HARDWOOD PALLET MANUFACTURING

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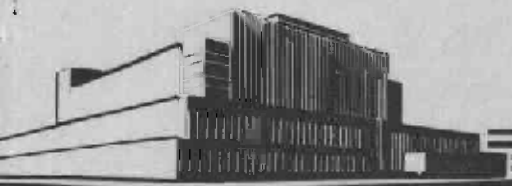

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

HARDWOOD PALLET MANUFACTURING

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Introduction

An extensive pallet industry has developed as a result of the rapidly expanding use of mechanical handling equipment. Forklift and hand trucks provide sufficient power or mechanical advantage to bulk-handle a variety of large loads of industrial and agricultural products. Pallets provide the foundation upon which to assemble these loads. Advantages of palletization are many and varied, but of sufficient importance to justify considerable expenditure for pallets.

Wood is the basic raw material used for most of the pallets produced in the hardwood region. Because of this, several surveys have been made by the Forest Products Laboratory and Forest Experiment Stations to determine the types of pallets produced and the materials, methods and equipment used, as well as problems and other factors related to the industry.

This report is intended as a reference for the industry, particularly for those who desire to provide design services and buyers who desire to purchase quality goods; therefore, considerable information is included on wood and nails. Although this information is available in the Wood Handbook (6)[2] and other references (2), (10), it is included here to be readily available. Material of special interest to the pallet industries is also included (1), (3), (4), (5), (7), (8), and (9).

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

[2] Underlined numbers in parenthesis refer to literature cited at the end of this report.

Pallet Construction

Pallets are generally simple in design and their fabrication involves little use of skilled labor or special machinery. They absorb the lower grades of lumber and cuttings from woods and mill waste. They can be made from short logs, slabs, or other scrap. Pallet production can often be integrated with that of box, dimension, and other lumber at the mill. However, pallet producers do need a thorough knowledge of the characteristics of wood and the defects that are permissible in pallets.

In general, the quality of lumber used in pallet manufacture may be characterized by the kinds and sizes of defects. Knots, checks, and splits must be limited to make certain that satisfactory pallets will result. The lower grades of lumber are economical if defects can be cut out or so placed in the finished pallet that they do not impair its strength and serviceability.

It is important that the manufacturer become familiar with how his customer will use the pallets. It is up to the producer to furnish a pallet that will perform according to the user's expectation. There should be close laison between supplier and buyer as to how the product will be handled and what construction details are critical. Future orders can be jeopardized if the quality of the lumber or the workmanship are not what the customer expected.

Size of Plants

Pallet plants vary in size from one- or two-man operations to factories employing 75 or more persons. Equipment used by manufacturers likewise varies considerably, but includes all types of machinery normally used in similar wood-using industries. A high percentage of these plants, particularly the larger ones, also manufacture other items from wood. About two-thirds of the pallet plants operate or control sawmills; the others purchase lumber and timbers. A large percentage of these operating sawmills also purchase lumber. There is no accurate census of the pallet plants in the hardwood region, but persons familiar with the industry estimate that there are several hundred.

Types of Pallets

Pallets are classified into three general groups; expendable, general purpose, and special purpose. Expendables (fig. 1) are usually one-trip structures and are also frequently referred to as shipping pallets. General purpose pallets (figs. 2 and 3) are reusable for use in warehousing and shipping and are sometimes referred to as warehouse pallets. Special purpose pallets

(fig. 4) are for a particular product or are patented pallets that may contain any feature of construction that will assure proper performance. The majority of plants manufacture both expendable and general purpose pallets as well as some special purpose pallets. Others specialize in either expendables or nonexpendables, while a few specialize in producing shook or parts to be assembled into pallets by the user. Parts to be used for repair are also produced by some plants.

Pallets can also be subdivided into two styles; single face and double face. The single-face pallets have only one deck -- the top; they are sometimes referred to in the industry as skids, particularly if they have only two stringers or runners. Double-face pallets have both top and bottom decks.

Any of the foregoing groups or styles can be made to provide either two-way or four-way entry. Entry refers to the number of sides with openings for insertion of the tines on forklift trucks. The majority of expendable hardwood pallets are four-way entry, made with nine blocks. Another four-way entry design has stringers notched to permit forklift entry in two directions (fig. 3).

The ends of the deck boards may be flush with the stringers or project beyond them in single- or double-wing constructions (fig. 2). The pallet manufacturer must be familiar with all of the variations in size and construction, as well as with important factors in production costs. These variables are the reason why some plants specialize in certain types, styles, or designs.

There is no standard size of pallet. Dimensions vary from a minimum of less than 2 feet to a maximum of over 6 feet. The two most common dimensions are 40 and 48 inches, although a dimension such as 41-1/2 inches is not uncommon. The width of freight cars and truck beds often dictates pallet dimensions. Other pallets may often be built to conform to spaces between posts and walls in warehouses. The American Standards Association has proposed a set of 11 standard sizes for noncaptive pallets (pallets which will probably be used by more than one enterprise), and is urging that these sizes be used wherever possible:

Rectangular Pallets	Square Pallets
24 by 32 inches	36 by 36 inches
32 by 40 inches	42 by 42 inches
36 by 42 inches	48 by 48 inches
32 by 48 inches	
36 by 48 inches	
40 by 48 inches	
48 by 60 inches	
48 by 72 inches	

Pallet manufacturers define the first dimension of the pallet size as length of stringer in the case of pallet designs described as two-way entry or partial four-way entry, and as length of stringer or sub-deckboard in full four-way entry.

Designs and Engineering

The proper size and type of pallet is essential to the user, but it is equally important to him that the pallets be made according to accepted manufacturing standards. Too often pallets are bought on the basis of price alone. Sometimes little thought is given to basic features of good construction practices. The results of this kind of pallet buying are damaged goods, frequent repairs, expensive maintenance, and short service life.

Nearly all pallets are built according to a set of specifications that has been derived from 1 of 4 sources: (1) Progressive fabricators provide this type of engineering service and can thereby often avoid design errors, unnecessary features, and unusual or uneconomical sizes that add significantly to the cost; (2) Other manufacturers provide design service through contract with an engineer or pallet broker who works with several manufacturers; (3) The pallet consumer or possibly the fork truck distributor may be the source of the design and he may or may not be familiar with fabricating problems, nail-type efficiencies, and strength of the several species of wood; (4) There are several established specifications in general use:

Federal Specifications

NN-P-71 - Pallets; Materials-Handling, Wood (General Construction Requirements)

NN-P-0074 - Pallets; Wood, Stringer Design, Maximum Capacity 2,500 Pounds

Military Specifications

MIL-P-3938 - Pallets, Materials Handling, Hardwood, Four-Way, Partial, 40 by 48 Inches

MIL-P-4894 - Pallets, Materials Handling, Box Type, Wood (Light Duty)

MIL-P-10709 - Pallets, Stevedoring, Wood, 4 by 6 Foot, Knockdown

MIL-P-15943A - Pallets, Wood, 48- by 72-Inch, Two-Way, Stevedore (Cargo)

MIL-P-16496 - Pallets, Softwood (Hardwood Posts), 40- by 48-Inch, Four-Way Nailed Construction, General Purpose

MIL-P-25244A(USAF) - Pallets, Storage, Rocket, Mobile, Type MB-1

MIL-P-26966A - Pallets, Material Handling, Lightweight, Air Cargo

National Wooden Pallet Manufacturers Association

Minimum Standard Specifications for Warehouse or Returnable Wooden Pallets

Army Ordnance Purchase Description

OAC-PD-14 - Wood Pallet Units for Shipment of Shell and Projectile: Ammunition

Military Standard

MIL-STD-147 - Palletized Unit Loads (40- by 48-Inch, Four-Way Partial and Four-Way Pallets)

Federal specifications may be purchased from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Requests for military specifications or standards should be directed to one of the following custodians:

Chief of Engineers
Department of the Army
Attn: ENGHP
Washington 25, D. C.

