge strip flooring is made. The grades are the same, but the thicknesses and widths differ, as indicated below:

Thickness (inch)	*Width (inches)*
$^{5}/_{16}$	⅞, 1, 1⅛, 1¼, 1⅓, 1½, 2
$^{11}/_{32}$	1½, 2

Three grades of prefinished flooring are recognized: Prime, Standard, and Tavern. In prefinished flooring, the red oak and white oak are separated after sanding and finishing.

Maple, Beech, and Birch

Flooring of these species is graded under the rules of the Maple Flooring Manufacturers' Association and also under the rules of the National Oak Flooring Manufacturers' Association (tables 2 and 3). The requirements under both sets of rules are essentially the same. Both generally disregard normal color variations, but, as indicated earlier, special grades are available in which uniformity of color is a requirement.

Most of the beech, birch, and maple flooring used in homes is in the $^{25}/_{32}$-inch thickness, but thinner sizes are available for use where service is light. Thicker flooring is made, but is not generally used in homes.

In addition to the more common end- and side-matched flooring, some square-edge (or jointed) flooring is made. Thicknesses are the same as for the standard pattern (⅜, ½, ⅝, and $^{25}/_{32}$ inch),

TABLE 2.—*Grades, description, and dimensions* [1] *of northern hard maple, beech, and birch flooring* [2]

Kind of wood	Grade		Standard length
	Name	Description	
			Feet
Beech, birch, and maple.	First grade	Shall have the face practically free from all defects, but the varying natural color of the wood shall not be considered a defect.	2 and up. Not over 30 percent under 4 feet.
Do	Second grade	Will admit tight sound knots and slight imperfections in dressing, but must lay without waste.	2 and up. Not over 45 percent under 4 feet.
Maple	Selected first grade, light northern hard maple.[3]	Special stock selected for uniformity of color. It is almost ivory white and is the finest grade.	2 and up. Not over 30 percent under 4 feet.
Do	Selected first grade, amber northern hard maple.[3]	Special stock selected for uniform brown color. It has more grain pattern than other types.	Do.
Beech and birch	Selected first grade, red.[3]	Made from all-red-faced stock especially selected for color.	Do.

[1] All grades are made in the following combinations of thickness and width: 25/32-inch thickness, 3¼-, 2¼-, 2-, and 1½-inch widths; 5/8-, ½-, and 3/8-inch thicknesses, 2¼-, 2-, and 1½-inch widths.

[2] Data are from grading rules of the Maple Flooring Manufacturers' Association in effect December 4, 1956. All flooring listed is kiln-dried, grade-marked, trade-marked, and side and end matched. The hollow back is optional. For lower grades than those listed above and for jointed (square-edge) flooring, see the latest issue of the grading rules of the Maple Flooring Manufacturers' Association, 35 East Wacker Drive, Chicago, Ill.

[3] Special grade.

but the widths differ somewhat, being 2¼, 2½, 3¼, 3⅜, and 3½ inches.

The first grade is especially suitable where fine appearance and high wear resistance are both desired. The second grade is about equally serviceable, but because of small imperfections does not present so good an appearance. The third grade is chiefly used where the main requirement is service rather than appearance.

Southern Pine

Southern pine is regularly manufactured in side- and end-matched flooring and also in plain-end flooring that is side matched only. All southern

TABLE 3.—*Grade, description, and dimensions* [1] *of beech, birch, hard maple, and pecan flooring* [2]

Kind of wood	Grade		Standard length
	Name	Description	
			Feet
Beech, birch, and maple.	First grade	Shall have the face practically free from all defects, but the varying color of the wood shall not be a defect.	2 and up. Not over 30 percent of 2 and 3.
Do	Second grade	Will admit tight sound knots and slight imperfections in dressing, but must lay without waste.	2 and up. Not over 45 percent of 2 and 3.
Maple	First grade, white hard maple.	Special stock selected for uniformity of color. It is almost ivory white and is the finest grade.	2 and up. Not over 30 percent of 2 and 3.
Beech and birch	First grade, red beech and birch.	All-red-faced stock especially selected for color	Do.
Pecan	First grade	Shall be practically free from defects, but the varying natural color of the wood shall not be considered a defect.	2 and up. Not over 25 percent of 2 and 3.
Do	First grade, red	Same as first grade except that face shall be all heartwood.	2 and up. Not over 25 percent of 2 and 3.
Do	First grade, white	Same as first grade except that face shall be all bright sapwood.	Do.
Do	Second grade	Will admit tight, sound knots or their equivalent, pinworm holes, streaks, light stain, and slight imperfections in working. Shall be of such nature as to lay a sound floor without cutting.	1¼ and up. Not over 40 percent of 1¼ to 3.

[1] All grades are made in the following combinations of thickness and width: 25/32-inch thickness, 3¼-, 2¼-, 2- and 1½-inch widths; ½- and 3/8-inch thicknesses, 2- and 1½-inch widths.

[2] Data are from grading rules of the National Oak Flooring Manufacturers' Association in effect June 27, 1957. All flooring listed is kiln-dried, grade-marked, trade-marked, hollow backed, and side and end matched. For lower grades than those listed above and for jointed (square-edge) flooring, see the latest issue of the grading rules of the National Oak Flooring Manufacturers' Association, 814 Sterick Bldg., Memphis, Tenn.

TABLE 4.—*Grades, descriptions, and dimensions [1] of southern pine flooring [2]*

Kind of flooring	Grade		Standard length
	Name	Description	
			Feet
Flat-grain	A	Clear or practically clear, requires best manufacture, and admits very small surface checks and very light warp.	4–20 with 5 percent of 8 and/or 9.
	B	Admits checks, small surface checks; firm red heart, on not over 5 percent of face; knots, one sound-intergrown pin knot in any 4 feet of length in 4 to 20 feet or one in each piece if under 4 feet long; manufacture, standard B manufacture; pitch, one very small closed pitch pocket and one small pitch streak in any 4 feet of length in 4 to 20 feet or one in each piece if under 4 feet long, diffused general pitch not permitted; stain, light stain only and on not over 15 percent of face; warp, light warp.	Do.
	C	Admits somewhat larger and more numerous characteristics than B.	4–20 with 5 percent of 6 and/or 7 and 7 percent of 8 and/or 9.
Edge-grain (or vertical-grain).	A, B, and C.	Same as for flat-grain, except lumber has an average of at least six annual rings per inch across its face at each point in length, and the annual rings form an angle of 45° or more with the face. When the angle becomes less than 45° at any point, the lumber may be classed as flat-grain or near-rift, as the case may be.	4–20.
Near-rift	A, B, and C.	Same as for flat-grain, except lumber either has fewer rings per inch than required in edge-grain but otherwise conforms to the edge-grain provision, or has an average of at least six annual rings per inch across the face at each point in the length and has only one edge of the grain on the face but forms an angle of less than 45° with the face side.	4–20.

[1] Made in thicknesses of 5/16, 7/16, 9/16, and 25/32 inch and in widths of 1½, 2⅜, 3¼, 4¼, and 5¼ inches.

[2] Data are from the rules of the Southern Pine Association in effect June 1, 1956. Specifications apply to kiln-dried flooring. It may be plain-end or end-matched. Unless otherwise specified, orders are construed as applying to plain-end, flat-grain, or mixed grain. Standard working is either scratch backed or hollow backed. Grade-marking and trade-marking are optional.

pine flooring, irrespective of how it is worked to pattern, is available in both flat-grain [3] and edge-grain [4] stock (fig. 1). A class of southern pine flooring intermediate between edge-grain and flat-grain stock is known as near-rift flooring (table 4). This is not flat grain, and yet the angle of the rings in such flooring does not meet the requirements for edge-grain material. Because of this fact, one of the grade requirements for near-rift flooring is that it must show an average of six or more annual growth rings measured anywhere across the face of the piece.

Edge-grain southern pine flooring, because of its better wearing quality and the more pleasing appearance of its uniform grain pattern, is suited to the rooms on the living floors of the house, while the flat-grain stock adequately meets the requirements of bedroom floors. Southern pine flooring is graded under the rules of the Southern Pine Association (table 4).

[3] Flat-grain lumber is that in which the annual rings form an angle of less than 45° with the surface of the piece. Synonymous terms: Flat-sawed, plainsawed.

[4] Edge-grain flooring has at least 6 annual rings across its face, and the annual rings form an angle of 45° or more with the surface of the piece. Synonymous terms: Rift-grain, vertical-grain, quartersawed.

Douglas-fir

With the exception of the B and Better grade, which is manufactured only from vertical-grain material, Douglas-fir flooring in the upper grades is regularly manufactured in both vertical-grain and flat-grain stock. B and Better Douglas-fir flooring is also selected for density, allowing only such material as shows not less than six annual growth rings per inch on either end of the piece. As does southern pine, vertical-grain Douglas-fir possesses better wearing qualities than does flat-grain Douglas-fir flooring. Douglas-fir flooring is tongued and grooved, but not end matched. All flooring of this species is graded under the rules of the West Coast Lumbermen's Association (table 5).

Western hemlock

The grades of western hemlock flooring are identical with those for Douglas-fir. It, too, is graded under the rules of the West Coast Lumbermen's Association (table 5), as are spruce and western redcedar flooring.

TABLE 5.—*Grades, descriptions, and dimensions* [1] *of Douglas-fir and western hemlock flooring* [2]

Kind of flooring	Grade		Standard length
	Name	Description	
			Feet
Vertical-grain (edge-grain).	B & Btr	Pieces of this grade are of sound wood and are vertical grain, with not less than 6 annual rings per inch. Most pieces are entirely clear or have only a few minor and unimportant characteristics, such as very slightly torn grain, three very small pitch pockets or their equivalents, tongue 1/16 inch narrow.	4 to 16 or longer. Not less than 90 percent 8 to 16 or longer. Not more than 3 percent 4 and/or 5.
	C	Pieces of this grade are of sound wood with not less than 4 annual rings per inch. Pieces are vertical grain except that occasional pieces may have an angle of grain between 45° and 60° from vertical. Pieces of this grade may have one or more characteristics which are of such size and number that the piece is not of "B & Btr." grade. Some pieces may have light stain, 25 percent; two small seasoning checks; slightly torn grain; two small, sound, tight knots or their equivalent; or three small pitch pockets or their equivalent; tongue 1/16 inch narrow. A 3-inch cutout 4 feet or more from either end of pieces 12 feet and longer is permissible in 10 percent of the shipment if the piece is otherwise "B & Btr."	Do.
	D	Admits somewhat larger and more numerous characteristics than C.	4 to 16 or longer. Not less than 80 percent 8 to 16 or longer.
Flat-grain or mixed grain.	C & Btr	Pieces of this grade are of sound wood. Most pieces are entirely clear or have only a few minor and unimportant characteristics, such as medium stained wood; two small seasoning checks; slightly torn grain; two small, sound, tight knots or their equivalent; or three small pitch pockets or their equivalent; tongue 1/16 inch narrow. A 3-inch cutout 4 feet or more from either end of pieces 12 feet and longer is permissible in 5 percent of the shipment if the piece is otherwise of a high type.	Same as B & Btr. and C above.
	D	Same as D vertical-grain	Same as D above.

[1] Made in thickness of 25/32 and in widths of 2 3/8, 3 1/4, and 5 3/16 inches.

[2] Data are from the rules of the West Coast Lumbermen's Association in effect March 15, 1956. Specifications apply to kiln-dried flooring. The back of the pieces may be partially surfaced or hollow or scratch backed. Grade-marking and trade-marking are optional. Western hemlock is graded like Douglas-fir in the same grades and types of grain, with the following exception. In describing hemlock grades, the term "bark pockets" is used where the fir grades use the term "pitch pockets." The grading rules also include spruce (VG and FG) and western redcedar (VG only).

TYPES AND GRADES OF WOOD BLOCK AND PLANK FLOORING

Block Flooring

Two basic types of construction are used in the manufacture of wood block flooring. In one, variously called "block," "unit block," or "solid unit block," short lengths of standard strip flooring are joined together edgewise to form square units (fig. 3, *A*), generally with wood or metal splines embedded in the lower surface. In the second type, three or more plies of veneer are bonded with adhesive to obtain the desired thickness, the grain direction of the center ply being at right angles to that of the two surface plies (fig. 3, *B*). This latter type is generally known as "laminated" block or as "plywood" block.

In addition to the two basic types described above, there is a variety of other constructions, too numerous to attempt to describe in detail. One type, however, utilizes thin, square-edged strips bonded to a flexible membrane, usually paper (fig. 3, *C*). In at least one instance, small squares of wood are bonded to paper to form a mosaic pattern. The function of the paper bonded to the upper face is simply to hold the strips or squares as a unit until the block is laid; it is then stripped off. These types are generally composed of relatively small squares, a number of which are assembled for laying as a unit.

Still another type might be more properly termed a tile rather than a block. It is made of specially dried hardwood veneer and is from 1/8 to 1/10 inch thick. Thus, in size and in method of laying, it resembles the resilient tiles. The flooring is made by press drying the veneer so that it is

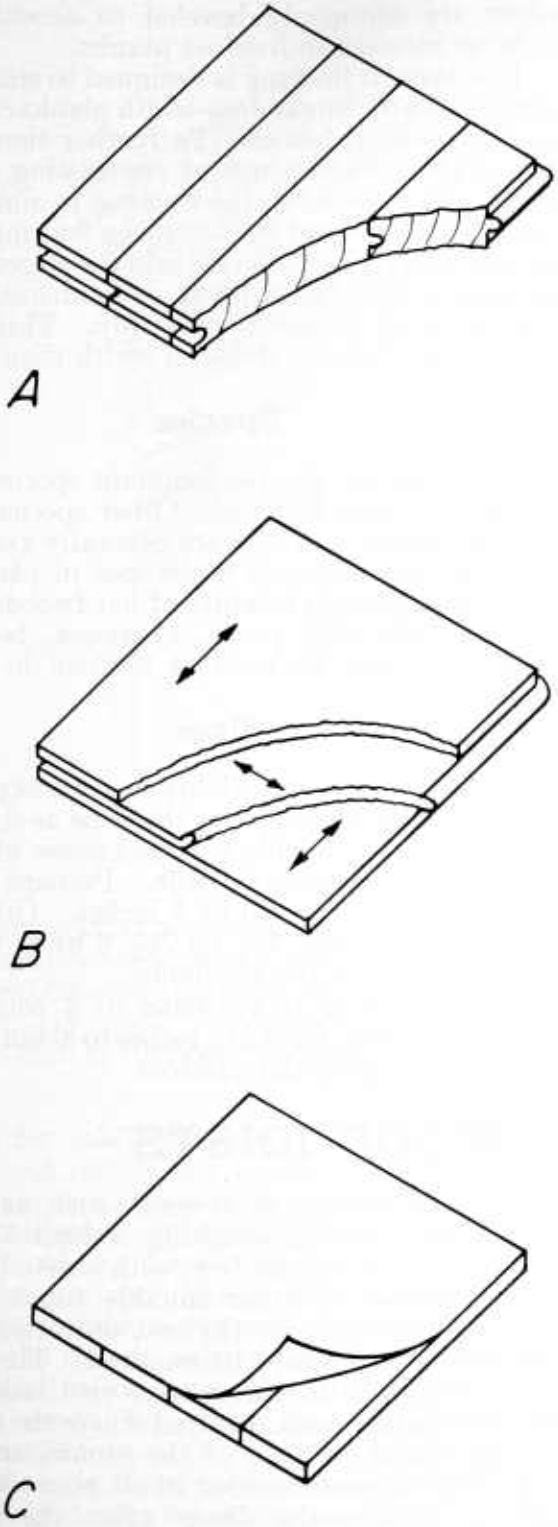

FIGURE 3.—Typical flooring blocks: *A*, Unit block; *B*, laminated (plywood) block; *C*, strips bonded to membrane.

restrained from shrinking during the drying process. This method results in numerous small, inconspicuous, uniformly distributed checks that materially reduce shrinkage and swelling across the grain with changes in moisture content and make the veneer rather flexible.

There are no generally accepted grades for block flooring,[5] probably because of the multiplicity of patterns and constructions. The unit block, however, may generally be purchased in the same grades as standard strip flooring, some manufacturers having, in addition, special grades. Manufacturers' literature on the laminated blocks sometimes refers to grades for the wearing surface which indicates that they adhere to generally the same requirements as for strip flooring, but generally in the higher grades. The laminated (plywood) block, by reason of its cross-laminated construction, shrinks and swells less than the strip. Less difficulty from changes in moisture content may therefore be expected.

Block flooring, whether unit or laminated, is generally tongued on two adjoining or opposing edges and grooved on the other two to assure alinement between adjoining blocks. Some manufacturers produce square-edged blocks, and at least one grooves all four edges and furnishes splines for insertion between adjoining blocks. Both types are designed to be installed either by nailing to a subfloor or by laying directly in a mastic. The membrane-supported type and the veneer tile are designed to be laid directly in mastic.

A wide choice of pattern is available in the unit-type block flooring. The most common pattern is that in which the strips are all laid with the grain directions parallel. In others, however, a variety of effects is possible by combining four small squares into a single unit, by banding the edges, and the like.

If a laminated or plywood flooring is to give satisfactory service, the glue bonds between the plies must be well made with glues that can withstand the probable conditions of service and remain intact during the life of the flooring. Service conditions can be expected to vary in different areas and in the different individual installations. In addition to the variations in moisture content typical of interior woodwork, some parts of the flooring may be in contact with or near sources of heat, such as radiators, space heaters, or steam pipes, where they will be heated well above the human comfort range. In other installations in warm, moist areas, as along the southern coast, conditions may be damp and warm enough to favor mold growth.

The different glues that are currently available to the woodworkers vary rather widely in their resistance to the various conditions of service, but include some that are practically immune to moisture, extremes in temperature, and molds or other micro-organisms. It is thus only necessary to employ the proper kind of glue in manufacture to secure satisfactory bonding to meet any requirements in service.

The most resistant adhesive types are phenol resin, resorcinol resin, resorcinol-phenol resin, and melamine resin. Joints well made with these glues

[5] Federal Specification NN-B-350, Block, Floor, Wood (Solid Unit and Laminated Hardwood) describes three grades for the solid unit block—Clear, Select, and No. 1 Common—that are very similar to those shown in table 1.

can be expected to withstand any type of service for which wood itself is suitable. Their resistance is distinctly higher than would be required by normal use of laminated flooring.

The melamine-urea resin type of glue is not so highly resistant as those mentioned above but, if reasonably high in melamine resin, may be expected to give results that are quite adequate for laminated flooring.

Urea-resin glues, casein glues, soybean glues, animal glues, starch glues, and polyvinyl glues can form joints that are strong in the dry condition, and some of them are moderately resistant to occasional exposure to water or to high humidities. Because the integrity of bonds in laminated block flooring with these adhesives cannot be assured under all conditions of service that could be considered normal for flooring, their use is not recommended.

