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WOOD PALLET MANUFACTURING

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By

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U.S. Department of Agriculture

Abstract

Some facets of pallet construction, design and production are discussed here. Information is included on properties of both hardwoods and softwoods, as well as comments about fastener systems as related to pallet production and design. Some discussion is included regarding wood pallet plant operation, economics, and layouts.

INTRODUCTION

An extensive pallet industry has become established as a result of the rapidly expanding use of mechanical handling equipment. Unitized loads of industrial and agricultural products are handled by a variety of mechanical handling equipment such as lift trucks, racks, conveyors, slings, booms, and stackers. Pallets provide one of the foundations upon whichtoassemble these loads. Advantages of palletization are many and varied, but of a magnitude that makes their production from low-grade lumber economically feasible.

This report is intended to be a reference for the industry, particularly for those who desire to provide design services, and buyers who desire to purchase quality goods. Information of particular interest may be found in reference materials at the end of this report (2,3,4,5,7,8,18,20).[3]

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[1] "Hardwood Pallet Manufacturing," written in 1958 by T. B. Heebink and E. W. Fobes and published as Forest Products Laboratory report No. 2132.

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

[3] Underlined numbers in parentheses refer to references at the end of this report.

Pallet Construction

Pallets are generally simple in design and fabrication. They can utilize much of the lower grades of lumber and cuttings from woods and mill residue. Some pallets may require--and market conditions may justify--use of better quality lumber. Pallet production can often be integrated with that of box, dimension, and other lumber products at the mill. Pallet producers can benefit from greater knowledge of the characteristics of wood and thefactors that are most important in pallets.

In general, the quality of lumber usedinpallet manufacture may be characterized by the kinds and sizes of defects. Knots, checks, and splits must be limited in size and number to make certain that satisfactory pallets will result. The lower grades of lumber can be economical if defects are cut out or SO placed in the finished pallet that they do not impair its assembly, 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. Close liaison between supplier and buyer will provide understanding of 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 is not up to the customer's expectations.

Types and Sizes of Pallets

Pallets are classified into three general groups: Expendable or nonreturnable, general purpose or reusable, 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 suitable for Continuous service in warehousing and shipping and are sometimes referred to as warehouse pallets. Special-purpose pallets (fig. 4) are for a particular product or service. They may be patented pallets that contain features of construction that will assure proper performance. Another form of special-purpose pallet is the bin pallet. This is a pallet with three or four vertical sides to form a box or container (fig. 5). Sometimes bin pallets are equipped with tops and sometimes part of one side is removable or collapsible so they may be used as supply bins. The majority of plants manufacture all three types of pallets. Others specialize in either expendables or nonexpendables, while a few specialize in producing shook--parts to be assembled into pallets by the user. Parts to be used for repair are also produced by some plants.

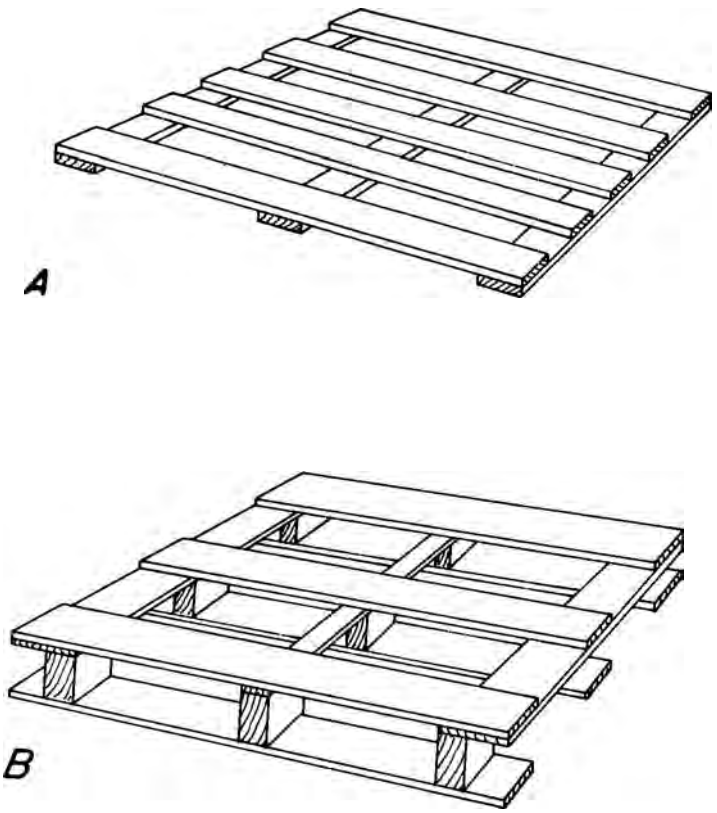

Figure 1.--Expendable pallets: A, no-block type; B, nine-post type.
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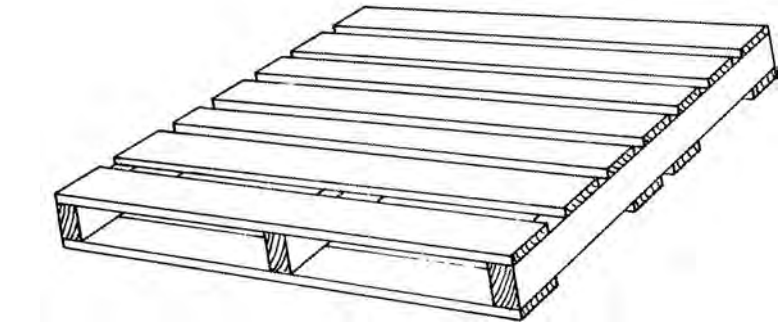

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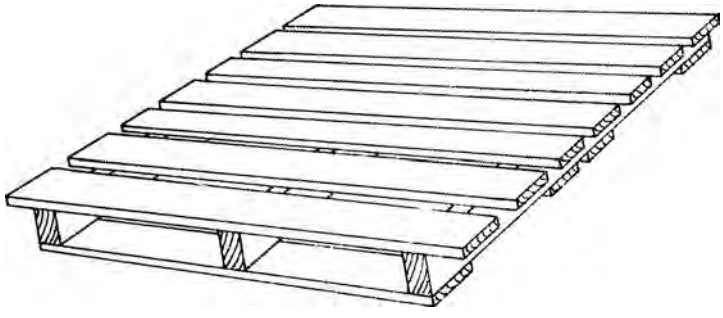

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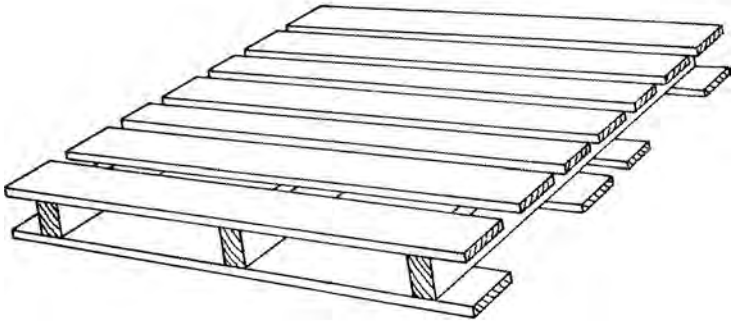

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Figure 2.--Two-way entry, general-purpose, nonreversible pallets: A, flush-stringer type; B, single-wing type; C, double-wing type.