Commander
Wright Air Development Center
Attn: WCXP
Wright Patterson Air Force Base, Ohio

Chief of Ordnance
Department of the Army
Washington 25, D. C.

Chief, Bureau of Supplies and Accounts
Attn: Code S-33
Department of the Navy
Washington 25, D. C.

The National Wooden Pallet Manufacturing Association is located in the Barr Building, Washington 6, D. C.

Materials

Wood

Strength.--Because wood is a product of nature, it is not a homogeneous material. Thus, it has not the same strength across the grain as parallel to the grain. Its tensile strength may vary as much as 40 to 1, its crushing strength 7 to 1, and the modulus of elasticity 150 to 1. Also, its strength properties not only vary with different species, but wood of the same species and even wood from the same tree may vary to a considerable degree, depending upon the growth conditions under which the wood was formed.

As used in pallets, wood is loaded as a beam and therefore its strength in bending parallel to the grain is most important. Column 2 of table 1 presents the average value of modulus of rupture (a measure of the ability of a beam to support a slowly applied load for a short time) for green lumber of the various hardwood species. Basic stresses (generalized working stresses for clear wood of a species) are presented in column 3. These basic stress values have been reduced from the average laboratory values in order to conform more closely to the conditions of the use of lumber.

Grades.--Practically all species of hardwood are used for pallets. Purchased lumber is generally No. 2 or 3, except in the nonmarketable or low-value species. In these species, all grades are used. Plants that own sawmills also use only the No. 2 or 3 lumber for pallets and sell the better grades for higher quality products. Sometimes these producers buy only low-grade logs that will yield very little lumber of No. 1 grade or better. All pallet lumber is sized to uniform thickness by planing or resawing. Most of the 1-inch lumber and stringers are sized by planing. Most of the lumber of 1/2 inch and thinner is sized by resawing.

Plainsawed and quartersawed lumber.--Lumber generally is cut from trees in either of two planes with respect to the annual growth rings: (1) Quartersawed -- along the radius of the annual rings, exposing the radial surface; and (2) plainsawed -- tangent to the annual rings, exposing the tangential surface.

Oftentimes the annual rings will run diagonally across the end of a board, so that it cannot be said to be either strictly plainsawed or quartersawed. The difference in strength properties of quartersawed or plainsawed lumber of the same species is not sufficient to warrant consideration in pallet construction.

Weight of wood.--Table 1 gives the average weights of the more important woods currently used in pallet construction. The tabulated weights of green wood, column 5, include the moisture present in the boards when they are green or freshly sawed. The weights shown in column 4 are for wood that has been dried to a moisture content of 22 percent. This represents the moisture condition that might be reached by hardwood lumber in stickered outdoor piles after drying from 3 months to a year.

In lumber that has been dried to 22 percent moisture content, the weight per 1,000 board-feet will rarely vary more than 10 percent from the average value shown in the table. With green lumber, however, the variation may occasionally be as high as 20 percent. This is due to large differences in moisture content.

Decay resistance.--Regardless of species, wood that is kept constantly dry, or at a moisture content of less than 20 percent, does not decay. Thus, with pallets that will be used in protected areas, decay resistance is not an important consideration. With pallets that will be used in unprotected outdoor storage, decay resistance is a significant factor in their serviceability.

When a pallet is used under conditions that favor decay, as in a warm, wet climate, wood of low decay resistance may last less than 1 year, but the heartwood of some hardwood species may give several years of satisfactory service. If outdoor exposure is less severe, several years of service may be expected from wood of low decay resistance. Most commercially important hardwood pallet species have moderate or low resistance to decay. In all woods the sapwood has lower decay resistance than the heartwood.

Moisture content of green wood.-- In living trees and freshly sawed boards, the sapwood generally contains more water than the heartwood. In many hardwoods, however, the moisture content of heartwood and sapwood is quite uniform.

Living trees often contain more than 100 percent of moisture. In such instances, the cell walls are fully saturated, and the cell cavities are almost filled with water.

Relative humidity and temperature.--When wood is exposed to a constant temperature and relative humidity, it will in time come to a definite moisture content that is in balance with the amount of moisture in the surrounding air. This moisture content is called the equilibrium moisture content. Under constant temperature conditions, the moisture content increases as the relative humidity increases; under constant relative humidity conditions, the moisture content decreases as the temperature increases. Moisture content variations in pallets in service can be minimized by fabricating them from

wood at a moisture content that corresponds to the average moisture content anticipated for the locality where the pallets will be used.

Shrinkage of wood.--Below the fiber-saturation point, wood shrinks as it loses moisture and swells as it absorbs moisture. Wood from the tree may contain from 30 to 250 percent water, based on the weight of the ovendry wood. This water is held in the wood in two ways -- water bound in the walls of the wood cells and free water in the cell cavities. When wood begins to dry, it loses the free water first and then the bound water. The fiber-saturation point is that condition in which all the free water has come out of the wood, but all the bound water remains. The fiber-saturation point is approximately 30 percent moisture content.

Wood shrinks only if its moisture content is reduced below the fiber-saturation point. In seasoning green wood, however, the surface dries more rapidly than the interior and reaches the fiber-saturation point first; shrinkage may therefore start while the average moisture content is considerably above the fiber-saturation point. Wood shrinks most in the direction of the annual growth rings (tangentially), about one-half to two-thirds as much across these rings (radially), and very little along the grain (longitudinally).

Shrinkage during drying is proportional to the moisture lost below the fiber-saturation point. Approximately 40 percent of the total shrinkage possible has occurred in wood seasoned to 18 percent moisture content. If wood is properly seasoned, manufactured, and installed at a moisture content in accord with its service conditions, there is every prospect of satisfactory performance without distortion or serious change in size.

In general, the heavier species of wood shrink more across the grain than the lighter ones. Heavier pieces of the same species also shrink more than lighter pieces.

Moisture content of seasoned lumber.--The trade terms of "green," "shipping dry," "air dry," and "kiln dried," although widely used, have no specific nor agreed meaning with respect to moisture content, except in a few instances where lumber association rules define moisture content limits for kiln-dried and air-dried lumber. The wide limitations of these terms, as ordinarily used, are covered in the following statements, but are not exact definitions:

"Green" lumber is lumber that may be freshly cut or partially seasoned but has not yet reached a shipping-dry or air-dry condition. The term may also be applied to lumber that has a higher moisture content than is acceptable for manufacturing into finished products.

