BRAZILIAN WOODS FOR WOODEN BOXES -- A GUIDELINE FOR WOODEN BOX MANUFACTURERS

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ABSTRACT

BRAZILIAN WOODS FOR WOODEN BOXES--A GUIDELINE FOR WOODEN BOX MANUFACTURERS

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The present study provides information on Brazilian woods, either natural or artificially grown, as a source for wooden boxes and crates.

A basic understanding of lumber characteristics for use in shipping container construction as well as their relationships with environments are described.

A guideline for wooden box manufacturers and users is provided with emphasis in export packaging. A selection and classification of wood that might be used in box and crate construction are presented based on its physical and mechanical properties.

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Kenshi Hayashida

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

The intensification of international trading in recent years in Brazil has forced much more participation in packaging which has been playing an important role in the general context of the Brazilian economy.

Brazil began to export manufactured products very recently so there is very little experience in the field of export packaging. Gradually problems are coming out regarding performance of packaging in overseas transportation.

Wood containers are among the oldest of all packaging products. In the early days of modern shipping, lumber was plentiful and inexpensive and box manufacturers, like nearly all users of wood, demanded high grades and ignored inferior materials. Little attention was given to designing boxes to obtain the maximum strength with the minimum amount of materials. The constant depleting of forest areas and the ever-increasing demand for lumber raised the prices of higher lumber grades and forced the boxmaker to use the lower and cheaper grades. In addition, the competition from other types of materials, primarily fibreboard and composition materials such as plywood, have also been responsible for the design of wooden containers at the least possible cost. Furthermore, ever-increasing freight costs are demanding the least tare weight and cubic capacity of shipping containers.

Regardless of the many competitive types of containers and materials, wood is still a major source of the packaging material used in Brazil and constitutes almost the totality of raw material for export packaging. It is probably used more in Brazil than in the United States because of the lag in the field of development. The general trends would suggest that perhaps wood will continue to play a leading role for at least a decade because of the vast supply and the fact that containers can be constructed of high strength rigidity and exceptional durability.

The Brazilian wooden box and crate industry in general has found itself completly unprepared to meet the present situation of an apparent wood crisis which is explained as follows: until recent times, industry depended on only one type of wood, i.e., Parana pine (Araucaria angustifolia Bert O. Kuntze).

Formerly Parana pine covered an extensive area in the southern region of the Continent, constituting a huge natural forestry, but which is now becoming scarce. It is a softwood with excellent physical and mechanical properties. For many years, excessive cutting and uncontrolled devastation rapidly depleted the supply which caused an impressive rise in price, in some instances up to 10 times that of previous years.

Therefore, the wood packaging industries have been compelled to utilize other types of wood without any previous experience. The lack of technological information of other species, such as sawing technique, drying and machinability, and indications of desirable properties for box use have constituted a serious problem. There is no inventory of available resources of native species where a great source of wood for boxes is supposed to exist. In addition to these problems, a very wide variety of species resulting in a heterogeneous forestry has created a difficulty in their economical utilization.

Originally, the Brazilian forestry area was estimated to be 5,200,000 km^2, i.e., about 61% of the total national area. By 1960 it had been reduced to 3,500,000 km^2 or 41% of the total area. About 83% of the forestry area is situated in the Amazon region. The southern part, mostly parana pine and 1.6% of the total forested area, is the section of major industrial investments in wood and remains a consistent and major contributor to the national economy.

A brief survey recently carried out in Brazil with respect to the wood packaging industries has revealed the immediate necessity of information about wood species that may substitute for Parana pine and other species that might be used for packaging purposes.

This work represents a condensation of several sources of data available on wood characteristics and zones of occurrence in Brazil. It is an attempt to apply the characteristics and basic knowledge of wood into packaging technology in order to make it available to box maker and users. A better selection of wood, where it can be found, its performance, the requirements of wood strength for certain products and a general knowledge about the nature of wood and its relationship to its environment.

II. WOOD CONTAINER IN BRAZIL

The cost of a container and its strength characteristics are greatly related to the type of wood.

There are five main types of wooden containers: (1) nailed boxes and crates, (2) wirebound boxes and cleated crates, (3) cooperage, including tanks, (4) veneer and plywood containers, (5) pallets and container pallets and skids.

Nailed boxes and crates are generally rectangular in shape, rigid, strong and resistant to shock and vibration. Usually they are made from sawed lumber, however, some are made of veneer, plywood and fiberboard. The kind of wood, the thickness of the wood used, and the manner in which the members are nailed or fastened governs the degree of strength and rigidity. In order to save transportation and storage, it is often the practice to sell nailed boxes in an unassembled state. These types of containers are very commonly used as export packaging.

Wirebound boxes and cleated crates are wooden frames or cleats faced with veneer slats or resawed lumber and reinforced by steel wires stapled to the faces and cleats. Although these containers are not as strong as nailed construction, they are generally lighter. They are primarily used when a substantial volume of the same size container is required for low priced products. They provide ventilation for commodities such as produce because the face pieces are usually not tightly fitted to each other. The advantages of the wirebound boxes are: (1) easier to handle than the nailed wooden box, (2) require less storage, (3) faster and easier to assemble than the nailed wooden boxes, (4) lighter in weight, (5) usually less expensive.[1]

Several applications of wirebound boxes are observed in use in Brazil.

Cooperage is a collective term describing a variety of wood containers more commonly referred to as barrels, kegs, tubs, pails, vats, tanks and other containers made of assemblies of staves and heads bound together by metal bands or hoops. The industry is an old one, dating back to Biblical times and has been a principal container, especially for liquids, for centuries. The liquid cooperage is better known as tight cooperage with the staves made from close-grained woods or species whose

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[1]Denver Research Institute. "A survey of wood and paper packaging in Brazil as related to a projected general packaging program at the Instituto de Pesquisas Tecnologicas." Phase Report. Denver, Co., September 1974, pp. 4-5. (Mimeographed)

pores are occluded with tyloses to make the wood impermeable to liquids. Non-liquid tight barrels are known as loose or slack cooperage.

Barrels are a well-engineered container because the bilge, the center bulge, forms a double arch. Every stave in a barrel acts as a keystone so that forces are distributed to all members of the container. Barrels are easily handled because of their shape and size. The contents are protected from the heat and cold because of the good thermal properties of wood. Barrels protect the product from being easily stolen and pilfered. Many wooden barrels are still in use in Brazil, however, they are gradually being replaced by fiber barrels and plastics.

On the other hand tanks and vats are very common industrial containers and should not be overlooked in the packaging field. The wood tank is well established in Brazil, and is used widely for storage of corrosive materials of all types. Some Brazilian hardwoods are ideally suited for tanks and should not be overlooked in providing a quality product with long service life.

Veneer and plywood have been used not only for nailed and wirebound boxes and crates but also for a variety of baskets, tills, and fruit boxes without nails or wires.

Pallets, palletized containers and skids are comparatively new innovations in the packaging field. They were introduced when mechanization and rapid transit received the attention of the packaging engineers. A pallet is a low, sturdy platform on which materials in process of manufacture or finished products may be stacked in order to expedite their handling, movement and storage with the aid of fork-lift trucks and cranes. Palletized containers are specialized and designed specifically for one use. The skids are runners under heavy and bulky commodities so as to facilitate the handling with fork-lifts. Actually pallets and skids are not packages in a true sense of a container, but they materially contribute to the ease of handling products, and important criterion of packaging. Their use often eliminates the need for secondary shipping containers.

Most pallets, palletized containers and skids are constructed of wood, either sawed lumber, plywood, or veneer. The growth of this segment of the packaging field has been developing at an astronomical rate. No leveling off is seen for the immediate future. Some inroads of other materials such as steel, fiberboard, corrugated board and polystyrene foams may be used to reduce the weight of pallets, but wooden pallets will remain the major material. Most pallets are the permanent type, a trend that should persist. The obvious needs emphasize standardization for industrial requirements and to develop and adopt specifications that are acceptable to all sectors of industry.[2]

In general, 50% of the total production of wooden containers have been made by manufacturers of the product to be packed. This percentage is tending to decrease due to the difficulty in obtaining the raw material (Parana pine), and is forcing the exporter to look for a specialized company. Some companies make almost every kind of wood containers and pallets. They also make kits for box and crates under special order. There are small companies that dedicate exclusively to the fabrication of kits; they buy lumber and finish it according to specification of customers. The assembling is done by the purchaser.

On the other hand, some industries design and make their own containers by purchasing only the raw material; others take advantage of parts of raw material utilized to manufacture their own products to make the container such as furniture manufacturing plants.

The transportation companies usually make their own container following their particular technique and specification. Some containers produced by those companies are known as "lift vans" and they are characterized by

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[2] Ibid., pp. 5-6.

having good resistance and being returnable and reusable several times. They are generally similar to the cleated box, relatively large in size to be carried by more than one person and used to carry many small items in one container. They are widely used by moving companies. The top of the container is easily screwed and unscrewed.

The production capacity of specialized companies vary in function of number of orders and availability of raw material. The production of transportation companies is relatively low because it is only for their own consumption; the same happens with furniture plants.

III. WOOD AS PACKAGING MATERIAL

Briefly, the purpose of packaging is to protect many kinds of products against damage and deterioration that may result from exposure to natural and man-made hazards encountered in handling, storage and shipment. The outer containers work together with interior containers to protect the product. The assembly of all these things into a functioning unit constitutes what is called packaging.

The need for a package to fulfill the function of providing protection for the contents implies that risks are involved and that hazards are present. Hazards commonly recognized are those inherent in physical handling and transportation as well as those posed by the atmospheric environment. It is apparent, therefore, that the choice of container for protecting a specific product is dependent upon the nature of the commodity and expected hazards as well as the manner in which it is packed in the container.

It is assumed that the package has served its function well if the contents for which it was intended to protect are not damaged when the packaging is delivered.

The susceptibility of an article to damage from these inputs is commonly referred to as the fragility of the article. Shock fragility can be readily determined for most articles. On the other hand, package damage is to be expected in any realistic situation. One way of looking at the package is that it is intended to absorb impacts, vibrations, pressure or the inputs which might cause product damage. The package can be damaged, however, to a point where it can not provide the protection necessary.[3] In case of wood containers, assuming that the packaging was made with a suitable type of wood, it is expected that it will withstand vibration and static pressure. The most important input to be considered in the performance of wood container should be the impact.

Basically the container should be one that will make the proper type of package, give the correct degree of protection, to lowest possible cost. If the articles to be shipped are perishable, the container needs to be sufficiently strong to withstand hazards of a rapid delivery system, yet light in weight to provide ease of handling and adequate protection. If the articles themselves are sufficiently sturdy to withstand the rough

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[3]Michigan State University. Project No. 3108. School of Packaging (East Lansing, Michigan), February 1974, pp. 1-7. (Typewritten)

handling incident to shipment, and if they are intended for use in contact with the element of weather, a reasonable assumption would be that a minimum of packaging would be required as handling aids. For articles which are more sophisticated, fragile or readily subjected to corrosion, containers should be used. Most containers should not only prevent corrosion but give ample support for the contents.

Consequently, because of the numerous commodities that must be delivered from the producers to the ultimate consumers, articles require individually designed packages. The final selection of the type of package should be made on relative cost, availability, individual processing procedures and storage and handling requirements. In order to obtain this information and to make packaging materials as useful as possible, the basic characteristics and properties of materials need to be known; the extent they can be obtained; the type of equipment necessary to process the materials; cost of the raw materials, and the cost to produce the packages.[4]

For most wood containers the wood properties that need to be considered are: (1) strength of wood as a beam, (2) shock resisting capacity, (3) nail-holding

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[4]Denver Research Institute, pp. 1-2.

ability, (4) tendency to split in nailing, (5) weight of the wood or lightness, (6) ease of machining.[5]

The selection and classification presented in this work have been based on study of density of wood by Forest Products Laboratory in the United States.

Generally the strength properties of the wood are a function of its density. The Forest Products Laboratory give the following functions relating mechanical properties to density (G), at 12% moisture content:[6]

Static bending:	
modulus of rupture (p.s.i.)	$25{,}700\ G^{1.25}$
modulus of elasticity (million p.s.i.) .	$2.8\ G$
Impact bending, height of drop causing complete failure (in)	$94.6\ G^{1.75}$
Compression parallel to grain:	
maximum crushing strength (p.s.i.) . . .	$12{,}200\ G$
modulus of elasticity (million p.s.i.) .	$3.38\ G$
Compression perpendicular to grain, fiber stress at proportional limit (p.s.i.) . . .	$4{,}630\ G^{2.25}$
Hardness:	
End (lb)	$4{,}800\ G^{2.25}$
Side (lb)	$3{,}770\ G^{2.25}$

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[5]Ibid., p. 21.

[6]U.S. Department of Agriculture. Agriculture Handbook No. 72 (Washington, D.C.: Government Printing Office), 1974, p. 4-25.

Also, the nail holding ability is directly proportional to the density of wood and also depends on the diameter of the nail and the depth of penetration. The relationship between nail holding ability for common steel wire nails and density is given by the formula:[7]

$$p = 7{,}850\ G^{5/2} D\ L$$

where

p = maximum load (lb)
L = depth of penetration (inches)
G = density of the wood based on ovendry weight and volume at 12% moisture content
D = diameter of the nail (inches).

The above formulas, except for impact bending applied in case of static loading condition. The strength of wood in dynamic loading is much higher than in static loading. This fact, however, is not necessarily true when dealing with a container. The performance of a wood container might be completely different from a single piece of wood and should be analyzed in different way. A wooden container which is composed of several heterogeneous pieces of wood placed in different directions, fastened with nails, screws or staples, evidently behaves differently compared to a single element. In other words, a group of factors are involved, which determine the performance of a wooden container.

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[7] Ibid., p. 7-2.