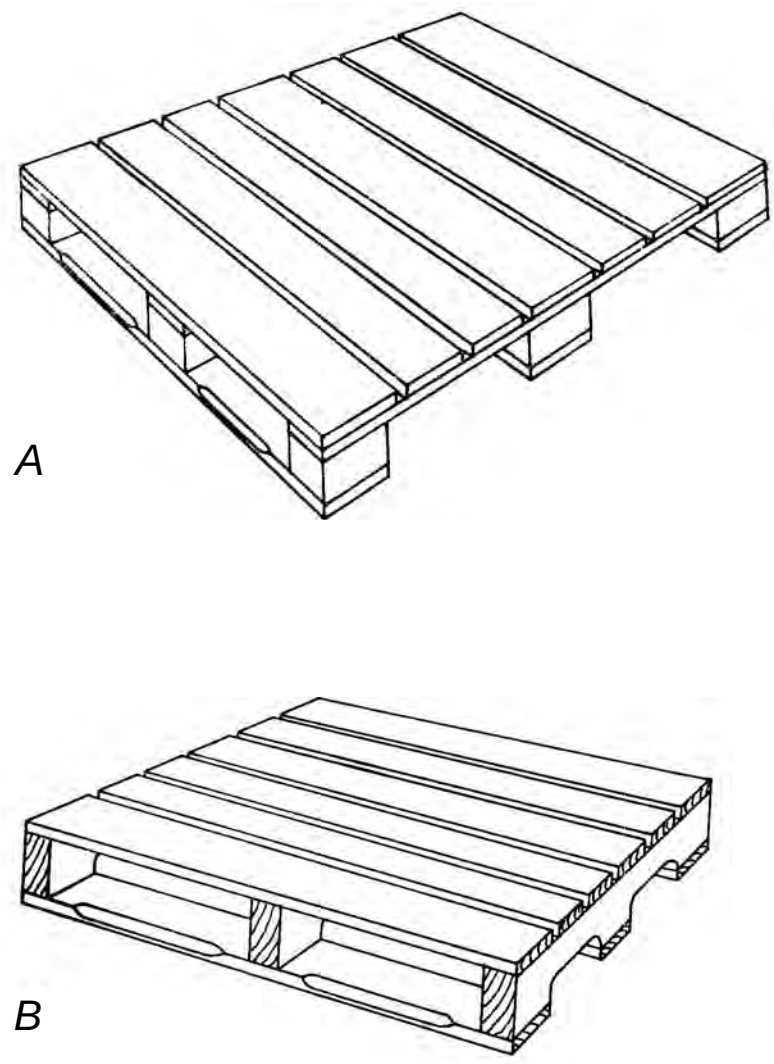

Figure 3.--Four-way entry, general-purpose, nonreversible pallets: A, block design; B, notched-stringer design (sometimes called partial four-way entry).

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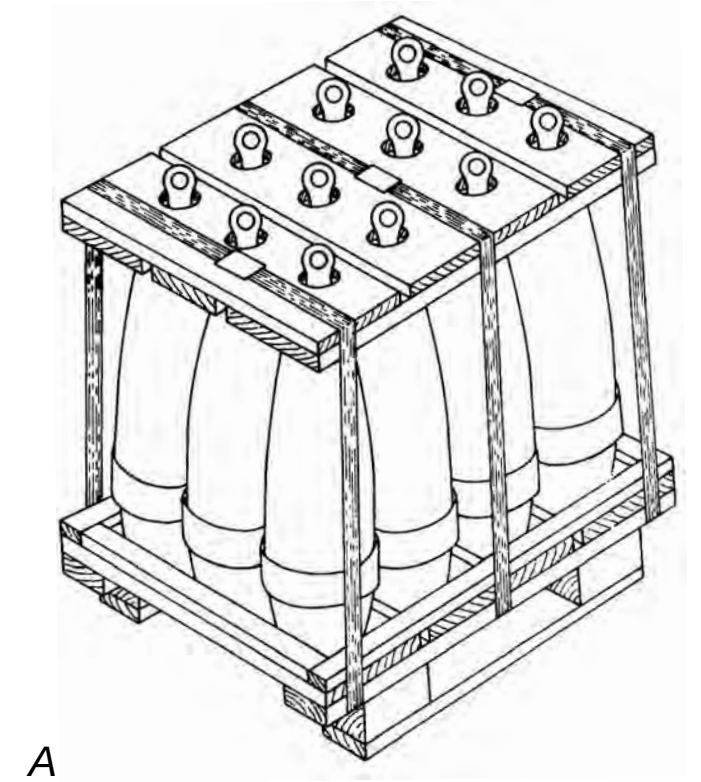

Figure 4.--Special-purpose pallets: A, ammunition pallet; B, stevedore pallet. If top leading edge deckboards were chamfered as are bottom leading edge deckboards, pallet would be reversible.

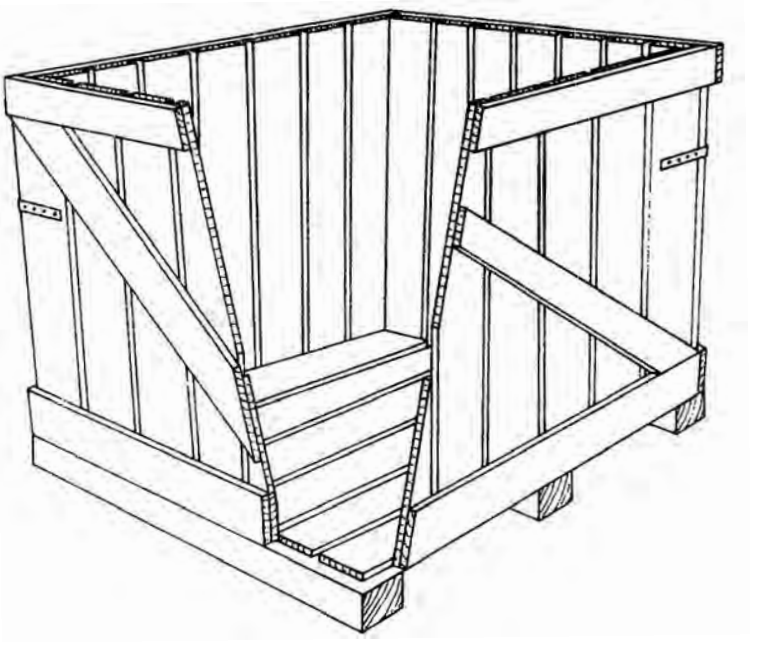

Figure 5.--Bin pallet. Also called container pallet or box pallet.

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Pallets also can be subdivided into two styles: Single face and double face. The single-face pallets have only a top deck; they are sametimes 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. The ends of the deckboards in either style may be flush with the stringers or project beyond them in single- or double-wing constructions (fig. 2).

Any of these 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 materials-handling equipment such as the tines on forklift trucks. Many expendable wood pallets are four-way entry with nine blocks, although there is a sizable demand for two-way expendable pallets. Another four-way entry design has notched stringers to permit forklift entry in two directions (fig. 3). This notched-stringer design is referred to as partial four-way entry.