As a general rule, the manufacturers of laminated flooring favor the melamine-urea resin type as a reasonable compromise between cost and resistance to moderately severe service conditions. The builder or the homeowner should make sure that a suitable type of adhesive has been used in the laminated blocks to meet his anticipated conditions of service.

Plank Flooring

Plank flooring is, in effect, strip flooring, except in greater widths. That is, it is usually the same thickness as strip flooring, is end and side matched, and may be installed in the same manner. It is generally available in random widths, and the edges are commonly beveled to accentuate the grooves between individual planks.

This type of flooring is designed to simulate the appearance of the random-width planks commonly used in colonial homes. To further simulate this appearance, wood plugs of contrasting color are sometimes inserted in the flooring to simulate the wood pins once used for fastening flooring, or pegs of various types may be set into the edges. Plank flooring is sometimes made in laminated form—that is, with a central cross ply. This form is more dimensionally stable in width than the solid form.

Species

Oak is by far the predominant species in both block and plank flooring. Other species, such as walnut, cherry, and teak are generally available in the block flooring and sometimes in plank flooring. Sometimes a mixture of hardwoods, such as hickory, ash, elm, pecan, sycamore, beech, and hackberry, may be used at random in a single block.

Sizes

Block flooring is available in a variety of sizes. Thicknesses commonly are the same as strip flooring ($^{25}/_{32}$ or $^{13}/_{16}$ inch), but thicknesses of $^{5}/_{16}$, $^{7}/_{16}$, and $^{1}/_{2}$ inch are also available. Perhaps the most common block size is 9 by 9 inches. Other sizes, such as $6^{3}/_{4}$ by $6^{3}/_{4}$, $7^{1}/_{2}$ by $7^{1}/_{2}$, 8 by 8, 10 by 10, and 12 by 12, are also available.

Plank flooring is available in a considerable range of widths, from $2^{1}/_{4}$ inches to about 8 inches. Lengths are generally random.

FLOORS LAID OVER WOOD JOISTS

Protection of Basementless Areas

Special consideration is required in floors for basementless houses having either a concrete slab laid directly on the ground or joists supported on foundations and separated from the soil by a crawl space. Both of these types of construction introduct the problem of keeping moisture from entering the wood floor from the soil below.

The crawl space below the floor of a basementless house and the space below porches supported on wood framing should be ventilated. Where there is a partial basement with one side adjacent to the crawl space, vents are not required in the outer walls of the crawl space if openings between the basement and the crawl space are equal to at least $^{1}/_{50}$ of the combined area of basement and crawl space. For crawl spaces where there is no basement, at least four foundation-wall vents should be provided near the corners of the building and having a total free ventilating area equal to $^{1}/_{160}$ of the ground area (fig. 4). Vent openings should be covered with corrosion-resistant screening having 4 to 8 meshes per inch.

Where a soil cover is used, such as smooth-surface roll roofing weighing at least 55 pounds per roll of 108 square feet, with sheets lapped at least 2 inches, or other suitable vapor resistant material such as polyethylene, only two foundation wall vents would be required. They should be so located as to assure cross ventilation. The free ventilating area required where the soil cover is used would be $^{1}/_{1600}$ of the ground area. The soil cover is recommended in all places where the soil is consistently damp after the house is completed.

The Subfloor

When joists or beams are used as floor supports, a subfloor should be laid over the framing. A subfloor serves several important functions. It brings the tops of the joists to a common level, helps stiffen the floor, blocks off cracks that may develop in finish flooring, serves as a safe working surface for workmen during construction, and provides a level base for finish floor and partition soleplates.

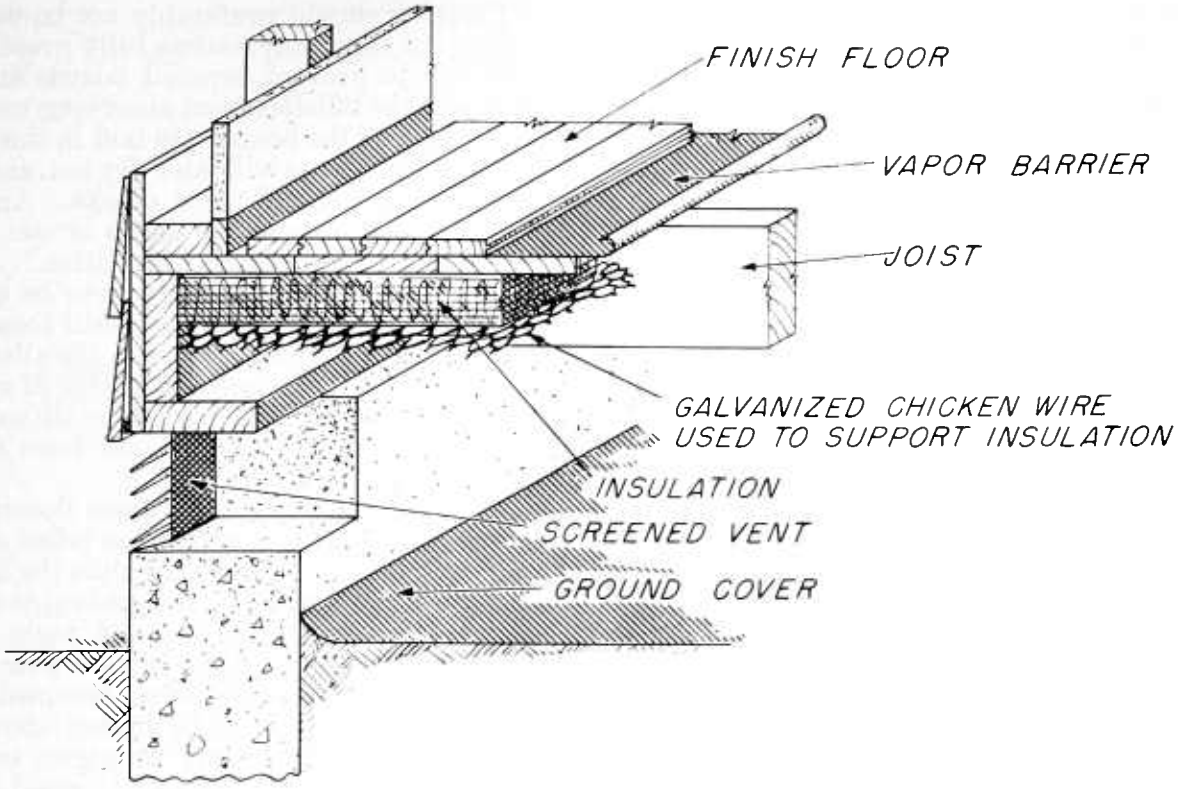

FIGURE 4.—Crawl-space ventilator and soil cover.

The requirements for subflooring include good stiffness, nail-holding power, and ease of application. Subflooring may be of nominal inch boards or plywood. Sometimes 2-inch plank decking is used as subflooring over beam framing.

Boards

Boards for subflooring may be of any species of wood, and should not be less than nominal 1 inch thick nor more than 8 inches wide. The optimum moisture content is about 12 percent in most parts of the United States. No. 3 Common is the minimum grade for such species as Douglas-fir, southern cypress, western hemlock, redwood, the cedars, eastern hemlock, tamarack, and southern yellow pine. No. 4 Common is the minimum grade for white fir, western larch, spruce (except Sitka), ponderosa pine, sugar pine, Idaho white pine, eastern white pine, and red pine.

Square-edged, shiplap, or tongued-and-grooved boards may be used. Tongued-and-grooved end-matched boards of random length are used, but must be long enough so that each board will bear on at least two joists and so installed that end joints of adjacent boards will not occur between the same pair of joists. With square-edged or shiplap boards, end joints should always be made over a joist. Boards less than 8 inches wide should be nailed at each joist with 2 eightpenny nails and 8-inch boards with 3 nails. Boards may be applied diagonally or at right angles to the joists, but commonly they are laid diagonally, since this method provides greater bracing.

The joist spacing should not exceed 16 inches, center to center, when finish strip flooring is laid parallel to the joists or the finish floor consists of parquet, block, or floor tile; nor 24 inches when strip flooring $^{25}/_{32}$ inch thick is laid at right angles to the joists.

If subfloors may be exposed to rain during construction, square-edged boards should be laid with open joints for drainage, and tongued-and-grooved boards should have holes at suitable intervals to allow runoff of rainwater. If the house is of balloon frame construction, blocking should be installed between ends of joists at the walls as a nailing base for the ends of diagonal subfloor boards and also where subflooring is cut away for plumbing, heating, or similar openings. A ½-inch clearance should be provided between the subfloor and masonry or concrete walls.

Plywood

Subfloors may be 5-ply structural interior plywood if used where it is fully protected, as over a heated basement, or 5-ply exterior plywood when exposed to dampness, such as may occur in crawl spaces. Plywood should be installed with the outer plies at right angles with the joists and with end joints meeting over joists.

Minimum plywood thicknesses and maximum joist spacings as required by the Federal Housing Administration are shown in table 6. Plywood ⅜ inch thick may be used under $^{25}/_{32}$-inch wood strip flooring for a working surface or construction deck, provided the joists are spaced not over

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16 inches on center, and the finish flooring is installed at right angles to the joists and nailed to them.

Plywood subfloor should be nailed at each bearing with eightpenny common nails or special types (such as grooved nails) of comparable size spaced 6 inches on center along all edges and 10 inches on center along intermediate bearing members. A ½-inch clearance between the plywood subfloor and masonry or concrete walls should be provided.

Occasionally the floor framing may be beams, somewhat larger and spaced at greater intervals than joists. When this occurs, the beams may be covered with thick plywood, such as that designated 2–4–1 by the industry. The plywood then serves the dual function of a structural floor and a subfloor.

TABLE 6.—*Minimum plywood subflooring thickness and maximum joist spacing for Douglas-fir and western softwood plywoods*

Plywood species	Minimum thickness	Maximum joist spacing (on center)	
		Wood strip flooring	Wood block [1]
	Inches	*Inches*	*Inches*
Douglas-fir	½	[2] 16	16
	⅝	[2] 20	20
	¾	24	24
Western softwoods	⅝	[2] 16	16
	¾	[2] 20	20
	⅞	24	24

[1] Solid blocking is used under all plywood edges at right angles to joists
[2] May be 24 inches on center where 25/32-inch strip floor is installed at right angles to the joist.

Plank

Plank subflooring is sometimes used over beam framing in place of joists and boards, the plank serving as a support for the finish floor. Plank should be of nominal 2-inch material, with tongued-and-grooved or splined edges and not over 8 inches wide. End joints should occur over a support, and no two adjacent planks should have joints over the same support.

Installation of the Finish Floor

Delivery and Storage of Flooring

The proper moisture content of flooring at time of installation is an all-important factor in obtaining a satisfactory floor. The manufacturer and dealer share the responsibility of providing properly dried material, and it is necessary, for best results, to use equal care to protect it from moisture at the construction site.

Flooring should preferably not be delivered on a damp or rainy day, unless fully protected. The object is to prevent exposed boards and ends of others in the bundles from absorbing moisture and swelling. If the boards are laid in this condition, the excess moisture will later dry out, and the flooring will shrink and show cracks. Any flooring inadvertently exposed to damp or wet conditions should be redried before installation.

If wet plaster or masonry is to be used in the home, it is preferable to wait until these are thoroughly dry before delivery and installation of the flooring. This prevents absorption of moisture by the flooring from the high humidities that prevail with moisture evaporation from the plaster and cement.

Another condition that causes flooring to pick up moisture during construction is less obvious but more common. Between the time the floor is laid and the house occupied, the general temperatures within the house both day and night are likely to be lower and the humidities higher than they would be if the house were occupied. At this stage the house should be heated above outdoor temperature, particularly at night, to keep the relative humidity low enough to avoid absorption of moisture by the wood.

In summary, five simple precautions should be observed to keep flooring dry, particularly strip and unit block types: (1) Do not truck or transfer flooring in rain or snow; (2) do not store flooring on the job outside of shelter or in a damp enclosure; (3) do not lay flooring when the building is cold and damp; wait until the plaster and cement work are thoroughly dry; (4) maintain a temperature inside the house at least 15° F. above outdoor temperatures during off-work periods and do not let it cool below about 70° F. during the summer or about 62° to 65° F. when the outdoor temperatures are below freezing (temperatures a little higher will do no harm, but severe overheating should be avoided); and (5) with interior conditions controlled as above, open the bundles of flooring and pile it loosely in the building for at least 4 days prior to laying so that it may come to equilibrium with conditions within the building.

Veneer tile flooring generally comes in moisture-resistant packages that are not to be opened until just before the flooring is laid. Other types may be similarly protected, and the manufacturer's instructions should be followed.

Desirable Moisture Content

The recommended average moisture content for flooring at time of laying is about 6 percent for the dry Southwestern States and about 7 percent (hardwood) or 8 percent (softwood) for the majority of the rest of the United States (table 7 and fig. 5). Substantial deviation from the recommended values may be expected to result in cracks between flooring boards if the initial moisture content is too high, or in buckled floors if the

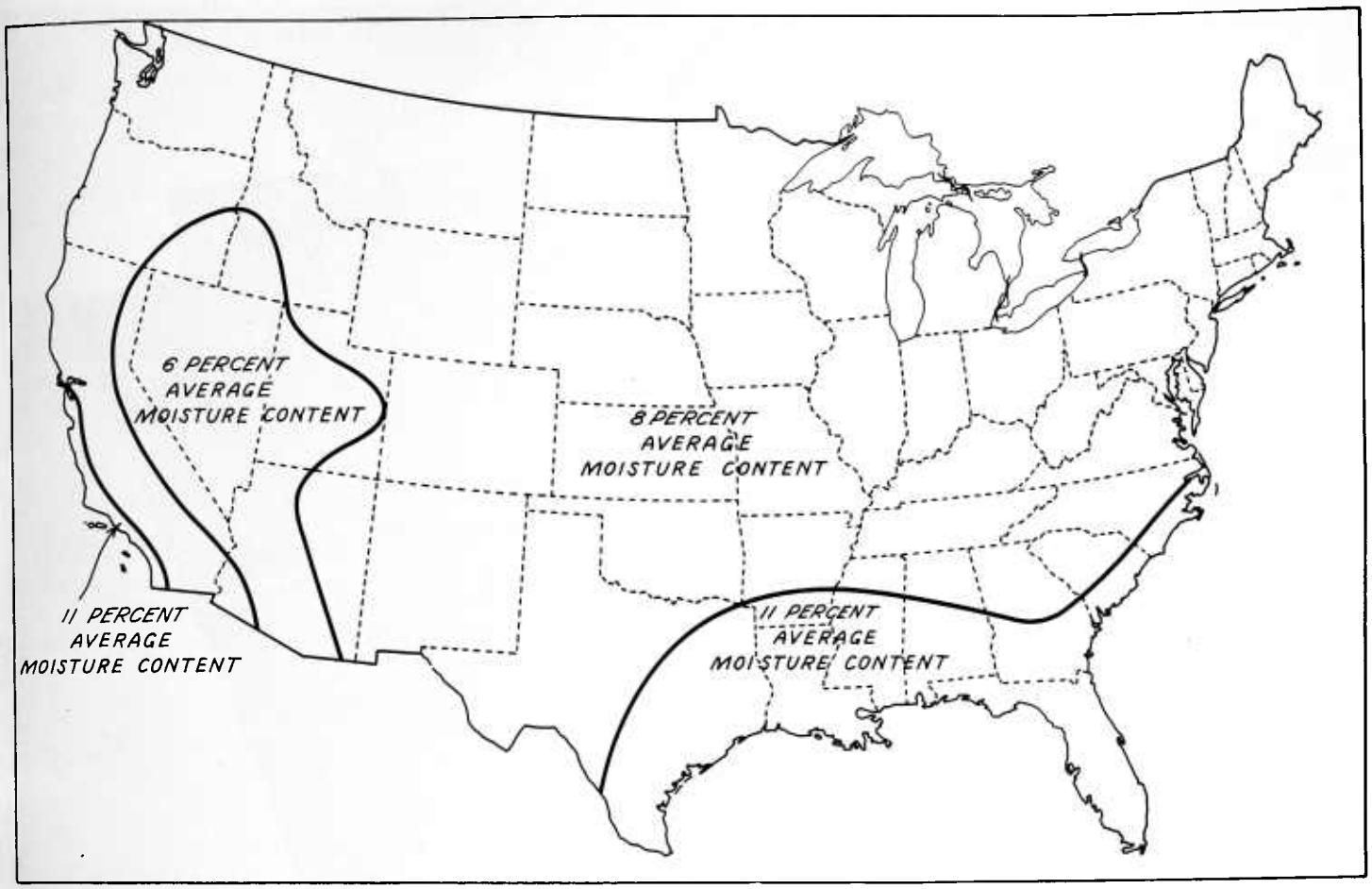

FIGURE 5.—Recommended moisture content averages for interior flooring installed over wood joist for use in various parts of the United States.

initial moisture content is too low. For floors laid over concrete slabs, slightly higher moisture contents are suitable, as indicated later.

Paper Over Subfloor

It is common practice to cover the subfloor with a deadening felt or heavy building paper, or both (fig. 6). This felt or paper serves one or more of several purposes. It will prevent dust from working up through the finish floor, acts as a sound deadener, reduces air infiltration from crawl spaces in basementless houses, retards moisture from rising through the floor from damp basements or from the soil under basementless houses. Papers and felts will reduce air infiltration in crawl-space houses, but this factor is relatively unimportant where curtain walls are used around the crawl space.

Moisture rising through the floor of basementless houses has been assumed to be one important source of moisture in houses subject to cold weather condensation. While there may be some question about this, a vapor-resistant paper would minimize this source of moisture. In general, paper or deadening felt appears unnecessary in one-story houses in mild climates, and the felt might be used under the second floor only in two-story houses.

TABLE 7.—*Recommended moisture content values for wood flooring at time of installation*

Location and type of flooring	Moisture content (percent of weight of ovendry wood)	
	Average [1]	Individual pieces
Dry Southwestern States: [2]	*Percent*	*Percent*
Softwood flooring	6	4–9
Hardwood flooring	6	5–8
Damp Southern Coastal States: [2]		
Softwood flooring	11	8–13
Hardwood flooring	10	9–12
Remainder of United States: [2]		
Softwood flooring	8	5–10
Hardwood flooring	7	6–9

[1] If the average moisture content is within ±1 percent of that recommended and the moisture content values of all the pieces tested fall within the prescribed range, the entire lot will probably be satisfactory. To obtain a realistic average, test at least 10 percent of each item.

[2] For limiting range, see figure 4.

Since plywood subflooring acts as a wind and dust stop, the principal purpose of using paper would be to deaden sound. Paper or felt is not generally used where resilient tile or wood floors are laid in mastic.

FIGURE 6.—Marking position of joists on paper and felt for guidance in nailing. M100945F

Installing Strip Flooring

The flooring strips should be started square with the room (fig. 7, *A*). Since, in modern house construction, thresholds are no longer used, all flooring is laid in one direction to avoid the unsightly break that would occur at each opening if the direction were varied in each room on the same floor. Strip flooring should be laid crosswise to the floor joists, and looks best when laid lengthwise in a rectangular room. Since joists generally span the short way in a living room, that room establishes the direction for flooring in other rooms.