Tests have shown that the performance of the container when dropped against the longest side is almost independent of the strength of the wood. However the length of the nails is then very important. A decrease from 60 to 55 mm decreases the performance with 25%. Also, the creep of the nails will influence the deformation of the containers. Only a few milimeters creep will make a great influence. Different nail patterns give different strength. The type of nail also influences, sometimes as much as 60%. The type is vital for the breakage performance. (See more detail on nails in Chapter IV.)

Weight per cubic meter or density is a relatively good measure of strength and resistance to nail withdrawal and also directly influences the cost of handling and transportation. It roughly indicates the amount of shrinking and warping likely to occur with changes in moisture content. Commonly dense woods are outstanding where high resistance to nail withdrawal is important but they must be more carefully nailed to prevent splitting and generally they shrink more than softer, lighter woods. As a rule, the lighter woods give less trouble in seasoning, manufacture, and storage of lumber than dense woods. Woods presenting very high percentage of shrinkage were disregarded in the present classification because it tends to show high degree of checks and splits.

The weight of dry lumber per cubic meter varies from about 230 kg for very light species to over 1200 kg for very heavy species. A definite way of expressing the weight of wood at a given moisture content is in kilogram per cubic meter or per square meter of a specified thickness.

In the same species of wood the weight of lumber varies considerably because of differences in density. Variations exist even within wood from the same tree.

The water in green wood often weighs more than the ovendry weight of the wood, but in thoroughly air-dried lumber the weight of water is usually about 12 to 15 percent of the ovendry weight of the wood, and in kiln-dried lumber it is often as low as 5 per cent.[8] The weight of some pieces of certain species such as slash pine is often materially increased by resin or gum. (More details on moisture content in Chapter IV.)

Table 1 shows a list of woods that might be used as boxes and crates, as a whole or as parts. They were grouped in 3 groups which were governed by density and selected from about 400 trees, representing approximately 200 different species studied in Brazil. Each specie selected was analyzed upon their physical and mechanical

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[8]U.S. Department of Agriculture. Agriculture Handbook No. 252 (Washington, D.C.: Government Printing Office), 1964, p. 5.

TABLE 1.--Groups of Woods that Might be Used for Boxes and Crates.*

Group I	Group II	Group III
Açacu	Açoita cavalo	Almecega
Andá-açu	Aguano or Araputanga	Amendoim
Boleiro	Amapá	Andiroba
Breu-sucuruba	Amapá da Terra Firme	Angelim-araroba
Caixeta	Amburana or Cerejeira	Angico branco
Canela-guaruva	Araribá	Arariba vermelho
Cedro	Baguaçu	Bicuiba rosa
Copaibarana	Barriga d'água	Bracatinga
Cuivira	Bicuiba	Breu preto
Faveira	Bicuiba branca	Cambará
Faveira-de-arara	Burici	Canela batalha
Figueira	Cajuaçu	Canela oiti
Guaricica	Canela branca	Canela parda
Imbiruçu	Cangalheiro	Canela rosa
Jacarandá-mimoso	Capixingui	Canjerana
Japacamin	Caroba	Coerana
Jequitibá-rosa	Freijó	Copaiba
Louro	Guaca	Eucalipto saligna
Mandioqueira	Guariuba	Grubixá
Maria mole	Imbuia	Grumixava
Pau de sangue	Ingá-chichi	Guatambu amarelo
Pará-pará	Jacareuba or Guanandi	Ipe peroba
Peroba d'água amarela	Mandioqueiro	Jequitiba-branco
Pinho do Paraná	Mototó	Louro inhamui
Pinho bravo	Mututi	Murici
Pinho eliote	Passariuva	Pau d'alho
Pinho teda	Quaruba-vermelha	Pau jacaré
Sangue de drago	Sorva	Pelada
Tacacazeiro	Sucuuba	Peroba de campos
Taperaba	Tamaraque	Peroba rosa
Tapiá	Tuchaua	Punhã
Tatapiririca	Ucuubarana	Quaruba jasmirana
Ucuuba		Quarubatinga
		Sangue de boi
		Tamboril branco
		Ucuubarana or Margonçalo

*Botanical names, ranges and properties of each wood are listed in the Appendix.

properties published by I.P.T. (Technological Research Institute) bulletin.

The reason for only 3 groups is due to the fact that IPT has already established and adopted three categories of quality: high, medium and low. According to density, woods are classified as:

Light - density less or equal 0.55 g/cm^3

Medium - density more than 0.55 g/cm^3 and less or equal 0.65 g/cm^3

Heavy - density more than 0.65 g/cm^3

The groups and their characteristics are described as follow:

Group I -softer woods of both the coniferous (softwood) and the broad-leaved (hardwoods) species. These woods do not split readily when nailed and have moderate nail-holding capacity, moderate strength as a beam, and moderate capacity to resist shock. They are soft, light in weight, easy to work, hold their shape well after manufacture, and usually are easy to dry.

Group II - medium density woods, which have greater nail-holding capacity and strength as a beam than the group I woods, but are less inclined to split and shatter. The hard summerwood bands often deflect nails and cause them to run out at the side of the piece.

Group III -heavy hardwoods species. They have the greatest capacity both to resist shock and hold nails. They are often desirable for load-bearing members, skids, or joists. They are difficult to nail and tend to split when nailed, but are especially useful where high nail-holding capacity is required.

Presented in the Appendices are some physical and mechanical properties available, and zones of occurrence (range) of each species selected.

In any species, a wide range in strength and other properties exist in lumber as it is sawed. Since these values were obtained from small, clear specimens, a number of factors must be applied to arrive at stress values suitable for the design of the crates. Designers using these values must recognize that they are averages for each specimen. Wide variations are possible in individual pieces of lumber.

IV. DESIGN AND CONSTRUCTION PRINCIPLES OF WOODEN CONTAINERS

Factors to be Considered in Designing Wooden Containers

The selection of a wooden container depends on, in general order of importance, contents, destination, method of transit, handling hazards, storage conditions and costs. These factors overlap, but each will be outlined separately to aid the designer or shipper in selecting the proper container.

Contents

The nature of the item is of fundamental importance in the selection of a shipping container. If the item is ruggedly constructed, such as an axle assembly for a large truck, it has probably been prepared to resist the weather. Hence, an open crate would be more economical than a closed one. While such an item could withstand a considerable amount of handling without damage, it would be easier to handle and store if it were crated. Items less rugged or requiring protection from the weather would be shipped in a fully closed container. In all cases, however, the container must be sturdy enough to (1) provide ample anchorage for the item, (2) resist rough handling, and (3) withstand superimposed loads. The type of base with which the item is equipped should also be considered. Certain items may be adaptable to the use of a crate with a sill-type base, but the majority are best suited to a skid-type base. The latter include equipment having a flat base with a distributed load or a base of the leg, single or double column, end frame, or pedestal type. For the purpose of classifying the contents which can be packed in wooden containers, three types of load categories have been defined:

Type 1, easy load: an easy load consists of contents having low or moderate density and filling the inside of the container completely. The contents also consist of articles of sufficient strength to withstand the forces encountered in handling and transportations and are of such shape as to fully contact all faces of the shipping container. Items such as boxed articles, chests or kits of tools, and wooden cabinets are examples of this type of load.

Type 2, average load: an average load consists of items which are moderately dense and which require a reasonable amount of protection. Items of this type may either be packed directly into the outer container or in

[9] Ibid., p. 2.

an intermediate package which aids in supporting the faces of the outer container. The items themselves or their packages must provide a moderate amount of support for all faces of the shipping container in order to be classified as a Type 2 load. In this group fall items in mental cans, bottles individually cushioned, and numerous other items which are first packed in individual cartons.

Type 3, difficult load: a difficult load consists of items which are highly concentrated or require a high degree of protection. Items in this category furnish no support to the faces of the shipping container but rather, in many instances, tend to apply concentrated forces to the containers surfaces. Bolts, nuts, and other dense items which are free to shift or flow, delicate instruments, assemblies, and others which do not completely fill the shipping container fall into this class.[10]

Destination and Method of Transit

The destination often automatically determines the style of container. In surface overseas shipment the container might either be placed in the hold of a ship or on the deck. For easy passage of a container through the average hatchway and into the hold the outside dimensions

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[10]Walter F. Friedman and Jerome J. Kipnees Industrial Packaging (New York: John Willey & Sons, 1960), pp. 228-233.

average hatchway and into the hold the outside dimensions should not exceed 12 meters in length, 2.70 meters in width, and 2.1 meters in height. Any container larger will likely be placed on the deck. A sheathed crate with a waterproof top is advisable for deck shipment. Since smaller crates are not always placed in the hold it would be logical to select a sheathed crate for most items that are destined for foreign ports. For rail shipment there is a limit of size, which is to assure proper clearances of crates on a flatcar going through tunnels, under bridges, and around curves. However, size limitations may change and a thorough check should be made with the transportation agencies. For truck transportation within the country, only a basic framework may be needed to conveniently handle the item. Shipment of material by airfreight usually requires only a light container or a skid base.

Handling Hazards

Wooden containers may be handled in a variety of ways, but the most important from the standpoint of design are end slinging, forklift handling, and grabhook lifting. Other stresses are placed on containers during shipment. They may be moved by pushing or skidding. The vibration of railroad cars may cause failure of fastenings or loosening of blocking and bracing. Transportation by motor truck also involves more shipping hazards than are apparent. Loads are often not secured to the truck bed, and containers are subjected to vertical and horizontal movements. End or side impacts and accidental dropping of one end of the crate are other hazards during handling that must be considered. The crushing stresses of slings or grabhooks are resisted by the joists or other members in the top. Racking stresses from end thrusts or humping are resisted by the diagonals in lumber-sheathed crates and by the plywood in plywood-sheathed crates. Correct nailing of the crate panels as they are fabricated and using enough fastenings in assembling panels into a crate will further insure adequate strength to resist vibration and other stresses. (More details on fastenings follow in this chapter.) The handling of containers in overseas shipments depends largely on the mechanical equipment available in each port. Containers are often placed aboard small lighters with the ship's gear and unloaded at the dock site by a variety of methods. The packaging designer should consider a design with a larger factor of safety to allow for such additional hazards.

Storage Conditions

A container that will be transported in a covered carrier and either unpacked immediately upon arrival or placed in a warehouse does not require sheathing for protection and an open crate might be selected. If the shipment is stored outdoors or exposed for a long time to the weather, the closed container is a logical selection.

All containers, open or closed, should be capable of withstanding top loads. When top loading of containers is not considered in design, failure or excessive deflection may occur and result in damaged contents. Under most conditions containers of like size and contents will be placed one atop another in warehouse or outdoor storage. This is called like-on-like stacking. The sides and ends of the lower containers support the load, and little stress is carried by the top panel. Crate tops are stressed when smaller containers are superimposed. Only like-on-like stacking is considered with open crates. They are usually not designed for top loading with smaller containers.

Costs

The selection of the proper type of wooden container may gain a saving in both construction and shipping costs. An open crate costs less than a sheathed crate. It generally involves less material, lower construction costs, and a lower shipping cost because of less weight and cubic displacement. The amount of lumber saved by using open crates rather than fully sheathed crates varies somewhat with the type of crate selected. For light and medium loads, the open crate uses a minimum of material and the saving is substantial. For heavy loads, the open crate uses proportionately more material and the saving is less. The nailed style open crate for heavy items requires the use of sheathing to provide fastening areas for assembly nailing to the base. This style is similar to a lumber-sheathed crate with some of the sheathing boards eliminated. The main saving of lumber in an open crate compared to a fully sheathed crate results from: (1) the reduction of sheathing in top, sides, and ends; (2) the elimination of joists except the lifting joist; and (3) the elimination of most of the covering material except diagonals for the base and crosspieces.[11]

Factors Affecting Wood Strength

The performance of wood sections, when fabricated into a box, in resisting stresses in tension, in compression parallel or perpendicular to the grain, in shear, in bending or in shock-resisting ability, is influenced by a number of factors. These factors are important, regardless of the wood grouping, and whenever possible they must be checked.