Although there is no pallet size common to all industry, some industries have standardized pallet sizes. Many companies have improved their operating procedures by standardizing.

Pallet dimensions vary from a minimum of 2 feet to over 6 feet. Pallet manufacturers define the first dimension of the pallet size as length of stringer for two-way entry or partial four-way entry pallets, and as length of stringer board or subdeckboard in full four-way entry. The most common pallet sizes in this country appear to be the 40- by 48-inch and the opposite size, the 48- by 40 inch. Pallet dimensions are often dictated by the interior dimensions of carrier equipment, the large intermodal containers, and special industrial requirements. The Pallet Committee of the American National Standards Institute has, at this time, approved standard sizes for noncaptive pallets (pallets which will probably be used by more than one enterprise). These are:

Rectangular Pallets			Square Pallets
24 x 32	or	32 x 24	36 x 36
32 x 40	or	40 x 32	42 x 42
36 x 42	or	42 x 36	48 x 48
32 x 48	or	48 x 32	
36 x 48	or	48 x 36	
40 x 48	or	48 x 40	
48 x 60	or	60 x 48	
48 x 72	or	72 x 48	
88 x 108	or	108 x 88	

Note: Because ANSI standards are reviewed periodically, changes may occur; the latest recommendations of the ANSI Pallet Committee should be consulted.

These sizes contain the three sizes recommended by the International Organization for Standardization (ISO) which are:

Inches			Millimeters		
32 x 40	or	40 x 32	800 x 1000	or	1000 x 800
32 x 48	or	48 x 32	800 x 1200	or	1200 x 800
40 x 48	or	48 x 40	1000 x 1200	or	1200 x 1000

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.

Designs and Engineering

The proper size and type of pallet is essential to the user, but equally important to him is 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. Results of this type of pallet buying are product damage, excessive costs of pallet repair and replacement, down time on companion materials handling equipment, and personnel accidents.

Nearly all pallets are built according to a set of specifications derived from one of four sources: (1) Progressive fabricators who provide this type of engineering service; (2) manufacturers who provide design service through contract with an engineer or pallet broker; (3) the pallet user; (4) the manufacturer or distributor of materials handling equipment.

Several established specifications are in general use such as those listed below. Modifications, revisions, deletions, and additions are made from time to time, especially in the Federal and Military specifications. The current index to these two broad specification categories should be consulted to assure reference to the latest document.

Federal Specifications

NN-P-71 - Pallets, Material Handling, Wood, Double Faced, Stringer Construction

NN-P-0073 - Pallets, Material Handling, Plywood, Double Faced, Stringer and Block Construction

Military Specifications

MIL-P-3938 - Pallets, Material Handling, Hardwood Stringer Construction, 4-Way (Partial)

MIL-P-15011 - Pallets, Material Handling, Wood Post Construction, 4-Way Entry

MIL-P-15943 - Pallets, Material Handling, Wood, Ship Cargo, Stevedoring, 48 Inches Long by 72 Inches Wide, 2-Way Entry

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

MIL-P-45449 - Pallets, Unit, Wood, for Shipment of Projectile Metal Parts, and Projectile Ammunition

Military Standards

MIL-STD-147 - Palletized and Containerized Unit Loads, 40" x 48" 4-Way (Partial) Pallet Skids, Runners or Pallet-Type Base

MIL-STD-731 - Quality of Wood Members for Containers and Pallets

The Department of Defense Index of Specifications and standards and the Index of Federal Specifications and Standards are for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. These documents contain instructions on how to obtain copies of the Federal and Military specifications and standards.

National Wooden Pallet and Container Association

Specifications and Grades for Hardwood, Warehouse Permanent or Returnable Pallets

Specifications and Grades for Warehouse Permanent, Returnable Pallets of West Coast Woods

Specifications for Softwood Plywood Pallets (In cooperation with the American Plywood Association)

The National Wooden Pallet and Container Association is located at 1619 Massachusetts Ave., N.W., Washington, D.C. 20036.

GMA Pallet

Recommended Pallet Specifications f or the Grocery Industry: Grocery Manufacturers of America, Inc., 205 E. 42nd St., New York, N.Y. 10017.

Can Pallet

Recommended Pallet Specifications for the Can Industry: Can Manufacturers Institute, 821 15th St., N.W., Washington, D.C. 20005.

MATERIALS

Lumber

Pallet parts generally come from the lower grades of either hardwood of softwood lumber. Some sound below-grade material may be included. Purchased lumber is usually No. 2 or 3 Common grade, except in nonmarketable or low-value species, where all grades are used. This means that practically all commercial species may be used for pallets.

For pallets, in general, most stringers and 1-inch thick lumber are sized by planing, and most lumber of 1/2 inch or less in thickness is sized by resawing.

Moisture Content of Pallet Lumber

The moisture content of wood that goes into pallets is important. Many pallets are built from green or partially green lumber because of lower cost and ease of nailing, especially dense hardwoods. These pallets may fail prematurely if the boards warp, cup, twist, or split at the nails. Such failures increase costs of upkeep and may offset many of the savings that can be realized by palletization. When air-dried or kiln-dried lumber is specified, the deckboards (especially hardwoods) may be predrilled to reduce splitting. The increased cost may be offset by better pallets and less repair.

Moisture Content Requirements.--Most pallet specifications contain specific requirements for the moisture content of the various pallet parts, Requirements vary, often related to whether the species is hardwood or softwood. Frequently the dense hardwoods are used at high moisture contents to facilitate nailing. The lower density hardwoods and most softwoods are more easily nailed regardless of moisture contents.

If moisture content is not specified, a general rule-of-thumb at the time of fabrication is for the deckboards not to exceed an average of 19 percent moisture content with no one deckboard exceeding 22 percent; stringers and blocks should not exceed 26 percent moisture content. For instance, softwood lumber manufactured under the requirements of Voluntary Product Standard 20-70 (9) will contain the designation S-Dry in the grade mark if it was surfaced at no more than 19 percent moisture content. If it was surfaced at any moisture content above 19 percent, it will contain the designation S-Grn. In some climates it may be necessary to stack green lumber in the open for a considerable time to achieve the suggested moisture contents. The improved durability and performance of the finished product will often more than justify the effort and increased cost.

Moisture content variations in pallets in service can be minimized by fabricating the pallets from wood of a moisture content that corresponds to the average moisture content anticipated for the environment in which they will be used.

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 generally accepted terms are covered in the following statements.

"Green" lumber is lumber that is freshly cut or sawed and has not received any intentional seasoning. It 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 the manufacture of finished products or of lumber above the fiber-saturation point (approximately 30 percent for most species).

"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 to minimize mold and stain in transit. It 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. 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.

"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 below the fiber-saturation point. 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.

Shrinkage of wood.--Below the fiber-saturation point, wood shrinks as it loses moisture and swells as it absorbs moisture. Shrinkage during drying is approximately proportional to the moisture lost below the fiber-saturation point.

Wood shrinks most in the direction of the annual growth rings (tangentially), and one-half to two-thirds as much across these rings (radially), and little along the grain (longitudinally). 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 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. Because the moisture content will vary in and between boards, a number of tests should be made with either method to obtain an average. Intelligent selection of test pieces and a suitable number of samples to represent the total log will minimize error.