"Shipping-dry" lumber is lumber that has been partially dried, either in a kiln or by air drying, to reduce weight and freight charges, and that still may have a moisture content of 30 percent or more.

"Air-dry" lumber is lumber that has been exposed to the air for any length of time. If exposed for a sufficient time, in summer in the arid Southwest, it may have a moisture content ranging upward from 6 percent; exposed in winter in the Pacific Northwest, the moisture content might be 24 percent. For the United States as a whole, the minimum moisture content range for thoroughly air-dry lumber is 12 to 15 percent in the summer, and the average is somewhat higher. Sometimes such terms as "90 days on sticks" or "4 months in the yard" are used instead of "air dry" to denote the length of time the lumber remained in the yard piles. Since lumber seasons more slowly in cold weather, less drying would take place during the winter than during the summer, and a given period in the yard would not mean the same degree of seasoning had occurred in cold or wet months as would occur in warm or dry months. Perhaps the most general use of the term "air-dry," in connection with hardwood lumber, is in reference to about 25 percent moisture content. This is at or slightly below the fiber saturation point for all domestic hardwoods and is a practical maximum for air drying of lumber to be subsequently kiln dried.

"Kiln-dried" lumber is lumber that has been dried in a kiln for any length of time. The term applies to lumber dried to "shipping dry," as defined previously, as well as to stock dried to a final moisture content of 12 percent or less. Specifications that cover kiln-dried lumber intended for immediate processing into a finished product should state the average moisture content, tolerance of individual pieces above and below the average, and moisture distribution between surface and center.

The moisture content of wood that goes into pallets is very important. Many pallets are built from green or partially green lumber because of lower cost and ease of nailing. These often fail prematurely as the boards warp, cup, twist, or split at the nails. These failures increase costs of repair and upkeep tremendously and offset many of the savings that can be realized by palletization. When air-dry lumber is specified, predrilling of the deck boards may be required to reduce splitting. Together, drying and predrilling can increase the cost of pallets as much as one-third. The increased cost may be offset by better pallets and less repair.

The softer hardwoods should have a moisture content not greater than 19 percent at the time they are used for building pallets. The denser hardwoods, indicated in table 1, should not contain more than 22 percent moisture for lumber of nominal 1-inch thickness or less, and 26 percent when thicknesses are over 1 inch. In some climates, it may be necessary to stack green

lumber in the open for a considerable time to achieve these moisture contents, but the improved durability of the finished products will more than justify the effort and increased cost of the finished product.

Moisture content determination.--Two methods of determining the moisture content of wood are recognized: (1) Drying a sample in an oven, and (2) using an electric moisture meter. The methods are not interchangeable but complement one another, since each has a distinct field of usefulness not covered by the other. Because the moisture content will vary between pieces in a given log or shipment, a number of tests must be made with either method to obtain an average. Intelligent selection of test pieces and a suitable number of samples to represent the total lot will minimize error.

Ovendry method.--The moisture content of a test section of wood can be determined accurately by the ovendry method, regardless of moisture distribution, size, species, density, or temperature of the wood being tested. On the other hand, this method necessitates cutting into and wasting part of the original board or plank, and requires 24 hours or more to complete.

Electric moisture meters.--Electric moisture meters give an instantaneous moisture content reading, based on the effect of moisture on the electrical resistance or capacity of wood. The values are affected by a number of factors, such as density, species, temperature, moisture distribution, and thickness of material. Many moisture meters are limited to readings covering a moisture content range between 7 and 25 percent.

Knots.--A knot is the base of a limb embedded in the tree trunk. Normally a knot starts at the pith and increases in diameter from the pith outward as long as the limb is alive.

When the limb is alive, its fibers interlace with those of the tree trunk, producing an intergrown knot. Many of the lower limbs die after a time as a result of shading or other causes, but they may not break off for many years. After the death of a limb, the wood formed in the tree trunk makes no further connection with the limb but grows around it. This produces an encased knot, which may be either so loose that it will drop out, or so tight that it will be held in position when the trunk is sawed into lumber.

When a knot is cut through transversely, a round knot results; when cut obliquely, an oval knot results; and when cut lengthwise, a spike knot results. A sound, tight knot is solid across its face, fully as hard as the surrounding wood, shows no signs of decay, and is so fixed by growth or position that it will firmly retain its place in the piece.

Knots are objectionable on account of the distortion and, in encased knots, the discontinuity of the grain that they produce; they also weaken the wood,

cause irregular shrinkage, and make machining more difficult. When lumber dries, the knots shrink more than the surrounding wood and may check or loosen. Loose knots are likely to drop out.

Knots that are permitted in pallet lumber are limited by the proportion of their width to the width of the piece of lumber containing them. Generally knots can be included in pallet parts if the knots comprise no more than three-eighths of the width of the member.

Checks, splits, and shakes.--Three types of longitudinal cracks that occur in wood are shakes, splits, and checks.

A check is a longitudinal crack, generally in the radial direction or across the annual rings. Checks usually result from shrinkage in seasoning. Thick lumber checks more severely than thin lumber. A split is a longitudinal crack that extends through the full thickness of a board. It often takes a radial direction and may be called a through check. A shake is a longitudinal crack between two annual rings. Shakes are present in green timber but they may be extended in seasoning. They indicate a weakness of bond between annual rings that extend lengthwise beyond the visible opening. Splits and shakes can be included in pallet lumber if they are no longer than two times the width of the piece.

Cross grain.--In cross-grained wood, the fibers are not parallel to the length of the board. The two principal types of cross grain are diagonal grain and spiral grain.

Diagonal grain results from sawing a board at an angle other than parallel with the bark. It is easily detected by noting the slope of the annual rings on an edge-grain or radial surface.

Spiral grain results when the fibers grow spirally around the trunk of a tree instead of in a vertical course. In lumber, it is not always apparent to the eye, but can often be detected by the direction followed by a split in the radial plane.

Cross grain can be tolerated in pallet parts if the slope is no steeper than 1 in 10. This slope is measured by the angle between the general direction of the grain and the long axis of the member. Slight local grain deviations, such as around knots, can be disregarded but, when a member contains both diagonal and spiral grain, the combined damaging effect should be taken into account.

Pockets and streaks.--A bark pocket is a patch of bark partially or wholly enclosed in the wood. Usually some slight separation, or at least a lack of cohesion, is involved and has a definite weakening effect.

Mineral streaks are dark brown or black streaks, frequently with a green tinge, and often contain mineral matter in sufficient quantities to dull sharp-edged tools. They vary in length from less than an inch to a foot or more along the grain and, at their widest portion, may extend 1/8 to 1 inch or more across the grain. Their limits may be sharply defined, or they may fade out gradually into the surrounding wood. Mineral streaks are frequently infected by fungus, and they check more easily in seasoning than normal wood. Mineral streaks are common in maple, hickory, basswood, yellow-poplar, and yellow birch, and are occasionally found in other hardwoods. Evidently they are often, if not always, due to some injury to the living tree, such as bird pecks, mechanical abrasion, or tappings for maple sugar. The streaks have little effect on strength or other mechanical properties and are not considered objectionable in pallet lumber.