Moisture Content

It is one of the principal factors affecting its strength. As wood dries, most of its strength properties are increased. This increase in strength, however, does not occur until the drying has reached the fibre-saturation

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[11]U.S. Department of Agriculture. Agriculture Handbook No. 252, pp. 2-4.

point, the condition in which the cell cavities are empty, but the cell walls are fully saturated. This condition usually prevails when the lumber has a moisture content of 25 to 30 per cent. Clear material of the thicknesses ordinarily used for containers dried to 12 per cent moisture content may be twice as strong in bending as green material which may have a moisture content as high as 250 per cent. If the lumber is kiln-dried to 5 per cent, its bending strength may be tripled. When green lumber is used for wooden boxes and crates, it may check or cup. Checking or cupping causes loosening of the nails and consequent weakening of the container. Green lumber also increases freight charges. For example, a wooden box having a tare weight of 6 kg when made with green lumber with a moisture content of 100 per cent would be reduced in weight to 3.5 kg, if seasoned lumber with a moisture content of 15 per cent were used. This equates to a saving of 2.5 kg in tare weight with a corresponding savings in freight charges.[12]

Duration of Load

Wood is able to support large overloads for short periods and small overloads for longer periods. This property is important if short-time load is contemplated, such as a one-trip crate shipped directly to its destination with no storage period. However, it is better to

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[12]Friedman, Industrial Packaging, p. 215.

disregard it in designing crates for longtime storage. A wood member can support continuously for one year only about two-thirds of the load required to cause failure in a standard strength test of only a few minutes duration. Wood under a continuous load, such as might be imposed on a crate in storage with other boxes or crates placed on top tends to deform. This deformation is greater when moisture content of the material is high.[13]

Defects in Lumber

a. Cross grain:--it is defined as wood cells or fibres which do not run parallel with the axis or sides of a piece of lumber. It is one of the most serious defects reducing strength in bending and increasing the susceptibility of wood to splitting in nailing. Divergence of the grain in any board more than 2.5 cm in 25 cm of length is not desirable.

b. Knots:--the weakening of the bending strength of lumber is nearly proportional to the knot diameter as measured across the width of the board. A knot is a portion of a branch or limb that has become incorporated in another branch or in the body of the tree. The wood fibres running out into the limb and those passing around the limb

[13] U.S. Department of Agriculture. Agriculture Handbook No. 252, p. 9.

and continuing in the main body produce cross grain. The weakening effect of knots results mainly from the cross grain around them. Knots weaken boards most if they are in the middle third of the length of the board. At no time should the knot diameter exceed one third the width of the board.

c. Checking:--it is caused by stresses introduced by non-uniform shrinkage. End checking is caused by wood drying more rapidly at the ends than away from the ends. This condition can often be avoided by painting or coating the ends to retard their drying or by reducing the circulation of air around the ends. Checks reduce the holding power of nails and may result in splits running the full length of the piece.[14]

d. Slope of grain:--it refers to the direction of the wood fibers in relation to the longitudinal axis of a piece of lumber. When these fibers are not parallel with the longitudinal axis, the wood is said to be cross grained. The slope, measured by the angle between the general direction of the grain and the axis, is expressed as a ratio, as one in twelve (1 cm. slope in a 12 cm distance). Slight local deviations of grain direction are usually disregarded. When cross grain is quite steep,

[14]Friedman, p. 216.

there is a marked reduction in strength. A slope of grain of 1 in 8 in a member subjected to bending under impact loads will result in its having 53 per cent of the strength of a piece without grain deviation. This requires a reduction in the assigned working stresses to offset the loss in strength. Besides having less strength, pieces with cross grain tend to twist with changes in moisture content. Slope of grain, therefore, must be limited for such crate parts as joists, load-bearing floorboards, struts, upper and lower frame members, diagonals, and skids of sheathed crates. Few restrictions on slope of grain exist for items such as lumber sheathing, rubbing strips, and nonstructural blocking and bracing than for structural members.

e. Decay:--it is a disintegration of the wood substance resulting from the action of wood-destroying fungi. Wood dried below 20 per cent moisture content and kept from re-absorbing moisture, rarely decays. Certain woods are subjected to insect attack in the green lumber, some in dry lumber, and some in insufficiently seasoned lumber. When small worm holes are found in lumber, they have a very slight deleterious effect on the strength, and if the material is otherwise satisfactory it is still satisfactory for wooden container use.

f. Blue stain:--also called sap stain, the bluish discoloration of the sapwood is caused by a fungus. It does not reduce the strength of the wood. However, the conditions that favor development of this fungus are ideal for the growth of wood-destroying fungi, so bad staining may indicate existence of decay. When blue stain is present in sheathing boards or frame members, it may obscure markings on the container.

g. Insect attack:--certain woods are subject to insect attack as green lumber, some as dry lumber, and some as partly seasoned lumber. The sapwood of some seasoned hardwoods is subject to attack by the powder-post beetle. Small wormholes have only a very slight effect on the strength and, if the wood is otherwise sound, it is quite satisfactory for boxes.

h. Wane:--it is either bark or lack of wood on the edge or corner of a piece of lumber. Acceptability of pieces with wane is usually restricted for structural members because of the reduced cross sectional area. Wane is less serious in lumber sheathing than in such crate parts as frame members and skids.

i. Shakes:--they represent a separation along the grain, largely between the growth rings, which occurs while the wood is seasoning. Shakes in members subjected to bending reduce the resistance to shear and therefore should be closely limited in structural members. Restrictions of shakes in boards are usually based on the length of the split or opening.

j. Warping:--is any variation of a piece of material from a true or plane surface and includes bow, crook, cup, and twist. Generally warping does not affect the strength of wooden container parts, but it makes fabrication more difficult and reduces the utility of the container.[15]

Factors Affecting Container Strength

Beside the factors directly related to the nature of wood, other factors related to the construction must be considered, which greatly affect the performance of a container.

The strength and rigidity of wooden containers are highly dependent on the fastenings. Nails, lag screws, bolts, screws, staples, and metal connectors, are the most important fastenings in the construction of wooden box and crates.

Among the fasteners, nails are still the most commonly used in box and crate construction. They are

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[15]Agriculture Handbook No. 252, pp. 9-10.

classified by primary function, special shapes and or coatings, gauge, size and type of head.

Basically, three types of nails are used for nailed wooden containers: the common or bright-nail, the barbed nail and the cemented-coated nail. A comparative test conducted on nails driven 28.4 mm in white pine have shown the following relationships: the withdrawal resistance of cemented-coated nails is approximately 40% greater than common nails. Barbed nails have a withdrawal resistance 40% less than common or bright nails.[16] The size of most nails is based on their length; the diameter varies by the length of the nail type.

In the United States nail size is usually expressed by the penny system, abreviated as d. For example, a sixpenny nail is expressed as 6d. The penny system is based on the weight of a thousand nails. For example, in the case of 6d, it represents one thousand nails weighing 6 lb. However, in Brazil, only common type nails are used for container construction and they are designated by two numbers separated by the symbol X. The first number refers to the total length (in mm) and the second number indicates its diameter (in 1/10 mm). For example 50 X 30 corresponds to a nail with 50 mm length and 3 mm diameter.

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[16]Friedman, p. 218.

The proper size of nails to use for any wooden box is determined by the thickness and species of wood in which the point of the nail is to be held. The sizes of nails recommended for different thickness and for the specific wood grouping are listed in Table 3.

A certain minimum spacing is recommended to be followed to prevent splitting of the sides, top or ends. Since nails driven in the end grain have less holding power than those nails driven into the side grain, a larger number of nails with a correspondingly close spacing is required for end-grain nailing. Table 2 describes the recommended nail spacing for side and end-grain nailing.

Where it is possible to clinch the nails, as in attaching cleats, the withdrawal resistance is increased 50 to 150 per cent.

Corner Construction

As discussed previously, when boxes are joined by nails, the design should permit side grain nailing whenever possible. The three way corner provides the strongest and most rigid corner construction for a box or crate because: (1) all nails are driven into side grain, (2) each member is nailed to a second member and has a third member nailed to it, and (3) if any member starts to work loose, one of the two sets of nails will counteract this tendency. (See Fig. 1)

TABLE 2.--Recommended Spacing for Side and End-Grain Nailing.

Size of Nail	Spacing When Driven Into Side Grain of End mm	End Grain of End mm
50 X 30 or Less	50	44
55 X 34	56	50
60 X 34	63	56
70 X 34	70	63
70 X 39	76	70
80 X 49	89	76
100 X 54	100	89

TABLE 3.--Recommended Nail Sizes by Wood Thickness and Wood Groups.

Species of Wood Holding the Points of the Nails	Size of Nails Thickness of Ends or Cleats to which sides, top and bottom are nailed (in mm). 9.5	11	13	14	16	18	20	22	25	31	38	44
Group I	40x24	40x27	40x27	50x30	55x34	60x34	60x34	70x34	70x39	80x49	30x49	100x54
Group II	40x24	40x24	40x27	40x27	50x30	50x34	50x34	60x34	70x34	70x39	80x49	80x49
Group III	28x18	28x18	40x24	40x24	40x24	40x27	50x30	55x34	55x34	70x34	70x39	80x49

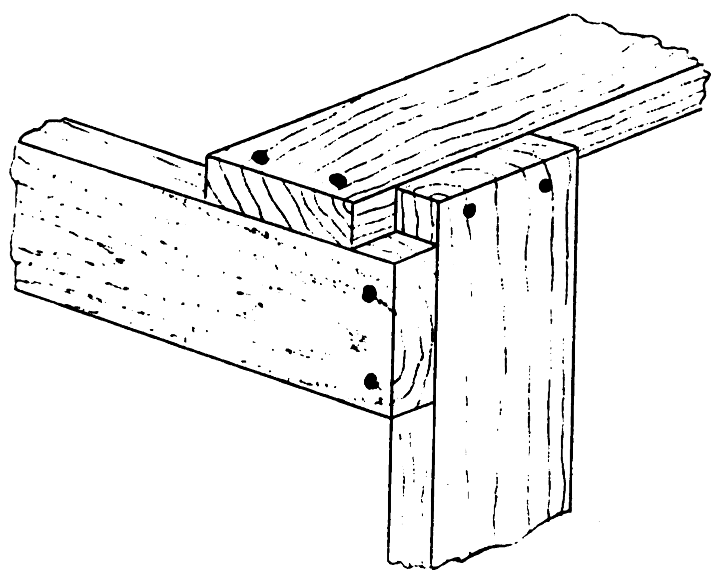

Figure 1.--Three way corner construction.

Diagonals

The use of diagonal bracing in the construction of boxes and crates increases considerabley the performance of containers. However its ultimate efficiency is attained when it is properly oriented and located. The closer the angle of the diagonals with respect to the horizontal member is to 45°, the greater is the resistance of the sides. When loads are applied to the corners of open crates, the stress in each member is dependent upon its length, as well as upon the distance to the diagonally opposite corner. The more nearly a cube the crate becomes, the more even are the stresses in each member. The ultimate in crate design is one in which all the diagonals are at an angle of 45° to the other members. The following principles are important to the crate designer:

a) Two diagonals crossing each other (X construction) make each panel considerably stronger than does a single diagonal.

b) All faces of the crate should be braced with diagonal members, unless the crated item can resist torsional stress or is suspended freely in the crate.

c) When all of the crate faces are braced and the item is properly supported, racking of the contents can not take place until the crate has failed.

d) If a crate has only five faces braced diagonally and is loaded on diagonally opposite corners or is stressed by any method that allows distortion to the unbraced face, all faces will twist very much alike. However, the diagonal distortion will be concentrated largely in the unbraced face and will be many times that of the braced faces. When all six faces are diagonally braced, both the twisting and diagonal distortion are quite uniform throughout the crate.

e) When one or more faces of a crate are not braced diagonally the contents can be racked without crate damage because of the extreme distortion in the unbraced face or faces.

Many times the contents of a large crate are found to be damaged even though the crate itself is apparently in good condition. In these instances the crate was distorted, the contents were damaged, and then the crate returned to its normal shape.[17]

Fig. 2 illustrates the relative strength to diagonal distortion of vertical and diagonal boards.

Besides providing strength to the container, steel bands discourage pilferage and may also reduce its cost. When boxes are provided with one or more metal straps, the sides, top, and bottom may be reduced in thickness by 20 per cent for one strap and by 35 per cent for two or more

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[17] Friedman, pp. 235-237; Agriculture Handbook No. 252, pp. 23,24.

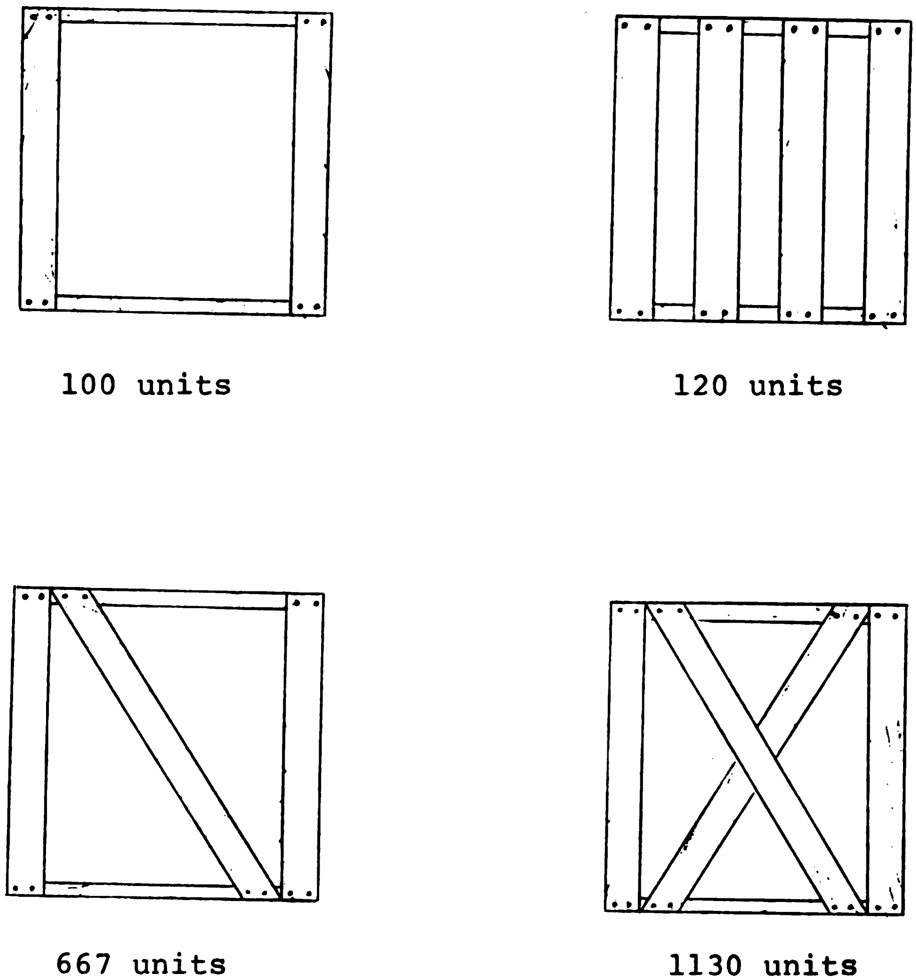

Figure 2.--Relative strength to diagonal distortion of vertical and diagonal boards.

straps, except that no thickness below 6 mm is to be specified.

Types of Wooden Containers

In this work the main types of wooden containers for export purposes will be described.