Detailed procedures for determining moisture content may be found in the Wood Handbook (17).

Weight of lumber.--The approximate weight of some commercial species at 20 percent moisture content are listed in table 1. This represents the moisture condition that might be reached by lumber in stickered outdoor piles after drying from 3 months to a year.

Weight at any other moisture content between 0 and 30 percent can be estimated from the tabulated value using the formula:

Table I.--Classes and weights of some commercial species

Species[1]	Weight per 1,000 board feet at 20 percent moisture content	Species[1]	Weight per 1,000 board feet at 20 percent moisture content
	Lb.		Lb.
	CLASS A		
Aspen (popple (I)	2,250	Fir, white (I)	2,370
Basswood (I)	2,060	Hemlock, eastern (II)	2,470
Buckeye (I)	2,180	Pine (except	
Cedar (I)	2,250	southern yellow (I)	2,470
Cottonwood (I)	2,370	Redwood (I)	3,110
Fir, subalpine (I)	2,000	Spruce (I)	2,370
Fir, balsam (I)	2,180	Willow (I)	2,180
Fir, noble (I)	2,370		
	CLASS B		
Ash (except white) (III)	3,100	Magnolia (I)	3,000
Baldcypress (I)	2,720	Maple, soft (III)	2,870
Butternut (I)	2,310	Pine, southern	
Douglas-fir (II)	2,940	yellow (II)	3,290
Elm, soft (III)	3,000	Sycamore (III)	3,000
Gum, sweet (III)	3,000	Tamarack (II)	3,170
Hemlock, western (II)	2,720	Tupelo (III)	3,000
Larch, western (II)	3,120	Yellow-poplar (I)	2,590
	CLASS C		
Ash, white (IV)	3,620	Hickory (IV)	4,240
Beech (IV)	3,680	Maple, hard (IV)	3,680
Birch, yellow (IV)	3,620	Oak (IV)	3,680
Elm, rock (IV)	3,750	Pecan (IV)	3,960
Hackberry (IV)	3,180		

[1] Numbers in parentheses indicate grouping of wood for container purposes.

$$\text{Weight at } MC_X = \text{Weight at } MC_{20}\left(\frac{100 + MC_x}{120}\right)$$

where MC_x means any moisture content average.

It is much more difficult to establish average green weights for various species of lumber. As a reasonable approximation, green weights may be obtained from table 1 by increasing the values for Class A or B species by 100 percent, and for Class C species by 75 percent. As an alternative, any lot of lumber can be weighed.

The values in table 1 were derived assuming that a board foot is 1 by 12 by 12 inches. For actual thicknesses different than 1 inch, but assumed to be an inch in estimating board footage, the table 1 values can be adjusted by multiplying them by the actual thickness in inches.

Decay resistance.--Regardless of species, decay resistance is not important for pallets kept at a moisture content of less than 20 percent but is an important factor when pallets are used in unprotected outdoor storage.

Pallets of wood of low decay resistance, used under conditions that favor decay, (as in a warm, wet climate), 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.

Preservative treatment can be used to advantage for the less durable species. There are various preservatives and methods of application from which the pallet manufacturer and user can select the combination best suited to end-use requirements. Some of the more popular preservatives are copper-8-quinalinolate, copper naphthenate, and pentachlorophenol. The addition of an effective water-repellent material to the preservative solution will retard moisture changes in the wood but will not prevent them This helps reduce dimensional changes due to moisture changes when the wood is exposed to rain, dew, or dampness for a short time.

Care should be taken in the selection of a preservative or water repellent to assure that the product complies with acceptable environmental and anti-pollution practices. Caution must be exercised if treated pallets are to be used with, or around, foodstuffs or other materials where toxic contamination is possible. The acceptability of preservatives for use in such instances falls under

the jurisdiction of the Food and Drug Administration. County agricultural agents or state regulatory officers can provide information on acceptable preservatives for the intended use of the pallets.

Properties Affecting Strength of Pallets

As used in pallets, wood is often loaded as a beam, and therefore, its bending strength is perhaps most important. Other properties--compressive strength, shock resistance, naturally occurring defects in wood, susceptibility to decay, and so on--also tend to have effects on wood in relation to desired pallet performance.

For a number of years, commercially important species have been divided into four groups according to properties of importance in container applications (19). In recent years, a somewhat more convenient grouping of species has become popular in the manufacture of pallets. This grouping is given in table 1. The species in Class A are weak tomoderately strong in bending strength; those in Class B are moderately weak to strong; and those in Class C are moderately strong to very strong. The classes also represent woods which are generally low density, medium density, and high density, respectively.

Knots.--Knots in pallet lumber are objectionable because distortion and discontinuity of grain surrounds them, This weakens the wood, causes irregular shrinkage, and makes machining more difficult. Whenlumber dries, knots shrink more than the surrounding wood and may check, loosen, or drop out. Knotholes are no more damaging than knots.

The size of knots permitted in various pallet parts is governed by the proportion of their width to the width of the piece containing them as well as by their location in the finished pallet part. Though a wide range of knot sizes is acceptable in pallet parts, the referenced pallet specifications should be consulted as they outline the limitations controlling the location and size of permissible knots.

Checks, splits, and shakes.--Three types of longitudinal cracks that occur in wood are checks, splits, and shakes. All are acceptable to some degree in pallet parts. Limitations are generally established by the specification documents.

A check is a longitudinal crack, generally in the radial direction (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 athrough check. A shake is a longitudinal crack between two annual

rings. Shakes are present in green timber and they may be extended in seasoning. They indicate a weakness of bond between annual rings. This weakness may extend lengthwise beyond the visible opening.

Cross grain.--The term cross grain indicates that the wood 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 often 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 vertically. In lumber, it is not always apparent to the eye, but can often be detected by the direction of a split in the radial plane.

Cross grain can be tolerated in pallet parts if the slope is no steeper than 1 in 10. Cross grain in members should, however, be avoided where possible, especially in leading edge deckboards.

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

Mineral streaks are dark brown or black streaks, frequently with a green tinge: they 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 from 1/8 to more than 1 inch across the grain. Their limits may be sharply defined, or they may fade out gradually into the surrounding wood. Mineral streaks may be 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. The streaks have little effect on strength or other mechanical properties and are not considered objectionable in pallet lumber.

Pitch pockets may be present in the pines, spruces, Douglas-fir, tamarack, and western larch. These are well-defined openings extending parallel to the annual rings. The effect of such pockets on the strength characteristics depends upon the number, size, and location in the board. A board with a large number of pitch pockets indicates a lack of bond between annual growth rings. Such a piece should be inspected for shakes, or separations along the grain.

Stain and decay.--Many stains and all forms of decay or rot are caused by fungi that grow on and in wood.

The most common stain is the Blue stain, or sap stain, that occurs in the sapwood of many species. The sapwood is mottled or streaked with a bluish or grayish stain, which, in advanced stages, 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. 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. Parts with incipient decay should be rejected.

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 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 does not appear to have a serious influence on the strength of pallet parts, but excessive wane might interfere with nailing or other fastener systems (6).

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 smoothly. 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.