Stain and decay.--Many stains and all forms of decay or rot are caused by fungi that grow on and in wood. Fungi are primitive plants made up of fine threads invisible to the eye unless massed or matted together. Fruiting bodies of these fungi may appear on the surface of the wood. The fruiting bodies of the staining fungi are always small. Those of decay fungi may be large, and take such forms as toadstools, conks, and brackets. Since they are not formed until the fungi have developed vigorously inside the wood, their presence indicates serious infection. Lumber with a moisture content kept below 20 percent will not stain nor decay.

The most common stain is the blue stain that occurs in the sapwood of many species of wood, and is often known as sap stain. The sapwood is mottled or streaked with a bluish or grayish stain. In advanced stages, the entire sapwood becomes dark blue-gray or almost black. A stain of this type ordinarily does not seriously affect wood strength and is not considered objectionable in pallet lumber. Its presence, however, indicates exposure to conditions that are also favorable to the development of decay, and stained pieces should be carefully examined for decay.

Incipient decay usually appears as a discoloration, often in rather irregular streaks or elongated areas having a reddish or brownish tinge. The streaks extend lengthwise in a board but are not limited to certain annual rings, as is the case with most normal color variations in wood. Decay in this stage has only moderate effect on those properties important in pallet lumber.

More advanced decay or rot results in a distinct change in color, a soft or brittle texture, a dry or "dead" appearance, and pronounced cross-cracking. Some types of decay produce discolorations in the wood known as zone lines. These are narrow black, orange, or yellow lines of various lengths that tend to run somewhat in the direction of the grain of the wood. They are often more prevalent at or near the border of the most conspicuously discolored

areas. Sometimes they border areas only slightly discolored, but their presence is certain evidence of decay.

Decay in any stage seriously reduces the strength and toughness of wood and should be excluded from pallet lumber. Small amounts of decay in knots (unsound knots) may be allowed if specifications permit and if the decay does not extend to adjacent areas outside the knots. Stain and discoloration that are not associated with decay are permitted in pallet construction.

Manufacturing defects.--Undersize or offsize lumber may result from errors in sawing. Specifications or accompanying drawings for pallets usually indicate permissible tolerances in size.

Wane is the presence of bark or lack of wood along one or both edges of boards that are sawed from the outer portion of the tree trunk. Wane that does not exceed three-fourths of the thickness and one-sixth of the width of the piece is not large enough to have a serious effect on the strength of a pallet member.

Lumber may be surfaced on 1 side (S1S), 2 sides (S2S), 1 edge (S1E), 2 edges (S2E), 4 sides (S4S), or some combination thereof. Some areas, where dimensions are scant, may not surface fully smooth. These areas are known as skips and may be defined and limited by area, depth, or both. A slight skip does not have measurable depth; a shallow skip is one that the planer knife failed to touch by not more than 1/32 inch and a deep skip by not more than 1/16 inch. The term "hit and miss" describes a series of surfaced areas with skips not more than 1/16 inch deep. This type of defect is not considered critical in pallets and is permitted up to 1/16 inch deep.

Where areas of irregular grain occur, a part of the wood may be torn out below the general dressed surface. Torn grain up to 1/32 inch deep is classed as slight, up to 1/16 inch as medium, and up to 1/8 inch as heavy. Torn grain up to 1/16 inch deep is permitted in pallets and may also be limited to a proportional part of the face area of a board.

Lumber may become crooked, bowed, twisted, or cupped during seasoning or kiln drying. Crook is deviation edgewise from a straight line from end to end of a piece. Bow is deviation flatwise from a straight line from end to end. Cup is a curve in a piece across the grain or width of a piece. It is measured by placing a straight-edge across the width and measuring the point of greatest deflection. Slight cup measures up to 1/4 inch, medium cup up to 3/8 inch, and deep cup up to 1/2 inch, based on a board 12 inches wide. Cup in a 6-inch board measures half as much or in like proportion for other widths. Deep cup is never permitted in pallets and quite often medium cup is reason for rejection. Twist is a distortion caused by the turning of the edges of a board so that the four corners of any face are no longer in the

same plane. Bow or twist in pallet deck boards can usually be straightened by nailing, but nailing the two edges of cupped boards may result in splitting.

Nails

Nails are the most common fastenings used for pallets. A pallet must be properly nailed to develop the maximum strength of its wood members. Many maintenance problems can be traced to the wrong number or size of nails.

In many expendable pallets, it is good practice to drive nails through the thinner into the thicker member and, when possible, clinch the nails on the back. Sinker, cooler, or corker nails are used for this purpose. If these nails are clinched it is not necessary to use nails with coatings, roughened surfaces, or deformed shanks. Clinching the nail across the grain is many times more effective than clinching with the grain, and the minimum clinch should be 1/4 inch.

Laboratory withdrawal tests show that for heavier members, where clinching is not practical, deformed shank nails have holding abilities -- under certain conditions -- of 2 to 3 times those of common or coated nails. Spiral- and annular-grooved nails have been developed (fig. 5) that are particularly effective in pallet construction.

Spiral-grooved nails should have at least 4 flutes and a helical angle of thread such that the projection of the thread across the axis of the nail makes an angle of about 30 degrees with the axis of the nail. The annular-grooved nails should have about 20 ring threads per inch, and the top surface of each ring should be approximately perpendicular to the axis of the nail. The sides of each ring should taper toward the point of the nail.

When nailing deck boards to stringers or posts, the nails should be long enough so that the portion penetrating the stringer or post is 2 to 2-1/2 times the thickness of the deck boards. The correct number of nails for each deck board crossing is 2 for material of less than nominal 6-inch width, 3 for nominal 6-inch widths and wider but less than 8 inches, and 4 for material of nominal 8-inch widths and wider. In order to prevent splitting and to provide greater holding power, the nails should be staggered. When predrilling of deck boards is indicated, the holes should be drilled approximately 1/32 inch larger than the nail shank.

Operating Procedures

Efficiency and cost of production depend on operating procedures. A very high percentage of the cost of production is in handling materials and manufacturers use lift trucks, belt conveyors, and other handling devices to reduce this cost. There is, however, considerable opportunity to increase materials handling efficiency in the majority of pallet plants; most operations appear just to have grown instead of being planned. Machinery and conveyors should be arranged so that materials flow as directly as possible to the assembly point.

At the assembly point, all parts and materials should be readily accessible to the workmen. In many instances workmen assembling pallets must take several steps to obtain parts for the next pallet. Very few bins or racks are used at the most convenient location. Stop-and-go conveyors are seldom used to move material to or from the assembly point.

When an order for pallets is received, a jig is made for that particular pallet from whatever material happens to be handy. When the order is finished, the jig is discarded. Well designed and constructed assembly jigs have proved to be a good investment in most industries. On the other hand, the argument against jigs is that "it would take a warehouse to hold the innumerable sizes." Even on repeat orders some companies will make slight modifications in dimensions. Nevertheless, one manufacturer makes good jigs of plywood and stores them for reuse. The number he had on hand was impressive, and indicated that design engineers and pallet users can contribute considerably to reduced cost through standardization of pallet sizes.

There is also the question of whether boards should first be resawed, ripped, or crosscut. Most plants crosscut first, but this may not be most efficient.