Nailed Boxes

There are 8 basic styles of nailed wooden boxes known as styles 1, 2, 2 1/2, 3, 4, 4 1/2, 5 and 6. (See Fig. 3). The main difference in the construction of these boxes is in the design of the ends. Style 1 is not cleated; it is not very strong and used for light products. Style 2, 2 1/2 and 3 have four cleats in each end, thus providing more strength and reinforcing against splitting. They can be used for heavy products for both overseas and domestic shipments for weight of contents not exceeding 500 kg. Styles 4, 4 1/2 and 5 are recommended to be used for both overseas and domestic shipments for weight of contents not exceeding 200 kg and for all load types. Two cleats in each end are applied, which increases the strength of the container. Style 6 is commonly termed the "lock corner box." It is constructed with ends and sides fitted together by tenons which are glued. This construction provides a package with tight corners, which is of particular value for those commodities that are

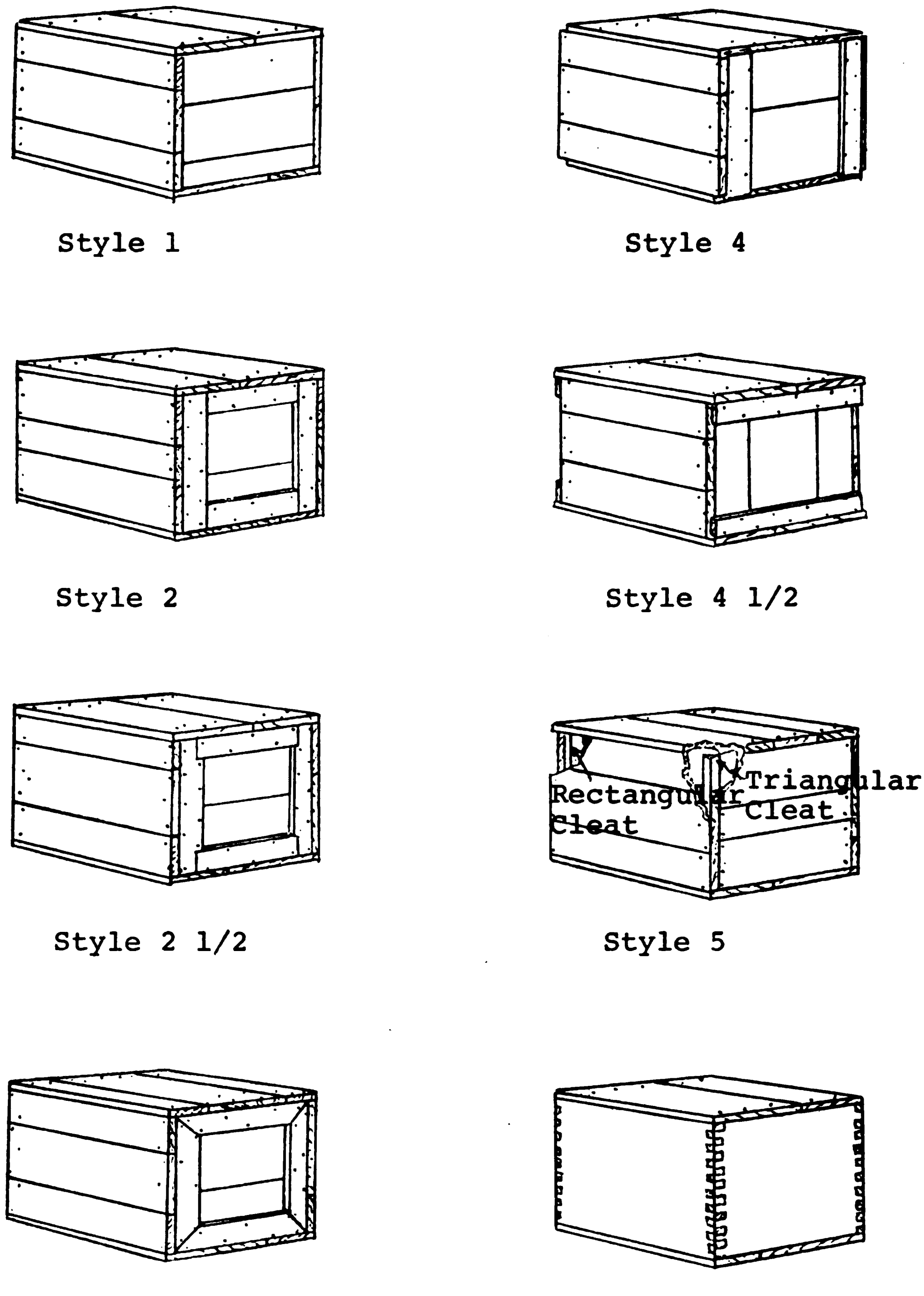

Figure 3.--Styles of nailed wooden boxes.

subjected to sifting or that require a particularly rigid box.[18]

Crates

A wood crate is a structural framework of members fastened together to form a rigid enclosure, which protects the contents during shipping and storage. This enclosure is usually of rectangular outline and may or may not be sheathed.

A crate differs from a nailed wood box in that the framework of members in sides and ends provides the basic strength, whereas a box must rely for its strength solely on the boards of the sides, ends, top and bottom.

Basically there are two styles of crates: (1) sheathed or closed crates (Fig. 4) and (2) unsheathed or open crates (Fig. 5).

Sheathed crates are generally required when complete puncture resistance on all parts of the container is desired. The sheathing material is usually plywood and fiberboard. Open crates are frequently used if the product is rugged enough and is made to be exposed to different weather conditions.[19]

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[18] Friedman, pp. 223-225; Joseph F. Hanlon, Handbook of Package Engineering (McGraw-Hill Book Co., 1971), pp. 5-15.

[19] Friedman, p. 225.

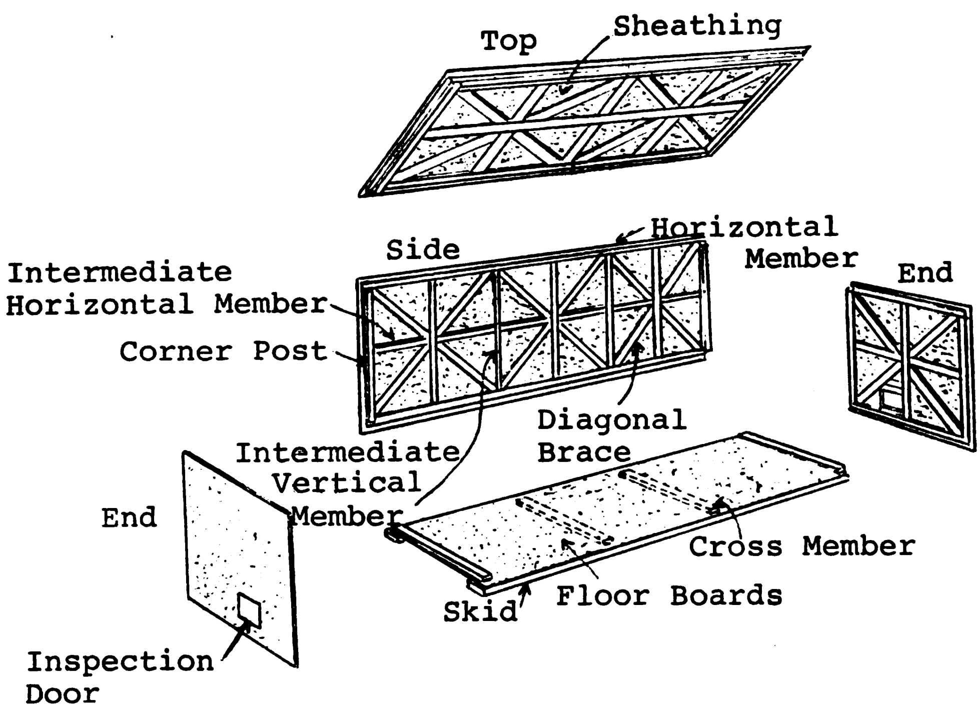

Figure 4.--Sheathed Crate.

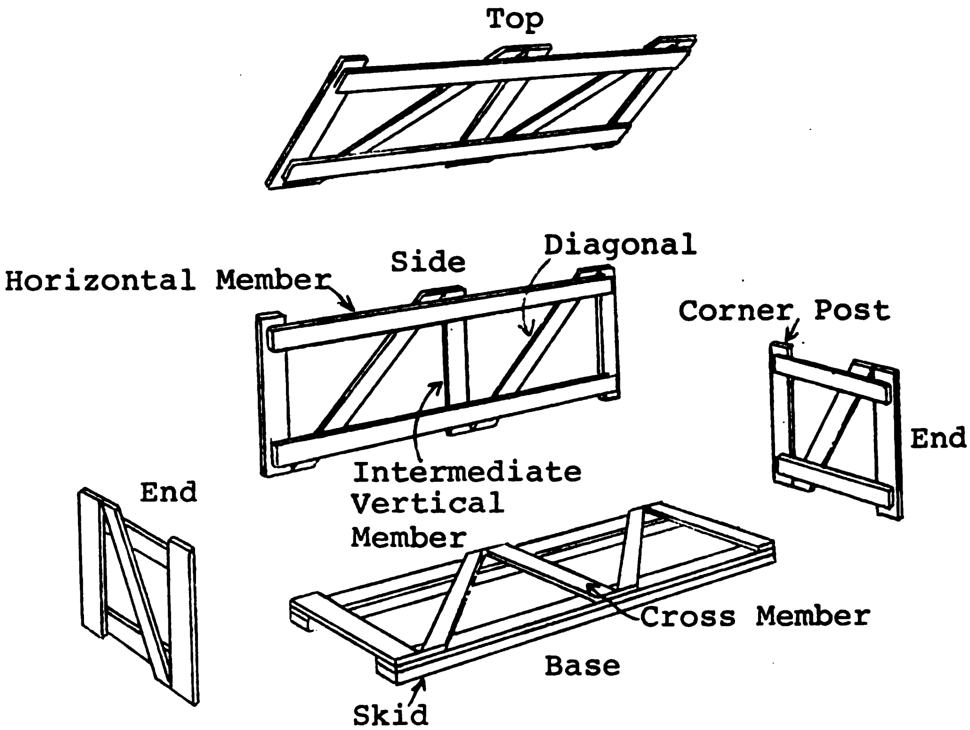

Figure 5.--Unsheathed Crate.

Internal air circulation in sheathed crates is sometimes desirable. This is possible by making small holes on the sides and ends (in the lower part), which may be covered by a steel plate, also, perforated called inspection and ventilation window.

The base must be the strongest part of a crate, because all the load is concentrated on it. Several types of base can be constructed; some of them are shown in Figure 6.

Wirebound Boxes

Wirebound boxes are usually made from wood veneer and utilize the strength of wires as a reinforcement. They are relatively lighter in weight and then very convenient for air transportation. They are shipped and stored in the flat to conserve space. Whereas nailed wood boxes can be made in any carpenter shop, and are therefore more readily available, wirebound boxes require very sophisticated equipment for attaching wires and cleats.

Wirebound boxes are classified based on the type of closure. There are four styles of wire closures to hold the cover in place for shipment: style 1 has straight wires that are twisted together; it can not be opened and reclosed as readily as the other styles. Style 2 has the wire turned back to form loops that are hooked into each other and bent back. Style 2A also has loops, but in addition to being turned back, the end of the wire is twisted on itself for greater security. Style 3 has a looped wire closure, the same as style 2, but in addition has wire across the ends in place of battens; it is not recommended for severe conditions of shifting loads, frequent handling, or overseas shipments.[20]

Cleated Boxes

Cleated boxes use single pieces of stock of fibre, wood or combination materials for the ends, sides, top and bottom, and edge cleats, which form the structure of the container. The stock for the faces consists of such materials as plywood or similar materials.

There are several styles of cleated boxes in use. Originally the style designations of these from Style A to Style K were applied only to cleated plywood boxes. However, the same standard style designations are now also applied to cleated boxes using facing materials other than plywood (Fig. 7). Style A, using cleats for the top and bottom which overlap all cleats of the sides, is easy to open and thus is recommended if re-use or in-transit or storage inspection is required. Style B, which incorporates a three-way corner construction, is more

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[20]Hanlon, pp. 15-7, 15-8.