The first strip of flooring is placed parallel to the wall with the tongue edge out and is face nailed near the groove edge. The nails should be driven into the joists and near enough to the edge of the strip so that they will be covered by the shoe molding (fig. 7, *B*). Alternatively, the first strip of flooring may be nailed through the tongue. Figure 7, *C* shows that the nail is driven in where the tongue adjoins the shoulder and at an angle between 45° and 50°. The nail should not be driven completely down with the hammer as the edge of the flooring may be easily struck and damaged (fig. 7, *D*). A nail set, in the position shown in figure 7, *D*, should be used for the final driving. Predrilling the holes through the tongue is sometimes necessary to avoid splitting the flooring, and makes it easier to drive the nails into the joist.

Several types of nailing machines have been developed to facilitate the nailing of the various patterns of flooring. Some of these are mechanical devices that use conventional nails and drop one nail at a time into position to be driven into the wood by a plunger that is struck with a hammer. Other devices use special types of nails in which the head is the same thickness as the shank and are

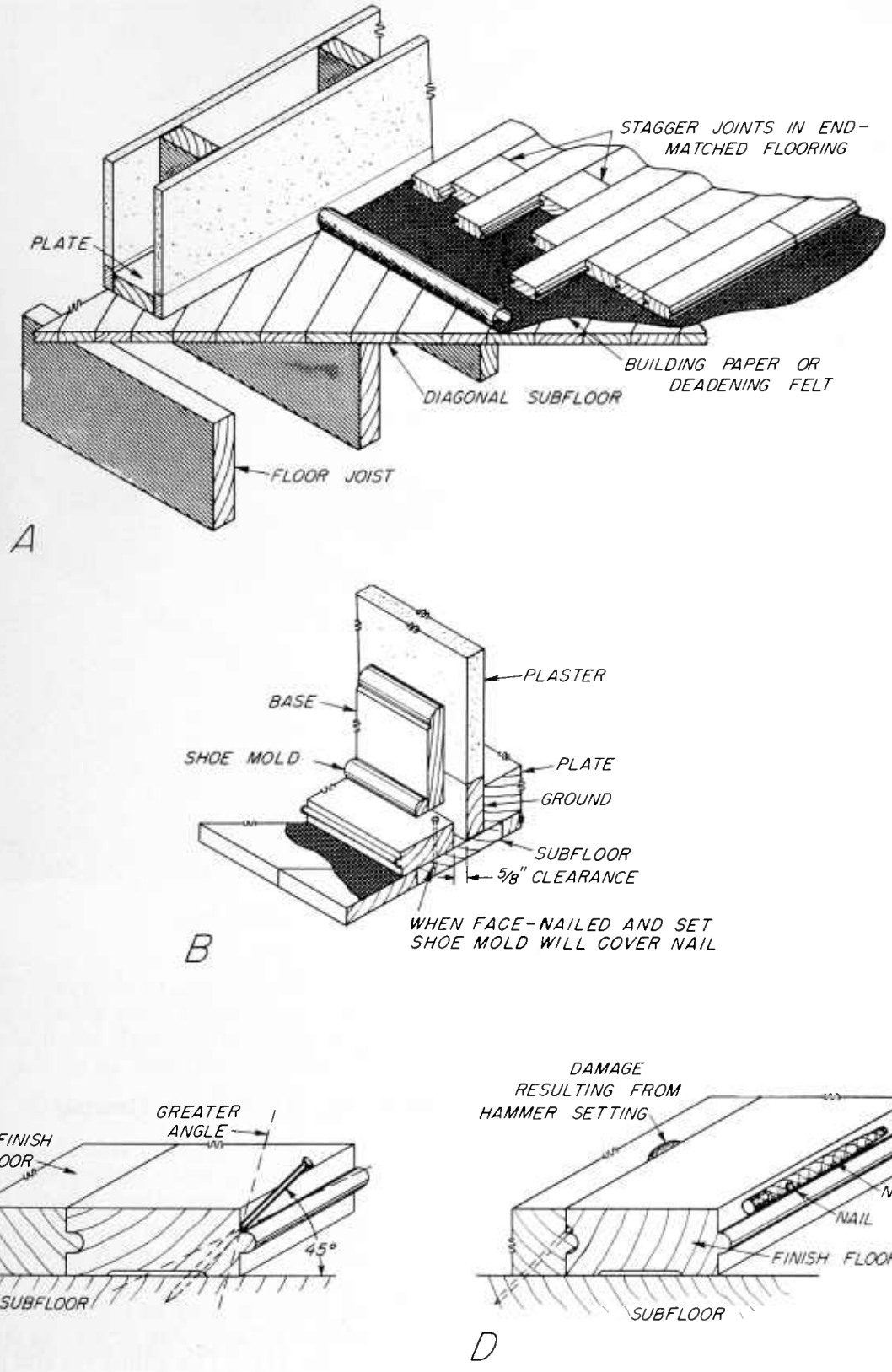

FIGURE 7.—Application of strip flooring: *A*, General application; *B*, laying first strip; *C*, nailing method; *D*, suggested method for setting nails.

fastened together lightly into clips. These clips, when installed in the machine (fig. 8), feed the nails one at a time beneath a plunger that drives the nail into the wood (fig. 9). The plunger can be adjusted so that the head of the nail, either in blind or face nailing, can be set below the surface of the wood (fig. 10).

For the second course of flooring, select the pieces so that the butt joints will be well separated from those in the first course. For floors to be covered with rugs, the long lengths could be used at the sides of the room and the short lengths in the center where they will be covered. Each board should be driven up snugly. To avoid crushing

FIGURE 8.—Installing nail clips in floor nailing machine. M100946F

the tongue with the hammer, a piece of scrap flooring should be used as a driving block. Slightly crooked pieces may require wedging to force them into alinement. Pieces with serious crook should be rejected.

Floor squeaks are caused by the movement of one board against another. Adequate nailing is one important means of minimizing floor squeaks. When possible, nail the finish floor through the subfloor into the joist—it is much better than nailing the finish floor only into the subfloor. Various types of nails are used in nailing various thicknesses of flooring. For $^{25}/_{32}$-inch flooring, eightpenny steel cut flooring nails are recommended; for $^{1}/_{2}$-inch, sixpenny, and for $^{3}/_{8}$-inch, fourpenny bright wire casing nails. All the foregoing are to be blind-nailed at a uniform spacing not greater than 10 inches.

For square-edge flooring, $1^{1}/_{8}$-inch barbed wire flooring brads, No. 16, are recommended. This style of flooring is face-nailed every 7 inches with 2 nails, one near each edge of the strip.

Other types of nails have been developed in recent year for nailing of flooring. These include annularly grooved and the spirally grooved nails. In using these nails, check the flooring manufacturer's recommendations as to size and spacing.

Installing Wood Block Flooring

The styles and types of wood block flooring vary somewhat among manufacturers, so that no general installation procedure applicable to all can be outlined. Rather, obtain detailed installation instructions from the manufacturer whose product is being used.

Block flooring may be installed on a wood subfloor either by mailing or by laying directly in mastic (fig. 11). The adhesives and general methods of handling block flooring when bonding over wood subfloors are similar to those described later in the section on bonding wood flooring to concrete. As with strip flooring, an allowance for expansion must be made with blocks of the unit type made from short lengths of strip flooring. With laminated blocks, however, less allowance for expansion is needed.

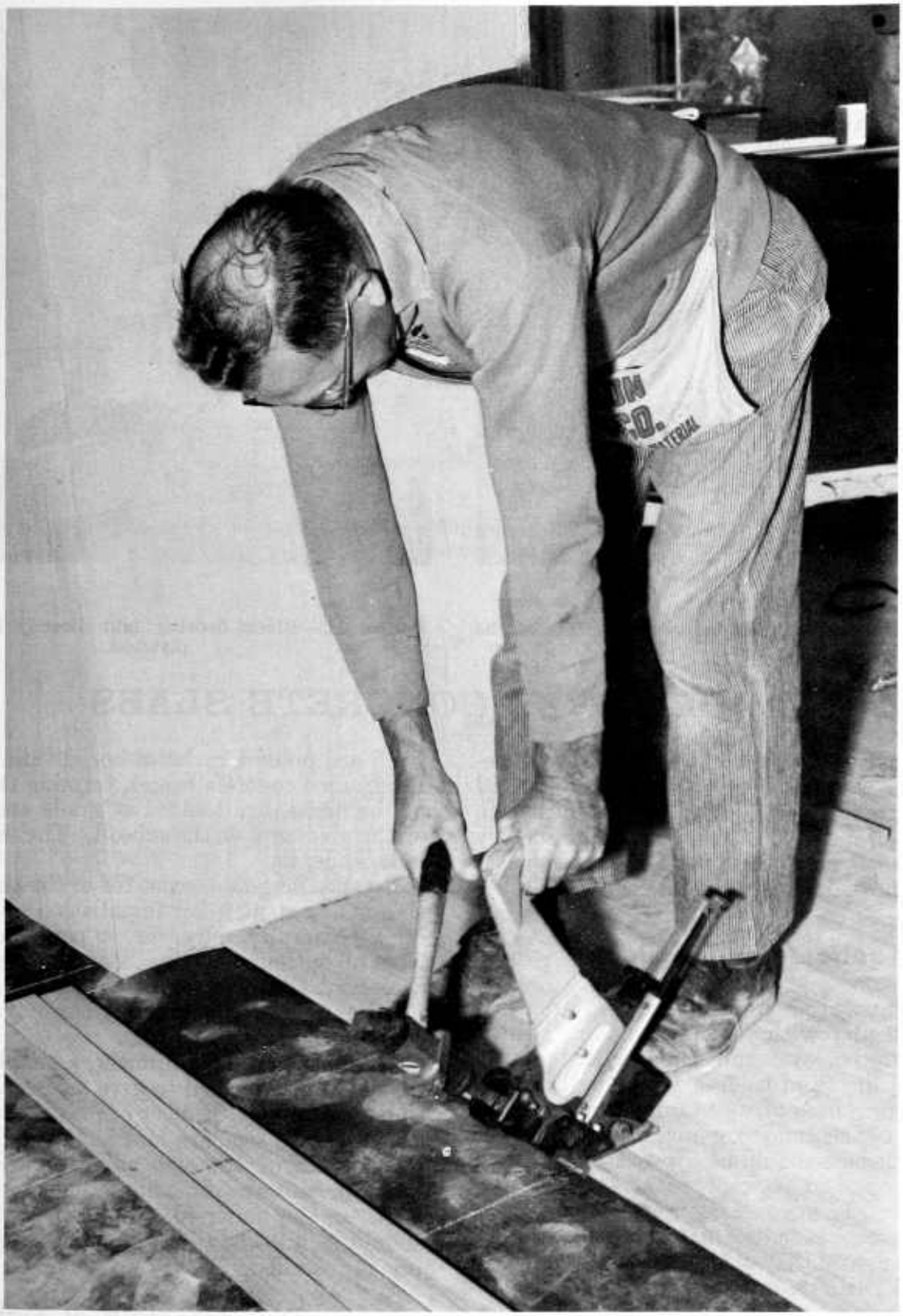

FIGURE 9.—Installing hardwood strip flooring with nailing machine. M100947F

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FIGURE 10.—Hand setting nail below the surface of the wood.

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FIGURE 11.—Block flooring laid directly in mastic on plywood.

FLOORS OVER CONCRETE SLABS

A common type of floor construction for basementless houses is a concrete slab on the ground over which wood flooring may be laid either in mastic or on sleepers. To assure fully satisfactory service, the slab must meet certain requirements as to smoothness, drainage, dampproofing, and the like.

Requirements for Slabs

The slab must meet certain basic requirements to avoid difficulty with the finish floor. Principally, it must be level and smooth, laid over a firm base, be dry, and be free from spalling and dusting. A firm base of well-tamped subsoil, free from roots, debris, and organic matter must be provided; this base should be covered with at least 4 inches of crushed rock or coarse gravel, well tamped down. The gravel layer and a continuous vapor barrier over it reduce materially the amount of subsoil moisture that can come in contact with the slab and perhaps work up through it. Suitable nonorganic moisture-resistive insulation around the perimeter of the wall is necessary in many climates to reduce heat loss and provide comfortable floor temperature in cold weather. Adequate drainage away from the walls is important to prevent surface moisture from entering the floor.

Suitable details of construction for slab floors of several types are shown in figures 12 to 16. Another type, not illustrated, is the grade beam and pier type. In this type, cylindrical concrete piers are poured in holes bored into the subsoil. Reinforced concrete beams, forming the perimeter of the house, are located at grade and supported on the piers and on the subsoil. The slab is poured independently.

No specific guides exist for evaluating when the slab is dry enough for installation of wood flooring. Generally, however, a period of 30 to 60 days of optimum drying conditions is considered necessary, although conditions vary so greatly that it is impossible to establish accurately the number of days of drying required.

Without special equipment, a simple procedure that may be expected to give a reasonable indication is as follows: Rubber or plastic sheets, at least 2 by 2 feet in size, are laid at several locations on the surface of the slab and weighted to insure uniform contact. If, after 24 hours, moisture appears on the underside of the sheet, the concrete should be allowed to dry further before the flooring is installed.

Dampproofing of Slab

Figures 12 to 16 show a vapor barrier in contact with the lower surface of the slab. This barrier not only retards movement of water and vapor from the soil upward through the slab, but also prevents the flow of the concrete mix into the porous layer beneath the slab.

Vapor barriers are essential for the proper performance of wood and other types of flooring installed on slabs on grade. Opinions differ consid-

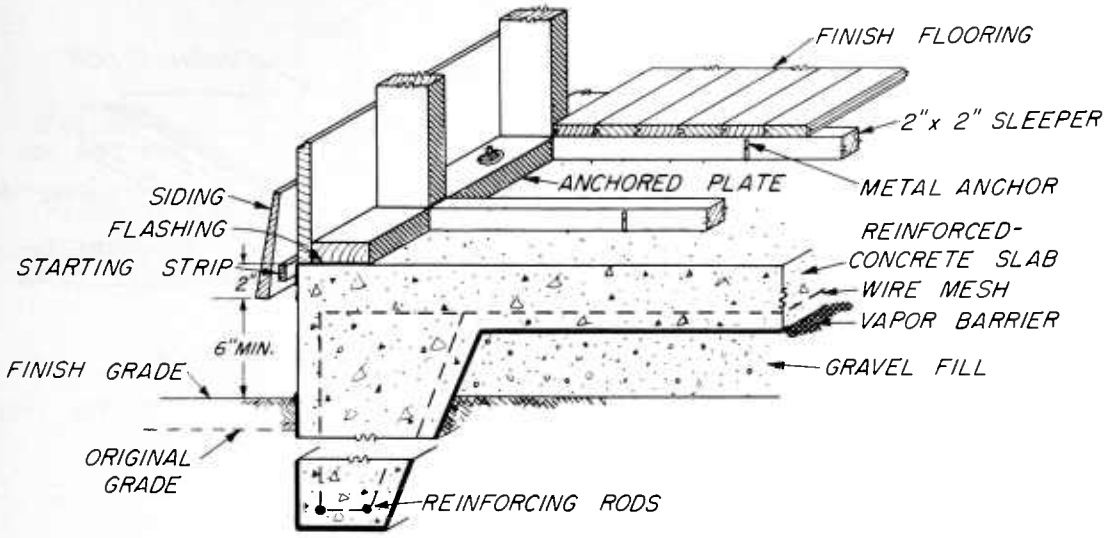

FIGURE 12.—Combined slab and foundation. The gravel fill should be of a size that will be retained on a 1-inch mesh screen.

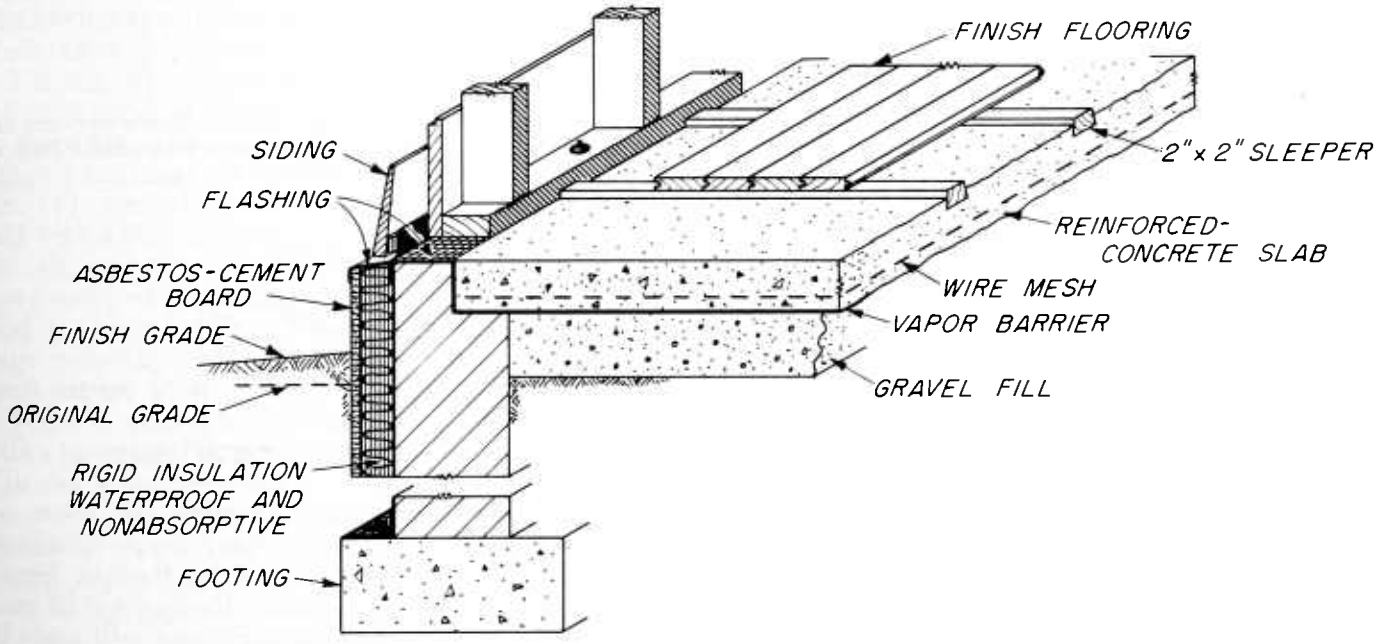

FIGURE 13.—Independent slab and foundation walls. In the method of construction shown, insulation is located at the exterior surface of the wall. This method of installation may also be used on existing slab houses to minimize cold floors. One method of laying the finish floor is shown. Sleepers shown are 2 by 2 wood members impregnated with preservative and embedded in the concrete.