Many concerns also manufacture items other than pallets. These are items that make use of the same machinery, such as boxes, crates, and car blocking. There is an advantage in being able to switch products as markets change, and this has a bearing on plant layout as well as operating procedures.

Equipment

The number and type of machines vary according to the products produced and size of operation. There are, however, certain machines that can be considered standard requirements for pallet production. Even the smallest operations have some sort of cutoff saw and planer.

The predominating type of cutoff saw in use is the radial arm saw, but a few semiautomatic and gang cutoff saws are used. Although the radial arm saw is slow it is the most versatile. Next in importance is a single-head planer for sizing lumber. A number of operators use 2- or 4-head planers.

For hand nailing, the 16-ounce claw hammer with wood handle is universally used. Metal handles transmit too much shock or sting, especially when using hardened nails.

A sturdy assembly table or bench with bins on the side for nails completes the list of the most essential equipment. There appears to be very little attention given to the design of the bench. Jigs to hold pallet parts in their proper position while nailing are essential. Incorporation of an adjustable jig and bench to accommodate different-sized pallets might be a worthwhile improvement.

Although radial arm saws can be used for both crosscutting and ripping, most operations have a separate ripsaw. Very frequently this is a straight-line ripsaw that is used for sizing stringers or cants as well as ripping boards.

Next in importance, especially to operators making expendable pallets, is a resaw. The majority of these resaws are single circular machines, although a few are band or gang circular resaws. Most of the circular saws have carbide-tipped or hardened steel teeth and make smooth cuts. The feasibility of using sash gang saws is being considered by a few companies.

Less than one-third of the pallet manufacturers have drill presses for preboring deck boards. Multiple-head drilling machines may be necessary for efficiency in meeting competition.

Hand nailing is done in almost all plants although some also use nailing machines. Most of these machines are in plants that also produce items other than pallets. Nailing machine efficiency depends upon adequate jigs and rapid layup procedures that will keep the machine operating. This can be accomplished by using two or more jigs with a merry-go-round or return conveyor. Edge boards of some warehouse pallets are chamfered or beveled. Spindle shapers, jointers, or saws are used for this purpose.

Pallet Plant Layout

A suggested plant layout is shown in figure 6. Rough lumber can be brought into the plant through doors at point A, directly into the planer (1). Small doors can be provided at B and C for lumber that does not require surfacing or that will be surfaced after it is cut to size.

Rolls R-1 are intended for timbers and heavy material that will be ripped to width at (2) and crosscut to length at the cutoff saw (3) into stringers or posts. These come to the saw either through door C or through the planer across the transfer chains or rolls T-1. The cutoffs travel by belt to diagonal gates where they are shunted into bins.

Rolls R-2 are intended for deck board material coming from the planer or through the auxiliary door at B. Machine (4) can be either a rip or resaw. If both types of machines are needed, one can be placed at (5) with a set of rolls that will raise up between the transfer chains. This would permit the lumber to go directly from (1) to (5). Stop-and-go transfer chains, T-3, are used to store and even out the flow of lumber to (6), a cutoff saw. Both (4) and (5) can be bypassed if desired.

Deck boards from (6) move on a belt and may be shunted into bins. If deck boards are to be predrilled, they can continue on the belt to the drill press at (7). Drilled boards can be placed on a belt or in the bins behind the operator or they can be picked up from the belt and chamfered at (8).

If it is desirable for any reason to partially process material and then hold it in storage, openings in the building can be provided at D, E, F, and G. As an example, a custom planing job could be processed from A through (1) and out of the building at D or F without interrupting work in the rest of the plant. Edgings and waste from the rip or resaw can be shunted out at E, G, or other openings.

Bins can be built on wheels or casters. They can also be designed for hand or power-lift trucks. When full of pallet material, they are placed next to nailing tables. Here one deck is nailed to the stringers at a time and then the pallet is turned over and the opposite deck nailed. If desirable, a nailing machine can be used to replace the tables. Area H can be used for such special machines as jointers and shapers or for storage.

A crew of three men can operate the plant by shifting from one operation to the next; that is, by moving from production of stringers or blocks, to deck boards, to nailing. All operations can proceed at the same time by expanding the crew.

This plant layout is one that can grow. It need not be fully equipped to start production of pallets. The minimum equipment requirements to start an operation are the planer at (1) and a radial arm saw at (2). This latter machine can be used for both ripping and crosscutting.

This plant can also be used for other purposes, such as custom planing, production of car blocking, furniture squares, cut stock, and precut house

rafters.

Machines.--Here is a list of the different types of machines suitable for each location shown on the floor plan:

(1)

Single surfacer
Double surfacer
Matcher and molder

(2) and (4)

Straight line ripsaw
Single or gang resaw
Radial arm saw

(3) and (6)

Swing cutoff saw
Automatic cutoff saw
Radial arm saw

(5)

Straight line ripsaw
Single or gang resaw

(7)

Single head drill press
Multiple head drill press

(8)

Jointer
Shaper
Bevel saw

H

Stringer notching machine

Costs

Cost of lumber and nails comprises nearly half the value of a pallet. This is probably the reason why the price of a hardwood pallet is generally quoted by the board-foot. The price of 36- by 36-inch pallets may be the same as 40- by 48-inch pallets on a board-foot basis. However, the price of a 50- by 52-inch pallet is generally higher. This is because the manufacturer must compute his costs on the basis of the lumber he uses. The first two sizes can be made without waste by using lumber 6, 8, 10, and 12 feet long, or standard lengths. Manufacture of the other pallet, however, causes considerable waste. Its price, based on the lumber used, may be the same as the other two, but based on the lumber in the finished pallet it is higher per board-foot. Since the pallet industry is very competitive and waste is a very important cost factor, this material cost should be carefully considered.

Screw-type nails are an expensive item, so that the number to be used is carefully determined. An additional allowance, usually 5 to 10 percent, is made to cover losses and bent or damaged nails.

The next major item of cost is labor. A high percentage of this is used in assembling and nailing. This is one reason why good jigs are important. Some manufacturers compute nailing costs on the basis of the number of nails used. This method, however, may not give accurate results. A good nailer can drive up to 1,000 nails per hour when making fully decked warehouse pallets that require many nails. The same man, however, may drive less than 500 nails per hour when making slat-type expendable pallets. The difference is in the time required to assemble material and remove finished pallets. Extra handling is the reason some manufacturers claim it costs more per board-foot to make expendable pallets than warehouse pallets.

The total volume of lumber used in pallet construction varies from 200 to 800 board-feet per man-day. This includes all the men working in the plant, but excludes the men in the sawmill. Considering the minimum wage of $8 per day, this cost is from 1 to 4 cents per board-foot. Nailers alone will nail from 500 to 1,800 board-feet per man-day, depending upon the type of pallet and plant efficiency.

Overhead, machine operation and maintenance, depreciation, and taxes must be added to the above costs. The price of the normal pallet is determined after computing all of the above. Additional costs are then computed for extras such as rounded corners, chamfered end boards, and notched stringers.