Where areas of irregular grain occur, apart 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 my also be limited to a proportional part of the face area of a board.

Lumber may become crooked, bowed, cupped, or twisted during air 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 across the grain or width of a piece. Deep cup (3/8 to 1/2 inch deflection across a 12-inch-wide board--or in like proportion for other widths) is never permitted in pallets and, in stringent situations, cup may be 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 deckboards can usually be straightened by nailing, but nailing the two edges of cupped boards may result in splitting.

Plywood

As compared with solid wood, the chief advantages of plywood are its approach to equalization of strength properties along the length and width of the panel, greater resistance to checking and splitting, and less change in dimensions with changes in moisture content. The greater the number of plies for a given thickness, the more nearly equal are the strength and shrinkage properties along and across the panel and the greater the resistance to splitting (17).

Plywood used for pallets generally conforms to the applicable commercial standard or product standard and makes use of exterior quality glues. Plywood pallet decks tend to splinter after repeated edge impact by the handling equipment.

Fasteners

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 cam 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. 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 symmetrically deformed shanks. Clinching the nail across the grain is many times more effective than clinching with the grain. Minimum clinch should be 1/4 inch.

Laboratory withdrawal tests show that for heavier members, where clinching is not practical, symmetrically deformed shank nails have withdrawal resistance--under certain conditions--oftwo to three times that of common or coated nails. Helically and annularly threaded nails have been developed (fig. 6) that are particularly effective in pallet construction.

When nailing deckboards 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 deckboards. The correct number of nails for each deckboard crossing varies: Two nails for material of less than nominal 6-inch width; three for nominal widths of 6 to 8 inches; and four for material of nominal 8-inch widths and wider. To prevent splitting and to provide maximum performance, the nails should be staggered. If pallet parts are predrilled to reduce splitting, these lead holes should be about 75 to 80 percent of the outside diameter of the nail shank.

Excessive overdriving of nails or imbedding their heads in the wood crushes the fibers and reduces the resistance to shearing out of the shanks and pulling through of the heads. This condition is more critical with thin boards where the reduction in performance is almost directly in proportion to the amount the nail is overdriven. Slight overdriving not to exceed 1/16 inch in thicker deckboards (nominal 1 inch or more) is sometimes acceptable to reduce the tendency for snagging goods on protruding nailheads. It also tends to compensate for any eventual shrinkage. If pallet assembly is by use of multitrack nailing machines, uniform thickness of pallet parts is critical to avoid excessive overdriving or underdriving.

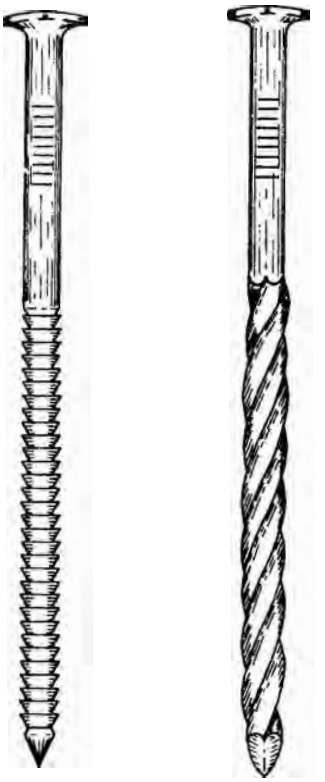


Figure 6.−−Symmetrically deformed shank nails: Left, annularly threaded; right, helically threaded.

M 139 427

Staples

Recent developments in pneumatic driving equipment and the introduction of staples with longer legs have generated interest in their use for assembling pallets. Staples are not as universally accepted as nails and they may or may not be acceptable to the buyer or user, depending upon his requirements or the specifying documents.

Staples for pallets are made from different gages of wire with the most popular being in the 14- to 16-gage range. The legs--usually about 2-1/2 inches long--are coated or etched to improve withdrawal resistance. The staples should have a crown width of at least 7/16 inch.

Staples have been developed with various modifications to fulfill either general or specific requirements. Many of the factors that influence the performance of nails have similar influence on the performance of staples. Because staple legs are smaller in diameter than nails, they generally cause less splitting; however, to obtain comparable pallet joint performance, it maybe necessary to use somewhat more staples. Staples should be driven so that the crown makes an angle of about 45° with the grain of the wood.

Adhesives

The use of adhesives or mastics for assembling pallets has been shown (6) to be promising. Because such assembly methods are relatively new for pallet fabrication, little actual service experience has been accumulated and thus little is known about the durability of pallets assembled in this manner.

The mastic, adhesive, or sealant should have a degree of resiliency to withstand the rough handling associated with the shipping, storage, and materials-handling environment. This may require a glueline of some appreciable thickness, such as 1/32 inch. Pallets assembled with suitable adhesives tend to retain their original squareness when dropped on an edge corner. These pallets deform momentarily but exhibit little or no residual distortion in the plane of the pallet deck. To compensate for the imperfection in surfacing pallet lumber, the adhesive, mastic, or sealant should have gap-filling characteristics.

Both user and producer should be fully aware of the limitations associated with this assembly method. Some adhesives or mastics will work with wood at high moisture contents while others may necessitate a moisture content of 20 percent or less to form an adequate bond. Also, in general, the system does not lend itself to high-speed production at this time.

A pallet user or producer who is contemplating the use or fabrication of pallets employing adhesives or mastics should recognize that this technology has not advanced to the same degree as that associated with the use of nails.

Pallet Production

The technology of pallet production has in recent years shown remarkable advances. With new concepts being devised, indications are that the industry will continue to expand its procedures and equipment in manufacture of this valuable product. Some of the principal areas to be considered will be mentioned here.

Additional information may be obtained from the technical literature and books relating to the subject. A number of reputable consulting firms can also provide assistance and guidance in planning and organizing a modern operational procedure.

Size of Plants

Pallet plants vary in size from one- or two-man operations to factories employing 75 or more persons. Generally, plants specialize in the manufacture of pallets or pallet containers. Many of the larger companies are diversified, with other product lines such as wood boxes, millwork, and lumber. There are over 1,100 pallet manufacturers in the United States but of these, less than half (400 to 450) produce pallets full time. A limited number of pallet manufacturers control or operate their own sawmills. Currently, the trend is to more integration in this direction.

Directories listing pallet plants may be obtained by writing the State Forester in most states.

Operating Procedures

Efficiency and cost of production depend largely on operating procedures. To reduce cost and increase handling efficiency, consideration should be given to the use of materials-handling equipment. Machinery and conveyors should be arranged to provide a direct flow from receipt of the raw materials to the shipment of finished pallets. Consideration should also be given to the disposal of residues such as sawdust, slabs, edgings, and trims.

Pallet plants may be a separate operation starting with raw material in the form of rough lumber or they may be integrated with a sawmill where the raw material is in the form of logs.

There are a number of ways to reduce logs to lumber. Probably the lowest cost system to produce lumber from small logs is a combination of a circular-splitter saw, a horizontal or vertical band resaw, and a combination edger. The circular-splitter saw splits the logs in half lengthwise. The half-log is repeatedly fed through the resaw, producing boards until the remaining slab is too thin to yield another board. Since all the lumber produced at the resaw has bark or wane on both edges, it should be passed through an edger. Finally, a trimmer may be used to salvage some boards with rotten or split ends. If pallet lumber is to be sold, trimming may be required.