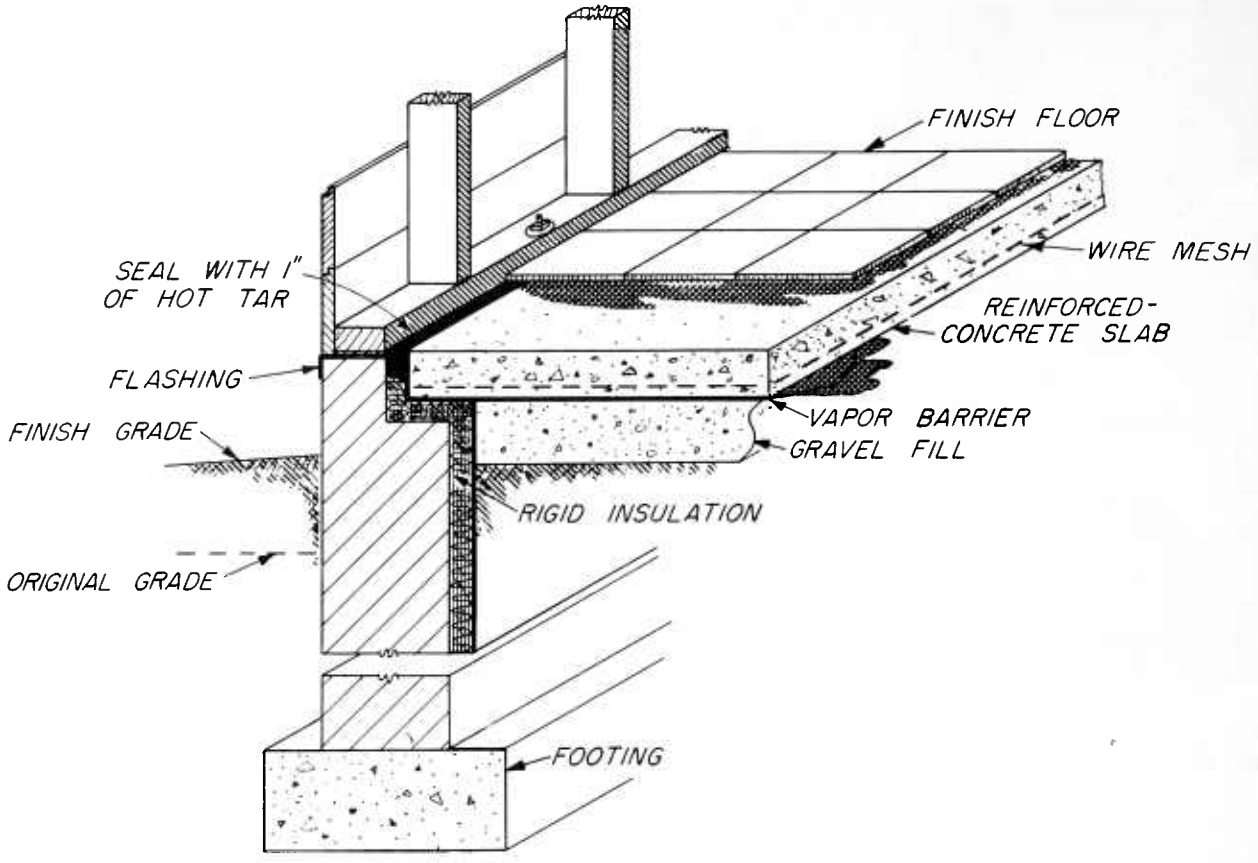

FIGURE 14.—Concrete slab with foundation walls. Insulation is located around the exterior walls. Vapor barriers are installed below the slab and on the warm side of the insulation, as shown. Insulation extends to within 1 inch of top of floor slab, and the space above the insulation to the top of the slab is sealed off with hot tar.

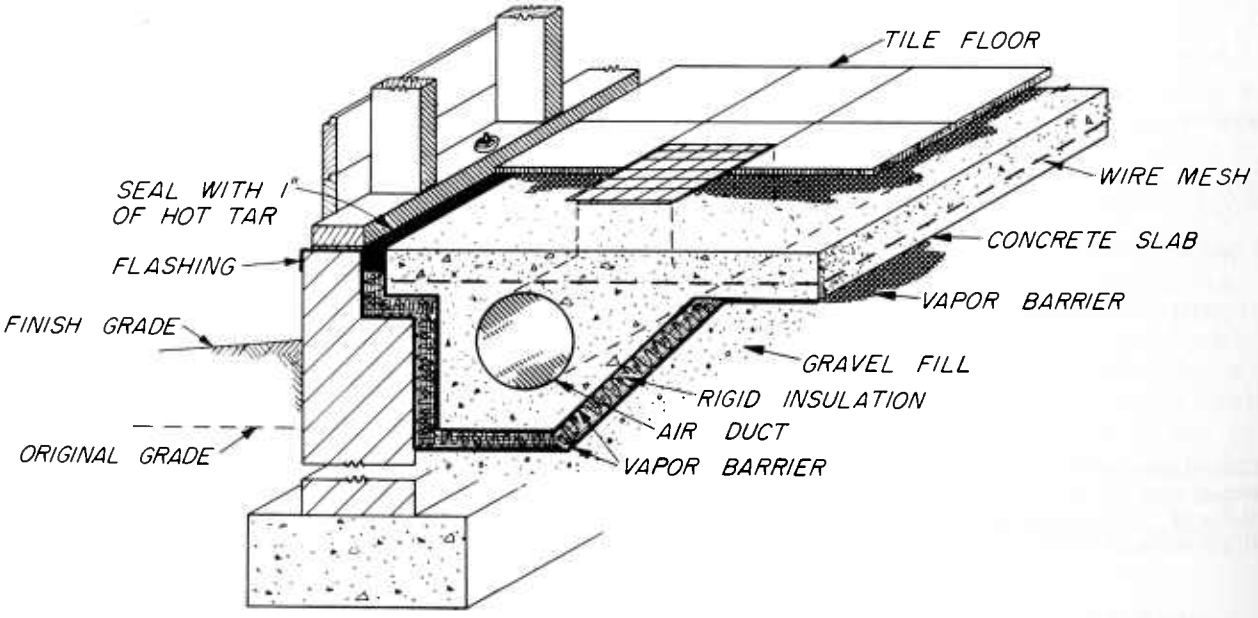

FIGURE 15.—Independent concrete floor slab and foundation wall. Duct work located in slab around exterior wall. A permanent type of vapor barrier is provided on both sides of insulation to stop soil moisture and to provide protection from cold weather condensation.

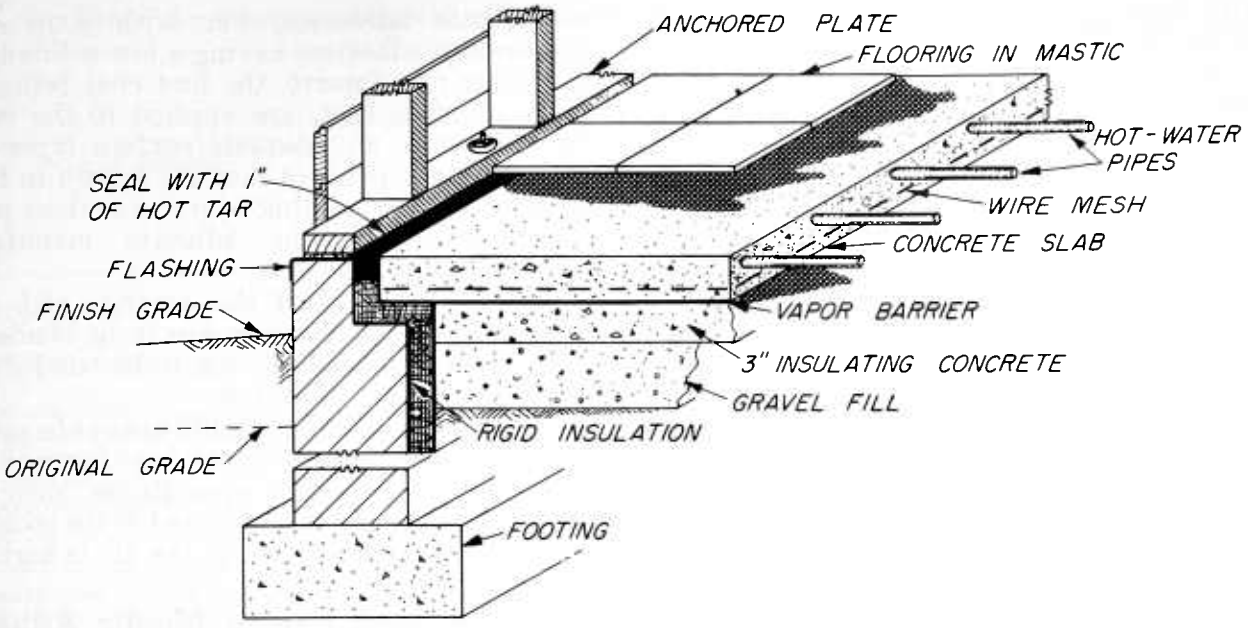

FIGURE 16.—Independent concrete floor slab and concrete walls. Radiant-heating pipes are embedded in the floor.

erably as to whether the barrier should be at the lower or the upper surface of the slab, each location having specific advantages and disadvantages. Most commonly, it is placed below the slab.

For use below the slab, the barrier should have not only good vapor resistance, but also resistance to moisture and decay, and the ability to stand rough handling. Two materials commonly used are (1) smooth-surface 55-pound roll roofing, laid with a 6-inch lap and with the lap sealed with asphalt, and (2) three layers of roofer's felt, each layer mopped with hot asphalt. Other materials used as vapor barriers under slabs include heavy-gage polyethylene and polyethylene bonded to kraft paper.

There is some question about the ability to provide a successful and permanent bond between the slab and a barrier placed on top of it. However, the wood flooring industry reportedly has had success in recent years with (1) two layers of 15-pound asphalt-saturated felt laid in successive coats of hot asphalt mastic, and (2) a 4-mil polyethylene film sandwiched between coats of a cold asphalt mastic. Suitable types of polyethylene film are available, and recommendations on this point should be obtained from the flooring manufacturer.

The use of membranes over the slab is open to question if the flooring is to be bonded with a rigid adhesive designed to resist dimensional changes (thereby placing high stresses in the bond between flooring and base), or if the adhesive contains solvents likely to soften asphaltic compounds. Cutback asphalt adhesives, however, are frequently used in bonding flooring over these membranes.

Moisture Content of Wood Flooring on Concrete Slab

When wood flooring is placed in direct contact with a concrete slab on grade, it is likely to have a slightly higher moisture content than ordinarily exists in wood frame construction. The average moisture content of hardwood flooring on a slab will be about 11 percent for the Southern Coastal States and about 8 percent for the remainder of the United States (compare table 7).

The procedures suggested earlier for insuring proper moisture content at time of installation should be followed for flooring to be installed on slabs. These include thorough drying of concrete and plaster, proper temperatures, opening of flooring bundles when recommended, and the like.

Flooring Installed in Mastic

Long lengths of strip flooring are not ordinarily laid directly in mastic. Where they are used in special cases, or where short lengths are laid, as in the herringbone pattern, standard patterns with hollow backs may be selected. Special types of strip flooring, however, are available as described earlier (fig. 2).

In most unit blocks, the individual strips are not tightly joined. These blocks have some advantage over more rigid blocks in their ability to conform to minor irregularities in the concrete surface. In addition, any openings resulting from shrinkage are distributed as a series of small cracks between strips, rather than as fewer but larger ones between blocks.

As with flooring laid on joists, provision must be made for expansion of flooring laid in mastic. With laminated blocks, particularly when laid in a rigid adhesive, this is not so necessary because of the much smaller dimensional change with moisture.

Preparation of the Slab

Leveling.—Irregularities in the concrete surface may require the use of leveling compounds to produce a suitable finished floor. Not all the usual compounds are compatible with all the adhesives, particularly because of possible deleterious effects of solvents in the adhesive on the leveling compound; this point should be checked with the flooring or adhesive manufacturer. Some also may lack the adhesive strength to hold down all types of flooring.

A mixture of latex and cement forming a rubberized compound may be used for leveling irregular concrete surfaces. It is strong and can be applied in thin coats and to feather edges. The mixture should not, however, be applied in thicknesses greater than ¼ inch. It is suitable for use over heated slabs.

Mixtures of emulsified asphalt, sand, and cement are less expensive than the latex compounds. They will, however, be softened by the solvents in certain types of adhesives, such as the rubber-base adhesives described later. Underlayment compounds based on combinations of epoxy resins, elastomers, cement, and sand are becoming available for use in leveling concrete floors where high strength and resistance to solvent action are required.

Various patching products, such as mixtures of sand, gypsum, and cement, are manufactured. These are generally low in strength and not suitable for leveling. They may be used to fill holes in the slab.

Priming of surface.—After the concrete subfloor has been properly cured, dried, and any necessary leveling done, the floor should be well swept and then a prime coat brush-applied over the entire slab at a coverage rate of 150 to 250 square feet per gallon. With the cutback asphalt mastic adhesives, the prime coat consists of a cutback asphalt adhesive further reduced with a hydrocarbon solvent to a brushable consistency. Commercial priming solutions of this type are available. This type of primer should be applied at least 24 hours prior to the application of the asphalt adhesive to insure that most of the solvent has been removed. Dilute solutions of the asphalt emulsion adhesives are also available for use in priming prior to the use of asphalt emulsion adhesives.

It is the purpose of the primers to bond the concrete "fines" to the base slab, to result in easier troweling of the mastic, and to give better wetting and adhesion of the mastic to the subfloor. Priming is not generally required for use with the rubber-base adhesives, but with some of the rubber-base adhesives having a low-solids content, two coats of adhesive, the first coat being essentially a prime coat, are applied to the concrete slab to insure an adequate surface layer of adhesive. Only primers that are known to be compatible with the bonding adhesive or those primers recommended by the adhesive manufacturer should be used.

Asphalt priming of the concrete slab is also used when vapor barriers are to be bonded over the slab or when screeds are to be bonded on the slab with asphalt adhesives.

Adequate ventilation should always be provided when using primers containing flammable solvents. No smoking or open flames, such as gas pilot lights, should be permitted in the room while the solvent concentration in the air is high.

Selection and Use of Mastic Adhesives for Bonding Wood Flooring to Concrete

While the application of wood flooring over concrete is usually done by mastic bonding, the thicker types of strip flooring can also be applied by nailing them to wood screeds or sleepers attached to the concrete subfloor.

The mastic adhesives used for this bonding of wood flooring to concrete differ considerably from the conventional woodworking adhesives in their composition and properties. Exact classification of mastic adhesives is difficult because of the many asphalt, rubber, and resin compounds that are combined to form these adhesives. These types of mastic adhesives are usually less rigid and produce joints of lower strength than do the woodworking adhesives, and are formulated for on-the-job application with little or no bonding pressure. Even within one general type of mastic adhesive, the amounts and type of solvents and fillers used can greatly influence the working characteristics of the adhesive. Therefore, when available, the manufacturer's instructions on the use of his adhesive should be closely followed.

Information on the use of mastic adhesives summarized here is intended for guidance purposes only, and is based primarily on information obtained from brochures prepared by manufacturers of mastic adhesives and wood flooring. The mastic adhesives currently known to be used in bonding wood flooring to concrete can be broadly classified into the following types:

I. Asphalt base.
   1. Hot-melt.
   2. Cutback.
   3. Emulsion.
II. Rubber base.
   1. Reclaimed, solvent-type.
   2. Synthetic, solvent-type.
   3. Emulsion.
III. Asphalt-rubber base.
IV. Miscellaneous special types.

TABLE 8.—*Guide for selection of adhesive for bonding different types of wood flooring to concrete*

Type of flooring	Adhesive						
	Hot-melt asphalt [1]	Cutback asphalt [1]	Emulsion asphalt [1]	Solvent-type reclaimed rubber	Solvent-type synthetic rubber	Latex emulsion	Asphalt-rubber
Wood strip (parquet):							
Restrained edges [2]	Excellent	Excellent	Good [3]	Fair	Fair	Fair	Fair.
Unrestrained edges [2]	Fair	Poor	Poor	do	Good	Good [3]	Good.
Unit block:							
Restrained edges [2]	Excellent	Excellent	Good [3]	do	Fair	Fair	Fair.
Unrestrained edges [2]	Fair	Poor	Poor	do	Good	Good [3]	Good.
Laminated block (plywood):							
Restrained edges [2]	Excellent	Excellent	Good [3]	Good	Excellent	Excellent [3]	Excellent.
Unrestrained edges [2]	Fair	Poor	Poor	do	do	do [3]	Do.
Veneer	Poor	do	do	do	do	Fair	Good.

[1] Not recommended for use with flooring having unrestrained edges, or for use over radiant-heated slabs exceeding 85° F., because of low creep-resisting properties of adhesives.

[2] Restrained edges—where the edges of adjacent strips or blocks are held in alinement, as by splines or tongue-and-groove. Unrestrained edges—no provision for holding adjacent edges together as in square-edged strips or blocks.

[3] These mastics can be used with the thicker types of flooring providing most of the moisture is removed from the mastic by using the proper assembly period, as outlined in the manufacturer's instructions.

The selection of the type of adhesive to be used is largely dependent on the type and construction of the flooring. General recommendations for selection are given in table 8.

For the thicker types of flooring, having tongued-and-grooved or splined edges, which maintain alinement between edges of adjacent flooring pieces, and in which the entire flooring section can act as a "floating section," one of the asphalt mastics is usually recommended. These adhesives flow slightly with continuously applied stresses and have good rebonding characteristics. For the thinner types of flooring, or for flooring without splined edges such that each individual piece must be well bonded, rubber-base adhesives are usually recommended as having higher strengths to retain the individual pieces in place.

Much of the information on the selection of the type of mastic adhesive to be used is based on field research or on observations of the working characteristics of the adhesives. Strength tests of small test specimens have little practical value in determining the possible performance in a flooring installation.

These mastic adhesives, in particular those of asphalt base, require that temperatures be at least 65° to 70° F. to obtain adequate bonding. This temperature requirement applies to all materials, the concrete slab, the wood flooring, the adhesive, and the air above the slab.