Items of a cost estimate are as follows:

Materials	In pallet	Used	Cost per pallet	
Lumber (bd.-ft.)	_____	_____	$_____	
Nails (lb.)	_____ ±10 percent	_____	$_____	
Total material cost				$_____

Labor

Nailers (daily wages divided by number of pallets)	$_____	
Others (daily wages divided by number of pallets)	$_____	
Social Security, insurance	$_____	
Total labor cost		$_____

Equipment

Power cost	_____	
Maintenance	_____	
Depreciation	_____	
Small tool replacement	_____	
Total equipment cost		$_____

Overhead

Administrative salaries	_____	
Supervision	_____	
Rent	_____	
Office expense, timekeeping	_____	
Telephone	_____	
Plant and equipment insurance	_____	
Taxes	_____	
Total overhead		$_____

Total cost of pallet at plant	$_____
Cost of extras not figured in the above	$_____
Transportation cost	$_____
Delivered pallet cost	$_____
Selling expense	$_____
Profit and risk	$_____
Selling price of pallets	$_____

Marketing

Markets for pallets have been steadily increasing in recent years. The number of pallets being used annually exceeds 40 million. In addition, many pallets are used by the military as well as other government agencies. Pallets are used for movement and storage of a vast variety of products, including most manufactured or packaged products. New uses for pallets are appearing regularly, such as bin-type pallets used in harvesting fruit and potatoes. Potential markets exist in practically every manufacturing plant, warehouse, or city.

Pallets are bulky and therefore expensive to ship, so they are generally sold to delivery points less than 150 miles away. Transportation of finished pallets is generally by truck.

Some pallet manufacturers market direct to the user. Others market their product through a broker or sales commissionman. Often these latter are materials-handling-equipment dealers, whose major business is the sales of lift trucks. Some, however, provide pallet design or engineering services

to their customers as well as to the pallet producer.

The potential market in a given area can be determined by making a list of all manufacturing plants, warehouses, and government agencies within a reasonable hauling distance. The U. S. Government Purchasing Directory lists the addresses of all government offices that purchase pallets. A copy can be obtained from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., for 50 cents a copy.

There is considerable competition in the pallet industry, but buyers are always looking for a good product and a reliable supply. This last point is especially important. Many small producers of pallets have lost their market by not making delivery on time.

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Table 1.--Strength and weight of common species of hardwood used for pallets

Species	Modulus of rupture of green lumber	Basic stress	Weight per 1,000 board-feet	
			22 percent moisture content	Green
	P.s.i.	P.s.i.	Lb.	Lb.
Ash (except white:	6,000	1,450	2,900	3,400
Ash (white)[1]	9,600	2,050	3,100	3,400
Aspen	5,100	1,300	2,000	3,000
Basswood	5,000	1,300	1,900	2,900
Beech[1]	8,600	2,200	3,300	3,800
Birch[1]	6,400	2,200	3,100	4,000
Buckeye	4,800	1,100	1,900	3,400
Chestnut	5,600	1,350	2,300	3,800
Cottonwood	4,800	1,100	2,000	3,300
Hackberry	6,500	1,750	2,800	3,500
Hickory[1]	10,500	2,800	3,700	4,400
Elm (soft)	7,200	1,600	2,800	3,800
Elm (rock)[1]	9,500	2,200	3,300	3,700
Magnolia	6,800	1,600	2,600	3,600
Maple (soft)	5,800	1,400	2,700	3,500
Maple (hard)[1]	7,700	2,200	3,300	3,900
Oak[1]	6,900	2,050	3,400	4,400
Pecan[1]	9,100	2,800	3,400	4,300
Sweetgum	7,100	1,600	2,600	3,500
Sycamore	6,500	1,600	2,600	3,600
Tupelo	7,000	1,600	2,700	3,900
Willow	3,800	1,000	2,000	3,500
Yellow-poplar	6,000	1,450	2,300	3,500

[1] Dense hardwoods.

Glossary

Pallet

A materials-handling platform that consists of one or two faces, separated or supported by structural members that provide clearance for slings and the fingers of forklift trucks.

Noncaptive Pallet

One whose use cycle extends through one or more enterprises (private, corporate, or military) and usually includes a common carrier service.

Pallet Sizes

Dimensions should always be stated in inches with the length given before the width. The width should be given as the dimension parallel to the top deck boards.

Pallet Designs

Two-way entry.--A pallet design that permits entry of mechanical handling equipment from two sides only.

Four-way entry.--A pallet design that permits entry of mechanical handling equipment from all four sides.

Nine-block design.--A pallet whose structural members that separate the decks are nine wood blocks, and whose design permits four-way entry of both forklift and hand pallet trucks.

Notched-stringer design.--A pallet whose structural members that separate the decks are notched stringers, and whose design permits four-way entry only with forklift trucks and two-way entry with hand pallet trucks.

Pallet Styles

Single-face style.--A pallet with only one deck, the top surface.

Double-face style.--A pallet with two decks, forming the top and bottom surfaces. The bottom deck distributes the load when piled on other material and contributes to the strength of the pallet.

Pallet Types

Flush stringer.--A pallet in which the outside stringers are flush with the ends of the deck boards. Also called warehouse or standard pallets.

Single wing.--A pallet in which the outside stringers are set inboard a number of inches on the top deck, while the stringers are flush with the ends of the bottom deck boards. Also called airplane-type construction.

Double wing.--A pallet in which the outside stringers are set inboard of both top and bottom deck boards to accommodate bar slings for handling the pallet. Also called stevedore, general purpose, or cootie-type construction.

Pallet Parts

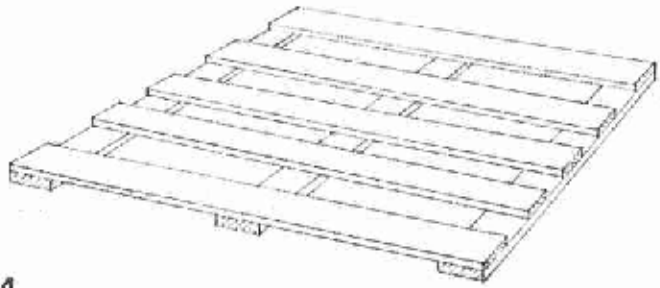
Deck.--Pallets have top and bottom decks. The top deck is the top face of a pallet that carries the load. The bottom deck is the bottom face of a pallet that helps to distribute the load more uniformly.

Deck boards.--Members that make up the faces of a pallet and that are referred to as top and bottom deck boards.

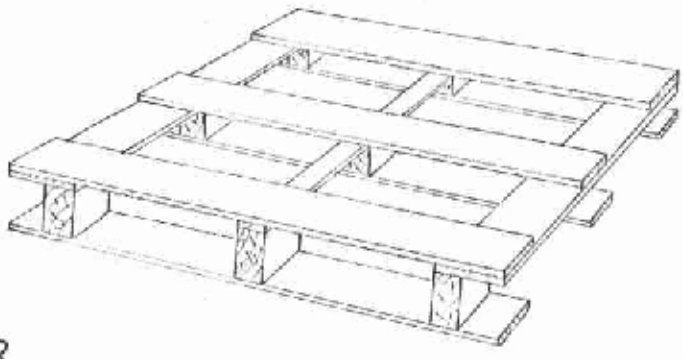
Stringers.--Wood runners or structural members to which deck boards are fastened. They serve as spacers to permit entry of the fingers of forklift trucks.

Stringer boards.--Members that tie the blocks together and to which the top deck boards are fastened in a four-way, block-type pallet.