Production by such a typical systemcould run from 15,000 to 25,000 board feet per 8-hour day and employ three to five men, depending upon the degree of plant automation.

Many mills that produce pallet lumber also produce higher grade material which is separated and sold for a higher price. Generally speaking, because the price of pallet lumber alone may not be sufficient to make a profit aver costs of logs and sawing, a mill may show its profit from the sale of the higher grades, while the sale of pallet lumber helps to pay expenses.

Whether the pallet plant operates independently or in conjunction with a sawmill, its main purpose is to take the rough-sawn lumber as the raw material and convert it into pallet parts or assembled pallets. Pallet plants vary in size, equipment, and degree of sophistication. Some have the minimum amount of equipment and handling devices, while others are highly mechanized and automated, incorporating ingenuity and innovation to accomplish the desired end result.

In general, the raw pallet lumber has to be ripped to width, cut to length, surface planed, and possibly resawn to thickness before being assembled. The order of accomplishing these operations has been the subject of much discussion: but consideration should be given such factors as present equipment available, present space available, present market, and future plans and expansion.

Other operations that may be required are chamfering leading edge deckboards, notching stringers, and storing finished pallets and pallet parts.

Pallet plants that purchase their lumber on the open market might want to consider the utilization of cants and cut-to-size pallet shook. Cants can be so dimensioned that the resawing process yields exact-sized pallet parts. For example, 48- by 4- by 1-inch pallet deckboards can be obtained from a 48- by 6- by 4-inch cant. In some areas the current trend is for sawmills to process small and low-quality logs into cants and timbers rather than convert the logs directly into pallet grade boards. This method of operation offers the mills an opportunity to reduce sawmill production costs. Lumber cants may be readily available, expecially during periods of short supply of grade lumber.

Pallet production facilities located in or near metropolitan areas might want to study the feasibility of using cut-to-size pallet shook. Some of the advantages of an assembly-type production operation are: (1) Simplification of material cost calculations; (2) elimination of high labor costs required in processing rough lumber; (3) reduction of storage area required for raw material; and (4) elimination of wood residue disposal problems.

Lumber and raw material procurement by pallet firms should be thoroughly and continually reviewed by top management. This is one of the chief cost factors in wood pallet manufacture.

Equipment

The number, type, and kind of machines and equipment will vary according to type of pallets, other products, size of operation, and desired degree of automation. During recent years market conditions, demand, and competition have dictated a need to mass-produce pallets. This has resulted in the wood pallet industry becoming as sophisticated and automated as many other wood-using industries. Perhaps the most dynamic change has occurred in the methods and equipment used to produce wood pallets. Although some pallets are still manufactured manually, these operations are no longer prevalent. Modern Competition has forced the majority of pallet millstoresort to some degree of automation.

Modern pallet manufacturing facilities may become specialized due to a variety of market conditions, Some plants produce all types of pallets; others may limit their production to only one type. These facts contribute to the problem of equipment requirements and selection. Naturally, the variety of machines required will vary according to the products manufactured and the size of the operation.

Following is a list of the machines and equipment generally used throughout the industry:

Cutoff saw
  (a) Multiple cutoff
  (b) Radial arm cutoff
  (c) Swinging cutoff
Ripsaw
Band resaw
Planer
Chamfering machine
Stringer notching machine
Nailing machines
  (a) Pneumatically operated, single shot, gun-type nailers or staplers
  (b) Multi-track mechanical or hydraulic nailers
Pallet stacker
Lift truck

In addition, the following specialty items are sometimes employed:

Grooving machine
Edger
Double arbor edger
Strap notching machine
Molder
Linderman jointer
Handhole machine
Lumber stacker
Lumber unscrambler
Nailing machine feeders
Pallet turners
Raggle board cutter
Corner rounder
Sander
Matcher
Butt jointer
Strapping machine
Screw machine
Drill press
Branding machine
Conveyors
  (a) Roller
  (b) Chain
  (c) Belts

The type and capacity of equipment required will be governed by the number and types of pallets to be produced, as well as anticipated unit volume levels and expected market conditions and demands. For example, a single radial arm saw would probably suffice to service one nailing machine. However, a multiple cutoff saw will probably be necessary to provide sufficient material to two or more nailing stations.

To equip a newly organized pallet plant is a matter of great importance. It should involve consultation with the manufacturers and distributors as well as others knowledgeable in the field to determine exact requirements and the most efficient way to provide them.

Pallet Plant Layout

Sufficient space should be allowed in a plant layout for ease of pallet assembly. Adequate facilities such as nailing tables and benches should be provided; supplies of pallet parts and fasteners should be easily accessible. Proper attention should be given to ventilation, lighting, and safety precautions. The use of certain machines is a matter of preference and they may or may not be used, depending on the size of the order and degree of mechanization of the assembly equipment. Consideration may also be given to the manufacture of other items that make use of all or most of the same machinery.

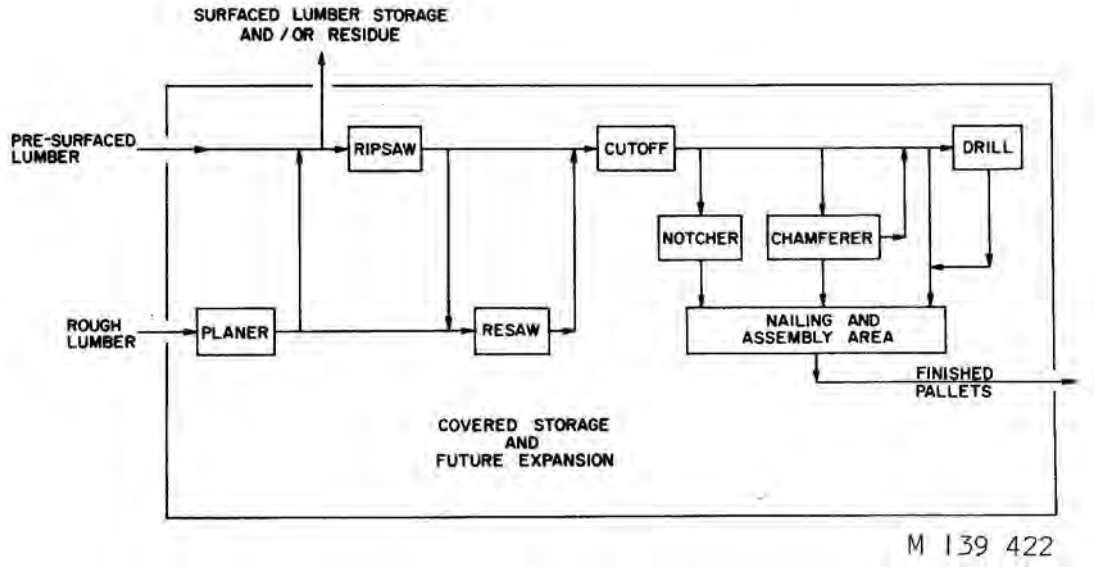
Some suggested layouts for pallet plants are given in figures 7, 8, and 9. Additions and deletions of steps, and rearrangement of equipment and flow patterns, should be made to economically produce acceptable pallets.