Hot-Melt Asphalt Mastics

The hot-melt mastics have been widely used in the United States since 1890 in the bonding of wood parquet flooring to concrete subfloors. The early hot-melt mastics were made from either coal-tar pitch or asphalt, while the hot-melt mastics

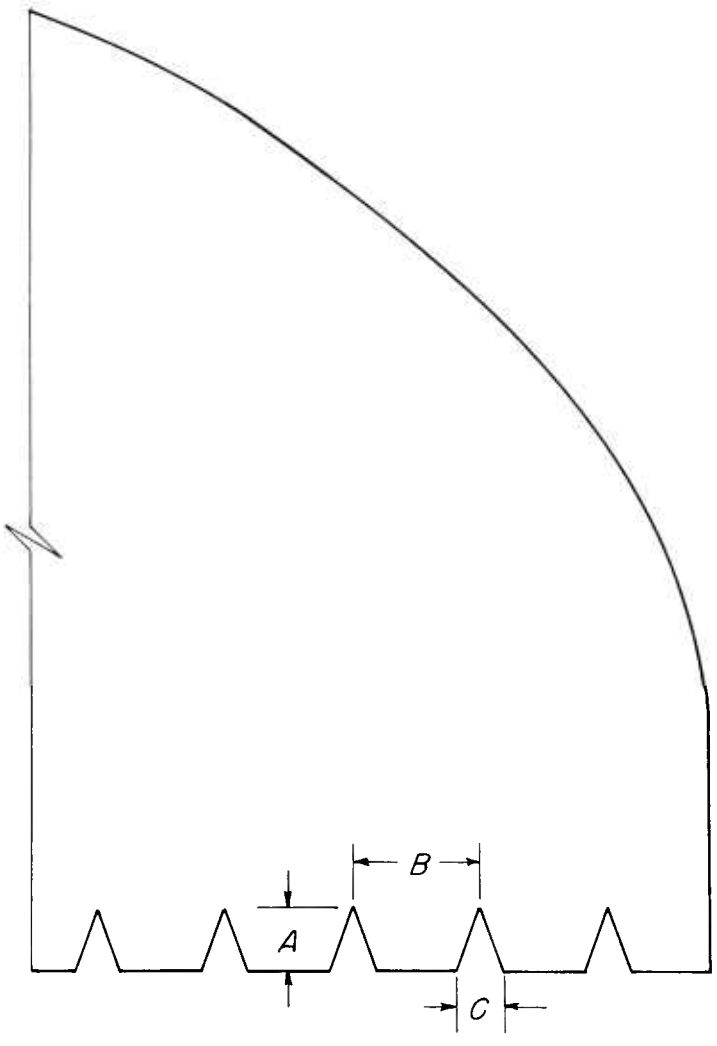

FIGURE 17.—Typical tooth pattern for trowel spreaders. (Based on information supplied by adhesive and flooring manufacturers.)

currently being used in this country are mainly of asphalt base. The refined native asphalts are mixed with softer varieties of petroleum asphalt to obtain an adhesive having the proper flow characteristics at both the temperature at which the adhesive is applied and at room temperature service conditions.

The hot-melt asphalt mastics are usually heated to a temperature of approximately 240° F. so that they liquefy and can be applied with a notched spreader to the concrete subfloors. This is frequently done by heating the pail or drum on an open fire outside the house. The liquid mastic is generally poured directly on the subfloor in limited quantities such as can be well troweled before cooling. A typical trowel-tooth pattern used for spreading a hot-melt mastic is shown in figure 17 and detailed in table 9. When such a trowel is properly used, a gallon of hot-melt mastic should cover 25 to 35 square feet of surface (table 9). Sometimes, as an alternative to spreading, the lower surface of the wood flooring is immersed in the melted mastic.

After applying the hot mastic to the concrete subfloor or flooring, the flooring is laid directly in place. Some manufacturers supplying this type of adhesive recommend waiting until the surface of the mastic glazes over (15 minutes to several hours, depending on the temperature and humidity in the room) before laying the floor. However, good results may generally be obtained even if the mastic adhesive is allowed to "set" overnight before the flooring pieces are laid in place.

When the wood flooring is laid in the hot-melt mastics, it is not considered necessary to apply any pressure other than a slight tap to bring the pieces of flooring into their proper place. Walking over the floor during use will embed the flooring into the mastic.

This type of mastic is now generally recommended only for use with the grooved or splined types of wood parquet block floor or for use with the short lengths of tongued-and-grooved strip flooring used in herringbone pattern flooring, although the early type floors in Europe having square edges were bonded with good success with this general type of adhesive. Laminated-block floors can also be bonded with this type of adhesive, but as the adhesive requirements for bonding the laminated-block flooring to the subfloor are not so restrictive, other types of adhesives, either cutback or emulsions of asphalt or rubber, which are easier to apply, are more widely used.

With the splined types of block or strip flooring, the asphalt mastic flows with any slow change in dimensions of the flooring, and the entire floor acts as a floating section with the edges of the individual pieces restrained from coming up by the tongue-and-groove or splines. With the thinner floors not having the tongue-and-grooves or splines, or with square-edged flooring, asphalt adhesives in general, because of their plastic flow nature, cannot for long restrain any tendencies of the edges of the flooring to warp.

These unmodified asphalt mastic adhesives, because of their plastic flow characteristics, are not generally recommended for use in floors containing radiant heat coils.

The hot-melt mastic adhesives have the following advantages, as compared to the cutback asphalt mastics described later: (1) They do not contain flammable solvents that must be removed into the atmosphere of the room; (2) they quickly lose their fluid properties after spreading, and therefore are not so likely to squeeze up between the flooring boards during laying; (3) they have a long record of successful use.

Cutback Asphalt Mastics

The cutback asphalt mastics, of the general type formulated for use in the bonding of asphalt tile, have been found satisfactory for bonding wood flooring to "on and above grade" concrete slabs. These cutback types are generally more convenient to apply than the hot asphalt mastics. Cutback asphalt mastics are usually formulated by reducing the hot-melt asphalt mastics with hydrocarbon solvents. A small percentage of asbestos fibers,

TABLE 9.—*Dimensions for adhesive trowel spreader and approximate floor coverage*

Adhesive	Trowel part [1]			Approximate coverage per gallon [2]
	A	B	C	
	Inches	*Inches*	*Inches*	*Square feet*
Hot-melt asphalt	1/4	5/16	3/16	25 to 35
Cutback asphalt	1/4 to 3/8	1/2	3/16 to 1/4	30 to 40
Emulsion asphalt	1/4 to 3/8	1/2	3/16 to 1/4	30 to 40
Solvent-type reclaimed rubber	3/16	7/16 to 1/2	3/16 to 1/4	45 to 60
Solvent-type synthetic rubber	1/8 to 3/16	5/16	1/8 to 3/16	45 to 60
Rubber emulsion	3/16	5/16	3/16	45 to 60
Cutback asphalt-rubber	1/4 to 3/8	1/2	3/16 to 1/4	30 to 40

[1] Trowel parts illustrated in figure 17.

[2] Spreader to be inclined during use to obtain proper coverage. For the more viscous types of mastics, teeth may sometimes be of a rectangular shape with a slight reduction in size.

or sometimes ground cork, is added to some mixtures to stabilize them and to adjust the consistency for better application.

The cutback asphalt mastics should be formulated with the proper asphalt materials and fillers to result in a nonhardening mastic that will flow and embed the flooring, and also permit the entire section of flooring to act as a floating slab. On the other hand, the mastic should be rigid enough to hold down the edges of the flooring, to resist any sudden stressing, and to prevent the adhesive from squeezing up between the flooring strips or blocks.

These cutback asphalt adhesives are not normally recommended for use over concrete slabs containing radiant heat coils, but some manufacturers classifying their adhesives as cutback asphalt will permit their use on splined wood floors having a maximum temperature of 85° F. Adhesives that are a combination of asphalt and reclaimed rubber, described later, are generally considered more suitable for use over radiant heated slabs.

The cutback asphalt mastics should be applied to the primed subfloor, using a trowel of the type shown in figure 17, in amounts covering 30 to 40 square feet per gallon (table 9). Typical trowel spreading of a mastic adhesive on a concrete subfloor is shown in figure 18. The spread mastic should be air-dried for at least 2 hours before the flooring is laid in place. With some mastics, installation may be safely delayed up to 72 hours if necessary. A good test to determine the proper minimum time for laying is to rub the fingers lightly over the ridges of the spread mastic. As soon as the mastic has dried sufficiently so that it does not adhere to the fingers, the flooring can be laid and tapped lightly in place.

The flooring will become embedded in the mastic during use. However, to improve the uniformity of bonding, pressure may be applied immediately after the floor is laid by rolling it with a felt-covered floor roller. Flooring that is laid too soon after the adhesive is applied will slip excessively while being laid, and the mastic will be squeezed up between flooring pieces.

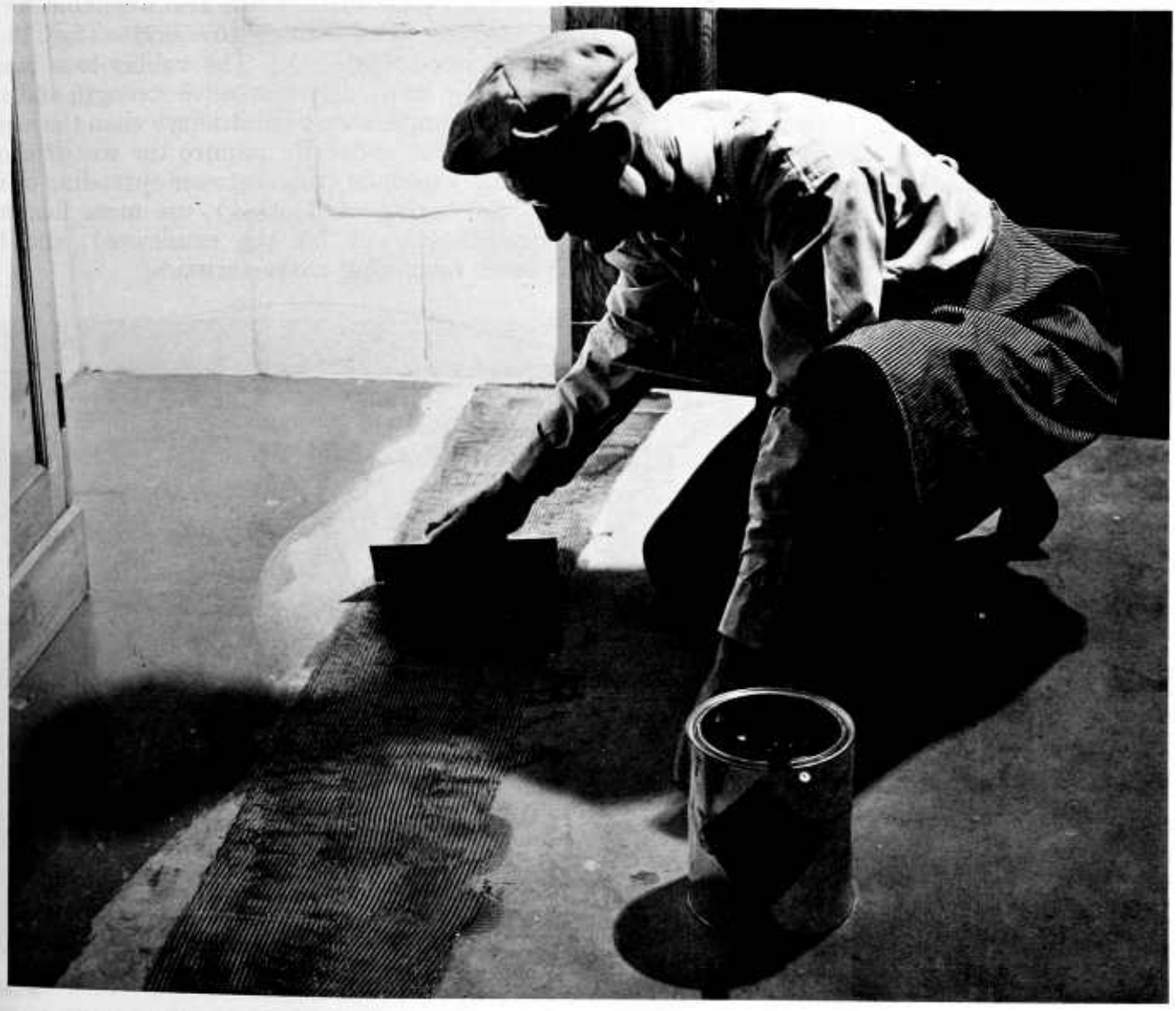

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FIGURE 18.—Troweling mastic adhesive on a concrete subfloor.

The use of short assembly periods could be the cause for "snapping" sounds sometimes heard when one walks over installations bonded with these adhesives. When a short assembly period is used, some of the wet adhesive is transferred to the back of the flooring piece. In certain areas, contact may not be obtained because of nonuniform concrete surfaces, warped flooring pieces, or nonuniform adhesive spread, except when one walks over the flooring. The two adhesive surfaces will come in contact and rebond together momentarily, but then break apart with a snapping sound.

This type of adhesive can be used for bonding all the types of flooring that are conventionally bonded with hot-melt asphalt adhesives. This adhesive also gives excellent performance in bonding plywood-block flooring. Because of its low adhesive strength and high flow characteristics, it is not normally recommended for the bonding of square-edged or veneer types of flooring.

The cutback asphalt has the advantages of: (1) being more convenient to apply and spread than the hot-melt asphalt mastics; (2) being less sensitive to the air-drying period than the solvent-type synthetic rubber-base mastics described later; (3) solvents being less flammable than those used in solvent-type rubber-base mastics; (4) adhesive remaining plastic and having better rebonding properties than do the rubber-base mastics.

Emulsion Asphalt Mastics

Asphalt mastics are also supplied as water emulsions, stabilized by either clay or alkaline chemicals. These mastics have properties similar to those of the cutback asphalt mastics, except that a longer open assembly must normally be used to insure that the water is removed from the adhesive before the flooring is laid.

The asphalt mastic is applied to the primed concrete subfloor with a notched trowel (fig. 17) at rates given in table 9 and then dried for 12 to 24 hours before the flooring is laid in place. The remainder of the procedure is the same as that used with the cutback asphalt mastics.

The emulsion asphalt mastics have the advantage, as compared to the cutback asphalt mastic, of containing no flammable solvents that must escape into the atmosphere of the room.

Their disadvantages are as follows: (1) Care must be taken that the adhesive is not stored under freezing conditions, which might deteriorate the adhesive; (2) a long open assembly must be used to remove moisture from the adhesive film; and (3) asphalt emulsion mastics are generally considered to be less resistant to high moisture and alkaline conditions than are the cutback asphalt mastics.

Rubber-Base Mastics

Rubber-base mastics are also available for use in bonding wood flooring to concrete (figs. 19, 20) or plywood (fig. 21). The rubber-base mastics generally have higher cohesive strength and show less flow under stress (plasticity) than the asphalt mastics, but generally require the use of shorter assembly periods (time between spreading of mastic and laying of flooring), use more flammable solvents (except for the emulsions), and have poorer rebonding characteristics.

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FIGURE 19.—Laying veneer strip flooring in rubber-base mastic on concrete.

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FIGURE 20.—Tapping veneer flooring in place in mastic on concrete floor.

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FIGURE 21.—Tapping wood block flooring firmly in place in rubber-base mastic laid over plywood.

Solvent-type reclaimed rubber.—These mastics are applied much the same as are the cutback asphalt mastics, except that the adhesive spread may be reduced to a coverage of 45 to 60 square feet per gallon. Heavier spreads may be required if the concrete subfloor is not smooth. The maximum assembly period between spreading of the adhesive and laying of the flooring should not normally exceed 15 minutes.

These adhesives, in contrast to the asphalt adhesives, require that sufficient pressure be applied to the flooring to maintain adhesive contact until the adhesive has gained sufficient strength to hold the flooring down. Initial contact is usually sufficient. Rolling of the flooring with a heavy roller is a desirable method of obtaining proper adhesive contact. Pressure can be applied by lightly hammering the flooring with a rubber mallet to insure contact at the corners and edges (figs. 20, 21). If any of the corners of the flooring will not stay in place after being lightly hammered, they should be held down overnight with weights.

These rubber-base mastics are much more rigid (less plastic), once the solvents have been removed, than are the asphalt mastics. It is, therefore, an advantage to use this type of adhesive for bonding thin veneer flooring without tongues or grooves, which tends to turn up at the edges. With long strips of thicker flooring, however, stresses may develop during seasonal changes that would be great enough to rupture these more rigid adhesives. The bond is then permanently damaged, as these adhesives do not have the good rebonding properties of the asphalt mastics.

Some of the rubber-base mastics are reported to be formulated to withstand temperatures up to 140° F. without appreciable softening or deterioration, and therefore would normally give better performance than the asphalt mastics for bonding flooring to slabs in which radiant heating

tubes are embedded. Solvent-type rubber-base adhesives contain more flammable solvents (open cup flash point of less than 40° F.) than the cutback asphalt adhesives, and care must be taken that there is sufficient ventilation to remove the solvents and no possible source of ignition is in the room.

Solvent-type synthetic rubber.—Synthetic rubber-base mastics, usually with a butadiene-styrene copolymer (GR–S) or neoprene base, have working characteristics similar to those of the reclaimed rubber mastics, except that they usually have better "tack" properties and can be used with longer open assembly periods than the latter.

One of the solvent-type synthetic rubber mastics (believed to have a GR–S base) can be used for bonding wood flooring to concrete by applying the mastic to the concrete with a notched spreader (fig. 17) to obtain a coverage of 45 to 60 square feet per gallon (table 9). The flooring can then be laid after a drying period of from 15 minutes to approximately 1 hour. Good contact of the flooring to the mastic adhesive should be obtained, at least momentarily, during the first hour after spreading, while the adhesive still has high "tack." Pressure can be applied in the same manner as for solvent-type reclaimed rubber mastics.

This type of adhesive gives good performance in the bonding of thin veneer flooring or flooring without tongued-and-grooved or splined edges because of its high initial tack and strength. Because of the high cost, however, the use of highly flammable solvents, and relatively short assembly period of the solvent-type synthetic rubber adhesives, the asphalt mastics are better suited for bonding strip parquet, wood block, or laminated block flooring, with tongued-and-grooved or splined edges.

The "contact" cements, which are solvent-type synthetic rubber (neoprene) mastics developed for bonding high-pressure plastic laminates to counter tops, have been found to give the best performance of the various types of adhesives in bonding veneer flooring to concrete. These adhesives must be applied to both the concrete subfloor and to the back of the flooring pieces. A paint roller or a notched spreader (fig. 17) can be used for spreading the adhesive on the concrete surface.

With the more viscous types of these contact cements, which are the more suitable ones for this type of bonding, the coverage should be about 65 square feet of flooring area per gallon (table 9), half the adhesive being applied to the concrete and the other to the back of the flooring pieces. If a thinner type of "contact" cement is used, two coats should be applied to each surface, with 1 hour of air-drying between coats. The adhesive should be dried, following the final coat, for at least 20 minutes before the flooring is placed in contact with it on the slab surface.

Care should then be taken that the flooring is laid exactly in position, for no movement is possible because of the high "tack" of these adhesives. Final pressure can be applied by forcing down the flooring, with hand or foot, supplemented if necessary by tapping it with a rubber mallet (figs. 20, 21) or by rolling with a felt-covered floor roller. The manufacturer's instructions should be followed regarding the maximum period between spreading of the adhesive and the laying of the flooring. Sometimes this waiting period can be up to 16 hours, and even longer if a light wipe with lacquer thinner or the application of mild heat with an iron can be used.

Caution must be taken in using these solvent-type synthetic rubber cements because many contain extremely flammable solvents (open cup flash point less than 0° F.).