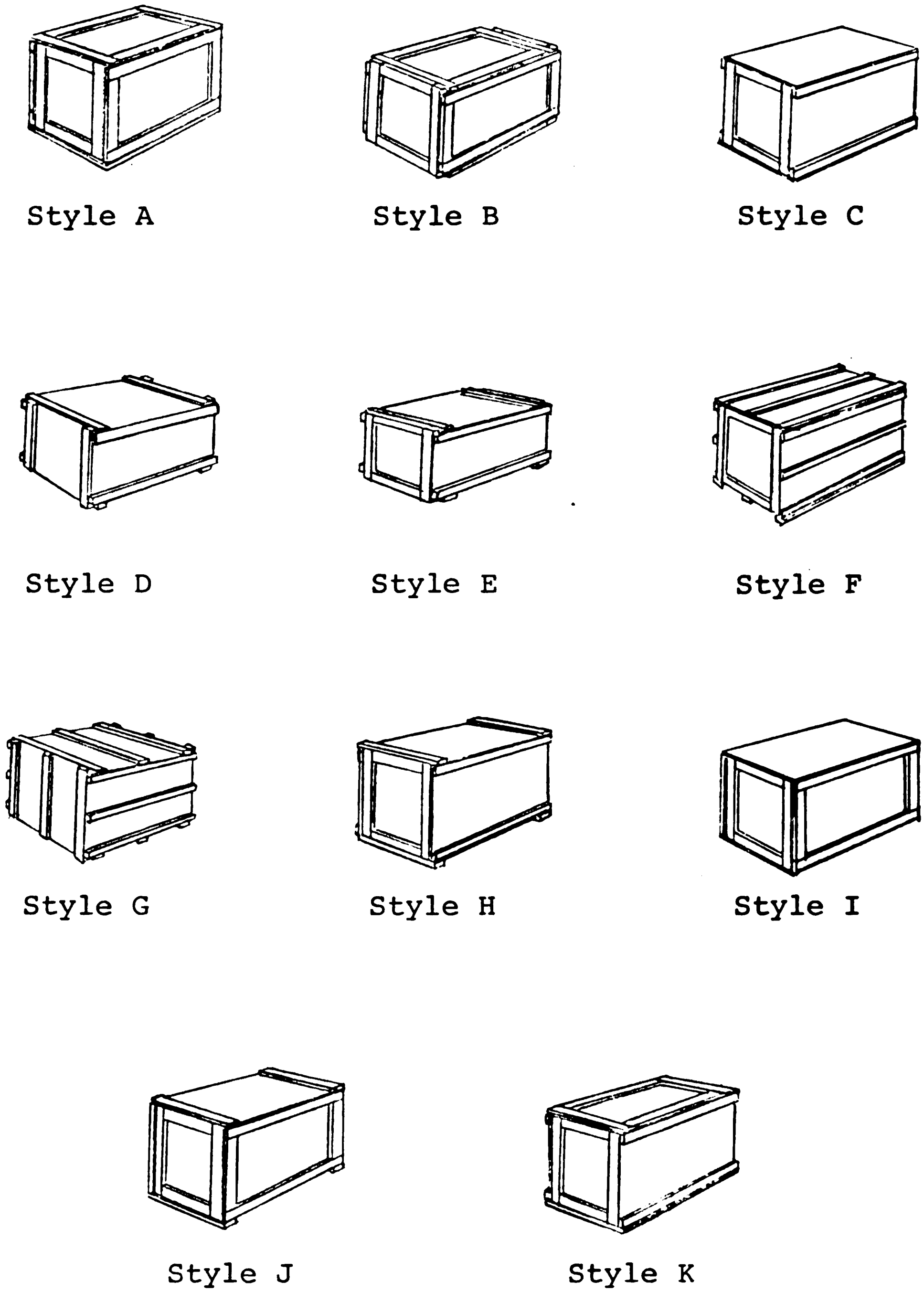

Figure 7.--Styles of cleated boxes.

rigid than most of the other styles. On the other hand, this box is difficult to open, and a nail puller must be employed if the container is to have re-use applications. The most economical among all styles of cleated box is style D, which is designed with the three-way corner and with only two cleats for each of the six box panels. Similarly constructed is the style G container which has additional intermediate cleats for strengthening of the box panels.

All other styles are variations of styles A, B and D. Selection of a specific style of container depends on such items as strength, internal blocking, opening and re-use requirements, and the size and shape of box, as well as the panel material employed. Intermediate panel cleats may be placed in any number and desired spacing for support of internal members of the product or for additional panel strength on large-sized containers.

Either staples or nails are used to fasten the facing material to the cleats.

For best results, plywood consisting of three plies of the same thickness with the grain of the face plies of each box face running in the shortest dimension is recommended. This arrangement permits maximum bending strength and thus good performance. For good rigidity of the container the grain of the face plies should be run parallel to the width of the box face (longest dimension of box face).

For export applications and other uses in which exposure to the elements is anticipated, water-resistant plywood is generally specified.[21]

Selection Guide to the Use of Wooden Boxes for Export

In Table 4 recommended nailed wooden box styles, lumber thickness, and lumber grouping for export requirements for varying gross weights up to 450 kg are listed, based on the data of National Wooden Box Association in United States. Those data however, are based on experiences with North American woods only. Even though woods in each group present similar properties, so that no great difference is expected from American woods, the values provided in the table for each group of Brazilian woods must be confirmed or modified by laboratory and field tests.

The minimum thickness of the lumber for the top, bottom and sides of the box can be obtained by use of a formula developed by the Forest Products Laboratory in the United States:

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[21]Friedman, pp. 264-266.

TABLE 4.--Selection Guide to the Use of Wooden Boxes for Export.

Type of Load	Export Maximum Weight kg	Box Style	Group I and II Woods* S.T.B. mm	Ends mm	Cleats mm	Group III Woods* S.T.B. mm	Ends mm	Cleats mm
1 or 2	27	1	10	19		9	19	
1 or 2	27	4,4½,5	10	16	16x45	8	16	16x45
1 or 2	45	4,4½,5	11	16	16x45	8	16	16x45
3	45	4,4½,5	13	19	19x57	11	16	16x45
3	45	2,2½	13	16	16x57	11	16	16x45
1 or 2	116	4,4½,5	14	19	19x57	13	18	18x57
1 or 2	116	2	14	16	16x57	13	16	16x45
3	116	4 or 5	16	20	20x67	13	19	19x57
3	116	2,2½	16	19	19x57	13	16	16x57
1 or 2	180	4,4½,5	18	20	20x67	14	19	19x57
1 or 2	180	2,2½	18	19	19x67	14	18	18x57
3	180	4,4½,5	19	27	27x83	16	21	21x70
3	180	2,2½	19	19	27x83	16	19	19x70
1 or 2	270	2,2½,3	20	20	20x67	16	19	19x57
3	270	2,2½,3	20	20	27x83	18	21	21x70
3	360	2,2½,3	21	27	27x83	19	21	21x70
3	450	2,2½,3	27	33	33x105	22	27	27x92

*Wood groups are listed on Table 1. S.T.B. means: Side, top, bottom.

$$t = 3/4\sqrt{W/b} \quad \text{where,}$$

t - thickness of sides, top and bottom, in centimeter

W - gross weight of box and contents, in kg

b - width of top or sides across grain, in centimeter.

The thickness of ends and cleats is determined by the thickness of the sides, top or bottom, whichever is the thicker. A relationship in thickness between sides, cleats, and ends of standard styles of unstraped wooden boxes is listed in Table 5.

Cleats of rectangular cross section should have a width of at least equal to twice their thickness plus 7.5 mm. As an example, a cleat which is 13 mm thick should have a width not less than 4.4 cm.[22]

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[22]Ibid., p. 233.

TABLE 5.--Thickness of Ends and Cleats Based on Thickness of Side.

Style of Box	Thickness of End	Thickness of Cleats
Style 1	2 times thickness side*	1.25 times thickness side**
Style 2, 2 1/2, 3	1.25 times thickness side*	1.5 times thickness side**
Style 2, 2 1/2, 3	1 times thickness side*	1.5 times thickness side**
Style 4, 5	1.5 times thickness side*	1.5 times thickness side**
Style 4, 5	1.75 times thickness side*	1 times thickness side**

*End and cleat thickness should be based on thickness of top if latter is thicker than side.

**Minimum allowable thickness 11mm.

V. WOODEN BOXES AND THE NATURAL ENVIRONMENT

Besides mechanical hazards and inherent characteristics of wood previously discussed, some other important environmental factors are necessary to be known, in order to provide a better protection to the product. These types of protections are against: variations in temperature, variations in moisture, biological action, pilferage and corrosion.

Protection Against Temperature and Moisture Variation

The great variations in temperature generally occur from day to night, affecting commodities stored in the open air and those being transported. In air transportation the altitude is the decisive factor in temperature variation. The sudden variation may also damage certain products, such as sensitive equipments, foods, beverages, etc. Others are damaged due to effects caused by variations such as moisture condensation, where sudden decrease in temperature may transform the vapor surrounding the surface of the product in liquid phase. In certain regions, the solar irradiation may cause temperature increases on the surface of packaging above 60°C. Also, due to heat transfer, it may cause an increase in temperature in the interior of the package. In designing a package, these aspects must be taken into consideration. Also, depending on the product, it may be more convenient to use thermal insulation material, such as foamed polystyrene.

The thermal conductivity of wood is around 0.9 BTU, so wooden containers act as thermal insulators. However if the temperature change is held for long periods of time, it causes equilibrium between the internal ambient of container and the external atmosphere. To better protect the contents, the use of a proper insulator is recommended. Felt and foamed polystyrene are typical examples of those materials.

Moisture is found almost always in every ambient or places by which a package passes. The percentage of moisture is variable. It is convenient that the shipper knows the climatic conditions through the transportation cycle in order to get the moisture activity reduced or eliminated. In order to protect the product against moisture it is convenient to make as impermeable as possible, which in a box or crate is done internally, wrapping the product with aluminum sheet, resin coated paper, betumen paper, plastic sheet, etc. The betumen paper provides less permeability to moisture compared to kraft paper and has good resistance to chemicals. It tends to be brittle when wrinkled, especially in cold weather. The low density polyethylene is chemically inert, with good mechanical resistance; it is good water and moisture insulator, but it is permeable to the oxygen and inorganic vapours. The high density polyethylene is chemically strong and inert. It is permeable to gas, but it requires lamination or lining to protect against moisture. Kraft paper laminated with polyethylene has good resistance to chemical and it is a good moisture-proof material. Aluminum and plastic foil are impermeable to some gases, liquids and vapour, but they are relatively expensive.

In many cases, besides impermeabilization, a moisture absorber such as activated alumina and silica gel is used in the container in order to keep the ambient dry. In order to determine the proper amount of silica gel the following formula might be used:

$$G = 40 \times R \times Y \times M + D/2$$ where,

G - silica gel in gram

R - the water vapour rate in g/m^2 per 24 hours

Y - the surface of barrier material in m^2

M - transportation and storage time in months

D - weight of materials in grams from which water vapour comes.

Example:

R = polyethylene with 1.5 g/m^2

$Y = 4.4\ m^2$

M = 3 month

D = 1000 gr.

The amount of silica gel (G) necessary will be 1.3 kg.

Biological Protection

Some products are easily attacked by mold or even bacteria especially in case of food. To minimize this effect, some method of preservation are utilized, such as refrigeration, dehidration or using chemical process. The following procedures might be used to protect against fungus.

Control of Moisture

The fungus does not need water in the liquid form but can utilize humid atmosphere for growth. One form of control is to eliminate the humidity in the package by using desiccants.

Control of Temperature

Maintaining low temperatures may prevent the development of fungus. This is the reason of using refrigerated metalic containers.

Sterilization

There are several methods of sterilization which kills the spore of fungus. The sterilization is done in some preserved foods, pharmaceutical products, etc.

Fungicides

For each product there is a specific fungicide. In wood, creosote, copper naftenate, chromates, etc. are used. In all cases care must be taken with respect to compatibility, corrosion, toxicity, etc.

Packages are attacked by insects and rodents when stored. Special care must be taken in stacking conditons as well as in the design of the package in order to easily control the infestations. The stacks must also be easily checked. The use of preserved wood may prevent the insect attack.

Protection Against Pilferage

Usually it occurs when the packages are stored. The use of second hand boxes is not recommended because they are deficient in strength and do not permit detection of pilferage.

Protection Against Corrosion

In the transportation and storage of metalic products, the most important aspect to be considered is corrosion.

The principal causes of corrosion during transportation and storage are the moisture, some polutant elements and some natural constituents of atmosphere surrounding the product. In general, the latter only has effect in the presence of moisture, since the process of atmosphere corrosion at normal temperature is electrochemical, the presence of water, as electrolyte, is necessary.

Care must be taken to choose wood properly to a specific product, to prevent possible corrosive effect on the metalic product. But, wood may only be corrosive when its moisture exceeds 18 to 20%. These numbers may be increased when the containers are left under atmospheric conditions with more than 85% relative humidity.

Many species of wood produce a liquid acid extract, which in extreme cases, may have a pH up to 3.0. Wood contains a variety of organic constituents, some of them may be corrosive to metals. The most common is the acetic acid or a complex of it. It was observed that even with 0.5 ppm of acetic acid in the air, there may be corrosion in metals if the relative humidity is higher than 85% and in some metals with a relative humidity above 70%. There is no direct relations between chemical composition of wood and metal corrosion, but some woods have classified as follow:

very corrosive: oak, European oak

moderately to very corrosive: fir, thuya, Fagus silvatica

moderately corrosive: teak, beech

slightly corrosive: Parana pine, elm, mahogany, walnut.

Except for Parana pine, there is still no data about corrosive characteristics of Brazilian woods.

The preservative used to improve the durability of wood contains a wide range of chemical substances, some of them may cause intensive corrosion in metals. The effect of each type of preservative depend on the nature of metal.[23]

Special care must be taken with containers made from plywood or particle boards from which water vapour or some chemicals substances are emitted which may promote corrosion in metal products. During fabrication of plywood and particle board some chemical substances are added. These materials present high corrosivity characteristics as a consequence of vapours emaneted, especially under high humidity and temperature conditions.

The corrosive characteristics of some woods are presented in Table 6.

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[23]Ministério da Industria e do Comércio, Embalagens de Transporte-Guia de Uso (IPT, São Paulo, 1975), p. 38.

TABLE 6.--Corrosivity of Some Woods.[24]

Species	Treatment	Severity of Corrosion	Volatiles Identified
Oak and Sweet-chestnut, and certain other woods especially certain Australian and tropical woods, containing free acetic acid in the natural state.	Air-drying at ambient temperatures (natural seasoning)	Very corrosive	Acetic acid
Other than above	Air-drying at ambient temperatures (natural seasoning)	Non-corrosive to slightly corrosive (may become more corrosive on exposure to hot e.g. tropical wet conditions)	
All woods	Kiln dried, steam treated, force dried after aqueous impregnation (rot-and fire-proofed), hot bonded	Moderately to very corrosive	Acetic acid, some formic and traces of higher acids

[24]P.D. Donovan and J. Stringer, Corrosion of Metals and their Protection in Atmospheres containing Organic Acid Vapours, British Corrosion Journal, 6 (May 1971), p. 134.