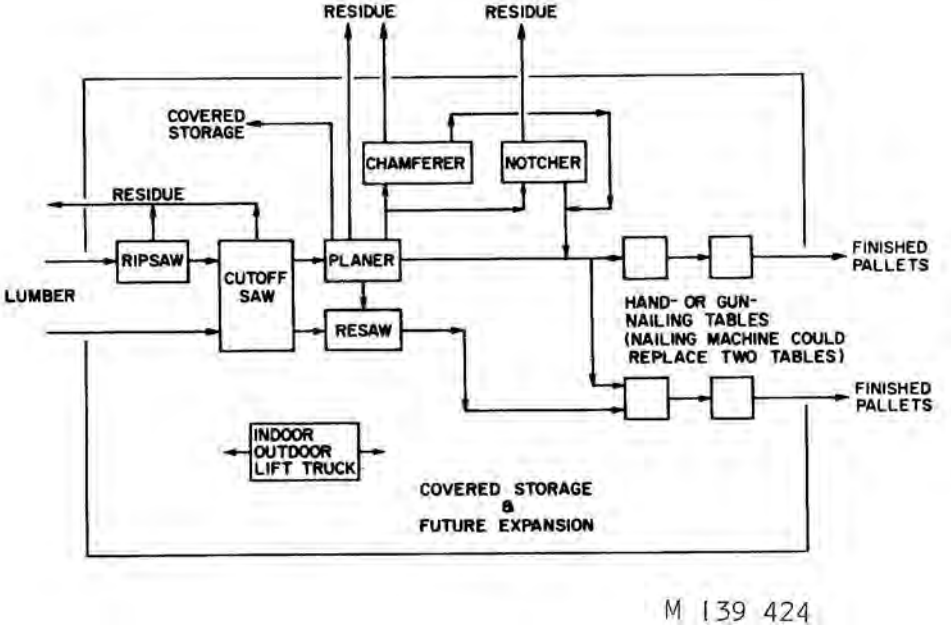
In the plans, a certain degree of flexibility is desirable: Some deckboards can be chamfered and then directed to the assembly area to be used as bottom leading edge deckboards, or stringers can be diverted to the notching operation for construction of partial four-way-entry pallets.

Consideration should also be given to providing backup or storage areas where finished pallet parts may be diverted in the event of a breakdown or stoppage in the assembly area; thus the entireplant would not have to shut down. Similarly, material may be drawn from this backlog in the event the cutup area should develop problems.

Provisions should be made for removing the residues. This is only good housekeeping which, in turn, promotes efficiency and safety. In disposing of residues, efforts should be made to locate or develop other uses to promote maximum whole tree utilization. Also to be considered are rules and regulations regarding environment pollution and solid waste disposal.

There are a number of ways to move the material through a plant. This can be done manually with wheeled bins or trucks, or by a highly sophisticated system of mechanical conveyors. A system of mechanized conveyors involves larger capital expenditures but might eliminate some labor. Consideration should be given to the economics of both systems, not only for the immediate future but also for the long-range operations.





Figures 7 and 8.--Two suggested arrangements for initial planning of limited small pallet plants. The maximum capacity of either layout probably would not exceed 500 units per 8-hour day. This would require a lumber supply of between 10,000 to 15,000 board feet. Either layout might require 16 to 18 men as follows: 1 supervisor and repairman, 4 operators for cutup and lumber breakdown operation, 3 cutup and residue off-bearers, 6 to 8 nailers, 1 nailing off-bearer, and 1 lift truck operator.

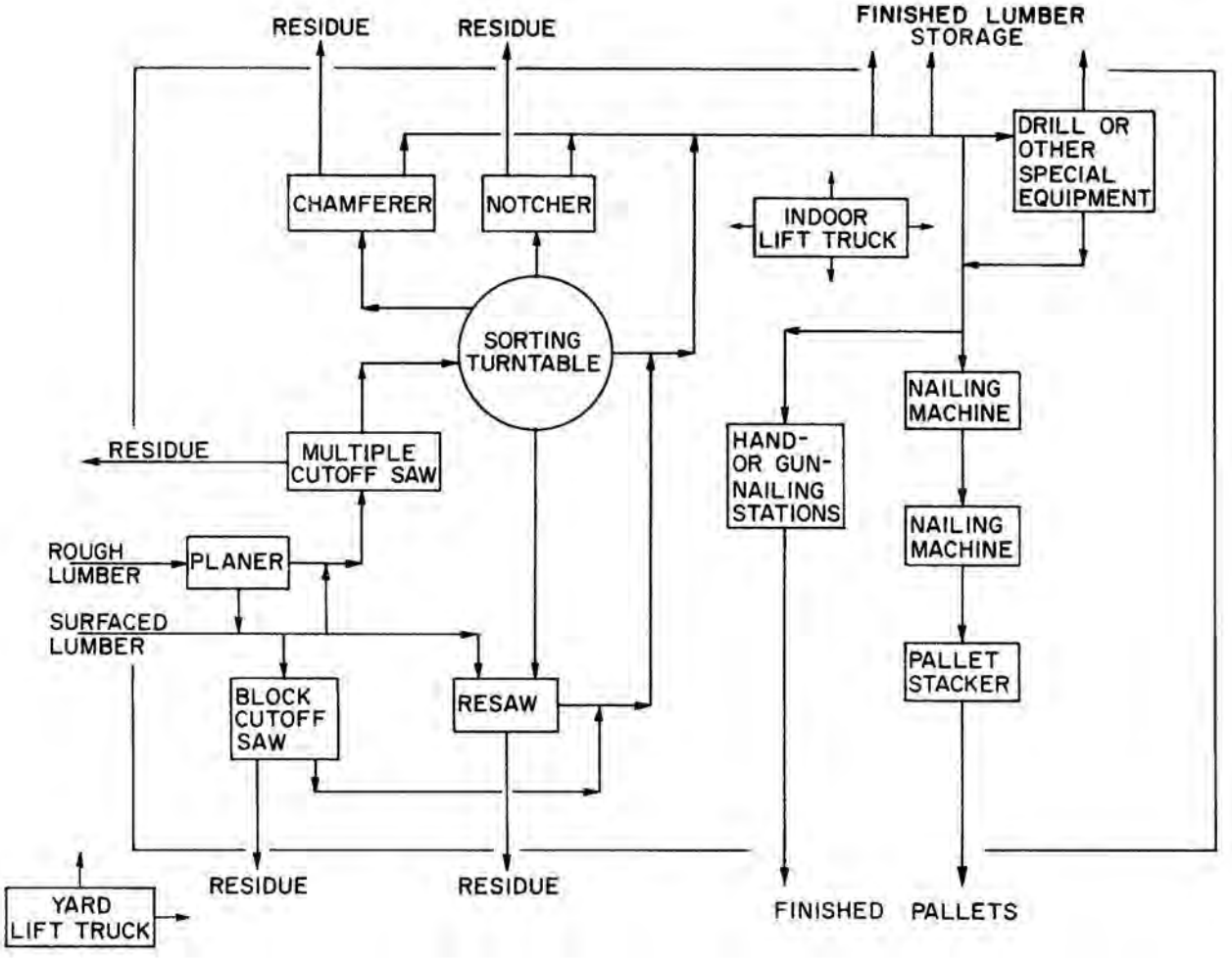


Figure 9.--Suggested initial planning layout for medium-sized general-purpose pallet plant. The estimated capacity might approach 1,000 pallets per 8-hour shift and require 20,000 to 25,000 board feet of lumber. This suggested layout assumes the lumber will be available in uniform widths. If not, a ripsaw station will be required with necessary additional personnel. In addition to office and management personnel, the suggested layout might require 20 men as follows: 1 plant supervisor, 1 planer, 1 multiple cutoff sawyer, 1 block or resaw sawyer, 1 chamfer or stringer notcher, 4 turntable off-bearers, 2 hand or gun nailers, 4 machine nailers, 1 nailing machine off-bearer or grader, 1 interior lift truck operator, 1 outside lift truck operator, 1 maintenance man, and 1 general-purpose helper. M 139 423