Rubber emulsions.—The rubber adhesives, including natural, reclaimed, and synthetic, are also available as water emulsions or dispersions. These emulsions, however, have not been so widely used as the solvent types for bonding wood flooring to concrete, primarily because of the water which they might add to the wood flooring when used with short assembly periods. The emulsions are also generally regarded as not being so durable as the solvent types, and applications of the emulsion types, when used, have generally been limited to bonding on dry "above grade" slabs. The principal advantages of the emulsion adhesives are their lower cost and lack of flammability.

Asphalt-Rubber Mastics

Solvent-type cutback adhesives formulated from a combination of asphalt and reclaimed rubber are available for bonding wood flooring to concrete. These adhesives are excellent for bonding laminated block flooring to concrete and can also be used, if properly formulated, to bond strip or wood block flooring with or without splined edges. These adhesives are reported to have greater strength and rigidity and show better resistance to heat than do the regular unmodified cutback asphalt adhesives. This type of adhesive can also be used for bonding flooring to radiant-heated slabs, provided the temperature at the bond will not exceed 110° F.

The adhesive should be applied to concrete with a notched spreader of the type shown in figure 17 to obtain a coverage of 30 to 40 square feet per gallon (table 9). The wood flooring should then be laid directly in place, normally within 20 minutes after the adhesive is spread, using a moderate pressure obtainable in the same general manner as for solvent-type reclaimed rubber mastics. The principal disadvantages of this type of adhesive as compared to the cutback asphalt adhesives are the shorter allowable assembly period, higher cost, and poorer rebonding characteristics.

Miscellaneous Special Types of Adhesives

Several special types of flooring adhesives have been used to a limited extent for bonding wood

flooring to concrete, including polyamidepoxy, alcohol-soluble oleoresinous, and 2-part "chemical set" latex adhesives. Their current use for this purpose, however, has not been extensive enough to indicate if any of these types have sufficient advantages to result in wider usage in bonding of wood flooring.

Floors Laid Over Sleepers

Where strip flooring is used over concrete slabs, it should be laid over wood sleepers (screeds) attached to the slab. The sleepers may be embedded in the concrete (fig. 13) although more commonly they are laid in mastic or attached to the concrete by clips (fig. 12). Sleepers should be pressure treated with a suitable wood preservative. Creosote is not recommended, since it may stain the finish floor if it bleeds through the nail holes. Alternatively, the sleepers may be heartwood of a durable species.

Mastic bonding the sleepers to the concrete has been widely used. Information on the method has been supplied by the National Oak Flooring Manufacturers' Association. Essentially this method consists, after proper installation and priming of the concrete slab, of applying hot-melt or cutback asphalt mastic to the surface of the slab with a notched trowel (fig. 17) or by direct pouring to result in a mastic depth of $\frac{3}{32}$ to $\frac{1}{4}$ inch (25 square feet per gallon). The mastic can be applied to either the entire area of the floor, resulting in some resistance to permeation of water vapor, or to only the areas where the sleepers are to be placed.

Dry, flat 2- by 4-inch or 2- by 2-inch lumber sleepers should then be immediately embedded into the mastic, before the adhesive gains initial "set." The sleepers, in random lengths from 18 to 48 inches, are laid at right angles to the proposed direction of the final floor and in a series of staggered rows, 12 inches on center as shown in figure 22, or 16 inches if a subfloor is used. The ends of the individual sleepers should overlap each other 4 inches, and the sleeper ends should be at least 1 inch from the base plate. When the sleepers are attached by anchors, generally full-length sleepers are used.

The most common method of anchoring wood sleepers is by means of sheetmetal strips embedded in the concrete at intervals along the length. After the sleeper has been wedged to the desired level position, the projecting ends of the anchors are folded over the sleeper and nailed to it. Anchor bolts embedded in the hardened concrete may be used, but the cost of installation is so high as to be prohibitive. Power-driven fasteners may also be used to fasten sleepers to the concrete. With this type, a special nail is driven through the wood into the concrete by means of a gun, the driving power being supplied by a power cartridge. This method eliminates the necessity for presetting clips in the soft concrete at predetermined locations.

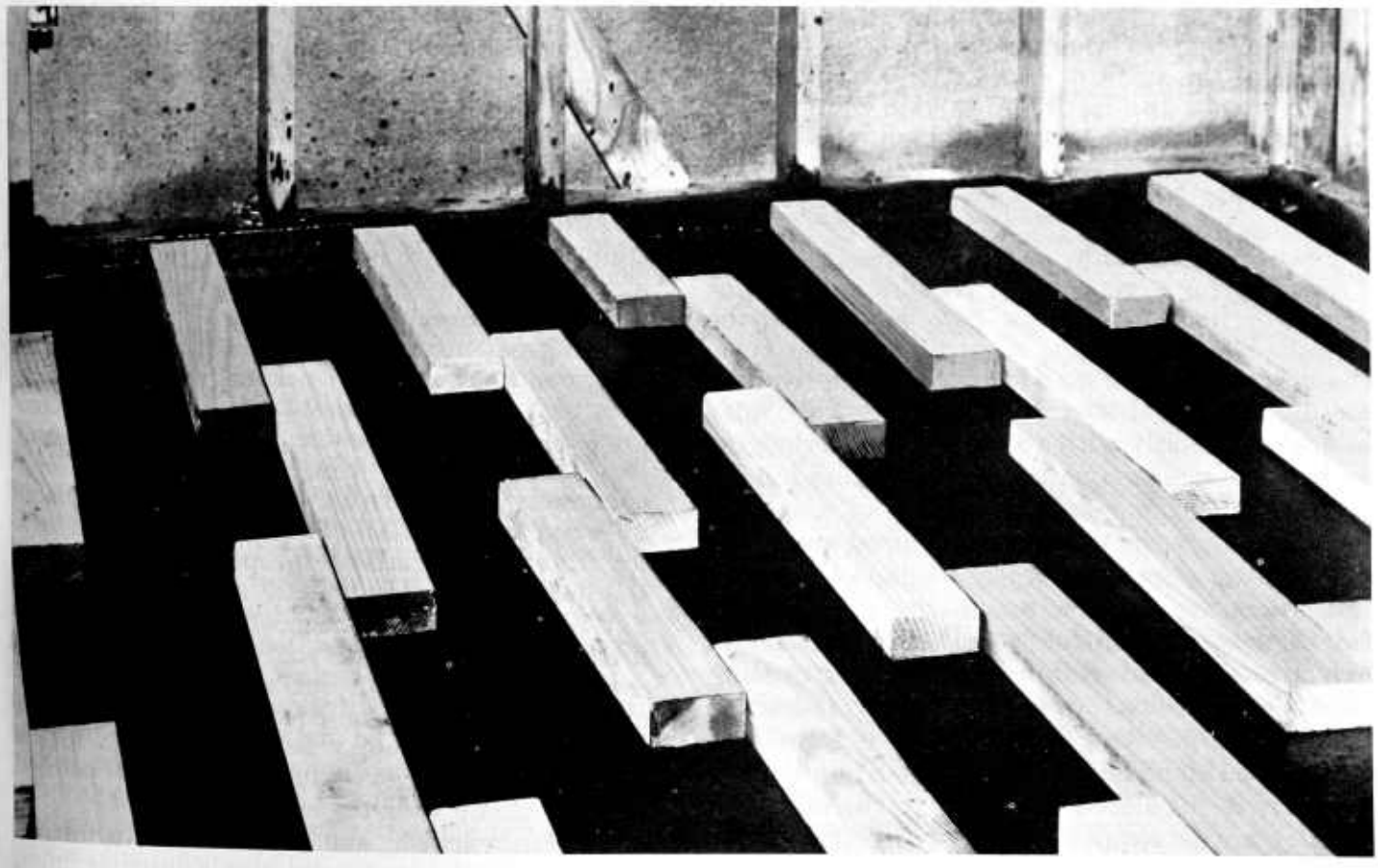

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FIGURE 22.—Arrangement of mastic-bonded sleepers over concrete subfloor for use in installation of nailed strip flooring.

Installation of subfloor and finish floor is essentially the same as when they are installed over joists. The flooring is laid at right angles to the sleepers, and each strip should bear on at least two sleepers. Flooring should be nailed to each sleeper and where a strip passes over the lap between sleepers, it should be nailed to both. Square-edge flooring should not be used.

Wood Floors Below Grade

Because of the difficulties that may be encountered when wood floors are exposed to condensation or prolonged high humidity, wood flooring is generally not recommended for use at locations below grade where such conditions may be expected. Basement areas are characteristically cool, and the cooling of outside summer air as it enters the basement increases the relative humidity markedly as well as increasing the possibility of condensation on cool surfaces, such as water pipes and perhaps concrete walls and floors. Both will result in swelling of a wood floor and perhaps in its buckling. Beyond this, however, there is also the possibility of decay from continued exposure to free water, such as might exist from condensation on the lower surface of flooring in contact with the concrete, or to extremely high humidities that might exist in unventilated areas, such as that below flooring on sleepers.

Modern developments, however, tend to reduce the hazard. Insulation of floor slabs reduces the temperature loss. Effective vapor barriers reduce the amount of moisture that can move from the slab to the wood floor. Beyond this, dehumidification offers considerable opportunity for reducing the overall relative humidity of basement areas and thereby the chances for condensation. The relative humidity level that can be maintained in a basement area by a dehumidification unit will depend, of course, upon the room volume and on the capacity of the unit. In general, however, substantial improvement over the usual basement conditions may be expected.

Thus, much of the objection to the below-grade use of wood floors may be eliminated. The homeowner anticipating such use, however, should consider carefully all the factors and insure that all the construction features and other steps needed to reduce the moisture problem have been included.

FINISHING AND MAINTAINING WOOD FLOORS

General Requirements

After laying a wood floor, four steps may be needed to complete the finishing process, namely sanding of the surface, application of a filler for certain woods, application of a stain to unify the color, and selection and application of the kind of finish to be used. Whether fillers or stains are needed depends on the species of wood used and individual preference.

A careful sanding to provide a smooth surface is essential for a good finish because any irregularities or roughness in the base surface will be magnified by the finish, regardless of the type. The production of a satisfactory surface requires sanding in several steps with progressively finer sandpaper, usually with a machine, unless the area is small. Since the quality of the sanding job determines in large part the quality of the final finish and since the techniques required are exacting, sanding should generally be done by a man who specializes in such work.

A filler is required for woods with large pores, such as oak, walnut, and teak, if a smooth coating without depressions over the pores is desired. Fillers come in either liquid or paste form (the latter to be thinned before application) and either transparent or colored according to the effect desired. Care is required in applying the fillers; otherwise the final finish may appear uneven and smeared.

Stains are sometimes used to obtain a more nearly uniform color pattern when the individual boards vary too much in their natural color. Various stains are available, generally named for the woods they are to imitate. The stain should be of a type, such as an oil-base stain, that will not raise the grain of the wood. It should be remembered that stains penetrate wood to a trifling depth only; the protective finish must be carefully maintained to prevent wearing through the stained layer, since it is difficult to renew the stain at worn spots in such a way as to match the color of surrounding areas.

The great preference is for a finish that leaves the wood floor as nearly natural in appearance as possible. The transparent finishes now in common use are wood sealer, shellac, varnish, and, less often, lacquer. Linseed and other oils once commonly used have now largely been displaced by wood sealers. All of them can give good service if good materials are properly applied and if the finish is suitably maintained.

Wood sealers, now the most popular and widely used finishes, penetrate the wood just enough to avoid formation of a surface coating of appreciable thickness. Consequently, although more frequent attention may be required than with a coating, traffic areas can generally be patched without going over the entire floor.

Shellac, varnish, and lacquer form a distinct coating over the wood and give a lustrous finish, usually glossy. They are suitable where it is de-

sired to let the floors go as long as possible without attention other than regular sweeping or dry mopping and where it is convenient to go to more trouble when renewal is required. Such transparent coatings wear out in areas of highest traffic and, since it is generally not possible to do a fully satisfactory job of patching the worn areas, the flooring in a whole room or series of rooms must be refinished. In addition, shellac waterspots readily, and lacquer is difficult to apply because it dries too quickly.

Opaque finishes, such as paints or enamels, are seldom used in the interiors of homes. When used, the labels should state specifically that they are suitable for wood floors, since many paints are not tough enough or sufficiently abrasion-resistant to be suitable. The same is true of various varnishes.

The durability of floor finishes can be improved by keeping them waxed. Paste waxes generally give the best appearance and durability, particularly if polished by machine. Water-emulsion floor waxes require no polishing—they are merely mopped on the floor and allowed to dry. While commonly used, they give a somewhat less attractive and less durable wax finish than does a machine-polished paste wax.

Best maintenance practice requires at least partial refinishing as soon as the finish wears thin in the traffic areas but before the wood has been left unprotected. Within limits, even the transparent coating finishes can be renewed in spots one or more times. Eventually, however, the old finish must be removed entirely. This is best done by power sanding, but may be done with varnish removers or other materials, the technique depending upon the nature of the original finish.

Finely finished floors should never be scrubbed with water. Sweeping or dry mopping should be adequate for routine cleaning. Water, ink, or other spots may offer some difficulty, but generally techniques are available for handling them without complete removal and renewal of the finish unless the penetration and extent of the spot are too great.

Sanding

All finishes require the surface of wood flooring to be made smooth by sanding or scraping just before the first coat of finishing material is applied. Just as the finish brings out the full beauty of the wood, it also reveals any defects or roughness left in the surface. Even irregularities that can scarcely be seen before finishing become conspicuous afterward. Unless prefinished, flooring usually has not been sanded by the manufacturer and bears slight ridges left by the planer. Such planer marks may seem unimportant at first but will mar the appearance later on when the finish has been applied. Moreover, if much time passes between the finish sanding and the application of finish, some roughness may develop from raising of the grain of the wood brought about by changing moisture content. Floors therefore should be sanded immediately before finishing is begun—if possible, the day when the first finish coat is to be applied.

Sanding or scraping can, of course, be done by hand, but that is usually far too laborious a method for areas of much size. Nevertheless, some handwork may be necessary in places that are inaccessible to power machines. Most floor sanding is done with electrically driven sanding machines. The machine should be well designed, ruggedly built, with its bearings well alined and kept in good condition. A machine with badly worn bearings may do more harm than good.

Floor sanding machines can often be rented at retail paint or hardware stores or from concerns that specialize in the renting of power equipment. It should be pointed out, however, that sanding is by far the most exacting step in floor finishing. Nothing can be done later that will make up for defects of a poor sanding job. It is therefore advisable, whenever possible, to have floors sanded by a man who specializes in such work.

Sandpaper acts by gouging fine slivers from the wood surface, leaving scratches, the size of which is governed by the size of the grits on the paper. Coarse grits act rapidly, but the scratches they leave are conspicuous, especially if they cross the grain of the wood. Fine grits act slowly, but, if fine enough, the scratches left are too small to see. Scratches are least noticeable when they run with the grain of a wood with open texture (large pores), such as oak. Scratches must be especially fine to escape detection on a wood with close texture, such as maple, and must be still finer to remain unnoticed if they cross the grain of the wood.

In sanding a floor, time is saved by starting with coarse sandpaper to remove the grosser roughness and imperfections and to make the floor level as quickly as possible. The scratches left by the coarse grits are then removed by successive sandings, each one with a finer sandpaper than the one before, until the scratches left by the last paper are too small to be observed even after finish has been applied.

Sanding Machines

Sanding machines are of two types, drum sanders and disk sanders. In drum sanders (fig. 23) the sandpaper is mounted on a cylindrical drum that rotates on an axis parallel to the plane of the floor and at right angles to the direction in which the machine is moved. Thus the sandpaper makes its scratches in straight lines in the direction of movement of the machine. In disk sanders the sandpaper is mounted on a disk that rotates in a circle in the plane of the floor (fig. 24). As a disk sander is moved over the floor, the grits make spiral scratches that necessarily cross the grain of the wood. The last sandpaper used with a disk sander therefore may need to be a grade or two

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FIGURE 23.—Electrically driven drum type flooring sander.

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FIGURE 24.—Electrically driven disk type flooring sander.

finer than is necessary with a drum sander on a floor in which all pieces run in the same direction. A drum sander, however, cannot reach the last few inches of floor nearest the baseboard. Electric edgers, which are small disk sanders, are available for sanding these edges of floor not reached by the drum sanders (fig. 25).

Provision for varying the speed of rotation of floor sanding machines is useful. If the speed is too great, enough heat may be generated by friction to heat the wood to incipient charring temperatures and thereby produce dark marks called burns, which can be removed only by sanding away more wood than is otherwise necessary. On the other hand, the operator wishes to use the highest speed practicable to get the work done as rapidly as possible. Burns can also be produced if the machine is allowed to stand at one place while the drum or disk is rotating.

Types of Sandpaper

Sandpaper, despite the name, is not made with sand. The abrasive grits may be flint, garnet, or emery, which are natural minerals, or the manufactured products aluminum oxide or silicon carbide. The backing may be paper, cloth, or a combination of paper and cloth. Flint is the cheapest, but wears out most rapidly and is seldom recommended for sanding machines. Garnet and aluminum oxide are most widely used for woodworking. Aluminum oxide is generally preferred for high-speed machines such as floor sanders. A few professional floor men use silicon carbide. Paper backing is satisfactory for floor sanding machines, although combination paper and cloth backing may be desirable for very coarse grits.

Each kind of sandpaper comes in a number of grades according to the coarseness or fineness of the grits. There are two systems of grading, by arbitrary numbers that indicate the size of the grits or by the number of meshes per inch in the sieves through which the grits have been passed. The customary grades are indicated in table 10. The mark "3/0," for example, is a contraction for the older way of writing "000," which in words is referred to as "three ought." When both grit number and mesh number are given, they may be written "3/0(120)" or "3/0–120."

Sandpaper is sold in sheets 9 by 11 inches in size for handwork, in pieces precut to sizes to fit any one of the various models of drum sanders, and in circular disks to fit the disk sanders. In ordering, the make and model of the sanding machine should be specified. Sandpaper is also sold in rolls 50 yards long and of various widths from which the user may cut pieces with a suitable template to fit his sanding machine. There are also "thrift rolls" that are long enough to make 10 pieces for drum sanders.

Sanding Procedure

The floor should be swept clean before beginning the sanding. No water should be used.