The problem of preventing atmospheric corrosion of metal surfaces during transit and storage can be solved by a number of different approaches. The use of paper impregnated with corrosion inhibitor, such as sodium chromate or sodium benzoate, as is common with wrapping paper. Such inhibitor, also called contact inhibitor provides an additional protection to the metal.

Other types of inhibitors used are volatile inhibitors VPI (vapour phase inhibitor or volatile corrosion inhibitor). They are essentially soluble inhibitors, which form thin layers on the surface of metal consisting of nitrate ions, benzoate and or carbonate, connected to organic cations, such as dicycle-hexil amonium nitrate.[25]

Another type of protection is termed temporary protectives which is readily removed. The surface coating provided by temporary protectives range from thin oil films to thick solid coatings, depending on the type used and the method of application. In addition to being easily removed there is also the practical advantage that certain types will act as lubricants for short term service and therefore do not necessarily need to be removed from working surfaces.

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[25] Ministério da Industria e do Comércio, pp. 42, 43.

There are a number of temporary protectives, but they may be grouped in 8 categories (according to British Standard Packaging Code B.S. 1133, Section 6, 1966):

Type TP 1: solvent-deposited materials forming hard films and often possessing de-watering properties. After the fluid has been applied (usually by imersion or spray) to the metal surface, the solvent evaporates, leaving a hard protective film. There are three kinds: TP 1a - fast drying; TP 1b - slow drying; and TP 1c - slow drying, with water displacement.

Type TP 2: solvent deposited material forming soft films and consisting of a protective solution, such as lanolin in a volatile solvent. After the fluid has been applied (usually by imersion or spray) to the metal surface, the solvent evaporates, leaving a thin and soft film. There are two kinds: TP 2a - normal type; TP 2b - water displacement type. The type TP 2b has similar properties as type TP 1c.

Type TP 3: hot-dip protectives, they are soft solids at room temperature and are designed to be melted before application. On cooling, the protective layer is soft and grease-like and varies in thickness between 0.05 and 0.5 mm or even thicker depending on the number of coatings. This type is widely used for the protection of bare metals exposed to severe conditions for long periods.

Type TP 4: corrosion inhibited greases. These are soft film greases that combine the function of a lubricant and a protective. Applied to a working surface, materials of this type would not need to be removed until they become contaminated. There are two types: TP 4a - grease based on mineral soap; TP 4b - grease based on castor oil. Type TP 4a is a type of conventional grease used as a protector, while TP 4b is a special composition grease to be applied to metalic parts joined with a rubber.

Type TP 5: semi-fluid, soft film, applied with brush until a thin film is formed. This type is based in solution of protectives (such as a by product of cotton fat) in mineral oil or in mixture of mineral oil and vaseline.

Type TP 6: non-drying oils. They consist of lubricant oils including soluble protectives, and are generally applied by imersion or spray. They are primarily designed for rust prevention but may be used as temporary lubricants. There are two kinds: TP 6a - oil type for general use; TP 6b - oil type for motors.

Type TP 7: removable coatings obtained by hot-dip and consisting of ethylcellulose and a small amount of mineral oil with plastifier, resins and stabilizers. After having been applied, they form strong impermeable films easily removed.

Type TP 8: removable coating applied cold by brushing, spraying or imersion. It is based on protectives such as vinil copolimer resin, plastifier and stabilizer in flamable or not flamable solvents. After applied they form a strong impermeable film easily removed.

The selection of the most appropriate type of protective depends on a number of factors but the most important are: (1) transportation and storage conditions and (2) duration of protection required.

Temporary protectives are supplied for ready use. It is essential that the surface to be coated be clean and free from any rust or other contaminats such as oil, grease and volatile substances. Also, the surface must be dry unless it is intended to use de-watering protectives of types TP 1 or TP 2.

The methods of application of temporary protectives varies according to the product. A selection guide of temporary protectives is listed in Table 7. After considering the two main factors mentioned above, the following factors should be taken into account: (1) complexity of article (single piece or moulded); (2) special characteristics of article - existance of rubber,

TABLE 7.--Selection Guide of Temporary Protectives.

Characteristics of Article	Temporary Protective
Small article packed together (Ex. nuts, screws)	Oil film-TP 6a and VPI
Articles with single shape	TP 1, TP 2, TP 3, TP 4a, TP 5, TP 6a, TP 7, TP 8 and VPI.
Wet articles with water after cleaning or manufacturing	De-watering type - TP 1c, TP 2b
Metalic article with rubber	TP 4b
Article with none of characteristics above. Ex. simple hardware, gears.	TP 1a, TP 1b, TP 2a, TP 4a, TP 5, TP 7, TP 8, VPI
Articles of some complexity with great proportion of simple surface	TP 4a only on working surface or whole article treated with TP 1a, TP 1b, TP 2 or TP 8
Articles with difficult interior accessibility	TP 6a plus a vapour barrier
Delicated mechanism	TP 6a plus a vapour barrier or no temporary protective; packaging resistant to water vapour with desiccant
Simple article or moulded, valuable, particularly when precise external surface	TP 7

delicated mechanisms; (3) number of articles and (4) cost of protectives and of application.[26]

[26]Ibid., pp. 43-45; R. Bryde, Temporary Protectives for Preventing Corrosion of Plant and Machinery, British Corrosion Journal, 6 (Nov. 1970), pp. 252-253.

VI. SUMMARY AND FINAL COMMENTS

A simple guideline has been given describing for people directly or indirectly interested in wooden containers, especially oriented to export.

Several factors involved in designing and construction of wooden containers as well as a selection guide of Brazilian woods that might be used for packaging purposes have been included in this work.

Since packaging has been one of the fastest growing segments of the manufacturing complex in Brazil, it is obvious that a continuous supply of raw materials should exist.

Because of the shortages of packaging material that exists currently in Brazil, an ongoing study or program must be implemented to achieve the greatest advantages of resources available. Trends in the packaging field in other countries may not be the best for Brazil.

The present forestry program of the Brazilian federal government must be stimulated and the reforestation has to be intensified in order to meet the future demand for wood.

The wood technology in Brazil requires immediate improvement and support. An intensive research on thousands of species that exist in the Amazon region should be carried out because that region has a tremendous potential for wood supply.

The importance of keeping down the weight and volume of containers suggests the necessity for studying other types of material for packaging as a substitute for wood. In many stages of the distribution cycle in the domestic market, a study of feasibility of using corrugated fiberboard should be developed.

VII. ADDITIONALY SUGGESTED IMPLEMENTATION STUDIES

Since the classification of wood presented in this work represents a first approach to the problem related to its use as a packaging material, further improvements are suggested by means of some implementation studies.

The selected species would be better evaluated if studies on their machinability characteristics are accomplished, such as saving, planning, shaping, sanding, etc.

A further study on different grades of lumber might generate a second degree of classification, which will complement the findings already presented.

Other areas suggested for wood packaging research and development are:

Techniques for nailing.

Rigidity in crate construction.

Standards for boxes and crates testing for Brazilian conditons.

Design and field performance tests of nailed boxes and crates for domestic and export packaging.

Study on the degree of corrosivity of wooden boxes made from different species.

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APPENDIX

PROPERTIES OF BRAZILIAN WOODS THAT MIGHT BE USED FOR BOX AND CRATE CONSTRUCTION

COMMON AND BOTANICAL NAME	DENSITY 1/		SHRINKAGE						STATIC BENDING 2/				COMPRESSION PARALLEL TO FIBRES 2/			
	g/cm³	clas	Radial %	Clas.	Tang. %	Clas.	Volum %	Clas.	Mod. Rupture kg/cm²	clas	Mod. Elasticity kg/cm²	clas	Mod. Rupture kg/cm²	clas	Mod. Elasticity kg/cm²	clas
AÇOITA-CAVALO (Luchea divaricata)	0.64	M	3.5	L	8.3	M	12.4	M	745	M	85100	M	320	M	98500	M
AGUANO OR ARAPUTANGA (Swietenia macrophyla)	0.63	M	3.2	L	4.5	L	8.6	L	821	M	92900	M	396	M	108700	M
ALMACEGUEIRA (Protium heptaphyllum)	0.75	H	5.7	H	11.7	M	19.3	M	719	M	113800	M	325	M	152300	M
AMAPA' (Parahancornia amapa)	0.60	M	—		—		—		—		—		—		—	
AMAPA'DA TERRA FIRME (Brosimum potabile)	0.63	M	—		—		—		—		—		—		—	
AMBURANA OR CEREJEIRA (Amburana crarensis)	0.60	M	2.9	L	6.2	L	9.3	L	696	M	94600	M	329	M	108800	M
AMENDOIM (Pterogine nitens)	0.77	H	3.5	L	6.5	L	11.0	L	840	M	113400	M	398	M	121800	M
ANDA-AÇU OR BOLEIRO (Joannesia princeps)	0.49	L	3.0	L	6.5	L	10.9	L	439	L	75200	L	187	L	91500	L
ANDIROBA (Carapa guianensis)	0.72	H	4.3	M	7.4	B	13.4	M	790	M	11600	M	375	M	144700	M
ANGELIM-ARAROBA (Vataireopsis araroba)	0.68	H	4.6	M	6.6	L	11.0	L	626	L	102100	M	344	N	126000	M
ANGICO-BRANCO (Piptadenia peregrina)	0.70	H	2.7	L	7.3	L	11.5	L	864	M	106800	M	345	M	137700	M
ARARIBA (Sickingia sp)	0.64	M	3.0	L	8.9	M	11.8	L	761	M	84400	M	353	M	148300	M
ARARIBA-VERMELHO (Centrolobium robustum)	0.79	H	3.1	L	5.8	L	9.7	L	823	M	100200	M	395	M	120500	M
ASSACU (Hura crepitans)	0.40	L	3.2	L	4.9	L	8.6	L	359	L	58000	L	166	L	70700	L
BAGUAÇU (Talauma ovata)	0.56	M	3.9	M	9.4	M	14.4	M	515	L	97100	M	222	L	114600	M
BARRIGA D'ÁGUA (Hidrogaster trinerve)	0.63	M	3.4	L	9.1	M	13.4	M	733	M	9100	M	331	M	122500	M
BICUIBA (Virola bicuhyba)	0.64	M	5.3	M	8.4	M	15.4	M	660	M	106200	M	260	L	127300	M
BICUIBA-BRANCA (Virola sp.)	0.56	M	5.7	H	10.3	M	17.8	M	528	L	112200	M	268	L	135700	M
BICUIBA-ROSA (Virola officinalis)	0.74	H	5.6	H	12.0	H	14.7	M	744	M	124400	M	343	M	158300	M
BOLEIRO OR ANDÁ-AÇU (Joannesia princeps)	0.49	L	3.0	L	6.5	L	10.9	L	439	L	75200	L	187	L	91500	L
BRACATINGA (Mimosa bracatinga)	0.67	H	5.0	M	12.8	H	18.6	M	754	M	131800	M	296	M	146500	M
BREU-PRETO (Irattinickia sp.)	0.70	H	—		—		—		—		—		—		—	
BREU-SUCURUBA (Irattinickia spp.)	0.55	L	—		—		—		—		—		—		—	
BURICI (Meliosna brasiliensis)	0.61	M	4.2	M	11.9	M	19.2	M	545	M	88300	M	256	L	98900	L
CAIXETA (Tabebuia cassinioides)	0.39	L	3.3	L	5.9	L	10.0	L	442	L	56300	L	198	L	71000	L
CAJUAÇU (Anacardium giganteum)	0.57	M	—		—		—		—		—		—		—	
CAMBARÁ (Moquinia polymorpha)	0.75	H	4.0	M	6.8	L	12.6	M	660	M	[illegible]	L	330	M	92900	L
CANELA BATALHA (Criptocarya mandioccana)	0.72	H	4.2	M	9.9	M	16.5	M	785	M	108200	M	307	M	135200	M

1 - Based on air dried wood (15 pct moisture content)
2 - Based on green wood
L - density ≥ 055 g/cm³
M - density > 055 and < 0.65 g/cm³
H - density > 0.65 g/cm³