Posts.--Rectangular or round blocks employed on some four-way entry pallets in place of stringers, and serve the same purpose.



A



B

Figure 1.--Expendable pallets; A, no-block type; B, nine-post type.

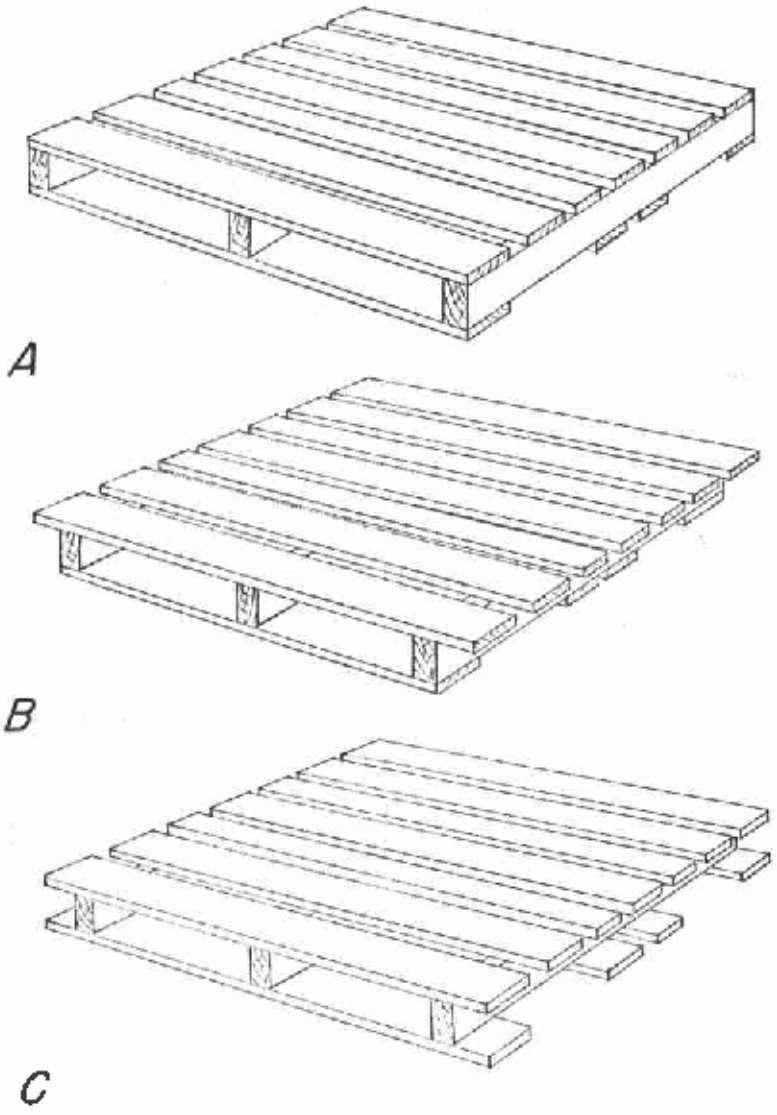


Figure 2.--Two-way entry general purpose pallets. A, flush-stringer type; B, single-wing type; C, double-wing type.

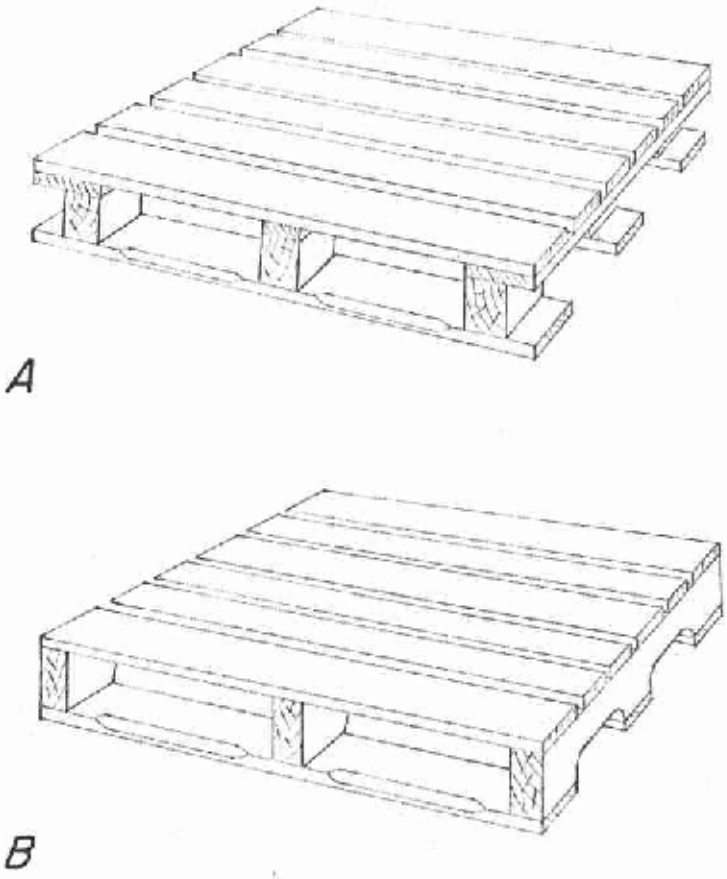
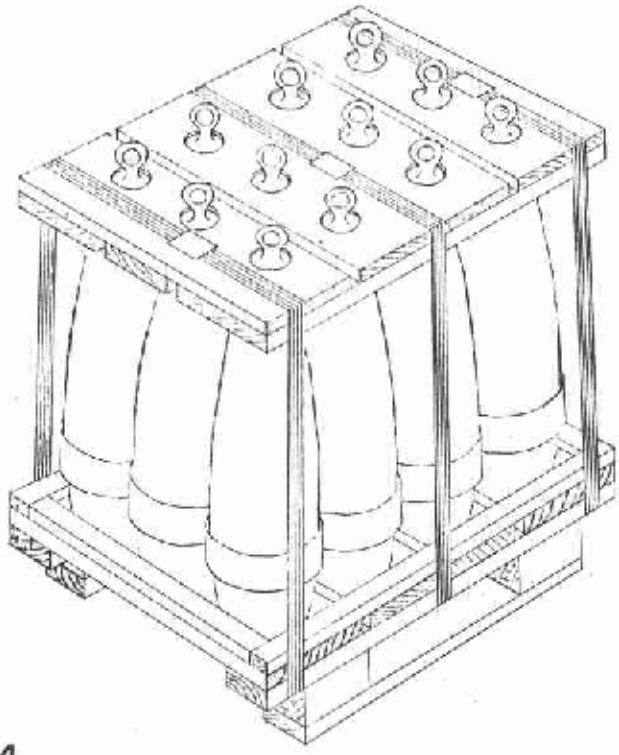
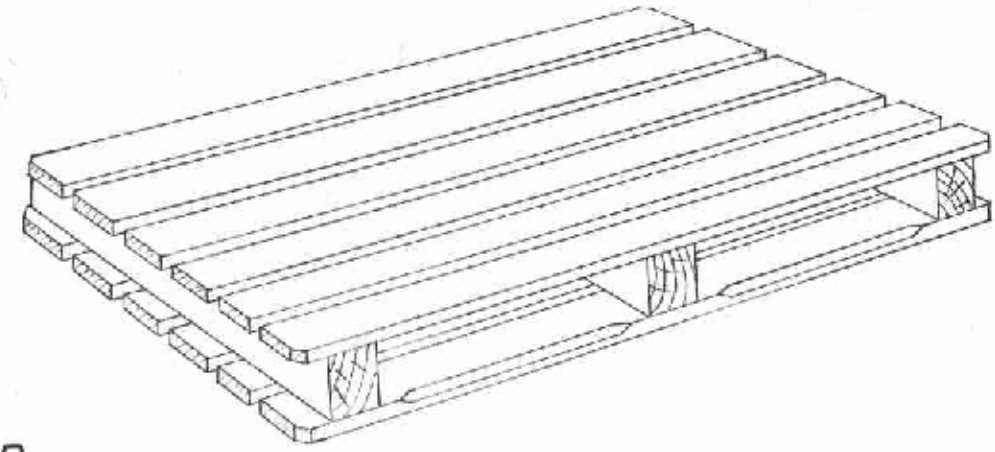