Newly laid hardwood floors should be traversed with the sanding machine at least three times, first

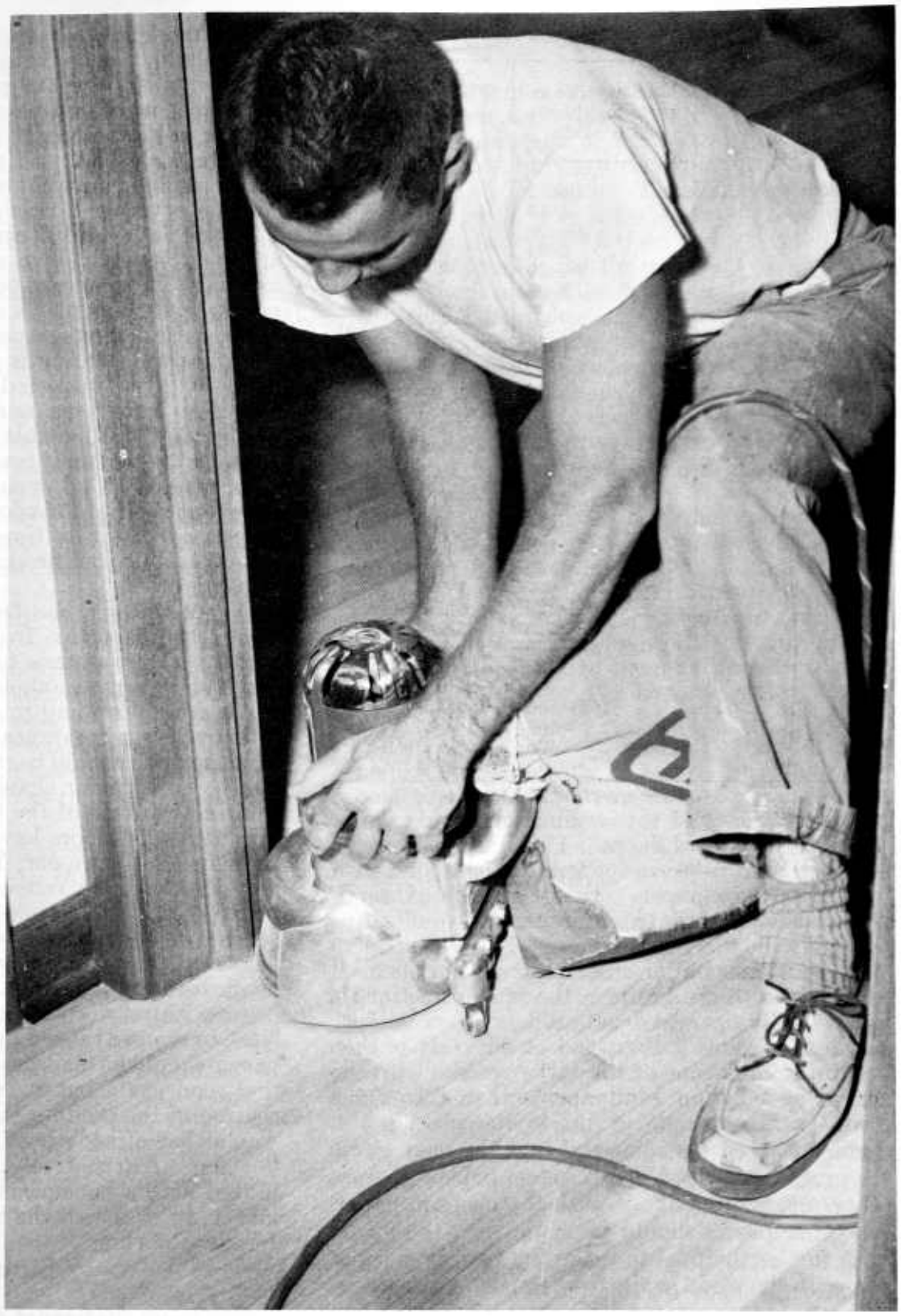

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FIGURE 25.—Small disk sanders are used for sanding the edges of floor that are not reached by drum sanders.

with coarse sandpaper of grade No. 2½–30 or No. 2–36, then with medium paper of grade No. 1–50 or No. ½–60, and finally with fine paper of grade No. 0–80 or No. 2/0–100. Although acceptable results are sometimes obtained with only two passes, three are generally recommended. For an especially smooth finish, the third pass should be made with No. 0–80 paper, followed by a fourth pass with No. 2/0–100 paper, and even a fifth pass with No. 3/0–120 paper.

Another method is to buff the hardwood floor with steel wool of No. 1 coarseness after the third pass with No. 0–80 sandpaper. Such buffing can be done by machine, because there are available rolls of steel wool that can be substituted for the drum in drum sanders. Steel wool, however, should not be used on oak floors unprotected by finish, because minute particles of steel left in the wood may later cause iron stains under certain conditions.

TABLE 10.—*Grading chart for sandpaper*

Type	Garnet, silicon carbide, aluminum oxide	Flint paper	Emery cloth
Very coarse	4½–12		
	4–16		
	3½–20		
	3–24	3½	
Coarse	2½–30	3	3
	2–36		
		2½	
	1½–40	2	2½
Medium	1–50	1½	
			2
	½–60		
		1	1½
	0–80		1
		½	½
Fine	2/0–100		
		0	0
	3/0–120		
		2/0	
	4/0–150		2/0
	5/0–180		3/0
		3/0	
Very fine	6/0–220	4/0	
	7/0–240	5/0	
	8/0–280		
	9/0–320		
	–360		
	10/0–400		
	–500		
	–600		

Two traverses of the sanding machine usually suffice for softwood floors. The first pass may be made with No. 2–36 sandpaper and the second with No. ½–60 sandpaper. Finer grades of sandpaper usually fail to improve the results appreciably.

On strip flooring or other patterns in which all pieces lie with the grain in the same direction, it is possible to operate drum sanders either with or across the grain of the wood at will. It is then helpful to make one of the earlier passes with the coarse or medium sandpaper either across the grain or at an angle of 45° to the wood grain. Some authorities recommend that the pass across the grain be made with the coarse paper, whereas others prefer to make it with the medium paper. All other passes should be made with the grain. It is further helpful to make the two passes that run with the wood grain from opposite directions. Some floor men prefer a disk sander for the last traverse, even when a drum sander is used for the earlier passes.

On parquet or unit block flooring, it is necessary to cross the grain of many of the pieces at each traverse. Each pass may well be made in a different direction, say two at right angles to each other and the third at 45° to the first two. Disk sanders necessarily cross the wood grain at each pass. Extra care should be taken to see that each traverse after the first is deep enough to remove all scratches left by the previous pass, and the last pass should be made with No. 2/0–100 or, if necessary, with No. 3/0–120 paper. Disk sanders are sometimes preferred over drum sanders for parquet or unit block floors.

After each pass with a drum sander, an edger should be used for the parts of the floor near the edges that are not reached by the drum sander. Even with a large disk sander, there may be places at the corners where an edger may be used to advantage. If there are places inaccessible even to an edger, such as places near radiator pipes, they must be sanded or scraped by hand.

Before the sanding is considered complete, the floor should be inspected carefully to see that all blemishes have been removed, a smooth surface produced, and all visible scratches removed. Defects can be seen most readily if the floor is viewed against light at a low angle of incidence so that any ridges will cast shadows. Remember that any defects left at this time will show much more prominently after finishing materials have been applied.

When sanding has been completed, the floor should be swept free from dust and may well be wiped with a painter's tack-rag. The walls, windows, and doors also should be dusted to keep dust motes from dropping into wet finishing materials to mar their appearance. Application of finishing materials should begin promptly so that there will be no time for changing moisture conditions to raise the grain of the wood again.

When wood floors have once been finished and the finish has worn out, it is usually expected that the finish can be renewed without sanding the floors again. Sometimes, however, floors become scarred or discolored by accident or abuse or from neglected maintenance to a point where sanding again becomes necessary. The sanding may then begin with very coarse sandpaper, No. 4–16 or No. 3–24, to remove the old finish and blemishes. Two passes should be made, each 45° to the direction of the wood grain but at 90° to each other. From that point the sanding should proceed in the same way as has already been described for newly laid flooring. Alternatively, the old finish may be removed with a nonaqueous (no water) varnish remover, after which the floor should be sanded as for new flooring.

Staining

The usual preference on hardwood floors is for a floor finish that leaves the wood as nearly in its natural color as possible. All finishing materials, however, even though entirely without color themselves, apparently deepen the natural color of wood, for the same reason that wood always appears more richly colored when wet than when dry. Deeply penetrating finishes, such as linseed oil and the "floor oils" that were often used in former times, deepen the wood color more than less penetrating finishes, such as wood sealers, shellac, and

lacquers. Of course, if the finishing material itself has considerable color, this color will be added to the overall effect.

A further enrichment of the color of wood floors comes with age. Light, even the subdued light inside houses, slowly deepens and browns the very thin superficial layer of the wood into which the light penetrates, producing the patina so much prized on old wood pieces. In addition, light and oxygen gradually act on varnishes and wood sealers to form colored decomposition products. The extent to which wood floors change in color with age from these two processes depends both on the kind of wood and the properties of the finishing materials. Fortunately, the color changes are usually of a pleasing nature.

When desired, the color of a hardwood floor may be altered without obscuring the grain of the wood by applying a wood stain of suitable color. Floors laid with wood of the lower grades in which there may be conspicuous variation in natural color may be rendered more nearly uniform in appearance by use of fairly dark stain. The color of wood stains is often indicated by naming them for the wood on which they are to be used or whose color they are to imitate, with further qualification for the shade or character of color. Thus there are light oak, dark oak, walnut, red mahogany, brown mahogany wood stains, and others. The stain should be an oil stain or at least a stain made without water, such as that known as "non-grain-raising" stain.

No stain penetrates wood uniformly to more than a trifling depth. For that reason the subsequent protective finish on stained floors must be maintained with particular care. If it is not and the surface is allowed to wear away at places of greatest traffic, unstained wood will be revealed to mar the appearance. It is rarely possible to renew the stain at worn spots in such a way as to match the color of the unworn areas. Penetration of stains is especially shallow in very hard woods of close texture, such as maple. It may be slightly deeper in birch and beech and still deeper in open-textured hardwoods, such as oak, walnut, and teak.

Although stains penetrate somewhat deeper into softwood than into the hardwoods commonly used for flooring, the softwoods do not take stains well. The springwood, which is the softer, lighter colored part of the grain, takes up more stain and becomes more highly colored than the harder, naturally darker colored part of the grain. Thus there is a reversal of the natural color gradations of softwoods that is generally considered unattractive.

Instead of using stain, color may be imparted to wood later on during application of a wood sealer. Suitable oil stain may be mixed with the first coat of sealer, or wood sealers may be purchased that already contain the color.

Filling

Wood fillers may be used on floors made of hardwoods with pores larger than those in birch; namely, oak, walnut, or teak. Filler is useless on softwoods and on hardwoods with small pores, such as maple or beech. The pores in birch are large enough to take filler when it is desired to accentuate the grain of the wood by making the pores dark in color but the pores are small enough to go without filler if darkening is not required.

Filler accomplishes one or both of two purposes. It plugs the voids in the wood surface left by large pores to make the surface smooth and level, and if colored it makes the pores show more prominently. Fillers therefore are of two kinds, natural fillers that are transparent and without color, and colored fillers that are opaque and usually dark brown to black in color. Colored fillers are commonly named for the wood on which they are considered especially appropriate, for example, oak, walnut, cherry, or mahogany wood filler. Fillers may be a liquid, ready for application, or a paste to be thinned with mineral spirits or turpentine (paint thinners) before application. The directions given by the manufacturer usually should be followed. The paste is better for fine work.

Filler is applied best with a 4-inch flat brush. The first strokes should be across the grain of the wood, then a light stroke with the grain. Care should be taken not to cover too large an area at once, because there is further work to be done before the filler has had time to dry. Soon after the initial glossy "wet" appearance gives way to a dull "dry" appearance, the excess filler must be wiped off with burlap, excelsior, or other suitable material. Wipe first across the grain to pack the filler into the pores and then finish with a few lighter strokes with the grain. Care in wiping should be taken to see that all excess filler is removed; otherwise the finish may appear uneven and smeared.

Filler usually should be allowed to dry for 24 hours before further finish is applied. However, there are fast-drying fillers for which the manufacturer may indicate that less drying time is sufficient.

Manufacturers of some wood sealers for floors recommend that the application of filler be deferred until the first coat of sealer has been applied and has dried. Others recommend that the usual practice of filling before sealing be followed. Still others say that filler may be omitted entirely even on hardwoods with large pores when their sealers are used. In general, it is practicable to dispense with filling if the sealer is buffed with steel wool before it has hardened, as is described later. But when shellac, varnish, or lacquer is used for the final finish, hardwoods with large pores should always be filled.

Choice of Final Finish

The transparent finishes now in common use for floors are shellac, varnish, wood sealer, and, much less frequently, lacquer. In former times floors were often finished with linseed oil or with cheaper floor oils obtained largely from petroleum, but such finishes gradually made wood very dark in color and have now been entirely displaced by wood sealers.

Wood floors can be maintained in good condition with any one of the available floor finishes if good materials are applied properly and if maintenance methods appropriate for each kind of finish and for the degree of wear to which the floor is subjected are used. No type of finish can be said to be superior in all respects, and none will long continue to give good service unless suitably maintained. The secret of good floors lies in thorough understanding of the nature and limitations of the particular kind of finish chosen and in carefully following the appropriate maintenance program. Choice of finish should be dictated primarily by the appearance desired and the methods of maintenance considered most convenient.

If a highly glossy, lustrous finish is desired, the choice may well be shellac, varnish, or lacquer. Such materials form coatings over the wood surface a few thousandths of an inch thick. A more natural appearance with less gloss and resinous luster is obtained by the wood sealer finish. In using sealers, a thin layer of wood at the surface is saturated with the finishing material, and any excess is wiped or buffed off so that no coating of appreciable thickness is left on the wood surface.

Transparent Coatings

The coating finishes—shellac, varnish, and lacquer—suit the needs of those people who wish to let their floors go as long as possible without attention other than regular sweeping or dry mopping and are willing to go to more trouble when further maintenance finally becomes necessary. When the finish eventually must be renewed, it is usually necessary to refinish the entire room or, if the flooring runs without break from room to room, all flooring on a given story.

As a rule, limited areas of a floor receive a preponderance of wear from traffic. The finish wears out in such traffic lanes, while other parts of the floor remain unworn. It is seldom possible to renew coating finishes in the traffic channels alone without having the edges of the patching show. Moreover, after three or four renewals of a coating finish, the areas of little or no traffic acquire an unduly thick layer of finishing material, the older parts of which have darkened with age, and will no longer blend in color with the thinner coatings on the traffic channels. It is then necessary to remove all the old finish either with varnish remover or by resanding the floors before a new finish of uniform appearance can be applied.

Among the coating finishes, shellac has the merit of drying so rapidly that a floor may be finished or refinished and put back into service overnight. Varnishes, even the quick-drying, require longer intervals between coats and remain tender for some time, so that the floor should be kept out of service for several days, although with care light service often may be permitted within a day after the last coat has been applied. Landlords and some painters are inclined to prefer shellac finish; the owner-occupant is likely to prefer varnish or sealer finish.

Varnish is more resistant than shellac to water that may be spilled on a floor. Water or even prolonged exposure to high humidity turns shellac white. Good varnish finishes are also tougher and less easily scratched than shellac. Most varnishes gradually darken with age, whereas shellac does not.

Lacquer dries as rapidly as shellac, is as resistant to water as varnish, and seldom darkens with age. The lacquers widely used on furniture or on automobiles are made for application by spray gun rather than by brush. Lacquers made for brushing are more expensive and are still rather difficult to apply evenly on large surfaces such as floors. Moreover, lacquers contain much less nonvolatile material than varnish, so that more coats are required to make a finish comparable in luster to that obtained with varnish. For such reasons, lacquers are used much less than the other finishes for floors.

Opaque Coatings

Opaque paint or enamel can be used to finish wood floors when it is desired to hide the grain of the wood entirely and perhaps to provide colors that are not satisfactorily attainable in transparent finishes. Hardwood floors inside buildings, however, are seldom painted, because most users prefer to take advantage of the natural beauty of the wood. Softwoods are considered less attractive in appearance. In former times, when softwoods were sometimes used for interior floors of homes for economy, they were often painted. Some commercial buildings still use painted softwood floors.

Floors exposed to the weather, such as porch floors, are predominantly of softwoods and are usually painted. None of the transparent finishes resist weather well enough to last very long out of doors. Good floor paint or enamel proves much more durable.

Sealers

Sealer finishes require more frequent attention, but the maintenance is simple and involves little inconvenience. If all goes well, sealer finishes may be maintained indefinitely without removing the old finish. Since no more than enough material to saturate the wood surface is applied, there is no buildup of coating thickness on areas of little

wear, and traffic channels can be patched without going over the entire floor. Wood sealer finishes have gained especially wide use for wood floors exposed to unusually heavy traffic, such as gymnasiums, schools, stores, offices, and public buildings.

Application of Final Finish

Varnishes, lacquers, and wood sealers are made for many different uses. Only products made specifically for finishing floors should be used for that purpose. Spar varnish made for surfaces exposed to the weather may be too soft to withstand the abrasion of traffic, and cabinet finishing varnish made for furniture may lack the toughness required for floors. It is best to use floor varnish that is clearly so labeled by its manufacturer. So-called all-purpose varnish should be used only if the label says specifically that it is suitable for floor finishing. Similar caution applies to lacquers and wood sealers.

Varnish Finish

The floor and room should be clean and as free from dust as possible before varnishing begins. Dust motes falling into wet varnish impair the smoothness and appearance of the finish. The room should be at 70° F. or somewhat warmer, with plenty of fresh air. Varnish requires oxygen from the air for its drying, and there should be circulation to carry off the fumes of the volatile thinners in the varnish. Damp weather may be objectionable, since varnish dries slowly when the air is very humid. It is well to test the drying power of the varnish a day ahead of time by applying it on a nonabsorptive surface such as glass, metal, or well-primed wood.

Some varnishes lose their ability to dry promptly after long storage on a dealer's shelf. Poorly drying varnish can be exchanged for fresher stock, or its drying properties may be restored by adding about a teaspoonful of paint drier to a quart of varnish.

Varnish is applied with a wide brush. The brush should be cleaned well before using. Particles of old varnish or paint left in the brush may work their way into the fresh varnish to mar the finish. Even a new brush may well be washed with soap and water, shaken out, and dried before using. First spread a brushful of varnish with the grain of the wood, then stroke it across the grain, and finally brush it lightly with the grain again. Then go on to the next area with a fresh brushful. Do not go back to restroke areas that have been covered previously.

At least 16 hours should elapse before the second coat of varnish is applied. Three coats will be needed as a rule if the floor was not filled. If filler was applied, two coats of varnish may suffice. After the last coat of varnish, at least 24 hours, better 48 hours, should elapse before traffic is allowed on the floor. Varnish does not acquire its full resistance to wear for several days.

Lacquer Finish

Lacquer is applied much like varnish except that the work must be done more rapidly because lacquer dries so rapidly. The initial spreading, cross brushing, and final stroking must be done very quickly. Lacquer if brushed too long will not level out with a smooth surface. Lacquer holds its "wet edge" for a very limited time only. As far as possible, the edges of brush strokes therefore should coincide with the edges of boards in the floor, and the beginning of a second brushful must be joined to the end of the previous one very promptly. With lacquer, an hour or two between coats may be enough. The manufacturer's directions should indicate the required time.