Plant layouts should consider possible future expansion or means of increasing production to take advantage of increased sales and market growth. From time to time, modernization might be considered to take advantage of improved technology and to improve efficiency.

Another matter for consideration in a plant layout is whether or not the facilities are to be used to manufacture other products such as car blocking and bracing, dunnage, furniture squares, cut stock, or box and crate material.

Estimating Pallet Costs

Because lumber and nails comprise about 50 percent of the cost of a pallet, the price of pallets at mills is usually quoted by the board foot. Though it is based on a valid principle (varying lumber requirements), this cost-figuring method does not properly compensate the mill for differences in the number of fastenings, handlings, labor, etc., involved in various sizes and types of pallets. The manufacturer should be aware of this fallacy in the system when making cost analyses,

Reliable cost estimates dictate accurate determination of nail requirements. Herein lies another fallacy: Some manufacturers compute nailing costs solely on the basis of thenumber of nails per pallet or unit. The number of nails driven and wasted (bent, broken, etc.) per hour--even by an expert--varies with the characteristics of the wood, type of pallet construction, and the number of hours worked by the nailer. Experience indicates that an additional allowance of 10 percent should be added to the actual number of nails in the pallet cost computation to compensate for the bent, damaged, and lost nails.

Pallet production is no different than other manufacturing operations in that labor is a major cost. Producers oftenfailto take into account the differences in time required to assemble the material involved in various constructions, and the time needed to remove the finished pallets from the working area.

Machinery operation and maintenance, depreciation, taxes, overhead, fringe benefits, and other expenses must be added to the costs of material and labor. The normal finished pallet price is computed after all of the above is estimated. Additional costs are then included for extras such as rounded corners, eased edges, notched stringers, and chamfers. These additional costs usually represent those often forgotten or ignored by many mills. These partially account for the depressed profits experienced by some.

A suggested enumeration of the items involved in estimating pallet costs is given in the cost computation sheet.

Date _____

SUGGESTED PALLET COST COMPUTATION SHEET

Customer: _____

_____

Specifications:

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

Labor

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

Manufacturing Expense

Electric power cost	$_____
Machinery maintenance	_____
Depreciation	_____
Small tool replacement	_____
Building repairs	_____
Water and gas	_____
Lift truck maintenance	_____
Total manufacturing expense	$_____

Overhead

Administrative salaries	$_____
Supervision	_____
Rent	_____
Office expense, timekeeping	_____
Telephone	_____
Plant and equipment insurance	_____
Taxes	_____
Auto and motor truck expense	_____
Interest paid	_____
Dues and subscriptions	_____
Office supplies	_____
Office salaries	_____
Miscellaneous	_____
Total of overhead	$_____

Total cost of pall at plant

Cast of extras no figured in the above

Drilling	$_____
Notching	_____
Chamfering	_____
Countersinking	_____
Bolting	_____
Branding	_____
Corner rounding	_____
Eased edges	_____
End-coating	_____
Wood preservative	_____
Total cost of extras	$_____

Freight and Transportation Costs

Loading	$_____
Strapping in bundles	_____
Freight charges	_____
Total freight and transportation costs	$_____

Delivered pallet cost $_____

Selling Expense

Sales commissions	$_____
Sample costs	_____
Travel expense	_____
Advertising costs	_____
Entertaining	_____
Total selling expense	$_____

Profit $_____

SELLING PRICE OF PALLETS $_____

Marketing

The demand for pallets has been steadily increasing in the past decade. By 1970 the number of units produced and sold annually exceeded 125 million--double the production of 10 years earlier. Predictions estimate the pallet market will reach a demand of 200 million units by 1975. Wood pallets are used for material handling, shipping, and storage by just about every conceivable manufacturing and distribution industry, including government agencies. Company, industry-wide, national, and international pallet pools currently exist and are expanding.

Pallets are bulky and therefore expensive to ship. Thus they are generally sold to delivery points within a radius of 150 miles from the plant. A few manufacturers economically ship up to 1,500 miles or more.

Some pallet manufacturers market direct to the user. Others sell their products through a broker or manufacturer's representative. Sometimes the representative also sells other materials-handling equipment such as lift trucks, conveyors, and racks. Generally, these professional pallet salesmen, located near the customer, are able to give personalized service to the pallet user.

Many pallet manufacturers, located in outlying areas, are unable to render this service economically, and therefore rely on the pallet broker as a market outlet.

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 Forest Service's Northeastern Forest Experiment Station, Upper Darby, Pa., from time to time issues publications dealing with the use of wood pallets in various industries. Also, the U.S. Government Purchasing and Sales Directory lists government agencies that purchase pallets. A copy may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

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Partial 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 tines 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 be stated with the length given before the width. The width should be given as the dimension parallel to the top deck boards. In stringered pallets, the length of the stringer is the length of the pallet.

Pallet De signs

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 decks are separated by nine wood blocks which permit four-way entry of both forklift and hand pallet trucks.

Notched-stringer design.--A pallet whose decks are separated by notched stringers, which permit four-way entry with forklift trucks only and two-way entry with hand pallet trucks. Sometimes called partial four-way entry.

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 thepallet. If top and bottom decks are identical, the pallet is reversible.

Pallet Types

Flush stringer.--A pallet in which the outside stringers are flush with the ends of the deckboards.

Single wing..--A pallet in which the outside stringers are set inboard from the ends of the top deck, but are flush with the ends of the bottom deckboards.

Double-wing.--Apallet in which the outside stringers are set inboard from the ends of both the top and bottom deckboards to accommodate bar slings for handling the pallet.

Bin pallet.--A pallet having at least three vertical sides for use as a box or container. It may or may not have a top and the sides may be fixed, removable, or collapsible.

Pallet Parts

Deck.--Pallets have top and bottom decks. The top deck is the surface that carries the load. The bottom deck is the surface that helps to distribute the load when the pallet is at rest.

Deckboards.--Members that make up the faces of a pallet. Referred to as top and bottom deckboards.

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

Stringer boards.--Members that rest on the blocks in a four-way, block-type pallet. The top deckboards are fastened to these stringer boards, sometimes called subdeckboards.

Posts.--Rectangular or round blocks employed as spacers on some four-way-entry pallets.

Additional information on terminology and definitions may be found in references (1, 10, 11, 12, 13, 14, 15, 16).

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