IMPACT BENDING [1/] W in kg.m	Clas	HARDNESS [2/] END GRAIN kg	Clas	OTHER COMMON NAMES	RANGE
3.25	M	463	M	CAOVETE, ESTRIVEIRA, IVITINGUI, IVITINGA, SOITA-CAVALO	SOUTH OF MINAS GERAIS TO RIO GRANDE DO SUL
1.31	L	504	M	ARAPUTANGA, CEDRO-I, MOGNO, ACAJU, CAOBA	MATO GROSSO AND ACRE, JUNCTION OF AMAZONIAN RIVERS, FROM CACERES; PARÁ NEAR MARABÁ AT MEDIUM TOCANTINS
2.82	M	453	M	ALMÉCEGA, ALMESCA	MAR MOUNTAINS - SÃO PAULO, PARANÁ AND SANTA CATARINA
—		—		—	AMAZON
—		—		—	AMAZON
1.78	L	339	L	AMBURANA-DE-CHEIRO, CEREJEIRA-RAJADA CUMARE, CUMARU-DE-CHEIRO, EMBURANA, IMBURANA-DE-CHEIRO LOURO INGÁ	RIO DOCE VALLEY, SOUTHERN FORESTS OF BAHIA, MATO GROSSO AND AMAZON
4.10	M	609	M	AMENDOIN-BRAVO, JACUTINGA, OLEO BRANCO PAU-AMENDOIN, VIRARO	INTERIOR OF SAO PAULO, MOSTLY IN THE MOGI-GUAÇU VALLEY AND WESTERN REGION, ALONG APÁ RIVER AT MATO GROSSO, PARANAPANEMA RIVER VALLEY IN SÃO PAULO AND PARANÁ
1.48	L	212	L	COCO-DE-GENTIO, COCO-DE-PURGA COTIEIRA, INDA-AÇU	ESPIRITO SANTO, RIO DOCE VALLEY, ZONA DA MATA, EASTERN REGION; MINAS GERAIS, SOUTH OF BAHIA
3.60	M	487	M	CARAPA, IANDIROVA, JANDIROVA NANDIROVA	ISLES OF PARÁ, AMAPÁ, TOCANTINS AND SOLIMÕES BASIN, ABUNDANT IN THE GUIANAS
1.53	L	355	L	ANGELIM-AMARGOSO, ARAROBA MOINA	SOUTH OF BAHIA, RIO DOCE VALLEY, ESPIRITO SANTO AND MINAS GERAIS, NORTH OF RIO DE JANEIRO, ZONA DA MATA-MINAS SERAIS
4.42	H	509	M	ANGICO, ANGICO-DE-CURTUME, ANGICO-DO-CERRADO, CAUBI, CURUPAIBA, NIOPO, PARICA-DA-TERRA-FIRME	STATES OF MINAS GERAIS AND SÃO PAULO
1.49	L	487	M	ANTUPARANA, DUPARANA AND MAIATE	MOUNTAINS IN THE COASTAL REGIONS OF SÃO PAULO, PARANÁ AND SANTA CATARINA
1.99	L	600	M	ARARIBÁ-AMARELO, ARARIBÁ-VERMELHO, ARARIBA-UVA	FORESTS IN THE COASTAL REGIONS FROM SOUTH OF BAHIA TO SANTA CATARINA, ZONA DA MATA AND RIO DOCE VALLEY MG, RIO DO SUL AND ITAJAI-SC. MATAS SÃO PATRICIO-SOUTH OF GOIAS
0.81	L	184	L	UAÇACU	AMAZON
1.57	L	269	L	ARATICUM-FRUTA-DE-PAU, FRUTA-DE PAU, MAGNOLIA-DO-BREJO, PAU-PALHETA, PINHA-DO-BREJO,UVAGUAÇU	SOUTH OF MINAS GERAIS TO RIO GRANDE DO SUL, PARANÁ AND SANTA CATARINA
1.89	L	409	M	—	RIO DOCE VALLEY, NORTH OF ESPIRITO SANTO AND SOUTH OF BAHIA
1.73	L	319	L	BUCUVA, BUCUVUÇU, AVINHOZ, BICUIBA-BRANCA, BICUIBA-VERMELHA	FORESTS IN THE COASTAL REGIONS OF SÃO PAULO, MOSTLY IN THE RIBEIRA RIVER VALLEY, ALSO COVERING PARANÁ AND SANTA CATARINA
1.52	L	128	L	BUCUVA, BUCUVUÇU	SOUTHEAST OF BAHIA, RIO DOCE VALLEY, MINAS GERAIS, NORTH OF ESPIRITO SANTO.
1.86	L	370	L	BOCUVA, BUCUVUÇU	SOUTHEAST OF BAHIA, NORTH OF ESPIRITO SANTO, RIO DOCE VALLEY, MINAS GERAIS
1.48	L	212	L	COCO-DE-GENTIO, COCO-DE-PURGA, COTIEIRA, INDA- AÇU	ESPIRITO SANTO, RIO DOCE VALLEY, ZONA DA MATA, EASTERN REGION; MINAS GERAIS SOUTH OF BAHIA
3.44	M	507	M	—	STATE OF PARANA
—		—		SUCURUBA	FORESTS IN THE COASTAL REGIONS OF SÃO PAULO AMAZON, GOIAS AND PARA
—		—		BREU	AMAZON
1.50	L	304	L	CANELA-CAJU, CANELA-VERMELHA	FORESTS IN THE COASTAL REGIONS OF SÃO PAULO
0.94	L	190	L	PAU-CAIXETA, MALACACHETA, TACIBEBUIA, TARAVEVURA, TAMANGUEIRA, PAU-DE-TAMANCO	COASTAL REGIONS FROM ESPIRITO SANTO TO SANTA CATARINA
—		—		CAJU-DA-MATA, CAJUI	AMAZON
3.20	M	564	M	CAMBARÁ-BRANCO	CERRADO ZONE - SÃO PAULO
2.06	M	487	M	CANELA-BRANCA, BATALHA, CANELA-LAJEANA, CANELA-BASTARDA	FORESTS IN THE COASTAL REGIONS OF SÃO PAULO

COMMON AND BOTANICAL NAME	DENSITY 1/ g/cm³	DENSITY clas	SHRINKAGE Radial %	Clas.	SHRINKAGE Tang. %	Clas.	SHRINKAGE Volum %	Clas.	STATIC BENDING 2/ Mod. Rupture kg/cm²	clas	STATIC BENDING Mod. Elasticity kg/cm²	clas	COMPRESSION PARALLEL TO FIBRES 2/ Mod. Rupture kg/cm²	clas	COMPRESSION PARALLEL TO FIBRES Mod. Elasticity kg/cm²	clas
CANELA-BRANCA (Criptocaria moschata)	0.58	M	3.3	L	8.8	M	13.1	M	722	M	114500	M	309	M	117100	M
CANELA-GUARUVA (Nectandra sp.)	0.53	L	3.7	M	6.7	L	11.1	L	661	M	88900	M	300	M	97400	L
CANELA-OITI (Beilschmiedia sp.)	0.75	H	4.5	M	10.5	M	16.0	M	732	M	121200	M	326	M	120000	M
CANELA-PARDA (Nectandra sp.)	0.69	H	3.3	L	7.4	L	11.8	L	845	M	96200	M	373	M	106900	L
CANELA-ROSA (Persea racemosa)	0.68	H	4.5	M	8.1	M	16.2	M	617	L	97600	M	278	L	125700	M
CANGALHEIRO (Belangera glabra)	0.58	M	3.1	L	7.3	L	12.6	M	531	L	64300	L	299	M	77500	L
CANJERANA (Cabralea cangerana)	0.67	H	3.6	M	7.0	L	11.6	L	710	M	95600	M	400	M	116000	M
CAPIXINGUI (Croton floribundum)	0.60	M	3.2	L	9.0	M	14.0	M	598	L	103700	M	300	M	112600	M
CAROBA (Jacaranda semisserrata)	0.57	M	3.4	L	11.1	M	20.8	H	459	L	57400	L	200	L	64200	L
CEDRO (Cedrela fissilis)	0.53	L	4.0	M	6.2	L	11.6	L	640	L	85000	M	286	L	98200	L
COERANA (Chrysophyllum viride)	0.70	H	4.3	M	11.2	M	17.1	M	663	M	103400	M	270	L	121500	M
COPAIBA (Copaifera langsdorffii)	0.80	H	4.2	M	8.8	M	14.2	M	953	M	120200	M	423	M	137200	M
COPAIBARANA (Copaifera sp.)	0.55	L	3.4	L	7.1	L	11.5	L	604	L	95500	M	275	L	119800	M
CUIVIRA (Solanum inaequale)	0.53	L	3.3	L	9.5	M	14.0	M	568	L	82900	L	242	L	89400	L
EUCALIPTO (Eucaliptus saligna)	0.69	H	6.8	H	13.4	H	23.4	H	789	M	121100	M	327	M	135500	M
FAVEIRA-DE-ARARA (Parkia multijuga)	0.50	L	—		—		—		—		—		—		—	
FAVEIRA (Macrolobium acaciaefolium)	0.45	L	—		—		—		—		—		—		—	
FIGUEIRA (Ficus pohliana)	0.55	L	3.4	L	7.7	M	12.6	M	543	L	75800	L	253	L	102000	L
FREIJO (Cordia goeldiana)	0.59	M	3.2	L	6.7	L	9.1	L	815	M	113200	M	373	M	149200	M
GRUBIXA (Micropholis sp.)	0.70	H	4.4	M	8.8	M	15.4	M	850	M	123300	M	377	M	126600	M
GRUMIXAVA (Micropholis gardnerianum)	0.66	H	3.8	M	8.0	M	12.8	M	784	M	103500	M	351	M	112600	M
GUACA (Ecclinusa sp.)	0.65	M	4.2	M	9.8	M	14.4	M	719	M	100400	M	313	M	125000	M
GUARICICA (Vochysia laurifolia)	0.50	L	3.1	L	11.8	M	16.7	M	539	L	101600	M	218	L	107900	L
GUARIUBA (Clarisia racemosa)	0.56	M	2.2	L	4.4	L	7.3	L	734	M	81200	L	376	M	117400	M
GUATAMBU-AMARELO (Aspidosperma ramiflorum)	0.71	H	3.7	M	9.0	M	13.7	M	818	M	102600	M	393	M	117600	M
IMBIRUÇU (Bombax endecaphyllum)	0.39	L	3.8	M	6.9	L	13.9	M	281	L	37600	L	116	L	55000	L
IMBUIA (Phoebe porosa)	0.65	M	2.7	L	6.3	L	9.8	L	784	M	78900	L	326	M	90000	L
INGA-CHICHI (Inga alba)	0.63	M	3.2	L	7.0	L	11.9	L	699	M	100100	M	330	M	127000	M
IPE-PEROBA (Paratecoma peroba)	0.73	H	4.0	M	7.0	L	11.7	L	900	M	105300	M	459	M	123900	M

IMPACT BENDING [1/] W in kg.m	Clas	HARDNESS [2/] END GRAIN kg	Clas	OTHER COMMON NAMES	RANGE
1.70	L	379	L	CANELA-BATALHA, CANELA-NOZ-MOSCADA, BATALHA, NHOTINGA-BRANCA	MAR MOUNTAIN - SÃO PAULO
1.75	L	351	L	CANELA-AMARELA	COASTAL REGIONS OF SÃO PAULO, SANTA CATARINA AND PARANÁ
2.32	M	481	M	CANELA-BRANCA-SEDOSA, BATALHA, CANELA-TAPINHA, CANELA-BATALHA	FORESTS IN THE COASTAL REGIONS OF SÃO PAULO
1.25	L	586	M	CANELA-ESCURA, CANELA-PRETA	COASTAL REGIONS OF SÃO PAULO, PARANÁ AND SANTA CANJARANA
3.01	M	271	L	ABACATE-DO-MATO, PAU-ANDRADE	COASTAL REGIONS OF SÃO PAULO, PARANÁ, SANTA CATARINA AND RIO DE JANEIRO
1.13	L	378	L	GUAPERÊ	COASTAL REGIONS OF SÃO PAULO
1.70	L	556	M	CANCHERANA, CANJARANA, PAU-SANTO, CAJARANA, CAVERANA, CEDRO-CANGERANA	ZONA DA MATA, MINAS GERAIS, RIO DE JANEIRO AND SOUTHERN STATES; XAPECÓ VALLEY, URUGUAI RIVER VALLEY
1.77	L	365	L	—	STATE OF SÃO PAULO
1.36	L	342	L	CAIXETA, CAROBEIRA, CAROBINHA, PAU-DE-COLHER, PAU-SANTO, JACARANDÁ-CAROBA, CAROBA-BRANCA, CAXETA	SOUTH OF BAHIA TO RIO GRANDE DO SUL
2.01	M	320	L	CEDRO-BATATA, CEDRO-BRANCO, CEDRO-ROSA, CEDRO-VERMELHO	AMAZON, SOUTH OF BAHIA, RIO DOCE VALLEY, SANTA CATARINA, SÃO PAULO, NORTH OF PARANÁ, MATO GROSSO
3.35	M	398	M	CAXETA, CAROBA, GUAPEVÃO	
3.60	M	507	M	CAOBI, COPAI, COPAÚVA, ÓLEO-BRANCO, OLEO-AMARELO, OLEO-COPAIBA, PAU-DE-ÓLEO, COPAIBA VERMELHA	—
1.85	L	329	L	—	MANAUS-AMAZON
1.54	L	289	L	—	COASTAL REGION OF SÃO PAULO
3.28	M	462	M	—	NORTH OF SÃO PAULO
—		—		CAURÊ, FAVEIRA-CAURÉ	AMAZON
—		—		—	AMAZON
1.89	L	315	L	—	FORESTS IN THE COASTAL REGIONS OF SÃO PAULO, PARANÁ AND SANTA CATARINA
1.12	M	401	M	FREI-JORGE	PARÁ, MOSTLY IN THE REGION OF LOW TOCANTINS
0.80	L	510	M	BACUMIXA, CUBIXA, CURUBIXÁ, PAU-DE-REMO, SALGUEIRO	SOUTH OF BAHIA, NORTH OF ESPIRITO SANTO, RIO DOCE VALLEY, MINAS GERAIS
2.00	M	494	M	BACOMIXÁ, BACOMIXAVA, GUMBIJAVA, GUMBIXAVA-VERMELHA, PRIJUI, REMEIRO, SALGUEIRO, GUARAJÁ	MAR MOUNTAIN, COASTAL REGION OF SAO PAULO AND ESPIRITO SANTO
3.05	M	406	M	ACÁ	MOUNTAINS OF COASTAL REGIONS OF SAO PAULO, PARANA AND SANTA CATARINA
1.39	L	332	L	—	RIBEIRA RIVER VALLEY, COASTAL REGIONS OF SAO PAULO
1.00	L	493	M	CATRUZ, JAVITA, OITICICA-AMARELA, QUARIUBA, TATAJUBA-AMARELA	SOUTH OF BAHIA, RIO DOCE VALLEY, ZONA DA MATA IN MINAS GERAIS AND ESPIRITO SANTO
2.60	M	562	M	GUATAMBU, TAMBU-PEROBA	SÃO PAULO AND MINAS GERAIS
0.95	L	148	L	EMBIRUÇU, IMBIRAÇU IMBIRIBUÇU	COASTAL REGION OF SÃO PAULO AND PARANA
2.10	M	436	M	CANELA-IMBUIA, EMBUIA, IMBUIA-AMARELA, IMBUIA-BRAZINA, IMBUIA-CLARA, IMBUIA-PARDA, IMBUIA-ROSADA	INTERIOR OF SOUTH OF PARANA AND NORTH OF SANTA CATARINA, GENERALLY ASSOCIATED WITH PARANA PINE
1.73	L	425	M	—	STATES OF PARÁ AND AMAZON
3.80	M	652	M	IPÈ-CLARO, PEROBA-AMARELA, PEROBA-BRANCA, PEROBA-DE-CAMPO, PEROBA-MANCHADA, PEROBA -TREMIDA, PEROBINHA	SOUTH OF BAHIA, RIO DOCE VALLEY, ZONA DA MATA IN MINAS GERAIS AND ESPIRITO SANTO