Shellac Finish

Shellac for floors should be purchased in the form of 5-pound cut shellac varnish, that is, 5 pounds of shellac resin in 1 gallon of alcohol. It should be pure shellac varnish, unadulterated with cheaper resins. The bleached shellac, commonly called white shellac, is preferred for its pale color. Orange shellac imparts far too much color. Always test shellac varnish to see that it dries promptly without tackiness before applying it on a floor. When stored too long, white shellac varnish loses its ability to dry hard as a result of chemical reaction between the resin and the alcohol.

Shellac should be sold either in glass containers or in metal containers that are lined with lead or other coating to keep the varnish away from iron. Shellac varnish contaminated with iron may produce black stains on woods that contain tannins, such as oak.

The correct thinner for shellac varnish is 188-proof No. 1 denatured alcohol. For application, 5-pound cut shellac varnish should be thinned with 1 quart of alcohol per gallon. It should be applied with a wide brush that will cover three boards of strip flooring at a stroke and with long, even strokes, taking care to joint the laps quickly and smoothly.

The first coat on bare wood requires 15 to 20 minutes to dry. It should then be rubbed lightly with fine steel wool or sandpaper and the floor swept clean. A second coat should be applied, allowed to dry 2 to 3 hours, and then gone over with steel wool or sandpaper, swept, and a third coat applied. If possible, the floor should not be put back into service until the next morning, but if necessary, it may be walked on carefully about 3 hours after finishing.

FIGURE 26.—Applying sealer to hardwood floor. M100957F

If wax is to be used, it should not be applied less than 8 hours after the last coat of shellac. Paste wax is suitable. Water-emulsion wax should be avoided because water may turn shellac white.

Floor Sealer

Manufacturers' directions for applying floor sealer vary widely and sometimes are very inadequate. In general, floor sealers may be brushed on with a wide brush or mopped on with a squeegee or lamb's wool applicator, working first across the grain of the wood and then smoothing out in the direction of the grain (fig. 26). After an interval of 15 minutes to an hour, according to the characteristics of the sealer, the excess is wiped off with clean rags or a rubber squeegee. For best results, the floor should then be buffed with No. 2 steel wool, although the buffing may be omitted by those who are willing to sacrifice something in appearance and service. (On oak floors, presence of the sealer makes it unlikely that any particles of steel wool will become embedded in the surface as previously mentioned for bare floors.)

If possible, the buffing should be done by a rugged power-driven machine designed for buffing with steel wool. The next best procedure is buffing with pads of steel wool attached to the bottom of a sanding machine. Buffing may be done by hand if no machine is available. One coat of sealer may suffice if it is applied very carefully, but a second coat is generally recommended for floors that have just been sanded. The floor should be swept clean before making the second application.

A correct interval of time between application of sealer and buffing is very important. If the interval is too short, the sealer may still be too fluid to buff properly. If it is too long, the excess

sealer "gums" the steel wool badly, is removed from the floor with difficulty, and where not removed becomes blackened with detritus from the steel wool. If the manufacturer of the sealer does not specify the correct interval clearly, the user should determine it for himself by trial on samples of flooring or in some inconspicuous places where imperfect results will not prove too disappointing. Once the user has learned how to work successfully with one brand of sealer, he will do well to continue using that brand, since he might have to learn the technique all over again with another brand.

Floor sealers are now offered by a number of manufacturers of floor finishing materials and equipment, who are usually able to give precise and reliable instructions for the proper application and maintenance of their products. Sealers are also sold by most of the larger paint and varnish manufacturers, although the preference of their dealers is usually for floor varnishes.

Waxing Floors

Waxing of floors is done to best advantage with paste floor wax and an electric polishing machine designed for the purpose. For best appearance and durability there is no satisfactory substitute for the polishing machine; polishing by hand is far too laborious for the modern household and too expensive for the business building. The paste wax is mopped on the floor, allowed to stand until the volatile thinner evaporates, which may take 15 to 30 minutes, and the floor is then polished with the machine.

The most modern type of floor waxing machine applies the wax and polishes in the same operation. For those who wish to get along without a polishing machine and are willing to accept a somewhat less attractive and less durable wax finish, there are water-emulsion floor waxes that are merely mopped on the floor and allowed to dry.

Floor Paint or Floor Enamel

Paint or enamel for use on wood floors should be made especially for such use. The wear of traffic requires paint that is hard enough to withstand abrasion and yet tough enough to withstand impact. Paints or enamels made for other purposes may not have such properties in sufficient degree. The manufacturer's label should say clearly that the product is intended for use on wood floors. Paints made for concrete floors may serve also for wood, but there is no assurance that they will unless the label so states. For porch floors exposed to the weather the label should also state clearly that the paint or enamel is suitable for exterior use.

On new floors or floors just sanded, at least two coats of floor paint or enamel are necessary. The first coat should be thinned moderately with paint thinner in accordance with the manufacturer's directions. Subsequent coats usually should be applied unthinned. Each coat should stand at least 16 hours for drying before the next coat is applied or before the floor is opened to traffic. Porch floors should be painted in warm, dry weather.

It is generally necessary to repaint the entire floor when the coating becomes worn through at the traffic channels. Freshly applied paint, even from the same lot as the original paint, does not present the same appearance as the older paint. After a few repaintings, the coating tends to become too thick on the areas of least wear and may begin to crack and scale at the thick places. To postpone such condition as long as possible, apply a first coat of new paint in the worn parts of the traffic channels only and then apply a single finish coat over the entire floor, brushing it out as thin as practicable on the areas that receive little wear. Once the coating begins to crack and scale badly, it becomes necessary to remove all the old coatings by sanding or with paint remover so that the painting can be started over again with a coating of even thickness.

Cracks in Floors

When floors are laid originally with insufficient regard for control of moisture content, they may present a problem of cracks or gaps between boards by the time refinishing is in order. There is no satisfactory way of eliminating such cracks short of taking up the floor and relaying it.

Cracks open wider in winter when the wood reaches a minimum moisture content and become narrower in summer when the wood is more moist. If the cracks are filled with a soft putty or crack filler in winter, some of the filler may be squeezed out during the following summer to be tracked over the floor. If a hard filler is used, the wood may be further compressed during the summer. In either situation the cracks will open again during the next winter and may become worse than they were before the filler was applied. Filler applied in the summer will be insufficient to fill the gaps when they become wider again in the winter. On the whole, when cracks develop it is best to learn to put up with them unless they are bad enough to justify relaying the floor.

Wide cracks, of course, tend to collect dust and dirt. If they become completely filled with foreign matter, the cracks may no longer widen and narrow with seasonal change in moisture in the wood. As a result the cracks may become wider, just as though they had been filled with a hard filler. Regular use of a vacuum cleaner in normal house cleaning should serve to keep the cracks open. If necessary, compacted dirt may be pried loose with a blunt instrument. For much the same reason, floors with wide cracks, into which some finishing material is bound to flow, are refinished

to best advantage in the late summer season when the cracks are at their narrowest. When oak floors with wide cracks are buffed with steel wool in refinishing, it is well to use a vacuum cleaner a few days later to remove any particles of steel wool from the cracks.

Refinishing Floors

Best maintenance requires at least partial refinishing as soon as the finish wears thin in the traffic channels but before the wood has been left unprotected there. If the floor has been waxed, it is necessary to remove the wax before new finish is applied because wax interferes with the drying and adhesion of new finish. Most of the wax should be scrubbed off with rags kept moistened with turpentine or other paint thinner. The rest of the wax should be washed off with soap and warm water, doing the work as rapidly as possible so that the water will have too little time to reach the wood or to turn a shellac coating white. After the surface has dried again, new finish may be applied.

With wood sealer finish no more may be necessary than to mop fresh sealer on the worn areas of the traffic channels, wipe up any excess, and buff the surface as has already been described for the last coat on new floors. With the coating finishes, varnish, lacquer, or shellac, two coats may be advisable on the worn areas but would be altogether too much on the areas of little wear. It may therefore be practicable to apply a first coat in the worn areas only, ending all brush strokes at joints between boards, and then to apply a second coat over the entire floor.

After varnish, lacquer, or shellac finish has been renewed several times, it may no longer be possible to refinish the worn areas to match the appearance of the unworn areas where too much old finish discolored by age remains. It is then time to remove the old finish entirely.

The best way to remove old finish is by power sanding, which is necessary if the wood has become badly scuffed or marred. But there is a limit to the number of times a floor may be sanded because each sanding removes a substantial amount of wood as sander dust. Other methods of removing old finish therefore may be needed at times.

Floors Originally Finished With Oil

An old linseed oil finish embedded in the wood may cause some difficulty. If a steel-wool buffing machine is available, an attempt should first be made to clean the floor sufficiently merely by buffing with No. 3 steel wool. If this is not feasible or proves ineffective, a chemical treatment will be necessary. Mild alkalies change oil and many sealers or varnishes into soap that can be scrubbed off with water. The alkali used may be a water solution of trisodium phosphate, washing soda, or a commercial cleanser. Lye is inadvisable because it is strong enough to discolor some woods or even to swell and soften them. Since alkaline solutions are hard on the hands, rubber gloves should be worn while using them.

In applying the alkali, flush a small area of the floor at a time with the solution and allow it to stand for a few minutes, then scrub with a stiff brush or No. 1 steel wool. Next flush the area with clean water and scrub to remove the soap that has been formed, and finally remove all the water possible by mopping and let the floor dry thoroughly. If the floor turns gray in color as a result of the action of the alkali and water, bleach it with a saturated solution of oxalic acid in water (oxalic acid is poisonous and must be handled with care). Rinse off the oxalic acid thoroughly with clean water, mop, and let the floor dry completely. Any raised grain or roughening of the surface of the boards should be smoothed with sandpaper or steel wool before new finish is applied.

Floors Originally Finished With Varnish or Lacquer

Old varnish or lacquer can be removed with liquid varnish remover. The remover should be one made with organic liquids and should contain no water. The directions for using the liquid remover should be followed closely.

If the first coat of the original varnish was thinned too much and penetrated into the wood too far, some of it may still remain embedded. It will not interfere with the new finish except for the darker color it produces. If the color is unacceptable, it may be possible to remove the embedded varnish by the treatment with alkali described for floors originally finished with oil.

Floors Originally Finished With Shellac

Old shellac finish can be removed by scouring the floor with No. 3 steel wool and denatured alcohol diluted half and half with water. If the floor boards are level and are not warped or cupped, the scouring can be done to advantage with a floor-polishing machine fitted with a wire brush to which a pad of No. 3 steel wool is attached. After the scouring, the floor should be rinsed with a minimum amount of clean water and allowed to dry thoroughly before refinishing with shellac.

When white spots have developed in shellac finish from accidental contact with water, they may often be taken out by rubbing lightly with a soft cloth moistened with denatured alcohol diluted half and half with water. The alcohol, however, must be used with care to avoid cutting the shellac coating.

Floor Maintenance

Specific rules for the frequency of maintenance of floor finishes cannot be set forth, because the determining factor is the amount and kind of traffic, which varies greatly. In many homes so much of the flooring is covered by rugs or carpets

that there may be no appreciable wear on the floor finish except perhaps near doors between rooms. Finish wears especially rapidly on bare floors near doors to the exterior where water may be tracked in during wet weather and those entering may have gritty footwear. Foot mats near exterior doors, of course, can be helpful in reducing the wear on floor finishes from such sources.

The kind of footwear worn by the occupants and their habits of walking also affect the wear on floor finishes. Soft-soled footwear causes little or no wear unless it is wet or gritty. On the other hand, leather heels nailed in place and used on concrete sidewalks until the nailheads project seriously impair the durability of floor finishes and may even scratch wood badly enough to require resanding the floor. The small heels on women's high-heeled shoes, which concentrate the load on a small area, may be especially damaging.

The durability of floor finishes can be improved by keeping them waxed. In homes, renewal of the wax every 4 to 6 months may suffice, but more frequent renewal may be necessary where traffic is heavier. Well-waxed floors are easier to keep clean by dry mopping. Wax over coating finishes tends to make floors slippery unless the wax layer is kept very thin. Over sealer finishes, wax is usually less slippery. Some floor waxes are made with special ingredients to improve their resistance to slip.

Floor finishes in gymnasiums, schoolrooms, and commercial or public buildings are subjected to much more severe service, as a rule, than are floors in homes. Accordingly inspection and maintenance must be more regular and more frequent. Some makers of floor finishing materials and equipment will train a maintenance man for their customers in the methods of keeping floors in good condition. Sealer finishes applied and maintained adequately with electric buffing machines have proved especially satisfactory for heavy-duty floors. Although frequent attention is required, the work can be done in a few hours at night or on weekends without interrupting the normal use of the floor.

Use of gymnasium floors can usually be restricted to persons in shoes soled with rubber or other nonabrasive footwear. Fast action in such games as basketball produces sharp friction between footwear and floor finish that tends to produce "rubber burns" that mark some finishes more seriously than others. Special sealers that resist such marring especially well are made for gymnasium floors. If rubber burns are not too severe, they can be removed by scrubbing with naphtha or paint thinner.

Wood floors with fine finishes should never be scrubbed with water or unnecessarily brought in contact with water except in connection with refinishing old floors as already described. Sweeping or dry mopping should be all that is necessary for routine cleaning.

A soft cotton floor mop kept barely dampened with a mixture of 3 parts of kerosene and 1 part of paraffin oil is excellent for dry mopping. Commercial preparations are available for the purpose also. When the mop becomes dirty, it should be washed in hot water and soap, dried, and again dampened with the mixture of kerosene and paraffin oil. Exceptional patches of dirt that cannot be removed in this way, or rubber burns from friction between rubber footwear and floor, may be removed by rubbing lightly with fine steel wool moistened with turpentine or paint thinner.

Badly soiled spots, such as gray spots where water or pets' urine has been allowed to stand on the floor for a time, may offer difficulty. Where the finish is a floor sealer, the stained area can be sanded by hand, patched with fresh sealer, and buffed with a pad of steel wool. Similar patching with varnish, lacquer, or shellac may not blend perfectly with the rest of the floor but will usually prove much less objectionable than the stain. Where the water stain has penetrated the wood too deeply to be removed by hand sanding, it is necessary to remove the finish by sanding and then to bleach the wood with oxalic acid as described for floors originally finished with oil.

Stains from some writing inks also can be bleached with oxalic acid or with other commercial wood bleaches, such as alkaline hydrogen peroxide bleaches. Stains from vegetable oils or greases usually will yield to the treatment with alkali described for old oil finishes, but petroleum oils or greases that become embedded in the wood may resist all practicable treatments except that of sanding off all the stained wood.

Varnish coatings and other finishes are not effective in preventing long-term moisture changes such as occur seasonally. They do, however, retard the entrance and exit of water and thus may be expected to moderate the effects of short-term changes, such as water spillage or short periods of extremely high humidity. It is desirable, therefore, to refinish worn areas as promptly as possible to reduce the possibility of excessive swelling, and perhaps buckling, from short-term effects such as those mentioned.

Eliminating Squeaks in Floors

Floor squeaks are caused by relative movement of the tongue of one flooring strip in the groove of its neighbor. Such movement may occur for any one of a number of reasons. For example, if the floor joists are somewhat small for the span, they may deflect sufficiently to permit movement in the flooring. Similarly, if sleepers are not held down tightly to a concrete slab, or come loose in service, enough movement may be possible to cause squeaks. Poorly manufactured flooring in which the tongues are undersize and thus do not fit tightly in the grooves may also lead to squeaks. Warped flooring or subflooring may permit the boards to

rock under traffic; this is unlikely to be a factor with hollow-back flooring. An unusual case, which might occur occasionally, is one where the joists change direction in adjoining rooms while the flooring direction is constant. Where this occurs, the flooring in one room would be parallel to the joists and deflection of the subfloor might permit sufficient movement to cause squeaks. Finally, and perhaps most commonly, squeaks may result from inadequate nailing.

Obviously, the best method of eliminating flooring squeaks is to install well-made flooring on a sound floor system, taking particular care in installation, especially with the nailing. If, however, squeaks do occur in a finished floor, a number of steps may be taken.

First, determine the cause of movement so that proper steps may be taken for correction. Regardless of cause, one expedient is to lubricate the tongue with mineral oil introduced into the opening between adjacent boards. The oil must be used sparingly, however; too much may result in stains in the flooring.

A fairly common and effective procedure is to drive a nail through the face of the flooring into the subfloor—preferably also into a joist. The nail should be driven near the tongue edge of the flooring strip, then set and the hole filled.

Where flooring is warped and the under surface of the floor is exposed, screws through the subfloor and into the finish floor will be effective in reducing movement. This procedure will be somewhat less objectionable than face nailing from the standpoint of appearance.

When the flooring strips run parallel to the joists, as described earlier, little can be done if there is a finished ceiling below the floor. Where it is open, however, as in a garage or basement, solid blocking may be fitted between and nailed to the joists and snugly fitted against the subfloor. The blocking needs to be at sufficiently close intervals to provide support for the subfloor and finish floor. Adequate nailing to the joists is necessary so that the blocking will maintain its position.

Experimental Flooring Types

In addition to the more usual types of wood flooring described earlier, many attempts have been made to develop types which have special properties or which use lesser amounts of the high-grade material generally most in demand because of its good appearance. The Forest Products Laboratory has been active in this field and a few of its experimental floors are described below.

The stabilized veneer tiles described earlier represent one method of using this type of material. Experimental floors using strips rather than squares of this material have given good results when proper laying procedures were used.

Attempts to minimize the amount of high-grade material are well illustrated by a veneer-lumber flooring developed by the Forest Products Laboratory. It consists of a $\frac{1}{8}$-inch layer of high-grade veneer glued to a $\frac{5}{8}$-inch lumber backing, with the grain of the two at right angles. The backing lumber may be of any species denser than 25 pounds per cubic foot and may contain knots, checks, splits, and other defects, so long as there is an essentially sound surface adjacent to the face veneer. After the two components are glued together, the backing is grooved parallel to its grain at 1-inch intervals with the grooves extending almost through the backing. The cross-laminated construction provides considerable dimensional stability, and the grooving provides flexibility, permitting installation over somewhat uneven surfaces.

The unit block flooring described earlier generally consists of short tongued-and-grooved strips held together by splines. A Laboratory-developed flooring eliminates not only the tongue-and-groove, but also the dressing of the edges of the individual pieces. Random-width strips are assembled edge to edge and wood or hardboard splines glued into the end-grain edges of the assembly. The improvement in utilization is obvious, since random-width strips are used, and the dressing and matching are eliminated. The rough-sawed edges have proved preferable to planed edges, since they allow more room for expansion.

Resin-impregnated paper has been glued to the surface of wood and plywood to impart improved properties. Some high-density types of overlays have been used experimentally on plywood for flooring. The major improvement attained with them has been to impart a hard, abrasion-resistant, highly decorative wearing surface to softwood plywood, which would otherwise not be suitable for finish flooring.

Wood has been modified in various ways to improve its dimensional stability and other properties. One such material, termed staypak, is made by compressing wood under optimum conditions of moisture content and temperature. An experimental floor of this material has given good results over a period of several years.

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