Figure 3.--Four-way entry general purpose pallets. A, block design; B, notched-stringer design.



A



B

Figure 4.--Special purpose pallets; A, ammunition pallet; B, stevedore pallet.

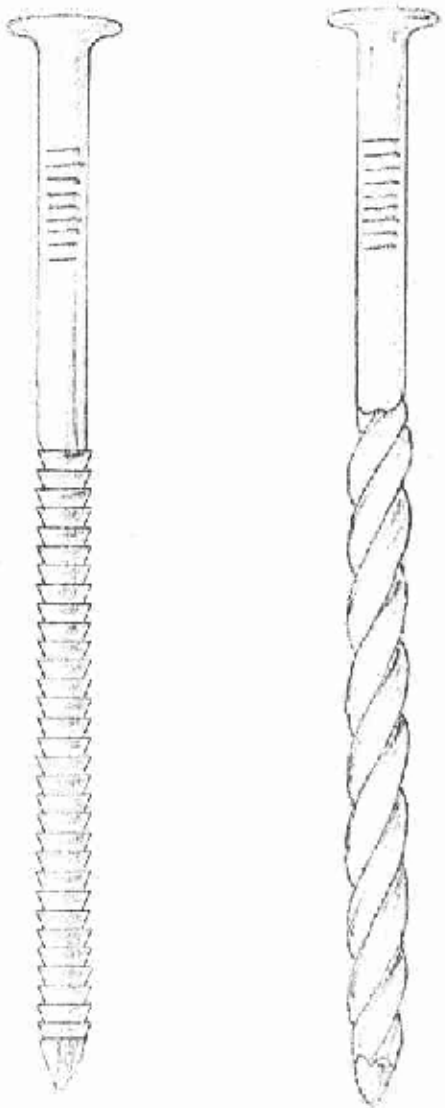


Figure 5.--Deformed shank nails. Left, annular grooved; right, spiral grooved.

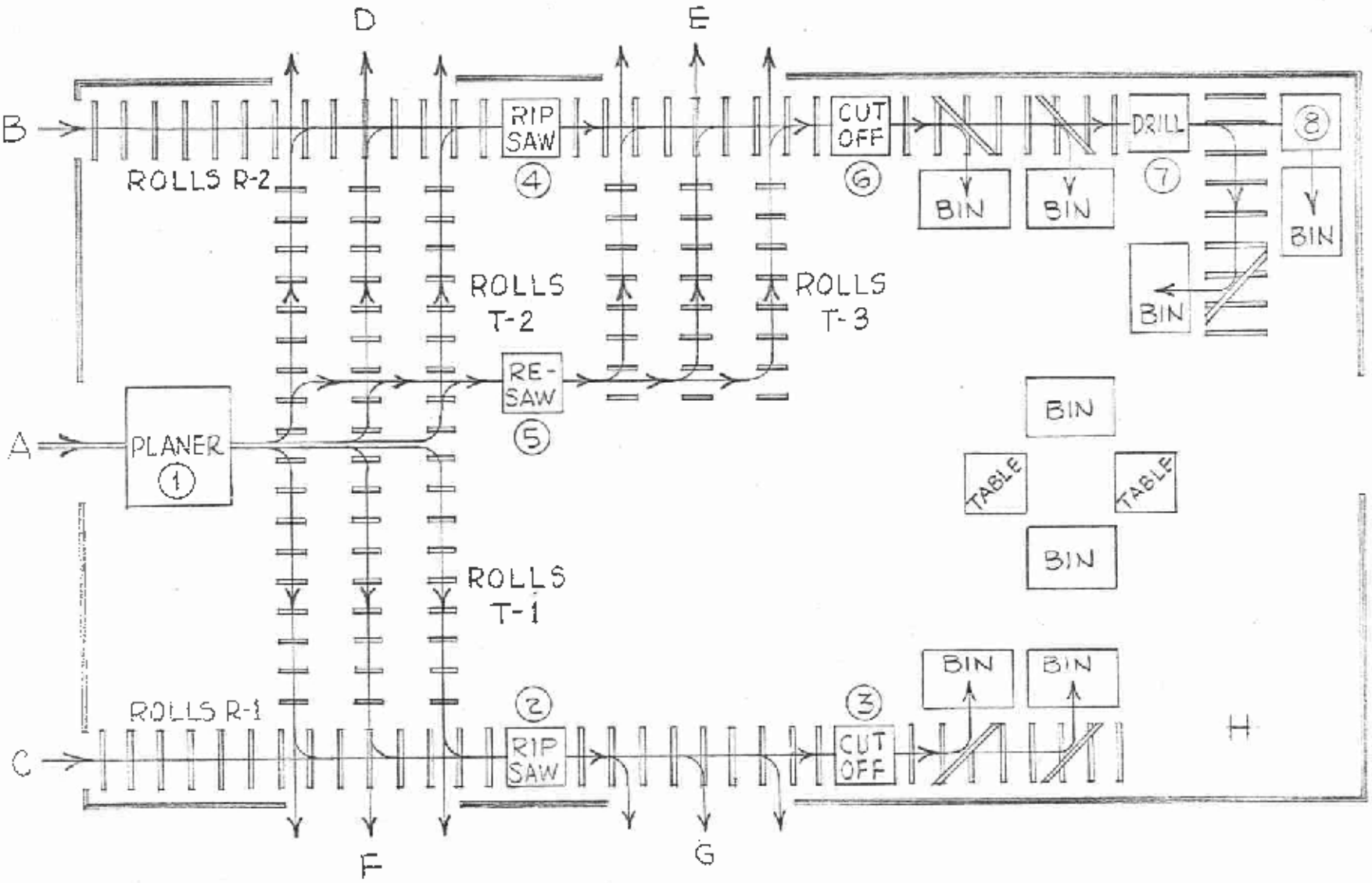


Figure 6.--A suggested pallet-plant layout. Rough lumber can go directly from A to the planer and then to its ultimate use. Lumber that does not need to be surfaced or will be surfaced after it is cut can come in at B or C. If it is desirable to process material partially and then store it, openings can be provided at D, E, F, and G.

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