COMMON AND BOTANICAL NAME	DENSITY [1] g/cm^3	clas	SHRINKAGE Radial %	Clas.	Tang. %	Clas.	Volum %	Clas.	STATIC BENDING [2] Mod. Rupture kg/cm^2	Clas	Mod. Elasticity kg/cm^2	clas	COMPRESSION PARALLEL TO FIBRES [2] Mod. Rupture kg/cm^2	clas	Mod. Elasticity kg/cm^2	clas
JACARANDA-MIMOSO (Jacaranda acutifolia)	0.52	L	3.3	L	6.0	L	10.9	L	480	L	46500	L	216	L	52200	L
JACAREUBA (Calophyllum brasiliense)	0.62	M	5.3	M	10.1	M	17.1	M	637	L	86700	M	289	L	110200	M
JAPACANIM (Parkia oppositifolia)	0.45	L	—		—		—		—		—		—		—	
JEQUITIBA-BRANCO (Cariniana estrellensis)	0.78	H	3.9	M	8.4	M	13.8	M	1077	H	133500	M	472	M	148800	M
JEQUITIBA-ROSA (Cariniana brasiliensis)	0.53	L	3.0	L	5.7	L	9.8	L	719	M	87000	M	325	M	107800	L
LOURO (Ocotea sp.)	0.54	L	2.6	L	5.6	L	8.9	L	651	L	86600	M	298	M	107900	L
LOURO INHAMUI (Nectandra elaiophora)	0.66	H	3.9	M	8.1	M	13.6	M	780	M	108700	M	359	M	153800	M
MANDIOQUEIRA (Didymopanax calvum)	0.52	L	5.6	H	9.6	M	18.2	M	465	L	91100	M	209	L	119500	M
MANDIOQUEIRO (Qualea albiflora)	0.65	M	4.5	M	8.9	M	15.1	L	623	L	112400	M	324	M	139700	M
MARIA-MOLE (Torrubia alferiana)	0.50	L	5.1	M	8.8	M	14.7	M	360	L	58400	L	161	L	80400	L
MOROTOTO (Didymopanax morototoni)	0.60	M	—		—		—		—		—		—		—	
MURICI (Byrsonima verbacifolia)	0.78	H	4.4	M	9.7	M	16.0	M	630	L	87800	M	294	L	111800	M
MUTUTI (Pterocarpus spp)	0.58	M	—		—		—		—		—		—		—	
PARA-PARA (Jacaranda copaia)	0.40	L	—		—		—		—		—		—		—	
PASSARIUVA (Sclerolobium spp)	0.57	M	4.1	M	8.5	M	13.9	M	574	M	92000	M	255	L	105600	L
PAU DE SANGUE (Pterocarpus spp)	0.52	L	3.3	L	6.6	L	10.3	L	569	L	84900	M	239	L	94900	L
PAU-D'ALHO (Gallesia integrifolia)	0.66	H	3.8	M	8.7	M	14.6	M	704	M	93200	M	314	M	115000	M
PAU-JACARÉ (Piptadenia communis)	0.75	H	3.8	M	7.9	M	13.6	M	845	M	94900	M	372	M	103800	L
PELADA (Terminalia januarensis)	0.79	H	4.0	M	8.0	M	12.2	L	1051	H	123600	M	508	H	141900	M
PEROBA D'ÁGUA-AMARELA (Tetrorchidium sp)	0.49	L	3.2	L	7.2	L	11.7	L	437	L	86300	M	236	L	94300	L
PEROBA-ROSA (Aspidosperma polyneuron)	0.79	H	4.0	M	7.8	M	13.1	M	899	M	94300	M	424	M	119700	M
PINHO DO PARANÁ (Araucaria angustifolia)	0.55	L	4.0	M	7.8	M	13.2	M	609	L	109300	M	268	L	137800	M
PINHO BRAVO (Podocarpus sp)	0.45	L	2.7	L	6.7	L	10.6	L	457	L	55100	L	209	L	62200	L
PINHO-ELIOTE (Pinus elliottii)	0.48	L	3.4	L	6.3	L	10.5	L	489	L	65900	L	189	L	90200	L
PINHO TEDA (Pinus taeda)	0.40	L	2.9	L	6.9	L	10.5	L	373	L	49000	L	155	L	68000	L
PUNHÃ (Iryanthera juruensis)	0.70	H	—		—		—		—		—		—		—	
QUARUBA-JASMIRANA (Vochysia sp)	0.68	H	4.0	H	12.6	H	17.8	M	896	M	151800	H	408	M	196500	H
QUARUBA-VERMELHA (Erisma uncinatum)	0.59	M	3.3	L	7.7	M	12.5	M	739	M	96500	M	344	M	123400	M

IMPACT BENDING 1/ W in kg.m	Clas	HARDNESS 2/ END GRAIN kg	Clas	OTHER COMMON NAMES	RANGE
1.92	L	355	L	JACARANDA-DE-FLORES-ROXAS	SOUTHERN STATES
1.84	M	411	M	CEDRO-DO-PANTANO, GUANANDI, GUANADI-CEDRO, LANDI, MANGUE-SECO, OLANDIM, PAU-DE-MARIA, GUANANDI-PIOLHO, GUANANI-ROSA	FORESTS IN THE COASTAL REGION FROM PARA TO SANTA CATARINA, AMAZON, ZONA DA MATA IN MG, GO AND MT
—		—		ESPONJEIRO	AMAZON
3.88	M	604	M	ESTOPEIRO	RIO DOCE VALLEY, STATES OF MINAS GERAIS, ESPIRITO SANTO, SANTA CATARINA
2.26	M	392	L	JEQUITIBA, JEQUITIBA-VERMELHO, PAU-CAIXÃO, PAU-CARGA, GEQUITIBA	FORESTS IN THE COASTAL REGION FROM BAHIA TO RIO DE JANEIRO; COMMON IN SÃO PAULO, RIO PARDO VALLEY, ESPIRITO SANTO, MINAS GERAIS
2.33	M	258	L	LOURO-COMUM	AMAZON
2.68	M	437	M	LOURO-MAMORIM	AMAZON
1.89	L	247	L	—	COASTAL REGION OF SÃO PAULO, PARANA AND SANTA CATARINA
2.05	M	394	M	—	STATE OF PARA
1.34	L	166	L	CAPOROROSA, CAPA-ROSA, PIRANHA	FORESTS IN THE COASTAL REGION OF SÃO PAULO PARANÁ AND SANTA CATARINA
—		—		MARUPAUBA-FALSA	STATES OF AMAZON AND PARÁ
0.95	L	623	M	PAU-DE-CORTUME	RIO DOCE VALLEY, MINAS GERAIS, ESPIRITO SANTO, AMAZON, GOIAS, MATO GROSSO
—		—		—	STATE OF PARÁ
—		—		—	AMAZON, MOSTLY IN THE STATE OF PARÁ
2.64	M	394	M	TAXI, CAINGÁ, ARAPAÇU, CANELA-LOURO-REVESSA, INGÁ-UÇU TAIPÁ, TAPASSARÉ, CANELA-FREIJÓ	AMAZON, PARÁ, COASTAL REGION FROM PARÁ TO SANTA CATARINA, COMMON IN SÃO PAULO
2.46	M	290	L	ANGU, DRAGOCIANA, SANGUEIRO, MATUTI, TINTERIA, CORTICEIRA	MAR MOUNTAIN, FROM PARÁ TO SANTA CATARINA-JOINVILLE REGION
1.60	L	445	M	—	INTERIOR OF SÃO PAULO AND PARANÁ
4.29	M	641	M	JACARE	SAO PAULO
2.65	M	661	M	—	RIO DOCE VALLEY AND FORESTS IN THE COASTAL REGIONS OF NORTH OF ESPIRITO SANTO
1.44	L	222	L	BAUNA, CAIXETA-JURUTÈ, COERANA, FARINHA-SECA, MANDIOQUEIRA	FORESTS IN THE COASTAL REGIONS FROM ESPIRITO SANTO TO PARANA
2.38	M	691	M	AMARGOSO, PEROBA-MIRIM, PEROBA-RAJADA, PEROBA-UÇU, SOBRO	PARANA RIVER BASIN COVERING MATO GROSSO, GOIAS, MINAS GERAIS, SAO PAULO; RIO DOCE VALLEY AND SOUTH OF BAHIA
1.50	L	274	L	PINHO, PINHO-BRASILEIRO, CURI	PARANA, SANTA CATARINA, RIO GRANDE DO SUL
0.81	L	221	L	PINHEIRINHO	MANTIQUEIRA MOUNTAIN TO PARANA
1.48	L	197	L	—	SAO PAULO, PARANA, SANTA CATARINA RIO GRANDE DO SUL
0.88	L	177	B	—	SAO PAULO
—		—		UCUUBARANA	AMAZON
2.90	M	507	M	QUARUBA	AMAZON
2.19	M	392	L	JABOTI, QUARIUBA, QUARUBATINGA	STATE OF PARÁ, MOSTLY IN GURUPA

COMMON AND BOTANICAL NAME	DENSITY 1/ g/cm³	clas	SHRINKAGE Radial %	Clas.	Tang. %	Clas.	Volum %	Clas.	STATIC BENDING 2/ Mod. Rupture kg/cm²	clas	Mod. Elasticity kg/cm²	clas	COMPRESSION PARALLEL TO FIBRES 2/ Mod. Rupture kg/cm²	clas	Mod. Elasticity kg/cm²	clas
QUARUBATINGA (Vochysia sp)	0.75	H	—		—		—		—		—		—		—	
SANGUE-DE-BOI (Hieronyma alchornecides)	0.77	H	5.6	H	11.9	M	19.8	H	755	M	106900	M	333	M	124700	M
SANGUE-DE-DRAGO (Croton echinocarpus)	0.49	L	2.5	L	6.4	L	9.6	L	650	L	95100	M	290	L	100000	L
SORVA (Couma guianensis)	0.58	M	—		—		—		—		—		—		—	
SUCUUBA (Himatanthus articulathus)	0.64	M	—		—		—		—		—		—		—	
TACACAZEIRO (Sterculiaceae)	0.50	L	—		—		—		—		—		—		—	
TAMARAQUE (Larix laricinia)	0.63	M	5.0	M	7.7	M	14.1	M	489	L	101900	M	218	L	126200	M
TAMBORIL (Enterolobium timbouva)	0.54	L	2.2	L	4.6	L	7.7	B	634	L	77000	L	288	L	90900	L
TAPERIBÁ (Spondias mombim)	0.53	L	—		—		—		—		—		—		—	
TAPIÁ (Alchornea triplinerves)	0.46	L	2.5	L	6.7	L	10.3	L	413	L	70800	L	189	L	85800	L
TATAPIRIRICA (Tapirira guianensis)	0.51	L	2.9	L	7.3	L	11.7	L	591	L	91300	M	273	L	100800	L
TUCHAVA (Laetia procera)	0.60	M	—		—		—		—		—		—		—	
UCUUBA (Virola surinamensis)	0.48	L	4.7	M	7.0	L	11.6	L	380	L	83700	L	190	L	106800	L
UCUUBARANA (Ostrophlocum platyspermum)	0.60	M	—		—		—		—		—		—		—	

IMPACT BENDING 1/		HARDNESS 2/ END GRAIN		OTHER COMMON NAMES	RANGE
W in kg.m	Clas	kg	Clas		
—		—		—	AMAZON
2.07	M	510	M	ARICURANA, LICORANA, MAGONCALO ORICURANA, PAU-DE-QUINA, URUCURANA-DE-LEITE, URINANA	FORESTS IN THE COASTAL REGIONS FROM AMAZON - BREVES ISLES TO STATE OF SANTA CATARINA
1.60	L	322	L	PAU-DE-SANGUE	COASTAL REGIONS OF SÃO PAULO, PARANÁ AND SANTA CATARINA
—		—		SORVA-GRANDE, CUMÃUASSU	AMAZON
—		—		SURUUBA-VERDADEIRE	AMAZON
—		—		—	STATE OF PARA, MOSTLY IN THE REGION OF BELEM
1.97	L	331	L	LARIX	SÃO PAULO
1.70	L	360	L	TIMBOUVA, CHIMBÓ, ORELHA-DE-NEGRO, PACARÁ, TIMBAUVA, TIMBÓ, TIMBURI	FROM SÃO PAULO TO RIO GRANDE DO SUL; MATO GROSSO, GOIAS
—		—		CAJÁ, CAJÁ-MIRIM, CAJAZEIRO	AMAZON
1.56	L	223	L	BOLEIRO, CAIXETA, CANELA-SAMAMBAIA, MALACACHETA, PAU-DE-BOLO, TAPIÁ-GUACU, TAPIÁ-MIRIM	CANTAREIRA AND PARANAPIACABA MOUNTAINS
1.45	L	319	L	FRUTA-DE-POMBA, CEDROI, PAU-POMBO, ARIPIRI, TAPIRIRICA	AMAZON
—		—		—	STATE OF PARÁ, MOSTLY IN THE BELEM REGION
0.68	L	217	L	UCUUBA -BRANCA	AMAZON
—		—		—	AMAZON